New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs –

Residential, Multi-Family, and Commercial/Industrial Measures

Version 9

Issue Date – August 30, 2021
Effective Date – January 1, 2022

New York State Joint Utilities

Version History of the New York State Technical Resource Manual

Version	Title	Issued
n/a	**New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs –** *Selected Residential and Small Commercial Measures (Electric)*	12/28/2008
n/a	**New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs (Gas)** – *Selected Residential and Small Commercial Gas Measures*	3/25/2009
n/a	**New York Standard Approach for Estimating Energy Savings from Energy Efficiency Measures in Multi-family Programs**	7/9/2009
n/a	**New York Standard Approach for Estimating Energy Savings from Energy Efficiency Measures in Commercial Industrial Programs**	9/1/2009
n/a	**New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs –** *Single Family Residential Measures*	12/16/2009
1	**New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs –** *Residential, Multi-family, and Commercial/Industrial Measures*	10/15/2010
2	**New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs –** *Residential, Multi-family, and Commercial/Industrial Measures*	12/10/2014
3	**New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs –** *Residential, Multi-family, and Commercial/Industrial Measures*	6/1/2015
4	**New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs –** *Residential, Multi-family, and Commercial/Industrial Measures*	4/29/2016
5	**New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs –** *Residential, Multi-family, and Commercial/Industrial Measures*	7/17/2017
5.1	**New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs –** *Residential, Multi-family, and Commercial/Industrial Measures*	3/15/2018

5.2	**New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs –** *Residential, Multi-family, and Commercial/Industrial Measures*	4/10/2018
6	**New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs –** *Residential, Multi-family, and Commercial/Industrial Measures*	4/16/2018
6.1	**New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs –** *Residential, Multi-family, and Commercial/Industrial Measures*	1/31/2019
7	**New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs –** *Residential, Multi-family, and Commercial/Industrial Measures*	4/15/2019
8	**New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs –** *Residential, Multi-family, and Commercial/Industrial Measures*	7/31/2020
9	**New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs –** *Residential, Multi-family, and Commercial/Industrial Measures*	8/30/2021

Acknowledgements The *New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs – Residential, Multi-family, and Commercial/Industrial Measures*, Version 9, dated August 30, 2021, was updated by the Technical Resource Manual Management Committee led by the Joint Utilities[1] in consultation with New York State Department of Public Service. In accordance with the Commission's February 26, 2015 Order in Case 14-M-0101 – Proceeding on the Motion of the Commission in Regard to Reforming the Energy Vision, Staff has transferred this document to the Joint Utilities as of June 1, 2015 to support the Joint Utilities in assuming responsibility for the ongoing maintenance of the Technical Resource Manual.

[1] Central Hudson Gas and Electric Corporation ("Central Hudson"), Consolidated Edison Company of New York, Inc. ("Con Edison"), National Fuel Gas Distribution Corporation ("National Fuel"), New York State Electric & Gas Corporation ("NYSEG"), Niagara Mohawk Power Corporation d/b/a National Grid, The Brooklyn Union Gas Company d/b/a National Grid NY and KeySpan Gas East Corporation d/b/a National Grid (collectively "National Grid"), Orange and Rockland Utilities, Inc. ("O&R"), and Rochester Gas and Electric Corporation ("RG&E")

Table of Revisions/Changes

Revision Number	Addition/ Revision	Issue Date	Effective Date	Measure	Description of Change	Location/Page in TRM
12-20-01	R	12/31/2020	1/1/2022	R/MF Insulation – Hot Water and Steam Pipe	Expanded default tables to include 0.5 inch diameter pipe; Updated language regarding other pipe materials from "under evaluation" to "ineligible due to limited savings"	Pg. 73
12-20-02	R	12/31/2020	1/1/2022	R/MF Insulation – Opaque Shell	Added language to Measure Description regarding wall and ceiling insulation; Revised savings estimation methodology, variable terms, definitions and default tables to rely on from application insulation upgrades, weather data, and HVAC efficiency, removing dependency on Appendix E	Pg. 80
12-20-03	A	12/31/2020	12/31/2020	R/MF Adaptive Photonic Control	New Measure Added	Pg. 273
12-20-04	R	12/31/2020	1/1/2022	R/MF Pool Pump	Reworded Measure Description for clarity; Revised savings estimation methodology, variable terms, definitions, deemed savings values, and default tables to reflect updated ENERGY STAR savings calculator; Updated Summer Peak Coincident Demand Savings to N/A	Pg. 336
12-20-05	A	12/31/2020	12/31/2020	C/I Electric Deck Oven	New Measure Added	Pg. 419
12-20-06	R	12/31/2020	1/1/2022	C/I Insulation – Hot Water and Steam Pipe	Corrected Equipment Type description for Steam, Oil Fired boiler efficiency; Expanded default tables to include 0.5 inch diameter pipe; Updated language regarding other pipe materials from under evaluation to ineligible due to limited savings	Pg. 505
12-20-07	A	12/31/2020	12/31/2020	C/I Adaptive Photonic Control	New Measure Added	Pg. 771
12-20-08	A	12/31/2020	12/31/2020	C/I Boiler Economizer	New Measure Added	Pg. 645
12-20-10	R	12/31/2020	12/31/2020	C/I Notched and Synchronous Belt	Updated algorithm to include HVAC interactive effects; Added algorithm to estimate fuel savings; Modified Ancillary Fossil Fuel/Electric Savings Impacts to reflect included HVAC impacts	Pg. 857
12-20-11	A	12/31/2020	12/31/2020	C/I Pool Pump	New Measure Added	Pg. 869
12-20-13	R	12/31/2020	1/1/2022	R/MF Interior and Exterior Lighting	Updated Measure Description regarding EISA 2007 regulations; Updated Coincidence Factor; Updated baseline wattage default lookup tables; Modified Operating Hours to include location dependency	Pg. 320

Revision Number	Addition/ Revision	Issue Date	Effective Date	Measure	Description of Change	Location/Page in TRM
3-21-02	R	4/14/2021	1/1/2022	R/MF Air Leakage Sealing	Added language to Measure Description detailing qualifying circumstances of application without blower door testing; Added detail specifying application of algorithm methods; Updated variable terms for consistency with other measures; Added change in infiltration rate default value when blower door test is not feasible	Pg. 67
3-21-03	R	4/14/2021	1/1/2022	R/MF Blown-In Insulation	Changed Measure Name and Measure Description to expand measure to any blown-in insulation material and application in walls, in addition to attics; Corrected heating component of Annual Electric Energy Savings equation; Corrected Equipment Type description for Steam, Oil Fired boiler efficiency	N/A - REMOVED
3-21-05	R	4/14/2021	4/14/2021	R/MF Insulation – Opaque Shell	Corrected heating component of Annual Electric Energy Savings equation; Removed restriction of central equipment only on existing cooling consideration;	Pg. 80
3-21-09	A	4/14/2021	4/14/2021	C/I Clothes Washer	New Measure Added	Pg. 394
3-21-10	R	4/14/2021	1/1/2022	C/I Refrigerators and Freezers	Updated Measure Description, Baseline Efficiencies, Compliance Efficiency, and sources to include ENERGY STAR® laboratory grade refrigerators and freezers	Pg. 459
3-21-11	A	4/14/2021	4/14/2021	C/I Air Leakage Sealing	New Measure Added	Pg. 491
3-21-12	A	4/14/2021	4/14/2021	C/I Insulation – Opaque Shell	New Measure Added	Pg. 513
3-21-13	R	4/14/2021	4/14/2021	C/I Instantaneous Water Heater	Clarified Baseline Efficiencies default as application for new construction only; updated new construction Baseline Efficiencies default to100-gallon storage type water heater	Pg. 567
3-21-14	A	4/14/2021	4/14/2021	C/I Drain Water Heat Recovery (DWHR)	New Measure Added	Pg. 590
3-21-15	A	4/14/2021	4/14/2021	C/I PEI-Rated Clean Water Pump	New Measure Added	Pg. 864
3-21-16	A	4/14/2021	4/14/2021	C/I High Efficiency Transformer	New Measure Added	Pg. 889
3-21-17	A	4/14/2021	4/14/2021	C/I High Frequency Battery Charger	New Measure Added	Pg. 895
3-21-21	R	4/14/2021	1/1/2022	R/MF Adaptive Photonic Control for HVAC Fan Motors	Modified savings algorithm, variable terms, and definitions to differentiate between savings associated with cooling, heating, and fan components; Updated Annual Fuel Energy Savings equation to consider retrofitted system space heating input fuel rating; Added detail to Operating Hours	Pg. 273

Revision Number	Addition/ Revision	Issue Date	Effective Date	Measure	Description of Change	Location/Page in TRM
3-21-22	R	4/14/2021	1/1/2022	R/MF Steam Trap – Low Pressure Space Heating	Modified Measure Description to clarify application; Revised variable terms and definition to capture hours trap is pressurized	Pg. 286
3-21-23	R	4/14/2021	1/1/2022	C/I Adaptive Photonic Control for HVAC Fan Motors	Modified savings algorithm, variable terms, and definitions to differentiate between savings associated with cooling, heating, and fan components; Updated Annual Fuel Energy Savings equation to consider retrofitted system space heating input fuel rating; Added detail to Operating Hours	Pg. 771
3-21-24	R	4/14/2021	1/1/2022	C/I Steam Trap – Low Pressure Space Heating	Modified Measure Description to clarify application; Revised variable terms, definition, default hours and source to capture hours trap is pressurized	Pg. 803
3-21-25	R	4/14/2021	1/1/2022	C/I Steam Trap Monitoring System – Low Pressure Space Heating	Modified Measure Description to clarify application; Revised variable terms, definition, default hours and source to capture hours trap is pressurized	Pg. 808
7-21-02	A	08/30/2021	08/30/2021	R/MF Dehumidifier Recycling	New Measure Added	Pg. 53
7-21-03	R	08/30/2021	1/1/2022	R/MF Air Conditioner – Room (RAC) Cover and Gap Sealer	Added language to Measure Description to clarify applicability of measure to permanently installed RACs	Pg. 62
7-21-05	R	08/30/2021	1/1/2022	R/MF Insulation – Opaque Shell	Changed Measure Description to incorporate provisions for Blown-In Insulation; Added baseline defaults for uninsulated walls and ceilings. Revised savings estimation methodology	Pg. 71
7-21-06	A	08/30/2021	08/30/2021	R/MF Window- Film	New Measure Added	Pg. 96
7-21-07	R	08/30/2021	1/1/2022	R/MF Heat Pump Water Heater	Added language to Measure Description detailing direction for baseline assumptions for new construction/major renovation; Added baseline heating efficiency default options; Added electric demand penalty option	Pg. 111
7-21-09	R	08/30/2021	1/1/2022	R/MF Interior and Exterior Lighting	Modified Baseline Efficiencies lumen bins to eliminate gaps	Pg. 320
7-21-10	A	08/30/2021	08/30/2021	R/MF Heat Pump Pool Heater	New Measure Added	Pg. 341
7-21-11	R	08/30/2021	1/1/2022	R/MF Solar Pool Heater	Measure Description expanded to include multiple solar heating technologies; Updated Annual Fossil Fuel Energy Savings algorithm.	Pg. 354

Revision Number	Addition/ Revision	Issue Date	Effective Date	Measure	Description of Change	Location/Page in TRM
7-21-12	R	08/30/2021	1/1/2022	C/I High Speed Fan	Added detail specifying application of algorithm to include all fan types; Updated Baseline Efficiencies and Compliance Efficiency defaults to include all fan types under CFM/W; Updated operating hours for exhaust/ventilation fans.	Pg. 360
7-21-14	A	08/30/2021	08/30/2021	C/I Central – Pumped GSHP	New Measure Added	Pg. 717
7-21-15	R	08/30/2021	08/30/2021	C/I High Volume Low Speed Fan	Revised savings estimation methodology, variables terms, definitions, and default tables to reflect lbf/kW.	Pg. 741
7-21-16	C	08/30/2021	08/30/2021	C/I Advanced RTU Control	Updated algorithm, terms, and variables to include electric heating impacts; Revised fan control energy savings factor; Updated unit energy savings tables; Moved compliance detail from Measure Description to Compliance Efficiency	Pg. 779
7-21-18	A	08/30/2021	08/30/2021	C/I Heat Pump Pool Heater	New Measure Added	Pg. 880
7-21-19	A	08/30/2021	08/30/2021	C/I Solar Pool Cover	New Measure Added	Pg. 902
7-21-20	R	08/30/2021	1/1/2022	C/I EC Motor – Refrigerated Case or Walk-in	Revised language in the Summary of Variables and Data Sources table to allow COP values to come from application when manufacture/nameplate data is missing.	Pg. 943
7-21-21	R	08/30/2021	1/1/2022	Appendix P	Updated EUL entries for all measures in this Record of Revision	Pg. 1271
7-21-22	R	08/30/2021	1/1/2022	R/MF Low-Flow Showerhead	Added baseline assumption for LMI application; Updated person per household to allow from application	Pg. 153
7-21-23	C	08/30/2021	08/30/2021	R/MF Thermostatic Radiator Valve (TRV) – one Pipe Steam Radiator	Corrected deemed average fuel savings	Pg. 310

Revision Number	Addition/ Revision	Issue Date	Effective Date	Measure	Description of Change	Location/Page in TRM
7-21-24	R	8/30/2021	1/1/2022	Multiple Sections	Added guidance pertaining to LMI applications to Introduction. Added example calculation sections to each measure. Added oil-fired furnace and oil-fired steam boiler baselines to relevant tables. Modified “baseline” and “ee” subscript definitions. Provided “from application” option for C&I HDD/CDD. Included guidance for a new custom measure category (Category 5) in Custom Measure section. Correction applied to EFLH values in Appendix G. Revised standby loss calculation for storage type water heaters. Removed default water heater setpoint temperature. Removed Et baseline option for smaller gas-fired heating equipment to eliminate ambiguity. Included guidance for establishing gas peak load shape factors in a new appendix (Appendix Q). Minor edits to correct typos and apply consistent language and formatting throughout. Broken in-document links restored.	Throughout

TABLE OF CONTENTS

INTRODUCTION.....1

History.....1
System Peak Demand Definition.....3
Natural Gas Peak Savings Definition.....4
Coincidence Factor.....4
Ancillary Non-Gas Fossil Fuel Impacts.....5
Annual/Life-cycle Savings.....5
Equivalent Full Load Hours (EFLH), for Heating or Cooling.....5
Application of Methods for Low- and Moderate-Income (LMI) Residential.....5

SINGLE AND MULTI-FAMILY RESIDENTIAL MEASURES.....6

APPLIANCE 6
Air Purifier.....6
Clothes Dryer.....10
Clothes Washer.....15
Dehumidifier.....22
Dishwasher.....26
Fireplace.....32
Refrigerator and Freezer.....36
Soundbar.....41
APPLIANCE – CONTROL 44
Advanced Power Strip (APS).....44
APPLIANCE RECYCLING 48
Air Conditioner - Room (RAC) Recycling.....48
Dehumidifier Recycling.....53
Refrigerator and Freezer Recycling.....57
BUILDING SHELL 62
Air Conditioner – Room (RAC) Cover and Gap Sealer.....62
Air Leakage Sealing.....67
Insulation - Hot Water and Steam Pipe.....73
Insulation - Opaque Shell.....80
Window.....88
Window – Film.....96
Window - Low-E Storm.....105
DOMESTIC HOT WATER 111
Heat Pump Water Heater (HPWH) – Air Source.....111
Indirect Water Heater.....124
Storage Tank and Instantaneous Domestic Water Heater.....130
DOMESTIC HOT WATER – CONTROL 139
Drain Water Heat Recovery (DWHR).....139
Low-Flow - Faucet Aerator.....146
Low-Flow - Showerhead.....153
Thermostatic Shower Restriction Valve.....160
HEATING, VENTILATION AND AIR CONDITIONING (HVAC) 169
Air Conditioner - Central (CAC).....169
Air Conditioner - Room (RAC).....173
Air Conditioner and Heat Pump – Packaged Terminal.....178
Boiler, Furnace and Unit Heater.....186
Boiler and Furnace - Combination ("Combi") Boiler and Furnace.....191

Duct Sealing and Insulation *199*
Electronically Commutated (EC) Motor – HVAC Blower Fan *206*
Electronically Commutated (EC) Motor – Hydronic Circulator Pump *210*
Energy and Heat Recovery Ventilator *214*
Heat Pump – Air Source (ccASHP) *225*
Heat Pump – Water-to-Air Ground Source (GSHP) *241*
Refrigerant Charge Correction & Tune Up – Air Conditioner and Heat Pump *261*
Tune-Up - Boiler *267*
Tune-Up - Furnace *270*
HEATING, VENTILATION AND AIR CONDITIONING (HVAC) – CONTROL 273
Adaptive Photonic Control for HVAC Fan Motors *273*
Boiler – Advanced Control *280*
Outdoor Temperature Setback Control for Hydronic Boiler *283*
Steam Trap – Low Pressure Space Heating *286*
Submetering *291*
Thermostat - Learning *294*
Thermostat - Programmable Setback *300*
Thermostat - Wi-Fi (Communicating) *306*
Thermostatic Radiator Valve (TRV) – One Pipe Steam Radiator *310*
Smart Thermostatic Radiator Enclosure (TRE) *314*
LIGHTING 320
Interior and Exterior Lighting *320*
LIGHTING - CONTROL 330
MOTORS AND DRIVES 331
Pool Circulator Timer *331*
Pool Pump *336*
OTHER 341
Heat Pump Pool Heater *341*
Pool Heater *350*
Solar Pool Heater *354*

COMMERCIAL AND INDUSTRIAL MEASURES 360

AGRICULTURAL EQUIPMENT 360
High Speed Fan *360*
Milk Pre-Cooler Heat Exchanger *366*
Refrigeration Heat Recovery – Dairy Farms *371*
Scroll Compressor – Dairy Farms *377*
AGRICULTURAL EQUIPMENT – CONTROL 382
Engine Block Heater Timer *382*
Variable Speed Drive Vacuum Pump – Dairy Farms *385*
APPLIANCE 389
Clothes Dryer *389*
Clothes Washer *394*
Combination Oven *400*
Conveyor Broiler *410*
Dishwasher *413*
Electric Deck Oven *419*
Fireplace *425*
Ice Maker *429*
Infrared Charbroiler *435*
Infrared Salamander Broiler *440*
Insulated Holding Cabinet *443*
Oven, Steamer, Fryer and Griddle *448*
Refrigerators and Freezers *459*

APPLIANCE – CONTROL 465
Advanced Power Strip (APS) *465*
Vending Machine and Novelty Cooler Control *469*
APPLIANCE RECYCLING 475
Air Conditioner – Room (RAC) Recycling *475*
BUILDING SHELL 481
Air Curtain *481*
Air Leakage Sealing *491*
Cool Roof *501*
Insulation - Hot Water and Steam Pipe *505*
Insulation - Opaque Shell *513*
Window - Film *519*
Window - Glazing *523*
COMPRESSED AIR 528
Air Compressor *528*
Compressed Air Heat Recovery *532*
Compressed Air Flow Controller *537*
Compressed Air - Low Pressure Drop Filters *542*
Engineered Air Nozzle *547*
No Air Loss Water Drain *551*
Refrigerated Air Dryer *555*
DOMESTIC HOT WATER 558
Indirect Water Heater *558*
Instantaneous Water Heater *567*
Storage Tank Water Heater *575*
DOMESTIC HOT WATER (DHW) – CONTROL 582
Central Domestic Hot Water (DHW) Control *582*
Drain Water Heat Recovery (DWHR) *590*
Low-Flow - Faucet Aerator *596*
Low-Flow - Pre-Rinse Spray Valve (PRSV) *602*
Low-Flow - Salon Valve *607*
Low-Flow - Showerhead *612*
HEATING, VENTILATION AND AIR CONDITIONING (HVAC) 616
Air Conditioner and Heat Pump – Packaged Terminal *616*
Air Conditioner and Heat Pump - Unitary & Applied *623*
Boiler, Furnace and Unit Heater *632*
Boiler and Furnace - Combination ("Combi") Boiler and Furnace *636*
Boiler Economizer *645*
Chiller - Air and Water Cooled *649*
Chiller - Cooling Tower *653*
Duct Sealing and Insulation *656*
Economizer - Dual Enthalpy Air Side *662*
Electronically Commutated (EC) Motor - HVAC Blower Fan *665*
Electronically Commutated (EC) Motor – Hydronic Circulator Pumps *670*
Energy and Heat Recovery Ventilator *677*
Heat Pump – Air Source (ccASHP) *686*
Heat Pump – Water-to-Air Ground Source (GSHP) *702*
Heat Pump – Water-to-Air Ground Source (GSHPs) in Systems with Central Pumping *717*
High-Volume Low Speed (HVLS) Fan *741*
Infrared Heater *746*
Kitchen Demand Control Ventilation (KDCV) *750*
Refrigerant Charge Correction & Tune Up - Air Conditioner and Heat Pump *754*
Tune-Up - Boiler *760*
Tune-Up - Chiller System *763*

Tune-Up - Furnace *767*
HEATING, VENTILATION AND AIR CONDITIONING (HVAC) – CONTROL 771
Adaptive Photonic Control for HVAC Fan Motors *771*
Advanced RTU Control *779*
Demand Control Ventilation (DCV) *786*
Energy Management System (EMS) - Guest Room *790*
Outdoor Temperature Setback Control for Hydronic Boiler *796*
Pneumatic System to Direct Digital Control (DDC) System Upgrade *799*
Steam Trap – Low Pressure Space Heating *803*
Steam Trap Monitoring System – Low Pressure Space Heating *808*
Thermostat - Wi-Fi (Communicating) *813*
Thermostatic Radiator Valve (TRV) *817*
LIGHTING 821
Interior and Exterior Lighting *821*
Refrigerated Case LED *828*
LIGHTING – CONTROL 832
Bi-Level Lighting *832*
Interior Lighting Control *837*
MOTORS AND DRIVES 843
Elevator Modernization *843*
Motor *851*
Notched and Synchronous Belt *857*
PEI-Rated Clean Water Pump *864*
Pool Pump *869*
Variable Frequency Drive (VFD) - Fan and Pump *873*
OTHER 876
Pool Heater *876*
Heat Pump Pool Heater *880*
High Efficiency Transformer *889*
High Frequency Battery Charger *895*
Solar Pool Cover *902*
PROCESS EQUIPMENT 910
Ozone Generator for On-Premises Laundry *910*
Process Exhaust Filtration and Recirculation *915*
Steam Trap - Other Application *919*
Steam Trap Monitoring System – Other Applications *925*
REFRIGERATION 930
Air-Cooled Refrigeration Condenser *930*
Automatic Door Closer for Walk-In Cooler/Freezer *933*
Cooler and Freezer Door Gasket *936*
Cooler and Freezer Door Strip *939*
Electronically Commutated (EC) Motor - Refrigerated Case or Walk-In Cooler/Freezer Evaporator Fan *943*
Evaporator Fan Motor – with Permanent Magnet Synchronous Motor (PMSM), for Refrigerated Case or Walk-In Cooler/Freezer *950*
Refrigerated Case Door *954*
Refrigerated Case Night Cover *959*
REFRIGERATION - CONTROL 963
Anti-Condensation Heater Control *963*
Evaporator Fan Control *967*
Floating Head Pressure Control *970*

CUSTOM MEASURES 974

DEFINITIONS 974
CUSTOM MEASURES 975

Category 1 – Unique Measures/Projects *975*
Category 2 – Measures Including Prescriptive Measures Not in the TRM *976*
Category 3 – Measures in TRM but Used in a Different Application/Environment *976*
Category 4 – Whole-Building Analysis *977*
Category 5 – Residential Retrofit Standardized Simulation for Measure Packages *980*

APPENDIX A 999

BUILDING TYPES 999
PROTOTYPICAL BUILDING DESCRIPTIONS 1000
Residential Building Prototypes *1000*
Single-family Residential Prototype *1000*
Multi-family Low-Rise *1003*
Multi-family High-Rise *1006*
Commercial Building Prototypes *1009*

APPENDIX B 1038

HVAC WEIGHTING FACTORS 1038
Single-family Residential Building Calculations *1038*
Multi-family Residential Building Calculations *1039*
Commercial Building Calculations *1040*

APPENDIX C 1041

STANDARD FIXTURE WATTS 1041
Compact Fluorescent Fixtures *1041*
EXIT Sign Fixtures *1045*
Linear Fluorescent Fixtures *1047*
Circline Fluorescent Fixtures *1068*
U-Tube Fluorescent Fixtures *1069*
Standard Incandescent Fixtures *1070*
Halogen Incandescent Fixtures *1072*
QL Induction Fixtures *1073*
High Pressure Sodium Fixtures *1074*
Metal Halide Fixtures *1074*
Mercury Vapor Fixtures *1076*

APPENDIX D 1078

HVAC INTERACTIVE EFFECTS MULTIPLIERS 1078
Default Values *1078*
Single-family Residential *1078*
Multi-family Low-rise *1079*
Multi-family High-rise *1079*
Small Commercial Buildings *1080*
Large Commercial Buildings *1082*
College Dormitory *1083*
Refrigerated Warehouse *1084*

APPENDIX E 1085

OPAQUE SHELL MEASURE SAVINGS 1085
Single-family Residential Insulation Upgrades *1085*
Multi-Family Low-rise Insulation Upgrades *1106*
Multi-Family High-rise Insulation Upgrades *1127*
Infiltration Reduction *1137*
Commercial Ceiling Insulation Upgrade *1139*

APPENDIX F **1162**

WINDOW AND HIGH PERFORMANCE GLAZING 1162
Single-family Residential Energy Star® Windows *1162*
Multi-family Low-rise Energy Star® Windows *1163*
Commercial High Performance Windows *1165*
Window Film *1177*

APPENDIX G **1180**

EQUIVALENT FULL-LOAD HOURS (EFLH), FOR HEATING AND COOLING 1180
Single-family Detached Cooling EFLH by Vintage and City *1180*
Multi-family Low-Rise Cooling EFLH by Vintage and City *1181*
Multi-family High-Rise Cooling EFLH by Vintage and City *1181*
Single-family Detached Heating EFLH by Vintage and City *1181*
Multi-family Low-Rise Heating EFLH by Vintage and City *1181*
Multi-family High-Rise Heating EFLH by Vintage and City *1182*
Small Commercial Cooling EFLH *1183*
Large Commercial Cooling EFLH *1183*
Small Commercial Heating EFLH *1184*
Large Commercial Heating EFLH *1184*

APPENDIX H **1186**

HVAC DISTRIBUTION EFFICIENCIES 1186

APPENDIX I **1192**

COOL ROOF 1192

APPENDIX J **1195**

COMMERCIAL HVAC UNIT SAVINGS 1195
Air Side Economizer *1195*
Close Approach Cooling Towers *1196*
Economizer *1197*

APPENDIX K **1202**

VARIABLE FREQUENCY DRIVES 1202

APPENDIX L **1205**

MINIMUM MOTOR EFFICIENCY – ECCCNYS 1205

APPENDIX M **1206**

GUIDELINES FOR EARLY REPLACEMENT CONDITION 1206

APPENDIX N **1257**

SPECIAL CIRCUMSTANCE 1257

APPENDIX O **1267**

COMMERCIAL AND INDUSTRIAL LIGHTING POLICY 1267
Introduction *1267*
The Overall Principles *1268*
Discussion by Type of Equipment Replaced *1268*
Eligibility for Rebates *1269*
Costs to be Modeled *1269*

APPENDIX P **1271**

EFFECTIVE USEFUL LIFE (EUL) 1271

Single and Multi-family Residential Measures *1271*

Commercial and Industrial Measures *1277*

APPENDIX Q **1287**

PEAK LOAD SHAPE FACTORS 1287

Natural Gas *1287*

Natural Gas Peak Savings Definition *1287*

Peak-Day Gas Impact Calculation Methodology *1287*

FORMS **1290**

TYPICAL MEASURE HEADINGS 1290

GLOSSARY **1292**

INTRODUCTION

The Commission is committed to using the best possible information in the estimation of savings from measures installed through ratepayer funded energy efficiency programs. Information contained within this manual supersedes information contained in earlier versions and is effective as of the date specified.

HISTORY

In a series of Commission orders related to approving the portfolio of programs associated with the Energy Efficiency Portfolio Standard (EEPS), the Commission approved technical manuals designed to provide a standardized, fair, and transparent approach for measuring program energy savings. The five technical manuals approved between December 2008 and December 2009 covered a variety of measures applicable to the single-family, multi-family, and commercial/industrial sectors. They were consolidated into one manual entitled, *New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs- Residential, Multi-family, and Commercial/Industrial Measures* ("the Consolidated Technical Resource Manual") dated October 15, 2010[2] with an effective date of January 1, 2011.

On December 10, 2014, the Department of Public Service Staff (Staff), released the *New York Standard Approach for Estimating Energy Savings from Energy Efficiency Program – Single and Multi-Family Residential, and Commercial/Industrial Measures, Version 2* (Version 2) incorporating all revisions between October 15, 2011 and September 30, 2014, with an effective date of December 10, 2014.

The release of the *New York Standard Approach for Estimating Energy Savings from Energy Efficiency Program – Single and Multi-Family Residential, and Commercial/Industrial Measures, Version 3* (Version 3) incorporated all revisions between December 10, 2014 and June 1, 2015, with an effective date of January 1, 2016.

The release of the *New York Standard Approach for Estimating Energy Savings from Energy Efficiency Program – Single and Multi-Family Residential, and Commercial/Industrial Measures, Version 4* (Version 4) incorporated all revisions between December 10, 2014 and June 1, 2015, with an effective date of January 1, 2017.

The release of the *New York Standard Approach for Estimating Energy Savings from Energy Efficiency Program – Single and Multi-Family Residential, and Commercial/Industrial Measures, Version 5* (Version 5) incorporates all revisions between April 29, 2016 and June 30, 2017, with an effective date of January 1, 2018.

The release of the *New York Standard Approach for Estimating Energy Savings from Energy Efficiency Program – Single and Multi-Family Residential, and Commercial/Industrial Measures, Version 5.1* (Version 5.1) incorporated all revisions between July 1, 2017 and December 31, 2017

[2] For purposes of tracking Technical Resource Manual updates, the October 15, 2010 Consolidated Technical Resource Manual will also be referred to as Version 1, with the protocol of all subsequent Consolidated Updates being released with sequential Version numbers.

with an effective date of January 1, 2018. Version 5.1 was filed for administrative purposes so that information effective January 1, 2018 is published in one location.

The release of the *New York Standard Approach for Estimating Energy Savings from Energy Efficiency Program – Single and Multi-Family Residential, and Commercial/Industrial Measures, Version 5.2* (Version 5.2) incorporated all revisions between July 1, 2017 and December 31, 2017 with an effective date of January 1, 2018. Version 5.2 was filed for administrative purposes so that information effective January 1, 2018 was published in one location. Version 5.2 includes omissions found in the compiling of Q3-2017 Records-of Revision into Version 5.1.

The release of the *New York Standard Approach for Estimating Energy Savings from Energy Efficiency Program – Single and Multi-Family Residential, and Commercial/Industrial Measures, Version 6* (Version 6) incorporated all revisions between July 1, 2017 and March 29, 2018, with an effective date of January 1, 2019, new measures between December 31, 2017 and March 29, 2018 with an effective date of March 29, 2018 as well as the removal of one measure effective March 30, 2018.

The release of the *New York Standard Approach for Estimating Energy Savings from Energy Efficiency Program – Single and Multi-Family Residential, and Commercial/Industrial Measures, Version 6.1* (Version 6.1) incorporated all revisions between April 17, 2018 and January 25, 2019, with an effective date of January 31, 2019. Version 6.1 was filed for administrative purposes so that information effective January 1, 2019 was published in one location. Version 6.1 also included revisions applied to establish consistent language, content and formatting throughout the TRM.

The release of the *New York Standard Approach for Estimating Energy Savings from Energy Efficiency Program – Single and Multi-Family Residential, and Commercial/Industrial Measures, Version 7* (Version 7) incorporated all revisions between January 1, 2019 and March 29, 2019, with an effective date of January 1, 2020, and new measures and corrections between January 31, 2019 and March 29, 2019 with an effective date of March 29, 2019. Version 7 also included revisions applied to establish consistent language, content and formatting throughout the TRM.

The release of the *New York Standard Approach for Estimating Energy Savings from Energy Efficiency Program – Single and Multi-Family Residential, and Commercial/Industrial Measures, Version 8* (Version 8) incorporated all revisions between March 29, 2019 and July 31, 2020, with an effective date of January 1, 2021, and new measures and corrections between March 29, 2019 and July 31, 2020 with an effective date of July 31, 2020. Version 8 also included revisions applied to establish consistent language, content and formatting throughout the TRM.

This current release of the *New York Standard Approach for Estimating Energy Savings from Energy Efficiency Program – Single and Multi-Family Residential, and Commercial/Industrial Measures, Version 9* (Version 9) incorporates all revisions between July 31, 2020 and August 30, 2021, with an effective date of January 1, 2022, and new measures and corrections between July 31, 2020 and August 30, 2021 with an effective date of August 30, 2021. Version 9 also includes revisions applied to establish consistent language, content and formatting throughout the TRM.

For a reference of historical changes to measures presented in the Technical Resource Manual (TRM), each measure chapter includes a section titled "Record of Revision." If the measure was not revised between its original publication (in 2008-2009) and its publication in the Consolidated Technical Resource Manual, the Revision Number is 0. If the measure was added/revised between its original publication (in 2008-2009) and its publication in the Consolidated Technical Manual, the Revision Number will correspond to the number of changes/additions of that measure (ex. 1 or 2). Since the publication of the Consolidated Technical Resource Manual, dated October 15, 2010, Staff has worked with the E^2 Working Group[3] and its Technical Resource Manual/Measure Classification Lists Subcommittee to review and approve proposed revisions utilizing the process established by Commission Order[4]. These revisions have been documented through the issuance of Record of Revisions and the Revision Number will correspond to the Revision Number assigned on its date of issue. These Revision Numbers identifies the month and year of the Record of Revision in which the measure appeared and includes an index number, which indicates the order in which that measure appeared in the identified Record of Revision (e.g. Revision Number "1-17-5" refers to the fifth measure appearing in the Record of Revision published in January 2017). Revisions made subsequent to the release of Version 9 have been compiled for ease of reference in the "Table of Revisions/Changes" located just before the Table of Contents in this manual. These revisions are issued concurrent with Version 9.

SYSTEM PEAK DEMAND DEFINITION

System peak demand typically refers to the highest amount of electricity being consumed at any one point in time across the entire system network. In most cases, the system network referred to is the New York Control Area, managed by the New York Independent System Operator. It is the maximum level of hourly demand during a specific period. The peak periods most commonly identified are annual and seasonal (summer and winter). [5] Peak coincident demand is the demand of a measure that occurs at the same time as the system peak.

The TRM equations are developed to estimate peak electric savings (kW) along with electric consumption and fossil fuel consumption savings. The definition of the peak demand period for conducting engineering simulations and estimating coincidence factors are as follows:

Electricity – Summer Peak

According to the NYISO, system peaks generally occur during the hour ending at 5 pm on the hottest non-holiday weekday. The peak day can occur in June, July, or August, depending on the weather. Program Administrators (PAs) should calculate coincident peak demand savings based on the hottest summer non-holiday weekday during the hour ending at 5pm.

[3] The E^2 Working Group was formed on February 28, 2014 per the December 26, 2013 Commission Order in Case 07-M-0548 which directed the merger of the functions of the former Implementation Advisory Group (IAG) and the Evaluation Advisory Group (EAG) and directed Staff to work with NYSERDA and the utilities to form an E^2 Working Group.

[4] Case 07-M-0548, Order Approving Modifications to the Energy Efficiency Portfolio Standard (EEPS) Program to Streamline and Increase Flexibility in Administration (issued June 20, 2011).

[5] Glossary of Terms, Version 2.1, Northeast Energy Efficiency Partnerships, A project of the Regional Evaluation, Measurement and Verification Forum, Prepared by Paul Horowitz PAH Associates, p.25.

Building energy simulation programs or other calculation techniques using the Typical Meteorological Year version 3 (TMY3) data from the National Renewable Energy Laboratory (NREL) shall use the calendar year definition and day of the year as shown below:

City	Date	Temperature	Calendar Year
Albany	July 21	96	1995
Binghamton	August 14	93	1998
Buffalo	July 21	89	1995
Massena	August 15	94	1997
NYC	July 13	98	1990
Poughkeepsie	June 10	92	2005
Syracuse	July 4	97	2003

Note: For peak demand simulations, the calendar year is defined so that the days above fall on a non-holiday Friday. For Syracuse, this requires redefining the July 4th holiday.

Building energy simulation programs or other calculation techniques using different weather data sets shall choose a coincident peak demand hour consistent with the NY ISO definition above.

Electricity – Winter Peak

At this time, the TRM does not prescribe definitions of winter peak nor does it include provisions for estimating winter system peak savings. This content will be developed by the TRM Management Committee based on ongoing evaluation work and added in a future revision.

Natural Gas

The peak gas definition is based on the program-induced change in the average daily gas flow in which the distribution system, on average, reaches its pumping/consumption capacity such that as the temperature falls lower (or the heating degree days go higher) gas consumption does not increase. Setting the peak gas definition for this condition means that the gas peak is calculated to reflect the decreased cubic feet of natural gas expected to not flow through the distribution system during the 24-hour period as a result of the impacts of the gas energy efficiency program.

NATURAL GAS PEAK SAVINGS DEFINITION

Up State: The number of therms saved during a day, a 24 hour period starting at 10:00AM, in which the average temperature is minus nine -9ºF (-22.8 ºC).

Down State: The number of therms saved during a day, a 24 hour period starting at 10:00AM, in which the average temperature is zeroºF (-17.8ºC).

COINCIDENCE FACTOR

For purposes used in this manual, the Coincidence Factor (CF) is expressed as a ratio with the numerator being the simultaneous demand of a similar group of electrical appliances (measures) within a specified period, to the sum of their individual maximum demands within the same period.

ANCILLARY NON-GAS FOSSIL FUEL IMPACTS

The measures in this Manual that provide non-gas fuel interactions shall use the therm impact equations, with the following conversion factors:

Fuel	Heating Value	Conversion Factor
Propane	71,000 BTU/gal	1.41 gal per therm
#2 Fuel Oil	115,000 BTU/gal	0.87 gal per therm
#6 Fuel Oil	124,000 BTU/gal	0.81 gal per therm

ANNUAL/LIFE-CYCLE SAVINGS

The energy savings estimation methodologies presented in this Manual are designed to provide first year annual gross energy savings. Life cycle energy savings are calculated by multiplying first year gross energy savings by the EUL.

EQUIVALENT FULL LOAD HOURS (EFLH), FOR HEATING OR COOLING

The equivalent hours that a measure would need to operate at its peak capacity in order to consume its estimated annual kWh consumption (annual kWh/connected kW).[6] The ratio of the annual building energy (cooling or heating) consumed to the peak energy required is used to calculate EFLH. The listing of heating and cooling Equivalent Full Load Hours for seven cities in New York State can be found in Appendix G. Accordingly, the ratio for EFLH cooling is shown below:

$$EFLH_{cooling} = \frac{Annual\ kWh_{cooling}}{kW_{peak,cooling}}$$

APPLICATION OF METHODS FOR LOW- AND MODERATE-INCOME (LMI) RESIDENTIAL

The energy savings estimation methodologies presented in this Manual are applicable to LMI-eligible customers. Unless otherwise specified, measure methods shall be applied unaltered for LMI customers; however, where available, details of existing conditions may be substituted for prescribed and/or assumed baseline parameters utilized in estimation of energy savings.

Return to Table of Contents

[6] Massachusetts Technical Reference Manual for Estimating Savings from Energy Efficiency Measures, 2013-2015 Program Years – Plan Version, October 2012

SINGLE AND MULTI-FAMILY RESIDENTIAL MEASURES

APPLIANCE

AIR PURIFIER

Measure Description

This measure covers the installation of high efficiency room air purifiers. Room air purifiers - sometimes referred to as "room air cleaners" - are portable, electric appliances that remove fine particles, such as dust and pollen, from indoor air.[7] This measure applies to residential air purifiers (cleaners) meeting the minimum qualifying efficiency standards established under the ENERGY STAR® Program.[8]

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times (kWh_{baseline} - kWh_{ee})$$

$$kWh_{ee} = (8{,}760 - hrs) \times \frac{standby_{ee}}{1{,}000} + hrs \times \frac{CADR}{Eff_{ee} \times 1{,}000}$$

$$kWh_{baseline} = (8{,}760 - hrs) \times \frac{standby_{baseline}}{1{,}000} + hrs \times \frac{CADR}{Eff_{baseline} \times 1{,}000}$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \left(\frac{\Delta kWh}{hrs}\right) \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed
baseline	= Characteristic of baseline condition
ee	= Characteristic of energy efficient condition, per ENERGY STAR® eligibility criteria
hrs	= Operating hours per year

[7] ENERGY STAR® Air Purifiers (Cleaners): https://www.energystar.gov/products/appliances/air_purifiers_cleaners/
[8] ENERGY STAR® Product Specification for Room Air Cleaners, Eligibility Criteria, V2.0, April 2020

standby = Standby Power (Watts)
CADR = Clean Air Delivery Rate (CADR), a measure of the amount of contaminant-free air delivered by the qualified air purifier (cubic feet per minute)[2]
Eff = Efficiency (dust CADR/Watt); the ENERGY STAR® specification for room air purifiers measures energy efficiency by using a Clean Air Delivery Rate-to-Watt ratio.[9]
CF = Coincidence factor
8,760 = Hours per year
1,000 = Conversion factor, one kW equals 1,000 Watts

Summary of Variables & Data Sources

Variable	Value	Notes
hrs	5,840	Based on ENERGY STAR® Calculator default assumptions[10]
$standby_{ee}$		Based on ENERGY STAR® manufacture rating (Watts)
$standby_{baseline}$	1.0	Watts
CADR		Based on ENERGY STAR® manufacture rating
Eff_{ee}		Based on ENERGY STAR® manufacture rating (CADR/Watt)
$Eff_{baseline}$	1.0	CADR/Watt
CF	0.67	Assumes equal likelihood of usage at any time of day (16/24 hours)

Ratings are based on ENERGY STAR® Eligibility Criteria and the Savings Calculator for ENERGY STAR® Qualified Appliances.[4]

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.67.

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a standard efficiency room air purifier with an assumed efficiency of 1.0 CADR/Watt and a standby power of 1.0 Watts (from the ENERGY STAR® calculator default assumptions).

Compliance Efficiency from which Incentives are Calculated

The compliance condition is an ENERGY STAR® qualified room air purifier with minimum efficiency established per the table below.

Smoke CADR Rating	Minimum Smoke CADR/W
$30 \leq CADR < 100$	1.9
$100 \leq CADR < 150$	2.4

[9] ENERGY STAR® Product Specification for Room Air Cleaners, Eligibility Criteria, V2.0, April 2020
[10] ENERGY STAR® Savings Calculator for ENERGY STAR® Qualified Appliances (last updated October 1, 2016) https://www.energystar.gov/sites/default/files/asset/document/appliance_calculator.xlsx

Smoke CADR Rating	Minimum Smoke CADR/W
CADR ≥ 150	2.9

Additionally, qualified equipment must produce a minimum of 30 CADR for smoke, measured according to guidance provided in the latest ANSI/AHAM AC- and partial on-mode power allowance of 1.0 Watts for non Wi-Fi connected products and 2.0 Watts for connected products.

Operating Hours

The energy savings calculations use 16 hours of operation per day, 365 days a year, totaling 5,840 hours/year, per the Savings Calculator for ENERGY STAR® Qualified Appliances.

Example Calculation *(Not to be used as default)*

An existing residential customer installs a 45 CADR air purifier that meets the minimum qualifying standards established by ENERGY STAR®. The efficient air purifier has a rated efficiency of 2.2 CADR/Watt and standby power of 0.9W. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

$$\Delta kWh = units \times (kWh_{baseline} - kWh_{ee})$$

$$kWh_{ee} = (8{,}760 - hrs) \times \frac{standby_{ee}}{1{,}000} + hrs \times \frac{CADR}{Eff_{ee} \times 1{,}000}$$

$$kWh_{baseline} = (8{,}760 - hrs) \times \frac{standby_{baseline}}{1{,}000} + hrs \times \frac{CADR}{Eff_{baseline} \times 1{,}000}$$

$$\Delta kW = units \times \left(\frac{\Delta kWh}{hrs}\right) \times CF$$

units =1, from application
$standby_{ee}$ = 0.9 watt, from application
Eff_{ee} = 2.2 CADR/Watt, from application
CADR = 45, from application
$standby_{baseline}$ = 1.0 watt, from Summary of Variables and Data Sources table
$Eff_{baseline}$ = 1.0 CADR/Watt, from Summary of Variables and Data Sources table
hrs = 5,840, from Summary of Variables and Data Sources table
CF = 0.67, from Summary of Variables and Data Sources table

$$kWh_{ee} = (8{,}760 - 5{,}840) \times \frac{0.9}{1{,}000} + 5{,}840 \times \frac{45}{2.2 \times 1{,}000} = 122.08\ kWh$$

$$kWh_{baseline} = (8{,}760 - 5840) \times \frac{1.0}{1{,}000} + 5{,}840 \times \frac{45}{1.0 \times 1{,}000} = 265.72\ kWh$$

$$\Delta kWh = 1 \times (265.72 - 122.08) = 143.64\ kWh$$

$$\Delta kW = 1 \times \left(\frac{143.64}{5{,}840}\right) \times 0.67 = 0.0165\ kW$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. ENERGY STAR® Air Purifiers (Cleaners)
   Available from:
   https://www.energystar.gov/products/appliances/air_purifiers_cleaners/key_product_criteria
2. ENERGY STAR® Product Specification for Room Air Cleaners, Eligibility Criteria, V2.0, April 2020
   Available from:
   https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Final%20Version%202.0%20Room%20Air%20Cleaners%20Specification%20%28Rev.%20April%202020%29_0.pdf
3. Purchase energy-saving products, Savings Calculator for ENERGY STAR® Qualified Appliances (last updated October 2016)
   Available from: https://www.energystar.gov/buildings/facility-owners-and-managers/existing-buildings/save-energy/purchase-energy-saving-products

Record of Revision

Record of Revision Number	Issue Date
6-17-11	6/30/2017

Return to Table of Contents

CLOTHES DRYER

Measure Description

This measure covers residential grade clothes dryers meeting the criteria established under the ENERGY STAR® Program, Version 1.1, effective May 5, 2017 installed in residential settings.[11] ENERGY STAR® clothes dryers have a higher combined energy factor (CEF), and save energy through a combination of more efficient drying and reduced runtime of the drying cycle. More efficient drying is achieved through increased insulation, modifying operating conditions, improving air circulation, and improved efficiency of motors. Reduced dryer runtime is achieved through automatic termination of the dryer cycles based on temperature and moisture sensors. Clothes dryers originally qualified for the ENERGY STAR® label in May 2014. Clothes dryers that have earned this label are approximately 20% more efficient than non-qualified models.[12]

This measure applies to clothes dryers installed in single family homes and in-unit multifamily equipment.[13] For residential grade clothes dryers installed in multifamily common areas, the Clothes Dryer measure prescribed in the Commercial and Industrial section of this manual should be used.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times Cycles_{annual} \times Load \times \left(\frac{F_{elec,baseline}}{CEF_{baseline}} - \frac{F_{elec,ee}}{CEF_{ee}}\right)$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \frac{\Delta kWh}{hrs} \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = units \times Cycles_{annual} \times Load \times \left(\frac{F_{fuel,baseline}}{CEF_{baseline}} - \frac{F_{fuel,ee}}{CEF_{ee}}\right) \times \frac{3{,}412}{1{,}000{,}000}$$

where:

ΔkWh = Annual electric energy savings
ΔkW = Peak coincident demand electric savings

[11] ENERGY STAR® Program Requirements Product Specification for Clothes Dryers, Eligibility Criteria Version 1.1, May 2017
[12] Efficiency of ENERGY STAR® products: https://www.energystar.gov/products/appliances/clothes_dryers
[13] The Retail Products Platform (RPP) Evaluation Report, conducted by EMI Consulting d/b/a Con Edison (approved June 15, 2018), was reviewed for findings relevant to this measure. The findings of this report, which estimates the short-term energy savings and demand reduction attributable to the program's activities and assesses key components of the program's logic model, do not directly inform the algorithms, key inputs or default values found in this energy savings estimation methodology. As such, no changes have been applied as a result of this review.

ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
$Cycles_{annual}$	= Number of dryer cycles per year
Load	= Average total weight (lbs) of clothes per drying cycle
$_{baseline}$	= Characteristic of baseline condition
$_{ee}$	= Characteristic of energy efficient condition
F_{elec}	= Percentage of energy consumed that is derived from electricity
F_{fuel}	= Percentage of energy consumed that is derived from fossil fuel
CEF	= Combined energy factor (lb/kWh)
hrs	= Annual run hours of clothes dryer
CF	= Coincidence Factor
3,412	= Conversion factor, one kWh equals 3,412 BTU
1,000,000	= Conversion factor, one MMBtu equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
$Cycles_{annual}$		Lookup based on efficient dryer type in table below.[14]
Load		Lookup based on efficient dryer type in table below.[15]
$F_{elec,baseline}$		Lookup based on efficient dryer type in table below.[16]
$F_{elec,ee}$		Lookup based on efficient dryer type in table below.[17]
$F_{fuel,baseline}$		Lookup based on efficient dryer type in table below.[18]
$F_{fuel,ee}$		Lookup based on efficient dryer type in table below.[19]
$CEF_{baseline}$		Lookup based on efficient dryer type in table below.[20]
CEF_{ee}		Lookup based on efficient dryer type in table below.[21]
hrs		Lookup based on efficient dryer type in table below.[22]
CF	0.029	

Key Variables Lookup Table

Variable	Dryer Type				
	Vented Gas Dryer	*Ventless or Vented Electric, Standard ≥ 4.4 ft^3*	*Ventless or Vented Electric, Compact (120V) < 4.4 ft^3*	*Vented Electric, Compact (240V) < 4.4 ft^3*	*Ventless Electric, Compact (240V) < 4.4 ft^3*
$Cycles_{annual}$	283	283	283	283	283

[14] Savings calculator for ENERGY STAR® Qualified Appliances (accessed 10/18/2017)
[15] Ibid.
[16] ENERGY STAR® Program Requirements Product Specification for Clothes Dryers, Eligibility Criteria Version 1.1, May 2017
[17] Ibid.
[18] Ibid.
[19] Ibid.
[20] 10 CFR 430.32 (h)(3)
[21] ENERGY STAR® Program Requirements Product Specification for Clothes Dryers, Eligibility Criteria Version 1.1, May 2017
[22] Savings calculator for ENERGY STAR® Qualified Appliances (accessed 10/18/2017)

Variable	Dryer Type				
	Vented Gas Dryer	*Ventless or Vented Electric, Standard ≥ 4.4 ft³*	*Ventless or Vented Electric, Compact (120V) < 4.4 ft³*	*Vented Electric, Compact (240V) < 4.4 ft³*	*Ventless Electric, Compact (240V) < 4.4 ft³*
Load	8.45	8.45	3.00	3.00	3.00
$F_{elec,baseline}$	0.05	1.00	1.00	1.00	1.00
$F_{elec,ee}$	0.05	1.00	1.00	1.00	1.00
$F_{fuel,baseline}$	0.95	0.00	0.00	0.00	0.00
$F_{fuel,ee}$	0.95	0.00	0.00	0.00	0.00
$CEF_{baseline}$	3.30	3.73	3.61	3.27	2.55
CEF_{ee}	3.48	3.93	3.80	3.45	2.68
hrs	290	290	290	290	290

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.029.[23]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a standard efficiency, residential grade clothes dryer with operating specifications as defined in the Key Variables Lookup Table above.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a residential grade clothes dryer appearing on the ENERGY STAR® qualified products list.

Operating Hours

Operating hours for residential clothes dryers are provided in the Key Variables Lookup Table above.

Example Calculation *(Not to be used as default)*

An existing residential customer installs a vented gas dryer that meets the criteria established by ENERGY STAR®. Annual Electric Energy Savings, Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta kWh = units \times Cycles_{annual} \times Load \times \left(\frac{F_{elec,baseline}}{CEF_{baseline}} - \frac{F_{elec,ee}}{CEF_{ee}}\right)$$

[23] Based on metered data from Navigant Consulting, "EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (6/1/2012 – 5/31/2013) Appliance Rebate Program." March 2014, page 36. This report is not publicly available, but is referenced by the Mid-Atlantic Technical Reference Manual, Version 9.0, October 2019

$$\Delta kW = \frac{\Delta kWh}{hrs} \times CF$$

$$\Delta MMBtu = units \times Cycles_{annual} \times Load \times \left(\frac{F_{fuel,baseline}}{CEF_{baseline}} - \frac{F_{fuel,ee}}{CEF_{ee}}\right) \times \frac{3{,}412}{1{,}000{,}000}$$

units = 1, from application
$Cycles_{annual}$= 283, from Key Variables Lookup Table based on dryer type from application
Load = 8.45, from Key Variables Lookup Table based on dryer type from application
$F_{elec,baseline}$ =0.05, from Key Variables Lookup Table based on dryer type from application
$CEF_{baseline}$ = 3.30, from Key Variables Lookup Table based on dryer type from application
$F_{elec,ee}$ =0.05, from Key Variables Lookup Table based on dryer type from application
CEF_{ee} = 3.48, from Key Variables Lookup Table based on dryer type from application
$F_{fuel,baseline}$ = 0.95, from Key Variables Lookup Table based on dryer type from application
$F_{fuel,ee}$ = 0.95, from Key Variables Lookup Table based on dryer type from application
hrs = 290, from Key Variables Lookup Table based on dryer type from application
CF = 0.029, from Summary of Data Sources and Variables

$$\Delta kWh = 1 \times 283 \times 8.45 \times \left(\frac{0.05}{3.30} - \frac{0.05}{3.48}\right) = 1.87\ kWh$$

$$\Delta kW = \frac{0.85}{290} \times 0.029 = 0.000187\ kW$$

$$\Delta MMBtu = 1 \times 283 \times 8.45 \times \left(\frac{0.95}{3.30} - \frac{0.95}{3.48}\right) \times \frac{3{,}412}{1{,}000{,}000} = 0.12\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

A clothes dryer releases heat to the surrounding environment. Conventional vented dryers also vent air outside the building. The associated HVAC impact of dryers depends upon a number of variables including climate and placement of a dryer (i.e., in a conditioned or unconditioned space). It is an area of ongoing research.[24] These impacts are excluded from the methodology prescribed herein until they can be quantified and substantiated through independent research.

Ancillary Electric Savings Impacts

See Ancillary Fossil Fuel Savings Impacts section above.

[24] ENERGY STAR® Market & Industry Scoping Report: Residential Clothes Dryers, November 2011

References

1. ENERGY STAR® Program Requirements Product Specification for Clothes Dryers, Eligibility Criteria Version 1.1, May 2017
   Available from:
   https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Final%20Version%201.1%20Clothes%20Dryers%20Specification%20-%20Program%20Commitment%20Criteria%20and%20Eligibility%20Criteria.pdf
2. Purchase energy-saving products, Savings Calculator for ENERGY STAR® Qualified Appliances (last updated October 2016)
   Available from: https://www.energystar.gov/buildings/facility-owners-and-managers/existing-buildings/save-energy/purchase-energy-saving-products
3. 10 CFR 430.32 Energy and water conservation standards and their compliance dates.
   Available from: http://www.ecfr.gov/cgi-bin/text-idx?SID=a9921a66f2b4f66a32ec851916b7b9d9&mc=true&node=se10.3.430_132&rgn=div8
4. Navigant Consulting, EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (6/1/2012 – 5/31/2013) Appliance Rebate Program, March 2014 *via Mid-Atlantic Technical Reference Manual Version 9.0, May 2019*
   Available from:
   https://neep.org/sites/default/files/resources/Mid_Atlantic_TRM_V9_Final_clean_wUpdateSummary%20-%20CT%20FORMAT.pdf

Record of Revision

Record of Revision Number	Issue Date
6-16-1	6/30/2016
12-17-1	12/31/2017
12-18-1	12/28/2018

Return to Table of Contents

CLOTHES WASHER

Measure Description

This measure covers residential grade clothes washers meeting the criteria established under the ENERGY STAR® Program, Version 8.0, effective February 5, 2018, installed in residential settings.[25] ENERGY STAR® clothes washers have a higher Integrated Modified Energy Factor (IMEF) and a lower Integrated Water Factor (IWF), saving energy and water with greater tub capacities and sophisticated wash and rinse systems. Rather than filling the tub with water, efficient wash cycles are achieved by spinning or flipping clothes through a stream of water. Efficient rinse cycles are achieved through high-pressure spraying instead of soaking clothes. Reduced dryer load represents additional energy savings associated with the thorough removal of water from the clothes in the washer. Clothes washers originally qualified for the ENERGY STAR® label in 1997. Clothes washers that have earned this label use approximately 25% less energy and 45% less water than comparable non-qualified models.[26]

This measure addresses installation of top and front-loading residential clothes washers with capacities greater than 1.6 ft^3 and less than 8.0 ft^3. This measure applies to residential equipment installed in single-family homes or in multifamily buildings within the residential unit; it is not intended for use with washers in multifamily common areas.

The algorithms, inputs, and savings presented below assume a normal replacement scenario.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings[27]

Annual Electric Energy Savings

$$\Delta kWh = units \times \left[\Delta kWh_{washer} + (\Delta kWh_{wh} \times ElecSF_{wh}) + (\Delta kWh_{dryer} \times ElecSF_{dryer})\right]$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \frac{\Delta kWh}{hrs} \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = units \times \left[(\Delta MMBtu_{wh} \times FuelSF_{wh}) + (\Delta MMBtu_{dryer} \times FuelSF_{dryer})\right]$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program

[25] ENERGY STAR® Program Requirements Product Specification for Clothes Washers, Eligibility Criteria Version 8.0, February 2018
[26] Efficiency of ENERGY STAR® products: https://www.energystar.gov/products/appliances/clothes_washers
[27] Savings calculator for ENERGY STAR® Qualified Appliances (accessed 2/8/2018)

ΔkWh_{washer} = Annual clothes washer electric energy savings
ΔkWh_{wh} = Annual electric water heating energy savings
ΔkWh_{dryer} = Annual electric dryer energy savings
$ElecSF_{wh}$ = Electric Savings Factor for water heaters
$ElecSF_{dryer}$ = Electric Savings Factor for dryers
$\Delta MMBtu_{wh}$ = Annual fossil fuel water heating energy savings
$\Delta MMBtu_{dryer}$ = Annual fossil fuel dryer energy savings
$FuelSF_{wh}$ = Fossil fuel Savings Factor for water heaters
$FuelSF_{dryer}$ = Fossil fuel Savings Factor for dryers
hrs = Annual run hours of clothes washer
CF = Coincidence Factor

Summary of Variables and Data Sources

Variable	Value	Notes
ΔkWh_{washer}		Lookup from Per Unit Savings table below, based on product class.
ΔkWh_{wh}		Lookup from Per Unit Savings table below, based on product class.
ΔkWh_{dryer}		Lookup from Per Unit Savings table below, based on product class.
$ElecSF_{wh}$	Electric WH: 1.0 Fossil Fuel WH: 0 Unknown: 0.34	Based on EIA Residential Energy Consumption Survey (RECS) 2015 for Middle Atlantic States.[28]
$ElecSF_{dryer}$	Electric Dryer: 1.0 Gas Dryer: 0 Unknown: 0.67	Based on EIA Residential Energy Consumption Survey (RECS) 2015 for Middle Atlantic States.[29]
$\Delta MMBtu_{wh}$		Lookup from Per Unit Savings table below, based on product class.
$\Delta MMBtu_{dryer}$		Lookup from Per Unit Savings table below, based on product class.
$FuelSF_{wh}$	Electric WH: 0 Fossil Fuel WH: 1.0 Unknown: 0.66	Based on EIA Residential Energy Consumption Survey (RECS) 2015 for Middle Atlantic States.[30]

[28] EIA Residential Energy Consumption Survey (RECS) 2015 for Middle Atlantic States, Table HC1.7 ("Unknown" calculated as the number of homes with electric water heating divided by the total number of homes with electric or gas water heating)
[29] EIA Residential Energy Consumption Survey (RECS) 2015 for Middle Atlantic States, Table HC3.7 ("Unknown" calculated as the number of homes with electric dryers divided by the total number of homes with electric or gas dryers)
[30] EIA Residential Energy Consumption Survey (RECS) 2015 for Middle Atlantic States, Table HC1.7 ("Unknown" calculated as the number of homes with gas water heating divided by the total number of homes with electric or gas water heating)

Variable	Value	Notes
$FuelSF_{dryer}$	Electric Dryer: 0 Gas Dryer: 1.0 Unknown: 0.33	Based on EIA Residential Energy Consumption Survey (RECS) 2015 for Middle Atlantic States.[31]
hrs	295	
CF	0.029	

Integrated Modified Energy Factor, IMEF[32] (ft^3/kWh/cycle), is the energy performance metric for ENERGY STAR® certified residential clothes washers as of March 7, 2015.

IMEF is a measure of energy efficiency that considers the energy used by the washer during the cycle and while on standby, the energy used to heat the water, and the energy used to run the dryer. IMEF is the quotient of the cubic foot (or liter) capacity of the clothes container divided by the sum of the machine electrical energy consumption, the hot water energy consumption, the energy required for removal of the remaining moisture in the wash load, and the combined low-power mode energy consumption. A higher IMEF value reflects a more efficient clothes washer.[33]

Integrated Water Factor, IWF[34] is the water performance metric for residential clothes washers that allows the comparison of clothes washer water consumption independent of clothes washer capacity. Manufacturers must submit their water consumption factors with their ENERGY STAR® certified residential clothes washers. IWF is the quotient of the total weighted per-cycle water consumption for all wash cycles in gallons divided by the cubic foot (or liter) capacity of the clothes washer. A lower value reflects a more efficient clothes washer[35].

Per Unit Savings[36,37,38,39]

Product Class	Clothes Washer (ΔkWh_{washer})	Elec. DHW (ΔkWh_{wh})	Fossil Fuel DHW ($\Delta MMBtu_{wh}$)	Elec. Dryer (ΔkWh_{dryer})	Gas Dryer ($\Delta MMBtu_{dryer}$)
ENERGY STAR® Front Load Washer ≤ 2.5 ft^3	4	15	0.07	19	0.07
ENERGY STAR® Front Load Washer > 2.5 ft^3	6	35	0.16	169	0.65
ENERGY STAR® Top Load Washer ≤ 2.5 ft^3	4	17	0.08	75	0.29
ENERGY STAR® Top Load Washer > 2.5 ft^3	12	46	0.21	144	0.55
ENERGY STAR® Most Efficient Front Load Washer ≤ 2.5 ft^3	6	22	0.10	28	0.11

[31] EIA Residential Energy Consumption Survey (RECS) 2015 for Middle Atlantic States, Table HC3.7 ("Unknown" calculated as the number of homes with gas dryers divided by the total number of homes with electric or gas dryers)
[32] 10 CFR 430 Subpart B, Appendix J2
[33] ENERGY STAR® Program Requirements Product Specification for Clothes Washers, Eligibility Criteria Version 8.0 February 2018
[34] 10 CFR 430 Subpart B, Appendix J2
[35] ENERGY STAR® Program Requirements Product Specification for Clothes Washers, Eligibility Criteria Version 8.0, February 2018
[36] Savings Calculator for ENERGY STAR® Qualified Appliances (accessed 2/8/2017)
[37] ENERGY STAR® Clothes Washers Key Product Criteria
[38] ENERGY STAR® Most Efficient 2018, Recognition Criteria Clothes Washers
[39] CEE Super Efficient Home Appliances Initiative, Residential Clothes Washer Specifications

Product Class	Clothes Washer (ΔkWh_{washer})	Elec. DHW (ΔkWh_{wh})	Fossil Fuel DHW ($\Delta MMBtu_{wh}$)	Elec. Dryer (ΔkWh_{dryer})	Gas Dryer ($\Delta MMBtu_{dryer}$)
ENERGY STAR® Most Efficient Front Load Washer > 2.5 ft^3	10	39	0.18	188	0.72
ENERGY STAR® Most Efficient Top Load Washer ≤ 2.5 ft^3	5	20	0.09	88	0.34
ENERGY STAR® Most Efficient Top Load Washer > 2.5 ft^3	22	90	0.41	279	1.07
CEE Tier 1 Front Load Washer ≤ 2.5 ft^3	4	15	0.07	19	0.07
CEE Tier 1 Front Load Washer > 2.5 ft^3	9	35	0.16	169	0.65
CEE Tier 1 Top Load Washer ≤ 2.5 ft^3	4	17	0.08	75	0.29
CEE Tier 1 Top Load Washer > 2.5 ft^3	21	84	0.38	260	0.99
CEE Tier 2 Front Load Washer ≤ 2.5 ft^3	6	22	0.10	28	0.11
CEE Tier 2 Front Load Washer > 2.5 ft^3	10	39	0.18	188	0.72
CEE Tier 2 Top Load Washer ≤ 2.5 ft^3	5	20	0.09	88	0.34
CEE Tier 2 Top Load Washer > 2.5 ft^3	20	80	0.36	248	0.95
CEE Advanced Tier Front Load Washer > 2.5 ft^3	11	43	0.20	206	0.79
CEE Advanced Tier Top Load Washer > 2.5 ft^3	21	85	0.39	264	1.01

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.029.[40]

Baseline Efficiencies from which Energy Savings are Calculated

Clothes washers manufactured and distributed in commerce, as defined by 42 U.S.C. 6291(16), after January 1, 2018, must meet the energy conservation standards shown in the table below, as specified in the Code of Federal Regulations.[41]

Product Class	IMEF	IWF
Top-loading, Compact (< 1.6 ft^3)	≥ 1.15	≤ 12.0
Top-loading, Standard (≥ 1.6 ft^3)	≥ 1.57	≤ 6.5
Front-loading, Compact (< 1.6 ft^3)	≥ 1.13	≤ 8.3
Front-loading, Standard (≥ 1.6 ft^3)	≥ 1.84	≤ 4.7

Compliance Efficiency from which Incentives are Calculated

For ENERGY STAR® qualified eligibility, clothes washers must be front or top-loading with capacities greater than 1.6 ft^3 and less than 8.0 ft^3 and not designated as Combination All-In One Washer-Dryers or Residential Clothes Washers with Heating Drying Functionality.[42] Additional qualifying product criteria are provided in the table below in order to capture anticipated savings associated with higher efficiency models. The highest efficiency "Product Class" that the

[40] Based on metered data from Navigant Consulting, "EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (6/1/2012 – 5/31/2013) Appliance Rebate Program." March 2014, page 36. This report is not publicly available, but is referenced by the Mid-Atlantic Technical Reference Manual, Version 9.0, October 2019.
[41] 10 CFR 430.32(g)(4)
[42] ENERGY STAR® Program Requirements Product Specification for Clothes Washers

qualifying unit is eligible for should be used to establish savings from the Per Unit Savings table above.

ENERGY STAR® [43] and Consortium for Energy Efficiency (CEE)[44] Product Criteria Levels are shown in the table below:

Product Class	IMEF	IWF
ENERGY STAR® Clothes Washer ≤ 2.5 ft^3	≥ 2.07	≤ 4.2
ENERGY STAR® Front Load Washer > 2.5 ft^3	≥ 2.76	≤ 3.2
ENERGY STAR® Top Load Washer > 2.5 ft^3	≥ 2.06	≤ 4.3
ENERGY STAR® Most Efficient Washer ≤ 2.5 ft^3	≥ 2.20	≤ 3.7
ENERGY STAR® Most Efficient Washer > 2.5 ft^3	≥ 2.92	≤ 3.2
CEE Tier 1 Clothes Washer ≤ 2.5 ft^3	≥ 2.07	≤ 4.2
CEE Tier 1 Clothes Washer > 2.5 ft^3	≥ 2.76	≤ 3.2
CEE Tier 2 Clothes Washer ≤ 2.5 ft^3	≥ 2.20	≤ 3.7
CEE Tier 2 Clothes Washer > 2.5 ft^3	≥ 2.92	≤ 3.2
CEE Advanced Tier Clothes Washer > 2.5 ft^3	≥ 3.10	≤ 3.0

Operating Hours

An average of 295 annual one-hour active wash cycles is assumed in order to estimate conventional and qualifying unit consumption and demand savings.[45]

Example Calculation *(Not to be used as default)*

An existing residential customer installs an ENERGY STAR® Top Load Washer ≤ 2.5 ft^3 where the water heating fuel type is gas and the home's dryer is electric. Annual Electric Energy Savings, Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta kWh = units \times \left[\Delta kWh_{washer} + (\Delta kWh_{wh} \times ElecSF_{wh}) + (\Delta kWh_{dryer} \times ElecSF_{dryer})\right]$$

$$\Delta kW = \frac{\Delta kWh}{hrs} \times CF$$

$$\Delta MMBtu = units \times \left[(\Delta MMBtu_{wh} \times FuelSF_{wh}) + (\Delta MMBtu_{dryer} \times FuelSF_{dryer})\right]$$

units = 1, from application
ΔkWh_{washer} = 4, from Per Unit Savings Table
ΔkWh_{wh} = 17, from Per Unit Savings Table

[43] ENERGY STAR® Most Efficient 2018, Recognition Criteria Clothes Washers
[44] CEE Super Efficient Home Appliances Initiative, Residential Clothes Washer Specifications
[45] 10 CFR 430 Subpart B, Appendix J2

$ElecSF_{wh}$ = 0, from Summary of Variables and Data Sources table based on application
ΔkWh_{dryer} = 75, from Per Unit Savings Table
$ElecSF_{dryer}$ = 1, from Summary of Variables and Data Sources table based on application
hrs = 295, from Summary of Data Sources and Variables table
CF = 0.029, from Summary of Data Sources and Variables table
$\Delta MMBtu_{wh}$ = 0.08, from Per Unit Savings Table
$FuelSF_{wh}$ = 1, from Summary of Variables and Data Sources table based on application
$\Delta MMBtu_{dryer}$ = 0.29, from Per Unit Savings Table
$FuelSF_{dryer}$ = 0, from Summary of Variables and Data Sources table based on application

$$\Delta kWh = 1 \times [4 + (17 \times 0) + (75 \times 1)] = 79\ kWh$$

$$\Delta kW = \frac{79}{295} \times 0.029 = 0.00777\ kW$$

$$\Delta MMBtu = 1 \times [(0.08 \times\ 1) + (0.29 \times 0)] = 0.08\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

High efficiency clothes washers more effectively remove moisture from clothing during spin cycles. This reduces the amount of time necessary for drying cycles and leads to energy savings. Clothes dryer energy savings are considered in overall energy savings calculations above.

Ancillary Electric Savings Impacts

High efficiency clothes washers more effectively remove moisture from clothing during spin cycles. This reduces the amount of time necessary for drying cycles and leads to energy savings. Clothes dryer energy savings are considered in overall energy savings calculations above.

References

1. ENERGY STAR® Program Requirements Product Specification for Clothes Washers, Eligibility Criteria Version 8.0, February 2018
   Available from:
   https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Final%20Version%208.0%20Clothes%20Washer%20Partner%20Commitments%20and%20Eligibility%20Criteria.pdf
2. ENERGY STAR® Certified Products, Appliances, Clothes Washers
   Available from: https://www.energystar.gov/products/appliances/clothes_washers/

3. Purchase energy-saving products, Savings Calculator for ENERGY STAR® Qualified Appliances (last updated October 2016)Available from: https://www.energystar.gov/buildings/facility-owners-and-managers/existing-buildings/save-energy/purchase-energy-saving-products
4. EIA Residential Energy Consumption Survey (RECS) 2015 Survey Data for Middle Atlantic States.
   Available from:
   https://www.eia.gov/consumption/residential/data/2015/hc/php/hc1.7.php
5. 10 CFR 430 Subpart B, Appendix J2 - Uniform Test Method for Measuring the Energy Consumption of Automatic and Semi-automatic Clothes Washers
   Available from: https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=6dc64a198ad50a16b0ff6af63189872b&mc=true&n=pt10.3.430&r=PART&ty=HTML#ap10.3.430_127.j2
6. ENERGY STAR® Clothes Washers Key Product Criteria
   Available from:
   https://www.energystar.gov/products/appliances/clothes_washers/key_product_criteria/
7. ENERGY STAR® Most Efficient 2018, Recognition Criteria Clothes Washers
   Available from:
   https://www.energystar.gov/ia/partners/downloads/most_efficient/2018/Clothes%20Washers%20ENERGY%20STAR%20Most%20Efficient%202018%20Final%20Criteria.pdf?9183-14f6
8. CEE Super Efficient Home Appliances Initiative, Residential Clothes Washer Specifications
   Available from:
   https://library.cee1.org/system/files/library/13445/CEE_ResidentialClothesWasherSpecification_05Feb2018.pdf
9. Navigant Consulting, EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (6/1/2012 – 5/31/2013) Appliance Rebate Program, March 2014 *via Mid-Atlantic Technical Reference Manual Version 9.0, May 2019*
   Available from:
   https://neep.org/sites/default/files/resources/Mid_Atlantic_TRM_V9_Final_clean_wUpdateSummary%20-%20CT%20FORMAT.pdf
10. 10 CFR 430.32 Energy and water conservation standards and their compliance dates.
    Available from: http://www.ecfr.gov/cgi-bin/text-idx?SID=a9921a66f2b4f66a32ec851916b7b9d9&mc=true&node=se10.3.430_132&rgn=div8

Record of Revision

Record of Revision Number	Issue Date
1	10/15/2010
1-17-1	12/31/2016
3-18-6	3/29/2018

Return to Table of Contents

DEHUMIDIFIER

Measure Description

This measure covers the installation of residential stand-alone or whole-house dehumidifiers meeting the minimum qualifying efficiency standards established under the ENERGY STAR® Program, Version 5.0, effective October 31, 2019.[46] With a higher Energy Factor than comparable non-qualified models, ENERGY STAR® dehumidifiers have more efficient refrigeration coils, compressors, and fans that use less energy to remove moisture in residential buildings. Dehumidifiers originally qualified for the ENERGY STAR® label in January 2001. Dehumidifiers that have earned this label are approximately 15% more efficient than non-qualified models. This measure is restricted to dehumidifiers with a product moisture removal capacity of less than or equal to 185 pints/day.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times \frac{pints/day \times 0.473 \times hrs}{24} \times \left(\frac{1}{IEF_{baseline}} - \frac{1}{IEF_{ee}}\right)$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \frac{\Delta kWh}{hrs} \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
pints/day	= Product capacity to remove moisture (pints/day)
hrs	= Annual run hours of dehumidifier
baseline	= Characteristic of baseline condition
ee	= Characteristic of energy efficient condition
IEF	= Integrated Energy Factor
CF	= Coincidence factor
0.473	= Conversion factor (liters/pint)
24	= Hours in one day

[46] ENERGY STAR® Program Requirements Product Specification for Dehumidifiers, Eligibility Criteria Version 5.0, October 2019

Summary of Variables and Data Sources

Variable	Value	Notes
pints/day		From application.
$IEF_{baseline}$		Look up based on type and product capacity (pints/day) or case volume from Baseline Efficiencies section below.
IEF_{ee}		From application, or look up based on product capacity (pints/day) in Compliance Efficiency section below.
Hrs	1,632	Assumes 68 days of 24-hour operation.[47]
CF	0.56	

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.56.[48]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a stand-alone or whole-house dehumidifier meeting the minimum effective federal standard for performance.

Dehumidifiers manufactured and distributed in commerce on or after June 13, 2019 must meet the energy conservation standards shown in the tables below, rated in Integrated Energy Factor as specified in the Code of Federal Regulations.[49]

Stand-Alone Dehumidifiers	
Product Capacity (pints/day)	**Integrated Energy Factor (liters/kWh)**
≤ 25.00	1.30
25.01 to 50.00	1.60
≥50.01	2.80

Whole-House Dehumidifiers	
Product Case Volume (ft^3)	**Integrated Energy Factor (liters/kWh)**
≤ 8.0	≥1.77
> 8.0	≥2.41

Compliance Efficiency from which Incentives are Calculated

The compliance condition is an ENERGY STAR® qualified stand-alone or whole-house dehumidifier. [50]

[47] Savings Calculator for ENERGY STAR® Qualified Appliances (accessed 1/18/2018)
[48] A. Mendyk & D. Cautley, Dehumidifier Metering Study, Home Energy, January 2011: Summer duty cycle used as a proxy for CF.
[49] 10 CFR 430.32(v)(2)
[50] ENERGY STAR® Program Requirements Product Specification for Dehumidifiers, Eligibility Criteria Version 5.0, October 2019

Stand-Alone Dehumidifiers	
Product Capacity (pints/day)	**Integrated Energy Factor (liters/kWh)**
≤ 25.00	≥1.57
25.01 to 50.00	≥1.80
≥50.01	≥3.30

Whole-House Dehumidifiers	
Product Case Volume (ft^3)	**Integrated Energy Factor (liters/kWh)**
≤ 8.0	≥2.09
> 8.0	≥3.30

Operating Hours

The dehumidifier is assumed to be operating 1,632 hours per year based on 68 days of 24 hour operation.[51]

Example Calculation *(Not to be used as default)*

An existing residential customer replaces their stand-alone dehumidifier with a stand-alone ENERGY STAR® dehumidifier with 30 pints/day capacity and an IEF_{ee} rating of 1.9 . Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

$$\Delta kWh = units \times \frac{pints/day \times 0.473 \times hrs}{24} \times \left(\frac{1}{IEF_{baseline}} - \frac{1}{IEF_{ee}}\right)$$

$$\Delta kW = \frac{\Delta kWh}{hrs} \times CF$$

units = 1 from application
pints/day = 30, from application
hrs = 1,632, from Summary of Variables and Data Sources table
$IEF_{baseline}$ =1.60, from Baseline Efficiency section stand-alone dehumidifier table based on product capacity
IEF_{ee} = 1.9, from Compliance Efficiency section stand-alone dehumidifier table based on product capacity
CF = 0.56, from Summary of Variables and Data Sources table

$$\Delta kWh = 1 \times \frac{30 \times 0.473 \times 1{,}632}{24} \times \left(\frac{1}{1.60} - \frac{1}{1.90}\right) = 95.2\ kWh$$

[51] Savings Calculator for ENERGY STAR® Qualified Appliances (accessed 1/18/2018)

$$\Delta kW = \frac{95.2}{1{,}632} \times 0.56 = 0.0327\ kW$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Reduction in energy usage will have a negligible impact on space heating. Consideration of these effects is not included in this methodology.

Ancillary Electric Savings Impacts

Reduction in energy usage will have a negligible impact on space heating. Consideration of these effects is not included in this methodology.

References

1. ENERGY STAR® Program Requirements Product Specification for Dehumidifiers, Eligibility Criteria Version 5.0, October 2019.
   Available from:
   https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Dehumidifiers%20Version%205.0%20Program%20Requirements.pdf
2. A. Mendyk & D. Cautley, Dehumidifier Metering Study, Home Energy, January 5, 2011
   Available from: http://homeenergy.org/public/index.php/show/article/id/777/viewFull/
3. Purchase energy-saving products, Savings Calculator for ENERGY STAR® Qualified Appliances (last updated October 2016)
   Available from: https://www.energystar.gov/buildings/facility-owners-and-managers/existing-buildings/save-energy/purchase-energy-saving-products

4. 10 CFR 430.32 Energy and water conservation standards and their compliance dates.
   Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=39bdf94d4be5c5dac50be36d83225fe4&mc=true&node=pt10.3.430&rgn=div5#ap10.3.430_127.x1

Record of Revision

Record of Revision Number	Issue Date
0	10/15/2010
11-13-1	11/26/2013
3-18-12	3/29/2018

Return to Table of Contents

DISHWASHER

Measure Description

This measure covers the installation of ENERGY STAR® qualified residential dishwashers.[52] A dishwasher is a cabinet-like appliance that, with the aid of water and detergent, washes, rinses, and dries (when a drying process is included) dishware, glassware, eating utensils, and most cooking utensils by chemical, plumbing and/or electrical means and discharges to the plumbing drainage system. ENERGY STAR® rated machines run more efficiently while washing dishes through improved technology such as soil sensors, improved water filtration, more efficient jets, and innovative dish rack designs. Qualified dishwashers are 12% more efficient than non-certified models.[53]

This measure only applies to standard and compact residential grade equipment, as defined below.

Standard Dishwasher – A dishwasher that has a capacity equal to or greater than eight place settings plus six serving pieces as specified in ANSI/AHAM DW-1-2010 (incorporated by reference; see §430.3), using the test load specified in section 2.7 of 10 CFR 430, Subpart B, Appendix C1.[54]

Compact Dishwasher – A dishwasher that has a capacity of less than eight place settings plus six serving pieces as specified in ANSI/AHAM DW-1-2010 (incorporated by reference; see §430.3), using the test load specified in section 2.7 of 10 CFR 430, Subpart B, Appendix C1.[55]

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times [(kWh_{baseline} - kWh_{ee}) \times (F_{machine} + F_{wh} \times ElecSF_{wh})]$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \frac{\Delta kWh}{hrs} \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = units \times (kWh_{baseline} - kWh_{ee}) \times F_{wh} \times FuelSF_{wh} \times \frac{RE_{elec}}{RE_{fuel}} \times \frac{3{,}412}{1{,}000{,}000}$$

where:

ΔkWh = Annual electric energy savings

[52] ENERGY STAR® Program Requirements Product Specification for Residential Dishwashers Eligibility Criteria Version 6.0, January 2016

[53] Efficiency of ENERGY STAR® Dishwashers (accessed 4/4/2018) https://www.energystar.gov/products/appliances/dishwashers

[54] 10 CFR 430, Subpart B, Appendix C1

[55] Ibid

ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
$_{baseline}$	= Characteristic of baseline condition
$_{ee}$	= Characteristic of energy efficient condition
kWh	= Annual rated electric energy use
$F_{machine}$	= Fraction of energy used for the dishwasher machine
F_{wh}	= Fraction of energy used for the water heater
$ElecSF_{wh}$	= Electric Savings Factor for water heaters
$FuelSF_{wh}$	= Fossil Fuel Savings Factor for water heaters
RE_{elec}	= Recovery efficiency of electric water heater
RE_{fuel}	= Recovery efficiency of fossil fuel water heater
CF	= Coincidence factor
3,412	= Conversion factor, one kWh equals 3,412 BTU
1,000,000	= Conversion factor, one MMBtu equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
$kWh_{baseline}$		Look up based on Dishwasher Type in Baseline Efficiencies section below.
kWh_{ee}		From application.
F_{wh}	0.56	Based on ENERGY STAR®.[56]
$F_{machine}$	0.44	Based on ENERGY STAR®.[57]
$ElecSF_{wh}$	Electric WH: 1.00 Fossil Fuel WH: 0 Other: 0 Unknown: 0.20	Based on NYSERDA Residential Statewide Baseline Study of New York State – July 2015.[58] "Unknown" shall only be applied when the collection of information on water heating fuel is not feasible due to program configuration of delivery mechanism.
$FuelSF_{wh}$	Electric WH: 0 Fossil Fuel WH: 1.00 Other: 0 Unknown: 0.54	Based on NYSERDA Residential Statewide Baseline Study of New York State – July 2015.[59] "Unknown" shall only be applied when the collection of information on water heating fuel is not feasible due to program configuration of delivery mechanism.
RE_{elec}	0.98	Recovery efficiency of typical electric storage type water heater. [60]

[56] ENERGY STAR® Appliance Calculator
[57] Ibid
[58] NYSERDA Residential statewide Baseline Study. Volume 1: Single Family Report, Table 38: Water Heating Fuel Type by Climate Zone. Overall statewide averages applied. ElecSF and FuelSF "unknown" factors may not sum to 100% due to the presence of other water heating fuels. In the condition of other water heating fuels in home, the designation "Other" shall be applied.
[59] Ibid.
[60] Per 10 CFR 430 Subpart B Appendix E – Uniform Test Method for Measuring the Energy Consumption of Water Heaters: *6.3.2 Recovery Efficiency*

Variable	Value	Notes
RE_{fuel}	0.75	Recovery efficiency of typical fossil fuel storage type water heater.[61]
hrs	301	Code of Federal Regulations. [62]
CF	0.029	

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.029.[63]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a residential dishwasher as defined in the Measure Description section above with type equivalent to the efficient case meeting the minimum effective federal performance standards. The baseline water heating system is a standard efficiency storage type electric or fossil fuel system (fuel type equivalent to the actual existing condition). Current federal annual energy consumption performance standards for dishwashers are provided in the table below.[64]

Dishwasher Type	$kWh_{baseline}$
Compact	222
Standard	307

Compliance Efficiency from which Incentives are Calculated

The compliance condition is an ENERGY STAR® qualified residential dishwasher as defined in the Measure Description section above. Qualifying equipment must have rated annual energy consumption at or below the ENERGY STAR® qualified specifications as indicated the table below, based on dishwasher type.[65] Energy rating is to be taken from application.

Dishwasher Type	kWh_{ee}
Compact	203
Standard	270

[61] Per 10 CFR 430, typical recovery efficiency of a gas water heater is 0.75. See for example, 10 CFR 430 Subpart B Appendix C1, 5.6.1.1.
[62] 10 CFR 430 Appendix C1 (5) Uniform Test Method for Measuring the Energy Consumption of Dishwashers
[63] Based on 8,760 end use data for Missouri, provided to VEIC by Ameren for use in the Illinois TRM. The average dishwasher load during peak hours is divided by the peak load. In the absence of a New York specific load shape, this is deemed a reasonable proxy because load shapes are not expected to vary significantly by region. Data from Ameren was adjusted to account for the difference in assumed annual operating hours (252 hours were used in the referenced study whereas 301 hours are cited in this document) and peak range was adjusted to reflect New York peak time (the hour ending in 5PM) from Illinois peak time (1PM to the hour ending 5PM).
[64] 10 CFR 430.32 (f)(1)
[65] ENERGY STAR® Program Requirements Product Specification for Residential Dishwashers Eligibility Criteria Version 6.0, January 2016, Table 1: Annual Energy Consumption Base Allowances

Operating Hours

An average of 215 annual 1.4-hour dishwasher cycles is assumed in order to estimate conventional and qualifying energy ratings, for a total of 301 hours of active use per year. [66]

Example Calculation *(Not to be used as default)*

An existing residential customer installs an ENERGY STAR® rated compact dishwasher, with an annual consumption of 200 kWh. The home has a gas water heater. Annual Electric Energy Savings, Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta kWh = units \times [(kWh_{baseline} - kWh_{ee}) \times (F_{machine} + F_{wh} \times ElecSF_{wh})]$$

$$\Delta kW = \frac{\Delta kWh}{hrs} \times CF$$

$$\Delta MMBtu = units \times (kWh_{baseline} - kWh_{ee}) \times F_{wh} \times FuelSF_{wh} \times \frac{RE_{elec}}{RE_{fuel}} \times \frac{3{,}412}{1{,}000{,}000}$$

units = 1, from application
$kWh_{baseline}$ = 222, from Dishwasher Type table from baseline efficiency section based on application
kWh_{ee} = 200, from application
$F_{machine}$ = 0.44, from Summary of Variables and Data Sources table
F_{wh} = 0.56, from Summary of Variables and Data Sources table
$ElecSF_{wh}$ = 0, from Summary of Variables and Data Sources table based on application
hrs = 301, from Summary of Variables and Data Sources table
CF = 0.029, from Summary of Variables and Data Sources table
$FuelSF_{wh}$ = 1, from Summary of Variables and Data Sources table based on application
RE_{elec} = 0.98, from Summary of Variables and Data Sources table
RE_{fuel} = 0.75, from Summary of Variables and Data Sources table

$$\Delta kWh = 1 \times [(222 - 200) \times (0.44 + 0.56 \times 0)] = 9.68\ kWh$$

$$\Delta kW = \frac{9.68}{301} \times 0.029 = 0.000933\ kW$$

$$\Delta MMBtu = 1 \times (222 - 200) \times 0.56 \times 1 \times \frac{0.98}{0.75} \times \frac{3{,}412}{1{,}000{,}000} = 0.0549\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

[66] 10 CFR 430 Appendix C1 (5) Uniform Test Method for Measuring the Energy Consumption of Dishwashers

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. ENERGY STAR® Program Requirements Product Specification for Residential Dishwashers, Eligibility Criteria Version 6.0, January 2016
   Available from:
   https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Residential%20Dishwasher%20Version%206.0%20Final%20Program%20Requirements_0.pdf
2. ENERGY STAR® Certified Products, Appliances, Dishwashers
   Available from: https://www.energystar.gov/products/appliances/dishwashers
3. 10 CFR 430 Subpart B Appendix C1 Uniform Test Method for Measuring the Energy Consumption of Dishwashers
   Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=aae04a703cdc86ce4c2f95a211f420f2&mc=true&node=pt10.3.430&rgn=div5#ap10.3.430_127.c1
4. Savings Calculator for ENERGY STAR® Qualified Appliances (last updated October 2016)
   Available from: https://www.energystar.gov/buildings/facility-owners-and-managers/existing-buildings/save-energy/purchase-energy-saving-products
5. NYSERDA Residential Statewide Baseline Study of New York State – July 2015
   Available from:
   https://www.nyserda.ny.gov/About/Publications/Building%20Stock%20and%20Potential%20Studies/Residential%20Statewide%20Baseline%20Study%20of%20New%20York%20State
6. 10 CFR 430 Subpart B Appendix E Uniform Test Method for Measuring the Energy Consumption of Water Heaters
   Available from: https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=6dc64a198ad50a16b0ff6af63189872b&mc=true&n=pt10.3.430&r=PART&ty=HTML#ap10.3.430_127.e
7. 10 CFR 430.32 Energy and water conservation standards and their compliance dates.
   Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=c46beaae860c6caba80d2be690e27cac&mc=true&node=pt10.3.430&rgn=div5#se10.3.430_132

Record of Revision

Record of Revision Number	Issue Date
0	10/15/2010
6-18-1	6/26/2018
12-19-1	12/23/2019

Return to Table of Contents

FIREPLACE

Measure Description

This measure covers the installation of direct-vented, gas fireplaces with fireplace efficiency (FE) greater than or equal to 70% tested in accordance with the Canadian Standards Association (CSA) CSA-P.4 method and electric, intermittent pilot lights. This measure is only applicable to the installation of gas fireplaces for use as a supplemental heat source.

This analysis leverages the DOE Technical Support Document (TSD) for baseline fireplaces and pilot lights and a survey of US utilities for efficient fireplaces.

Method for Calculating Annual Energy and Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times \Delta kWh_{PilotLight}$$

Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = units \times \left[\frac{kBTUh_{out}}{1{,}000} \times \left(\frac{1}{FE_{baseline}} - \frac{1}{FE_{ee}}\right) \times hrs + \Delta MMBtu_{PilotLight}\right]$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
$\Delta kWh_{PilotLight}$	= Change in electric consumption of pilot light
$kBTUh_{out}$	= Output capacity of fireplace in kBTU/h
baseline	= Characteristic of baseline condition
ee	= Characteristic of energy efficient condition
FE	= Rated efficiency of fireplace
hrs	= Annual operating hours of fireplace
$\Delta MMBtu_{PilotLight}$	= Change in fossil fuel consumption of pilot light
1,000	= Conversion factor, one MMBtu equals 1,000 kBTU

Summary of Variables and Data Sources

Variable	Value	Notes
$\Delta kWh_{PilotLight}$	-13.6	Baseline direct, vented gas fireplaces with a standing pilot light consumes no electric energy but consumes gas energy. Intermittent pilot lights consume electricity but save gas.[67]
$kBTUh_{out}$		From application
$FE_{baseline}$	0.64	Average efficiency of baseline fireplace[68]
FE_{ee}		From application.
hrs	157	Annual hours of use of fireplace[69]
$\Delta MMBtu_{PilotLight}$	3.49	Average MMBtu savings from switching from baseline, standing pilot light to intermittent pilot light[70]

Coincidence Factor (CF)

The prescribed coincidence factor for this measure is N/A. While there is an electric energy penalty due to the intermittent pilot light, there are no recommended demand savings due to fireplaces being operated during the heating season.[71]

Baseline Efficiencies from which Savings are Calculated

The baseline fireplace, as defined by DOE, is a direct-vented, gas fireplace with an FE of 64% and a standing pilot light.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a direct-vented gas fireplace with an FE of 70% or greater tested in accordance with the Canadian Standards Association (CSA) CSA-P.4 method and an intermittent pilot light.

Operating Hours

The operating hours are assumed to be 157 hours per year. This assumption is based on the average of the range of hearth product burner operating hours among sample households.[72]

---

[67] DOE Technical Savings Document, Table 7.4.1: Average Annual Energy Consumption and Savings for Hearth Products
[68] DOE Technical Savings Document, page 7-7.
[69] DOE Technical Savings Document, Table 7.3.5: Range of Burner Operating Hours for Hearth Products
[70] DOE Technical Savings Document, Table 7.4.1: Average Annual Energy Consumption and Savings for Hearth Products
[71] Technical Support Document: Energy Conservation Program for Consumer Products: Energy Conservation Standards for Hearth Products. Chapters 7 and 8. The most common form of electronic ignition system found in hearth products is the intermittent pilot ignition. In an intermittent pilot ignition, the pilot light is only lit when there is a call for heat, and the pilot light is automatically extinguished after the burner is turned off. In order to ignite the pilot light, these systems require an outside power source, often supplied by either a battery or an electrical connection.
[72] Technical Support Document: Energy Conservation Program for Consumer Products: Energy Conservation Standards for Hearth Products. Table 7.3.5.

Example Calculation *(Not to be used as default)*

An existing residential customer installs a direct-vented gas fireplace with fireplace efficiency of 80% and a 70 kBTUh output capacity. The intermittent pilot light in the efficient fireplace consumes electricity but the fireplace saves gas. Summer Peak Coincident Demand Savings are not applicable. Annual Electric Energy Savings and Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta kWh = units \times \Delta kWh_{PilotLight}$$

$$\Delta MMBtu = units \times \left[\frac{kBTUh_{out}}{1{,}000} \times \left(\frac{1}{FE_{baseline}} - \frac{1}{FE_{ee}}\right) \times hrs + \Delta MMBtu_{PilotLight}\right]$$

units = 1, from application
$\Delta kWh_{PilotLight}$ = -13.6, from Summary of Variables and Data Sources
$\Delta MMBtu_{PilotLight}$ = 3.49, from Summary of Variables and Data Sources
$kBTUh_{out}$ = 70 kBTU/h, from application
$FE_{basline}$ = 0.64, from Summary of Variables and Data Sources
FE_{ee} = 0.80, from application
hrs = 157, from Summary of Variables and Data Sources

$$\Delta kWh = 1 \times -13.6 = -13.6\ kWh$$

$$\Delta MMBtu = 1 \times \left[\frac{70}{1{,}000} \times \left(\frac{1}{0.64} - \frac{1}{0.80}\right) \times 157 + 3.49\right] = 6.92\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. Technical Support Document: Energy Conservation Program for Consumer Products: Energy Conservation Standards for Hearth Products. Chapters 7 and 8. Department of Energy (DOE). January 30, 2015.
   Available from: https://www.regulations.gov/document?D=EERE-2014-BT-STD-0036-0002.
2. A survey of US utilities offering rebates for high efficiency fireplaces and/or fireplaces with intermittent pilot lights found the minimum qualifying FE to be 70%. Utilities and organizations include Energy Trust of Oregon, CenterPoint Energy, Puget Sound Energy, Minnesota Energy Resources, and Dominion Energy Utah. Retrieved using *E-Source*.

Record of Revision

Record of Revision Number	Issue Date
12-19-4	12/23/2019
3-20-15	3/30/2020

Return to Table of Contents

REFRIGERATOR AND FREEZER

Measure Description

This measure covers the replacement of inefficient residential grade refrigerators and freezers with ENERGY STAR® compliant equipment. Residential refrigerators and freezers include electric refrigerators, electric refrigerator-freezers, and freezers, having a source of refrigeration requiring single phase, alternating current electric energy input only. Known collectively as "refrigeration products," these appliances chill and preserve food and beverages, provide ice and chilled water, and freeze food.[73]

This measure does not apply to refrigerators and refrigerator-freezers with a total refrigerated volume exceeding 39 ft^3 or freezers with a total refrigerated volume exceeding 30 ft^3.[74]

Savings are calculated between the energy consumption of the baseline unit and that of the more efficient replacement meeting ENERGY STAR® minimum performance specification of at least 10% lower energy consumption than that mandated by federal standards.[75]

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times (kWh_{baseline} - kWh_{ee}) \times (1 + HVAC_c) \times F_{occ}$$

Summer Peak Coincident Demand Savings

$$\Delta kW = units \times \left(\frac{kWh_{baseline} - kWh_{ee}}{8{,}760}\right) \times (1 + HVAC_d) \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = units \times (kWh_{baseline} - kWh_{ee}) \times HVAC_{ff} \times F_{occ}$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
baseline	= Characteristic of baseline condition
ee	= Characteristic of energy efficient condition

[73] The Retail Products Platform (RPP) Evaluation Report, conducted by EMI Consulting d/b/a Con Edison (approved June 15, 2018), was reviewed for findings relevant to this measure. The findings of this report, which estimates the short-term energy savings and demand reduction attributable to the program's activities and assesses key components of the program's logic model, do not directly inform the algorithms, key inputs or default values found in this energy savings estimation methodology. As such, no changes have been applied as a result of this review.
[74] 10 CFR 430.32(a)
[75] ENERGY STAR® Refrigerators & Freezers Key Product Criteria

kWh = Annual electric energy consumption
$HVAC_c$ = HVAC interaction factor for annual electric energy consumption
$HVAC_d$ = HVAC interaction factor at utility summer peak hour
$HVAC_{ff}$ = HVAC interaction factor for annual fossil fuel consumption
F_{occ} = Adjustment factor to account for number of occupants
CF = Coincidence factor
8,760 = Hours in one year

Summary of Variables and Data Sources

Variable	Value	Notes
$kWh_{baseline}$		See Baseline Efficiencies section below.
kWh_{ee}		From application.
F_{occ}		See Occupant Adjustment Factor section below.
$HVAC_c$		HVAC interaction factor for annual electric energy consumption (dimensionless). Vintage and HVAC type weighted average by city. If unknown, assume Single Family Home building type, New vintage, and AC with Fuel heat HVAC type. See Appendix D.
$HVAC_d$		HVAC interaction factor for peak demand at utility summer peak hour (dimensionless). Vintage and HVAC type weighted average by city. If unknown, assume Single Family Home building type, New vintage, and AC with Fuel heat HVAC type. See Appendix D.
$HVAC_{ff}$		HVAC interaction factor for annual fossil fuel energy consumption (MMBtu/kWh). Vintage and HVAC type weighted average by city. If unknown, assume Single Family Home building type, New vintage, and AC with Fuel heat HVAC type. See Appendix D.
CF	1.0	

Occupant Adjustment Factor (F_{occ})

The occupant adjustment factor is used to adjust the energy savings according to the number of occupants in the residence (if applicable), as shown in the table below. If unknown, apply 0 occupants as a default value.

Number of Occupants	F_{occ}[76]
0 occupants	1.00
1 occupant	1.05
2 occupants	1.10
3 occupants	1.13
4 occupants	1.15
5 or more	1.16

[76] The Occupant Adjustment Factor is developed from simulating audits within the ORNL weatherization tool, National Energy Audit Tool (NEAT), Oak Ridge National Laboratory, 2012.

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 1.0.[77]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a minimally code compliant refrigerator, refrigerator-freezer or freezer as defined in the Measure Description section above. Baseline annual electric consumption (kWh/yr) shall align with federally mandated maximum energy use associated with the Product Class and Adjusted Volume (AV in ft^3 or av in L) of the qualifying equipment. Federal standard annual electric consumption data is provided in the directory of ENERGY STAR® qualified Refrigerators[78] and Freezers[79] according to the make and model of the qualifying equipment. The values specified by ENERGY STAR® incorporate conversion from total capacity to Adjusted Volume as dictated by the Code of Federal Regulations.[80] For this reason, $kWh_{baseline}$ must be determined from the ENERGY STAR® directory.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is an ENERGY STAR® qualified refrigerator, refrigerator-freezer or freezer as defined in the Measure Description section above. Annual energy consumption of the compliance condition shall be determined from the directory of ENERGY STAR® qualified Refrigerators[81] and Freezers[82] according to the make and model of the qualifying equipment.

Operating Hours

Refrigeration products are assumed to be plugged into an electrical outlet 8,760 hours per year. Compressor cycling is inherent in the specified annual energy consumption of baseline and qualifying equipment.

Example Calculation *(Not to be used as default)*

An existing residential customer living in single-family home with 4 occupants in NYC equipped with air conditioning and fuel heat installs a 20 ft^3 side-by-side ENERGY STAR® compliant refrigerator which has 560 kWh annual electric energy consumption. Annual Electric Energy Savings, Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are calculated as below.

[77] *No source specified – update pending availability and review of applicable references.*
[78] ENERGY STAR® Certified Residential Refrigerators Product Finder
https://www.energystar.gov/productfinder/product/certified-residential-refrigerators/results
[79] ENERGY STAR® Certified Residential Freezers Product Finder
https://www.energystar.gov/productfinder/product/certified-residential-freezers/results
[80] 10 CFR 430 Subpart B, Appendices A and B
[81] ENERGY STAR® Certified Residential Refrigerators Product Finder
https://www.energystar.gov/productfinder/product/certified-residential-refrigerators/results
[82] ENERGY STAR® Certified Residential Freezers Product Finder
https://www.energystar.gov/productfinder/product/certified-residential-freezers/results

$$\Delta kWh = units \times (kWh_{baseline} - kWh_{ee}) \times (1 + HVAC_c) \times F_{occ}$$

$$\Delta kW = units \times \left(\frac{kWh_{baseline} - kWh_{ee}}{8{,}760}\right) \times (1 + HVAC_d) \times CF$$

$$\Delta MMBtu = units \times (kWh_{baseline} - kWh_{ee}) \times HVAC_{ff} \times F_{occ}$$

units = 1, from application
$kWh_{baseline}$ = 610 kWh/yr, per the ENERGY STAR directory
kWh_{ee} = 560 kWh/yr, from application
$HVAC_c$ = 0.077, from Appendix D based on location, HVAC configuration, and facility type
$HVAC_d$ = 0.085, from Appendix D based on location, HVAC configuration, and facility type
$HVAC_{ff}$ = -0.002, from Appendix D based on location, HVAC configuration, and facility type
F_{occ} = 1.15, from Occupant Adjustment Factor table based on occupancy from application
CF =1.0, from Summary of Variables and Data Sources table

$$\Delta kWh = 1 \times (610 - 560) \times (1 + 0.077) \times 1.15 = 61.9\ kWh$$

$$\Delta kW = 1 \times \left(\frac{610 - 560}{8{,}760}\right) \times (1 + 0.085) \times 1 = 0.00619\ kW$$

$$\Delta MMBtu = 1 \times (610 - 560) \times (-0.002) \times 1.15 = -0.115\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

High-efficiency refrigeration products reject less heat into the conditioned space than standard equipment, increasing space heating requirements while decreasing cooling load. The HVAC interaction factors calculated from the prototypical building DOE-2 models as a function of the building and HVAC system type are shown in Appendix D.

Ancillary Electric Savings Impacts

High-efficiency refrigeration products reject less heat into the conditioned space than standard equipment, increasing space heating requirements while decreasing cooling load. The HVAC interaction factors calculated from the prototypical building DOE-2 models as a function of the building and HVAC system type are shown in Appendix D.

References

1. 10 CFR 430.32 Energy and water conservation standards and their compliance dates. Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=39bdf94d4be5c5dac50be36d83225fe4&mc=true&node=pt10.3.430&rgn=div5#se10.3.430_132
2. ENERGY STAR® Refrigerators & Freezers Key Product Criteria, Sept 15, 2014 Available from: https://www.energystar.gov/products/appliances/refrigerators/key_product_criteria
3. Oak Ridge National Laboratory, National Energy Audit Tool (NEAT), 2012 Available from: https://weatherization.ornl.gov/obtain/
4. ENERGY STAR® Certified Residential Refrigerators Product Finder Available from: https://www.energystar.gov/productfinder/product/certified-residential-refrigerators/results
5. ENERGY STAR® Certified Residential Freezers Product Finder Available from: https://www.energystar.gov/productfinder/product/certified-residential-freezers/results
6. 10 CFR 430 Subpart B, Appendix A – Uniform Test Method for Measuring the Energy Consumption of Refrigerators, Refrigerator-Freezers, and Miscellaneous Refrigeration Products Available from https://www.ecfr.gov/cgi-bin/text-idx?SID=39bdf94d4be5c5dac50be36d83225fe4&mc=true&node=pt10.3.430&rgn=div5#ap10.3.430_127.b
7. 10 CFR 430 Subpart B, Appendix B – Uniform Test Method for Measuring the Energy Consumption of Freezers Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=39bdf94d4be5c5dac50be36d83225fe4&mc=true&node=pt10.3.430&rgn=div5#ap10.3.430_127.b

Record of Revision

Record of Revision Number	Issue Date
1	10/15/2010
7-13-3	7/31/2013
7-13-41	7/31/2013
9-13-1	9/27/2013
3-18-7	3/29/2018

Return to Table of Contents

SOUNDBAR

Measure Description

This measure covers soundbars in residential applications meeting the minimum qualifying efficiency standards established under the ENERGY STAR® program, Program Requirements for Audio/Video Version 3.0, effective December 2014.[83] A soundbar is a mains-connected product that offers audio amplification housed in a wide horizontal enclosure. ENERGY STAR® rated soundbars have a lower power draw when in sleep and idle modes and a higher amplifier efficiency than conventional models.[84] Qualified soundbars use about 70% less energy than unqualified equipment.[85]

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times (kWh_{baseline} - kWh_{ee})$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \frac{\Delta kWh}{8{,}760} \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
baseline	= Characteristic of baseline condition
ee	= Characteristic of energy efficient condition
kWh	= Annual rated electric energy use
CF	= Coincidence factor
8,760	= Hours in one year

[83] ENERGY STAR® Program Requirements Product Specification for Audio/Video Eligibility Criteria Version 3.0, Rev. December 2014
[84] Consumer Messaging Guide for ENERGY STAR® Certified Consumer Electronics
[85] ENERGY STAR® Sound Bars (accessed 10/2/2018) https://www.energystar.gov/products/holiday/sound_bars

Summary of Variables and Data Sources

Variable	Value	Notes
$kWh_{baseline}$	77	Retail Products Platform. [86]
kWh_{ee}	29	Retail Products Platform. [87]
CF	0.8	

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.8.[88]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a non-ENERGY STAR® qualified soundbar in a residential application.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is an ENERGY STAR® qualified soundbar in a residential application with power performance specifications meeting or exceeding the requirements of ENERGY STAR® Program Requirements for Audio/Video Version 3.0, effective December 2014.[89]

Operating Hours

Soundbars are assumed to be plugged into an electrical outlet 8,760 hours per year.

Example Calculation *(Not to be used as default)*

An existing residential customer located near NYC replaces their two existing soundbars for two soundbars that meet or exceed the ENERGY STAR ® Program Requirements.. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

$$\Delta kWh = units \times (kWh_{baseline} - kWh_{ee})$$

$$\Delta kW = \frac{\Delta kWh}{8{,}760} \times CF$$

units = 2, from application
$kWh_{baseline}$ = 77, from summary of Variables and Data Sources table
kWh_{ee} = 29, from summary of Variables and Data Sources table
CF = 0.8, from summary of Variables and Data Sources table

$$\Delta kWh = 2 \times (77 - 29) = 96\ kWh$$

[86] Retail Products Platform: Product Analysis, Last updated May 25, 2016
[87] Retail Products Platform: Product Analysis, Last updated May 25, 2016 – ENERGY STAR® + 15% annual consumption increased by 15% to reflect minimum compliance with ENERGY STAR® Specification V3.0
[88] *No source specified – update pending availability and review of applicable references.*
[89] ENERGY STAR® Program Requirements for Audio/Video Version 3.0, December 2014

$$\Delta kW = \frac{96}{8{,}760} \times 0.8 = 0.00877\ kW$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. ENERGY STAR® Program Requirements Product Specification for Audio/Video, Eligibility Criteria Version 3.0, December 2014
   Available from:
   https://www.energystar.gov/sites/default/files/Final%20Version%203.0%20AV%20Program%20Requirements%20%28Rev%20Dec-2014%29.pdf
2. US EPA Consumer Messaging Guide for ENERGY STAR® Certified Consumer Electronics
   Available from:
   https://www.energystar.gov/ia/partners/downloads/CE_Consumer_Messaging.pdf
3. ENERGY STAR® Sound Bars
   Available from: https://www.energystar.gov/products/holiday/sound_bars
4. Retail Products Platform Product Analysis, Last Updated May 25, 2016.
   Available from:
   https://drive.google.com/file/d/0B9Fd3ckbKJp5OEpWSHg1eksyZ1U/view

Record of Revision

Record of Revision Number	Issue Date
12-18-6	12/28/2018

Return to Table of Contents

APPLIANCE – CONTROL

ADVANCED POWER STRIP (APS)

Measure Description

This measure covers the installation of Tier 1 and Tier 2 advanced power strips (APS) installed in home entertainment centers (AV Equipment) and home offices (IT Equipment). An APS reduces energy consumption by shutting off the supply power to electronic devices when they are not in active use. This measure applies to power strips with 5 outlets or more.

Tier 1 APS, also known as master-controlled APS, are designed to reduce standby energy waste by monitoring the power state of a master device (typically a TV or desktop computer) using current-sensing technology and cutting power to controlled (or switched) devices when the master device is off. This reduces the energy and power consumption of interconnected equipment (i.e. entertainment centers and home offices) by eliminating standby loads and consumption of devices left on but not in use. Tier 1 APS applies to both home office and entertainment center equipment.

Tier 2 APS reduce active and standby energy waste by monitoring user engagement and cutting power to all devices when a set period of inactivity is detected. This is accomplished through the use of infrared (IR) sensing and motion-sensing technology, in addition to the master/switched capability of a Tier 1 APS. Active power waste occurs when electronic equipment is on, but the equipment is not being used. Standby power loss occurs when energy is consumed by equipment while it is turned off and in idle mode, but is still plugged in. Tier 2 APS realize savings by reducing both active and standby power loss, which can provide significant energy savings over a Tier 1 Advanced Power Strip. For the purposes of this measure, Tier 2 APS apply to entertainment center equipment only; there are no incremental savings associated with installation of a Tier 2 APS in a home office.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times (\Delta kWh/unit)$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \frac{\Delta kWh}{hrs_{off}} \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

where:

ΔkWh = Annual electric energy savings
ΔkW = Peak coincident demand electric savings

ΔMMBtu = Annual fossil fuel energy savings
units = Number of measures installed under the program
(ΔkWh/unit) = Annual electric energy savings per unit
hrs_{off} = Annual hours that the connected system is not in use or is turned off
CF = Coincidence Factor

Summary of Variables & Data Sources

Variable	Value	Notes
(ΔkWh/unit)		Lookup based on tier, connected equipment type and existing condition in Annual Electric Energy Savings per Unit table below.
hrs_{off}	Tier 1: 7,340 Tier 2: 8,048	See Operating Hours section below
CF	0.8	

Annual Electric Energy Savings per Unit (ΔkWh/unit)
Annual electric energy savings are shown in the table below, where the baseline condition is equivalent to the existing case and Connected Equipment is the type of equipment to be controlled with the installed APS. Unknown designations are provided for use in retailer or online market place point-of-sale programs, in which the application or existing condition is unknown.

APS Tier	Connected Equipment	Baseline	ΔkWh/unit
Tier 1	AV Equipment	Standard Power Strip	75.1[90]
Tier 1	IT Equipment	Standard Power Strip	31[91]
Tier 1	Unknown	Standard Power Strip	57.5[92]
Tier 2	AV Equipment	Standard Power Strip	234[93]
Tier 2	AV Equipment	Tier 1 Power Strip	158.9[94]
Tier 2	AV Equipment	Unknown	158.9[95]

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.8.[96]

[90] New York State Energy Research and Development Authority, Advanced Power Strip Research Report, August 2011, p. 30.
[91] Ibid.
[92] Ibid, p. 7. Calculated with weighted average where 60% of Tier 1 APS applications are used for AV equipment and 40% for IT and other smaller load applications.
[93] San Diego Gas & Electric, Tier 2 Advanced Power Strips in Residential and Commercial Applications, April 2015, p. 3
[94] Ibid. Calculated as incremental savings over a Tier 1 APS (234 – 75.1 = 158.9 kWh).
[95] Ibid. Conservatively assumes savings associated with replacement of a Tier 1 APS.
[96] *No source specified – update pending availability and review of applicable references.*

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition for Tier 1 APS is AV or IT equipment plugged into a standard power strip. The baseline condition for Tier 2 APS is AV equipment plugged into either a standard power strip or Tier 1 APS.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a Tier 1 or Tier 2 APS as defined in the Measure Description.

Operating Hours

Power strips are assumed to be plugged in at all times. The hrs_{off} term used above for the purposes of estimating Summer Peak Coincident Demand Savings adopts a usage profile associated with AV equipment, as this provides the most conservative demand savings estimate. This equipment is assumed to be off for 20.11 hours per day and on but not in use for 1.94 hours per day.[97] For Tier 1 APS, only off hours lead to savings, thus the operating hours are 365 x 20.11 = 7,340. Savings are achieved for Tier 2 APS when equipment is off or on but not in use. Thus, the hours of operation used to determine demand savings are 365 x (20.11 + 1.94) = 8,048. No savings are achieved during the remaining 712 hours per year when equipment is in active use. This reporting of AV off hours aligns well with the NYSERDA APS research study, which found television off hours to be 19.1 per day in New York State.[98]

Example Calculation *(Not to be used as default)*

An existing residential customer located near Albany replaces their standard power strip installed in a home-office with a Tier 1 Advanced Power Strip. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

$$\Delta kWh = units \times (\Delta kWh/unit)$$

$$\Delta kW = \frac{\Delta kWh}{hrs_{off}} \times CF$$

units = 1, from application
ΔkWh/unit = 31, from Annual Electric Energy Savings per unit table based on Tier and connected equipment from application
hrs_{off} = 7,340, from Summary of Variables and Data Sources table based on Tier from application
CF = 0.8, from Summary of Variables and Data Sources table

$$\Delta kWh = 1 \times 31 = 31\ kWh$$

[97] California Plug Load Research Center, Tier 2 Advanced Power Strip Evaluation for Energy Saving Incentive, May 2014, p. 36
[98] New York State Energy Research and Development Authority, Advanced Power Strip Research Report, August 2011, p. 8

$$\Delta kW = \frac{31}{7{,}340} \times 0.8 = 0.00338\ kW$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. New York State Energy Research and Development Authority, Advanced Power Strip Research Report, August 2011
   Available from: https://energy.mo.gov/sites/energy/files/advanced-power-strip-research-report.pdf
2. San Diego Gas & Electric, Tier 2 Advanced Power Strips in Residential and Commercial Applications, April 2015
   Available from: http://www.etcc-ca.com/sites/default/files/reports/et14sdg8031_commerical_tier_2_aps.pdf
3. California Plug Load Research Center, Tier 2 Advanced Power Strip Evaluation for Energy Saving Incentive, May 2014
   Available from: http://embertec.com/assets/pdf/CalPlug_Tier2_APS_Evaluation.pdf

Record of Revision

Record of Revision Number	Issue Date
1	12/31/2015
1-17-2	12/31/2016
3-18-1	3/29/2018

Return to Table of Contents

APPLIANCE RECYCLING

AIR CONDITIONER - ROOM (RAC) RECYCLING

Measure Description

In many cases where an air conditioning unit is replaced by a homeowner, the existing unit is retained, sold, or donated for use elsewhere and represents additional load on the grid. This measure covers recycling of the existing functional equipment, thereby eliminating the consumption associated with that equipment. Air conditioner recycling programs (also called "bounty" programs) receive energy savings credit for permanently removing inefficient functional air conditioners from the electric grid. Only recycled equipment 5 years old or older are eligible for energy savings.

This measure covers the recycling of inefficient room air conditioners in residential applications. A room air conditioner is a consumer product, other than a "packaged terminal air conditioner," which is powered by a single phase electric current and which is an encased assembly designed as a unit for mounting in a window or through the wall for the purpose of providing delivery of conditioned air to an enclosed space. It includes a prime source of refrigeration and may include a means for ventilating and heating.[99]

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times \frac{(BTU/h)/unit}{1{,}000} \times \frac{1}{CEER_{baseline}} \times EFLH_{cooling}$$

Summer Peak Coincident Demand Savings

$$\Delta kW = units \times \frac{(BTU/h)/unit}{1{,}000} \times \frac{1}{CEER_{baseline}} \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures recycled under the program
(BTU/h)/unit	= British Thermal Units per hour of air conditioning per unit
baseline	= Characteristic of baseline condition
CEER	= Combined Energy Efficiency Ratio

[99] 10 CFR 430.2

$EFLH_{cooling}$ = Cooling equivalent full-load hours
CF = Coincidence factor
1,000 = Conversion factor, one kW equals 1,000 Watts

Summary of Variables and Data Sources

Variable	Value	Notes
(BTU/h)/unit		From application, or use 7,829 as default.[100]
$CEER_{baseline}$		If known, use the nameplate efficiency of the recycled equipment, from application. Nameplate EER may be converted to CEER by dividing EER by 1.01 (EER/1.01 = CEER).[101] If unknown, see Baseline Efficiencies section below.
$EFLH_{cooling}$		Cooling equivalent full-load hours, lookup from Operating Hours section below based on location.
CF	0.3	

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.3.[102] The average Seasonal CF based on 2007 weather data used for this measure aligns with results of a sampling study conducted in Con Edison territory, citing a CF = 0.31.[103]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is equivalent to the existing equipment. $CEER_{baseline}$ shall be set equal to the nameplate efficiency of the existing unit, converted from EER to CEER via the conversion CEER = EER/1.01, if necessary. If nameplate efficiency is unavailable, use the rated efficiency ratio based on recycled equipment type and capacity per the table below.

The CEER values listed in the table below reflect the minimum performance required by the Code of Federal Regulations effective October 1, 2000 to May 31, 2014.[104]

[100] RLW Analytics, Coincidence Factor Study: Residential Room Air Conditioners, June 2008, p. 22 (based on population average)
[101] Conversion factor developed by comparing EER and CEER values reported in ENERGY STAR® Program Requirements for Room Air Conditioners Version Eligibility Criteria 3.1
[102] RLW Analytics, Coincidence Factor Study: Residential Room Air Conditioners, June 2008, p. iv (based on average Seasonal CF for all load zones using 2007 weather data)
[103] Northeast Energy Efficiency Partnerships, Loadshape Report and Catalogue
[104] 10 CFR 430.32(b), CFR EER values were converted to CEER values by dividing by 1.01. Conversion factor developed by comparing EER and CEER values reported in ENERGY STAR® Program Requirements for Room Air Conditioners Version Eligibility Criteria 4.1.

Product Type	Product Class Capacity (BTU/h)	Federal Standard With Louvered Sides (CEER)	Federal Standard Without Louvered Sides (CEER)
RAC without Reverse Cycle	< 6,000	9.6	8.9
	6,000 to 7,999	9.6	8.9
	8,000 to 10,999	9.7	8.4
	11,000 to 13,999	9.7	8.4
	14,000 to 19,999	9.6	8.4
	20,000 to 27,999	8.4	8.4
	≥ 28,000	8.4	8.4
RAC with Reverse Cycle	< 14,000	8.9	8.4
	14,000 to 19,999	8.9	7.9
	≥ 20,000	8.4	7.9
Casement Only	All	8.6	
Casement-Slider	All	9.4	

Compliance Efficiency from which Incentives are Calculated

The compliance condition is the recycling of an existing room air conditioner as defined in the Measure Description section above.

Operating Hours

Cooling equivalent full load hours for residential room air conditioners shall be established based on location per the table below. $EFLH_{cooling}$ values below were determined by calculating the ratio of RAC cooling EFLH in Albany[105] to average cooling EFLH in Albany per Appendix G and applying it to the average EFLH for each city. EFLH was averaged from Appendix G over vintage and building type for each city.

City	$EFLH_{cooling}$
Albany	224
Binghamton	171
Buffalo	219
Massena	187
NYC	364
Poughkeepsie	282
Syracuse	226

Example Calculation *(Not to be used as default)*

A single-family homeowner located near Massena recycles an existing functional air conditioning unit with 7,800 BTU/h capacity and louvered sides. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident

[105] RLW Analytics, Coincidence Factor Study: Residential Room Air Conditioners, June 2008, p. iv (based on 2007 FLEH for Albany)

Demand Savings are calculated as below.

$$\Delta kWh = units \times \frac{(BTU/h)/unit}{1{,}000} \times \frac{1}{CEER_{baseline}} \times EFLH_{cooling}$$

$$\Delta kW = units \times \frac{(BTU/h)/unit}{1{,}000} \times \frac{1}{CEER_{baseline}} \times CF$$

units = 1, from application
(BTU/h)/unit = 7,800BTU/h, from application
$CEER_{baseline}$ = 9.6, from Baseline Efficiencies section based on Product Type, Class and Capacity
$EFLH_{cooling}$ = 187, from Operating Hours section based on location
CF = 0.3, from Summary of Variables and Data Sources table

$$\Delta kWh = 1 \times \frac{7{,}800}{1{,}000} \times \frac{1}{9.6} \times 187 = 151.94 \text{ kWh}$$

$$\Delta kW = 1 \times \frac{7{,}800}{1{,}000} \times \frac{1}{9.6} \times 0.3 = 0.24\ kW$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. 10 CFR 430.2 Definitions
   Available from: https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=6dc64a198ad50a16b0ff6af63189872b&mc=true&n=pt10.3.430&r=PART&ty=HTML#se10.3.430_12

2. RLW Analytics, Final Report Coincidence Factor Study: Residential Room Air Conditioners. June 23, 2008
   Available from:
   http://www.puc.state.nh.us/electric/Monitoring%20and%20Evaluation%20Reports/National%20Grid/124_SPWG%20Room%20%20AC%20Evaluation%20FINALReport%20June%2023%20ver7.pdf
3. ENERGY STAR® Program Requirements Product Specification for Room Air Conditioners Eligibility Criteria Version 4.1
   Available from:
   https://www.energystar.gov/sites/default/files/asset/document/ENERGY%20STAR%20Version%204.1%20Room%20Air%20Conditioners%20Specification.pdf
4. Northeast Energy Efficiency Partnerships, Loadshape Report and Catalogue
   Available from: http://neep.org/loadshape-report-and-catalogue
5. 10 CFR 430.32 Energy and water conservation standards and their compliance dates
   Available from: https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=6dc64a198ad50a16b0ff6af63189872b&mc=true&n=pt10.3.430&r=PART&ty=HTML#se10.3.430_132

Record of Revision

Record of Revision Number	Issue Date
1	10/15/2010
7-13-37	7/31/2013
3-18-8	3/29/2018

Return to Table of Contents

DEHUMIDIFIER RECYCLING

Measure Description

In many cases, when a dehumidifier is replaced by a homeowner, the existing unit is retained, sold or donated for use elsewhere, representing additional load on the grid. This measure covers recycling of existing, functional, portable dehumidifiers, thereby eliminating the consumption associated with that equipment. This measure should target, but not be limited to dehumidifiers put into service prior to June 2019. If provided data indicate the unit is replaced rather than retired, savings shall be based on the Residential Dehumidifier measure in this TRM.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times capacity \times \frac{0.473}{24} \times hrs \times \frac{1}{L/kWh}$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \frac{\Delta kWh}{hrs} \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures recycled under the program
capacity	= Capacity of the unit (pints/day)
hrs	= Annual operating hours
L/kWh	= Dehumidifier efficiency (L/kWh)
CF	= Coincidence Factor
0.473	= Conversion factor to convert pints to liters
24	= Constant to convert liters/day to liters/hour

Summary of Variables and Data Sources

Variable	Value	Notes
capacity		From application.
L/kWh		Liters of water removed per kWh consumed, as provided in the Baseline Efficiencies section below.

Variable	Value	Notes
hrs	1,632	Run hours based on 68 days per year, 24 hours of operation.[106]
CF	0.56	

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.56.[107]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is equivalent to the existing equipment. If specific equipment efficiency is unavailable, use the dehumidifier efficiency based on manufacture date, capacity and ENERGY STAR® labeling status per the table below.

Capacity Range (pints/day)	ENERGY STAR® Labeled (L/kWh)[108]	Non- ENERGY STAR® Labeled	
		Manufacture date before Nov. 2012 (≥L/kWh)[109]	Manufacture date of Nov. 2012 or later (≥L/kWh)[110]
≤ 25	1.57	1.00	1.35
> 25 to ≤ 35	1.80	1.20	1.35
> 35 to ≤ 45	1.80	1.30	1.50
> 45 to ≤ 50	1.80	1.30	1.60
> 50 to ≤ 54	3.30	1.30	1.60
> 54 to ≤ 75	3.30	1.50	1.70
> 75 to ≤ 185	3.30	2.25	2.50

Compliance Efficiency from which Incentives are Calculated

The compliance condition is the recycling of an existing dehumidifier as defined in the Measure Description section above.

Operating Hours

The dehumidifier is assumed to be operating 1,632 hours per year based on 68 days of 24 hour operation.[111]

[106] Savings Calculator for ENERGY STAR® Qualified Appliances (accessed 05/11/2021)
[107] A. Mendyk & D. Cautley, Dehumidifier Metering Study, Home Energy, January 2011: Summer duty cycle used as a proxy for CF.
[108] ENERGY STAR® Program Requirements for Dehumidifiers, Version 5.0, February 2019
[109] 42 U.S.C, Title 42 Chapter 77, Subchapter III, Part A, (cc)(1)
[110] Ibid, (cc)(2)
[111] Savings Calculator for ENERGY STAR® Qualified Appliances (accessed 05/11/2021)

Example Calculation *(Not to be used as default)*

An existing residential customer in Albany recycles an operational dehumidifier with 30 pints/day capacity. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

$$\Delta kWh = units \times capacity \times \frac{0.473}{24} \times hrs \times \frac{1}{L/kWh}$$

$$\Delta kW = \frac{\Delta kWh}{hrs} \times CF$$

Units	= 1, from application
capacity	= 30 pints/day, from application
hrs	= 1,632 hours, from operating hours section
L/kWh	= 1.25 L/kWh, from application
CF	= 0.56, from Summary of Variables and Data sources table

$$\Delta kWh = 1 \times 30 \times \frac{0.473}{24} \times 1{,}632 \times \frac{1}{1.25} = 771.94\ kWh$$

$$\Delta kW = \frac{771.94}{1{,}632} \times 0.56 = 0.26\ kW$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. A. Mendyk & D. Cautley, Dehumidifier Metering Study, Home Energy, January 2011.
   Available from: http://www.homeenergy.org/show/article/id/777
2. 42 U.S.C, Title 42 Chapter 77, Subchapter III, Part A
   Available from: https://www.govinfo.gov/content/pkg/USCODE-2016-title42/html/USCODE-2016-title42-chap77-subchapIII-partA-sec6295.htm

3. Savings Calculator for ENERGY STAR® Qualified Appliances
   Available from: https://energy.mo.gov/sites/energy/files/energy-star-appliance-calculator.xlsx
4. ENERGY STAR® Program Requirements for Dehumidifiers, Version 5.0, February 2019
   Available from:
   https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Dehumidifiers%20Version%205.0%20Program%20Requirements.pdf

Record of Revision

Record of Revision Number	Issue Date
7-21-2	8/30/2021

Return to Table of Contents

REFRIGERATOR AND FREEZER RECYCLING

Measure Description

In many cases, when a refrigerator or freezer is replaced by a homeowner, the existing unit is retained, sold or donated for use elsewhere, representing additional load on the grid. This measure covers recycling of the existing, functional equipment, thereby eliminating the consumption associated with that equipment. Refrigerator and freezer recycling programs (also called "bounty" programs) receive energy savings credit for permanently removing inefficient, functional refrigerators and freezers from the electric grid.

This measure covers the recycling of primary (i.e. installed in a kitchen) and secondary (i.e. installed elsewhere) refrigerators, refrigerator-freezers and freezers. To account for the fact that secondary equipment is occasionally installed and operating for only part of the year, a part-time use adjustment factor has been developed and embedded within the gross savings estimate for secondary units to establish average annual per unit deemed electric savings.

This measure does not cover the recycling of equipment classified by the Code of Federal Regulations as "Compact refrigerator/refrigerator-freezer/freezer". This refers to any refrigerator, refrigerator-freezer or freezer with a total refrigerated volume of less than 7.75 ft^3 (220 liters), where the total refrigerated volume has been determined in accordance with the procedure prescribed in Appendix A (refrigerators and refrigerator-freezers) or B (freezers) of 10 CFR 430 Subpart B.[112]

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times (\Delta kWh/unit)$$

Summer Peak Coincident Demand Savings

$$\Delta kW = units \times \Delta kWh/8{,}760 \times TAF \times LSAF \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures recycled under the program
(ΔkWh/unit)	= Gross deemed annual electric savings per unit
TAF	= Temperature Adjustment Factor
LSAF	= Load Shape Adjustment Factor

[112] 10 CFR 430.2

CF = Coincidence Factor
8,760 = Hours in one year

Summary of Variables and Data Sources

There are several conditions that impact the estimated savings available from a refrigerator and/or freezer-recycling program. Factors such as the average type, make, model, size, and age of units recycled significantly impact the savings. Variances in these conditions have a significant impact of the level of savings that can be achieved. In addition, the average number of hours these units are plugged in and operating impact savings. Likewise, the environmental and operational conditions also impact the energy savings. These variables make establishing a projected engineering-based calculation approach for per unit savings a complex task that is prone to error because of the effects of the compounding uncertainty associated with the potential variance within each of the key estimation variables. However, savings projections in this measure are based on impact evaluations completed in New York State conducted in compliance with the National Renewable Energy Laboratory's Uniform Methods Project (UMP) Refrigerator Recycling Evaluation Protocol.[113]

The following deemed energy impact estimates shall be used in New York for refrigerator and freezer recycling programs.

Variable	Value	Notes
(ΔkWh/unit)	Primary Refrigerator: 1,218 Secondary Refrigerator: 794 Freezer: 846	Refrigerator based on Cadmus memo to Consolidated Edison. [114] Freezer based on Energy & Resource Solutions[115]
TAF	1.22	Temperature Adjustment Factor; reflects load variance during summer peak due to increased ambient temperature conditions.[116]
LSAF	1.06	Load Shape Adjustment Factor; reflects the instantaneous differential from annual average load coincident with peak.[117]
CF	1.0	

[113] NREL, The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures. January 2010-September 2016. Chapter 7: Refrigerator Recycling Evaluation Protocol
[114] Cadmus memo to Consolidated Edison, "Recommended Gross Savings Values for Refrigerator Recycling Programs", December 17, 2015
[115] Based on Energy & Resource Solutions "Con Edison EEPS Programs - Impact Evaluation of Residential Appliance Bounty Program", May 2015. Filed under Item Number 3788. Gross unit consumption of 1,267 kWhs x part use factor of 0.685 = 846 kWhs
[116] Blasnik, Michael, "Measurement and Verification of Residential Refrigerator Energy Use, Final Report, 2003-2004 Metering Study", July 29, 2004. It assumes 58% of New York homes have central air conditioning.
[117] Ibid.

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 1.0.[118]

Baseline Efficiencies from which Energy Savings are Calculated

The savings calculations above apply to recycling of a functioning primary[119] or secondary refrigerator, refrigerator-freezer or freezer with total refrigerated volume of 7.75 ft^3 (220 liters) or more.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is the recycling of an existing room refrigerator or freezer as defined in the Measure Description section above.

Operating Hours

Primary refrigerators or freezers are assumed to be connected to an electrical outlet 8,760 hours per year. Secondary units may only be connected part-time, but 8,760 hours per year is utilized in these cases as well for the sake of establishing conservative estimates of Summer Peak Coincident Demand Savings.

Example Calculation *(Not to be used as default)*

An existing residential customer recycles a primary refrigerator unit. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

$$\Delta kWh = units \times (\Delta kWh/unit)$$

$$\Delta kW = units \times \Delta kWh/8{,}760 \times TAF \times LSAF \times CF$$

units = 1, from application
ΔkWh/unit = 1,218, from Summary of Variables and Data Sources table based on application
TAF = 1.22, from Summary of Variables and Data Sources table
LSAF = 1.06, from Summary of Variables and Data Sources table
CF = 1.0, from Summary of Variables and Data Sources table

$$\Delta kWh = 1 \times 1{,}218 = 1{,}218 \text{ kWh}$$

$$\Delta kW = 1 \times 1{,}218/8{,}760 \times 1.22 \times 1.06 \times 1.0 = 0.18\ kW$$

[118] *No source specified – update pending availability and review of applicable references*
[119] Savings can be claimed for recycling a primary refrigerator as long as savings for that replacement were not claimed by another energy efficiency program.

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. 10 CFR 430.2 Definitions.
   Available from: https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=433d4d2525eac3e38a1ede79f3b5c0ed&mc=true&n=pt10.3.430&r=PART&ty=HTML#se10.3.430_12
2. NREL, The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures. January 2010-September 2016. Chapter 7: Refrigerator Recycling Evaluation Protocol.
   Available from: https://www.nrel.gov/docs/fy18osti/70472.pdf
3. Cadmus memo to Consolidated Edison, "Recommended Gross Savings Values for Refrigerator Recycling Programs", December 17, 2015
4. Con Edison EEPS Programs – Impact Evaluation of Residential Appliance Bounty Program, Energy & Resource Solutions (ERS), filed under Item Number 3788, May 4, 2015
   Available from:
   http://documents.dps.ny.gov/public/MatterManagement/MatterFilingItem.aspx?FilingSeq=148044&MatterSeq=27802
5. Blasnik, Michael, "Measurement and Verification of Residential Refrigerator Energy Use, Final Report, 2003-2004 Metering Study", July 29, 2004
   Available from: https://nascsp.org/wp-content/uploads/2018/02/blasnik_measurement-and-verification-of-residential-refrigerator.pdf
6. National Renewable Energy Laboratory, The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures, Chapter 7: Refrigerator Recycling Evaluation Protocol, April 2013.
   Available from: https://www.energy.gov/sites/prod/files/2013/05/f0/53827-7.pdf

Record of Revision

Record of Revision Number	Issue Date
2	10/15/2010
7-13-4	7/31/2013
9-13-2	9/2/2013
6-15-2	6/1/2015
12-17-2	12/31/2017
6-19-4	6/28/2019

Return to Table of Contents

BUILDING SHELL

AIR CONDITIONER – ROOM (RAC) COVER AND GAP SEALER

Measure Description

This measure covers the installation of a rigid, insulated cover installed on the inside of a room air conditioner (RAC) and a cover or sealing on the gap surrounding the unit. The cover is designed for permanently installed RAC units, which comprise window air conditioners and through-the-wall air conditioners, left in place throughout the heating season and reduces heating load by limiting the infiltration of cold outside air. To ensure persistence of savings, homeowner/building staff shall be instructed on proper annual removal and reinstallation. This measure assumes the cover is in place outside of the cooling season for the duration of the measure EUL.

Method for Calculating Annual Energy and Peak Coincident Demand Savings

Annual Electric Energy Savings (Electric Heating Equipment Only)

$$\Delta kWh = units \times \frac{1.08 \times CFM \times HDD \times 24}{Eff_{heating} \times 3{,}412}$$

Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings (Fossil Fuel Heating Equipment Only)

$$\Delta MMBtu = units \times \frac{1.08 \times CFM \times HDD \times 24}{Eff_{heating} \times 1{,}000{,}000}$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
CFM	= Cubic foot per minute
HDD	= Heating degree day
$Eff_{heating}$	= Efficiency of heating system
1.08	= Specific heat of air × density of inlet air @ 70˚F × 60 min/hr[120]
24	= Hours in one day
3,412	= Conversion factor, one kWh equals 3,412 BTU
1,000,000	= Conversion factor, one MMBtu equals 1,000,000 BTU

[120] The sensible heat constant at standard conditions of 1.08 is applied in accordance with standard HVAC industry practice. While the underlying assumptions are not representative characteristics of a NY heating season, the impacts to this value due to average heating season temperature and NY mean elevation offset such that the NY heating season specific value is approximately 1.08.

Summary of Variables and Data Sources

Variable	Value	Notes
CFM	19	Based on a negative pressure differential of 10 Pa. [121,122]
HDD		Look up in Heating Degree Days section below based on location.
$Eff_{heating}$		From application, based on existing equipment nameplate efficiency. If unknown, look up in table below based on equipment type and size. For electric resistance heat, use a value of 1.0.

Heating Degree Days

The table below presents the heating degree days (HDD) for several NY cities throughout the heating season (October 1st through May 31st).[123] Heating degree days represent the annual summation of the number of degrees that each day's average temperature is below some baseline temperature. The values below are distinct from HDD values used elsewhere in this TRM because they exclude degree days that fall on cooler evenings during the cooling season when the cover would not be in place. The baseline temperature reflects the temperature below which it is assumed a building needs to be heated. The HDD values below are based on 30-year averages of U.S annual climate normals between 1981 and 2010 using a baseline temperature of 65° F.[124]

City	HDD
Albany	6,464
Binghamton	6,857
Buffalo	6,397
Massena	7,828
NYC	4,560
Poughkeepsie	6,099
Syracuse	6,425

Coincidence Factor (CF)

The prescribed value for the coincidence factor is N/A.

Baseline Efficiencies from which Savings are Calculated

The baseline condition is a room air conditioning unit in a multifamily building left in place through the heating season without a cover.

The baseline efficiency of the heating system is the nameplate efficiency of the existing equipment. If unknown, the baseline efficiency is that of a minimally code compliant system of type and capacity equivalent to the existing case.

[121] Steven Winter Associates, There Are Holes in Our Walls, April 2011, pg 13
[122] TRANE Engineers Newsletter, Managing the Ins and Outs of Commercial Building Pressurization, 2002, pg 6. A conservative estimation of building pressure differential throughout New York State during the heating season.
[123] NYC Department of Housing Preservation and Development, Residential Heat and Hot Water Requirements
[124] HDD during heating season calculated from NOAA National Centers for Environmental Information

If the existing equipment efficiency is unknown, the baseline efficiency for fossil fuel fired heating systems serving single-family homes and individual units is defined by the Code of Federal Regulations as shown in the table below.

Fossil Fuel Fired Heating System Baseline Efficiencies: Systems Serving Single Units[125]

Equipment Type	Size Range	ECCCNYS Minimum Efficiency for Climate Zones 4, 5 and 6
Warm Air Furnace, Gas Fired	All Capacities	0.80 AFUE
Warm Air Furnace, Oil Fired	All Capacities	0.83 AFUE
Boiler, Hot Water, Gas Fired	All Capacities	0.82 AFUE
Boiler, Hot Water, Oil Fired	All Capacities	0.84 AFUE
Boiler, Steam, Gas Fired	All Capacities	0.80 AFUE
Boiler, Steam Oil Fired	All Capacities	0.82 AFUE

If the existing equipment efficiency is unknown, the baseline efficiency for heating systems serving multiple dwelling units is defined by International Energy Conservation Code[126] and subsequently adopted by the Energy Conservation Construction Code of New York State (ECCCNYS) as shown in the table below.

Fossil Fuel Fired Heating System Baseline Efficiencies: Systems Serving Multiple Dwelling Units

Equipment Type	Size Range	ECCCNYS Minimum Efficiency for Climate Zones 4, 5 and 6
Warm Air Furnace, Gas Fired	< 225 kBTU/h	0.80 AFUE
	≥ 225 kBTU/h	0.80 Et
Warm Air Furnace, Oil Fired	< 225 kBTU/h	0.83 AFUE
	≥ 225 kBTU/h	0.80 Et
Warm Air Unit Heaters, Gas Fired	All Capacities	0.80 Ec
Warm Air Unit Heaters, Oil Fired	All Capacities	0.80 Ec
Boiler, Hot Water, Gas Fired	< 300 kBTU/h	0.82 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.80 Et
	> 2,500 kBTU/h	0.82 Ec
Boiler, Hot Water, Oil Fired	< 300 kBTU/h	0.84 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.82 Et
	> 2,500 kBTU/h	0.84 Ec
Boiler, Steam, Gas Fired, All Except Natural Draft	< 300 kBTU/h	0.80 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.79 Et
	> 2,500 kBTU/h	0.79 Et

[125] 10 CFR 430.32(e)
[126] ECCCNYS 2020, Table C403.3.2(4) & Table C403.3.2(5)

Equipment Type	Size Range	ECCCNYS Minimum Efficiency for Climate Zones 4, 5 and 6
Boiler, Steam, Gas Fired, Natural Draft	< 300 kBTU/h	0.80 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.77 Et
	> 2,500 kBTU/h	0.77 Et
Boiler, Steam, Oil Fired	< 300 kBTU/h	0.82 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.81 Et
	> 2,500 kBTU/h	0.81 Et

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a room air conditioning unit in a multifamily building with a cover and/or sealing on the surrounding gap through the heating season (October 1st through May 31st).[127] Building staff shall be instructed on proper annual removal and reinstallation to ensure persistence of savings.

Operating Hours

Assumed equipment operating hours are embedded in Heating Degree Day values.

Example Calculation *(Not to be used as default)*

Two (2) covers are installed on room air conditioners in a multi-family residence located near Albany. The residence is equipped with electric resistance heat with an efficiency rating of 1.0 COP. Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings are calculated as below.

$$\Delta kWh = units \times \frac{1.08 \times CFM \times HDD \times 24}{Eff_{heating} \times 3{,}412}$$

units = 2, from application
CFM = 19, from Summary of Variables and Data Sources table
HDD = 6,464, from Heating Degree Day table based on location from application
$Eff_{heating}$ = 1.0, from Summary of Variables and Data Sources table based on application

$$\Delta kWh = 2 \times \frac{1.08 \times 19 \times 6{,}464 \times 24}{1 \times 3{,}412} = 1{,}866\ kWh$$

Effective Useful Life (EUL)

See Appendix P.

[127] NYC Department of Housing Preservation and Development, Residential Heat and Hot Water Requirements

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. There Are Holes in Our Walls; A Report Prepared for the Urban Green Building Council, by Steven Winter Associates, April 2011.
   Available from:
   https://urbangreencouncil.org/sites/default/files/there_are_holes_in_our_walls.pdf
2. TRANE Engineers Newsletter, Managing the ins and outs of Commercial Building Pressurization, Volume 31, No. 2, 2002
   Available from: https://www.trane.com/content/dam/Trane/Commercial/global/products-systems/education-training/engineers-newsletters/airside-design/admapn003en_0502.pdf
3. ECCCNYS 2020 Table C403.2.3(4): Warm-Air Furnaces And Combination Warm-Air Furnaces/Air-Conditioning Units, Warm-Air Duct Furnaces And Unit Heaters, Minimum Efficiency Requirements
   Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-[ce]-commercial-energy-efficiency#NYSECC2020P1_CE_Ch04_SecC403
4. NOAA National Centers for Environmental Information – NCEI 1981-2010 Climate Normals
   Available from: https://www.ncdc.noaa.gov/cdo-web/datatools/normals
5. NYC Department of Housing Preservation and Development, Residential Heat and Hot Water Requirements
   Available from: https://www1.nyc.gov/nyc-resources/service/1815/residential-heat-and-hot-water-requirements

Record of Revision

Record of Revision Number	Issue Date
6-14-1	6/19/2014
9-18-3	9/28/2018
3-19-3	3/29/2019
7-21-3	8/30/2021

Return to Table of Contents

AIR LEAKAGE SEALING

Measure Description

This measure covers methods of sealing air leakage paths to reduce the natural air infiltration rate of a building through the installation of products and repairs to the building envelope, including, but not limited to, caulking, gasketing, and weather stripping. Sealing the thermal envelope reduces passive convective heat transfer between conditioned and unconditioned spaces or outside air, thereby reducing heating and cooling loads and improving occupant comfort. This measure is only applicable as a retrofit in existing buildings. This measure is not applicable to gut rehab/major renovation projects, which entail whole-building envelope alterations that trigger more stringent code provisions, limiting potential incremental savings.

The exterior envelope, as well as interior walls/partitions between conditioned and unconditioned spaces should be inspected and all gaps sealed. At a minimum, the following items shall be inspected, and sealing measures may be implemented based upon inspection results:

- Caulk and weather strip doors and windows that leak air
- Repair or replace doors leading from conditioned to unconditioned space
- Seal air leaks between unconditioned (including unconditioned basement and attics) and conditioned spaces, to include, but not limited to, plumbing, ducting, electrical wiring, wall top plates, chimneys, flues, and dropped soffits.
- Use foam sealant on larger gaps around windows, baseboards, and other places where air leakage, either infiltration or exfiltration may occur.

Methods are provided below for single-family, low-rise multifamily and high-rise multifamily applications with and without blower door testing conducted before and after implementation of air sealing treatments. A blower door test is performed to measure the leakage rate by depressurizing the building to a standard pressure difference of 50 Pascals or 0.2 inches of water. The measured flowrate indicates the leakage rate, or infiltration and exfiltration rate, of the building shell. The first method below only applies to high-rise multifamily applications where blower door testing is not conducted. All other scenarios shall be addressed using the second set of algorithms below.

Blower door tests shall be performed whenever possible. The method provided below for single family/low-rise multifamily without blower door testing should only be used if blower door testing is not feasible due to health or safety concerns, e.g. the presence of a hazardous material like asbestos or mold, ongoing construction in the home or concerns regarding COVID-19.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings *(high-rise multifamily without blower door test)*

Annual Electric Energy Savings

$$\Delta kWh = units \times \frac{SF}{1{,}000} \times (\Delta kWh/kSF)$$

Summer Peak Coincident Demand Savings

$$\Delta kW = units \times \frac{SF}{1{,}000} \times (\Delta kW/kSF) \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = units \times \frac{SF}{1{,}000} \times \frac{(\Delta therms/kSF)}{10}$$

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings
(with blower door test or single-family/low-rise multifamily without blower door test)

Annual Electric Energy Savings

$$\Delta kWh = units \times \left(\frac{\Delta CFM_{50}}{F_n \times F_h}\right) \times (\Delta kWh/CFM)$$

Summer Peak Coincident Demand Savings

$$\Delta kW = units \times \left(\frac{\Delta CFM_{50}}{F_n \times F_h}\right) \times (\Delta kW/CFM) \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = units \times \left(\frac{\Delta CFM_{50}}{F_n \times F_h}\right) \times \frac{(\Delta therms/CFM)}{10}$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
SF	= Square footage of conditioned floor area affected by installation (ft^2)
(ΔkWh/kSF)	= Annual electric energy savings per thousand square feet
(ΔkW/kSF)	= Peak coincident demand electric savings per thousand square feet
(Δtherms/kSF)	= Annual fossil fuel energy savings per thousand square feet
ΔCFM_{50}	= Change in infiltration rate (cubic foot per minute) before and after air leakage sealing as determined by blower door testing at a negative pressure differential of 50 Pa (see Summary of Variables and Data Sources for derivation for single-family and low-rise multifamily applications without blower door testing)
F_n	= Infiltration-Leakage Ratio, used to convert pressurized blower door testing results to natural infiltration rates, climate zone factor
F_h	= Infiltration-Leakage Ratio, used to convert pressurized blower door testing results to natural infiltration rates, building height factor

(ΔkWh/CFM) = Annual electric energy savings per cubic foot per minute of reduced air leakage at 50 Pa
(ΔkW/CFM) = Peak coincident demand electric savings per cubic foot per minute of reduced air leakage at 50 Pa
(Δtherms/CFM) = Annual fossil fuel energy savings per cubic foot per minute of reduced air leakage at 50 Pa
CF = Coincidence factor
1,000 = Conversion factor from square feet (SF) to 1,000 square feet (kSF)
10 = Conversion factor, one MMBtu equals 10 therms

Summary of Variables and Data Sources

Variable	Value	Notes
SF		From application.
(ΔkWh/kSF)		Look up from Appendix E based on city and building vintage.
(ΔkW/kSF)		Look up from Appendix E based on city and building vintage.
(Δtherms/kSF)		Look up from Appendix E based on city and building vintage.
ΔCFM_{50}		From application, results from blower door test. For single-family and low-rise multifamily homes, if conducting a blower door test is not feasible due to health and safety concerns, multiply affected area square footage by a deemed ΔCFM_{50}/SF of 0.50 (i.e., ΔCFM_{50} = 0.50 x SF).[128]
F_n	19	Value chosen from the range of 17-19 to reflect a conservative estimate of savings.[129]
F_h	1 story: 1.00 1.5 stories: 0.90 2 stories: 0.81 2.5 stories: 0.76 3+ stories: 0.70	Based on the number of conditioned stories in the building. [130] The selected value should reflect the number of stories located inside the conditioned envelope of the building. Unconditioned basements and attics should not be included. Half-story values are provided for upper levels without full height perimeter walls.
(ΔkWh/CFM)		Look up from Appendix E based on HVAC type and city.
(ΔkW/CFM)		Look up from Appendix E based on HVAC type and city.
(Δtherms/CFM)		Look up from Appendix E based on HVAC type and city.

[128] Default ΔCFM_{50}/SF of 0.50 is the median value of single-family blower door test data provided by ConEdison, conducted 2018-2020.
[129] LBL, Estimation of Infiltration from Leakage and Climate Indicators, December 1986, pg. 84
[130] Ibid. The value for 2.5 stories was interpolated from presented data.

Variable	Value	Notes
CF	0.69	

Unit energy and demand savings were calculated from a DOE-2.2 simulation of a series of prototypical single and multifamily residential buildings. The prototype building characteristics are described in Appendix A. The unit energy and demand savings are shown in Appendix E.

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.69.[131]

Baseline Efficiencies from which Energy Savings are Calculated

Baseline natural infiltration air changes per hour of 1.0 NACH for old vintage buildings and 0.5 NACH for average vintage buildings are assumed to estimate energy and demand savings tabulated in Appendix E.

A baseline SEER value of 13 and EER value of 11.1 are used in the simulations, as detailed in Appendix A, to estimate energy and demand savings tabulated in Appendix E.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is the application of air leakage sealing treatments to an existing building envelope (excluding gut rehab/major renovations) such that the exterior envelope, as well as interior walls/partitions between conditioned and unconditioned spaces have been inspected and all gaps sealed. At a minimum, the following items shall be inspected, and sealing measures may be implemented based upon inspection results:

- Caulk and weather strip doors and windows that leak air
- Repair or replace doors leading from conditioned to unconditioned space
- Seal air leaks between unconditioned (including unconditioned basement and attics) and conditioned spaces, to include, but not limited to, plumbing, ducting, electrical wiring, wall top plates, chimneys, flues, and dropped soffits.
- Use foam sealant on larger gaps around windows, baseboards, and other places where air leakage, either infiltration or exfiltration may occur.

Operating Hours

HVAC system operating hours are embedded into the deemed savings shown in Appendix E and vary by building type. See Appendix A for details on prototype building simulation parameters.

[131] Based on BG&E 'Development of Residential Load Profile for Central Air Conditioners and Heat Pumps' research, the Maryland Peak Definition coincidence factor is 0.69. This study is not publicly available, but is referenced by M. M. Straub, Using Available Information for Efficient Evaluation of Demand-Side Management Programs, Electricity Journal, September 2011 and supported by research conducted by Cadmus on behalf of the RM Management Committee.

Example Calculation *(Not to be used as default)*

Caulking was performed to seal air leakage in a 2-story multi-family building located near Albany after a blower door test was conducted. The pre and post insulation duct blaster testing demonstrated a change in CFM_{50} of 1,300. The building has central air conditioning and gas heat. Annual Electric Energy Savings, Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta kWh = units \times \left(\frac{\Delta CFM_{50}}{F_n \times F_h}\right) \times (\Delta kWh/CFM)$$

$$\Delta kW = units \times \left(\frac{\Delta CFM_{50}}{F_n \times F_h}\right) \times (\Delta kW/CFM)$$

$$\Delta MMBtu = units \times \left(\frac{\Delta CFM_{50}}{F_n \times F_h}\right) \times \frac{(\Delta therms/CFM)}{10}$$

units = 1, from application
ΔCFM_{50} = 1,300, from application
F_n = 19, from Summary of Variables and Data Sources table
F_h = 0.81, from Summary of Variables and Data Sources table based on building type from application
ΔkWh/CFM = 1.5, from Appendix E based on HVAC type and city from application
ΔkW/CFM = 0.004, from Appendix E based on HVAC type and city from application
Δtherms/CFM = 2.4, from Appendix E based on HVAC type and city from application

$$\Delta kWh = 1 \times \left(\frac{1{,}300}{19 \times 0.81}\right) \times 1.5 = 126.71\ kWh$$

$$\Delta kW = 1 \times \left(\frac{1{,}300}{19 \times 0.81}\right) \times 0.004 = 0.34\ kW$$

$$\Delta MMBtu = 1 \times \left(\frac{1{,}300}{19 \times 0.81}\right) \times \frac{2.4}{10} = 20.27\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. Lawrence Berkeley Laboratory, Estimation of Infiltration from Leakage and Climate Indicators, Sherman, M. December 1986
   Available from: http://eta-publications.lbl.gov/sites/default/files/estimation_of_inflitration_from_leakage_and_climate_indicators.pdf
2. BG&E: Development of Residential Load Profile for Central Air Conditioners and Heat Pumps
3. ECCCNYS 2020 Section C402.5.1 Air Barrier Testing
   Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-[ce]-commercial-energy-efficiency#NYSECC2020P1_CE_Ch04_SecC403
4. ECCCNYS 2020 Section R402 Building Thermal Envelope
   Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-[re]-residential-energy-efficiency#NYSECC2020P1_RE_Ch04_SecR402
5. NYSMC 2020; Section 401.2 Ventilation Required
   Available from: https://codes.iccsafe.org/content/NYSMC2020P1/chapter-4-ventilation

Record of Revision

Record of Revision Number	Issue Date
1	10/15/2010
7-13-25	7/31/2013
9-18-19	9/30/2018
12-18-2	12/28/2018
3-19-1	3/29/2019
3-21-2	4/9/2021

Return to Table of Contents

INSULATION - HOT WATER AND STEAM PIPE

Measure Description

This measure covers the installation of fiberglass, rigid foam and cellular glass pipe insulation on uninsulated copper or steel piping with a nominal diameter between 0.50" and 4.00" in hot water and steam space heating and domestic hot water (DHW) distribution systems in residential buildings. Estimation of energy savings depends on the type and size of the pipe, type and thickness of the insulation, hot water temperature and ambient temperature.

This measure is applicable in retrofit applications only and must be installed by a qualified contractor complying with all relevant construction and safety codes and standards. Only insulation materials certified and rated in accordance with all pertinent ASTM thermal insulation standards may be installed under this measure. This measure is restricted to lengths of existing uninsulated piping in unconditioned spaces only.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = \frac{(UA/L)_{baseline} - (UA/L)_{ee}}{E_{t,elec} \times 3{,}412} \times l \times \Delta T \times hrs \times ElecSF$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \frac{\Delta kWh}{8{,}760} \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = \frac{(UA/L)_{baseline} - (UA/L)_{ee}}{E_{t,fuel} \times 1{,}000{,}000} \times l \times \Delta T \times hrs \times FuelSF$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
baseline	= Characteristic of baseline condition
ee	= Characteristic of energy efficient condition
(UA/L)	= Overall heat transfer coefficient per unit length (BTU/h-°F-ft)
E_t	= Thermal efficiency of hot water source
l	= Length of installed insulation (ft)
ΔT	= Temperature difference between hot water in pipe and surrounding ambient air temperature (°F)
hrs	= Annual operating hours
ElecSF	= Electric Savings Factor: Adjustment to electric energy savings based on fuel type

FuelSF = Fossil fuel Savings Factor: Adjustment to fossil fuel energy savings based on fuel type
CF = Coincidence factor
3,412 = Conversion factor, one kW equals 3,412 BTU/h
1,000,000 = Conversion factor, one MMBtu equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
$(UA/L)_{baseline}$		Lookup from Baseline Efficiencies section below, based on pipe diameter, pipe material and application.
$(UA/L)_{ee}$		Lookup from Compliance Efficiency section below, based on pipe diameter and insulation type and thickness.
$E_{t,elec}$	DHW: 0.98	Recovery efficiency of typical electric storage type water heater.[132]
$E_{t,fuel}$	DHW: 0.75 Gas-Fired HW Boiler: 0.84 AFUE Gas-Fired Steam Boiler: 0.82 AFUE Oil-Fired HW Boiler: 0.86 AFUE Oil-Fired Steam Boiler: 0.85 AFUE	Recovery efficiency of typical gas and oil storage type water heater and baseline efficiency of residential-size space heating boilers. [133,134]
l		From application
ΔT	$T_{pipe} - T_{amb}$	
T_{pipe}	DHW: 125 HW Boiler: 160 Steam Boiler: 212	Average temperature of hot water in distribution system piping (°F). [135]
T_{amb}	DHW: 70 Space Heat: 50	Surrounding average ambient air temperature (°F). [136,137]

[132] Per 10 CFR 430 Subpart B Appendix E – Uniform Test Method for Measuring the Energy Consumption of Water Heaters: *6.3.2 Recovery Efficiency*
[133] Per 10 CFR 430, typical recovery efficiency of a gas water heater, which is used for the purposes of this measure as a proxy for thermal efficiency, is 0.75. See for example, 10 CFR 430 Subpart B Appendix C1, 5.6.1.1.
[134] 10 CFR 430.32(e)(iii)(A)
[135] 10 CFR 430 Appendix E to Subpart B of Part 430 Uniform Test Method for Measuring the Energy Consumption of Water Heaters, Section 2. Test Conditions, 2.5 Set Point Temperature.
[136] Average annual ambient temperature in unconditioned spaces
[137] Average ambient temperature based on typical heating season conditions of unconditioned basements

Variable	Value	Notes
ElecSF	Electric WH: 1.00 Fossil Fuel WH: 0 Unknown WH: 0.31 Space Heat: 0	Based on EIA Residential Energy Consumption Survey (RECS) 2015 for Middle Atlantic States.[138] "Unknown" shall only be applied when the collection of information on water heating fuel is not feasible due to program configuration or delivery mechanism.
FuelSF	Electric WH: 0 Fossil Fuel WH: 1.00 Unknown WH: 0.56 Space Heat: 1.00	Based on EIA Residential Energy Consumption Survey (RECS) 2015 for Middle Atlantic States.[139] "Unknown" shall only be applied when the collection of information on water heating fuel is not feasible due to program configuration or delivery mechanism.
hrs	DHW: 8,760 Space Heat: $EFLH_{heating}$ (Appendix G)	See Operating Hours section below.
CF	DHW: 1.0 Space Heat: N/A	

Coincidence Factor (CF)

The prescribed value for the coincidence factor for domestic water heating is 1.0.[140]
The prescribed value for the coincidence factor for space heating is N/A.

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a length of uninsulated copper or steel domestic hot water or space heating piping located in an unconditioned space. Prescribed $(UA/L)_{baseline}$ values are provided in the table below based on the diameter of pipe, pipe material, and application. Pipe wall resistance and exterior film resistance were not considered in the derivation of the values below. Values were developed using NAIMA's 3E Plus software program .[141] Insulation of CPVC, PEX and HDPE piping is not eligible for savings under this measure.[142]

[138] EIA Residential Energy Consumption Survey (RECS) 2015 for Middle Atlantic States, Table HC8.7, Fuel used by main water heater ("Unknown" calculated as the number of homes with electric water heating divided by the total number of homes with water heating)
[139] EIA Residential Energy Consumption Survey (RECS) 2015 for Middle Atlantic States, Table HC8.7, fuel used by main water heater ("Unknown" calculated as the number of homes with gas water heating divided by the total number of homes with water heating)
[140] *No source specified – update pending availability and review of applicable references.*
[141] Insulation Institute, 3E Plus® Version 4.1
[142] These piping materials were found to have limited savings potential through preliminarily modeling in 3E Plus® Version 4.1

Pipe Diam. (in)	$(UA/L)_{baseline}$				
	Bare Copper Piping			Bare Steel Piping	
	Domestic Hot Water	Hot Water Heat	Steam Heat	Hot Water Heat	Steam Heat
0.50	0.44	0.48	0.53	0.53	0.59
0.75	0.54	0.58	0.64	0.65	0.72
1.00	0.65	0.70	0.78	0.79	0.88
1.25	0.80	0.86	0.96	0.97	1.09
1.50	0.90	0.97	1.09	1.10	1.23
2.00	1.10	1.19	1.33	1.34	1.51
2.50	1.31	1.42	1.58	1.60	1.80
3.00	1.57	1.70	1.90	1.92	2.16
3.50	1.77	1.92	2.15	2.18	2.45
4.00	1.98	2.14	2.40	2.43	2.73

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a length of copper or steel service hot water or space heating hot water/steam distribution piping insulated in accordance with ECCCNYS[143] which require hot water piping with 0.50" nominal diameter and larger to be insulated with a minimum thermal resistance of R-3. The R-value is the thermal resistance of the insulating material, which is derived by dividing the thickness of the material by the material's thermal conductivity, or k-value. Thermal transmittance, or the material's U-factor, is the inverse of the R-value.

The $(UA/L)_{ee}$ values associated with fiberglass, rigid foam and cellular glass insulation of various thicknesses provided in the table below shall be used to establish the compliance condition heat transfer coefficient. Pipe diameter and insulation type and thickness shall be taken from the application. The values below were calculated using a k-value of 0.25 BTU-in/h-°F-ft^2 for fiberglass and 0.35 BTU-in/ h-°F-ft^2 for rigid foam and cellular glass insulation at 100°F. Pipe wall resistance and exterior film resistance were ignored in the derivation of the values below. Values were developed using NAIMA's 3E Plus software program.[144]

Pipe Diam. (in)	$(UA/L)_{ee}$											
	Fiberglass						Rigid Foam/Cellular Glass					
	0.5 in	1 in	1.5 in	2 in	2.5 in	3 in	0.5 in	1 in	1.5 in	2 in	2.5 in	3 in
0.50	0.13	0.09	0.08	0.07	0.06	0.06	0.15	0.12	0.10	0.09	0.09	0.08
0.75	0.14	0.11	0.09	0.08	0.07	0.07	0.17	0.13	0.11	0.10	0.10	0.09
1.00	0.17	0.12	0.10	0.09	0.08	0.07	0.19	0.15	0.13	0.12	0.11	0.10
1.25	0.20	0.14	0.11	0.10	0.09	0.08	0.23	0.17	0.15	0.13	0.12	0.11
1.50	0.22	0.15	0.12	0.11	0.10	0.09	0.25	0.19	0.16	0.14	0.13	0.12
2.00	0.26	0.18	0.14	0.12	0.11	0.10	0.29	0.22	0.18	0.16	0.14	0.13
2.50	0.30	0.20	0.16	0.14	0.12	0.11	0.34	0.25	0.20	0.18	0.16	0.15
3.00	0.35	0.24	0.18	0.16	0.14	0.12	0.39	0.29	0.23	0.20	0.18	0.16

[143] ECCCNYS 2020, R403.5.3
[144] Insulation Institute, 3E Plus® Version 4.1

Pipe Diam. (in)	$(UA/L)_{ee}$											
	Fiberglass						Rigid Foam/Cellular Glass					
	0.5 in	1 in	1.5 in	2 in	2.5 in	3 in	0.5 in	1 in	1.5 in	2 in	2.5 in	3 in
3.50	0.40	0.26	0.20	0.17	0.15	0.13	0.44	0.32	0.26	0.22	0.20	0.18
4.00	0.44	0.29	0.22	0.18	0.16	0.14	0.48	0.35	0.28	0.24	0.21	0.19

Operating Hours

Domestic hot water heaters are assumed to be available for operation 8,760 hours per year.

Operating hours for water and steam boilers in space heating systems are established on the basis of equivalent full-load hours. Heating equivalent full-load hours were calculated from a DOE-2.2 simulation of prototypical single and multi-family residential buildings. Operating hour assumptions for the prototypical building models are described in Appendix A. The heating EFLH for residential buildings in NY by location, building type and vintage are tabulated in Appendix G.

Example Calculation *(Not to be used as default)*

An existing residential customer living near Poughkeepsie installs 0.5" fiberglass pipe insulation on 20 feet of bare copper domestic hot water piping with a 1.00" diameter. The home has electric water heating. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

$$\Delta kWh = \frac{(UA/L)_{baseline} - (UA/L)_{ee}}{E_{t,elec} \times 3{,}412} \times l \times \Delta T \times hrs \times ElecSF$$

$$\Delta kW = \frac{\Delta kWh}{8{,}760} \times CF$$

$(UA/L)_{baseline}$ = 0.65, from baseline efficiency based on pipe material, size, and application
$(UA/L)_{ee}$ = 0.17, from compliance efficiency based on insulation material and thickness and pipe size
$E_{t,elec}$ = 0.98, from Summary of Variables and Data
$\Delta T = T_{pipe} - T_{amb}$ = 125-70 = 55, from Summary of Variables and Data Sources table based on pipe application
hrs = 8,760, from Operating hours section based on pipe application
l = 20, from application
ElecSF = 1.0, from Summary of Variables and Data Sources table based on application
CF = 1.0, from Summary of Variables and Data Sources table based on application

$$\Delta kWh = \frac{(0.65 - 0.17)}{0.98 \times 3{,}412} \times 20 \times 55 \times 8{,}760 \times 1.0 = 1{,}383.26\ kWh$$

$$\Delta kW = \frac{1{,}383.26}{8{,}760} \times 1.0 = 0.16\ kW$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. 10 CFR 430 Subpart B – Test Procedures, Appendix E – Uniform Test Method for Measuring the Energy Consumption of Water Heaters
   Available from: https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=9624a8ba0987aaae248454c49194a661&mc=true&n=pt10.3.430&r=PART&ty=HTML#ap10.3.430_127.e
2. 10 CFR 430 Subpart B – Test Procedures, Appendix C1 - Uniform Test Method for Measuring the Energy Consumption of Dishwashers
   Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=9acb5e05dd1d96230c64079cf0c03102&mc=true&node=pt10.3.430&rgn=div5#ap10.3.430_127.c1
3. 10 CFR 430.32 Energy and water conservation standards and their compliance dates.
   Available from: http://www.ecfr.gov/cgi-bin/text-idx?SID=a9921a66f2b4f66a32ec851916b7b9d9&mc=true&node=se10.3.430_132&rgn=div8
4. 10 CFR 430 Appendix E to Subpart B of Part 430 Uniform Test Method for Measuring the Energy Consumption of Water Heaters, Section 2. Test Conditions, 2.5 Set Point Temperature
   Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=80dfa785ea350ebeee184bb0ae03e7f0&mc=true&node=ap10.3.430_127.e&rgn=div9
5. EIA Residential Energy Consumption Survey (RECS) 2015 Survey Data for Middle Atlantic States, February 2015
   Available from:
   https://www.eia.gov/consumption/residential/data/2015/hc/php/hc8.7.php
6. 3E Plus, NAIMA, Insulation Institute, Version 4.1
   Available from: https://insulationinstitute.org/tools-resources/free-3e-plus/

7. ECCCNYS 2020 R403.5.3 Hot water pipe insulation (Prescriptive) Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-[re]-residential-energy-efficiency#NYSECC2020P1_RE_Ch04_SecR402

Record of Revision

Record of Revision Number	Issue Date
1	10/15/2010
7-13-15	7/31/2013
6-18-2	6/26/2018
12-20-1	12/31/2020

Return to Table of Contents

INSULATION - OPAQUE SHELL

Measure Description

This measure covers the installation of wall and ceiling insulation to reduce the thermal conductance of the building envelope. Energy and demand savings are realized through reductions in the building's heating and cooling loads. Existing (baseline) and installed (qualifying) shell R-values must be captured to estimate energy savings.

This measure includes, but is not limited to, blown-in insulation in walls and ceilings. Cellulose is the most common blown-in insulation material; other materials include mineral fiber, loose-fill fiberglass, and Styrofoam pellets. Cellulose insulation is made from a cellular plant source, most commonly wood or paper, and treated with fire and pest resistant chemicals. Cellulose insulation is installed in three primary forms: loose-fill, stabilized and wall-cavity spray. Loose-fill insulation is a dry install that is blown into joist cavities in uninsulated attics or applied over existing batts. Stabilized cellulose is similar to loose-fill and applied in the same way but contains a moisture-activated adhesive that serves to increase the density of the cellulose and limit settling. Wall-cavity spray is typically applied prior to drywall installation in new construction, however insertion into existing walls is possible.

This measure is only applicable as a retrofit in existing single and multi-family buildings, excluding gut rehab/major renovation projects. These projects entail whole-building envelope alterations that trigger more stringent code provisions, limiting potential incremental savings.

For applications involving both wall and ceiling insulation, evaluate each component separately via the method below and sum together to determine total estimated energy savings.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = \Delta kWh_{cooling} + \Delta kWh_{heating}$$

$$\Delta kWh_{cooling} = \frac{\left(\frac{1}{R_{baseline}} - \frac{1}{R_{baseline} + \Delta R}\right) \times A \times \left(1 - F_{framing}\right) \times CDD \times 24 \times F_{ElecCool}}{1{,}000 \times SEER}$$

$$\Delta kWh_{heating} = \frac{\left(\frac{1}{R_{baseline}} - \frac{1}{R_{baseline} + \Delta R}\right) \times A \times \left(1 - F_{framing}\right) \times HDD \times 24 \times F_{ElecHeat}}{1{,}000 \times HSPF}$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \frac{\left(\frac{1}{R_{baseline}} - \frac{1}{R_{baseline} + \Delta R}\right) \times A \times \left(1 - F_{framing}\right) \times F_{ElecCool}}{1{,}000 \times EER} \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = \frac{\left(\frac{1}{R_{baseline}} - \frac{1}{R_{baseline} + \Delta R}\right) \times A \times \left(1 - F_{framing}\right) \times HDD \times 24 \times F_{FuelHeat}}{1{,}000{,}000 \times Eff_{FuelHeat}}$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
$\Delta kWh_{cooling}$	= Annual electric cooling energy savings
$\Delta kWh_{heating}$	= Annual electric heating energy savings
$R_{baseline}$	= R-value of existing insulation (ft^2-F°-h/BTU)
ΔR	= Difference in R-value between installed insulation and existing insulation (ft^2-F°-h/BTU)
A	= Area of insulated surfaces (ft^2)
$F_{framing}$	= Framing factor
$F_{ElecCool}$	= Electric cooling factor; used to account for the presence or absence of an electric cooling system
CDD	= Cooling Degree Days - The number of degrees that a day's average temperature is above some baseline temperature, which represents the temperature above which buildings need to be cooled. The baseline temperature is typically 65°F, but may vary based on application.
HDD	= Heating Degree Days - The number of degrees that a day's average temperature is below some baseline temperature, which represents the temperature below which buildings need to be heated. The baseline temperature is typically 65°F, but may vary based on application.
$F_{ElecHeat}$	= Electric heating factor, used to account for the presence or absence of an electric heating system
$F_{FuelHeat}$	= Fossil fuel heating factor, used to account for the presence or absence of a fossil fuel heating system
SEER	= Seasonal average energy efficiency ratio over the cooling season, BTU/watt-hour, used for average U.S. location/region
HSPF	= Heating seasonal performance factor, BTU/watt-hour, total heating output (supply heat) in BTU (including supplemental heaters) during the heating season / total electric energy heat pump consumed (in watt-hour)
EER	= Energy efficiency ratio under peak conditions (BTU/watt-hour)
$Eff_{FuelHeat}$	= Efficiency of fuel heating equipment (AFUE, Et, or Ec)
CF	= Coincidence factor
24	= Hours in one day
1,000	= Conversion factor, one kW equals 1,000 watts
1,000,000	= Conversion factor, one MMBtu equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
$R_{baseline}$		From application. If unknown, lookup in Baseline Efficiency section below, based on building vintage and building envelope component. Assume default for uninsulated surfaces to be R-2 for ceilings and R-4 for walls, per the pre-war uninsulated brick vintage values in the table below.
ΔR		From application.
A		From application.
$F_{framing}$	Walls: 0.25 Ceilings: 0.07	ASHRAE.[145]
$F_{ElecCool}$		If an electric cooling system is present, set equal to 1. Otherwise, set equal to 0.
CDD		Lookup based on location in Heating and Cooling Degree Days table below.
HDD		Lookup based on location in Heating and Cooling Degree Days table below.
$F_{ElecHeat}$		Use a value of 1.0 if the building is electrically heated. Otherwise, use 0.0.
$F_{FuelHeat}$		Use a value of 1.0 if the building is fuel heated. Otherwise, use 0.0.
SEER		From application. If unknown use 13 SEER, assuming a minimally code compliant, 3-ton, split system AC.[146]
HSPF		From application. If unknown use 8.2 HSPF, assuming a 3-ton central ASHP system.[147] For electric resistance heating and electric furnaces, use 3.4 HSPF. If taken from application, COP must be converted to HSPF using the equivalency HSPF = COP x 3.412.
EER		From application. If unknown, baseline EER is established as follows[148]: $EER = (1.12 \times SEER) - (0.02 \times SEER^2)$
$Eff_{FuelHeat}$		From application. If unknown, lookup based on system size and type in Baseline Efficiencies from which Energy Savings are Calculated section below.
CF	0.69	

[145] ASHRAE, 2001, "Characterization of Framing Factors for New Low-Rise Residential Building Envelopes (904-RP)," Table 7.1.
[146] ECCCNYS 2020, Table C403.3.2(1))
[147] Ibid.
[148] DOE, Building America House Simulation Protocols, October 2010

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.69.[149]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a building envelope with insufficient insulation (i.e., not compliant with all applicable construction code requirements). R-value of existing insulation shall come from application. If unknown, lookup in the Existing Building Envelope R-value table below based on building vintage and building envelope component. Alternatively, R-3.1 per inch of existing insulation may be applied.[150]

Existing Building Envelope R-value

Vintage	Wall	Ceiling
Pre-war uninsulated brick[151]	4	2
Prior to 1979[152]	7	11
From 1979 through 2006[153]	11	19
From 2007 through the present[154]	19	38 (Climate Zones 4 & 5) 49 (Climate Zone 6)

The baseline efficiency for fossil fuel fired heating systems serving single-family homes and individual units is the nameplate efficiency of the existing equipment. If unknown, the baseline efficiency is defined by the Code of Federal Regulations as shown in the table below.

Fossil Fuel Fired Heating System Baseline Efficiencies: Systems Serving Single Units[155]

Equipment Type	Size Range	ECCCNYS Minimum Efficiency for Climate Zones 4, 5 and 6
Warm Air Furnace, Gas Fired	All Capacities	0.80 AFUE
Warm Air Furnace, Oil Fired	All Capacities	0.83 AFUE
Boiler, Hot Water, Gas Fired	All Capacities	0.82 AFUE
Boiler, Hot Water, Oil Fired	All Capacities	0.84 AFUE
Boiler, Steam, Gas Fired	All Capacities	0.80 AFUE

[149] Based on BG&E 'Development of Residential Load Profile for Central Air Conditioners and Heat Pumps' research, the Maryland Peak Definition coincidence factor is 0.69. This study is not publicly available, but is referenced by M. M. Straub, Using Available Information for Efficient Evaluation of Demand-Side Management Programs, Electricity Journal, September 2011 and supported by research conducted by Cadmus on behalf of the TRM Management Committee.

[150] DOE, Energy Saver, Insulation Materials. Assumes "low-density" fiberglass batts for 2 by 4 inch stud-framed wall (R-11/3.5 inch = R-3.1 per inch of insulation).

[151] Wall insulation assumes three 4'' brick layers; no insulation; 2'' air gap resistance only, Ceiling assumes no ceiling insulation, as captured in Appendix A of this TRM for Multi-Family Low-Rise

[152] Wall insulation assumes wood frame with siding; no insulation in 2 by 4 wall; 3.5 inch air gap resistance only, Ceiling assumes Minimal ceiling insulation, as captured in Appendix A of this TRM for Multi-Family Low-Rise

[153] Wall insulation assumes wood frame with siding; Fiberglass insulation in 2 by 4 wall per MEC 1980, Ceiling insulation assumes Fiberglass insulation per MEC 1980, as captured in Appendix A of this TRM for Multi-Family Low-Rise

[154] ECCCNYS 2007 as captured in Appendix A of this TRM for Multi-Family Low-Rise

[155] 10 CFR 430.32(e)

Equipment Type	Size Range	ECCCNYS Minimum Efficiency for Climate Zones 4, 5 and 6
Boiler, Steam, Oil Fired	All Capacities	0.82 AFUE

The baseline efficiency for heating systems serving multiple dwelling units is the nameplate efficiency of the existing system. If unknown, the baseline efficiency is defined by International Energy Conservation Code[156] and subsequently adopted by the Energy Conservation Construction Code of New York State (ECCCNYS) as shown in the table below.

Fossil Fuel Fired Heating System Baseline Efficiencies: Systems Serving Multiple Dwelling Units

Equipment Type	Size Range	ECCCNYS Minimum Efficiency for Climate Zones 4, 5 and 6
Warm Air Furnace, Gas Fired	< 225 kBTU/h	0.80 AFUE
	≥ 225 kBTU/h	0.80 Et
Warm Air Furnace, Oil Fired	< 225 kBTU/h	0.83 AFUE
	≥ 225 kBTU/h	0.80 Et
Warm Air Unit Heaters, Gas Fired	All Capacities	0.80 Ec
Warm Air Unit Heaters, Oil Fired	All Capacities	0.80 Ec
Boiler, Hot Water, Gas Fired	< 300 kBTU/h	0.82 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.80 Et
	> 2,500 kBTU/h	0.82 Ec
Boiler, Hot Water, Oil Fired	< 300 kBTU/h	0.84 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.82 Et
	> 2,500 kBTU/h	0.84 Ec
Boiler, Steam, Gas Fired, All Except Natural Draft	< 300 kBTU/h	0.80 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.79 Et
	> 2,500 kBTU/h	0.79 Et
Boiler, Steam, Gas Fired, Natural Draft	< 300 kBTU/h	0.80 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.77 Et
	> 2,500 kBTU/h	0.77 Et
Boiler, Steam, Oil Fired	< 300 kBTU/h	0.82 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.81 Et
	> 2,500 kBTU/h	0.81 Et

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a residential opaque building shell with increased insulation meeting or exceeding applicable construction code requirements. The installed R-value must be captured and included in the program application.

[156] ECCCNYS 2020, Table C403.3.2(4) & Table C403.3.2(5)

Opaque shell insulation improvements performed under this measure shall be installed such that that all altered envelope components comply with all federal, state, local and municipal codes and standards applicable to alterations to existing buildings, including but not limited to Section R503.1 of ECCCNYS 2020[157] requiring all existing ceiling, wall, and floor cavities exposed during construction to be filled with insulation. Thermal envelope components not altered as part of this measure (e.g. continuous insulation in wood-framed buildings) are not required to meet code for compliance.

Operating Hours

Effective heating and cooling hours associated with benefits of opaque shell insulation are established via the Heating and Cooling Degree Days section below.

Heating and Cooling Degree Days[158]

City	HDD	CDD
Albany	6,680	597
Binghamton	7,193	382
Buffalo	6,617	544
Massena	8,196	363
NYC	4,671	1,160
Poughkeepsie	6,210	671
Syracuse	6,651	570

Example Calculation *(Not to be used as default)*

An existing residential customer in a single-family home located near Binghamton with R-12 roof insulation, a gas fired warm air furnace with an efficiency of 0.80 AFUE and no cooling system is adding R-20 of blown-in loose fill cellulose insulation in 500 SF of attic space. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are not applicable. Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta MMBtu = \frac{\left(\frac{1}{R_{baseline}} - \frac{1}{R_{baseline} + \Delta R}\right) \times A \times \left(1 - F_{framing}\right) \times \ HDD \ \times 24 \times F_{FuelHeat}}{1{,}000{,}000 \times Eff_{FuelHeat}}$$

$R_{baseline}$ = 12, from application
ΔR= 20, from application
A = 500 SF, from application
$F_{framing}$ = 0.07, from Summary of Variables and Data Sources table based on application
HDD = 7,193, from Heating Degree Day table based on location from application
$F_{FuelHeat}$ = 1.0, from Summary of Variables and Data Sources table from HVAC system from application
$Eff_{FuelHeat}$ = 0.80 AFUE, from application

[157] ECCCNYS 2020, Section R503 Building Thermal Envelope
[158] HDD/CDD taken from NCEI 1981-2010 climate normal using a 65 °F balance point.

$$\Delta MMBtu = \frac{\left(\frac{1}{12} - \frac{1}{12+20}\right) \times 500 \times (1 - 0.07) \times \ 7{,}193 \ \times 24 \times 1.0}{1{,}000{,}000 \times 0.80} = 5.23\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. BG&E: Development of Residential Load Profile for Central Air Conditioners and Heat Pumps
2. ECCCNYS 2020 Section R402 Building Thermal Envelope
   Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-[ce]-commercial-energy-efficiency#NYSECC2020P1_CE_Ch04_SecC402
3. ECCCNYS 2020 Section R403 Systems
   Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-[re]-residential-energy-efficiency#NYSECC2020P1_RE_Ch04_SecR403
4. ECCCNYS 2020 Section R503 Alterations
   Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-5-re-existing-buildings
5. Building America House Simulation Protocols, Robert Henderon and Cheryn Engebrecht, National Renewable Energy Laboratory, October 2010
   Available from: https://www.nrel.gov/docs/fy11osti/49246.pdf
6. 10 CFR 430.32 Energy and water conservation standards and their compliance dates
   Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=dfe00d44cfd9ab9ead4019d69702652a&mc=true&node=pt10.3.430&rgn=div5#se10.3.430_132
7. ASHRAE, 2001, "Characterization of Framing Factors for New Low-Rise Residential Building Envelopes (904-RP)," Table 7.1.
8. NOAA National Centers for Environmental Information – NCEI 1981-2010 Climate Normals
   Available from: https://www.ncdc.noaa.gov/cdo-web/datatools/normals
9. DOE, Energy Saver, Insulation Materials
   Available from: https://www.energy.gov/energysaver/weatherize/insulation/insulation-materials#fiberglass

Record of Revision

Record of Revision Number	Issue Date
1	10/15/2010
7-13-25	7/31/2013
7-13-38	7/31/2013
9-18-2	9/28/2018
3-19-2	3/29/2019
12-19-2	12/23/2019
12-20-2	12/31/2020
3-21-5	4/9/2021
7-21-5	8/30/2021

Return to Table of Contents

WINDOW

Measure Description

This measure covers the installation of high efficiency windows with reduced thermal conductance and solar heat gain coefficient. For the purposes of this measure, a window is defined as an assembled unit consisting of a frame/sash component holding one or more pieces of glazing functioning to admit light and/or air into an enclosure and designed for a vertical installation in an external wall of a residential building.[159] This measure is only applicable to windows that serve as a barrier between conditioned spaces and outside air.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = \frac{SF}{100} \times (\Delta kWh/100\ SF)$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \frac{SF}{100} \times (\Delta kW/100\ SF) \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = \frac{SF}{100} \times \frac{(\Delta therms/100\ SF)}{10}$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
SF	= Total glazing area of installed windows (ft^2)
(ΔkWh/100 SF)	= Annual electric energy savings per 100^2 of window glazing area
(ΔkW/100 SF)	= Peak coincident demand electric savings per 100 SF of window glazing area
(Δtherms/100 SF)	= Annual fossil fuel energy savings per 100 SF of window glazing area
100	= Conversion from SF to 100 SF
10	= Conversion factor, one MMBtu equals 10 therms
CF	= Coincidence Factor

[159] ENERGY STAR® Product Specification Residential Windows, Doors, and Skylights, Eligibility Criteria, V6.0, January 2014

Summary of Variables and Data Sources

Variable	Value	Notes
SF		From application
(ΔkWh/100 SF)		Lookup from table below based on City, Baseline Window and HVAC System. For window replacement, existing conditions shall be used to determine Baseline Window and HVAC System. If HVAC system type is not known, assume a Code baseline window and AC w/ Fuel Heat.
(ΔkW/100 SF)		Lookup from table below based on City, Baseline Window and HVAC System. For window replacement, existing conditions shall be used to determine Baseline Window and HVAC System. If HVAC system type is not known, assume a Code baseline window and AC w/ Fuel Heat.
(Δtherms/100 SF)		Lookup from table below based on City, Baseline Window and HVAC System. For window replacement, existing conditions shall be used to determine Baseline Window and HVAC System. If HVAC system type is not known, assume a Code baseline window and AC w/ Fuel Heat.
CF	0.69	

Unit Energy and Demand Savings

Unit energy and demand savings were derived using LBNL's RESFEN V6.0 software. For additional detail on the derivation of these values, refer to the "NY TRM Residential Window Supplement.xlsx" workbook.

City	Baseline Window	HVAC System	ΔkWh/ 100 SF	ΔkW/ 100 SF	Δtherms/ 100 SF
Albany	Single-Pane	AC w/ Fuel Heat	133	0.29	74.3
		Heat Pump	855	0.29	0.0
		AC w/ Resistance Heat	1,578	0.29	0.0
		Fuel Heat Only	0	0.00	74.3
		Resistance Heat Only	1,445	0.00	0.0
	Double-Pane	AC w/ Fuel Heat	116	0.21	21.8
		Heat Pump	347	0.21	0.0
		AC w/ Resistance Heat	578	0.21	0.0
		Fuel Heat Only	0	0.00	21.8
		Resistance Heat Only	463	0.00	0.0
	Code	AC w/ Fuel Heat	39	0.06	1.3
		Heat Pump	62	0.06	0.0
		AC w/ Resistance Heat	86	0.06	0.0
		Fuel Heat Only	0	0.00	1.3
		Resistance Heat Only	47	0.00	0.0

City	Baseline Window	HVAC System	ΔkWh/ 100 SF	ΔkW/ 100 SF	Δtherms/ 100 SF
Binghamton	Single-Pane	AC w/ Fuel Heat	74	0.33	82.6
		Heat Pump	894	0.33	0.0
		AC w/ Resistance Heat	1,714	0.33	0.0
		Fuel Heat Only	0	0.00	82.6
		Resistance Heat Only	1,640	0.00	0.0
	Double-Pane	AC w/ Fuel Heat	68	0.24	24.1
		Heat Pump	328	0.24	0.0
		AC w/ Resistance Heat	587	0.24	0.0
		Fuel Heat Only	0	0.00	24.1
		Resistance Heat Only	519	0.00	0.0
	Code	AC w/ Fuel Heat	22	0.08	1.6
		Heat Pump	49	0.08	0.0
		AC w/ Resistance Heat	76	0.08	0.0
		Fuel Heat Only	0	0.00	1.6
		Resistance Heat Only	54	0.00	0.0
Buffalo	Single-Pane	AC w/ Fuel Heat	115	0.32	78.6
		Heat Pump	868	0.32	0.0
		AC w/ Resistance Heat	1,622	0.32	0.0
		Fuel Heat Only	0	0.00	78.6
		Resistance Heat Only	1,507	0.00	0.0
	Double-Pane	AC w/ Fuel Heat	102	0.23	24.1
		Heat Pump	346	0.23	0.0
		AC w/ Resistance Heat	590	0.23	0.0
		Fuel Heat Only	0	0.00	24.1
		Resistance Heat Only	488	0.00	0.0
	Code	AC w/ Fuel Heat	34	0.07	2.0
		Heat Pump	62	0.07	0.0
		AC w/ Resistance Heat	89	0.07	0.0
		Fuel Heat Only	0	0.00	2.0
		Resistance Heat Only	55	0.00	0.0

City	Baseline Window	HVAC System	ΔkWh/ 100 SF	ΔkW/ 100 SF	Δtherms/ 100 SF
Massena	Single-Pane	AC w/ Fuel Heat	106	0.29	85.4
		Heat Pump	1,181	0.29	0.0
		AC w/ Resistance Heat	2,256	0.29	0.0
		Fuel Heat Only	0	0.00	85.4
		Resistance Heat Only	2,150	0.00	0.0
	Double-Pane	AC w/ Fuel Heat	91	0.21	25.4
		Heat Pump	445	0.21	0.0
		AC w/ Resistance Heat	798	0.21	0.0
		Fuel Heat Only	0	0.00	25.4
		Resistance Heat Only	707	0.00	0.0
	Code	AC w/ Fuel Heat	29	0.06	1.8
		Heat Pump	71	0.06	0.0
		AC w/ Resistance Heat	112	0.06	0.0
		Fuel Heat Only	0	0.00	1.8
		Resistance Heat Only	83	0.00	0.0
NYC	Single-Pane	AC w/ Fuel Heat	155	0.32	55.8
		Heat Pump	613	0.32	0.0
		AC w/ Resistance Heat	1,072	0.32	0.0
		Fuel Heat Only	0	0.00	55.8
		Resistance Heat Only	918	0.00	0.0
	Double-Pane	AC w/ Fuel Heat	131	0.22	13.4
		Heat Pump	252	0.22	0.0
		AC w/ Resistance Heat	373	0.22	0.0
		Fuel Heat Only	0	0.00	13.4
		Resistance Heat Only	242	0.00	0.0
	Code	AC w/ Fuel Heat	41	0.07	4.7
		Heat Pump	83	0.07	0.0
		AC w/ Resistance Heat	125	0.07	0.0
		Fuel Heat Only	0	0.00	4.7
		Resistance Heat Only	84	0.00	0.0

City	Baseline Window	HVAC System	ΔkWh/ 100 SF	ΔkW/ 100 SF	Δtherms/ 100 SF
Poughkeepsie	Single-Pane	AC w/ Fuel Heat	144	0.30	65.1
		Heat Pump	734	0.30	0.0
		AC w/ Resistance Heat	1,325	0.30	0.0
		Fuel Heat Only	0	0.00	65.1
		Resistance Heat Only	1,181	0.00	0.0
	Double-Pane	AC w/ Fuel Heat	123	0.21	17.6
		Heat Pump	300	0.21	0.0
		AC w/ Resistance Heat	476	0.21	0.0
		Fuel Heat Only	0	0.00	17.6
		Resistance Heat Only	352	0.00	0.0
	Code	AC w/ Fuel Heat	40	0.07	3.0
		Heat Pump	73	0.07	0.0
		AC w/ Resistance Heat	106	0.07	0.0
		Fuel Heat Only	0	0.00	3.0
		Resistance Heat Only	66	0.00	0.0
Syracuse	Single-Pane	AC w/ Fuel Heat	110	0.25	76.0
		Heat Pump	871	0.25	0.0
		AC w/ Resistance Heat	1,633	0.25	0.0
		Fuel Heat Only	0	0.00	76.0
		Resistance Heat Only	1,524	0.00	0.0
	Double-Pane	AC w/ Fuel Heat	93	0.19	22.7
		Heat Pump	336	0.19	0.0
		AC w/ Resistance Heat	579	0.19	0.0
		Fuel Heat Only	0	0.00	22.7
		Resistance Heat Only	486	0.00	0.0
	Code	AC w/ Fuel Heat	30	0.06	1.7
		Heat Pump	56	0.06	0.0
		AC w/ Resistance Heat	83	0.06	0.0
		Fuel Heat Only	0	0.00	1.7
		Resistance Heat Only	53	0.00	0.0

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.69.[160]

[160] Based on BG&E 'Development of Residential Load Profile for Central Air Conditioners and Heat Pumps' research, the Maryland Peak Definition coincidence factor is 0.69. This study is not publicly available, but is referenced by M. M. Straub, Using Available Information for Efficient Evaluation of Demand-Side Management Programs, Electricity Journal, September 2011 and supported by research conducted by Cadmus on behalf of the TRM Management Committee.

Baseline Efficiencies from which Energy Savings are Calculated

Unit energy and demand savings are presented for three baseline window types and five HVAC system types for each city. The characteristics of each baseline window, HVAC system type and prototype housing model were determined using defaults presented in LBNL's RESFEN V6.0 software and applying a methodology consistent with that used by ENERGY STAR® to determine impacts of high-efficiency window installations.[161] For additional detail on inputs and assumptions used to derive the per unit savings values tabulated above, refer to the "NY TRM Residential Window Supplement.xlsx" workbook.

For window replacement, existing conditions shall be used to determine Baseline Window and HVAC System types. For New Construction and Time-of-Sale, assume a Code baseline window and AC w/ Fuel Heat.

Compliance Efficiency from which Incentives are Calculated

Installed windows must meet the minimum compliance criteria required by V6.0 of the ENERGY STAR® Residential Windows, Doors and Skylights Product Specification.[162] Installed window specifications assumed for derivation of unit energy and demand savings are as follows:

U-Value: 0.27 BTU/h-ft^2-°F
Solar Heat Gain Coefficient (SHGC) = 0.32
Air Leakage: 0.3 CFM/ft^2

Operating Hours

Unit energy and demand savings depend on assumed hours of operation of the home's HVAC system. These operating hours assumptions are embedded in the RESFEN prototype models used to derive energy and demand savings values. See the "NY TRM Residential Window Supplement.xlsx" workbook and RESFEN V6.0 User's Manual for additional detail.[163]

Example Calculation *(Not to be used as default)*

A single-family residential customer in Binghamton replaces their existing, single pane windows. The home has central air conditioning and gas heating. The glazing area of the installed windows is 120 SF. Annual Electric Energy Savings, Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta kWh = \frac{SF}{100} \times (\Delta kWh/100\ SF)$$

[161] Methodology for ENERGY STAR® Savings Estimates for Windows (https://www.energystar.gov/products/building_products/residential_windows_doors_and_skylights/methodology_energy_star_savings_estimates_windows)
[162] ENERGY STAR® Product Specification Residential Windows, Doors, and Skylights, Eligibility Criteria, V6.0, January 2014
[163] LBNL RESFEN6 for Calculating the Heating and Cooling Energy Use of Windows in Residential Buildings, December 2012

$$\Delta kW = \frac{SF}{100} \times (\Delta kW/100\ SF) \times CF$$

$$\Delta MMBtu = \frac{SF}{100} \times \frac{(\Delta therms/100\ SF)}{10}$$

ΔkWh/100SF = 74, from Unit Energy and Demand Savings table based on city, baseline window, and HVAC type from application
ΔkW/100SF = 0.33, from Unit Energy and Demand Savings table based on city, baseline window, and HVAC type from application
Δtherms/100SF = 82.6, from Unit Energy and Demand Savings table based on city, baseline window, and HVAC type from application
SF = 120, from application
CF = 0.69, from Summary of Variables and Data Sources

$$\Delta kWh = \frac{120}{100} \times (74) = 88.8\ kWh$$

$$\Delta kW = \frac{120}{100} \times (0.33) \times 0.69 = 0.27\ kW$$

$$\Delta MMBtu = \frac{120}{100} \times \frac{(82.6)}{10} = 9.91\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. ENERGY STAR® Product Specification Residential Windows, Doors, and Skylights, Eligibility Criteria, Version 6.0, January 2014
   Available from:
   https://www.energystar.gov/sites/default/files/ES_Final_V6_Residential_WDS_Spec.pdf
2. BG&E: Development of Residential Load Profile for Central Air Conditioners and Heat Pumps

3. Methodology for ENERGY STAR® Savings Estimates for Windows
   Available from:
   https://www.energystar.gov/products/building_products/residential_windows_doors_and_skylights/methodology_energy_star_savings_estimates_windows
4. LBNL RESFEN6 for Calculating the Heating and Cooling Energy Use of Windows in Residential Buildings, December 2012
   Available from: https://windows.lbl.gov/sites/default/files/Downloads/resfen60-user-manual.pdf

Record of Revision

Record of Revision Number	Issue Date
1	10/15/2010
6-17-1	6/30/2017
9-19-1	9/27/2019

Return to Table of Contents

WINDOW – FILM

Measure Description

This measure covers the installation of window film with reduced solar heat gain coefficient applied to single pane or double pane clear glass windows. Windows with lower solar heat gain coefficient reduce cooling loads within a conditioned space.

This measure is applicable to uncovered, single pane or double pane clear glass windows in existing buildings only.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = \frac{SF}{100} \times (\Delta kWh/100\ SF)$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \frac{SF}{100} \times (\Delta kW/100\ SF) \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = \frac{SF}{100} \times \frac{(\Delta therms/100\ SF)}{10}$$

where:

$$(\Delta kWh/100\ SF) = (\Delta kWh/100\ SF)_m \times SHGC_{ee} + (\Delta kWh/100\ SF)_b$$

$$(\Delta kW/100\ SF) = (\Delta kW/100\ SF)_m \times SHGC_{ee} + (\Delta kW/100\ SF)_b$$

$$(\Delta therms/100\ SF) = (\Delta therms/100\ SF)_m \times SHGC_{ee} + (\Delta therms/100\ SF)_b$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
SF	= Total glazing area of installed windows (SF)
(ΔkWh/100 SF)	= Annual electric energy savings per 100 SF of window glazing area
(ΔkW/100 SF)	= Peak coincident demand electric savings per 100 SF of window glazing area
(Δtherms/100 SF)	= Annual fossil fuel energy savings per 100 SF of window glazing area
$(\Delta kWh/100\ SF)_m$	= Annual electric energy savings per 100 SF of window glazing area, slope component
$(\Delta kWh/100\ SF)_b$	= Annual electric energy savings per 100 SF of window glazing area,

intercept component

$(\Delta kW/100\ SF)_m$ = Peak coincident demand electric savings per 100 SF of window glazing area, slope component

$(\Delta kW/100\ SF)_b$ = Peak coincident demand electric savings per 100 SF of window glazing area, intercept component

$(\Delta therms/100\ SF)_m$ = Annual fossil fuel energy savings per 100 SF of window glazing area, slope component

$(\Delta therms/100\ SF)_b$ = Annual fossil fuel energy savings per 100 SF of window glazing area, intercept component

$SHGC_{ee}$ = Solar Heat Gain Coefficient of window after installation of window film

100 = Conversion from SF to 100 SF

10 = Conversion factor, one MMBtu equals 10 therms

CF = Coincidence Factor

Summary of Variables and Data Sources

Variable	Value	Notes
SF		From application.
$(\Delta kWh/100\ SF)_m$		Lookup based on location, window type and HVAC system type Unit Energy and Demand Savings table below.
$(\Delta kWh/100\ SF)_b$		Lookup based on location, window type and HVAC system type Unit Energy and Demand Savings table below.
$(\Delta kW/100\ SF)_m$		Lookup based on location, window type and HVAC system type Unit Energy and Demand Savings table below.
$(\Delta kWh100\ SF)_b$		Lookup based on location, window type and HVAC system type Unit Energy and Demand Savings table below.
$(\Delta therms/100\ SF)_m$		Lookup based on location, window type and HVAC system type Unit Energy and Demand Savings table below.
$(\Delta therms/100\ SF)_b$		Lookup based on location, window type and HVAC system type Unit Energy and Demand Savings table below.
$SHGC_{ee}$		From application.
CF	0.69	

Unit Energy and Demand Savings

Unit energy and demand savings were derived based on linear regression analysis of results comparing energy consumption and SHGC of various window configurations modeled via LBNL's RESFEN V6.0 software. When the software was run, Solar Gain Reduction was set to typical. Typical shading is defined as: representing a statistically average solar gain reduction for a generic house, this option includes: Interior shades (Seasonal SHGC multiplier, summer value = 0.80, winter value = 0.90); 1' overhang; a 67% transmitting same-height obstruction 20' away intended to represent adjacent buildings. To account for other sources of solar heat gain reduction (insect screens, trees, dirt, building & window self-shading), the SHGC multiplier was further reduced by 0.1. This results in a final winter SHGC multiplier of 0.8 and a final summer SHGC multiplier of 0.7[164]. For additional detail on the derivation of these values, refer to the "NY TRM Residential Window Film Supplement.xlsx" workbook.

[164] LBNL RESFEN6 User Manual.

City	Baseline Window	HVAC System	(ΔkWh/ 100 SF)$_m$	(ΔkWh/ 100 SF)$_b$	(ΔkW/ 100 SF)$_m$	(ΔkW/ 100 SF)$_b$	(Δtherms/ 100 SF)$_m$	(Δtherms/ 100 SF)$_b$
Albany	Single-Pane	AC w/ Fuel Heat	-458.43	300.42	-0.74	0.47	12.10	-7.61
		Heat Pump	486.72	-295.07	-0.74	0.48	0.00	0.00
		AC w/ Resistance Heat	1431.88	-890.56	-0.74	0.48	0.00	0.00
		Fuel Heat Only	0.00	0.00	0.00	0.00	12.10	-7.61
		Resistance Heat Only	1890.32	-1190.97	0.00	0.00	0.00	0.00
	Double-Pane	AC w/ Fuel Heat	-447.82	268.99	-0.69	0.41	11.34	-6.52
		Heat Pump	465.63	-250.06	-0.73	0.42	0.00	0.00
		AC w/ Resistance Heat	1402.14	-776.04	-0.73	0.42	0.00	0.00
		Fuel Heat Only	0.00	0.00	0.00	0.00	11.34	-6.52
		Resistance Heat Only	1873.02	-1051.95	0.00	0.00	0.00	0.00

City	Baseline Window	HVAC System	(ΔkWh/ 100 SF)$_m$	(ΔkWh/ 100 SF)$_b$	(ΔkW/ 100 SF)$_m$	(ΔkW/ 100 SF)$_b$	(Δtherms/ 100 SF)$_m$	(Δtherms/ 100 SF)$_b$
Binghamton	Single-Pane	AC w/ Fuel Heat	-256.53	172.96	-0.94	0.59	13.34	-8.37
		Heat Pump	802.22	-494.03	-0.94	0.59	0.00	0.00
		AC w/ Resistance Heat	1860.97	-1161.03	-0.94	0.59	0.00	0.00
		Fuel Heat Only	0.00	0.00	0.00	0.00	13.34	-101.20
		Resistance Heat Only	1649.75	-1039.61	0.00	0.00	0.00	0.00
	Double-Pane	AC w/ Fuel Heat	-266.76	161.55	-0.98	0.54	-0.98	-7.38
		Heat Pump	778.47	-424.15	-0.98	0.54	0.00	0.00
		AC w/ Resistance Heat	1823.71	-1009.85	-0.98	0.54	0.00	0.00
		Fuel Heat Only	0.00	0.00	0.00	0.00	13.24	-7.38
		Resistance Heat Only	1630.05	-913.60	0.00	0.00	0.00	0.00
Buffalo	Single-Pane	AC w/ Fuel Heat	-390.58	259.11	-0.83	0.53	11.22	-7.04
		Heat Pump	493.76	-298.43	-0.83	0.53	0.00	0.00
		AC w/ Resistance Heat	1378.26	-856.00	-0.83	0.53	0.00	0.00
		Fuel Heat Only	0.00	0.00	0.00	0.00	11.22	-7.04
		Resistance Heat Only	1769.00	-1115.14	0.00	0.00	0.00	0.00
	Double-Pane	AC w/ Fuel Heat	-405.59	230.14	-0.85	0.50	11.21	-2.74
		Heat Pump	467.45	59.99	-0.85	0.50	0.00	0.00
		AC w/ Resistance Heat	1340.50	-110.17	-0.85	0.50	0.00	0.00
		Fuel Heat Only	0.00	0.00	0.00	0.00	11.21	-2.74
		Resistance Heat Only	1746.09	-340.31	0.00	0.00	0.00	0.00

City	Baseline Window	HVAC System	(ΔkWh/ 100 SF)$_m$	(ΔkWh/ 100 SF)$_b$	(ΔkW/ 100 SF)$_m$	(ΔkW/ 100 SF)$_b$	(Δtherms/ 100 SF)$_m$	(Δtherms/ 100 SF)$_b$
Massena	Single-Pane	AC w/ Fuel Heat	-350.81	232.13	-0.73	-0.02	13.77	-8.67
		Heat Pump	932.32	-579.05	-0.73	0.46	0.00	0.00
		AC w/ Resistance Heat	2215.36	-1390.19	-0.73	0.46	0.00	0.00
		Fuel Heat Only	0.00	0.00	0.00	0.00	13.77	-8.67
		Resistance Heat Only	1850.72	-1169.67	0.00	0.00	0.00	0.00
	Double-Pane	AC w/ Fuel Heat	-357.16	213.05	-0.73	0.42	13.77	-7.69
		Heat Pump	906.37	-497.96	-0.73	0.42	0.00	0.00
		AC w/ Resistance Heat	2170.01	-1208.98	-0.73	0.42	0.00	0.00
		Fuel Heat Only	0.00	0.00	0.00	0.00	13.77	-7.69
		Resistance Heat Only	1822.78	-1025.47	0.00	0.00	0.00	0.00
NYC	Single-Pane	AC w/ Fuel Heat	-548.72	356.72	-0.73	0.47	11.35	-7.14
		Heat Pump	283.86	-167.99	-0.73	0.47	0.00	0.00
		AC w/ Resistance Heat	1116.44	-692.70	-0.73	0.47	0.00	0.00
		Fuel Heat Only	0.00	0.00	0.00	0.00	11.35	-7.14
		Resistance Heat Only	1201.60	-756.79	0.00	0.00	0.00	0.00
	Double-Pane	AC w/ Fuel Heat	-559.35	323.17	-0.75	0.42	11.28	-6.29
		Heat Pump	268.83	-141.25	-0.75	0.42	0.00	0.00
		AC w/ Resistance Heat	1097.02	-605.67	0.75	0.77	0.00	0.00
		Fuel Heat Only	0.00	0.00	0.00	0.00	11.28	-6.29
		Resistance Heat Only	1195.42	-669.81	0.00	0.00	0.00	0.00

City	Baseline Window	HVAC System	(ΔkWh/ 100 SF)$_m$	(ΔkWh/ 100 SF)$_b$	(ΔkW/ 100 SF)$_m$	(ΔkW/ 100 SF)$_b$	(Δtherms/ 100 SF)$_m$	(Δtherms/ 100 SF)$_b$
Poughkeepsie	Single-Pane	AC w/ Fuel Heat	-503.58	328.57	-0.74	0.47	11.73	-7.38
		Heat Pump	385.29	-231.53	-0.74	0.47	0.00	0.00
		AC w/ Resistance Heat	1274.16	-791.63	-0.74	0.47	0.00	0.00
		Fuel Heat Only	0.00	0.00	0.00	0.00	11.73	-7.38
		Resistance Heat Only	1777.74	-1120.19	0.00	0.00	0.00	0.00
	Double-Pane	AC w/ Fuel Heat	-503.59	296.08	-0.72	0.41	11.31	-6.40
		Heat Pump	367.23	-195.66	-0.74	0.42	0.00	0.00
		AC w/ Resistance Heat	1249.58	-690.85	-0.74	0.42	0.00	0.00
		Fuel Heat Only	0.00	0.00	0.00	0.00	11.31	-6.40
		Resistance Heat Only	1764.70	-990.39	0.00	0.00	0.00	0.00
Syracuse	Single-Pane	AC w/ Fuel Heat	-371.71	243.85	-0.68	0.43	12.12	-7.60
		Heat Pump	587.88	-360.43	-0.69	0.43	0.00	0.00
		AC w/ Resistance Heat	1547.47	-964.72	-0.69	0.43	0.00	0.00
		Fuel Heat Only	0.00	0.00	0.00	0.00	12.12	-7.60
		Resistance Heat Only	1919.17	-1208.57	0.00	0.00	0.00	0.00
	Double-Pane	AC w/ Fuel Heat	-380.83	222.28	-0.69	0.39	11.98	-6.67
		Heat Pump	562.40	-306.13	-0.69	0.39	0.00	0.00
		AC w/ Resistance Heat	1505.18	-834.50	-0.69	0.39	0.00	0.00
		Fuel Heat Only	0.00	0.00	0.00	0.00	11.98	-6.67
		Resistance Heat Only	1885.57	-1056.74	0.00	0.00	0.00	0.00

Coincidence Factor (CF)

The recommended value for the coincidence factor is 0.69.[165]

[165] Based on BG&E 'Development of Residential Load Profile for Central Air Conditioners and Heat Pumps' research, the Maryland Peak Definition coincidence factor is 0.69. This study is not publicly available, but is referenced by M. M. Straub, Using Available Information for Efficient Evaluation of Demand-Side Management Programs, Electricity Journal, September 2011 and supported by research conducted by Cadmus on behalf of the TRM Management Committee.

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is an existing, untreated, single pane clear glass window with an assumed solar heat gain coefficient of 0.64 and U-value of 0.879 BTU/h- ft^2- °F. or double pane clear glass window with an assumed solar heat gain coefficient of 0.57 and U-value of 0.571 BTU/h- ft^2-°F.[166]

Compliance Efficiency from which Incentives are Calculated

The compliance condition is an existing window with added film with a solar heat gain coefficient of 0.40 or less.[167]

Operating Hours

These operating hours assumptions are embedded in the RESFEN prototype models used to derive energy and demand savings values. See the "NY TRM Residential Window Supplement.xlsx" workbook and RESFEN V6.0 User's Manual for additional detail.[168] Operating hour assumptions for the prototypical building models are described in Appendix A. The heating EFLH for C&I buildings in NY by location, building type and vintage are tabulated in Appendix G.

Example Calculation *(Not to be used as default)*

An existing residential customer in Albany installs window film on 120 SF of single-pane, clear glass windows to reduce the SHGC of their windows to 0.39. The building is equipped with central air conditioning and gas heat. Annual Electric Energy Savings, Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta kWh = \frac{SF}{100} \times (\Delta kWh/100\ SF)$$

$$\Delta kW = \frac{SF}{100} \times (\Delta kW/100\ SF) \times CF$$

$$\Delta MMBtu = \frac{SF}{100} \times \frac{(\Delta therms/100\ SF)}{10}$$

where:

$$(\Delta kWh/100\ SF) = (\Delta kWh/100\ SF)_m \times SHGC_{ee} + (\Delta kWh/100\ SF)_b$$

$$(\Delta kW/100\ SF) = (\Delta kW/100\ SF)_m \times SHGC_{ee} + (\Delta kW/100\ SF)_b$$

$$(\Delta therms/100\ SF) = (\Delta therms/100\ SF)_m \times SHGC_{ee} + (\Delta therms/100\ SF)_b$$

[166] RESFEN6.0 defaults for single-pane and double-pane window type.
[167] ECCCNYS 2020, Table R402.1
[168] LBNL RESFEN6 for Calculating the Heating and Cooling Energy Use of Windows in Residential Buildings, December 2012

$(\Delta kWh/100SF)_m$ = -458.43, from Unit Energy and Demand Savings table based on baseline window, HVAC system and City
$(\Delta kW/100SF)_m$ = -0.74, from Unit Energy and Demand Savings table based on baseline window, HVAC system and City
$(\Delta therms/100SF)_m$ = 12.10, from Unit Energy and Demand Savings table based on baseline window, HVAC system and City
$(\Delta kWh/100SF)_b$ = 300.42, from Unit Energy and Demand Savings table based on baseline window, HVAC system and City
$(\Delta kW/100SF)_b$ = 0.47, from Unit Energy and Demand Savings table based on baseline window, HVAC system and City
$(\Delta therms/100SF)_b$ = -7.61, from Unit Energy and Demand Savings table based on baseline window, HVAC system and City
$SHGC_{ee}$ = 0.39, from application
SF = 120, from application
CF= 0.69, from Summary of Variables and Data Sources

$$(\Delta kWh/100\ SF) = -458.43 \times 0.39 + 300.42 = 121.63$$

$$(\Delta kW/100\ SF) = -0.74 \times 0.39 + 0.47 = \ 0.18$$

$$(\Delta therms/100\ SF) = 12.10 \times 0.39 + -7.61 = -2.89$$

$$\Delta kWh = \frac{120}{100} \times 121.63 = 145.96\ kWh$$

$$\Delta kW = \frac{120}{100} \times 0.18 \times 0.69 = 0.15\ kW$$

$$\Delta MMBtu = \frac{120}{100} \times \frac{-2.89}{10} = -0.35\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. ECCCNYS 2020, Table R402.1 Insulation and Fenestration Requirements by Components.
   Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-re-residential-energy-efficiency ccsafe.org/content/NYSECC2020P1/chapter-4-ce-commercial-energy-efficiency
2. BG&E, Development of Residential Load Profile for Central Air Conditioners and Heat Pumps
3. LBNL RESFEN6 for Calculating the Heating and Cooling Energy Use of Windows in Residential Buildings, December 2012
   Available from: https://windows.lbl.gov/sites/default/files/Downloads/resfen60-user-manual.pdf
4. LBNL RESFEN6 User Manual.
   Available from: https://windows.lbl.gov/sites/default/files/Downloads/resfen60-user-manual.pdf

Record of Revision

Record of Revision Number	Issue Date
7-21-6	8/30/2021

Return to Table of Contents

WINDOW - LOW-E STORM

Measure Description

This measure covers the installation of storm windows with low-emissivity (low-e) glass on existing single or double pane windows. Low-e windows are designed to allow the optimal amount of solar heat through windows and lower infiltration rates to reduce passive convective heat transfer between conditioned and unconditioned spaces or outside air, thereby reducing heating and cooling loads and improving occupant comfort. Energy and demand saving are realized through reductions in the building's heating and cooling loads.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = \frac{SF}{100} \times (\Delta kWh/100\ SF)$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \frac{SF}{100} \times (\Delta kW/100\ SF) \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = \frac{SF}{100} \times \frac{(\Delta therms/100\ SF)}{10}$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
SF	= Total glazing area of installed windows (ft^2)
(ΔkWh/100 SF)	= Annual electric energy savings per 100 SF of window glazing area
(ΔkW/100 SF)	= Peak coincident demand electric savings per 100 SF of window glazing area
(Δtherms/100 SF)	= Annual fossil fuel energy savings per 100 SF of window glazing area
100	= Conversion from SF to 100 SF
10	= Conversion factor, one MMBtu equals 10 therms
CF	= Coincidence Factor

Summary of Variables and Data Sources

Variable	Value	Notes
(ΔkWh/100 SF)		Lookup in table below based on location, window configuration and HVAC type.
(ΔkW/100 SF)		Lookup in table below based on location, window configuration and HVAC type.

Variable	Value	Notes
(Δtherms/100 SF)		Lookup in table below based on location, window configuration and HVAC type.
SF		From application.
CF	0.69	

Unit Energy and Demand Savings

Unit energy and demand savings were derived using LBNL's RESFEN V6.0 software. For additional detail on the derivation of these values, refer to the "NY TRM Residential Low-E Storm Window Supplement.xlsx" workbook.

City	Baseline Window	HVAC System	ΔkWh/ 100 SF	ΔkW/ 100 SF	Δtherms/ 100 SF
Albany	Single-Pane	AC w/ Fuel heat	57	0.16	72.8
		Heat Pump	745	0.16	0.0
		AC w/ Resistance Heat	1,432	0.16	0.0
		Fuel Heat Only	0	0.00	72.8
		Resistance Heat Only	1,374	0.00	0.0
	Double-Pane	AC w/ Fuel Heat	52	0.11	32.5
		Heat Pump	364	0.11	0.0
		AC w/ Resistance Heat	677	0.11	0.0
		Fuel Heat Only	0	0.00	32.5
		Resistance Heat Only	625	0.00	0.0
Binghamton	Single-Pane	AC w/ Fuel Heat	30	0.18	80.7
		Heat Pump	810	0.18	0.0
		AC w/ Resistance Heat	1,589	0.18	0.0
		Fuel Heat Only	0	0.00	80.7
		Resistance Heat Only	1,560	0.00	0.0
	Double-Pane	AC w/ Fuel Heat	30	0.13	35.7
		Heat Pump	379	0.13	0.0
		AC w/ Resistance Heat	729	0.13	0.0
		Fuel Heat Only	0	0.00	35.7
		Resistance Heat Only	699	0.00	0.0
Buffalo	Single-Pane	AC w/ Fuel Heat	47	0.18	75.7
		Heat Pump	758	0.18	0.0
		AC w/ Resistance Heat	1,468	0.18	0.0
		Fuel Heat Only	0	0.00	75.7
		Resistance Heat Only	1,421	0.00	0.0
	Double-Pane	AC w/ Fuel Heat	44	0.12	33.7
		Heat Pump	361	0.12	0.0
		AC w/ Resistance Heat	678	0.12	0.0
		Fuel Heat Only	0	0.00	33.7
		Resistance Heat Only	634	0.00	0.0

City	Baseline Window	HVAC System	ΔkWh/ 100 SF	ΔkW/ 100 SF	Δtherms/ 100 SF
Massena	Single-Pane	AC w/ Fuel Heat	46	0.17	83.3
		Heat Pump	1,058	0.17	0.0
		AC w/ Resistance Heat	2,069	0.17	0.0
		Fuel Heat Only	0	0.00	83.3
		Resistance Heat Only	2,023	0.00	0.0
	Double-Pane	AC w/ Fuel Heat	42	0.11	37.5
		Heat Pump	502	0.11	0.0
		AC w/ Resistance Heat	962	0.11	0.0
		Fuel Heat Only	0	0.00	37.5
		Resistance Heat Only	920	0.00	0.0
NYC	Single-Pane	AC w/ Fuel Heat	70	0.19	57.0
		Heat Pump	531	0.19	0.0
		AC w/ Resistance Heat	991	0.19	0.0
		Fuel Heat Only	0	0.00	57.0
		Resistance Heat Only	921	0.00	0.0
	Double-Pane	AC w/ Fuel Heat	61	0.13	23.8
		Heat Pump	259	0.13	0.0
		AC w/ Resistance Heat	457	0.13	0.0
		Fuel Heat Only	0	0.00	23.8
		Resistance Heat Only	396	0.00	0.0
Poughkeepsie	Single-Pane	AC w/ Fuel Heat	64	0.18	64.9
		Heat Pump	638	0.18	0.0
		AC w/ Resistance Heat	1,212	0.18	0.0
		Fuel Heat Only	0	0.00	64.9
		Resistance Heat Only	1,148	0.00	0.0
	Double-Pane	AC w/ Fuel Heat	56	0.12	28.1
		Heat Pump	312	0.12	0.0
		AC w/ Resistance Heat	567	0.12	0.0
		Fuel heat Only	0	0.00	28.1
		Resistance Heat Only	511	0.00	0.0
Syracuse	Single-Pane	AC w/ Fuel heat	49	0.14	74.0
		Heat Pump	771	0.14	0.0
		AC w/ Resistance Heat	1,494	0.14	0.0
		Fuel Heat Only	0	0.00	74.0
		Resistance Heat Only	1,445	0.00	0.0
	Double-Pane	AC w/ Fuel Heat	43	0.10	33.1
		Heat Pump	366	0.10	0.0
		AC w/ Resistance Heat	689	0.10	0.0
		Fuel Heat Only	0	0.00	33.1
		Resistance Heat Only	647	0.00	0.0

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.69.[169]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline case for this measure is a single or double-pane window unit with clear glass without storm windows.

Unit energy and demand savings were derived using LBNL's RESFEN V6.0 software. Single and two-story houses were modeled assuming glazing area equal to 15% of total home floor area. The homes were modeled for the cities both without storm windows and with low-e storm windows with different emissivity ratings. The analysis assumes an equal weighting between three low-E storm window glass options. For reference, the Emissivity, Solar Transmission, U-factor and Solar Heat Gain Coefficient (SHGC) of the modeled baseline and low-e storm windows are shown in the table below.

Window Type	Glass Options (3 mm)	Emissivity	Solar Transmission	U-factor	SHGC
Low-E	AGC Comfort Select 73	0.15	0.69	0.356	0.458
	Guardian IS20	0.20	0.77	0.364	0.502
	PPG Sungate 500	0.22	0.69	0.367	0.468

For additional detail on the derivation of per unit savings values, refer to the "NY TRM Residential Low-E Storm Window Supplement.xlsx" workbook.

Compliance Efficiency from which Incentives are Calculated

The compliance case is a single or double-pane window unit fitted with low-e storm windows installed outside or inside the window unit. Installed storm windows must meet the minimum compliance criteria required by V1.0 of the ENERGY STAR® Exterior and Interior Storm Windows Product Specification.[170] To qualify, installed storm windows must meet the following specifications:

Emissivity: ≤ 0.22
Solar Transmittance: > 0.55
Air Leakage (Exterior Storm Windows): ≤ 1.5 CFM/SF
Air Leakage (Interior Storm Windows): ≤ 0.5 CFM/SF

[169] Based on BG&E 'Development of Residential Load Profile for Central Air Conditioners and Heat Pumps' research, the Maryland Peak Definition coincidence factor is 0.69. This study is not publicly available, but is referenced by M. M. Straub, Using Available Information for Efficient Evaluation of Demand-Side Management Programs, Electricity Journal, September 2011 and supported by research conducted by Cadmus on behalf of the TRM Management Committee.
[170] ENERGY STAR® Product Specification Exterior and Interior Storm Windows, V1.0, September 2018

Operating Hours

These operating hours assumptions are embedded in the RESFEN prototype models used to derive energy and demand savings values. See the "NY TRM Residential Window Supplement.xlsx" workbook and RESFEN V6.0 User's Manual for additional detail.[171] Operating hour assumptions for the prototypical building models are described in Appendix A. The heating EFLH for C&I buildings in NY by location, building type and vintage are tabulated in Appendix G.

Example Calculation *(Not to be used as default)*

An existing residential customer in Albany installs low-e storm windows on existing single-pane windows in a home with gas heating and no electric cooling. The glazing area of the installed windows is 168 SF. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are not applicable. Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta MMBtu = \frac{SF}{100} \times \frac{(\Delta therms/100\ SF)}{10}$$

SF = 168 SF
Δtherms/100SF = 72.8, from Unit Energy and Demand Savings table based on city, baseline window, and HVAC type from application

$$\Delta MMBtu = \frac{168}{100} \times \frac{(72.8)}{10} = 12.23\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

[171] LBNL RESFEN6 for Calculating the Heating and Cooling Energy Use of Windows in Residential Buildings, December 2012

References

1. ENERGY STAR® Product Specification Exterior and Interior Storm Windows Eligibility Criteria, Version 1.0, September 2018
   Available from:
   https://www.energystar.gov/sites/default/files/Storm%20Window%20Product%20Specification_Final_0.pdf
2. BG&E: Development of Residential Load Profile for Central Air Conditioners and Heat Pumps
3. LBNL RESFEN6 for Calculating the Heating and Cooling Energy Use of Windows in Residential Buildings, December 2012
   Available from: https://windows.lbl.gov/sites/default/files/Downloads/resfen60-user-manual.pdf

Record of Revision

Record of Revision Number	Issue Date
9-19-2	9/27/2019

Return to Table of Contents

DOMESTIC HOT WATER

HEAT PUMP WATER HEATER (HPWH) – AIR SOURCE

Measure Description

This measure covers the installation of electric storage tank water heaters that use heat pump technology to move heat from the air (in conditioned or unconditioned spaces) to the water storage tank and are designed to heat and store potable water at a thermostatically controlled temperature of less than 180°F. It is not intended for equipment delivering process or space heating hot water. It applies to electric heat pump water heaters with a maximum current rating of 24 amperes at a voltage no greater than 250 volts and with a rated storage tank capacity of 120 gallons or less.[172,173]

This measure applies to new construction/major renovation projects and replacement of existing water heaters. Baseline equipment in new construction/major renovation shall be a minimally code compliant, gas-fired storage type water heater where gas service is available and a minimally code compliant, electric storage type water heater elsewhere. Baseline efficiency for replacement of equipment shall be a minimally code compliant system of the same type as the existing equipment.

This measure applies to residential applications as well as residential-duty water heaters installed in commercial settings. In the latter case, this methodology shall be employed utilizing typical GPD values as defined in the "Gallons per Day (GPD)" section of the Commercial Storage Tank Water Heater measure detailed in this document.

Method for Calculating Annual Energy and Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times \frac{GPD \times 365 \times 8.33 \times \Delta T_{main}}{3{,}412} \times \left(\frac{F_{eDHW}}{UEF_{baseline}} - \frac{1}{UEF_{ee} \times F_{derate}}\right) + \Delta kWh_{cooling} - \Delta kWh_{heating}$$

$$\Delta kWh_{cooling} = units \times \frac{GPD \times 365 \times 8.33 \times \Delta T_{main}}{3{,}412} \times \frac{1}{UEF_{ee}} \times F_{Loc} \times \frac{F_{Cool}}{SEER/3.412}$$

$$\Delta kWh_{heating} = units \times \frac{GPD \times 365 \times 8.33 \times \Delta T_{main}}{3{,}412} \times \frac{1}{UEF_{ee}} \times F_{Loc} \times F_{ElecHeat} \times \frac{F_{Heat}}{HSPF/3.412}$$

Peak Coincident Demand Savings

$$\Delta kW = units \times (\Delta kW/unit)$$

[172] ENERGY STAR® Program Requirements Product Specification for Residential Water Heaters, Eligibility Criteria Version 3.2, September 2017
[173] 10 CFR 430.2

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = units \times \frac{GPD \times 365 \times 8.33 \times \Delta T_{main}}{1{,}000{,}000} \times \left[\frac{F_{FFDHW}}{UEF_{baseline}} + \frac{F_{BoilerDHW}}{AFUE} - \left(\frac{1}{UEF_{ee}} \times F_{loc} \times F_{FuelHeat} \times \frac{F_{Heat}}{AFUE}\right)\right]$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
$\Delta kWh_{cooling}$	= Annual electric cooling energy savings as a result of interactivity with the building's HVAC system (electric cooling bonus)
$\Delta kWh_{heating}$	= Annual electric heating energy savings as a result of interactivity with the building's HVAC system (electric heating penalty)
units	= Number of measures installed under the program
GPD	= Gallons per day
ΔT_{main}	= Average temperature difference between water heater set point temperature and the supply water temperature in water main (°F)
F_{eDHW}	= Electric water heating factor, used to exclude baseline electric water heating consumption if no baseline electric water heating is present
F_{FFDHW}	= Fossil fuel water heating factor, used to exclude baseline fossil fuel water heating consumption if no baseline fossil fuel fired direct water heating is present
$F_{BoilerDHW}$	= Fossil fuel water heating factor, used to exclude baseline fossil fuel water heating consumption if no baseline fossil fuel fired boiler-driven indirect water heating is present
baseline	= Characteristic of baseline condition
ee	= Characteristic of energy efficient condition
UEF	= Uniform energy factor
F_{derate}	= Efficiency derating factor used to account for the degradation of heat pump performance present in systems installed in unconditioned spaces
F_{Loc}	= Installation location factor, used to exclude interactive HVAC impacts for systems installed in unconditioned spaces
F_{Cool}	= Cooling factor, used to account for the percentage of heat extracted from ambient air by the heat pump water heater that reduces space cooling load
F_{Heat}	= Heating factor, used to account for the percentage of heat extracted from ambient air by the heat pump water heater that increases space heating load
$F_{ElecHeat}$	= Electric heating factor, used to exclude electric heating penalty if no electric heating is present
$F_{FuelHeat}$	= Fossil fuel heating factor, used to exclude fossil fuel heating penalty if no fossil fuel heating is present
SEER	= Seasonal average energy efficiency ratio over the cooling season, BTU/watthour, (used for average U.S. location/region)
HSPF	= Heating seasonal performance factor, BTU/watt-hour, total heating output (supply heat) in BTU (including electric heat) during the heating season / total electric energy heat pump consumed (in watt-hour)

AFUE = Annual fuel utilization efficiency, seasonal energy efficiency for fuel heating equipment
(ΔkW/unit) = Deemed peak coincident demand savings per measure
365 = Days in one year
8.33 = Energy required (BTU) to heat one gallon of water by one degree Fahrenheit
3,412 = Conversion factor, one kWh equals 3,412 BTU
3.412 = Conversion factor, one watt-hour equals 3.412 BTU
1,000,000 = Conversion factor, one MMBtu equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
GPD	17.2 X # of people	Calculated based on number of people served by the system. If unknown, use 46 GPD.[174]
ΔT_{main}	T_{set} - T_{main}	Average temperature difference between water heater set point temperature and the supply water temperature in water main (°F).
T_{set}	125	Water heater set point temperature (°F).[175]
T_{main}		Supply water temperature in water main (°F). Lookup in Cold Water Inlet Temperature table below based on nearest city.
F_{eDHW}		Use a value of 1.0 if the water was previously heated with electricity or if it is a new construction home with no gas access. Otherwise, use 0.0.
F_{FFDHW}		Use a value of 1.0 if the water was previously heated directly with fossil fuels or if it is a new construction home with gas access. Otherwise, use 0.0.
$F_{BoilerDHW}$		Use a value of 1.0 if the water was previously heated indirectly with fossil fuels through the boiler system. Otherwise, use 0.0.
$UEF_{baseline}$		Uniform Energy Factor of the baseline condition. See Baseline Efficiencies… section below for details regarding derivation of this input.
UEF_{ee}		Uniform Energy Factor of the energy efficient measure, from application.
F_{derate}		For equipment installed in unconditioned spaces, lookup in Derate Factor table below based on installation location and nearest city. For equipment installed in conditioned spaces, a value of 1.0 shall be used.
F_{Loc}		Use a value of 1.0 if the water heater is installed in a conditioned space. Otherwise, use 0.0.

[174] Water Research Foundation: Residential End Uses of Water, Version 2, April 2016, p. 5; 17.2 GPD equated from the report findings indicating an average 2.65 people per household and 45.5 GPD per household.
[175] 10 CFR 430 Appendix E to Subpart B of Part 430 Uniform Test Method for Measuring the Energy Consumption of Water Heaters, Section 2. Test Conditions, 2.5 Set Point Temperature.

Variable	Value	Notes
F_{Cool}		Lookup in HVAC Interactivity table below based on nearest city.
F_{Heat}		Lookup in HVAC Interactivity table below based on nearest city.
$F_{ElecHeat}$		Use a value of 1.0 if the building is electrically heated. Otherwise, use 0.0.
$F_{FuelHeat}$		Use a value of 1.0 if the building is fossil fuel heated. Otherwise, use 0.0.
SEER	13	Assumed efficiency of existing air conditioning system, based on a minimally code compliant, 3-ton, split system AC.[176]
HSPF	Heat Pump: 8.2 Electric Resistance: 3.412	Assumed efficiency of electric heating system, based on a COP of 1.0 for electric resistance heating and a minimally code compliant, 3-ton split system HP for heat pumps.[177]
AFUE		From application. If unknown, lookup from Baseline Efficiencies section based on existing equipment type. For new construction/gut rehab or if equipment type is unknown, assume an 80 MBH gas furnace.
(ΔkW/unit)		Deemed Summer Peak Coincident Demand Savings. Use a value of 0.17 if the water was previously heated with electricity in replacement scenarios and if there is no gas service available in new construction/gut rehab scenarios.[178] Otherwise, use -0.17 for an electric penalty.[179]

Cold Water Inlet Temperature (T_{main})

Supply water main temperatures vary according to climate, and are approximately equal to the annual average outdoor temperature plus 6°F.[180] Supply main temperatures based on the annual outdoor temperature are shown below.

City	Annual average outdoor temperature[181] (°F)	T_{main} (°F)
Albany	48.3	54.3
Binghamton	46.3	52.3
Buffalo	48.3	54.3

[176] ECCCNYS 2020, Table C403.3.2(1)
[177] ECCCNYS 2020, Table C403.3.2(2)
[178] "Field Testing of Pre-Production Prototype Heat Pump Water Heaters" Federal Energy Management Program, DOE/EE-0317, May 2007.
[179] "CT HVAC and Water Heater Process and Impact Evaluation and CT Heat Pump Water Heater Impact Evaluation", West Hill Energy and Computing, Final Report R1614/R1613, July 19, 2018
[180] Burch, Jay and Christensen, Craig, "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory
[181] Average annual outdoor temperatures taken from NCDC 1981-2010 climate normals

City	Annual average outdoor temperature[181] (°F)	T_{main} (°F)
Massena	43.5	49.5
NYC	55.4	61.4
Poughkeepsie	49.8	55.8
Syracuse	48.3	54.3

Derate Factor

Standard testing conditions for rating of heat pump water heaters require a dry bulb temperature of 67.5°F ± 1°F and a relative humidity of 50% ±2%.[182] The reported efficiency of heat pump water heaters is established at these conditions; however, heat pump efficiency degrades at lower ambient temperatures. The Derate Factor is established to adjust the published efficiency of the qualifying heat pump water heater when the system is installed in semi-conditioned or unconditioned spaces, namely, garages and basements. The values shown below were derived from Table 10 of Residential Heat Pump Water Heater Evaluation: Lab Testing & Energy Use Estimates published by Bonneville Power Administration in 2011[183] and verified via comparison with results from the 2013 NEEA Heat Pump Water Heater Field Study Report.[184] Average values from northwest heating zones 1 (<6,000 HDD), 2 (6,000 – 7,500 HDD) and 3 (>7,500 HDD)[185] from this analysis and comparison were then mapped to representative NY climate regions as shown below.

City	F_{derate} (Unconditioned Basement Installation)	F_{derate} (Garage Installation)
Albany	0.80	0.78
Binghamton	0.80	0.78
Buffalo	0.80	0.78
Massena	0.75	0.69
NYC	0.86	0.83
Poughkeepsie	0.80	0.78
Syracuse	0.80	0.78

HVAC Interactivity

Because heat pump water heaters operate via the transfer of heat from the ambient air to the water in the storage tank, systems installed in conditioned spaces will interact with the building's HVAC system. The values shown in the table below reflect the percentage of heat extracted from the ambient air by the heat pump that either decreases the building's cooling load (F_{Cool}) or increases the building's heating load (F_{Heat}). These values were derived from Table 12 of Residential Heat Pump Water Heater Evaluation: Lab Testing & Energy Use Estimates published by Bonneville

[182] 10 CFR 430 Subpart B Appendix E
[183] Residential Heat Pump Water Heater Evaluation: Lab Testing & Energy Use Estimates, Bonneville Power Administration, November 2011
[184] NEEA Heat Pump Water Heater Field Study Report, Fluid Market Strategies, October 2013
[185] NW Council Heating/Cooling zone maps

Power Administration in 2011[186] and key operating assumptions specified therein. Average values from northwest heating zones 1 (<6,000 HDD), 2 (6,000 – 7,500 HDD) and 3 (>7,500 HDD)[187] were then mapped to representative NY climate regions and scaled linearly based on regional HDD and CDD. The HDD and CDD values are based on 30-year averages of U.S annual climate normals between 1981 and 2010 using base 65° F.[188]

City	CDD	F_{Cool}	HDD	F_{Heat}
Albany	597	0.26	6,680	0.70
Binghamton	382	0.17	7,193	0.76
Buffalo	544	0.24	6,617	0.70
Massena	363	0.16	8,196	0.84
Poughkeepsie	671	0.29	6,210	0.65
NYC	1,160	0.51	4,671	0.49
Syracuse	570	0.25	6,651	0.70

Coincidence Factor (CF)

The recommended value for the coincidence factor is N/A. Deemed demand savings values incorporate system peak coincidence considerations.

Baseline Efficiencies from which Savings are Calculated

The baseline for a non-fuel switching normal replacement at end of the appliance effective useful life (EUL), in new construction, or substantial renovation scenarios is the minimally-compliant state or municipal energy code or federal standard, that is applicable to the measure or system being installed.

The baseline for a fuel switching installation at the end of the appliance effective useful life is the minimally-compliant, state or municipal energy code or federal standard, that is applicable to the measure or system, similar to the existing measure or system, that the consumer would have had installed without the influence of the energy efficiency program.

The baseline for a system being installed prior to the end of useful life of the existing on-site equipment may be considered as an Early Replacement; consistent with methods described in Appendix M, *Guidelines for Early Replacement* of this TRM. The non-fuel switching and fuel switching baselines detailed above shall be considered where applicable when calculating Remaining Useful Life (RUL).

$UEF_{baseline}$ shall be calculated as a function of qualifying equipment tank volume (v_t) per federal standards[189] as shown in the table below, using the qualifying equipment capacity and draw pattern. Draw pattern can be established based on the proposed equipment First Hour Rating (FHR), rated in gallons. See First Hour Rating vs. Draw Pattern table below. If FHR is unknown,

[186] Residential Heat Pump Water Heater Evaluation: Lab Testing & Energy Use Estimates, Bonneville Power Administration, November 2011
[187] NW Council Heating/Cooling zone maps
[188] HDD/CDD taken from NCEI 1981-2010 climate normals
[189] 10 CFR 430.32(d)

a Medium draw pattern should be assumed for equipment with rated storage capacity ≤50 gallons and a High draw pattern should be assumed otherwise.[190]

Product Class	Rated Storage Volume and Input Rating	Draw Pattern	$UEF_{baseline}$
Electric Storage Water Heater	≥ 20 gal and ≤ 55 gal	Very Small	0.8808 - (0.0008 x v_t)
		Low	0.9254 - (0.0003 x v_t)
		Medium	0.9307 - (0.0002 x v_t)
		High	0.9349 - (0.0001 x v_t)
	> 55 gal and ≤ 120 gal	Very Small	1.9236 - (0.0011 x v_t)
		Low	2.0440 - (0.0011 x v_t)
		Medium	2.1171 - (0.0011 x v_t)
		High	2.2418 - (0.0011 x v_t)
Gas-Fired Storage Water Heater	≥ 20 gal and ≤ 55 gal	Very Small	0.3456 – (0.0020 x v_t)
		Low	0.5982 – (0.0019 x v_t)
		Medium	0.6483 – (0.0017 x v_t)
		High	0.6920 – (0.0013 x v_t)
	> 55 gal and ≤ 100 gal	Very Small	0.6470 – (0.0006 x v_t)
		Low	0.7689 – (0.0005 x v_t)
		Medium	0.7897 – (0.0004 x v_t)
		High	0.8072 – (0.0003 x v_t)
Oil-Fired Storage Water Heater	≤ 50 gal	Very Small	0.2509 – (0.0012 x v_t)
		Low	0.5330 – (0.0016 x v_t)
		Medium	0.6078 – (0.0016 x v_t)
		High	0.6815 – (0.0014 x v_t)

*v_t = tank volume in gallons

First Hour Rating vs. Draw Pattern[191]

First Hour Rating	Draw Pattern
<18 gallons	Very Small
≥18 and <51 gallons	Low
≥51 and <75 gallons	Medium
≥75 gallons	High

The baseline efficiency for fossil fuel fired heating systems serving single-family homes and individual units is defined by the Code of Federal Regulations as shown in the table below.

[190] Based on review of typical usage bins for AHRI certified residential water heating equipment (https://www.ahridirectory.org/ahridirectory/pages/home.aspx)
[191] 10 CFR 429.17

Fossil Fuel Fired Heating System Baseline Efficiencies: Systems Serving Single Units[192]

Equipment Type	Size Range	ECCCNYS Minimum Efficiency for Climate Zones 4, 5 and 6
Warm Air Furnace, Gas Fired	All Capacities	0.80 AFUE
Warm Air Furnace, Oil Fired	All Capacities	0.83 AFUE
Boiler, Hot Water, Gas Fired	All Capacities	0.82 AFUE
Boiler, Hot Water, Oil Fired	All Capacities	0.84 AFUE
Boiler, Steam, Gas Fired	All Capacities	0.80 AFUE
Boiler, Steam, Oil Fired	All Capacities	0.82 AFUE

The baseline efficiency for heating systems serving multiple dwelling units is defined by International Energy Conservation Code[193] and subsequently adopted by the Energy Conservation Construction Code of New York State (ECCCNYS) as shown in the table below.

Fossil Fuel Fired Heating System Baseline Efficiencies: Systems Serving Multiple Dwelling Units

Equipment Type	Size Range	ECCCNYS Minimum Efficiency for Climate Zones 4, 5 and 6
Warm Air Furnace, Gas Fired	< 225 kBTU/h	0.80 AFUE
	≥ 225 kBTU/h	0.80 Et
Warm Air Furnace, Oil Fired	< 225 kBTU/h	0.83 AFUE
	≥ 225 kBTU/h	0.80 Et
Warm Air Unit Heaters, Gas Fired	All Capacities	0.80 Ec
Warm Air Unit Heaters, Oil Fired	All Capacities	0.80 Ec
Boiler, Hot Water, Gas Fired	< 300 kBTU/h	0.82 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.80 Et
	> 2,500 kBTU/h	0.82 Ec
Boiler, Hot Water, Oil Fired	< 300 kBTU/h	0.84 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.82 Et
	> 2,500 kBTU/h	0.84 Ec
Boiler, Steam, Gas Fired, All Except Natural Draft	< 300 kBTU/h	0.80 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.79 Et
	> 2,500 kBTU/h	0.79 Et
Boiler, Steam, Gas Fired, Natural Draft	< 300 kBTU/h	0.80 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.77 Et
	> 2,500 kBTU/h	0.77 Et
Boiler, Steam, Oil Fired	< 300 kBTU/h	0.82 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.81 Et
	> 2,500 kBTU/h	0.81 Et

[192] 10 CFR 430.32(e)
[193] ECCCNYS 2020, Table C403.3.2(4) & Table C403.3.2(5)

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a heat pump water heater meeting minimum performance requirements specified in ENERGY STAR® Program Requirements Product Specification for Residential Water Heaters, Eligibility Criteria Version 3.2.[194] Per that specification, heat pump water heaters with ≤55 gallon storage capacity must have a UEF ≥ 2.00 and heat pump water heaters with >55 gallon storage capacity must have UEF ≥2.20.

Operating Hours

Water heater run hours are not utilized in the estimation of energy or demand savings, but water heater is assumed to be available for operation 8,760 hours per year.

Example Calculation *(Not to be used as default)*

A 40-gallon heat pump water heater replaces an existing gas-fired storage water heater in a single family detached home located near Albany with 3 residents. The heat pump water heater has a UEF of 3.5 and a first hour rating of 60 gallons per hour. The water heater is installed in the home's conditioned utility closet, and the home's electric cooling system has a SEER of 15 while the gas heating system has an AFUE of 80%. Annual Electric Energy Savings, Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta kWh = units \times \frac{GPD \times 365 \times 8.33 \times \Delta T_{main}}{3{,}412} \times \left(\frac{F_{eDHW}}{UEF_{baseline}} - \frac{1}{UEF_{ee} \times F_{derate}}\right) + \Delta kWh_{cooling} - \Delta kWh_{heating}$$

$$\Delta kWh_{cooling} = units \times \frac{GPD \times 365 \times 8.33 \times \Delta T_{main}}{3{,}412} \times \frac{1}{UEF_{ee}} \times F_{Loc} \times \frac{F_{Cool}}{SEER/3.412}$$

$$\Delta kWh_{heating} = units \times \frac{GPD \times 365 \times 8.33 \times \Delta T_{main}}{3{,}412} \times \frac{1}{UEF_{ee}} \times F_{Loc} \times F_{ElecHeat} \times \frac{F_{Heat}}{HSPF/3.412}$$

$$\Delta kW = units \times (\Delta kW/unit)$$

$$\Delta MMBtu = units \times \frac{GPD \times 365 \times 8.33 \times \Delta T_{main}}{1{,}000{,}000} \times \left[\frac{F_{FFDHW}}{UEF_{baseline}} + \frac{F_{BoilerDHW}}{AFUE} - \left(\frac{1}{UEF_{ee}} \times F_{loc} \times F_{FuelHeat} \times \frac{F_{Heat}}{AFUE}\right)\right]$$

units = 1, from application
GPD = 17.2 x # of residents = 17.2 x 3 = 51.6

[194] ENERGY STAR® Program Requirements Product Specification for Residential Water Heaters, Eligibility Criteria Version 3.2, September 2017

GPD equation based on Summary of Variables and Data Source table
# of residents from application

$\Delta T_{main} = T_{set} - T_{main} = 125 - 54.3 = 70.7$

T_{set} from Summary of Variables and Data Sources table
T_{main} from Cold Water Inlet Temperature lookup table based on location from application

$F_{eDHW} = 0$, from Summary of Variable and Data Sources table based on baseline DHW fuel source from application

$UEF_{ee} = 3.5$, from application

$F_{derate} = 1$, from Summary of Variable and Data Sources table based on location from application

$F_{Loc} = 1$, from Summary of Variable and Data Sources based on location from application

$F_{cool} = 0.26$, from HVAC Interactivity section based on location from application

SEER = 15, from application

$F_{ElecHeat} = 0$, from Summary of Variable and Data Sources table based on location from application

HSPF = N/A, from application

(ΔkW/unit) = -0.17, from Summary of Variables and Data Sources table based on existing water heating system fuel from application

$F_{FFDHW} = 1$, from Summary of Variables and Data Sources table based on existing water heating system from application

$UEF_{baseline} = 0.6483 - (0.0017 \text{ x vt}) = 0.6483 - (0.0017 \text{ x } 40) = 0.5803$

$UEF_{baseline}$ equation lookup from Baseline Efficiencies section based on Product Class from baseline application and Rated Storage Volume and Draw Pattern from compliance equipment from application, where Draw Pattern is determined by the First Hour Rating based on application

vt from application of compliance equipment

$F_{BoilerDHW} = 0$, from Summary of Variables and Data Sources table based on existing water heating system from application

$F_{Heat} = 0.70$, from HVAC Interactivity section based on location from application

AFUE = 0.80, from application

$$\Delta kWh_{cooling} = 1 \times \frac{51.6 \times 365 \times 8.33 \times 70.7}{3{,}412} \times \frac{1}{3.5} \times 1 \times \frac{0.26}{15/3.412} = 4.72\ kWh$$

$$\Delta kWh_{heating} = 0$$

$$\Delta kWh = 1 \times \frac{51.6 \times 365 \times 8.33 \times 70.7}{3{,}412} \times \left(0 - \frac{1}{3.5 \times 1}\right) + 4.72 - 0 = -924.1\ kWh$$

$$\Delta kW = 1 \times (-0.17) = -0.17\ kW$$

$$\Delta MMBtu = 1 \times \frac{51.6 \times 365 \times 8.33 \times 70.7}{1{,}000{,}000} \times \left[\frac{1}{0.5803} + 0 - \left(\frac{1}{3.5} \times 1 \times 1 \times \frac{0.7}{0.8}\right)\right] = 16.3\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Heat pump water heaters installed in conditioned spaces will result in an increase in space heating load due to the extraction of heat from the ambient air. This interactivity is addressed in the prescribed methodology.

Ancillary Electric Savings Impacts

Heat pump water heaters installed in conditioned spaces will result in an increase in space heating load and a decrease in cooling load due to the extraction of heat from the ambient air. This interactivity is addressed in the prescribed methodology.

References

1. ENERGY STAR® Program Requirements Product Specification for Residential Water Heaters, Eligibility Criteria Version 3.2, September 2017
   Available from: https://www.energystar.gov/sites/default/files/Water%20Heaters%20Final%20Version%203.2_Program%20Requirements_0.pdf
2. 10 CFR 430.2 Definitions
   Available from: https://www.ecfr.gov/cgi-bin/text-idx?rgn=div8&node=10:3.0.1.4.18.1.9.2
3. Water Research Foundation: "Residential End Uses of Water, Version 2: Executive Report", April 2016
   Available from: http://www.waterrf.org/PublicReportLibrary/4309A.pdf
4. 10 CFR 430 Appendix E to Subpart B of Part 430 Uniform Test Method for Measuring the Energy Consumption of Water Heaters, Section 2. Test Conditions, 2.5 Set Point Temperature.
   Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=80dfa785ea350ebeee184bb0ae03e7f0&mc=true&node=ap10.3.430_127.e&rgn=div9
5. AHRI Directory of Certified Product Performance
   Available from: https://www.ahridirectory.org/ahridirectory/pages/home.aspx
6. ECCCNYS 2020 Table C403.3.2(1): Minimum Efficiency Requirements: Electrically Operated Unitary Air Conditioners and Condensing Units, Table C403.3.2(2): Minimum Efficiency Requirements: Electrically Operated Unitary and Applied Heat Pumps, Table C403.3.2(4): Warm-Air Furnaces and Combination Warm-Air Furnaces/Air-Conditioning Units, Warm-Air Duct Furnaces and Unit Heaters, Minimum Efficiency Requirements, & Table C403.3.2(5): Minimum Efficiency Requirements: Gas- And Oil-Fired Boilers
   Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-ce-commercial-energy-efficiency

7. 10 CFR 430.32 Energy and water conservation standards and their compliance dates. Available from: http://www.ecfr.gov/cgi-bin/text-idx?SID=a9921a66f2b4f66a32ec851916b7b9d9&mc=true&node=se10.3.430_132&rgn=div8
8. "Field Testing of Pre-Production Prototype Heat Pump Water Heaters" Federal Energy Management Program, DOE/EE-0317, May 2007
   Available from: https://energy.gov/sites/prod/files/2014/01/f7/heat_pump_water_heater_testing.pdf
9. "CT HVAC and Water Heater Process and Impact Evaluation and CT Heat Pump Water Heater Impact Evaluation", West Hill Energy and Computing, Final Report R1614/R1613, July 19, 2018
   Available from: https://www.energizect.com/sites/default/files/R1614-1613_ResHVAC_Report_Final_8.29.18.pdf
10. Burch, Jay and Craig Christensen; "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory.
    Available from: http://citeseerx.ist.psu.edu/viewdoc/download;jsessionid=05D73BA6EF5ECCF71969D083FB317991?doi=10.1.1.515.6885&rep=rep1&type=pdf
11. NOAA National Centers for Environmental Information – NCEI 1981-2010 Climate Normals
    Available from: https://www.ncdc.noaa.gov/cdo-web/datatools/normals
12. 10 CFR 430 Subpart B – Test Procedures, Appendix E – Uniform Test Method for Measuring the Energy Consumption of Water Heaters
    Available from: https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=9624a8ba0987aaae248454c49194a661&mc=true&n=pt10.3.430&r=PART&ty=HTML#ap10.3.430_127.e
13. "Residential Heat Pump Water Heater Evaluation: Lab Testing & Energy Use Estimates", Bonneville Power Administration, November 2011
    Available from: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.401.3815&rep=rep1&type=pdf
14. NEEA Heat Pump Water Heater Field Study Report, Fluid Market Strategies, October 2013
    Available from: http://neea.org/docs/default-source/reports/heat-pump-water-heater-field-study-report.pdf?sfvrsn=5
15. NW Council Heating/Cooling Zone Maps
    Available from: https://www.bpa.gov/EE/Sectors/Residential/Documents/PNWHeatingandCoolingClimateZoneAssignmentsbyCounty.pdf
16. 10 CFR 429.17 Water heaters.
    Available from: https://www.ecfr.gov/cgi-bin/text-idx?rgn=div5&node=10:3.0.1.4.17#se10.3.429_117

Record of Revision

Record of Revision Number	Issue Date
0	10/15/2010
6-13-3	6/30/2013
11-13-2	11/26/2013
12-17-7	12/31/2017
12-18-3	12/31/2018
2-20-1	2/28/2020
7-21-7	8/30/2021

Return to Table of Contents

INDIRECT WATER HEATER

Measure Description

This measure covers the installation of a fossil fuel indirect-fired storage water heating system in which the stored water is heated via hot water produced by a fossil fuel boiler rather than direct input from electric elements or fossil fuel burners. In such a system, a heat exchanger separates the potable water in the water heater from the boiler water. This measure applies to indirect-fired systems comprising a boiler with input heating capacity less than 300,000 BTU/h and a storage tank with a capacity of 20 to 120 gallons installed in residential applications. Larger equipment installed in whole building or multi-unit multifamily settings shall use the Commercial and Industrial Indirect Water Heater measure detailed in this document.

This measure estimates savings associated with the delivery of potable hot water only and assumes the installation of zone priority controls to interrupt demand for space heating hot water until domestic hot water demand is met.

This measure assumes baseline to be a minimally code compliant fossil fuel storage type water heater with storage capacity equivalent to the efficient water heater.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = N/A$$

Summer Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = units \times \left[\frac{GPD \times 365 \times 8.33 \times \Delta T_{main}}{1{,}000{,}000} \times \left(\frac{1}{Eff_{baseline}} - \frac{1}{Eff_{ee}}\right) + \left(\frac{UA_{baseline}}{Eff_{baseline}} - \frac{UA_{ee}}{Eff_{ee}}\right) \times \frac{\Delta T_{amb}}{1{,}000{,}000} \times 8{,}760\right]$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
GPD	= Gallons per day
ΔT_{main}	= Average temperature difference between water heater set point temperature and the supply water temperature in water main (°F)

ΔT_{amb} = Average temperature difference between water heater set point temperature and the surrounding ambient air temperature (°F)
baseline = Characteristic of baseline condition
ee = Characteristic of rnergy efficient condition
Eff = Efficiency
UA = Overall heat loss coefficient (BTU/h-°F)
365 = Days in one year
8.33 = Energy required (BTU) to heat one gallon of water by one degree Fahrenheit
1,000,000 = Conversion factor, one MMBtu equals 1,000,000 BTU
8,760 = Hours in one year

Summary of Variables and Data Sources

Variable	Value	Notes
GPD	17.2 X # of people	Calculated based on number of people served by the system. If unknown, use 46 GPD.[195]
ΔT_{main}	T_{set} - T_{main}	Average temperature difference between water heater set point temperature and the supply water temperature in water main (°F)
ΔT_{amb}	55 = T_{set} - T_{amb}	Average temperature difference between water heater set point temperature and the surrounding ambient air temperature (°F)
T_{set}	125	Water heater set point temperature (°F).[196]
T_{main}		Supply water temperature in water main (°F). Lookup in Cold Water Inlet Temperature table below based on nearest city.
T_{amb}	70	Surrounding ambient air temperature (°F).[197]
$Eff_{baseline}$	0.75	Efficiency of the baseline condition.[198]
Eff_{ee}		Efficiency of energy efficient indirect-system boiler (AFUE), from application.
$UA_{baseline}$	7.85	Overall heat loss coefficient of the baseline condition (BTU/h-°F).[199]

[195] Water Research Foundation: Residential End Uses of Water, Version 2, April 2016, p. 5; 17.2 GPD equated from the report findings indicating an average 2.65 people per household and 45.5 GPD per household.
[196] 10 CFR 430 Appendix E to Subpart B of Part 430 Uniform Test Method for Measuring the Energy Consumption of Water Heaters, Section 2. Test Conditions, 2.5 Set Point Temperature.
[197] Water heaters are generally located in conditioned or partially conditioned spaces with a typical average temperature of 65°F to 70°F to avoid freezing. A value of 70°F is used for the purposes of estimating tank/ambient air temperature differential, which aligns with standby loss specification testing standards.
[198] Per 10 CFR 430, typical recovery efficiency of a gas water heater, which is used for the purposes of this measure as a proxy for thermal efficiency, is 0.75. See for example, 10 CFR 430 Subpart B Appendix C1, 5.6.1.1.
[199] Based on computation of heat loss coefficients via conversion equations found in 10 CFR 429, 430, and 431 Docket No. EERE-2015-BT-TP-0007, Energy Conservation Program for Consumer Products and Certain Commercial and Industrial Equipment: Test Procedures for Consumer and Commercial Water Heaters. Heat loss coefficient was equated for two minimally code compliant gas storage water heaters found to be the most typical in terms of storage and input capacity, representing storage type water heaters of between 20 and 55 gallon capacity (40 gallon, 40,000 BTU/h assumed) and between 55 and 120 gallon capacity (75 gallon, 76,000 BTU/h assumed).

Variable	Value	Notes
UA_{ee}		Overall heat loss coefficient of the energy efficient measure (BTU/h-°F). Calculate per Qualifying Heat Loss Coefficient section below, based on qualifying equipment standby loss specification, rated in °F/hr. If unknown, assume UA_{ee} = 5.4.[200]

Cold Water Inlet Temperature (T_{main})

Supply water main temperatures vary according to climate, and are approximately equal to the annual average outdoor temperature plus 6°F.[201] Supply main temperatures based on the annual outdoor temperature are shown below.

City	Annual average outdoor temperature[202] (°F)	T_{main} (°F)
Albany	48.3	54.3
Binghamton	46.3	52.3
Buffalo	48.3	54.3
Massena	43.5	49.5
NYC	55.4	61.4
Poughkeepsie	49.8	55.8
Syracuse	48.3	54.3

Qualifying Heat Loss Coefficient (UA_{ee})

Indirect-fired water heater storage tanks are tested and rated for standby losses (in °F/hr) at standard testing conditions in accordance with testing standards.[203] The qualifying equipment standby loss specification (SL_{ee}), where available, shall be used in the formula below, along with tank volume (v_{ee}) to establish the qualifying equipment heat loss coefficient (UA_{ee}).

$$UA_{ee} = \frac{SL_{ee}}{70} \times v_{ee} \times 8.33$$

where:

UA_{ee} = Overall heat loss coefficient (BTU/h-°F) of the energy efficient condition
SL_{ee} = Standby loss specification (°F/hr) of the energy efficient condition
v_{ee} = Rated storage capacity (gallons) of the energy efficient condition
70 = Temperature differential (°F) utilized in standby loss testing procedure
8.33 = Energy required (BTU) to heat one gallon of water by one degree Fahrenheit

Results of heat loss coefficient evaluation at these two data points agreed to within 0.3%, so the lower of the two was selected to represent the $UA_{baseline}$ term.

[200] Based on the average standby loss specification (in °F/hr) of AHRI-certified Indirect Water Heater storage tanks, per the AHRI Directory.

[201] Burch, Jay and Christensen, Craig, "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory

[202] Average annual outdoor temperatures taken from NCEI 1981-2010 climate normals

[203] GAMA Testing Standard: Performance of Indirect-Fired Water Heaters, March 2003

Coincidence Factor (CF)

The prescribed value for the coincidence factor is N/A.

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a minimally code compliant fossil fuel storage type water heater with a recovery efficiency of 75%, tank volume equal to the energy efficient condition and heat loss coefficient as indicated above.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is an indirect fossil fuel-fired water heating system with efficiency meeting or exceeding 0.85 AFUE .

Operating Hours

Water heater run hours are not utilized in the estimation of energy or demand savings, but water heater is assumed to be available for operation 8,760 hours per year. Additionally, it is assumed standby losses are incurred 8,760 hours per year.

Example Calculation *(Not to be used as default)*

An existing residential customer located near Albany installs an indirect water heater with an AFUE of 90%, stand by loss of 1º/hr, and a 60 gallon storage tank. The system serves a single-family, detached home with 5 residents. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are not applicable. Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta MMBtu = units \times \left[\frac{GDP \times 365 \times 8.33 \times \Delta T_{main}}{1{,}000{,}000} \times \left(\frac{1}{Eff_{baseline}} - \frac{1}{Eff_{ee}}\right) + \left(\frac{UA_{baseline}}{Eff_{baseline}} - \frac{UA_{ee}}{Eff_{ee}}\right) \times \frac{\Delta T_{amb}}{1{,}000{,}000} \times 8{,}760\right]$$

units = 1, from application

GPD = 17.2 x # of residents = 17.2 x 5 = 86

GPD equation based on Summary of Variables and Data Source table

# of residents from application

$\Delta T_{main} = T_{set} - T_{main} = 125 - 54.3 = 70.7$

T_{set} from Summary of Variables and Data Sources table

T_{main} from Cold Water Inlet Temperature lookup table based on location from application

$Eff_{baseline} = 0.75$, from Summary of Variables and Data Sources table

$Eff_{ee} = 0.90$, from application

$UA_{baseline} = 7.85$, from Summary of Variables and Data Sources table

$UA_{ee} = (SL_{ee} / 70) \times v_{ee} \times 8.33 = (1 / 70) \times 60 \times 8.33 = 7.14$

UA_{ee} equation from Qualifying Heat Loss Coefficient section

SL_{ee} from application
v_{ee} from application
ΔT_{amb} = 55, from Summary of Variables and Data Sources table

$$\Delta MMBtu = 1 \times \left[\frac{86 \times 365 \times 8.33 \times 70.7}{1{,}000{,}000} \times \left(\frac{1}{0.75} - \frac{1}{0.90}\right) + \left(\frac{7.85}{0.75} - \frac{7.44}{0.90}\right) \times \frac{55}{1{,}000{,}000} \times 8{,}760\right] = 5.17\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Reduction in standby heat losses will have a negligible impact on space heating when the water heater is located in conditioned space. Consideration of these effects is not included in this methodology.

Ancillary Electric Savings Impacts

Reduction in standby heat losses will have a negligible impact on space heating and cooling when the water heater is located in conditioned space. Consideration of these effects is not included in this methodology.

References

1. Water Research Foundation: "Residential End Uses of Water, Version 2: Executive Report", April 2016
   Available from: http://www.waterrf.org/PublicReportLibrary/4309A.pdf
2. 10 CFR 430 Appendix E to Subpart B of Part 430 Uniform Test Method for Measuring the Energy Consumption of Water Heaters, Section 2. Test Conditions, 2.5 Set Point Temperature.
   Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=80dfa785ea350ebeee184bb0ae03e7f0&mc=true&node=ap10.3.430_127.e&rgn=div9
3. 10 CFR 430 Subpart B – Test Procedures, Appendix E – Uniform Test Method for Measuring the Energy Consumption of Water Heaters
   Available from: https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=9624a8ba0987aaae248454c49194a661&mc=true&n=pt10.3.430&r=PART&ty=HTML#ap10.3.430_127.e

4. 10 CFR 430 Subpart B – Test Procedures, Appendix C1 - Uniform Test Method for Measuring the Energy Consumption of Dishwashers
   Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=9acb5e05dd1d96230c64079cf0c03102&mc=true&node=pt10.3.430&rgn=div5#ap10.3.430_127.c1
5. 10 CFR 429, 430, and 431 Docket No. EERE-2015-BT-TP-0007, Energy Conservation Program for Consumer Products and Certain Commercial and Industrial Equipment: Test Procedures for Consumer and Commercial Water Heaters
   Available from: https://energy.gov/sites/prod/files/2016/08/f33/Water%20Heaters%20Test%20Procedure%20SNOPR.pdf
6. 10 CFR 431.110 Energy conservation standards and their effective dates.
   Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=7a74a124de079734b1fa6e7aef0cdc0c&mc=true&node=pt10.3.431&rgn=div5#se10.3.431_1110
7. AHRI Directory of Certified Product Performance
   Available from: https://www.ahridirectory.org/ahridirectory/pages/home.aspx
8. Burch, Jay and Craig Christensen; "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory.
   Available from: http://citeseerx.ist.psu.edu/viewdoc/download;jsessionid=05D73BA6EF5ECCF71969D083FB317991?doi=10.1.1.515.6885&rep=rep1&type=pdf
9. NOAA National Centers for Environmental Information – NCEI 1981-2010 Climate Normals
   Available from: https://www.ncdc.noaa.gov/cdo-web/datatools/normals
10. GAMA Testing Standard: Performance of Indirect-Fired Water Heaters, March 2003
    Available from: http://www.ahrinet.org/App_Content/ahri/files/standards%20pdfs/Indirect-Fired%20Water%20Heater%20Testing%20Standard03.pdf

Record of Revision

Record of Revision Number	Issue Date
0	10/15/2010
6-13-2	6/30/2013
7-13-5	7/31/2013
7-13-6	7/31/2013
7-13-29	7/31/2013
7-13-33	7/31/2013
7-13-34	7/31/2013
7-13-35	7/31/2013
11-13-2	11/26/2013
12-17-4	12/31/2017

Return to Table of Contents

STORAGE TANK AND INSTANTANEOUS DOMESTIC WATER HEATER

Measure Description

This measure covers the installation of storage tank water heaters designed to heat and store water at a thermostatically controlled temperature, as well as instantaneous type water heaters, which heat water but contain no more than one gallon of water per 4,000 BTU per hour of input. This measure applies to potable hot water delivery only; it is not applicable to hot water heaters used for process loads or space heating. Additionally, qualifying equipment must be designed to heat water to a temperature no greater than 180°F and, if electric power is required for operation, must use a single-phase external power supply.

Storage type units include residential fossil fuel storage water heaters with a nominal input of 75,000 BTU per hour or less and a rated storage capacity between 20 and 100 gallons, residential-duty commercial fossil fuel storage water heaters with a nominal input of greater than 75,000 BTU per hour and less than or equal to 105,000 BTU per hour and a rated storage capacity between 20 and 120 gallons and electric storage water heaters with an input of 12 kilowatts or less and a rated storage capacity between 20 and 120 gallons.

Instantaneous type units include fossil fuel instantaneous water heaters with a rated input capacity of greater than or equal to 50,000 and less than 200,000 BTU per hour and a manufacturer's specified storage capacity of less than 2 gallons, residential electric instantaneous water heaters with an input of 12 kilowatts or less and a manufacturer's specified storage capacity of less than 2 gallons and residential-duty commercial electric instantaneous water heaters with an input of greater than 12 kilowatts and less than or equal to 56.8 kilowatts and a manufacturer's specified storage capacity of 2 gallons or less.[204]

This measure applies to replacement of existing storage type and instantaneous water heaters using the same heating fuel (fossil fuel or electric) as the efficient case and assumes baseline to be a minimally code compliant water heater (as described in greater detail below) of the same type and heating fuel as the existing case. For new construction, this measure assumes baseline to be a minimally code compliant storage-type water heater using the same heating fuel (fossil fuel or electric) as the efficient case.

This measure applies to residential applications as well as residential-duty water heaters installed in commercial settings. In the latter case, this methodology shall be employed utilizing typical GPD values as defined in the "Gallons per Day (GPD)" section of the Commercial Storage Tank Water Heater measure detailed in this document.

[204] Definitions of qualifying system types and specifications per 10 CFR 430.2 and revised in accordance with the limitations imposed by 10 CFR 430.32(d) and 10 CFR 431.110(b).

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings (Electric Water Heating Only)

$$\Delta kWh = units \times \frac{GPD \times 365 \times 8.33 \times \Delta T_{main}}{3{,}412} \times \left(\frac{1}{UEF_{baseline}} - \frac{1}{UEF_{ee}}\right)$$

Summer Peak Coincident Demand Savings (Electric Water Heating Only)

$$\Delta kW = units \times \frac{(UA_{baseline} - UA_{ee}) \times \Delta T_{amb}}{3{,}412} \times CF$$

Annual Fossil Fuel Energy Savings (Fossil Fuel Water Heating Only)

$$\Delta MMBtu = units \times \frac{GPD \times 365 \times 8.33 \times \Delta T_{main}}{1{,}000{,}000} \times \left(\frac{1}{UEF_{baseline}} - \frac{1}{UEF_{ee}}\right)$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
GPD	= Gallons per day
ΔT_{main}	= Average temperature difference between water heater set point temperature and the supply water temperature in water main (°F)
ΔT_{amb}	= Average temperature difference between water heater set point temperature and the surrounding ambient air temperature (°F)
baseline	= Characteristic of baseline condition
ee	= Characteristic of energy efficient condition
UEF	= Uniform energy factor
UA	= Overall heat loss coefficient (BTU/h-°F)
CF	= Coincidence factor
365	= Days in one year
8.33	= Energy required (BTU) to heat one gallon of water by one degree Fahrenheit
3,412	= Conversion factor, one kWh equals 3,412 BTU
1,000,000	= Conversion factor, one MMBtu equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
GPD	17.2 X # of people	Calculated based on number of people served by the system. If unknown, use 46 GPD.[205] For residential-duty commercial water heaters, refer to GPD table in the commercial version of this measure.

[205] Water Research Foundation: Residential End Uses of Water, Version 2, April 2016, p. 5; 17.2 GPD equated from the report findings indicating an average 2.65 people per household and 45.5 GPD per household.

Variable	Value	Notes
ΔT_{main}	T_{set} - T_{main}	Average temperature difference between water heater set point temperature and the supply water temperature in water main (°F).
ΔT_{amb}	55 = T_{set} - T_{amb}	Average temperature difference between water heater set point temperature and the surrounding ambient air temperature (°F).
T_{set}	125	Water heater set point temperature (°F).[206]
T_{main}		Supply water temperature in water main (°F). Lookup in Cold Water Inlet Temperature table below based on nearest city.
T_{amb}	70	Surrounding ambient air temperature (°F).[207]
$UEF_{baseline}$		Uniform Energy Factor of the baseline condition. See Baseline Efficiencies… section below for details regarding derivation of this input.
UEF_{ee}		Uniform Energy Factor of the energy efficient measure, from application.
$UA_{baseline}$		Overall heat loss coefficient of the baseline condition (BTU/h-°F).[208] For Instantaneous water heaters, set $UA_{baseline}$ = 0. For storage type water heaters, set $UA_{baseline}$ = 7.85.
UA_{ee}		Overall heat loss coefficient of the energy efficient measure (BTU/h-°F). For instantaneous water heaters, set UA_{ee} = 0. For storage type water heaters, set UA_{ee} = 5.4.[209]
CF	0.8	

Cold Water Inlet Temperature (T_{main})

Supply water main temperatures vary according to climate, and are approximately equal to the annual average outdoor temperature plus 6°F.[210] Supply main temperatures based on the annual outdoor temperature are shown below.

[206] 10 CFR 430 Appendix E to Subpart B of Part 430 Uniform Test Method for Measuring the Energy Consumption of Water Heaters, Section 2. Test Conditions, 2.5 Set Point Temperature.

[207] Water heaters are generally located in conditioned or partially conditioned spaces with a typical average temperature of 65°F to 70°F to avoid freezing. A value of 70°F is used for the purposes of estimating tank/ambient air temperature differential, which aligns with standby loss specification testing standards.

[208] Based on computation of heat loss coefficients via conversion equations found in 10 CFR 429, 430, and 431 Docket No. EERE-2015-BT-TP-0007, Energy Conservation Program for Consumer Products and Certain Commercial and Industrial Equipment: Test Procedures for Consumer and Commercial Water Heaters. Heat loss coefficient was equated for two minimally code compliant gas storage water heaters found to be the most typical in terms of storage and input capacity, representing storage type water heaters of between 20 and 55 gallon capacity (40 gallon, 40,000 BTU/h assumed) and between 55 and 120 gallon capacity (75 gallon, 76,000 BTU/h assumed). Results of heat loss coefficient evaluation at these two data points agreed to within 0.3%, so the lower of the two was selected to represent the $UA_{baseline}$ term.

[209] Based on the average standby loss specification (in °F/hr) of AHRI-certified Indirect Water Heater storage tanks, per the AHRI Directory.

[210] Burch, Jay and Christensen, Craig, "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory

City	Annual average outdoor temperature[211] (°F)	T_{main} (°F)
Albany	48.3	54.3
Binghamton	46.3	52.3
Buffalo	48.3	54.3
Massena	43.5	49.5
NYC	55.4	61.4
Poughkeepsie	49.8	55.8
Syracuse	48.3	54.3

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.8.[212]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a minimally code compliant water heater of type (storage-type or instantaneous) equivalent to the existing water heater and with tank volume (where applicable), input capacity and draw pattern equivalent to the efficient water heater. For new construction, the baseline condition is a minimally code compliant storage-type water heater with tank volume, input capacity and draw pattern equivalent to the efficient water heater. For all instantaneous water heaters with a storage type baseline, a 40-gallon storage type water heater with input capacity and draw pattern equivalent to the efficient water heater shall be assumed.

$UEF_{baseline}$ shall be calculated as a function of qualifying equipment tank volume (v_t) for storage type water heaters or looked up for instantaneous water heaters per federal standards from the appropriate table (Residential Water Heaters or Residential-Duty Commercial Water Heaters) below, using the baseline equipment type and efficient case capacity and draw pattern. Draw pattern can be established based on the efficient equipment First Hour Rating (FHR), rated in gallons, for storage type water heaters or Max Gallons per Minute (GPM), rated in gallons/minute, for instantaneous water heaters. See the First Hour Rating vs. Draw Pattern and Max GPM vs. Draw Pattern tables below for storage type and instantaneous water heaters, respectively. If FHR or Max GPM is unknown, a Medium draw pattern should be assumed for storage type water heaters with rated storage capacity ≤ 50 gallons and a High draw pattern should be assumed otherwise.[213]

[211] Average annual outdoor temperatures taken from NCEI 1981-2010 climate normals
[212] *No source specified – update pending availability and review of applicable references.*
[213] Based on review of typical usage bins for AHRI certified residential water heating equipment (https://www.ahridirectory.org/ahridirectory/pages/home.aspx)

Residential Water Heaters[214]

Product Class	Rated Storage Volume and Input Rating	Draw Pattern	$UEF_{baseline}$
Gas-Fired Storage Water Heater	≥ 20 gal and ≤ 55 gal	Very Small	0.3456 - (0.0020 x V_r^*)
		Low	0.5982 - (0.0019 x V_r)
		Medium	0.6483 - (0.0017 x V_r)
		High	0.6920 - (0.0013 x V_r)
	> 55 gal and ≤ 100 gal	Very Small	0.6470 - (0.0006 x V_r)
		Low	0.7689 - (0.0005 x V_r)
		Medium	0.7897 - (0.0004 x V_r)
		High	0.8072 - (0.0003 x V_r)
Oil-Fired Storage Water Heater	≤50 gal	Very Small	0.2509 - (0.0012 x V_r)
		Low	0.5330 – (0.0016 x V_r)
		Medium	0.6078 – (0.0016 x V_r)
		High	0.6815 - (0.0014 x V_r)
Electric Storage Water Heater	≥ 20 gal and ≤ 55 gal	Very Small	0.8808 - (0.0008 x V_r)
		Low	0.9254 - (0.0003 x V_r)
		Medium	0.9307 - (0.0002 x V_r)
		High	0.9349 - (0.0001 x V_r)
	> 55 gal and ≤ 120 gal	Very Small	1.9236 - (0.0011 x V_r)
		Low	2.0440 - (0.0011 x V_r)
		Medium	2.1171 - (0.0011 x V_r)
		High	2.2418 - (0.0011 x V_r)
Instantaneous Gas-Fired Water Heater	< 2 gal and > 50,000 BTU/h	Very Small	0.80
		Low	0.81
		Medium	0.81
		High	0.81
Instantaneous Electric Water Heater	< 2 gal	Very Small	0.91
		Low	0.91
		Medium	0.91
		High	0.92

*V_r = Rated storage volume (in gallons)

Residential-Duty Commercial Water Heaters[215]

Product Class	Rated Storage Volume and Input Rating	Draw Pattern	$UEF_{baseline}$
Gas-Fired Storage Water Heater	> 75,000 BTU/h and ≤ 105,000 BTU/h and ≤ 120 gal	Very Small	0.2674 - (0.0009 x v_t^*)
		Low	0.5362 - (0.0012 x v_t)
		Medium	0.6002 - (0.0011 x v_t)
		High	0.6597 - (0.0009 x v_t)

[214] 10 CFR 430.32(d)
[215] 10 CFR 431.110(b)

Product Class	Rated Storage Volume and Input Rating	Draw Pattern	$UEF_{baseline}$
Oil-Fired Storage Water Heater	>105,000 BTU/h and ≤140,000 BTU/h and ≤ 120 gal	Very Small	0.2932 – (0.0015 x Vr)
		Low	0.5596 - (0.0018 x V_r)
		Medium	0.6194 – (0.0016 x V_r)
		High	0.6740 – (0.0013 x V_r)
Instantaneous Electric Water Heater	> 12 kW gal and ≤ 55 gal	Very Small	0.80
		Low	0.80
		Medium	0.80
		High	0.80

*v_t = tank volume in gallons

First Hour Rating vs. Draw Pattern (Storage Type Only)[216]

First Hour Rating	Draw Pattern
< 18 gallons	Very Small
≥ 18 and < 51 gallons	Low
≥ 51 and < 75 gallons	Medium
≥ 75 gallons	High

Max GPM vs. Draw Pattern (Instantaneous Only)[217]

Max GPM	Draw Pattern
< 1.7 gallons/minute	Very Small
≥ 1.7 and < 2.8 gallons/minute	Low
≥ 2.8 and < 4.0 gallons/minute	Medium
≥ 4.0 gallons/minute	High

Compliance Efficiency from which Incentives are Calculated

The compliance condition is an ENERGY STAR® rated fossil fuel or electric storage or instantaneous type water heater as directed by the measure description. Efficient fossil fuel and electric storage tank and instantaneous type water heaters must be eligible under ENERGY STAR® Program Requirements for Residential Water Heaters, Eligibility Criteria Version 3.2, effective April 2015.[218] Minimum UEF qualification for ENERGY STAR® equipment are shown in the table below.

[216] 10 CFR 429.17
[217] 10 CFR 429.17
[218] ENERGY STAR® Program Requirements Product Specification for Residential Water Heaters, Eligibility Criteria, Version 3.2, April 16, 2015

Residential Water Heaters

Product Class	Rated Storage Volume and Input Rating	Draw Pattern	UEF
Gas-Fired Storage Water Heater	≥ 20 gal and ≤ 55 gal	Medium	≥ 0.64
		High	≥ 0.68
	> 55 gal and ≤ 100 gal	Medium	≥ 0.78
		High	≥ 0.80
Electric Storage Water Heater	≥ 20 gal and ≤ 55 gal	All	≥ 2.00
	> 55 gal and ≤ 100 gal	All	≥ 2.20
Instantaneous Gas-Fired Water Heater	< 2 gal and > 50,000 BTU/h	All	≥ 0.87

Residential-Duty Commercial Water Heaters

Product Class	Rated Storage Volume and Input Rating	Draw Pattern	UEF
Gas-Fired Storage Water Heater	> 75,000 BTU/h and ≤ 105,000 BTU/h and ≤ 120 gal	All	≥ 0.80

Operating Hours

Water heater run hours are not utilized in the estimation of energy or demand savings, but water heater is assumed to be available for operation 8,760 hours per year. Additionally, it is assumed standby losses are incurred 8,760 hours per year.

Example Calculation *(Not to be used as default)*

An existing residential customer located near Albany replaces their existing storage tank gas-fired water heater with a high efficiency storage tank gas-fired water heater. The system serves a single-family, detached home with 5 residents. The high efficiency water heater has a tank capacity of 50 gallons and is rated for a medium draw pattern with a UEF of 0.68. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are not applicable. Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta MMBtu = units \times \frac{GPD \times 365 \times 8.33 \times \Delta T_{main}}{1{,}000{,}000} \times \left(\frac{1}{UEF_{baseline}} - \frac{1}{UEF_{ee}}\right)$$

units = 1, from application

GPD = 17.2 x # of residents = 17.2 x 5 = 86

GPD equation based on Summary of Variables and Data Source table

# of residents from application

$\Delta T_{main} = T_{set} - T_{main} = 125 - 54.3 = 70.7$

T_{set} from Summary of Variables and Data Sources table

T_{main} from Cold Water Inlet Temperature lookup table based on location from application

$UEF_{baseline} = 0.6483 - (0.0017 \times v_r) = 0.6483 - (0.0017 \times 50) = 0.5633$

$UEF_{baseline}$ equation from Residential Water Heaters table based on product class and draw pattern from application
V_r from application
UEF_{ee} = 0.68, from application

$$\Delta MMBtu = 1 \times \frac{(86) \times 365 \times 8.33 \times (70.7)}{1{,}000{,}000} \times \left(\frac{1}{(0.5633)} - \frac{1}{0.68}\right) = 5.63\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Reduction in standby heat losses will have a negligible impact on space heating when the water heater is located in conditioned space. Consideration of these effects is not included in this methodology.

Ancillary Electric Savings Impacts

Reduction in standby heat losses will have a negligible impact on space heating and cooling when the water heater is located in conditioned space. Consideration of these effects is not included in this methodology.

Gas water heaters with draft inducer fans may introduce additional electric load. Consideration of this effect is not included in this methodology.

References

1. ENERGY STAR® Program Requirements Product Specification for Residential Water Heaters, Eligibility Criteria, Version 3.2, April 16, 2015
   Available from:
   https://www.energystar.gov/sites/default/files/Water%20Heaters%20Final%20Version%203.2_Program%20Requirements.pdf
2. 10 CFR 430.2 Definitions.
   Available from: https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=78ea8c7c6bf5379d6e0fd2b41e335739&mc=true&n=pt10.3.430&r=PART&ty=HTML#se10.3.430_12
3. 10 CFR 430.32 Energy and water conservation standards and their compliance dates.
   Available from: http://www.ecfr.gov/cgi-bin/text-idx?SID=a9921a66f2b4f66a32ec851916b7b9d9&mc=true&node=se10.3.430_132&rgn=div8
4. 10 CFR 431.110 Energy conservation standards and their effective dates.
   Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=a69096e892b13c204bbe6da3a92f8111&mc=true&node=se10.3.431_1110&rgn=div8

5. Water Research Foundation: "Residential End Uses of Water, Version 2: Executive Report", April 2016
   Available from: http://www.waterrf.org/PublicReportLibrary/4309A.pdf
6. Appendix E to Subpart B of Part 430—Uniform Test Method for Measuring the Energy Consumption of Water Heaters, Section 2. Test Conditions, 2.5 Set Point Temperature.
   Available from: : https://www.ecfr.gov/cgi-bin/text-idx?SID=80dfa785ea350ebeee184bb0ae03e7f0&mc=true&node=ap10.3.430_127.e&rgn=div9
7. 10 CFR 430 Subpart B – Test Procedures, Appendix E – Uniform Test Method for Measuring the Energy Consumption of Water Heaters
   Available from: https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=9624a8ba0987aaae248454c49194a661&mc=true&n=pt10.3.430&r=PART&ty=HTML#ap10.3.430_127.e
8. 10 CFR 429, 430, and 431 Docket No. EERE-2015-BT-TP-0007, Energy Conservation Program for Consumer Products and Certain Commercial and Industrial Equipment: Test Procedures for Consumer and Commercial Water Heaters
   Available from:
   https://energy.gov/sites/prod/files/2016/08/f33/Water%20Heaters%20Test%20Procedure%20SNOPR.pdf
9. AHRI Directory of Certified Product Performance
   Available from: https://www.ahridirectory.org/ahridirectory/pages/home.aspx
10. Burch, Jay and Craig Christensen; "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory.
    Available from:
    http://citeseerx.ist.psu.edu/viewdoc/download;jsessionid=05D73BA6EF5ECCF71969D083FB317991?doi=10.1.1.515.6885&rep=rep1&type=pdf
11. NOAA National Centers for Environmental Information – NCEI 1981-2010 Climate Normals
    Available from: https://www.ncdc.noaa.gov/cdo-web/datatools/normals
12. 10 CFR 429.17 Water heaters.
    Available from: https://www.ecfr.gov/cgi-bin/text-idx?rgn=div5&node=10:3.0.1.4.17#se10.3.429_117

Record of Revision

Record of Revision Number	Issue Date
1	10/15/2010
6-13-1	6/30/2013
7-13-6	7/31/2013
11-13-2	11/26/2013
12-17-5	12/31/2017
3-19-4	3/29/2019

Return to Table of Contents

DOMESTIC HOT WATER – CONTROL

DRAIN WATER HEAT RECOVERY (DWHR)

Measure Description

This measure covers the installation of drain water heat recovery systems on a main waste drain in residential applications. Drain water heat recovery (DWHR) systems are drainage heat exchangers that recover heat from drain greywater to preheat cold water entering the water heater. By preheating cold water entering the storage tank, the water heater consumes less energy to heat the water to the desired temperature.

This measure is only applicable to buildings with storage type water heaters.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings (Electric Water Heating Only)

$$\Delta kWh = units \times \frac{GPD \times 365 \times 8.33 \times \Delta T_{main}}{3{,}412} \times \frac{1}{UEF} \times ESF$$

Summer Peak Coincident Demand Savings (Electric Water Heating Only)

$$\Delta kW = units \times \frac{UA \times \Delta T_{amb}}{3{,}412} \times \frac{1}{UEF} \times ESF \times CF$$

Annual Fossil Fuel Energy Savings (Fossil Fuel Water Heating Only)

$$\Delta MMBtu = units \times \frac{GPD \times 365 \times 8.33 \times \Delta T_{main}}{1{,}000{,}000} \times \frac{1}{UEF} \times ESF$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
GPD	= Gallons per day
ΔT_{main}	= Average temperature difference between water heater set point temperature and the supply water temperature in water main (°F)
ΔT_{amb}	= Average temperature difference between water heater set point temperature and the surrounding ambient air temperature (°F)
UEF	= Uniform energy factor
UA	= Overall heat loss coefficient (BTU/h-°F)
ESF	= Energy savings factor
CF	= Coincidence factor
365	= Days in one year
8.33	= Energy required (BTU) to heat one gallon of water by one degree Fahrenheit

3,412 = Conversion factor, one kWh equals 3,412 BTU
1,000,000 = Conversion factor, one MMBtu equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
GPD	17.2 X # of people	Calculated based on number of people served by the system. If unknown, use 46 GPD.[219]
ΔT_{main}	T_{set} - T_{main}	Average temperature difference between water heater set point temperature and the supply water temperature in water main (°F)
ΔT_{amb}	55 = T_{set} - T_{amb}	Average temperature difference between water heater set point temperature and the surrounding ambient air temperature (°F)
T_{set}	125	Water heater set point temperature (°F).[220]
T_{main}		Supply water temperature in water main (°F). Lookup in Cold Water Inlet Temperature table below based on nearest city.
T_{amb}	70	Surrounding ambient air temperature (°F).[221]
UEF		Uniform Energy Factor of the baseline condition, from application, or use default based on Uniform Energy factor section below
UA	7.85	Overall heat loss coefficient of the baseline condition (BTU/h-°F).[222]
ESF	0.25	Oak Ridge National Laboratory. [223]
CF	0.8	

Cold Water Inlet Temperature (T_{main})

Supply water main temperatures vary according to climate, and are approximately equal to the annual average outdoor temperature plus 6°F.[224] Supply main temperatures based on the annual

[219] Water Research Foundation: Residential End Uses of Water, Version 2, April 2016, p. 5; 17.2 GPD equated from the report findings indicating an average 2.65 people per household and 45.5 GPD per household.
[220] 10 CFR 430 Appendix E to Subpart B of Part 430 Uniform Test Method for Measuring the Energy Consumption of Water Heaters, Section 2. Test Conditions, 2.5 Set Point Temperature.
[221] Water heaters are generally located in conditioned or partially conditioned spaces with a typical average temperature of 65°F to 70°F to avoid freezing. A value of 70°F is used for the purposes of estimating tank/ambient air temperature differential, which aligns with standby loss specification testing standards.
[222] Based on computation of heat loss coefficients via conversion equations found in 10 CFR 429, 430, and 431 Docket No. EERE-2015-BT-TP-0007, Energy Conservation Program for Consumer Products and Certain Commercial and Industrial Equipment: Test Procedures for Consumer and Commercial Water Heaters. Heat loss coefficient was equated for two minimally code compliant gas storage water heaters found to be the most typical in terms of storage and input capacity, representing storage type water heaters of between 20 and 55 gallon capacity (40 gallon, 40,000 BTU/h assumed) and between 55 and 120 gallon capacity (75 gallon, 76,000 BTU/h assumed). Results of heat loss coefficient evaluation at these two data points agreed to within 0.3%, so the lower of the two was selected to represent the $UA_{baseline}$ term.
[223] GFX Evaluation, Oak Ridge National Laboratory, August 2000, lower end of the energy savings range (25-30%)
[224] Burch, Jay and Christensen, Craig, "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory

outdoor temperature are shown below.

City	Annual average outdoor temperature[225] (°F)	T_{main} (°F)
Albany	48.3	54.3
Binghamton	46.3	52.3
Buffalo	48.3	54.3
Massena	43.5	49.5
NYC	55.4	61.4
Poughkeepsie	49.8	55.8
Syracuse	48.3	54.3

Uniform Energy Factor

UEF shall be calculated as a function of existing equipment tank volume (v_t) with the appropriate equation, looked up based on existing equipment type, capacity and draw pattern. Draw pattern can be established based on the existing equipment First Hour Rating (FHR), rated in gallons; see the First Hour Rating vs. Draw Pattern table below. If FHR is unknown, a Medium draw pattern should be assumed for storage type water heaters with rated storage capacity ≤50 gallons and a High draw pattern should be assumed otherwise.[226]

Residential Water Heaters[227]

Product Class	Rated Storage Volume and Input Rating	Draw Pattern	$UEF_{baseline}$
Gas-Fired Storage Water Heater	≥ 20 gal and ≤ 55 gal	Very Small	$0.3456 - (0.0020 \times V_r^*)$
		Low	$0.5982 - (0.0019 \times V_r)$
		Medium	$0.6483 - (0.0017 \times V_r)$
		High	$0.6920 - (0.0013 \times V_r)$
	> 55 gal and ≤ 100 gal	Very Small	$0.6470 - (0.0006 \times V_r)$
		Low	$0.7689 - (0.0005 \times V_r)$
		Medium	$0.7897 - (0.0004 \times V_r)$
		High	$0.8072 - (0.0003 \times V_r)$
Oil-Fired Storage Water Heater	≤50 gal	Very Small	$0.2509 - (0.0012 \times V_r)$
		Low	$0.5330 – (0.0016 \times V_r)$
		Medium	$0.6078 – (0.0016 \times V_r)$
		High	$0.6815 - (0.0014 \times V_r)$

[225] Average annual outdoor temperatures taken from NCEI 1981-2010 climate normals
[226] Based on review of typical usage bins for AHRI certified residential water heating equipment (https://www.ahridirectory.org/ahridirectory/pages/home.aspx)
[227] 10 CFR 430.32(d)

Product Class	Rated Storage Volume and Input Rating	Draw Pattern	$UEF_{baseline}$
Electric Storage Water Heater	≥ 20 gal and ≤ 55 gal	Very Small	0.8808 - (0.0008 x V_r)
		Low	0.9254 - (0.0003 x V_r)
		Medium	0.9307 - (0.0002 x V_r)
		High	0.9349 - (0.0001 x V_r)
	> 55 gal and ≤ 120 gal	Very Small	1.9236 - (0.0011 x V_r)
		Low	2.0440 - (0.0011 x V_r)
		Medium	2.1171 - (0.0011 x V_r)
		High	2.2418 - (0.0011 x V_r)

*V_r = Rated storage tank volume (in gallons)

Residential-Duty Commercial Water Heaters[228]

Product Class	Rated Storage Volume and Input Rating	Draw Pattern	UEF
Gas-Fired Storage Water Heater	> 75,000 BTU/h and ≤ 105,000 BTU/h and ≤ 120 gal	Very Small	0.2674 - (0.0009 x v_t^*)
		Low	0.5362 - (0.0012 x v_t)
		Medium	0.6002 - (0.0011 x v_t)
		High	0.6597 - (0.0009 x v_t)
Oil-Fired Storage Water Heater	>105,000 BTU/h and ≤140,000 BTU/h and ≤ 120 gal	Very Small	0.2932 – (0.0015 x Vr)
		Low	0.5596 - (0.0018 x V_r)
		Medium	0.6194 – (0.0016 x V_r)
		High	0.6740 – (0.0013 x V_r)

*v_t = tank volume in gallons

First Hour Rating vs. Draw Pattern[229]

First Hour Rating	Draw Pattern
< 18 gallons	Very Small
≥ 18 and < 51 gallons	Low
≥ 51 and < 75 gallons	Medium
≥ 75 gallons	High

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.8.[230]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a storage type water heater without a DWHR system in a residential application.

[228] 10 CFR 431.110(b)
[229] 10 CFR 429.17
[230] *No source specified – update pending availability and review of applicable references.*

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a storage type water heater equipped with DWHR on the main waste drainage line in a residential application. DWHR units must have a minimum efficiency of 40% if installed for equal flow or a minimum efficiency of 52% if installed for unequal flow.[231] DWHR units shall comply with CSA B55.2 and shall be tested in accordance with CSA B55.1. Potable water-side pressure loss of DWHR units shall be less than 3 psi.[232]

Operating Hours

Water heater run hours are not utilized in the estimation of energy or demand savings, but water heater is assumed to be available for operation 8,760 hours per year. Additionally, it is assumed standby losses are incurred 8,760 hours per year.

Example Calculation *(Not to be used as default)*

An existing residential customer located near Albany installs a DWHR system in a single-family, detached home with 5 residents. The residence's electric storage tank water heater has a UEF of 0.9. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

$$\Delta kWh = units \times \frac{GPD \times 365 \times 8.33 \times \Delta T_{main}}{3{,}412} \times \frac{1}{UEF} \times ESF$$

$$\Delta kW = units \times \frac{UA \times \Delta T_{amb}}{3{,}412} \times \frac{1}{UEF} \times ESF \times CF$$

units = 1, from application
GPD = 17.2 x # of residents = 17.2 x 5 = 86
GPD equation based on Summary of Variables and Data Source table
# of residents from application
$\Delta T_{main} = T_{set} - T_{main} = 125 - 54.3 = 70.7$
T_{set} from Summary of Variables and Data Sources table
T_{main} from Cold Water Inlet Temperature lookup table based on location from application
UEF = 0.9, from application
ESF = 0.25, from Summary of Variables and Data Sources table
UA = 7.85, from Summary of Variables and Data Sources table
ΔT_{amb} = 55, from Summary of Variables and Data Sources table
CF = 0.8, from Summary of Variables and Data Sources table

$$\Delta kWh = 1 \times \frac{86 \times 365 \times 8.33 \times 70.7}{3{,}412} \times \frac{1}{0.9} \times 0.25 = 1{,}505.03\ kWh$$

[231] NYSERDA NYStretch Code – Energy 2020, Section R403.5.4.3 Drain water heat recovery units
[232] ECCCNYS 2020, Section R403.5.4 Drain Water Recovery Units

$$\Delta kW = 1 \times \frac{7.85 \times 55}{3{,}412} \times \frac{1}{0.9} \times 0.25 \times 0.8 = 0.0281\ kW$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. 10 CFR 430.2 Definitions.
   Available from: https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=78ea8c7c6bf5379d6e0fd2b41e335739&mc=true&n=pt10.3.430&r=PART&ty=HTML#se10.3.430_12
2. 10 CFR 430.32 Energy and water conservation standards and their compliance dates.
   Available from: http://www.ecfr.gov/cgi-bin/text-idx?SID=a9921a66f2b4f66a32ec851916b7b9d9&mc=true&node=se10.3.430_132&rgn=div8
3. 10 CFR 431.110 Energy conservation standards and their effective dates.
   Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=a69096e892b13c204bbe6da3a92f8111&mc=true&node=se10.3.431_1110&rgn=div8
4. Water Research Foundation: "Residential End Uses of Water, Version 2: Executive Report", April 2016
   Available from: http://www.waterrf.org/PublicReportLibrary/4309A.pdf
5. 10 CFR 430 Subpart B – Test Procedures, Appendix E – Uniform Test Method for Measuring the Energy Consumption of Water Heaters
   Available from: https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=9624a8ba0987aaae248454c49194a661&mc=true&n=pt10.3.430&r=PART&ty=HTML#ap10.3.430_127.e
6. GFX Evaluation, Oak Ridge National Laboratory, August 2000
   Available from: http://gfxtechnology.com/Duluth-Triplex.pdf
7. 10 CFR 430 Subpart B – Test Procedures, Appendix E – Uniform Test Method for Measuring the Energy Consumption of Water Heaters
   Available from: https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=9624a8ba0987aaae248454c49194a661&mc=true&n=pt10.3.430&r=PART&ty=HTML#ap10.3.430_127.e

8. 10 CFR 429, 430, and 431 Docket No. EERE-2015-BT-TP-0007, Energy Conservation Program for Consumer Products and Certain Commercial and Industrial Equipment: Test Procedures for Consumer and Commercial Water Heaters
   Available from: https://energy.gov/sites/prod/files/2016/08/f33/Water%20Heaters%20Test%20Procedure%20SNOPR.pdf
9. AHRI Directory of Certified Product Performance
   Available from: https://www.ahridirectory.org/ahridirectory/pages/home.aspx
10. Burch, Jay and Craig Christensen; "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory.
    Available from: http://citeseerx.ist.psu.edu/viewdoc/download;jsessionid=05D73BA6EF5ECCF71969D083FB317991?doi=10.1.1.515.6885&rep=rep1&type=pdf
11. NOAA National Centers for Environmental Information – NCEI 1981-2010 Climate Normals
    Available from: https://www.ncdc.noaa.gov/cdo-web/datatools/normals
12. 10 CFR 429.17 Water heaters.
    Available from: : https://www.ecfr.gov/cgi-bin/text-idx?rgn=div5&node=10:3.0.1.4.17#se10.3.429_117
13. NYSERDA NYStretch Code – Energy 2020, Section 403.5.4.3 Drain Water Heat Recovery Unit
    Available from: https://www.nyserda.ny.gov/All-Programs/Programs/Energy-Code-Training/NYStretch-Energy-Code-2020
14. ECCCNYS 2020 Section R403.5.4 Drain Water Heat Recovery Units
    Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-re-residential-energy-efficiency

Record of Revision

Record of Revision Number	Issue Date
12-18-7	12/28/2018

Return to Table of Contents

LOW-FLOW - FAUCET AERATOR

Measure Description

This measure covers the installation of low-flow aerators on residential faucets. A low-flow faucet aerator is a water saving device with rated gallons per minute (gpm) less than maximum allowable flowrate as mandated by federal, state, local and municipal codes and standards. Energy savings are realized through the decreased demand for hot water during faucet use. New York State construction code[233] dictate a maximum flowrate of 1.5 gpm for lavatory faucets and 2.2 gpm elsewhere. This is a retrofit direct install measure or a new installation in a residential application.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings (Electric Water Heating Only)

$$\Delta kWh = units \times H_2O_{savings} \times \Delta T_{main} \times \frac{8.33}{3{,}412} \times \frac{1}{UEF}$$

Summer Peak Coincident Demand Savings (Electric Water Heating Only)

$$\Delta kW = Negligible$$

Annual Fossil Fuel Energy Savings (Fossil Fuel Water Heating Only)

$$\Delta MMBtu = units \times H_2O_{savings} \times \Delta T_{main} \times \frac{8.33}{1{,}000{,}000} \times \frac{1}{UEF}$$

Note: to estimate the annual gallons of water saved from installation of measure:

$$H_2O_{savings} = \left(GPM_{baseline} \times Throttle_{fac,baseline} - GPM_{ee} \times Throttle_{fac,ee}\right) \times \frac{1}{\mathrm{F}_{faucet}} \times \frac{minutes}{person/day} \times \frac{person}{household} \times 365$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
$H_2O_{savings}$	= Water savings (gallons/day)
ΔT_{main}	= Average temperature difference between faucet operating temperature and the supply water temperature in water main (°F)
UEF	= Uniform Energy Factor
baseline	= Characteristic of baseline condition
ee	= Characteristic of energy efficient condition

[233] 2020 NYS Plumbing Code, Table 604.4

GPM = Gallon per minute
$Throttle_{fac}$ = Throttle factor
F_{faucet} = Faucets per household factor
8.33 = Energy required (BTU), to heat one gallon of water by one degree Fahrenheit
365 = Days in one year
3,412 = Conversion factor, one kW equals 3,412 BTU/h
1,000,000 = Conversion factor, one MMBtu equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
$GPM_{baseline}$	Non-lavatory: 2.2 Lavatory: 1.5	GPM for baseline measure, based on faucet type[234]
$Throttle_{fac,baseline}$	0.83	American Council for an Energy-Efficient Economy[235]
GPM_{ee}	Non-lavatory: 1.5 Lavatory: 1.0	From application. If unknown, assume minimum flow rates for compliance.
$Throttle_{fac,ee}$	0.95	American Council for an Energy-Efficient Economy[236]
F_{faucet}	Non-lavatory: 1 Lavatory: 1.6	Factor reflecting the number of faucets in an average New York household[237]
minutes/ person/day	Non-lavatory: 4.5 Lavatory: 1.6	Metered water consumption based on faucet type[238]
person/ household	Single family: 2.8 Multi-family: 2.0	Persons per household, based on housing type[239,240]
$H_2O_{savings}$	Non-lavatory, SF: 1,844 Non-lavatory, MF: 1,317 Lavatory, SF: 301 Lavatory, MF: 215	Calculated gallons of water saved per year based on default values of installation of energy efficient measure, from application
ΔT_{main}	$T_{faucet} - T_{main}$	Average temperature difference between faucet operating temperature and the supply water temperature in water main (°F).

[234] 2020 NYS Plumbing Code, Table 604.4
[235] Energy Related Water Fixture Measurements: Securing the Baseline for Northwest Single Family Homes, American Council for an Energy-Efficient Economy, August 2008, pg. 1-265
[236] Ibid
[237] American Housing Survey Table Creator, United States Census Bureau, Housing Unit Characteristics, New York 2017. The lavatory faucet factor was calculated by taking the average number of complete or half bathrooms per household.
[238] Michigan Evaluation Working Group Showerhead and Faucet Aerator Meter Study. June 2013, via 2014 Demand-Side Management Evaluation Final Report, Cadmus, June 30, 2015, Table 93
[239] Residential Statewide Baseline Study of New York State, July 2015. Volume 1: Single-Family Report, Table 9
[240] Residential Statewide Baseline Study of New York State, July 2015. Volume 2: Multifamily Report, Table 8

Variable	Value	Notes
T_{faucet}	Non-Lavatory: 93 Lavatory: 86 Unknown: 88	Faucet operating temperature (°F)[241]. Unknown is derived from the calculated weighted average based on statewide average assumptions: ((1*93)+(3*86))/(1+3)= 88
T_{main}		Supply water temperature in water main (°F). Lookup in Cold Water Inlet Temperature table below based on nearest city.
UEF	See UEF Table Below	Uniform Energy Factor based on product class, size, input rating and draw pattern (if unknown, assume medium draw pattern)[242]

Cold Water Inlet Temperature (T_{main})

Supply water main temperatures vary according to climate, and are approximately equal to the annual average outdoor temperature plus 6°F.[243] Supply main temperatures based on the annual outdoor temperature are shown below.

City	Annual average outdoor temperature[244] (°F)	T_{main} (°F)
Albany	48.3	54.3
Binghamton	46.3	52.3
Buffalo	48.3	54.3
Massena	43.5	49.5
NYC	55.4	61.4
Poughkeepsie	49.8	55.8
Syracuse	48.3	54.3

Coincidence Factor (CF)

The prescribed value for the coincidence factor is N/A.

Baseline Efficiencies from which Energy Savings are Calculated

The Summary of Variables and Data Sources provides the baseline (standard) and low flow aerator water flows, related input assumptions, and the resulting water savings. Assumptions regarding average duration of use and number of uses per day are also presented. Uniform Energy Factor is determined for the assumed water heater system configurations cited per the table below (from Code of Federal Regulations 10 CFR 430.32(d)).

UEF shall be calculated as a function of existing equipment tank volume (V_t) with the appropriate

[241] Michigan Evaluation Working Group Showerhead and Faucet Aerator Meter Study. June 2013, via 2014 Demand-Side Management Evaluation Final Report, Cadmus, June 30, 2015, Table 93

[242] 10 CFR 430.32(d); medium draw pattern default assumption based on review of typical usage bins for AHRI certified residential water heating equipment (https://www.ahridirectory.org/ahridirectory/pages/home.aspx)

[243] Burch, Jay and Christensen, Craig, "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory

[244] Average annual outdoor temperatures taken from NCEI 1981-2010 climate normals

equation, looked up based on existing equipment type, capacity and draw pattern. Draw pattern can be established based on the existing equipment First Hour Rating (FHR), rated in gallons; see the First Hour Rating vs. Draw Pattern table below.

If FHR is unknown, a Medium draw pattern should be assumed for storage type water heaters with rated storage capacity ≤ 50 gallons and a High draw pattern should be assumed otherwise.[245] If the type of existing water heater cannot be identified due to program delivery mechanism, assume 40-gallon rated storage volume, medium draw storage type system with primary water heater fuel from application.

Residential Water Heaters

Product Class	Rated Storage Volume and Input Rating	Draw Pattern	$UEF_{baseline}$
Gas-Fired Storage Water Heater	≥ 20 gal and ≤ 55 gal	Very Small	$0.3456 - (0.0020 \times V_r^*)$
		Low	$0.5982 - (0.0019 \times V_r)$
		Medium	$0.6483 - (0.0017 \times V_r)$
		High	$0.6920 - (0.0013 \times V_r)$
	> 55 gal and ≤ 100 gal	Very Small	$0.6470 - (0.0006 \times V_r)$
		Low	$0.7689 - (0.0005 \times V_r)$
		Medium	$0.7897 - (0.0004 \times V_r)$
		High	$0.8072 - (0.0003 \times V_r)$
Oil-Fired Storage Water Heater	≤50 gal	Very Small	$0.2509 - (0.0012 \times V_r)$
		Low	$0.5330 – (0.0016 \times V_r)$
		Medium	$0.6078 – (0.0016 \times V_r)$
		High	$0.6815 - (0.0014 \times V_r)$
Electric Storage Water Heater	≥ 20 gal and ≤ 55 gal	Very Small	$0.8808 - (0.0008 \times V_r)$
		Low	$0.9254 - (0.0003 \times V_r)$
		Medium	$0.9307 - (0.0002 \times V_r)$
		High	$0.9349 - (0.0001 \times V_r)$
	> 55 gal and ≤ 120 gal	Very Small	$1.9236 - (0.0011 \times V_r)$
		Low	$2.0440 - (0.0011 \times V_r)$
		Medium	$2.1171 - (0.0011 \times V_r)$
		High	$2.2418 - (0.0011 \times V_r)$
Instantaneous Gas-Fired Water Heater	< 2 gal and > 50,000 BTU/h	Very Small	0.80
		Low	0.81
		Medium	0.81
		High	0.81

[245] Based on review of typical usage bins for AHRI certified residential water heating equipment (https://www.ahridirectory.org/ahridirectory/pages/home.aspx)

Product Class	Rated Storage Volume and Input Rating	Draw Pattern	$UEF_{baseline}$
Instantaneous Electric Water Heater	< 2 gal	Very Small	0.91
		Low	0.91
		Medium	0.91
		High	0.92

*V_t = Rated Storage Volume (gal)

First Hour Rating vs. Draw Pattern[246]

First Hour Rating	Draw Pattern
< 18 gallons	Very Small
≥ 18 and < 51 gallons	Low
≥ 51 and < 75 gallons	Medium
≥ 75 gallons	High

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a lavatory faucet aerator with a flowrate of 1.0 GPM or less or a non-lavatory faucet aerator with a flowrate of 1.5 GPM or less.

Operating Hours

Non-lavatory faucet aerators are assumed to be in use 4.5 minutes per day per person and lavatory faucets are assumed to be in use 1.6 minutes per day per person. All faucet aerators are assumed to be available 365 days per year.

Example Calculation *(Not to be used as default)*

Two 0.5 GPM low-flow faucet aerators are installed on lavatory sinks in a single-family home located near Albany. The residence's gas-fired storage tank water heater has 40 gallon capacity and first hour recovery rating of 68 GPH. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are not applicable. Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta MMBtu = units \times H_2O_{savings} \times \Delta T_{main} \times \frac{8.33}{1{,}000{,}000} \times \frac{1}{UEF}$$

$$H_2O_{savings} = \left(GPM_{baseline} \times Throttle_{fac,baseline} - GPM_{ee} \times Throttle_{fac,ee}\right) \times \frac{1}{\mathrm{F}_{faucet}} \times \frac{minutes}{person/day} \times \frac{person}{household} \times 365$$

units = 2, from application
$GPM_{baseline}$ = 1.5, from Summary of Variables and Data Sources table

[246] 10 CFR 429.17

$Throttle_{fac,baseline}$ = 0.85, from Summary of Variables and Data Sources table
GPM_{ee} = 0.5, from application
$Throttle_{fac,ee}$ = 0.95, , from Summary of Variables and Data Sources table
$F_{facucet}$ = 1.6, from Summary of Variables and Data Sources table based on sink location
Minutes/person/day = 1.6, from Summary of Variables and Data Sources table based on sink location
Person/household = 2.8, from Summary of Variables and Data Sources table based on application
$\Delta T_{main} = T_{faucet} - T_{main} = 86 - 54.3 = 31.7$
T_{faucet} from Summary of Variables and Data Sources table based on sink location
T_{main} from Cold Water Inlet Temperature lookup table based on location from application
UEF = 0.6483 – (0.0017 x v_r) = 0.6483 – (0.0017 x 40) = 0.5803
$UEF_{baseline}$ equation from Residential Water Heaters table based on product class and draw pattern from application
v_r from application

$$H_2O_{savings} = (1.5 \times 0.85 - 0.5 \times 0.95) \times \frac{1}{1.6} \times 1.6 \times 2.8 \times 365 = 817.6$$

$$\Delta MMBtu = 2 \times 817.6 \times 31.7 \times \frac{8.33}{1{,}000{,}000} \times \frac{1}{0.5803} = 0.744\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. NYS Plumbing Code, 2020; Table 604.4: Maximum Flow Rates and Consumption for Plumbing Fixtures and Fixture Fittings
   Available From: https://codes.iccsafe.org/content/NYSPC2020P1/chapter-6-water-supply-and-distribution
2. Energy-related Water Fixture Measurements: Securing the Baseline for Northwest Single Family Homes, American Council for an Energy-Efficient Economy, August 2008
   Available from: http://www.seattle.gov/light/conserve/reports/paper_10.pdf

3. Michigan Evaluation Working Group Showerhead and Faucet Aerator Meter Study. June 2013, via 2014 Demand-Side Management Evaluation Final Report, Cadmus, June 30, 2015
   Available from: http://www.oracle.com/us/industries/utilities/cadmus-indianapolis-power-light-3697534.pdf%20
4. United States Census Bureau, American Housing Survey – Table Creator, New York, 2017, Housing Unit Characteristics
   Available from: https://www.census.gov/programs-surveys/ahs/data/interactive/ahstablecreator.html#?s_areas=a00036&s_year=s2017&s_tableName=Table0&s_byGroup1=a1&s_byGroup2=a1&s_filterGroup1=t1&s_filterGroup2=g1&s_show=S
5. Residential Statewide Baseline Study of New York State, July 2015.
   Available From:
   https://www.nyserda.ny.gov/About/Publications/Building%20Stock%20and%20Potential%20Studies/Residential%20Statewide%20Baseline%20Study%20of%20New%20York%20State
6. 10 CFR 430.32 Energy and water conservation standards and their compliance dates.
   Available from: http://www.ecfr.gov/cgi-bin/text-idx?SID=a9921a66f2b4f66a32ec851916b7b9d9&mc=true&node=se10.3.430_132&rgn=div8
7. 10 CFR 429.17 Water heaters.
   Available from: : https://www.ecfr.gov/cgi-bin/text-idx?rgn=div5&node=10:3.0.1.4.17#se10.3.429_117
8. NOAA National Centers for Environmental Information – NCEI 1981-2010 Climate Normals
   Available from: https://www.ncdc.noaa.gov/cdo-web/datatools/normals
9. Water mains temperatures estimated from annual average temperature taken from: Burch, Jay and Craig Christensen; "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory.
   Available from:
   http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.515.6885&rep=rep1&type=pdf
10. AHRI Directory of Certified Product Performance
    Available from: https://www.ahridirectory.org/ahridirectory/pages/home.aspx

Record of Revision

Record of Revision Number	Issue Date
1	10/15/2010
6-13-5	6/30/2013
7-13-7	7/31/2013
6-17-2	6/30/2017
3-19-5	3/29/2019
6-19-5	6/28/2019

Return to Table of Contents

LOW-FLOW - SHOWERHEAD

Measure Description

This measure covers the installation of low-flow showerheads. A low-flow showerhead is a water saving showerhead with rated gallons per minute (gpm) less than maximum allowable flowrate as mandated by federal, state, local and municipal codes and standards. Energy savings are realized through the decreased demand for hot water during shower use. New York State plumbing code[247] prescribes a maximum flowrate of 2.0 gpm for showerheads. This is a retrofit direct install measure or a new installation in a residential application.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings (Electric Water Heating Only)

$$\Delta kWh = units \times H_2O_{savings} \times (T_{shower} - T_{main}) \times \frac{8.33}{3{,}412} \times \frac{1}{UEF}$$

Summer Peak Coincident Demand Savings (Electric Water Heating Only)

$$\Delta kW = Negligible$$

Annual Fossil Fuel Energy Savings (Fossil Fuel Water Heating Only)

$$\Delta MMBtu = units \times H_2O_{savings} \times (T_{shower} - T_{main}) \times \frac{8.33}{1{,}000{,}000} \times \frac{1}{UEF}$$

Note: to estimate the annual gallons of water saved from installation of measure:

$$H_2O_{savings} = (GPM_{baseline} - GPM_{ee}) \times Throttle_{fac} \times \frac{1}{\mathrm{F}_{shower}} \times \frac{minutes}{use} \times \frac{uses}{person/day} \times \frac{person}{household} \times 365$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
$H_2O_{savings}$	= Water savings
baseline	= Characteristic of baseline condition
ee	= Characteristic of energy efficient condition
GPM	= Gallon per minute
$Throttle_{fac}$	= Throttle factor
F_{shower}	= Shower Factor

[247] 2020 NYS Plumbing Code, Table 604.4

T_{shower} = Temperature (°F) at showerhead
T_{main} = Temperature (°F) of supply water from main
UEF = Uniform Energy Factor
8.33 = Energy required (BTU), to heat one gallon of water by one degree Fahrenheit
365 = Days in one year
3,412 = Conversion factor, one kW equals 3,412 BTU/h
1,000,000 = Conversion factor, one MMBtu equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
GPM_{ee}		Gallons per minute for energy efficient measure, from application
$GPM_{baseline}$		For LMI projects, flowrate shall come from application or default to 2.5 GPM.[248] Otherwise, use 2.0 GPM.[249]
$Throttle_{fac}$	0.9	Used in LBNL study to adjust for average percent of full capacity that the shower valve is opened when in use[250]
F_{shower}	1.4	Factor capturing average number of showers per household[251]
minutes/use	8.2	Average shower duration per LBNL study.[252]
uses/person/day	0.75	LBNL showers per day per capita.[253]
person/ household		Persons per household, from application. If unknown, use 2.8 for Single Family[254] and 2.0 for Multifamily[255]. If housing type is unknown, use 2.4.[256]
T_{main}		Supply water temperature in water main (°F). Lookup in Cold Water Inlet Temperature table below based on nearest city.
T_{shower}	104	Average temperature at showerhead[257]
UEF	See UEF Table Below	Uniform Energy Factor based on product class, size, input rating and draw pattern (if unknown, assume medium draw pattern)[258]

[248] The Energy Policy Act (EPAct) of 1992 (https://afdc.energy.gov/files/pdfs/2527.pdf)
[249] 2020 NYS Plumbing Code, Table 604.4
[250] LBNL: Potential Water and Energy Savings from Showerheads, March 2006
[251] United States Census Bureau, American Housing Survey – Table Creator, New York, 2017, Housing Unit Characteristics. The shower factor was calculated by taking the average number of complete bathrooms per household. Granularity at the single vs. multifamily level was not available.
[252] LBNL: Potential Water and Energy Savings from Showerheads, March 2006
[253] Ibid.
[254] Residential Statewide Baseline Study of New York State, July 2015. Volume 1: Single-Family Report, Table 9
[255] Residential Statewide Baseline Study of New York State, July 2015. Volume 2: Multifamily Report, Table 8
[256] Unweighted average between single- and multifamily buildings
[257] Pilot Study for a Thermostatic Shower Restriction Valve, Cadmus, 2014
[258] 10 CFR 430.32(d); medium draw pattern default assumption based on review of typical usage bins for AHRI certified residential water heating equipment (https://www.ahridirectory.org/ahridirectory/pages/home.aspx)

Cold Water Inlet Temperature (T_{main})

Supply water main temperatures vary according to climate, and are approximately equal to the annual average outdoor temperature plus 6°F.[259] Supply main temperatures based on the annual outdoor temperature are shown below.

City	Annual average outdoor temperature[260] (°F)	T_{main} (°F)
Albany	48.3	54.3
Binghamton	46.3	52.3
Buffalo	48.3	54.3
Massena	43.5	49.5
NYC	55.4	61.4
Poughkeepsie	49.8	55.8
Syracuse	48.3	54.3

Coincidence Factor (CF)

The prescribed value for the coincidence factor is N/A.

Baseline Efficiencies from which Energy Savings are Calculated

The Summary of Variables and Data Sources provides the baseline (standard) water flow and related input assumptions. Assumptions regarding average duration of use and number of uses per day are also presented. Uniform Energy Factor (UEF) is determined for the assumed water heater system configurations cited per the table below (from Code of Federal Regulations 10 CFR 430.32(d)).

UEF shall be calculated as a function of existing equipment tank volume (V_t) with the appropriate equation, looked up based on existing equipment type, capacity and draw pattern. Draw pattern can be established based on the existing equipment First Hour Rating (FHR), rated in gallons; see the First Hour Rating vs. Draw Pattern table below.

If FHR is unknown, a Medium draw pattern should be assumed for storage type water heaters with rated storage capacity ≤ 50 gallons and a High draw pattern should be assumed otherwise.[261] If the type of existing water heater cannot be identified due to program delivery mechanism, assume a 40-gallon rated storage volume, Medium draw storage type system with primary water heater fuel from application.

[259] Burch, Jay and Christensen, Craig, "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory

[260] Average annual outdoor temperatures taken from NCEI 1981-2010 climate normals

[261] Based on review of typical usage bins for AHRI certified residential water heating equipment (https://www.ahridirectory.org/ahridirectory/pages/home.aspx)

Residential Water Heaters

Product Class	Rated Storage Volume and Input Rating	Draw Pattern	$UEF_{baseline}$
Gas-Fired Storage Water Heater	≥ 20 gal and ≤ 55 gal	Very Small	0.3456 - (0.0020 x V_r^*)
		Low	0.5982 - (0.0019 x V_r)
		Medium	0.6483 - (0.0017 x V_r)
		High	0.6920 - (0.0013 x V_r)
	> 55 gal and ≤ 100 gal	Very Small	0.6470 - (0.0006 x V_r)
		Low	0.7689 - (0.0005 x V_r)
		Medium	0.7897 - (0.0004 x V_r)
		High	0.8072 - (0.0003 x V_r)
Oil-Fired Storage Water Heater	≤50 gal	Very Small	0.2509 - (0.0012 x V_r)
		Low	0.5330 – (0.0016 x V_r)
		Medium	0.6078 – (0.0016 x V_r)
		High	0.6815 - (0.0014 x V_r)
Electric Storage Water Heater	≥ 20 gal and ≤ 55 gal	Very Small	0.8808 - (0.0008 x V_r)
		Low	0.9254 - (0.0003 x V_r)
		Medium	0.9307 - (0.0002 x V_r)
		High	0.9349 - (0.0001 x V_r)
	> 55 gal and ≤ 120 gal	Very Small	1.9236 - (0.0011 x V_r)
		Low	2.0440 - (0.0011 x V_r)
		Medium	2.1171 - (0.0011 x V_r)
		High	2.2418 - (0.0011 x V_r)
Instantaneous Gas-Fired Water Heater	< 2 gal and > 50,000 BTU/h	Very Small	0.80
		Low	0.81
		Medium	0.81
		High	0.81
Instantaneous Electric Water Heater	< 2 gal	Very Small	0.91
		Low	0.91
		Medium	0.91
		High	0.92

*V_t = Rated Storage Volume (gal)

First Hour Rating vs. Draw Pattern[262]

First Hour Rating	Draw Pattern
< 18 gallons	Very Small
≥ 18 and < 51 gallons	Low
≥ 51 and < 75 gallons	Medium
≥ 75 gallons	High

[262] 10 CFR 429.17

Compliance Efficiency from which Incentives are Calculated

Compliance flow rate is less than the specified baseline value (<2.0 gpm) or less than the more restrictive codes or guidelines of local governments, municipalities or entities which, for example, participate in the US EPA Water Sense® Partnership Program. [263]

Operating Hours

Estimate of energy savings assumes an average duration of 8 minutes, 12 seconds per shower event, 0.75 showers per person per day, and 2.8 persons per single family home and 2.0 persons per multifamily home.

Example Calculation *(Not to be used as default)*

Two 1.0 GPM low-flow showerheads are installed in a single-family home located near Albany. The residence's gas-fired storage tank water heater has 40 gallon capacity and first hour recovery rating of 68 GPH. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are not applicable. Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta MMBtu = units \times H_2O_{savings} \times (T_{shower} - T_{main}) \times \frac{8.33}{1{,}000{,}000} \times \frac{1}{UEF}$$

$$H_2O_{savings} = (GPM_{baseline} - GPM_{ee}) \times Throttle_{fac} \times \frac{1}{F_{shower}} \times \frac{minutes}{use} \times \frac{uses}{person/day} \times \frac{person}{household} \times 365$$

units = 2, from application
$GPM_{baseline}$ = 2.0, from Summary of Variables and Data Sources table
GPM_{ee} = 1.0, from application
$Throttle_{fac}$ = 0.9, from Summary of Variables and Data Sources table
F_{shower} = 1.4, from Summary of Variables and Data Sources table
Minutes/use = 8.2, from Summary of Variables and Data Sources table
Uses/person/day = 0.75, from Summary of Variables and Data Sources table
Person/household = 2.8, from Summary of Variables and Data Sources table based on application
T_{shower} = 104, from Summary of Variables and Data Sources table
T_{main} = 54.3, from Cold Water Inlet Temperature lookup table based on location from application
UEF = 0.6483 – (0.0017 x v_r) = 0.6483 – (0.0017 x 40) = 0.5803
$UEF_{baseline}$ equation from Residential Water Heaters table based on product class and draw pattern from application

[263] Find Water Sense Partners at the Environmental Protection Agency website: https://www.epa.gov/watersense/partners-directory

v_r from application

$$H_2O_{savings} = (2.0 - 1.0) \times 0.9 \times \frac{1}{1.4} \times 8.2 \times 0.75 \times 2.8 \times 365 = 4{,}040$$

$$\Delta MMBtu = 2 \times 4{,}040 \times (104 - 54.3) \times \frac{8.33}{1{,}000{,}000} \times \frac{1}{0.5803} = 5.77\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. NYS Plumbing Code, 2020; Table 604.4: Maximum Flow Rates and Consumption for Plumbing Fixtures and Fixture Fittings
   Available from: https://codes.iccsafe.org/content/NYSPC2020P1/chapter-6-water-supply-and-distribution
2. Lawrence Berkeley National Laboratory (LBNL): "Potential Water and Energy Savings from Showerheads", March 2006
   Available from: http://www.map-testing.com/assets/files/Biermayer,%20P.%20(2006)%20Potential%20Water%20and%20Energy%20Savings%20from%20Showerheads.pdf
3. United States Census Bureau, American Housing Survey – Table Creator, New York, 2017, Housing Unit Characteristics
   Available from: https://www.census.gov/programs-surveys/ahs/data/interactive/ahstablecreator.html#?s_areas=a00036&s_year=s2017&s_tableName=Table0&s_byGroup1=a1&s_byGroup2=a1&s_filterGroup1=t1&s_filterGroup2=g1&s_show=S
4. Residential Statewide Baseline Study of New York State, July 2015.
   Available From:
   https://www.nyserda.ny.gov/About/Publications/Building%20Stock%20and%20Potential%20Studies/Residential%20Statewide%20Baseline%20Study%20of%20New%20York%20State

5. 10 CFR 430.32 Energy and water conservation standards and their compliance dates. Available from: http://www.ecfr.gov/cgi-bin/text-idx?SID=a9921a66f2b4f66a32ec851916b7b9d9&mc=true&node=se10.3.430_132&rgn=div8
6. NOAA National Centers for Environmental Information – NCEI 1981-2010 Climate Normals
Available from: https://www.ncdc.noaa.gov/cdo-web/datatools/normals
7. Water mains temperatures estimated from annual average temperature taken from: Burch, Jay and Craig Christensen; "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory.
Available from: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.515.6885&rep=rep1&type=pdf
8. EPA WaterSense® Partnership Program
Available from: https://www.epa.gov/watersense/partners-directory
9. The Energy Policy Act (EPAct) of 1992
Available from: https://afdc.energy.gov/files/pdfs/2527.pdf

Record of Revision

Record of Revision Number	Issue Date
0	10/15/2010
6-13-4	6/30/2013
6-15-1	6/15/2015
6-17-4	6/30/2017
3-19-7	3/29/2019
6-19-6	6/28/2019
7-21-22	8/30/2021

Return to Table of Contents

THERMOSTATIC SHOWER RESTRICTION VALVE

Measure Description

This measure covers the installation of thermostatic shower restriction valves, which are valves attached to a showerhead supply for reduction of domestic hot water flow and associated energy usage. The device restricts hot water flow through the showerhead by activating the trickle or stop flow mode when water reaches a predetermined set temperature, as designed by the manufacturer. Although this device activates trickle/stop flow at a set temperature, it does not restrict flow when the valve is manually opened, and therefore should not be considered a safety measure to prevent scalding.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings (Electric Water Heating Only)

$$\Delta kWh = units \times (\Delta kWh/\text{unit})$$

Summer Peak Coincident Demand Savings (Electric Water Heating Only)

$$\Delta kW = Negligible$$

Annual Fossil Fuel Energy Savings (Fossil Fuel Water Heating Only)

$$\Delta MMBtu = units \times (\Delta MMBtu/\text{unit})$$

where:

ΔkWh = Annual electric energy savings
ΔkW = Peak coincident demand electric savings
ΔMMBtu = Annual fossil fuel energy savings
units = Number of measures installed under the program
(ΔkWh/unit) = Annual electric energy savings per unit
(ΔMMBtu/unit)= Annual fossil fuel energy savings per unit

Summary of Variables and Data Sources

Variable	Value	Notes
(ΔkWh/unit)	As defined in kWh Savings table below	Deemed annual electric energy savings for electric resistance storage tank water heater. Look up based on location and water usage rate (table below).
(ΔMMBtu/unit)	As defined in MMBtu Savings table below	Deemed annual fossil fuel energy savings for fossil fuel-fired storage tank water heater. Look up based on location and water usage rate (table below).

kWh Savings (ΔkWh/unit) – *Single Family*

Location	Flow Rate (GPM)				
	1	**1.25**	**1.5**	**1.75**	**2**
Albany	64	80	96	112	128
Binghamton	66	83	100	116	133
Buffalo	64	80	96	112	128
Massena	70	88	105	123	140
NYC	55	68	82	96	110
Poughkeepsie	62	77	93	108	124
Syracuse	64	80	96	112	128

kWh Savings (ΔkWh/unit) – *Multifamily*

Location	Flow Rate (GPM)				
	1	**1.25**	**1.5**	**1.75**	**2**
Albany	46	57	68	80	91
Binghamton	47	59	71	83	95
Buffalo	46	57	68	80	91
Massena	50	63	75	88	100
NYC	39	49	59	68	78
Poughkeepsie	44	55	66	77	89
Syracuse	46	57	68	80	91

The values in the kWh Savings table were calculated as follows, using the assumed values listed in the Summary of Variables and Data Sources table above:

$$(\Delta\text{kWh/unit}) = GPM \times Throttle_{fac} \times Waste\ Time \times \frac{1}{F_{shower}} \times \frac{Showers}{person/day} \times \frac{person}{household} \times 365\frac{days}{year} \times (T_{shower} - T_{main}) \times \frac{8.33}{3{,}412} \times \frac{1}{UEF_{elec}}$$

MMBtu Savings (ΔMMBtu/unit) – *Single Family*

Location	Flow Rate (GPM)				
	1	**1.25**	**1.5**	**1.75**	**2**
Albany	0.35	0.43	0.52	0.61	0.69
Binghamton	0.36	0.45	0.54	0.63	0.72
Buffalo	0.35	0.43	0.52	0.61	0.69
Massena	0.38	0.47	0.57	0.66	0.76
NYC	0.30	0.37	0.44	0.52	0.59
Poughkeepsie	0.34	0.42	0.50	0.59	0.67
Syracuse	0.35	0.43	0.52	0.61	0.69

MMBtu Savings (ΔMMBtu/unit) – *Multifamily*

Location	Flow Rate (GPM)				
	1	**1.25**	**1.5**	**1.75**	**2**
Albany	0.25	0.31	0.37	0.43	0.49

Location	Flow Rate (GPM)				
	1	1.25	1.5	1.75	2
Binghamton	0.26	0.32	0.39	0.45	0.51
Buffalo	0.25	0.31	0.37	0.43	0.49
Massena	0.27	0.34	0.41	0.47	0.54
NYC	0.21	0.26	0.32	0.37	0.42
Poughkeepsie	0.24	0.30	0.36	0.42	0.48
Syracuse	0.25	0.31	0.37	0.43	0.49

The values in the MMBtu Savings table were calculated as follows, using the assumed values listed in the Summary of Variables and Data Sources table above:

$$(\Delta\text{MMBtu/unit}) = GPM \times Throttle_{fac} \times Waste\ Time \times \frac{1}{F_{shower}} \times \frac{Showers}{person/day} \times \frac{person}{household} \times 365\frac{days}{year} \times (T_{shower} - T_{main}) \times \frac{8.33}{1{,}000{,}000} \times \frac{1}{UEF_{fuel}}$$

where:

GPM = Gallon per minute
$Throttle_{fac}$ = Throttle factor
Waste Time = Time water runs before shower begins
F_{shower} = Shower Factor
T_{shower} = Temperature (°F) at showerhead
T_{main} = Temperature (°F) of supply water from main
UEF = Uniform Energy Factor
8.33 = Energy required (BTU), to heat one gallon of water by one degree Fahrenheit
3,412 = Conversion factor, one kW equals 3,412 BTU/h
1,000,000 = Conversion factor, one MMBtu equals 1,000,000 BTU

Summary of Per Unit Savings Variables and Data Sources

Variable	Value	Notes
GPM		Gallons per minute for energy efficient measure, from application
$Throttle_{fac}$	0.9	Used in LBNL study to adjust for average percent of full capacity that the shower valve is opened when in use.[264]
Waste Time	0.98	Average value calculated from total water waste duration of 581 shower events (59 secs.)[265]

[264] LBNL: Potential Water and Energy Savings from Showerheads, March 2006
[265] Pilot Study for a Thermostatic Shower Restriction Valve, Cadmus, 2014

Variable	Value	Notes
F_{shower}	1.4	Factor capturing average number of showers per household[266]
Showers/ person/day	0.75	LBNL study, showers per day per capita[267]
Person/ household	Single Family: 2.8 Multifamily: 2.0	Persons per household [268,269]
T_{main}		Average inlet water temperature (°F) by location is shown below.
T_{shower}	104	Average temperature at showerhead[270]
UEF_{elec}	0.92	Uniform Energy Factor based on product class, size, input rating and draw pattern. Assumes electric storage water heater with 40-gal capacity at medium draw. [271] See Residential Water Heaters table below for calculating UEF for specific system types.
UEF_{fuel}	0.58	Uniform Energy Factor based on product class, size, input rating and draw pattern. Assumes natural gas storage water heater with 40-gal capacity at medium draw.[272] See Residential Water Heaters table below for calculating UEF for specific system types.

Cold Water Inlet Temperature (T_{main})

Supply water main temperatures vary according to climate, and are approximately equal to the annual average outdoor temperature plus 6°F.[273] Supply main temperatures based on the annual outdoor temperature are shown below.

City	Annual average outdoor temperature[274] (°F)	T_{main} (°F)
Albany	48.3	54.3
Binghamton	46.3	52.3

[266] United States Census Bureau, American Housing Survey – Table Creator, New York, 2017, Housing Unit Characteristics, All Housing Units. The shower factor reflects the average number of showers per household and was calculated by taking the average number of complete bathrooms per household, as follows: {[(number of homes with 1 bathroom)+(number of homes with 1.5 bathroom)]*1+[(number of homes with 2 bathrooms)+(number of homes with 2.5 bathrooms)]*2…etc} / (total number of homes). Per US Census data, average number of showers per home = {[4594+1199]*1+[1352+636.7]*2+[419.9]*3+[91.7]*4}/8293.3 = 1.37. Granularity at the single vs. multifamily level was not available.

[267] LBNL: Potential Water and Energy Savings from Showerheads, March 2006

[268] Residential Statewide Baseline Study of New York State, July 2015. Volume 1: Single-Family Report, Table 9

[269] Residential Statewide Baseline Study of New York State, July 2015. Volume 2: Multifamily Report, Table 8

[270] Pilot Study for a Thermostatic Shower Restriction Valve, Cadmus, 2014

[271] 10 CFR 430.32(d); medium draw pattern default assumption based on review of typical usage bins for AHRI certified residential water heating equipment (https://www.ahridirectory.org/ahridirectory/pages/home.aspx)

[272] Ibid.

[273] Burch, Jay and Christensen, Craig, "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory

[274] Average annual outdoor temperatures taken from NCEI 1981-2010 climate normals

City	Annual average outdoor temperature[274] (°F)	T_{main} (°F)
Buffalo	48.3	54.3
Massena	43.5	49.5
NYC	55.4	61.4
Poughkeepsie	49.8	55.8
Syracuse	48.3	54.3

Coincidence Factor (CF)

The prescribed value for the coincidence factor is N/A.

Baseline Efficiencies from which Energy Savings are Calculated

If known and in compliance with applicable code, the actual flowrate of the showerhead should be used for determination of per unit energy savings from the tables above. Otherwise, a baseline of 2.0 gallons per minute shall be used for compliance in New York State (per 2020 NYS Residential Code of New York State and 2020 NYS Plumbing Code). Uniform Energy Factor (UEF) is determined for the assumed water heater system configurations cited per the table below (from Code of Federal Regulations 10 CFR 430.32(d)).

UEF shall be calculated as a function of existing equipment tank volume (V_t) with the appropriate equation, looked up based on existing equipment type, capacity and draw pattern. Draw pattern can be established based on the existing equipment First Hour Rating (FHR), rated in gallons; see the First Hour Rating vs. Draw Pattern table below. If FHR is unknown, a Medium draw pattern should be assumed for storage type water heaters with rated storage capacity ≤ 50 gallons and a High draw pattern should be assumed otherwise.[275] If the type of existing water heater cannot be identified due to program delivery mechanism, assume a 40-gallon rated storage volume, medium draw storage type system with primary water heater fuel from application.

Residential Water Heaters

Product Class	Rated Storage Volume and Input Rating	Draw Pattern	Uniform Energy Factor
Gas-Fired Storage Water Heater	≥ 20 gal and ≤ 55 gal	Very Small	$0.3456 - (0.0020 \times V_t^*)$
		Low	$0.5982 - (0.0019 \times V_t)$
		Medium	$0.6483 - (0.0017 \times V_t)$
		High	$0.6920 - (0.0013 \times V_t)$
	> 55 gal and ≤ 100 gal	Very Small	$0.6470 - (0.0006 \times V_t)$
		Low	$0.7689 - (0.0005 \times V_t)$
		Medium	$0.7897 - (0.0004 \times V_t)$
		High	$0.8072 - (0.0003 \times V_t)$

[275] Based on review of typical usage bins for AHRI certified residential water heating equipment (https://www.ahridirectory.org/ahridirectory/pages/home.aspx)

Product Class	Rated Storage Volume and Input Rating	Draw Pattern	Uniform Energy Factor
Oil-Fired Storage Water Heater	≤50 gal	Very Small	0.2509 - (0.0012 x V_r)
		Low	0.5330 – (0.0016 x V_r)
		Medium	0.6078 – (0.0016 x V_r)
		High	0.6815 - (0.0014 x V_r)
Electric Storage Water Heater	≥ 20 gal and ≤ 55 gal	Very Small	0.8808 - (0.0008 x V_t)
		Low	0.9254 - (0.0003 x V_t)
		Medium	0.9307 - (0.0002 x V_t)
		High	0.9349 - (0.0001 x V_t)
	> 55 gal and ≤ 100 gal [276]	Very Small	1.9236 - (0.0011 x V_t)
		Low	2.0440 - (0.0011 x V_t)
		Medium	2.1171 - (0.0011 x V_t)
		High	2.2418 - (0.0011 x V_t)
Instantaneous Gas-Fired Water Heater	< 2 gal and >50,000 BTU/h	Very Small	0.80
		Low	0.81
		Medium	0.81
		High	0.81
Instantaneous Electric Water Heater	< 2 gal	Very Small	0.91
		Low	0.91
		Medium	0.91
		High	0.92

*V_t = Rated Storage Volume (gal)

First Hour Rating vs. Draw Pattern[277]

First Hour Rating	Draw Pattern
< 18 gallons	Very Small
≥ 18 and < 51 gallons	Low
≥ 51 and < 75 gallons	Medium
≥ 75 gallons	High

Compliance Efficiency from which Incentives are Calculated

The compliance condition requires the installation of a thermostatic restriction valve on a residential shower.

Operating Hours

Estimate of energy savings assumes 2 showers per day with an average of 59 seconds of wasted hot water, reflecting the amount of time the shower is running but not in use.

[276] Electric Storage Water Heaters > 55 gallons and ≤ 100 gallons are heat pump water heaters
[277] 10 CFR 429.17

Example Calculation *(Not to be used as default)*

A thermostatic shower restriction valve is installed in a single-family home located near Albany. The showerhead has a flowrate of 2 GPM and the residence's gas-fired storage tank water heater has 40 gallon capacity and first hour recovery rating of 68 GPH. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are not applicable. Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta MMBtu = units \times (\Delta MMBtu/\text{unit})$$

$$(\Delta MMBtu/\text{unit}) = GPM \times Throttle_{fac} \times WasteTime \times \frac{1}{F_{shower}} \times \frac{showers}{person/day} \times \frac{person}{household} \times 365\frac{days}{year} \times (T_{shower} - T_{main}) \times \frac{8.33}{1{,}000{,}000} \times \frac{1}{UEF_{fuel}}$$

units = 1, from application
GPM = 2, from application
$Throttle_{fac}$ = 0.9, from Summary of Variables and Data Sources table
WasteTime = 0.98, from Summary of Variables and Data Sources table
F_{shower} = 1.4, from Summary of Variables and Data Sources table
Showers/person/day = 0.75, from Summary of Variables and Data Sources table
Person/household = 2.8, from Summary of Variables and Data Sources table based on housing type from application
T_{shower} = 104, from Summary of Variables and Data Sources table
T_{main} = 54.3, from Cold Water Inlet Temperature lookup table based on location from application
UEF_{fuel} = 0.6483 – (0.0017 x v_r) = 0.6483 – (0.0017 x 40) = 0.5803
$UEF_{baseline}$ equation from Residential Water Heaters table based on product class and draw pattern from application
v_r from application

$$(\Delta MMBtu/\text{unit}) = 2 \times 0.9 \times 0.98 \times \frac{1}{1.4} \times 0.75 \times 2.8 \times 365 \times (104 - 54.3) \times \frac{8.33}{1{,}000{,}000} \times \frac{1}{0.5803} = 0.689$$

$$\Delta MMBtu = 1 \times 0.689 = 0.689\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. NYS 2020 Residential Code of New York State, November 2019: Chapter 29 – 2020 NYSRC Table P2903.2 (Maximum Flow Rates and Consumption for Plumbing Fixtures and Fixture Fittings)
   Available from: https://codes.iccsafe.org/content/NYSRC2020P1/chapter-29-water-supply-and-distribution
2. NYS Plumbing Code 2020; Table 604.4: Maximum Flow Rates and Consumption for Plumbing Fixtures and Fixture Fittings
   Available From: https://codes.iccsafe.org/content/NYSPC2020P1/chapter-6-water-supply-and-distribution
3. Lawrence Berkeley National Laboratory (LBNL): "Potential Water and Energy Savings from Showerheads", March 2006
   Available from: http://www.map-testing.com/assets/files/Biermayer,%20P.%20(2006)%20Potential%20Water%20and%20Energy%20Savings%20from%20Showerheads.pdf
4. Lawrence Berkeley National Laboratory (LBNL): "Water and Energy Wasted During Residential Shower Events: Findings from a Pilot Field Study of Hot Water Distribution Systems", September 2011
   Available from: https://efficiency.lbl.gov/sites/all/files/water_and_energy_wasted_during_residential_shower_events_findings_from_a_pilot_field_study_of_hot_water_distribution_systems_lbnl-5115e.pdf
5. United States Census Bureau, American Housing Survey – Table Creator, New York, 2017, Housing Unit Characteristics
   Available from: https://www.census.gov/programs-surveys/ahs/data/interactive/ahstablecreator.html#?s_areas=a00036&s_year=s2017&s_tableName=Table0&s_byGroup1=a1&s_byGroup2=a1&s_filterGroup1=t1&s_filterGroup2=g1&s_show=S
6. Pilot Study for a Thermostatic Shower Restriction Valve, Cadmus, 2014
   Available from: https://www.iepec.org/wp-content/uploads/2015/papers/164.pdf
7. Residential Statewide Baseline Study of New York State, July 2015.
   Available From: https://www.nyserda.ny.gov/About/Publications/Building%20Stock%20and%20Potential%20Studies/Residential%20Statewide%20Baseline%20Study%20of%20New%20York%20State
8. 10 CFR 430.32 Energy and water conservation standards and their compliance dates.
   Available from: http://www.ecfr.gov/cgi-bin/text-

idx?SID=a9921a66f2b4f66a32ec851916b7b9d9&mc=true&node=se10.3.430_132&rgn=div8

9. NOAA National Centers for Environmental Information – NCEI 1981-2010 Climate Normals
   Available from: https://www.ncdc.noaa.gov/cdo-web/datatools/normals
10. Water mains temperatures estimated from annual average temperature taken from: Burch, Jay and Craig Christensen; "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory.
    Available from:
    http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.515.6885&rep=rep1&type=pdf
11. Uniform Plumbing Code (UPC) certification under the International Association of Plumbing and Mechanical Officials standard IGC 244-2007a.
12. 10 CFR 429.17 Water heaters.
    Available from: : https://www.ecfr.gov/cgi-bin/text-idx?rgn=div5&node=10:3.0.1.4.17#se10.3.429_117
13. AHRI Directory of Certified Product Performance
    Available from: https://www.ahridirectory.org/ahridirectory/pages/home.aspx

Record of Revision

Record of Revision Number	Issue Date
6-14-2	6/19/2014
6-17-3	6/30/2017
3-19-6	3/29/2019
6-19-7	6/28/2019

Return to Table of Contents

HEATING, VENTILATION AND AIR CONDITIONING (HVAC)

AIR CONDITIONER - CENTRAL (CAC)

Measure Description

This measure covers the installation of high-efficiency central air conditioners in residential applications. A central air conditioner is a product, other than a packaged terminal air conditioner, which is powered by single phase electric current, air cooled, rated below 65,000 BTU/h, not contained within the same cabinet as a furnace with rated capacity above 225,000 BTU/h, and is a cooling unit only. A central air conditioner may consist of a single-package unit or an outdoor unit and one or more indoor units, including multi-head mini-split systems.[278] The baseline case shall be minimally code compliant equipment of the same type and capacity as in the efficient case, which shall be sized in accordance with federal, state, local and municipal codes and standards.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times tons/unit \times \left(\frac{12}{SEER_{baseline}} - \frac{12}{SEER_{ee}}\right) \times EFLH_{cooling}$$

Summer Peak Coincident Demand Savings

$$\Delta kW = units \times tons/unit \times \left(\frac{12}{EER_{baseline}} - \frac{12}{EER_{ee}}\right) \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
tons/unit	= Tons of air conditioning per unit, based on AHRI certification or nameplate data of condenser or matched pair (condenser and coil)
$_{baseline}$	= Characteristic of baseline condition
$_{ee}$	= Characteristic of energy efficient condition
SEER	= Seasonal average energy efficiency ratio over the cooling season, BTU/watt-hour, (used for average U.S. location/region)
$EFLH_{cooling}$	= Cooling equivalent full-load hours
EER	= Energy efficiency ratio under peak conditions
CF	= Coincidence factor

[278] 10 CFR 430.2

12 = (kBTU/h)/ton of air conditioning capacity

Summary of Variables and Data Sources

Variable	Value	Notes
Tons		From application, default to average system size from applications if unknown
$SEER_{baseline}$		Lookup from Baseline Efficiencies table below based on product class and size.
$SEER_{ee}$		From application
$EFLH_{cooling}$		Lookup based on building type, vintage and location from Appendix G.
$EER_{baseline}$		Lookup from Baseline Efficiencies table below based on product class and size.
EER_{ee}		From application
CF	0.69	

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.69.[279]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a central air conditioner as defined in the Measure Description section above, with rated SEER and EER per the table below. The SEER values listed in the table below reflect the minimum performance required by federal standards. Minimum EER requirements are not specified by federal standards for the state of New York, nor are they mandated by state or city code for residential equipment. For this equipment, baseline EER is established as follows[280]:

$$EER = (1.12 \times SEER) - (0.02 \times SEER^2)$$

Resultant values from application of this equation are tabulated in the baseline efficiencies table below.

Product Class	Seasonal Energy Efficiency Ratio (SEER)[281]	Energy Efficiency Ratio (EER)
Split System – Air Conditioner (<45 kBTU/h)	13.0	11.2
Split System – Air Conditioner (≥45 and <65 kBTU/h)	13.0	11.2

[279] Based on BG&E 'Development of Residential Load Profile for Central Air Conditioners and Heat Pumps' research, the Maryland Peak Definition coincidence factor is 0.69. This study is not publicly available, but is referenced by M. M. Straub, Using Available Information for Efficient Evaluation of Demand-Side Management Programs, Electricity Journal, September 2011 and supported by research conducted by Cadmus on behalf of the TRM Management Committee..

[280] DOE, Building America House Simulation Protocols, October 2010

[281] 10 CFR 430.32 (c)(1)

Product Class	Seasonal Energy Efficiency Ratio (SEER)[281]	Energy Efficiency Ratio (EER)
Single Package – Air Conditioner	14.0	11.8

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a central air conditioner as defined in the Measure Description section above. The efficiency of the compliant equipment must exceed the efficiency of the baseline equipment.

Operating Hours

Cooling EFLH data by location, building type and vintage are tabulated in Appendix G.

Example Calculation *(Not to be used as default)*

A 3-ton high-efficiency central air conditioner rated at 18 SEER is installed in a single family home constructd in 1995 located near Albany. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

$$\Delta kWh = units \times tons/unit \times \left(\frac{12}{SEER_{baseline}} - \frac{12}{SEER_{ee}}\right) \times EFLH_{cooling}$$

$$\Delta kW = units \times tons/unit \times \left(\frac{12}{EER_{baseline}} - \frac{12}{EER_{ee}}\right) \times CF$$

units = 1, from application
tons/unit = 3, from application
$SEER_{baseline}$ = 13.0, from Baseline Efficiencies section based on equipment type and size from application
$SEER_{ee}$ = 18, from application
$EFLH_{cooling}$ = 310, from Appendix G based on housing type, building vintage, and location from application.
$EER_{baseline}$ = 11.2, from Baseline Efficiencies section based on equipment type and size from application
EER_{ee} = 13, from application
CF = 0.69, from Summary of Variables and Data Sources table

$$\Delta kWh = 1 \times 3 \times \left(\frac{12}{13.0} - \frac{12}{18}\right) \times 310 = 238\ kWh$$

$$\Delta kW = 1 \times 3 \times \left(\frac{12}{11.2} - \frac{12}{13}\right) \times 0.69 = 0.307\ kW$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Minor heating interactions are expected with efficient furnace fans utilized in most high efficiency air conditioners. These impacts are expected to be negligible and have not been addressed in the prescribed methodology at this time.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. 10 CFR 430.2 Definitions.
   Available from: https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=5caa706c36f6a4bc5850185c41f2175f&mc=true&n=pt10.3.430&r=PART&ty=HTML#se10.3.430_12
2. BG&E, Development of Residential Load Profile for Central Air Conditioners and Heat Pumps
3. M. M. Straub, Using Available Information for Efficient Evaluation of Demand-Side Management Programs, Electricity Journal, September 2011
   Available from: https://www.sciencedirect.com/science/article/pii/S1040619011001941
4. Building America House Simulation Protocols, Robert Hendron and Cheryn Engebrecht, National Renewable Energy Laboratory, October 2010
   Available from: https://www1.eere.energy.gov/buildings/publications/pdfs/building_america/house_simulation_revised.pdf
5. 10 CFR 430.32 Energy and water conservation standards and their compliance dates.
   Available from: http://www.ecfr.gov/cgi-bin/text-idx?SID=a9921a66f2b4f66a32ec851916b7b9d9&mc=true&node=se10.3.430_132&rgn=div8

Record of Revision

Record of Revision Number	Issue Date
1	10/15/2010
12-17-6	12/31/2017

Return to Table of Contents

AIR CONDITIONER - ROOM (RAC)

Measure Description

This measure covers the installation of high-efficiency room air conditioners in residential applications. A room air conditioner is a consumer product, other than a packaged terminal air conditioner, which is powered by a single phase electric current and is an encased assembly designed as a unit for mounting in a window or through the wall for the purpose of providing delivery of conditioned air to an enclosed space. It includes a prime source of refrigeration and may include a means for ventilation and heating.[282] The baseline case shall be minimally code compliant equipment of the same type and capacity as in the efficient case, which shall be sized in accordance with federal, state, local and municipal codes and standards. This measure is not applicable to central air conditioner systems.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times \frac{(BTU/h)/unit}{1{,}000} \times \left(\frac{1}{CEER_{baseline}} - \frac{1}{CEER_{ee}}\right) \times EFLH_{cooling}$$

Summer Peak Coincident Demand Savings

$$\Delta kW = units \times \frac{(BTU/h)/unit}{1{,}000} \times \left(\frac{1}{CEER_{baseline}} - \frac{1}{CEER_{ee}}\right) \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
(BTU/h)/unit	= British Thermal Units per hour of air conditioning per unit
$_{baseline}$	= Characteristic of baseline condition
$_{ee}$	= Characteristic of energy efficient condition
CEER	= Combined Energy Efficiency Ratio
$EFLH_{cooling}$	= Cooling equivalent full-load hours
CF	= Coincidence factor
1,000	= Conversion factor, one kW equals 1,000 Watts

[282] 10 CFR 430.2

Summary of Variables and Data Sources

Variable	Value	Notes
(BTU/h)/unit		From application
$CEER_{baseline}$		Lookup from Baseline Efficiencies section below based on equipment type and capacity.
$CEER_{ee}$		From application
$EFLH_{cooling}$		Cooling equivalent full-load hours, lookup from Operating Hours section below based on location.
CF	0.3	

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.3.[283] The average Seasonal CF based on 2007 weather data used for this measure aligns with results of a sampling study conducted in Con Edison territory, citing a CF = 0.31.[284]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a room air conditioner as defined in the Measure Description section above with type and capacity equivalent to the efficient case and rated CEER per the table below. The CEER values listed in the table below reflect the minimum performance required by federal standards.[285]

Product Type	Product Class Capacity (BTU/h)	Federal Standard With Louvered Sides (CEER)	Federal Standard Without Louvered Sides (CEER)
RAC without Reverse Cycle	< 6,000	11.0	10.0
	6,000 to 7,999	11.0	10.0
	8,000 to 10,999	10.9	9.6
	11,000 to 13,999	10.9	9.5
	14,000 to 19,999	10.7	9.3
	20,000 to 27,999	9.4	9.4
	≥ 28,000	9.0	9.4
Casement Only	All	9.5	
Casement-Slider	All	10.4	

[283] RLW Analytics, Coincidence Factor Study: Residential Room Air Conditioners, June 2008, p. iv (based on average Seasonal CF for all load zones using 2007 weather data)
[284] Northeast Energy Efficiency Partnerships, Loadshape Report and Catalogue
[285] 10 CFR 430.32(b)

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a room air conditioner as defined in the Measure Description section above meeting ENERGY STAR V4.1 specifications for room air conditioners shown below.[286]

Units Without Reverse Cycle

Capacity (BTU/hour)	$CEER_{BASE}$ (units with louvered sides)	$CEER_{BASE}$ (units without louvered sides)
< 6,000	12.1	11.0
6,000 to 7,999		
8,000 to 10,999	12.0	10.6
11,000 to 13,999		10.5
14,000 to 19,999	11.8	10.2
20,000 to 27,999	10.3	10.3
> 28,000	9.9	

Units With Reverse Cycle

Capacity (BTU/hour)	$CEER_{BASE}$ (units with louvered sides)	$CEER_{BASE}$ (units without louvered sides)
< 14,000		10.2
> 14,000		9.6
< 20,000	10.8	
> 20,000	10.2	

Casement Units

Casement Type	$CEER_{BASE}$
Casement-Only	10.5
Casement-Slider	11.4

Connected Allowance

Product Type	$CEER_{Adder_Connected}$[287]
All RAC types covered in Tables 1, 2 and 3[288]	0.05 x $CEER_{BASE}$

[286] ENERGY STAR® Program Requirements Product Specification for Room Air Conditioners Eligibility Criteria Version 4.2

[287] Calculated allowance shall be rounded down to the nearest tenth before being applied in Equation 1.

[288] Product must be certified using the ENERGY STAR Test Method for Room Air Conditioners to Validate Demand Response (June 2017) to use the allowance

Operating Hours

Cooling equivalent full load hours for residential room air conditioners shall be established based on location per the table below. $EFLH_{cooling}$ values below were determined by calculating the ratio of RAC cooling EFLH in Albany[289] to average cooling EFLH in Albany per Appendix G and applying it to the average EFLH for each city. EFLH was averaged from Appendix G over vintage and building type for each city.

City	$EFLH_{cooling}$
Albany	224
Binghamton	171
Buffalo	219
Massena	187
NYC	364
Poughkeepsie	282
Syracuse	226

Example Calculation *(Not to be used as default)*

Ten 12,000 BTU/h room air conditioners with efficiency of 12 CEER are installed in a multifamily building near Albany. The RACs are without reverse cycles and without louvered sides. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

$$\Delta kWh = units \times \frac{(BTU/h)/unit}{1{,}000} \times \left(\frac{1}{CEER_{baseline}} - \frac{1}{CEER_{ee}}\right) \times EFLH_{cooling}$$

$$\Delta kW = units \times \frac{(BTU/h)/unit}{1{,}000} \times \left(\frac{1}{CEER_{baseline}} - \frac{1}{CEER_{ee}}\right) \times CF$$

units = 10, from application
(BTU/h)/unit = 12,000, from application
$CEER_{baseline}$ = 9.5, from Baseline Efficiencies table based on equipment type and capacity from application
$CEER_{ee}$ = 12, from application
$EFLH_{cooling}$ = 224, from the Operating Hours table based on location from application
CF = 0.69, from Summary of Variables and Data Sources table

$$\Delta kWh = 10 \times \frac{12{,}000}{1{,}000} \times \left(\frac{1}{9.5} - \frac{1}{12}\right) \times 224 = 589.5\ kWh$$

$$\Delta kW = units \times \frac{12{,}000}{1{,}000} \times \left(\frac{1}{9.5} - \frac{1}{12}\right) \times 0.69 = 1.82\ kW$$

[289] RLW Analytics, Coincidence Factor Study: Residential Room Air Conditioners, June 2008, p. iv (based on 2007 FLEH for Albany)

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. 10 CFR 430.2 Definitions.
   Available from: https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=ccdb0d0ac67a5eab52718c408f0739a1&mc=true&n=pt10.3.430&r=PART&ty=HTML#se10.3.430_12
2. RLW Analytics, Coincidence Factor Study: Residential Room Air Conditioners, June 2008
   Available from: https://library.cee1.org/system/files/library/8791/CEE_Eval_FinalReportCoincidenceFactorStudyResidentialRoomAirConditioners2008_23Jun2008.pdf
3. Northeast Energy Efficiency Partnerships, Loadshape Report and Catalogue June 2016
   Available from: http://www.neep.org/loadshape-report-and-catalogue
4. 10 CFR 430.32 Energy and water conservation standards and their compliance dates.
   Available from: http://www.ecfr.gov/cgi-bin/text-idx?SID=a9921a66f2b4f66a32ec851916b7b9d9&mc=true&node=se10.3.430_132&rgn=div8
5. ENERGY STAR® Program Requirements Product Specification for Room Air Conditioners Eligibility Criteria Version 4.2
   Available from: https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Final%20Version%204.2%20Room%20Air%20Conditioners%20Specification_0.pdf

Record of Revision

Record of Revision Number	Issue Date
1	10/15/2010
3-18-2	3/29/2018

Return to Table of Contents

AIR CONDITIONER AND HEAT PUMP – PACKAGED TERMINAL

Measure Description

This measure covers the installation of high efficiency packaged terminal air conditioners and heat pumps in residential and multifamily applications.

Packaged Terminal Air Conditioner (PTAC)

A wall sleeve and a separate un-encased combination of heating and cooling assemblies specified by the manufacturer and intended for mounting through the wall. It includes refrigeration components, separable outdoor louvres, forced ventilation, and heating availability by purchaser's choice of, at least, hot water, steam, or electrical resistance heat.

Note: *Models designated as "cooling only" units need not include heating elements if the physical characteristics and arrangement of the refrigeration system are identical to those of models with heating availability.*[290]

Packaged Terminal Heat Pump (PTHP)

A separate un-encased refrigeration system installed in a cabinet having a function and configuration similar to that of a packaged terminal air-conditioner. It uses reverse cycle refrigeration as its prime heat source and should have other supplementary heat source(s) available to purchasers with the choice of, at least, hot water, steam, or electric resistance heat.[291,292]

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times \left[\begin{array}{c} \left(\frac{kBTU/h_{cooling}}{unit} \times \left(\frac{F_{ElecCool}}{EER_{baseline}} - \frac{1}{EER_{ee}} \right) \times EFLH_{cooling} \right) \\ + \\ \left(\frac{kBTU/h_{heating}}{unit \times 3.412} \times \left(\frac{F_{ElecHeat}}{COP_{baseline}} - \frac{1}{COP_{ee}} \right) \times EFLH_{heating} \right) \end{array} \right]$$

Summer Peak Coincident Demand Savings

$$\Delta kW = units \times \left[\frac{kBTU/h_{cooling}}{unit} \times \left(\frac{F_{ElecCcool}}{EER_{baseline}} - \frac{1}{EER_{ee}} \right) \times CF \right]$$

[290] AHRI Standard 310/380 – 2014

[291] Ibid.

[292] Replacement unit shall be factory labeled as follows: "MANUFACTURED FOR REPLACEMENT APPLICATIONS ONLY: NOT TO BE INSTALLED IN NEW CONSTRUCTION PROJECTS." Replacement efficiencies apply only to units with existing sleeves less than 16 inches (406 mm) in height and less than 42 inches (1067 mm) in width.

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = units \times \left(\frac{kBTU/h_{heating}}{unit} \times \frac{F_{FuelHeat}}{Eff_{heating,baseline}} \times \frac{EFLH_{heating}}{1{,}000} \right)$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
$_{baseline}$	= Characteristic of baseline condition
$_{ee}$	= Characteristic of energy efficient condition
$kBTU/h_{cooling}$	= Output cooling capacity in kBTU/h (at AHRI standard rating conditions)
$kBTU/h_{heating}$	= Output heating capacity in kBTU/h (at AHRI standard high-temperature rating conditions)
$F_{ElecCool}$	= Electric cooling factor; used to account for the presence or absence of an electric cooling system
$F_{ElecHeat}$	= Electric heating factor; used to account for the presence or absence of an electric heating system
$F_{FuelHeat}$	= Fossil fuel heating factor; used to account for the presence or absence of a fossil fuel heating system
EER	= Energy efficiency ratio, measurement of cooling capacity for a unit (in BTU/hour) / electrical energy used (watts) (at AHRI standard rating conditions)
COP	= Coefficient of performance, ratio of output energy/input energy (at AHRI standard high-temperature rating conditions)
$Eff_{heating}$	= Fossil fuel heating energy efficiency rating of equipment.
$EFLH_{cooling}$	= Cooling equivalent full-load hours
$EFLH_{heating}$	= Heating equivalent full-load hours
CF	= Coincidence factor
3.412	= Conversion factor, one watt-hour equals 3.412 BTU
1,000	= Conversion factor, one MMBtu equals 1,000 kBTU

Summary of Variables and Data Sources

Variable	Value	Notes
$kBTU/h_{cooling}$		From application
$kBTU/h_{heating}$		From application
$F_{ElecCool}$		If an electric cooling system is present, set equal to 1. Otherwise, set equal to 0.
$F_{ElecHeat}$		If an electric heating system is present, set equal to 1. Otherwise, set equal to 0.
$F_{FuelHeat}$		If a fossil fuel-fired heating system is present, set equal to 1. Otherwise, set equal to 0.
$EER_{baseline}$		Calculate from Baseline Efficiencies table below based on equipment type, size category and capacity.
EER_{ee}		From application

Variable	Value	Notes
$COP_{baseline}$		Calculate from Baseline Efficiencies table below based on equipment type, size category and capacity.
COP_{ee}		From application
$Eff_{heating,baseline}$		From Fossil Fuel Fired Heating System Baseline Efficiencies table below.
$EFLH_{cooling}$		From application. If unknown, lookup based on building type, vintage and location from Appendix G.
$EFLH_{heating}$		From application. If unknown, lookup based on building type, vintage and location from Appendix G.
CF	0.69	

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.69.[293]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline for a non-fuel switching normal replacement at end of the appliance effective useful life (EUL), in new construction, or substantial renovation scenarios is the minimally-compliant state or municipal energy code or federal standard, that is applicable to the measure or system being installed. The baseline efficiencies are calculated based on rated equipment input capacity in BTU/h and are defined by International Energy Conservation Code[294] and subsequently adopted by the Energy Conservation Construction Code of New York State (ECCCNYS) as shown below. The formulas in the rightmost column shall be used to establish the baseline efficiency in the units specified (EER or COP).

Electric Cooling and Heating System Baseline Efficiencies

Equipment Type	Size Category (Input)	Subcategory or Rating Condition	Minimum Efficiency ECCCNYS[295]
PTAC (Cooling Mode) Standard Size	All Capacities	95°F db Outdoor Air	EER = 14.0 - (0.300 × Cap/1,000)

[293] Based on BG&E 'Development of Residential Load Profile for Central Air Conditioners and Heat Pumps' research, the Maryland Peak Definition coincidence factor is 0.69. This study is not publicly available, but is referenced by M. M. Straub, Using Available Information for Efficient Evaluation of Demand-Side Management Programs, Electricity Journal, September 2011 and supported by research conducted by Cadmus on behalf of the TRM Management Committee.

[294] ECCCNYS 2020, Table C403.3.2(3)

[295] "Cap" = The rated cooling capacity of the project in BTU/h. If the unit's capacity is less than 7,000 BTU/h, use 7,000 BTU/h in the calculation. If the unit's capacity is greater than 15,000 BTU/h, use 15,000 BTU/h in the calculations."

Equipment Type	Size Category (Input)	Subcategory or Rating Condition	Minimum Efficiency ECCCNYS[295]
PTAC (Cooling Mode) Replacements/ Nonstandard Size[296]	All Capacities	95°F db Outdoor Air	EER = 10.9 - (0.213 × Cap/1,000)
PTHP (Cooling Mode) Standard Size	All Capacities	95°F db Outdoor Air	EER = 14.0 - (0.300 × Cap/1,000)
PTHP (Cooling Mode) Replacements/ Nonstandard Size	All Capacities	95°F db Outdoor Air	EER = 10.8 - (0.213 × Cap/1,000)
PTHP (Heating Mode) Standard Size	All Capacities	—	NYS: COP = 3.2 – (0.026 × Cap/1,000) NYC: COP = 3.7 – (0.052 × Cap/1,000)
PTHP (Heating Mode) Replacements/ Nonstandard Size	All Capacities	—	COP = 2.9 - (0.026 × Cap/1,000)

The baseline for a fuel switching installation at the end of the appliance effective useful life is the minimally-compliant, state or municipal energy code or federal standard, that is applicable to the measure or system, similar to the existing measure or system, that the consumer would have installed without the influence of the energy efficiency program. The baseline efficiency for residential furnaces, boilers, and unit heaters is defined by the Code of Federal Regulations and subsequently adopted by the Energy Conservation Code of New York State.

The baseline efficiency for fossil fuel fired heating systems serving single-family homes and individual units is defined by the Code of Federal Regulations as shown in the table below.

Fossil Fuel Fired Heating System Baseline Efficiencies: Systems Serving Single Units[297]

Equipment Type	Size Range	ECCCNYS Minimum Efficiency for Climate Zones 4, 5 and 6
Warm Air Furnace, Gas Fired	All Capacities	0.80 AFUE
Warm Air Furnace, Oil Fired	All Capacities	0.83 AFUE
Boiler, Hot Water, Gas Fired	All Capacities	0.82 AFUE
Boiler, Hot Water, Oil Fired	All Capacities	0.84 AFUE
Boiler, Steam, Gas Fired	All Capacities	0.80 AFUE

[296] Replacement/Nonstandard size units must be factory labeled as follows: "MANUFACTURED FOR REPLACEMENT APPLICATIONS ONLY; NOT TO BE INSTALLED IN NEW CONSTRUCTION PROJECTS." Replacement/Nonstandard size efficiencies apply only to units being installed in existing sleeves having an external wall opening of less than 16 in. high or less than 42 in. wide and having a cross-sectional area less than 670 in.
[297] 10 CFR 430.32(e)

Equipment Type	Size Range	ECCCNYS Minimum Efficiency for Climate Zones 4, 5 and 6
Boiler, Steam, Oil Fired	All Capacities	0.82 AFUE

The baseline efficiency for heating systems serving multiple dwelling units is defined by International Energy Conservation Code[298] and subsequently adopted by the Energy Conservation Construction Code of New York State (ECCCNYS) as shown in the table below.

Fossil Fuel Fired Heating System Baseline Efficiencies: Systems Serving Multiple Dwelling Units

Equipment Type	Size Range	ECCCNYS Minimum Efficiency for Climate Zones 4, 5 and 6
Warm Air Furnace, Gas Fired	< 225 kBTU/h	0.80 AFUE
	≥ 225 kBTU/h	0.80 Et
Warm Air Furnace, Oil Fired	< 225 kBTU/h	0.83 AFUE
	≥ 225 kBTU/h	0.80 Et
Warm Air Unit Heaters, Gas Fired	All Capacities	0.80 Ec
Warm Air Unit Heaters, Oil Fired	All Capacities	0.80 Ec
Boiler, Hot Water, Gas Fired	< 300 kBTU/h	0.82 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.80 Et
	> 2,500 kBTU/h	0.82 Ec
Boiler, Hot Water, Oil Fired	< 300 kBTU/h	0.84 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.82 Et
	> 2,500 kBTU/h	0.84 Ec
Boiler, Steam, Gas Fired, All Except Natural Draft	< 300 kBTU/h	0.80 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.79 Et
	> 2,500 kBTU/h	0.79 Et
Boiler, Steam, Gas Fired, Natural Draft	< 300 kBTU/h	0.80 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.77 Et
	> 2,500 kBTU/h	0.77 Et
Boiler, Steam, Oil Fired	< 300 kBTU/h	0.82 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.81 Et
	> 2,500 kBTU/h	0.81 Et

The baseline for a system being installed prior to the end of useful life of the existing on-site equipment may be considered as an Early Replacement; consistent with methods described in Appendix M, *Guidelines for Early Replacement* of this TRM. The non-fuel switching and fuel switching baselines detailed above shall be considered where applicable when calculating Remaining Useful Life (RUL).

[298] ECCCNYS 2020, Table C403.3.2(4) & Table C403.3.2(5)

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a high efficiency packaged terminal air conditioner or heat pump system as defined in the Measure Description section above meeting or exceeding an efficiency rating of 10% better than code, as outlined in the Baseline Efficiencies section.

Operating Hours

Equipment heating and cooling equivalent full load hours shall be taken from the application. If unknown, default EFLH by facility type, vintage and location can be found in Appendix G.

Example Calculation *(Not to be used as default)*

Four standard size packaged terminal heat pump (PTHP) each fulfilling a cooling load of 17 kBTU/h and a heating load of 23 kBTU/h are installed in a two-story multifamily building located near Albany constructed in 1975. The PTHP has an EER of 10.4 and a COP of 3.2. The conditions prior to installation include an electric cooling system and a gas-fired warm air furnace. Annual Electric Energy Savings, Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta kWh = units \times \left[\begin{array}{c}\left(\frac{kBTU/h_{cooling}}{unit} \times \left(\frac{F_{ElecCool}}{EER_{baseline}} - \frac{1}{EER_{ee}}\right) \times EFLH_{cooling}\right) \\ + \\ \left(\frac{kBTU/h_{heating}}{unit \times 3.412} \times \left(\frac{F_{ElecHeat}}{COP_{baseline}} - \frac{1}{COP_{ee}}\right) \times EFLH_{heating}\right)\end{array}\right]$$

$$\Delta kW = units \times \left[\frac{kBTU/h_{cooling}}{unit} \times \left(\frac{F_{CEC}}{EER_{baseline}} - \frac{1}{EER_{ee}}\right) \times CF\right]$$

$$\Delta MMBtu = units \times \left(\frac{kBTU/h_{heating}}{unit} \times \frac{F_{FuelHeat}}{Eff_{heating,baseline}} \times \frac{EFLH_{heating}}{1{,}000}\right)$$

units = 4
$(kBTU/h_{cooling})$/unit = 17, from application
$F_{ElecCool}$ = 1, based on application
$EER_{baseline}$ = 14.0 – (0.300 x Cap/1,000) = 14.0 – (0.300 x 17,000/1,000) = 8.90
$EER_{baseline}$ equation from Electric Cooling and Heating System Baseline Efficiencies based on equipment type of compliance equipment from application
EER_{ee} = 10.4, from application
$EFLH_{cooling}$ = 286, from Appendix G based on housing type, building vintage, and location from application
$(kBTU/h_{heating})$/unit = 23, from application
$F_{ElecHeat}$ = 0, based on application
$COP_{baseline}$ = 3.2 – (0.026 x cap/1,000) = 3.2 – (0.026 x 23,000/1,000) = 2.60
COP_{ee} = 3.2, from application

$EFLH_{heating}$ = 1,030, from Appendix G based on housing type, building vintage, and location from application
CF = 0.69, from Summary of Variables and Data Sources table
$F_{FuelHeat}$ = 1, based on application
$EFF_{heating,baseline}$ = 0.80 from Fossil Fuel Fired Heating System Baseline Efficiencies table based on equipment type and building type from application

$$\Delta kWh = 4 \times \left[\left(17 \times \left(\frac{1}{8.90} - \frac{1}{10.4}\right) \times 286\right) + \left(\frac{23}{3.412} \times \left(\frac{0}{2.60} - \frac{1}{3.2}\right) \times 1{,}030\right)\right] = -8{,}364\ kWh$$

$$\Delta kW = 4 \times \left[17 \times \left(\frac{1}{8.90} - \frac{1}{10.4}\right) \times 0.69\right] = 0.76\ kW$$

$$\Delta MMBtu = 4 \times \left(23 \times \frac{1}{0.80} \times \frac{1{,}030}{1{,}000}\right) = 118.5\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. AHRI Standard 310/380 – 2014: Standard for Packaged Terminal Air-Conditioners and Heat Pumps
   Available from: http://www.ahrinet.org/App_Content/ahri/files/STANDARDS/AHRI/AHRI_Standard_310_380-2014_CSA_C744-14.pdf
2. BG&E, Development of Residential Load Profile for Central Air Conditioners and Heat Pumps
3. 10 CFR 430.32 Energy and water conservation standards and their compliance dates. Available from: http://www.ecfr.gov/cgi-bin/text-idx?SID=a9921a66f2b4f66a32ec851916b7b9d9&mc=true&node=se10.3.430_132&rgn=div8

4. ECCCNYS 2020 Table C403.3.2(3): Minimum Efficiency Requirements: Electrically Operated Unitary Packaged Terminal Air Conditioners, Packaged Terminal Heat Pumps, Single-Package Vertical Air Conditioners, Single Vertical Heat Pumps, Room Air Conditioners and Room Air Conditioner Heat Pumps, Table C403.3.22(4): Warm-Air Furnaces And Combination Warm-Air Furnaces/Air-Conditioning Units, Warm-Air Duct Furnaces And Unit Heaters, Minimum Efficiency Requirements & Table C403.3.2(5): Minimum Efficiency Requirements: Gas- And Oil-Fired Boilers.
   Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-ce-commercial-energy-efficiency

Record of Revision

Record of Revision Number	Issue Date
2-20-4	2/28/2020

Return to Table of Contents

BOILER, FURNACE AND UNIT HEATER

Measure Description

This measure covers the installation of high efficiency fossil fuel-fired furnaces, boilers, and unit heaters used for space heating. The baseline case shall be minimally code compliant equipment of the same type and capacity as in the efficient case, which shall be sized in accordance with federal, state, local and municipal codes and standards.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = N/A$$

Summer Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = units \times kBTU/h_{in} \times \left(\frac{Eff_{ee}}{Eff_{baseline}} - 1\right) \times \frac{EFLH_{heating}}{1{,}000}$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
$kBTU/h_{in}$	= Fuel Input Rating per unit
Eff_{ee}	= Efficiency of energy efficient condition
$Eff_{baseline}$	= Efficiency of baseline condition
$EFLH_{heating}$	= Heating equivalent full-load hours
1,000	= Conversion factor, one MMBtu equals 1,000 kBTU

Summary of Variables and Data Sources

Variable	Value	Notes
$kBTU/h_{in}$		Nominal heating input capacity is the nameplate input rating of the unit in kBTU/h, from application.
$Eff_{baseline}$		Lookup based on equipment type, size and applicable energy conservation code from the Baseline Efficiency section below.
Eff_{ee}		From application
$EFLH_{heating}$		Lookup based on building type and location, Appendix G

Efficiency is expressed as the ratio between the fuel input relative to the output. The efficiency of furnaces, boilers and unit heaters is customarily evaluated on the basis of one or more of three standards, and are referred to as Thermal Efficiency (E_t), Combustion Efficiency, (E_c) or Annual Fuel Utilization Efficiency (AFUE).

Presently, the AFUE value is only applicable to smaller units. For larger units, use thermal and combustion efficiencies referenced on manufacturer's nameplate data in accordance with nationally recognized standards and testing agencies.

Coincidence Factor (CF)

The prescribed value for the coincidence factor is N/A.

Baseline Efficiencies from which Energy Savings are Calculated

The baseline efficiency for residential furnaces, boilers, and unit heaters is defined by the Code of Federal Regulations and subsequently adopted by the Energy Conservation Code of New York State.

The baseline efficiency for fossil fuel fired heating systems serving single-family homes and individual units is defined by the Code of Federal Regulations as shown in the table below.

Fossil Fuel Fired Heating System Baseline Efficiencies: Systems Serving Single Units[299]

Equipment Type	Size Range	ECCCNYS Minimum Efficiency for Climate Zones 4, 5 and 6
Warm Air Furnace, Gas Fired	All Capacities	0.80 AFUE
Warm Air Furnace, Oil Fired	All Capacities	0.83 AFUE
Boiler, Hot Water, Gas Fired	All Capacities	0.82 AFUE
Boiler, Hot Water, Oil Fired	All Capacities	0.84 AFUE
Boiler, Steam, Gas Fired	All Capacities	0.80 AFUE
Boiler, Steam, Oil Fired	All Capacities	0.82 AFUE

The baseline efficiency for heating systems serving multiple dwelling units is defined by International Energy Conservation Code[300] and subsequently adopted by the Energy Conservation Construction Code of New York State (ECCCNYS) as shown in the table below.

Fossil Fuel Fired Heating System Baseline Efficiencies: Systems Serving Multiple Dwelling Units

Equipment Type	Size Range	ECCCNYS Minimum Efficiency for Climate Zones 4, 5 and 6
Warm Air Furnace, Gas Fired	< 225 kBTU/h	0.80 AFUE
	≥ 225 kBTU/h	0.80 Et

[299] 10 CFR 430.32(e)
[300] ECCCNYS 2020, Table C403.3.2(4) & Table C403.3.2(5)

Equipment Type	Size Range	ECCCNYS Minimum Efficiency for Climate Zones 4, 5 and 6
Warm Air Furnace, Oil Fired	< 225 kBTU/h	0.83 AFUE
	≥ 225 kBTU/h	0.80 Et
Warm Air Unit Heaters, Gas Fired	All Capacities	0.80 Ec
Warm Air Unit Heaters, Oil Fired	All Capacities	0.80 Ec
Boiler, Hot Water, Gas Fired	< 300 kBTU/h	0.82 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.80 Et
	> 2,500 kBTU/h	0.82 Ec
Boiler, Hot Water, Oil Fired	< 300 kBTU/h	0.84 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.82 Et
	> 2,500 kBTU/h	0.84 Ec
Boiler, Steam, Gas Fired, All Except Natural Draft	< 300 kBTU/h	0.80 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.79 Et
	> 2,500 kBTU/h	0.79 Et
Boiler, Steam, Gas Fired, Natural Draft	< 300 kBTU/h	0.80 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.77 Et
	> 2,500 kBTU/h	0.77 Et
Boiler, Steam, Oil Fired	< 300 kBTU/h	0.82 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.81 Et
	> 2,500 kBTU/h	0.81 Et

Compliance Efficiencies from which Incentives are Calculated

The compliance condition is a furnace, boiler or unit heater with efficiency exceeding that of the baseline equipment.

Operating Hours

Heating equivalent full-load hours were calculated from a DOE-2.2 simulation of prototypical single and multi-family residential buildings. Operating hour assumptions for the prototypical building models are described in Appendix A. The heating EFLH for commercial buildings in NY are shown in Appendix G.

Example Calculation *(Not to be used as default)*

A 120 kBTU/h warm air, gas fired furnace with 92% AFUE is installed in a single family, detached home located near Albany constructed in 1995. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are not applicable. Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta MMBtu = units \times kBTU/h_{in} \times \left(\frac{Eff_{ee}}{Eff_{baseline}} - 1\right) \times \frac{EFLH_{heating}}{1{,}000}$$

units = 1, from application
$kBTU/h_{in}$ = 120, from application
Eff_{ee} = 0.92, from application
$Eff_{baseline}$ = 0.80, from Baseline Efficiencies section based on equipment type and size from application
$EFLH_{heating}$ = 978, from Appendix G based on housing type, building vintage, and location from application

$$\Delta MMBtu = 1 \times 120 \times \left(\frac{0.92}{0.80} - 1\right) \times \frac{978}{1{,}000} = 17.6\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

High efficiency furnaces may be packaged with high efficiency cooling equipment and/or electronically commutated blower motors, which may provide electricity savings. Draft fans, when present, will increase electricity consumption.

References

1. 10 CFR 430.32 Energy and water conservation standards and their compliance dates. Available from: http://www.ecfr.gov/cgi-bin/text-idx?SID=a9921a66f2b4f66a32ec851916b7b9d9&mc=true&node=se10.3.430_132&rgn=div8
2. ECCCNYS 2020 Table C403.3.2(4): Warm-Air Furnaces And Combination Warm-Air Furnaces/Air-Conditioning Units, Warm-Air Duct Furnaces And Unit Heaters, Minimum Efficiency Requirements & Table C403.2.3(5): Minimum Efficiency Requirements: Gas- And Oil-Fired Boilers.
   Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-[ce]-commercial-energy-efficiency#NYSECC2020P1_CE_Ch04_SecC402
3. 2015 ASHRAE Handbook – HVAC Applications, Table 4: Comparison of Service Life Estimates

Record of Revision

Record of Revision Number	Issue Date
1	10/15/2010
7-13-32	7/31/2013
8-13-1	8/31/2013
6-15-5	6/1/2015
1-16-2	12/31/2015
6-17-5	6/30/2017
12-19-3	12/23/2019

Return to Table of Contents

BOILER AND FURNACE - COMBINATION ("COMBI") BOILER AND FURNACE

Measure Description

This measure covers the installation of residential fossil fuel-fired combination or "combi" boilers and furnaces, which are defined as high-efficiency, instantaneous water heaters with a heating designation. Combi-boilers are all-in-one high-efficiency space heating systems with integrated capability for providing instantaneous domestic hot water, while combi-furnaces supply both domestic tankless hot water and forced air heating. These units realize energy savings through increased thermal efficiency and by taking cold water straight from the main supply and heating it as needed, which eliminates the need for a separate hot water storage tank and avoids standby losses. Qualifying equipment must be in accordance with ASHRAE Standard 124-2007 (RA 2016).[301] This measure only applies to systems with modulating/staging capability and no water storage tank.

This measure only captures the fossil fuel savings impacts of combi-boilers and combi-furnaces. While electric combi-boilers exist, more investigation and research are required before an approach for estimating associated energy savings can be developed.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = N/A$$

Summer Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = \Delta MMBtu_{SH} + \Delta MMBtu_{DHW}$$

$$\Delta MMBtu_{SH} = units \times \frac{kBTU/h_{in}}{unit} \times \left(\frac{AFUE_{ee}}{AFUE_{baseline}} - 1\right) \times \frac{EFLH_{heating}}{1{,}000}$$

$$\Delta MMBtu_{DHW} = units \times \left[\frac{GPD \times 365 \times 8.33 \times \Delta T_{main}}{1{,}000{,}000} \times \left(\frac{1}{RE_{baseline}} - \frac{1}{AFUE_{ee}}\right) + \frac{UA_{baseline}}{RE_{baseline}} \times \frac{\Delta T_{amb}}{1{,}000{,}000} \times 8{,}760\right]$$

where:

ΔkWh = Annual electric energy savings
ΔkW = Peak coincident demand electric savings

[301] ASHRAE Standard 124-2007 (RA 2016) – Methods of Testing for Rating Combination Space-Heating and Water-Heating Appliances (ANSI Approved)

$\Delta MMBtu$ = Annual fossil fuel energy savings
$\Delta MMBtu_{DHW}$ = Annual domestic hot water savings associated with installation of a high-efficiency combi-boiler or combi-furnace
$\Delta MMBtu_{SH}$ = Annual space heating savings associated with installation of a high-efficiency combi-boiler or combi-furnace
units = Number of measures installed under the program
$kBTU/h_{in}$ = Space heating fuel input rating
$_{baseline}$ = Characteristic of baseline condition
$_{ee}$ = Characteristic of energy efficient condition
AFUE = Annual fuel utilization efficiency, seasonal energy efficiency for fossil fuel heating equipment
$EFLH_{heating}$ = Heating equivalent full-load hours
GPD = Gallons per day
ΔT_{main} = Average difference between the cold inlet temperature and the hot water delivery temperature (°F)
RE = Recovery efficiency
UA = Overall heat loss coefficient (BTU/h-°F)
ΔT_{amb} = Average temperature difference between water heater set point temperature and the surrounding ambient air temperature (°F)
8.33 = Energy required (BTU), to heat one gallon of water by one degree Fahrenheit
365 = Days in one year
1,000 = Conversion factor, one MMBtu equals 1,000 kBTU
8,760 = Hours in one year
1,000,000 = Conversion factor, one MMBtu equals 1,000,000 BTU

Summary of Variables & Data Sources

Variable	Value	Notes/References
$kBTU/h_{in}$		Nominal heating input capacity is the nameplate input rating of the unit in kBTU/h, from application.
$AFUE_{baseline}$		See Baseline Efficiencies section below.
$AFUE_{ee}$		From application.
$EFLH_{heating}$		Lookup based on building type and location in Appendix G.
GPD	17.2 X # of people	Calculated based on number of people served by the system. If unknown, use 46 GPD.[302]
ΔT_{main}	T_{set} - T_{main}	Average temperature difference between water heater set point temperature and the supply water temperature in water main (°F)
ΔT_{amb}	55 = T_{set} - T_{amb}	Average temperature difference between water heater set point temperature and the surrounding ambient air temperature (°F)

[302] Water Research Foundation: Residential End Uses of Water, Version 2, April 2016, p. 5; 17.2 GPD equated from the report findings indicating an average 2.65 people per household and 45.5 GPD per household.

Variable	Value	Notes/References
T_{set}	125	Water heater set point temperature (°F).[303]
T_{main}		Supply water temperature in water main (°F). Lookup in Cold Water Inlet Temperature table below based on nearest city.
T_{amb}	70	Surrounding ambient air temperature (°F).[304]
$RE_{baseline}$	0.75	Gas recovery efficiency.[305]
$UA_{baseline}$	7.85	Overall heat loss coefficient of the baseline condition (BTU/h-°F).[306]

Cold Water Inlet Temperature (T_{main})

Supply water main temperatures vary according to climate and are approximately equal to the annual average outdoor temperature plus 6°F.[307] Supply main temperatures based on the annual outdoor temperature are shown below.

City	Annual average outdoor temperature[308] (°F)	T_{main} (°F)
Albany	48.3	54.3
Binghamton	46.3	52.3
Buffalo	48.3	54.3
Massena	43.5	49.5
NYC	55.4	61.4
Poughkeepsie	49.8	55.8
Syracuse	48.3	54.3

Coincidence Factor (CF)

The prescribed value for the coincidence factor is N/A.

[303] 10 CFR 430 Appendix E to Subpart B of Part 430 Uniform Test Method for Measuring the Energy Consumption of Water Heaters, Section 2. Test Conditions, 2.5 Set Point Temperature .

[304] Water heaters are generally located in conditioned or partially conditioned spaces with a typical average temperature of 65°F to 70°F to avoid freezing. A value of 70°F is used for the purposes of estimating tank/ambient air temperature differential, which aligns with standby loss specification testing standards.

[305] Per 10 CFR 430, typical recovery efficiency of a fuel water heater, which is used for the purposes of this measure as a proxy for thermal efficiency, is 0.75. See for example, 10 CFR 430 Subpart B Appendix C1, 5.6.1.1.

[306] Based on computation of heat loss coefficients via conversion equations found in 10 CFR 429, 430, and 431 Docket No. EERE-2015-BT-TP-0007, Energy Conservation Program for Consumer Products and Certain Commercial and Industrial Equipment: Test Procedures for Consumer and Commercial Water Heaters. Heat loss coefficient was calculated for a minimally code compliant fuel storage water heater found to be the most typical in terms of storage and input capacity, representing storage type water heaters of between 20 and 55 gallon capacity (40 gallon, 40,000 BTU/h assumed). Results of heat loss coefficient evaluation for this assumed baseline is used to represent the $UA_{baseline}$ term.

[307] Burch, Jay and Christensen, Craig, "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory

[308] Average annual outdoor temperatures taken from NCEI 1981-2010 climate normals

Baseline Efficiencies from which Energy Savings are Calculated

Space Heating Component

The baseline efficiency for the space heating component of residential combi-boilers and combi-furnaces is defined by the Code of Federal Regulations and subsequently adopted by the Energy Conservation Code of New York State, as shown below.

The baseline efficiency for fossil fuel fired heating systems serving single-family homes and individual units is defined by the Code of Federal Regulations as shown in the table below.

Fossil Fuel Fired Heating System Baseline Efficiencies: Systems Serving Single Units[309]

Equipment Type	Size Range	ECCCNYS Minimum Efficiency for Climate Zones 4, 5 and 6
Warm Air Furnace, Gas Fired	All Capacities	0.80 AFUE
Warm Air Furnace, Oil Fired	All Capacities	0.83 AFUE
Boiler, Hot Water, Gas Fired	All Capacities	0.82 AFUE
Boiler, Hot Water, Oil Fired	All Capacities	0.84 AFUE
Boiler, Steam, Gas Fired	All Capacities	0.80 AFUE
Boiler, Steam, Oil Fired	All Capacities	0.82 AFUE

The baseline efficiency for heating systems serving multiple dwelling units is defined by International Energy Conservation Code[310] and subsequently adopted by the Energy Conservation Construction Code of New York State (ECCCNYS) as shown in the table below.

Fossil Fuel Fired Heating System Baseline Efficiencies: Systems Serving Multiple Dwelling Units

Equipment Type	Size Range	ECCCNYS Minimum Efficiency for Climate Zones 4, 5 and 6
Warm Air Furnace, Gas Fired	< 225 kBTU/h	0.80 AFUE
	≥ 225 kBTU/h	0.80 Et
Warm Air Furnace, Oil Fired	< 225 kBTU/h	0.83 AFUE
	≥ 225 kBTU/h	0.80 Et
Warm Air Unit Heaters, Gas Fired	All Capacities	0.80 Ec
Warm Air Unit Heaters, Oil Fired	All Capacities	0.80 Ec
Boiler, Hot Water, Gas Fired	< 300 kBTU/h	0.82 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.80 Et
	> 2,500 kBTU/h	0.82 Ec
Boiler, Hot Water, Oil Fired	< 300 kBTU/h	0.84 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.82 Et
	> 2,500 kBTU/h	0.84 Ec

[309] 10 CFR 430.32(e)

[310] ECCCNYS 2020, Table C403.3.2(4) & Table C403.3.2(5)

Equipment Type	Size Range	ECCCNYS Minimum Efficiency for Climate Zones 4, 5 and 6
Boiler, Steam, Gas Fired, All Except Natural Draft	< 300 kBTU/h	0.80 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.79 Et
	> 2,500 kBTU/h	0.79 Et
Boiler, Steam, Gas Fired, Natural Draft	< 300 kBTU/h	0.80 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.77 Et
	> 2,500 kBTU/h	0.77 Et
Boiler, Steam, Oil Fired	< 300 kBTU/h	0.82 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.81 Et
	> 2,500 kBTU/h	0.81 Et

Domestic Hot Water Component

The baseline condition is a standard efficiency 40-gallon storage type water heater with a recovery efficiency of 75%[311] and heat loss coefficient of 7.85 BTU/h-°F.[312]

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a combi-boiler unit with a heating designation efficiency of 90% AFUE or greater or a combi-furnace unit with a heating designation efficiency of 92% AFUE. Qualifying systems must be equipped with modulating/staging capability and no water storage tank. Units shall be in accordance with ASHRAE Standard 124-2007 (RA 2016).[313]

Operating Hours

Heating equivalent full-load hours were calculated from a DOE-2.2 simulation of prototypical single and multi-family residential buildings. Operating hour assumptions for the prototypical building models are described in Appendix A. The heating EFLH for residential buildings in NY are shown in Appendix G.

Domestic hot water heaters are assumed to be available for operation 8,760 hours per year, and it is assumed standby losses in the baseline case are incurred 8,760 hours per year.

[311] Per 10 CFR 430, typical recovery efficiency of a fuel water heater, which is used for the purposes of this measure as a proxy for thermal efficiency, is 0.75. See for example, 10 CFR 430 Subpart B Appendix C1, 5.6.1.1.

[312] Per 10 CFR 430, typical recovery efficiency of a fuel water heater, which is used for the purposes of this measure as a proxy for thermal efficiency, is 0.75. See for example, 10 CFR 430 Subpart B Appendix C1, 5.6.1.1.

[312] Based on computation of heat loss coefficients via conversion equations found in 10 CFR 429, 430, and 431 Docket No. EERE-2015-BT-TP-0007, Energy Conservation Program for Consumer Products and Certain Commercial and Industrial Equipment: Test Procedures for Consumer and Commercial Water Heaters. Heat loss coefficient was calculated for a minimally code compliant fuel storage water heater found to be the most typical in terms of storage and input capacity, representing storage type water heaters of between 20 and 55 gallon capacity (40 gallon, 40,000 BTU/h assumed). Results of heat loss coefficient evaluation for this assumed baseline is used to represent the $UA_{baseline}$ term.

[313] ASHRAE Standard 124-2007 (RA 2016) – Methods of Testing for Rating Combination Space-Heating and Water-Heating Appliances (ANSI Approved)

Example Calculation *(Not to be used as default)*

A "combi" boiler with 199 kBTU/h and 90% AFUE is installed in a single family, detached home with 5 residents located near Albany constructed in 1995. The conditions prior to installation include a gas-fired warm air furnace and gas storage tank water heater. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are not applicable. Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta MMBtu = \Delta MMBtu_{SH} + \Delta MMBtu_{DHW}$$

$$\Delta MMBtu_{SH} = units \times \frac{kBTU/h_{in}}{unit} \times \left(\frac{AFUE_{ee}}{AFUE_{baseline}} - 1\right) \times \frac{EFLH_{heating}}{1{,}000}$$

$$\Delta MMBtu_{DHW} = units \times \left[\frac{GPD \times 365 \times 8.33 \times \Delta T_{main}}{1{,}000{,}000} \times \left(\frac{1}{RE_{baseline}} - \frac{1}{AFUE_{ee}}\right) + \frac{UA_{baseline}}{RE_{baseline}} \times \frac{\Delta T_{amb}}{1{,}000{,}000} \times 8{,}760\right]$$

units = 1, from application
$(kBTU/h_{in})/unit$ = 199, from application
$AFUE_{ee}$ = 0.9, from application
$AFUE_{baseline}$ = 0.80, from Baseline Efficiencies section based on equipment type and size from application
$EFLH_{heating}$ = 978, from Appendix G based on housing type, building vintage, and location from application
GPD = 17.2 x # of residents = 17.2 x 5 = 86
GPD equation based on Summary of Variables and Data Source table
# of residents from application
$\Delta T_{main} = T_{set} - T_{main}$ = 125 – 54.3 = 70.7
T_{set} from Summary of Variables and Data Sources table
T_{main} from Cold Water Inlet Temperature lookup table based on location from application
$RE_{baseline}$ = 0.75, from Summary of Variables and Data Sources table
$UA_{baseline}$ = 7.85, from Summary of Variables and Data Sources table
ΔT_{amb} = 55, from Summary of Variables and Data Sources table

$$\Delta MMBtu_{SH} = 1 \times 199 \times \left(\frac{0.90}{0.80} - 1\right) \times \frac{978}{1{,}000} = 24.3\ MMBtu$$

$$\Delta MMBtu_{DHW} = 1 \times \left[\frac{86 \times 365 \times 8.33 \times 70.7}{1{,}000{,}000} \times \left(\frac{1}{0.8} - \frac{1}{0.9}\right) + \frac{7.85}{0.75} \times \frac{55}{1{,}000{,}000} \times 8{,}760\right] = 13.5\ MMBtu$$

$$\Delta MMBtu = 24.3 + 13.5 = 37.8\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

High efficiency furnaces may be packaged with high efficiency cooling equipment and/or electronically commutated blower motors, which may provide electricity savings. Draft fans, when present, will increase electricity consumption.

References

1. ASHRAE Standard 124-2007 (RA 2016) – Methods of Testing for Rating Combination Space-Heating and Water-Heating Appliances (ANSI Approved)
2. Water Research Foundation: "Residential End Uses of Water, Version 2: Executive Report", April 2016
   Available from:
   https://www.circleofblue.org/wp-content/uploads/2016/04/WRF_REU2016.pdf
3. 10 CFR 430 Appendix E to Subpart B of Part 430 Uniform Test Method for Measuring the Energy Consumption of Water Heaters, Section 2. Test Conditions, 2.5 Set Point Temperature.
   Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=80dfa785ea350ebeee184bb0ae03e7f0&mc=true&node=ap10.3.430_127.e&rgn=div9
4. 10 CFR 430 Subpart B – Test Procedures, Appendix C1 - Uniform Test Method for Measuring the Energy Consumption of Dishwashers
   Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=9acb5e05dd1d96230c64079cf0c03102&mc=true&node=pt10.3.430&rgn=div5#ap10.3.430_127.c1
5. 10 CFR 429, 430, and 431 Docket No. EERE-2015-BT-TP-0007, Energy Conservation Program for Consumer Products and Certain Commercial and Industrial Equipment: Test Procedures for Consumer and Commercial Water Heaters
   Available from:
   https://energy.gov/sites/prod/files/2016/08/f33/Water%20Heaters%20Test%20Procedure%20SNOPR.pdf
6. AHRI Directory of Certified Product Performance
   Available from: https://www.ahridirectory.org/ahridirectory/pages/home.aspx
7. Burch, Jay and Craig Christensen; "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory.
   Available from: http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.515.6885

8. NOAA National Centers for Environmental Information – NCEI 1981-2010 Climate Normals
   Available from: https://www.ncdc.noaa.gov/cdo-web/datatools/normals
9. ECCCNYS 2020 Table C403.3.2(4): Warm-Air Furnaces And Combination Warm-Air Furnaces/Air-Conditioning Units, Warm-Air Duct Furnaces And Unit Heaters, Minimum Efficiency Requirements & Table C403.2.3(5): Minimum Efficiency Requirements: Gas- And Oil-Fired Boilers.
   Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-[ce]-commercial-energy-efficiency#NYSECC2020P1_CE_Ch04_SecC402
10. CFR 430.32 Energy and water conservation standards and their compliance dates.
   Available from: http://www.ecfr.gov/cgi-bin/text-idx?SID=a9921a66f2b4f66a32ec851916b7b9d9&mc=true&node=se10.3.430_132&rgn=div8

Record of Revision

Record of Revision Number	Issue Date
9-18-16	9/28/2018

Return to Table of Contents

DUCT SEALING AND INSULATION

Measure Description

This measure covers the installation of sealing and insulation of the space heating and air conditioning duct distribution system in the unconditioned spaces of single-family and multi-family homes. Duct sealing and insulation reduces air and thermal leakage into unconditioned and outdoor spaces, improving system efficiency. Sealing and insulation installed under this measure shall meet or exceed all applicable construction code requirements. This measure is only applicable in existing buildings. Only ductwork located in unconditioned spaces is eligible for savings.

This measure shall be implemented with the assistance of a duct-blaster test on the distribution system pre and post-implementation. A duct blaster test, similar in concept to a whole-house blower door test, is turned on to pressurize the duct system to 25 Pascals (a pressure which represents typical operating pressures for forced-air systems). The airflow through the duct blaster fan (which is displayed in cfm on the duct blaster's manometer) equals the flow escaping through leaks in the duct system. The results are reported as "cfm @ 25 Pascals".

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

For AC and HP Units with Capacity <65,000 BTU/h

$$\Delta kWh = \frac{l_{duct,uncond}}{l_{duct}} \times \left\{ \left[tons \times \frac{12}{SEER} \times EFLH_{cooling} \times \left(1 - \frac{Eff_{dist,cooling,baseline}}{Eff_{dist,cooling,ee}}\right) \times \left(1 - TRF_{cooling}\right) \right] + \left[kBTU/h_{out} \times \frac{1}{HSPF} \times EFLH_{heating} \times \left(1 - \frac{Eff_{dist,heating,baseline}}{Eff_{dist,heating,ee}}\right) \times \left(1 - TRF_{heating}\right) \right] \right\}$$

For AC and HP Units with Capacity ≥65,000 BTU/h

$$\Delta kWh = \frac{l_{duct,uncond}}{l_{duct}} \times \left\{ \left[tons \times \frac{12}{IEER} \times EFLH_{cooling} \times \left(1 - \frac{Eff_{dist,cooling,baseline}}{Eff_{dist,cooling,ee}}\right) \times \left(1 - TRF_{cooling}\right) \right] + \left[\frac{kBTU/h_{out}}{3.412} \times \frac{1}{COP} \times EFLH_{heating} \times \left(1 - \frac{Eff_{dist,heating,baseline}}{Eff_{dist,heating,ee}}\right) \times \left(1 - TRF_{heating}\right) \right] \right\}$$

For Electric Furnaces

$$\Delta kWh = \frac{l_{duct,uncond}}{l_{duct}} \times kW_{in} \times EFLH_{heating} \times \left(1 - \frac{Eff_{dist,heating,baseline}}{Eff_{dist,heating,ee}}\right) \times \left(1 - TRF_{heating}\right)$$

Summer Peak Coincident Demand Savings

For AC and HP Units

$$\Delta kW = \frac{l_{duct,uncond}}{l_{duct}} \times tons/unit \times \frac{12}{EER} \times \left(1 - \frac{Eff_{dist,cooling,baseline}}{Eff_{dist,cooling,ee}}\right) \times (1 - TRF_{cooling}) \times CF$$

Annual Fossil Fuel Energy Savings

For Fossil Fuel-Fired Furnaces with Capacity < 225,000 BTU/h

$$\Delta MMBtu = \frac{l_{duct,uncond}}{l_{duct}} \times \frac{kBTU/h_{in}}{1{,}000} \times EFLH_{heating} \times \left(1 - \frac{Eff_{dist,heating,baseline}}{Eff_{dist,heating,ee}}\right) \times (1 - TRF_{heating})$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
tons	= Output cooling capacity in tons (at AHRI standard rating conditions)
$kBTU/h_{out}$	= Output heating capacity in kBTU/h (at AHRI standard high-temperature rating conditions)
kW_{in}	= Input heating capacity in kW
$kBTU/h_{in}$	= Input heating capacity in kBTU/h (at AHRI standard high-temperature rating conditions)
$l_{duct,uncond}$	= Length of ductwork in each unconditioned space
l_{duct}	= Total length of ductwork
TRF	= Thermal Regain Factor
SEER	= Seasonal energy efficiency ratio in BTU/watt-hour. Total cooling output of an air conditioner during its normal annual usage period for cooling in BTU, divided by the total electric energy input during the same period in watt-hours
IEER	= Integrated energy efficiency ratio in BTU/watt-hour. A weighted calculation of mechanical cooling efficiencies at full load and part load AHRI standard rating conditions
EER	= Energy efficiency ratio under peak conditions in BTU/watt-hour. Measurement of the cooling capacity for a unit in BTU/h divided by the connected electric power of the unit in watts (at AHRI standard rating conditions)
HSPF	= Heating seasonal performance factor, total heating output (supply heat) in BTU (including electric strip heat) during the heating season divided by the total electric energy heat pump consumed in watt-hours
COP	= Coefficient of performance, ratio of output energy/input energy (at AHRI standard high-temperature rating conditions)
$EFLH_{cooling}$	= Cooling equivalent full-load hours
$EFLH_{heating}$	= Heating equivalent full-load hours
baseline	= Characteristic of baseline condition
ee	= Characteristic of energy efficient condition
Eff_{dist}	= Distribution system efficiency
CF	= Coincidence factor

12 = (kBTU/h)/ton of air conditioning capacity
3.412 = Conversion factor, one watt-hour equals 3.412 BTU
1,000 = Conversion factor, one MMBtu equals 1,000 kBTU

Summary of Variables and Data Sources

Variable	Value	Notes
tons		From application.
$kBTU/h_{out}$		From application.
kW_{in}		From application.
$kBTU/h_{in}$		From application.
$L_{duct, uncond}$		From application.
L_{duct}		From application.
$TRF_{cooling}$		See table in the Thermal Regain Factor section below.
$TRF_{heating}$		See table in the Thermal Regain Factor section below.
SEER		Existing equipment nameplate SEER.
IEER		Existing equipment nameplate IEER.
EER		Existing equipment nameplate EER.
HSPF		Existing equipment nameplate HSPF.
COP		Existing equipment nameplate COP.
$EFLH_{heating}$		Look up based on building type, vintage and location from Appendix G.
$EFLH_{cooling}$		Look up based on building type, vintage and location from Appendix G.
$Eff_{dist,cooling,baseline}$		Look up in Appendix H for uninsulated duct system based on building type, location and duct leakage in cooling mode. For duct leakage values that fall between two values in Appendix H, interpolation is acceptable.
$Eff_{dist,heating,baseline}$		Look up in Appendix H for uninsulated duct system based on building type, location and duct leakage in heating mode. For duct leakage values that fall between two values in Appendix H, interpolation is acceptable.
$Eff_{dist,cooling,ee}$		Look up in Appendix H for R-6 insulated duct system based on building type, location and duct leakage in cooling mode. For duct leakage values that fall between two values in Appendix H, interpolation is acceptable.
$Eff_{dist,heating,ee}$		Look up in Appendix H for R-6 insulated duct system based on building type, location and duct leakage in cooling mode. For duct leakage values that fall between two values in Appendix H, interpolation is acceptable.
CF	0.69	

Thermal Regain Factor[314]

Some energy loss from poorly sealed and insulated ducts can be regained through conduction back

[314] Home Energy Saver & Score: Engineering Documentation, Thermal Distribution Efficiency

into conditioned spaces. The table below lists default thermal regain factors depending on the location of the ductwork. Ductwork in garages, crawl spaces and under slab should be treated as Unconditioned Basement for Appendix H lookup.

Duct Location	$TRF_{cooling}$	$TRF_{heating}$
Attic	0.10	0.10
Garage	0.10	0.10
Crawl space, unvented, uninsulated	0.60	0.60
Crawl Space, Unvented, Insulated Building Floor and Crawl Space walls	0.60	0.30
Crawl Space, Unvented, Insulated Floor Only	0.30	0.30
Crawl Space, Vented, Uninsulated	0.60	0.55
Crawl Space, Insulated Building Floor and Crawl Space Walls	0.63	0.60
Crawl Space, Vented, Insulated Floor Only	0.30	0.30
Basement, Uninsulated	0.50	0.50
Basement, Insulated Walls	0.60	0.60
Under-slab	0.20	0.20

For duct systems in multiple unconditioned spaces, evaluate the ductwork in each space separately and sum together to calculate the total energy savings. For each equation, use the length of the insulated ductwork in each specific unconditioned space.

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.69.[315]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a ducted HVAC system with insufficient sealing and insulation that has undergone duct-blaster testing. Look up baseline uninsulated distribution system efficiency from Appendix H based on building type, location and duct total leakage. For duct leakage values that fall between two values in Appendix H, interpolation is acceptable.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a sealed and insulated duct system in a retrofit application that has undergone post-implementation duct-blaster testing. Supply and return ducts shall be insulated to a minimum of R-8 where 3 inches in diameter or greater and R-6 where less than 3 inches in diameter. Total leakage shall be less than or equal to 4 cubic feet per minute per 100 ft^2 of conditioned floor area.[316]

[315] Based on BG&E 'Development of Residential Load Profile for Central Air Conditioners and Heat Pumps' research, the Maryland Peak Definition coincidence factor is 0.69. This study is not publicly available, but is referenced by M. M. Straub, Using Available Information for Efficient Evaluation of Demand-Side Management Programs, Electricity Journal, September 2011 and supported by research conducted by Cadmus on behalf of the TRM Management Committee.

[316] ECCCNYS 2020, R403.3.1 & R403.3.4.

Look up compliance distribution system efficiency from Appendix H based on building type, location and duct total leakage from duct blaster test. Models for HVAC distribution efficiency with R-8 insulation are currently under development; values associated with R-6 shall be used until R-8 data is available.

Operating Hours

Cooling and heating equivalent full-load hours were calculated from a DOE-2.2 simulation of prototypical single and multi-family residential buildings. Operating hour assumptions for the prototypical building models are described in Appendix A. The heating EFLH for residential buildings in NY are shown in Appendix G.

Example Calculation *(Not to be used as default)*

Duct sealing rated at R-6 is installed on 15 feet of a 6" diameter duct system of a vented crawl space under an insulated floor in a single-family home located near Albany. The total length of ductwork is 15 feet. A duct-blaster test conducted prior to implementation indicates total duct leakage of 25%, and follow up duct-blaster test conducted post implementation indicates a total duct leakage of 15%. The home has a 3-ton central electric cooling system with 15 SEER and 12 EER and a 70 kBTU/h gas furnace with 82% AFUE. Annual Electric Energy Savings, Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are calculated as below. Because electric heating is not present, terms related to electric heating impacts are represented with "N/A".

$$\Delta kWh = \frac{l_{duct,uncond}}{l_{duct}} \times \left\{ \left[tons \times \frac{12}{SEER} \times EFLH_{cooling} \times \left(1 - \frac{Eff_{dist,cooling,baseline}}{Eff_{dist,cooling,ee}}\right) \times \left(1 - TRF_{cooling}\right) \right] + N/A \right\}$$

$$\Delta kW = \frac{l_{duct,uncond}}{l_{duct}} \times tons/unit \times \frac{12}{EER} \times \left(1 - \frac{Eff_{dist,cooling,baseline}}{Eff_{dist,cooling,ee}}\right) \times (1 - TRF_{cooling}) \times CF$$

$$\Delta MMBtu = \frac{l_{duct,uncond}}{l_{duct}} \times \frac{kBTU/h_{in}}{1{,}000} \times EFLH_{heating} \times \left(1 - \frac{Eff_{dist,heating,baseline}}{Eff_{dist,heating,ee}}\right) \times (1 - TRF_{heating})$$

$l_{duct,uncond}$ = 15, from application
l_{duct} = 15, from application
tons = 3, from application
SEER = 15, from application

$EFLH_{cooling}$ = 310, from Appendix G based on housing type, building vintage, and location from application
$Eff_{dist,cooling,baseline}$ = 0.929, from Appendix H based on duct-blaster test leakage and location
$Eff_{dist,cooling,ee}$ = 0.968, from Appendix H based on duct-blaster test leakage and location
$TRF_{cooling}$ = 0.3, from on Thermal Regain Factor based on insulation location
EER = 12, from application
CF = 0.69, from Summary of Variables and Data Sources table
$kBTU/h_{in}$ = 70, from application
$EFLH_{heating}$ = 978, from Appendix G based on housing type, building vintage, and location from application
$Eff_{dist,cooling,baseline}$ = 0.948, from Appendix H based on duct-blaster test leakage and location
$Eff_{dist,cooling,ee}$ = 0.972, from Appendix H based on duct-blaster test leakage and location
$TRF_{heating}$ = 0.3, from on Thermal Regain Factor based on insulation location

$$\Delta kWh = \frac{15}{15} \times \left\{\left[3 \times \frac{12}{15} \times 310 \times \left(1 - \frac{0.929}{0.968}\right) \times (1 - 0.3)\right] + 0\right\} = 21.0\ kWh$$

$$\Delta kW = \frac{15}{15} \times 3 \times \frac{12}{12} \times \left(1 - \frac{0.929}{0.968}\right) \times (1 - 0.3) \times 0.69 = 0.0584\ kW$$

$$\Delta MMBtu = \frac{15}{15} \times \frac{70}{1{,}000} \times 978 \times \left(1 - \frac{0.948}{0.972}\right) \times (1 - 0.3) = 1.18\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. Home Energy Saver & Score: Engineering Documentation, Thermal Distribution Efficiency
   Available from: http://hes-documentation.lbl.gov/calculation-methodology/calculation-of-energy-consumption/heating-and-cooling-calculation/thermal-distribution-efficiency/thermal-distribution-efficiency

2. BG&E, Development of Residential Load Profile for Central Air Conditioners and Heat Pumps

3. ECCCNYS 2020 R403.3.1: Insulation (Prescriptive) & R403.3.4: Duct Leakage (Prescriptive)
Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-re-residential-energy-efficiency

Record of Revision

Record of Revision Number	Issue Date
1	10/15/2010
6-18-5	6/26/2018

Return to Table of Contents

ELECTRONICALLY COMMUTATED (EC) MOTOR – HVAC BLOWER FAN

Measure Description

This measure covers the retrofit of direct-drive Permanent Split Capacitor (PSC) motors with the installation of Electronically Commutated (EC) motors on fossil fuel-fired furnace distribution system supply fans in residential applications. Energy savings are realized through reductions in fan power due to improved motor efficiency.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times (\Delta kWh/unit)$$

Summer Peak Coincident Demand Savings

$$\Delta kW = units \times (\Delta kW/unit) \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

where:

ΔkWh = Annual electric energy savings
ΔkW = Peak coincident demand electric savings
ΔMMBtu = Annual fossil fuel energy savings
units = Number of motors installed under the program
(ΔkWh/unit) = Annual electric savings per motor installed
(ΔkW/unit) = Electric demand savings per motor installed
CF = Coincidence factor

Summary of Variables and Data Sources

Variable	Value	Notes
(ΔkWh/unit)		Lookup based on location and HVAC system type in table below.[317]
(ΔkW/unit)	Central AC: 0.117 No Central AC: 0	Derived from Focus on Energy evaluation.[318]
CF	0.68	

The deemed annual electric energy savings are determined for each New York location by scaling the energy savings derived from the evaluation of a 2014 Wisconsin ECM metering study using

[317] Cadmus Group, Focus on Energy Evaluated Deemed Savings Changes, November 2014
[318] Ibid.

heating degree days and cooling degree days for each location.[319] The Wisconsin study metered furnaces in 67 homes in Wisconsin in 2012 and 2013.

The total energy savings for each New York location are provided in the "Total" columns below. The energy savings are determined by summing the savings attributed to each furnace mode: circulation, heating and cooling. Homes with a central A/C receive the savings in the "Total (with Central A/C)" column. Homes without a central A/C receive the savings in the "Total (without Central A/C)": these savings exclude the "Cooling Mode" savings. The HDD and CDD values are based on 30-year averages of U.S annual climate normal for the period of 1981 to 2010 using base 65° F.[320]

City	Annual Energy Saved (ΔkWh/unit)					HDD	CDD
	Total (with Central A/C)	Total (without Central A/C)	Circulation Mode	Heating Mode	Cooling Mode		
Albany	404	333	211	122	71	6,680	597
Binghamton	388	342	211	131	46	7,193	382
Buffalo	397	332	211	121	65	6,617	544
Massena	404	361	211	150	43	8,196	363
NYC	435	296	211	85	139	4,671	1,160
Poughkeepsie	404	324	211	113	80	6,210	671
Syracuse	401	333	211	122	68	6,651	570

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.68.[321]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a residential furnace (with or without central AC) with a direct-drive PSC distribution system blower motor.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a residential furnace (with or without central AC) with an EC distribution system blower motor.

Operating Hours

While deemed savings are associated with operating hours, savings values are established based on a comparison of heating and cooling degree days for various locations in NY state and Wisconsin. As such, operating hours are not directly applied in the methodology prescribed for

[319] The percent difference in HDD is applied to the Heating Mode column kWh savings and the percent difference in the CDD is applied to the Cooling Mode column kWh savings.
[320] Annual/Seasonal Normals taken from http://www.ncdc.noaa.gov/cdo-web/datatools/normals
[321] Cadmus Group, Focus on Energy Evaluated Deemed Savings Changes, November 2014

this measure, though they are embedded in the derivation of deemed savings. Circulation mode savings and by association, operating hours, are assumed to align with findings of the Wisconsin ECM metering study. Thus, savings associated with circulation-only mode are equivalent across all climate zones.

Example Calculation *(Not to be used as default)*

A PSC motor driving a central AC w/ gas furnace supply fan is replaced by an EC motor in a single family home located near Albany. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

$$\Delta kWh = units \times (\Delta kWh/unit)$$

$$\Delta kW = units \times (\Delta kW/unit) \times CF$$

units = 1, from application
(ΔkWh/unit) = 404, from Annual Energy Saved (ΔkWh/unit) table based on location and conditions from application
(ΔkW/unit) = 0.117, from Summary of Variables and Data Sources table
CF = 0.68, from Summary of Variables and Data Sources table

$$\Delta kWh = 1 \times 404 = 404\ kWh$$

$$\Delta kW = 1 \times 0.117 \times 0.68 = 0.0796\ kW$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. Cadmus Group, Inc., Focus on Energy Evaluated Deemed Savings Changes, prepared for The Public Service Commission of Wisconsin, November 14, 2014
   Available from:
   https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf

2. Cadmus Group, Inc., June 4, 2014 ECM Metering Results Memo. Delivered to Carol Stemrich, PSC of Wisconsin.
3. NOAA National Centers for Environmental Information – 1981-2010 Normals. Available from: http://www.ncdc.noaa.gov/cdo-web/datatools/normals

Record of Revision

Record of Revision Number	Issue Date
0	10/15/2010
1	3/31/2016
6-16-2	6/30/2016
12-17-7	12/31/2017

Return to Table of Contents

ELECTRONICALLY COMMUTATED (EC) MOTOR – HYDRONIC CIRCULATOR PUMP

Measure Description

This measure covers the retrofit of standard efficiency permanent split capacitor (PSC) motors with electronically commutated (EC) motors in hydronic distribution circulators in residential heating and cooling systems. A circulator pump is a specific type of pump used to circulate liquids in a closed distribution system. They are commonly found circulating water in a hydronic heating or cooling system.

Circulator pumps used in hydronic systems are usually electrically powered centrifugal pumps. When used in homes, they are often small, sealed, and rated at a fraction of a horsepower. The sealed units used in home applications often have the motor rotor, pump impeller, and support bearings combined and sealed within the water circuit. This avoids one of the principal challenges faced by the larger, two-part pumps: maintaining a water-tight seal at the point where the pump drive shaft enters the pump body.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = \Delta kWh_{cooling} + \Delta kWh_{heating}$$

$$\Delta kWh_{cooling} = units \times hp \times \left(\frac{1}{Eff_{baseline}} - \frac{1}{Eff_{ee}}\right) \times LF \times 0.746 \left(\frac{kW}{hp}\right) \times hrs_{cooling}$$

$$\Delta kWh_{heating} = units \times hp \times \left(\frac{1}{Eff_{baseline}} - \frac{1}{Eff_{ee}}\right) \times LF \times 0.746\ (kW/hp) \times hrs_{heating}$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \frac{\Delta kWh}{hours} \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
hp	= Efficient circulator motor horsepower
baseline	= Characteristic of baseline condition
ee	= Characteristic of energy efficient condition
Eff	= Efficiency
LF	= Load factor

$hrs_{heating}$ = Operating hours during the heating season
$hrs_{cooling}$ = Operating hours during the cooling season
CF = Coincidence factor
0.746 = Conversion factor (kW/hp), 746 watts equals one electric horsepower

Summary of Variables and Data Sources

Variable	Value	Notes
hp		From application.
$Eff_{baseline}$	0.60	Baseline PSC motor efficiency[322]
Eff_{ee}	0.80	Efficient EC motor efficiency[323]
LF	0.9	Assumed value to reflect that motors do not typically run at 100% of rated power.
$hrs_{heating}$	3,504	Heating based on Assessment of New Energy Efficient Circulator Pump Technology. [324]
$hrs_{cooling}$	2,208	Cooling assumes three months (92 days) of 24 hour operation
CF	Heating: N/A Cooling: 0.8	

Coincidence Factor (CF)

The prescribed value for the coincidence factor for heating is N/A.
The prescribed value for the coincidence factor for cooling is 0.8.[325]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a hydronic circulator pump operating with a standard permanent split-capacitor (PSC) motor in a residential heating and/or cooling system.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a hydronic circulator pump operating with a high efficiency EC motor in a residential heating and/or cooling system. High efficiency circulators may include better impeller design that will further increase kWh savings, but these benefits are not considered in the prescribed savings estimation methodology.

Operating Hours

Annual circulator operating hours in a hydronic heating system are assumed to be 3,504, based on

[322] US DOE, Energy Savings Potential and Opportunities for High-Efficiency Electric Motors in Residential and Commercial Equipment, Table 2.1 Summary of Single-Phase AC Induction Motor Characteristics - Efficiency of the baseline condition is taken as the average full load efficiency rating range for a PSC motor.
[323] ACHR News, Comparing Motor Technologies, December 2009
[324] Assessment of New Energy Efficient Circulator Pump Technology, pg 4-3. Assumed circulator pump is utilized 40% of the year (0.40*8,760 = 3,504).
[325] *No source specified – update pending availability and review of applicable references.*

assumed 40% utilization of circulator pump. Savings will be less if the circulator cycles on and off with calls for heating.

Annual circulator operating hours in a hydronic cooling system are assumed to be 2,208, reflective of utilization of cooling systems for three months out of the year.

Example Calculation *(Not to be used as default)*

A ¼ hp PSC circulator pump motor in a hydronic heating system is replaced with an EC motor in a low-rise multifamily building. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

$$\Delta kWh = units \times hp \times \left(\frac{1}{Eff_{baseline}} - \frac{1}{Eff_{ee}}\right) \times LF \times 0.746\ (kW/hp) \times hrs$$

$$\Delta kW = \frac{\Delta kWh}{hours} \times CF$$

units = 1, from application
hp = 0.25, from application
$Eff_{baseline}$ =0.60, from Summary of Variables and Data Sources table
Eff_{ee} = 0.80, from Summary of Variables and Data Sources table
LF = 0.9, from Summary of Variables and Data Sources table
hrs = 3,504, from Summary of Variables and Data Sources table based on application
CF = 0.8, from Summary of Variables and Data Sources table

$$\Delta kWh = 1 \times 0.25 \times \left(\frac{1}{0.60} - \frac{1}{0.80}\right) \times 0.9 \times 0.746 \times 3{,}504 = 245.06\ kWh$$

$$\Delta kW = \frac{245.06}{3{,}504} \times 0.8 = 0.07\ kW$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Higher efficiency circulators may lead to increased fuel consumption. Reduction in waste heat from increased efficiency in motors results in additional heating requirement. These effects are not quantified in this methodology.

Ancillary Electric Savings Impacts

Higher efficiency circulators may lead to reduced electric consumption. Reduction in waste heat from increased efficiency in motors results in decreased cooling requirement. These effects are not quantified in this methodology.

References

1. Energy Savings Potential and Opportunities for High-Efficiency Electric Motors in Residential and Commercial Equipment, Building Technologies Office, US Department of Energy. December 2013.
   Available from:
   https://www.energy.gov/sites/prod/files/2014/02/f8/Motor%20Energy%20Savings%20Potential%20Report%202013-12-4.pdf
2. ACHR News, Comparing Motor Technologies, December 2009
   Available from: https://www.achrnews.com/articles/112674-comparing-motor-technologies
3. Assessment of New Energy Efficient Circulator Pump Technology, Electric Power Research Institute, November 2010
   Available from:
   https://publicdownload.epri.com/PublicDownload.svc/product=000000000001020132/type=Product

Record of Revision

Record of Revision Number	Issue Date
0	10/15/2010
6-18-4	6/26/2018

Return to Table of Contents

ENERGY AND HEAT RECOVERY VENTILATOR

Measure Description

This measure covers the installation of Energy Recovery Ventilators (ERV) and Heat Recovery Ventilators (HRV). ERVs and HRVs reduce heating and cooling loads while maintaining required ventilation rates by facilitating heat transfer between outgoing conditioned air and incoming outdoor air. ERVs and HRVs employ air-to-air heat exchangers to recover energy from exhaust air for the purpose of pre-conditioning outdoor air prior to supplying the conditioned air to the space, either directly or as part of an air-conditioning system.[326] This measure only applies in cases where ERV/HRV functionality is not required by federal, state, local or municipal codes or standards. For the purposes of this measure, ERVs and HRVs are distinguished as follows:

Energy Recovery Ventilator (ERV)
Transfers both sensible (heat content) and latent (moisture content) heat between supply and exhaust airstreams.

Heat Recovery Ventilator (HRV)
Transfers sensible heat only between supply and exhaust airstreams.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings (for ERVs)

Annual Electric Energy Savings

$$\Delta kWh = units \times \left(\Delta kWh_{cooling} + \Delta kWh_{heating}\right)$$

$$\Delta kWh_{cooling} = \left[\left(\frac{4.5 \times CFM \times Eff_{hx,total} \times \left(H_{outdoor,cooling} - H_{indoor,cooling}\right)}{1{,}000 \times Eff_{ElecCool}}\right) - kW_{fan}\right] \times hrs_{cooling} \times \frac{min/hr}{60}$$

$$\Delta kWh_{heating} = \left[\left(\frac{1.08 \times CFM \times Eff_{hx,sens} \times \left(T_{indoor,heating} - T_{outdoor,heating}\right)}{1{,}000 \times Eff_{ElecHeat}} \times F_{ElecHeat}\right) - kW_{fan}\right] \times hrs_{heating} \times \frac{min/hr}{60}$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \left[\left(\frac{4.5 \times CFM \times Eff_{hx,total} \times \left(H_{outdoor,cooling} - H_{indoor,cooling}\right)}{1{,}000 \times Eff_{ElecCool}}\right) - kW_{fan}\right] \times CF$$

[326] AHRI GUIDELINE V (I-P)-2011 Calculating the Efficiency of Energy Recovery Ventilation and its Effect on Efficiency and Sizing of Building HVAC Systems

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = \frac{1.08 \times CFM \times Eff_{hx,sens} \times \left(T_{indoor,heating} - T_{outdoor,heating}\right)}{1{,}000{,}000 \times Eff_{FuelHeat}} \times F_{FuelHeat} \times hrs_{heating} \times \frac{min/hr}{60}$$

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings (for HRVs)

Annual Electric Energy Savings

$$\Delta kWh = units \times \left(\Delta kWh_{cooling} + \Delta kWh_{heating}\right)$$

$$\Delta kWh_{cooling} = \left[\left(\frac{1.08 \times CFM \times Eff_{hx,sens} \times \left(T_{outdoor,cooling} - T_{indoor,cooling}\right)}{1{,}000 \times Eff_{ElecCool}}\right) - kW_{fan}\right] \times hrs_{cooling} \times \frac{min/hr}{60}$$

$$\Delta kWh_{heating} = \left[\left(\frac{1.08 \times CFM \times Eff_{hx,sens} \times \left(T_{indoor,heating} - T_{outdoor,heating}\right)}{1{,}000 \times Eff_{ElecHeat}} \times F_{ElecHeat}\right) - kW_{fan}\right] \times hrs_{heating} \times \frac{min/hr}{60}$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \left[\left(\frac{1.08 \times CFM \times Eff_{hx,sens} \times \left(T_{outdoor,cooling} - T_{indoor,cooling}\right)}{1{,}000 \times Eff_{ElecCool}}\right) - kW_{fan}\right] \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = \frac{1.08 \times CFM \times Eff_{hx,sens} \times \left(T_{indoor,heating} - T_{outdoor,heating}\right)}{1{,}000{,}000 \times Eff_{FuelHeat}} \times F_{FuelHeat} \times hrs_{heating} \times \frac{min/hr}{60}$$

where:

$$kW_{fan} = \sum\left(\frac{CFM \times \Delta P}{\frac{33{,}013}{5.202} \times Eff_{fanmech} \times Eff_{fanmotor}} \times 0.746\right)$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
$\Delta MMBtu$	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
kW_{fan}	= Total electric power of ERV/HRV supply and exhaust fans (kW). Sigma operator included to indicate that this term shall include consideration of all ERV/HRV fans.
heating	= Property of heating season
cooling	= Property of cooling season
CFM	= Volume of supply air in Cubic Feet per Minute
CF	= Coincidence Factor
$Eff_{hx,total}$	= Total effectiveness of heat exchanger per rating in accordance with AHRI Standard 1060 [327]
$Eff_{hx,sens}$	= Sensible effectiveness of heat exchanger per rating in accordance with AHRI Standard 1060
$Eff_{ElecCool}$	= Seasonal average energy efficiency of electric cooling equipment, BTU/watt-hour, using either SEER (<65,000 BTU/h) or IEER (≥65,000 BTU/h)
$Eff_{ElecHeat}$	= Seasonal average energy efficiency of electric heating equipment. Heating Seasonal Performance Factor, BTU/watt-hour, total heating output (supply heat) in BTU (including resistance heating) during the heating season / total electric energy heat pump consumed (in watt-hour); if equipment efficiency is reported in COP, convert to HSPF using the equivalency HSPF = COP x 3.412
$Eff_{FuelHeat}$	= Efficiency of fossil fuel heating equipment (AFUE, Et, or Ec)
$Eff_{fanmech}$	= Mechanical efficiency of ERV fans
$Eff_{fanmotor}$	= Efficiency of ERV fan motors
$F_{ElecHeat}$	= Electric heating factor, used to account for the presence or absence of an electric heating system
$F_{FuelHeat}$	= Fossil fuel heating factor, used to account for the presence or absence of a fossil fuel heating system
T_{indoor}	= Indoor air temperature, in °F
$T_{outdoor}$	= Outdoor air temperature, in °F
ΔP	= Pressure drop at nominal airflow in the ERV as rated in accordance with AHRI Standard 1060, in inches of water.
$H_{outdoor}$	= Enthalpy of outside air in BTU/lb
H_{indoor}	= Enthalpy of inside air at 70°F, in BTU/lb
$hrs_{heating}$	= Operating hours in the heating season
$hrs_{cooling}$	= Operating hours in the cooling season
min/hr	= Run time of ERV/HRV unit in minutes per hour, as configured by the installing contractor
4.5	= Density of inlet air at 70ºF x 60 min/hr, in lb-min/ft^3-hr

[327] Performance Rating of air-to-air exchanges for Energy Recovery Ventilation Equipment http://www.ahrinet.org/ERVcertification

1.08	= Specific heat of air × density of inlet air @ 70˚F × 60 min/hr[328] in BTU/h-ºF-CFM
1,000,000	= Conversion factor, one MMBtu equals 1,000,000 BTU
33,013	= Conversion factor from horsepower to ft.lb/min
5.202	= Conversion factor from inches of water to pounds per square ft (lb/sq.ft)
0.746	= Conversion factor (kW/hp), 746 watts equals one electric horsepower
60	= Minutes in one hour
1,000	= Conversion factor, one kW equals 1,000 Watts

Summary of Variables and Data Sources

Variable	Value	Notes
CFM		From application.
$Eff_{hx,total}$		From application.
$Eff_{hx,sens}$		From application.
$Eff_{ElecCool}$		From application or use 14 SEER, assuming a 3-ton central ASHP system.[329]
$Eff_{FuelHeat}$		From application, E_c, E_t, or AFUE shall be used, based on nameplate rating metric of existing equipment. If unknown, lookup in tables below based on equipment type and size.
$Eff_{ElecHeat}$		From application or use 8.2 HSPF, assuming a 3-ton central ASHP system. [330] For electric resistance heating and electric furnaces, use 3.4 HSPF. If taken from application, COP must be converted to HSPF using the equivalency HSPF = COP x 3.412.
$Eff_{fanmech}$		From application; if unknown use 0.67.[331]
$Eff_{fanmotor}$		Efficiency of supply and exhaust fan components of the ERV. From application, if unknown use 0.70 based on 1/4hp, 4-pole polyphase motor.[332]
$F_{ElecHeat}$		Use a value of 1.0 if the building is electrically heated. Otherwise, use 0.0.
$F_{FuelHeat}$		Use a value of 1.0 if the building is fossil fuel heated. Otherwise use 0.0.
$H_{outdoor}$		Lookup from Climate Data table below based on location[333]
H_{indoor}		If indoor set temperature is known, lookup from Indoor Enthalpy table below. Otherwise, use 25.3 based on 70°F and 50% RH indoor air conditions.
T_{indoor}		From application or use 70°F

[328] The sensible heat constant at standard conditions of 1.08 is applied in accordance with standard HVAC industry practice. While the underlying assumptions are not representative characteristics of a NY heating season, the impacts to this value due to average heating season temperature and NY mean elevation offset such that the NY heating season specific value is approximately 1.08.
[329] 10 CFR 430.32 (c)(1)
[330] Ibid.
[331] ASHRAE 90.1 2013, Section 6.5.3.1.3
[332] 10 CFR 431.446
[333] NCEI 1981-2010 Annual/Seasonal Climate Normals

Variable	Value	Notes
$T_{outdoor}$		Average of temperatures from the heating and cooling season based on the city. Lookup value from table below.
ΔP		From application.
$hrs_{heating}$		Lookup in the Operating Hours section table below based on location.
$hrs_{cooling}$		Lookup in the Operating Hours section table below based on location.
min/hr		From application.[334]
CF	0.69	

Indoor Enthalpy (H_{indoor})

Temperature (°F)	Relative Humidity	Enthalpy (H_{indoor})
65	50%	22.7
66	50%	23.2
67	50%	23.7
68	50%	24.2
69	50%	24.8
70	50%	25.3
71	50%	25.8
72	50%	26.4
73	50%	27.0
74	50%	27.5
75	50%	28.1
76	50%	28.7
77	50%	29.3
78	50%	29.9

Outdoor Air Temperature & Enthalpy

Look up outdoor air temperature and enthalpy based on the city in the table below. The table below summarizes the average outdoor air temperature and enthalpy during the Heating (<65°F) and Cooling (>65°F) seasons across a typical climatological year.

City	$T_{outdoor,heating}$ (°F)	$T_{outdoor,cooling}$ (°F)	$H_{outdoor,heating}$ (Btu/lb)	$H_{outdoor,cooling}$ (Btu/lb)
Albany	41.90	72.01	11.80	29.57
Binghamton	41.84	70.48	11.30	28.04
Buffalo	42.15	71.22	12.10	28.80

[334] Review of both ASHRAE Standard 62.2 – 2019 and ASHRAE Research Project 1663 "Best Practices for Home Design, Construction, Operation, and Maintenance" reveal that there is no standard guidance for configuring residential ERV operations. Best practices for determining "Minutes/Hour" depend on many variables related to how the ERV/HRV is installed (as part of bathroom exhaust, integrated into the return ductwork of an air-handler, completely decoupled from the home's HVAC system, etc.). As such, a representative value for "Minutes/Hour" of operation cannot easily be characterized and is inspectable.

City	$T_{outdoor,heating}$ (°F)	$T_{outdoor,cooling}$ (°F)	$H_{outdoor,heating}$ (Btu/lb)	$H_{outdoor,cooling}$ (Btu/lb)
Massena	42.61	71.82	12.10	29.18
NYC	45.93	73.69	14.34	30.86
Poughkeepsie	45.18	72.01	13.78	30.66
Syracuse	42.11	71.94	11.94	29.33

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.69.[335]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition for this measure is a single or multi-family dwelling with an ASHRAE 62.2-compliant exhaust fan system with no heat or energy recovery.

The baseline efficiency for fossil fuel fired heating systems serving single-family homes and individual units is defined by the Code of Federal Regulations as shown in the table below.

Fossil Fuel Fired Heating System Baseline Efficiencies: Systems Serving Single Units[336]

Equipment Type	Size Range	ECCCNYS Minimum Efficiency for Climate Zones 4, 5 and 6
Warm Air Furnace, Gas Fired	All Capacities	0.80 AFUE
Warm Air Furnace, Oil Fired	All Capacities	0.83 AFUE
Boiler, Hot Water, Gas Fired	All Capacities	0.82 AFUE
Boiler, Hot Water, Oil Fired	All Capacities	0.84 AFUE
Boiler, Steam, Gas Fired	All Capacities	0.80 AFUE
Boiler, Steam, Oil Fired	All Capacities	0.82 AFUE

The baseline efficiency for heating systems serving multiple dwelling units is defined by International Energy Conservation Code[337] and subsequently adopted by the Energy Conservation Construction Code of New York State (ECCCNYS) as shown in the table below.

[335] Based on BG&E 'Development of Residential Load Profile for Central Air Conditioners and Heat Pumps' research, the Maryland Peak Definition coincidence factor is 0.69. This study is not publicly available, but is referenced by M. M. Straub, Using Available Information for Efficient Evaluation of Demand-Side Management Programs, Electricity Journal, September 2011 and supported by research conducted by Cadmus on behalf of the RM Management Committee.
[336] 10 CFR 430.32(e)
[337] ECCCNYS 2020, Table C403.3.2(4) & Table C403.3.2(5)

Fossil Fuel Fired Heating System Baseline Efficiencies: Systems Serving Multiple Dwelling Units

Equipment Type	Size Range	ECCCNYS Minimum Efficiency for Climate Zones 4, 5 and 6
Warm Air Furnace, Gas Fired	< 225 kBTU/h	0.80 AFUE
	≥ 225 kBTU/h	0.80 Et
Warm Air Furnace, Oil Fired	< 225 kBTU/h	0.83 AFUE
	≥ 225 kBTU/h	0.80 Et
Warm Air Unit Heaters, Gas Fired	All Capacities	0.80 Ec
Warm Air Unit Heaters, Oil Fired	All Capacities	0.80 Ec
Boiler, Hot Water, Gas Fired	< 300 kBTU/h	0.82 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.80 Et
	> 2,500 kBTU/h	0.82 Ec
Boiler, Hot Water, Oil Fired	< 300 kBTU/h	0.84 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.82 Et
	> 2,500 kBTU/h	0.84 Ec
Boiler, Steam, Gas Fired, All Except Natural Draft	< 300 kBTU/h	0.80 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.79 Et
	> 2,500 kBTU/h	0.79 Et
Boiler, Steam, Gas Fired, Natural Draft	< 300 kBTU/h	0.80 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.77 Et
	> 2,500 kBTU/h	0.77 Et
Boiler, Steam, Oil Fired	< 300 kBTU/h	0.82 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.81 Et
	> 2,500 kBTU/h	0.81 Et

Compliance Efficiency from which Incentives are Calculated

The compliance condition for this measure is a single or multi-family dwelling with an ASHRAE 62.2-compliant exhaust fan system equipped with AHRI certified ERV or HRV components.

Operating Hours

Look up hours based on city in the table below. The table below summarizes the sum of heating and cooling hours across a typical climatological year.[338,339]

City	$hrs_{heating}$	$hrs_{cooling}$
Albany	5,673	1,571
Binghamton	5,788	1,266

[338] Using 65°F as the balance point, the cooling season is defined as when outdoor air temperature is above 65°F for the months of June through August and the heating season is defined as when outdoor air temperature is below 65°F for the months of October through April. Temperature values are based on the average of temperature during the cooling and heating seasons, respectively.

[339] NOAA National Center for Environmental Information – NCEI 1981 – 2010 Annual/Seasonal Climate Normals

City	$hrs_{heating}$	$hrs_{cooling}$
Buffalo	5,774	1,643
Massena	5,744	1,462
NYC	5,560	2,157
Poughkeepsie	5,683	1,973
Syracuse	5,709	1,523

Example Calculation *(Not to be used as default)*

An ERV delivering 200 CFM is installed in a high-rise multifamily building located near Albany constructed in 1965. The ERV has a sensible effectiveness of 88% and total effectiveness of 68%, and runtime is set at 50%, operating 30 minutes per hour. The building is cooled by a central air conditioner with 13 SEER and heated by an 80% thermal efficient gas furnace, where the indoor cooling temperature is set at 70ºF and the indoor heating temperature is set at 70ºF. The ERV fan has a motor efficiency of 80%, a mechanical efficiency of 65%, and a pressure drop of 0.4 inches of water. Annual Electric Energy Savings, Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta kWh = units \times \left(\Delta kWh_{cooling} + \Delta kWh_{heating}\right)$$

$$\Delta kWh_{cooling} = \left[\left(\frac{4.5 \times CFM \times Eff_{hx,total} \times \left(H_{outdoor,cooling} - H_{indoor,cooling}\right)}{1{,}000 \times Eff_{ElecCool}}\right) - kW_{fan}\right] \times hrs_{cooling} \times \frac{min/hr}{60}$$

$$\Delta kWh_{heating} = \left[\left(\frac{1.08 \times CFM \times Eff_{hx,sens} \times \left(T_{indoor,heating} - T_{outdoor,heating}\right)}{1{,}000 \times Eff_{ElecHeat}} \times F_{ElecHeat}\right) - kW_{fan}\right] \times hrs_{heating} \times \frac{min/hr}{60}$$

$$\Delta kW = \left[\left(\frac{4.5 \times CFM \times Eff_{hx,sens} \times \left(H_{outdoor,cooling} - H_{indoor,cooling}\right)}{1{,}000 \times Eff_{ElecCool}}\right) - kW_{fan}\right] \times CF$$

$$\Delta MMBtu = \frac{1.08 \times CFM \times Eff_{hx,sens} \times \left(T_{indoor,heating} - T_{outdoor,heating}\right)}{1{,}000{,}000 \times Eff_{FuelHeat}} \times F_{FuelHeat} \times hrs_{heating} \times \frac{min/hr}{60}$$

where:

$$kW_{fan} = \sum \left(\frac{CFM \times \Delta P}{\frac{33{,}013}{5.202} \times Eff_{fanmech} \times Eff_{fanmotor}} \times 0.746 \right)$$

units = 1, from application
CFM = 200, from application
$Eff_{hx,total}$ = 0.68, from application
$H_{outdoor,cooling}$ = 29.57 BTU/lb, from Outdoor Air Temperature & Enthalpy table based on location from application
$H_{indoor,cooling}$ = 25.3 BTU/lb, from on Indoor Enthalpy table based on indoor temperature from application
$Eff_{ElecCool}$ = 13, from application
kW_{fan} = (200 x 0.4) / (33,013/5.202 x 0.65 x 0.80) x 0.746 = 0.018
ΔP = 0.4, from application
$Eff_{fanmech}$ = 0.65, from application
$Eff_{fanmotor}$ = 0.80, from application
$hrs_{cooling}$ = 1,571, from Operating Hours table based on location from application
min/hr = 30, from application
$Eff_{hx,sens}$ = 0.88, from application
$T_{indoor,heating}$ = 70ºF, from application
$T_{outdoor,heating}$ = 41.90ºF, from Outdoor Air Temperature & Enthalpy table based on location from application
$Eff_{ElecHeat}$ = N/A, from application
$F_{ElecHeat}$ = 0, from application
$hrs_{heating}$ = 5,673, from Operating Hours table based on location from application
CF = 0.69, from Summary of Variables and Data Sources table
$Eff_{FuelHeat}$ = 0.80, from application
$F_{FuelHeat}$ = 1, from application

$$kW_{fan} = \sum \left(\frac{200 \times 0.4}{\frac{33{,}013}{5.202} \times 0.65 \times 0.80} \times 0.746 \right) = 0.018\ kW$$

$$\Delta kWh_{cooling} = \left[\left(\frac{4.5 \times 200 \times 0.68 \times (29.57 - 25.3)}{1{,}000 \times 13} \right) - 0.018 \right] \times 1{,}571 \times \frac{30}{60} = 143.76\ kWh$$

$$\Delta kWh_{heating} = (0 - 0.018) \times 5{,}673 \times \frac{30}{60} = -51.06\ kWh$$

$$\Delta kWh = 1 \times (143.76 + (-51.06\ ) = 92.7\ kWh$$

$$\Delta kW = \left[\left(\frac{4.5 \times 200 \times 0.68 \times (29.57 - 25.3)}{1{,}000 \times 13}\right) - 0.018\right] \times 0.69 = 0.13\ kW$$

$$\Delta MMBtu = \frac{1.08 \times 200 \times 0.88 \times (69 - 41.9)}{1{,}000{,}000 \times 0.80} \times 1 \times 5{,}673 \times \frac{30}{60} = 18.94\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Employing ERVs in the winter may exchange latent heat decreasing the need to run a humidifier, but the impact is expected to be negligible and is not quantified in the prescribed estimation methodology for this measure at this time.

References

1. ECCCNYS 2020 Table C403.3.2(4): Warm-Air Furnaces And Combination Warm-Air Furnaces/Air-Conditioning Units, Warm-Air Duct Furnaces And Unit Heaters, Minimum Efficiency Requirements
   Available from https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-[ce]-commercial-energy-efficiency#NYSECC2020P1_CE_Ch04_SecC403
2. 10 CFR 430.32 Energy and water conservation standards and their compliance dates.
   Available from: http://www.ecfr.gov/cgi-bin/text-idx?SID=a9921a66f2b4f66a32ec851916b7b9d9&mc=true&node=se10.3.430_132&rgn=div8
3. 10 CFR 431.446 Small electric motors energy conservation standards and their effective dates.
   Available from: https://gov.ecfr.io/cgi-bin/text-idx?SID=6fb7b94f1b9d3af4accb978144ba015c&mc=true&node=se10.3.431_1446&rgn=div8
4. AHRI GUIDELINE V (I-P)-2011 Calculating the Efficiency of Energy Recovery Ventilation and its Effect on Efficiency and Sizing of Building HVAC Systems Available from: http://www.ahrinet.org/App_Content/ahri/files/Guidelines/AHRI_Guideline_V_I-P_2011.pdf
5. NOAA National Center for Environmental Information – NCEI 1981 – 2010 Annual/Seasonal Climate Normals
   Available from: https://www.ncdc.noaa.gov/cdo-web/datatools/normals
6. BG&E: Development of Residential Load Profile for Central Air Conditioners and Heat Pumps

7. ASHRAE Standard 90.1-2013, Energy Standard for Buildings Except Low-Rise Residential Buildings (I-P) Edition.
8. Performance Rating of air-to-air exchanges for Energy Recovery Ventilation Equipment. Available from: http://www.ahrinet.org/ERVcertification

Record of Revision

Record of Revision Number	Issue Date
7-20-2	7/31/2020

Return to Table of Contents

HEAT PUMP – AIR SOURCE (CCASHP)

Measure Description

This measure covers the installation of cold climate Air Source Heat Pump (ccASHP) systems that provide heating and cooling for space conditioning in residential homes.[340,341] An air source heat pump is a product, other than a packaged terminal heat pump, which is powered by single phase electric current, air cooled, not contained within the same cabinet as a furnace with rated capacity above 225,000 BTU/h, and operates as a heat pump in both heating and cooling mode. This measure applies to central ducted systems, single zone split-systems with ductless indoor units that may be wall-mounted, floor-mounted, or ceiling-mounted and multi-zone split systems with one outdoor section and multiple indoor sections. These indoor sections may be a combination of ductless or compact ducted units.

This measure is based on several assumptions consistent with best practice design for a quality ASHP installation:

- Residential NYS code and Federal Standard (ECCCNYS 2020, Code of Federal Regulations 10 CFR 430.32) or local legislation applicable at the time of installation should be referenced for correct baseline system and efficiency values.

- Systems shall be sized in accordance with ACCA Manual S based on building design loads calculated in accordance with ACCA Manual J or other approved heating and cooling calculation methodologies.[342,343]

- The building design heating load in New York typically exceeds the design cooling load, therefore it is assumed that the ASHP is sized for the building or zone heat load.

The applicability of this measure for a whole-house application is limited to an ASHP system that is sized and installed to provide between 90% and 120% of the design heating load.[344] For a whole house application scenario, when the system is sized such that supplemental electric resistance heat is included within the heat pump to help meet the design heating load, the efficiency of the resistance heating is assumed to be equal to 1 in this analysis. Smaller system sizes are allowable for heating displacement applications in conformance with the NEEP *Guide to Sizing & Selecting Air-Source Heat Pumps in Cold Climates*[345].

The ASHP efficiency must meet the Northeast Energy Efficiency Partnerships (NEEP) Cold Climate Air Source Heat Pump (ccASHP) Specification (Version 3.0) effective January 1, 2019. The specification uses AHRI-certified performance ratings and manufacturer reported data to

[340] NEEP Cold Climate Air Source Heat Pump (ccASHP) Specification (Version 3.0) effective January 1, 2019
[341] "Residential homes" means detached one- and two-family dwellings and townhouses not more than three stories above-grade in height with a separate means of egress and their accessory structures, and one-family dwellings converted to bed and breakfast dwellings.
[342] ECCCNYS 2020, Section R403.7
[343] ECCCNYS 2020 requires that systems serving multiple dwelling units follow Sections C403 and C404.
[344] Code reference above. The 90% minimum does not include supplemental heat. Note that Manual S allows use of *low-speed* cooling capacity to determine the cooling size limit of 115% of design total cooling load.
[345] neep.org/sites/default/files/Sizing & Selecting ASHPs In Cold Climates.pdf

describe the efficiency and capacity of the unit under full and part load conditions. This equipment is rated under ANSI/AHRI 210/240.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = \left(\left(BCL \times \frac{1}{1{,}000} \times \left(\frac{1}{SEER_{baseline}} - \frac{1}{EER_{season,ee}}\right) \times BEFLH_{cooling} \times F_{load,cooling}\right) + \left(BHL \times \frac{1}{1{,}000} \times \left(\frac{F_{ElecHeat}}{COP_{season,baseline}} - \frac{1}{COP_{season,ee}}\right) \times \frac{1}{3.412} \times BEFLH_{heating} \times F_{load,heating,ElecHeat}\right) - \left(BHL \times \frac{1}{1{,}000} \times F_{ElecHeat,new} \times \frac{1}{3.412} \times BEFLH_{heating} \times \left(1 - F_{load,heating}\right)\right)\right)$$

Summer Peak Coincident Demand Savings

$$\Delta kW = BCL \times \frac{1}{1{,}000} \times \left(\frac{1}{EER_{baseline}} - \frac{1}{EER_{ee}}\right) \times F_{load,cooling} \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = BHL \times \frac{1}{1{,}000{,}000} \times \frac{F_{FuelHeat}}{AFUE_{baseline}} \times BEFLH_{heating} \times F_{load,heating,FuelHeat}$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
BCL	= Building Cooling Load at design conditions (BTU/h)
BHL	= Building Heating Load at design conditions (BTU/h)
$F_{ElecHeat}$	= Electric heating factor; used to account for the presence or absence of an electric heating system
$F_{ElecHeat,new}$	= New electric heating factor; used to account for a new heat pump's reliance on supplemental electric resistance heat to meet full heating load
$F_{FuelHeat}$	= Fossil fuel heating factor; used to account for the presence or absence of a fossil fuel heating system
baseline	= Characteristic of baseline condition
ee	= Characteristic of energy efficient condition
SEER	= Seasonal average energy efficiency ratio over the cooling season, BTU/watt-hour, used for average U.S. location/region
EER	= Full load energy efficiency ratio (BTU/watt-hour)
EER_{season}	= Seasonally adjusted average energy efficiency (BTU/watt-hour)
COP	= Coefficient of performance for heating, ratio of output energy/input energy
COP_{season}	= Seasonally adjusted average coefficient of performance

AFUE = Annual fuel utilization efficiency, seasonal efficiency for fossil fuel heating equipment
$BEFLH_{cooling}$ = Cooling equivalent full-load hours based on building design load
$BEFLH_{heating}$ = Heating equivalent full-load hours based on building design load
$F_{load,cooling}$ = Adjustment factor to account for the portion of the seasonal[346] cooling load met by the heat pump
$F_{load,heating}$ = Adjustment factor to account for the portion of the seasonal[347] heating load met by the heat pump
$F_{load,heating,ElecHeat}$ = Electric heating adjustment factor to account for the portion of the seasonal heating load met by the heat pump
$F_{load,heating,FuelHeat}$ = Fossil fuel heating adjustment factor to account for the portion of the seasonal heating load met by the heat pump
CF = Coincidence Factor
3.412 = Conversion factor, one watt-hour equals 3.412 BTU
1,000 = Conversion factor, one kilowatt equals 1,000 watts
1,000,000 = Conversion factor, one MMBtu equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
BCL		Building cooling load at design conditions, from application
BHL		Building heating load at design conditions, from application
$F_{ElecHeat}$		If the baseline heating system is an electric system, set equal to 1. Otherwise, set equal to 0.
$F_{ElecHeat,new}$		If the efficient case heat pump system relies on newly installed supplemental electric resistance heat capacity to meet the peak load, set equal to 1. Otherwise, set equal to 0.
$F_{FuelHeat}$		If the baseline heating system is a fossil fuel system, set equal to 1. Otherwise, set equal to 0.
$SEER_{baseline}$		Electric cooling seasonal energy efficiency rating of baseline equipment. See Baseline Efficiencies section below for details.
$EER_{baseline}$		Electric cooling full load energy efficiency rating of baseline equipment. See Baseline Efficiencies section below for details.
EER_{ee}		Electric cooling full load energy efficiency rating of efficient equipment. See Compliance Efficiency section below for details.
$EER_{season,ee}$		Seasonally adjusted energy efficiency ratio of the efficient equipment. See Compliance Efficiency section below for details.

[346] Fraction of annual (vs. design) cooling load served by the equipment as shown in the Cooling Load Factor table.
[347] Fraction of annual (vs. design) heating load served by the equipment as shown in the Heating Load Factor table.

Variable	Value	Notes
$COP_{season,baseline}$		Seasonally adjusted Coefficient of Performance of the baseline equipment. The assumed COP of an electric resistance/electric furnace system is 1.0. If the baseline is a conventional ASHP[348], use the baseline calculations below.
$COP_{season,ee}$		Seasonally adjusted Coefficient of Performance of the efficient equipment. See Compliance Efficiency section below for details.
$AFUE_{baseline}$		Seasonal fuel energy efficiency of the baseline equipment. See Baseline Efficiency section below for details.
$BEFLH_{cooling}$		Lookup based on building type, vintage and location from the appropriate table in the Operating Hours section below.
$BEFLH_{heating}$		Lookup based on building type, vintage and location from the appropriate table in the Operating Hours section below.
$F_{load,cooling}$		Lookup based on equipment sizing and control parameters from the Cooling Load Factor table below.
$F_{load,heating}$		Lookup based on equipment sizing and control parameters from the Heating Load Factor table below.
$F_{load,heating,ElecHeat}$		If the baseline heating system is an electric system that remains in place in the efficient case, or if the baseline heating system is a non-electric system, lookup based on equipment sizing and control parameters from the Heating Load Factor table below. Otherwise, set equal to 1.
$F_{load,heating,FuelHeat}$		If the baseline heating system is a fossil fuel system that remains in place in the efficient case, lookup based on equipment sizing and control parameters from the Heating Load Factor table below. Otherwise, set equal to 1.
CF	0.69	

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.69.[349]

Baseline Efficiencies from which Energy Savings are Calculated

The baselines used in this measure are determined by the type of equipment that would have been installed without the influence of the program supporting the installation of this measure. This allows for an analysis that does not depend on a typical 'like-for-like' replacement scenario.

[348] In this context, "conventional ASHP" is defined as a minimally code-compliant non-NEEP listed ASHP with efficiency ratings as indicated in the Baseline Efficiencies section below.

[349] Based on BG&E 'Development of Residential Load Profile for Central Air Conditioners and Heat Pumps' research, the Maryland Peak Definition coincidence factor is 0.69. This study is not publicly available, but is referenced by M. M. Straub, Using Available Information for Efficient Evaluation of Demand-Side Management Programs, Electricity Journal, September 2011 and supported by research conducted by Cadmus on behalf of the RM Management Committee.

An ASHP system can be considered a normal replacement scenario for electric resistance heating (with or without a central electric cooling system), an ASHP system (that provides space heating and cooling), or a fossil fuel fired heating system (with or without a central electric cooling system). The tables below provide baseline efficiencies for electric cooling and heating and fossil fuel fired heating systems.

For scenarios where there is new construction or substantial renovation, the baseline is assumed to be a fossil fuel fired warm air furnace of the fuel type most likely to be installed at the project site without the influence of the program with a central air conditioning system.

The baseline efficiency for electric cooling and heating systems is defined by the Code of Federal Regulations as shown in the table below.

Electric Cooling and Heating System Baseline Efficiencies

Product Class	Seasonal Energy Efficiency Ratio (SEER)[350]	Energy Efficiency Ratio (EER)	Heating Seasonal Performance Factor (HSPF)[351]
Split System – Air Conditioner (<45 kBTU/h)	13.0	11.2	N/A
Split System – Air Conditioner (≥45 and <65 kBTU/h)	13.0	11.2	N/A
Single Package – Air Conditioner	14.0	11.8	N/A
Split System – Heat Pump (<45 kBTU/h)	14.0	11.8	8.2
Split System – Heat Pump (≥45 and < 65 kBTU/h)	14.0	11.8	8.2
Single Package – Heat Pump (<65 kBTU/h)	14.0	11.8	8.0

The baseline efficiency for fossil fuel fired heating systems serving single-family homes and individual units is defined by the Code of Federal Regulations as shown in the table below.

Fossil Fuel Fired Heating System Baseline Efficiencies: Systems Serving Single Units[352]

Equipment Type	Size Range	ECCCNYS Minimum Efficiency for Climate Zones 4, 5 and 6
Warm Air Furnace, Gas Fired	All Capacities	0.80 AFUE
Warm Air Furnace, Oil Fired	All Capacities	0.83 AFUE

[350] 10 CFR 430.32(c)(1)
[351] 10 CFR 430.32(c)(1)
[352] 10 CFR 430.32(e)

Equipment Type	Size Range	ECCCNYS Minimum Efficiency for Climate Zones 4, 5 and 6
Boiler, Hot Water, Gas Fired	All Capacities	0.82 AFUE
Boiler, Hot Water, Oil Fired	All Capacities	0.84 AFUE
Boiler, Steam, Gas Fired	All Capacities	0.80 AFUE
Boiler, Steam, Oil Fired	All Capacities	0.82 AFUE

The baseline efficiency for heating systems serving multiple dwelling units is defined by International Energy Conservation Code[353] and subsequently adopted by the Energy Conservation Construction Code of New York State (ECCCNYS) as shown in the table below.

Fossil Fuel Fired Heating System Baseline Efficiencies: Systems Serving Multiple Dwelling Units

Equipment Type	Size Range	ECCCNYS Minimum Efficiency for Climate Zones 4, 5 and 6
Warm Air Furnace, Gas Fired	< 225 kBTU/h	0.80 AFUE
	≥ 225 kBTU/h	0.80 Et
Warm Air Furnace, Oil Fired	< 225 kBTU/h	0.83 AFUE
	≥ 225 kBTU/h	0.80 Et
Warm Air Unit Heaters, Gas Fired	All Capacities	0.80 Ec
Warm Air Unit Heaters, Oil Fired	All Capacities	0.80 Ec
Boiler, Hot Water, Gas Fired	< 300 kBTU/h	0.82 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.80 Et
	> 2,500 kBTU/h	0.82 Ec
Boiler, Hot Water, Oil Fired	< 300 kBTU/h	0.84 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.82 Et
	> 2,500 kBTU/h	0.84 Ec
Boiler, Steam, Gas Fired, All Except Natural Draft	< 300 kBTU/h	0.80 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.79 Et
	> 2,500 kBTU/h	0.79 Et
Boiler, Steam, Gas Fired, Natural Draft	< 300 kBTU/h	0.80 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.77 Et
	> 2,500 kBTU/h	0.77 Et
Boiler, Steam, Oil Fired	< 300 kBTU/h	0.82 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.81 Et
	> 2,500 kBTU/h	0.81 Et

For scenarios where the baseline heating system is electric resistance heat or an electric furnace, the baseline efficiency is assumed to be a COP of 1.0.

[353] ECCCNYS 2020, Table C403.3.2(4) & Table C403.3.2(5)

For scenarios where the baseline heating system is a conventional ASHP, additional consideration is given to account for the significant difference between the rating conditions for HSPF and the typical operating conditions in New York State, as shown below.

The HSPF is the AHRI-rated heating seasonal average efficiency expressed in terms of BTU/watt-hour. A seasonally adjusted $COP_{baseline}$ of a conventional air-source heat pump is used in the above equations. This adjusted baseline COP shall be calculated as:

$$COP_{season,baseline} = \frac{HSPF \times F_{HSPF}}{3.412}$$

where:

HSPF = Heating seasonal performance factor of the baseline system
F_{HSPF} = HSPF Climate Adjustment Factor, from table below
3.412 = Conversion factor, one watt-hour equals 3.412 BTU

HSPF Climate Adjustment Factor (F_{HSPF}) for Conventional ASHP Used as a Baseline

City	HSPF < 8.5	HSPF ≥ 8.5
Albany	0.70	0.67
Binghamton	0.68	0.65
Buffalo	0.73	0.70
Massena	0.59	0.56
NYC	0.80	0.78
Poughkeepsie	0.62	0.59
Syracuse	0.69	0.66

For scenarios where the baseline cooling system is a conventional ASHP, no additional consideration is given to account for the difference between the rating conditions for SEER and the typical operating conditions in New York State, because the differences between the rating conditions and the typical operating conditions are small.

Compliance Efficiency from which Incentives are Calculated

ASHPs are rated under ANSI/AHRI 210/240. Cold climate ASHPs must meet the Northeast Energy Efficiency Partnerships (NEEP) Cold Climate Air Source Heat Pump (ccASHP) Specification (Version 3.0) effective January 1, 2019. The specification uses AHRI-certified performance ratings and manufacturer reported data to describe the efficiency and capacity of the unit under full and part load condition

The average seasonal heating efficiency for an ASHP with a two stage or variable speed compressor is calculated as:

$$COP_{season,ee} = a + b\ x\ HSPF\ \ x\ \frac{1}{3.412}$$

The average seasonal cooling efficiency for a ccASHP with a variable speed compressor is calculated as:

$$EER_{season,ee} = c + d\ x\ SEER$$

where:

a & b = Offset and slope coefficients from Tables below for heating (select based on city and scenario)
c & d = Offset and slope coefficients from Tables below for cooling (select based on city and scenario)
HSPF = Rated Heating Season Performance Factor from AHRI
SEER = Rated Seasonal Energy Efficiency Ratio from AHRI
3.412 = Conversion factor, one watt-hour equals 3.412 BTU

Note that the cooling efficiency adjustments are quite large for some ASHP units (mini-splits) but much smaller for central ducted ASHP units. For the baseline conventional ASHP we assume that no adjustment to SEER is required. Appendix F in the ASHP White Paper explains why some ASHP units require a cooling efficiency adjustment while others do not.

Summary of Variables and Data Sources

Variable	Value	Source
a & b		Coefficients to represent offset and slope from the table below to determine seasonal heating efficiency ($COP_{season,ee}$) from HSPF. Depends on city and scenario.
c & d		Coefficients to represent offset and slope from the table below to determine seasonal cooling efficiency ($EER_{season,ee}$) from SEER. Depends on city and scenario.
HSPF		Rated heating season performance factor from AHRI.
SEER		Rated seasonal energy efficiency ratio from AHRI.

The scenarios shown in the first column of the Whole House and Displacement Scenarios table below represent various specific applications of heat pumps, with heat pump type, sizing, and control strategy shown. These scenarios may be considered "sub-measures" of this measure[354]. Assigning applicable scenario(s) to program participants or participant groups is the responsibility of program designers and implementers. For reference, the control strategies listed in the Whole House and Displacement Scenarios table below are defined as follows:

- **Separate:** The ASHP and backup heating system are on separate thermostats.
- **Integrated/Modulating:** The ASHP and backup heating system are on the same thermostat. The backup heater can modulate to meet the load without limiting the ASHP from delivering its maximum capacity. Also called "perfect" control.

[354] Detailed descriptions of these scenarios and their parameters are found in the white paper *Savings Calculations for Residential Air Source Heat Pumps: The Basis for Modifying EFLH and Seasonal Efficiency Factors for "Whole House" and "Displacement" Applications*, Tables 2 and 3, and the associated narrative.

- **Integrated/Fixed Capacity:** The ASHP and backup heating system are on the same thermostat. The backup heater has a fixed capacity to meet the load. The backup heater is larger than the ASHP, so the ASHP is not always able to deliver its maximum capacity (the backup heater supplies a larger share of the load when both are running).
- **DF/Either HP or Furnace:** The central ASHP is installed on the same ductwork as the fossil fuel-fired furnace. Once the ASHP can no longer meet the load (or when a changeover temperature is reached). The ASHP shuts off and the furnace meets the load.

Where participants fall between the numeric values in the column "HP Sizing," use the scenario with the lower of the values in the column. "Single-zone ductless" means the equipment is single-zone (1-to-1 indoor to outdoor units). There may be multiple single-zone systems to achieve the HP sizing shown. When multiple HPs are used, the capacity-weighted rated efficiencies (HSPF, SEER, and EER) for the installed units need to be determined. For cooling efficiency, use the rated cooling capacity at 95°F and the SEER and EER for each unit to find the weighted average. Similarly, for heating efficiency use the rated heating capacity at 17°F ($QH_{17,rated}$) for projects best represented by the New York City climate zone and maximum heating capacity at 5°F ($QH_{5,max}$) otherwise, as well as HSPF for each unit to find the weighted average.

Whole House and Displacement Scenarios

Scenario	Description	ASHP Type	Application	Controls	HP Sizing Ratio
1a	Central ASHP with different controls	Central, Ducted	Whole	Integrated/ Modulating	0.9
1b				Integrated/ Fixed Capacity	
1c				DF/Either HP or Furnace	
1d				Integrated/ Modulating	1.0
2a	Ductless Mini-Spilt sized at 30%, 50%, 70% and 90/100%	Single-Zone Ductless	Displace	Separate	0.3
2b					0.5
2c					0.7
2d				Integrated/ Fixed Capacity	0.3
2e					0.5
2f					0.7
2g			Whole	Integrated/ Modulating	0.9
2h					1.0
3a	Ductless Multi-Split sized to 70% and 90/100%	Multi-Zone Ductless	Displace	Separate	0.7
3b			Whole	Integrated/ Modulating	0.9
3c					1.0
4a	Compact Ducted Mini-Split sized to 50% ,70% and 90/100%	Single-Zone Compact Ducted	Displace	Separate	0.5
4b					0.7
4c			Whole	Integrated/ Modulating	0.9
4d					1.0

The HP Sizing Ratio should be determined using the rated heating capacity at 17°F ($QH_{17,rated}$) for projects best represented by the New York City climate zone and maximum heating capacity at 5°F from the NEEP Cold Climate Heat Pump List ($QH_{5,max}$) otherwise, and design heating load for the home:

$$\text{HP Sizing Ratio} = (QH_{17,rated} \text{ or } QH_{5,max}) / BHL$$

The HP Sizing Ratio corresponds to the rightmost column in the Whole House and Displacement Scenarios table above. Choose an appropriate scenario, then use the coefficients from the tables below to determine the seasonal efficiencies and load factors.

Coefficients for Seasonal Heating Efficiency: $COP_{season,ee} = a + b \times HSPF/3.412$														
Scenario	**Albany**		**Binghamton**		**Buffalo**		**Massena**		**New York**		**Poughkeepsie**		**Syracuse**	
	a	b	a	b	a	b	a	b	a	b	a	b	a	b
1a	-0.010	0.880	0.113	0.854	0.219	0.842	-0.185	0.838	0.767	0.798	0.333	0.796	0.124	0.860
1b	-0.040	0.891	0.092	0.863	0.197	0.851	-0.168	0.830	0.742	0.814	0.301	0.813	0.093	0.871
1c	0.056	0.906	0.220	0.870	0.310	0.849	-0.057	0.922	0.802	0.805	0.579	0.802	0.183	0.875
1d	-0.117	0.902	-0.003	0.879	0.081	0.876	-0.259	0.847	0.824	0.777	0.237	0.815	-0.007	0.890
2a	2.552	0.197	2.532	0.202	2.645	0.181	2.304	0.204	2.380	0.338	2.620	0.177	2.565	0.195
2b	2.351	0.256	2.419	0.243	2.644	0.188	2.011	0.290	2.506	0.296	2.470	0.228	2.500	0.217
2c	2.441	0.228	2.480	0.224	2.619	0.198	2.358	0.203	2.768	0.210	2.459	0.239	2.550	0.206
2d	2.615	0.113	2.637	0.113	2.702	0.108	2.312	0.150	2.923	0.131	2.725	0.104	2.655	0.107
2e	2.574	0.125	2.601	0.124	2.647	0.122	2.335	0.143	2.817	0.162	2.654	0.119	2.631	0.116
2f	2.458	0.160	2.493	0.155	2.546	0.153	2.322	0.145	2.760	0.180	2.588	0.135	2.513	0.154
2g	2.351	0.172	2.382	0.169	2.440	0.161	2.125	0.178	2.637	0.210	2.424	0.162	2.415	0.163
2h	2.336	0.179	2.386	0.169	2.422	0.168	2.030	0.205	2.674	0.198	2.372	0.177	2.414	0.168
3a	-3.334	1.993	-3.307	1.991	-3.485	2.065	-2.938	1.810	-3.793	2.217	-3.093	1.929	-3.339	2.006
3b	-2.683	1.735	-2.637	1.728	-2.720	1.770	-2.004	1.446	-3.436	2.064	-2.306	1.624	-2.710	1.757
3c	-2.823	1.775	-2.783	1.769	-2.832	1.800	-1.991	1.436	-3.598	2.110	-2.395	1.645	-2.861	1.800
4a	-0.333	1.141	-0.305	1.138	-0.251	1.137	-0.852	1.263	0.260	1.068	-0.407	1.194	-0.308	1.140
4b	-0.402	1.155	-0.393	1.160	-0.300	1.147	-0.865	1.261	0.145	1.086	-0.390	1.175	-0.385	1.160
4c	-0.166	1.004	-0.019	0.963	0.018	0.961	-0.234	0.972	-0.003	1.073	0.121	0.926	-0.006	0.962
4d	-0.240	1.024	-0.102	0.983	0.027	0.950	-0.321	0.993	-0.015	1.069	0.110	0.920	-0.127	1.001

Coefficients for Seasonal Cooling Efficiency: $EER_{season,ee} = c + d \times SEER$														
Scenario	**Albany**		**Binghamton**		**Buffalo**		**Massena**		**New York**		**Poughkeepsie**		**Syracuse**	
	c	d	c	d	c	d	c	d	c	d	c	d	c	d
1a	-0.540	0.961	0.920	0.914	-1.370	1.035	-0.390	0.936	2.910	0.786	-0.510	0.965	-0.810	0.988
1b	-0.540	0.961	0.920	0.914	-1.370	1.035	-0.390	0.936	2.910	0.786	-0.510	0.965	-0.810	0.988
1c	-0.540	0.961	0.920	0.914	-1.370	1.035	-0.390	0.936	2.910	0.786	-0.510	0.965	-0.810	0.988
1d	-0.460	0.946	-0.140	0.966	-1.670	1.041	-0.210	0.916	1.520	0.859	-0.590	0.961	-0.890	0.982
2a	12.330	0.118	11.950	0.116	12.240	0.130	12.360	0.135	11.070	0.165	12.100	0.111	12.180	0.123
2b	11.440	0.208	12.210	0.146	11.010	0.229	10.330	0.273	10.080	0.277	12.130	0.167	11.330	0.210
2c	9.810	0.306	10.940	0.232	9.590	0.302	9.160	0.321	9.440	0.323	10.310	0.282	9.740	0.308
2d	12.330	0.118	11.950	0.116	12.240	0.130	12.360	0.135	11.070	0.165	12.100	0.111	12.180	0.123
2e	11.440	0.208	12.210	0.146	11.010	0.229	10.330	0.273	10.080	0.277	12.130	0.167	11.330	0.210
2f	9.810	0.306	10.940	0.232	9.590	0.302	9.160	0.321	9.440	0.323	10.310	0.282	9.740	0.308
2g	9.400	0.314	9.950	0.300	8.130	0.366	8.500	0.351	8.670	0.353	9.080	0.328	9.080	0.327
2h	8.890	0.336	9.440	0.313	7.960	0.375	8.160	0.364	8.510	0.361	9.130	0.327	9.020	0.332
3a	17.760	-0.189	6.680	0.454	10.960	0.199	18.580	-0.218	11.600	0.196	16.240	-0.105	14.460	-0.008
3b	14.530	0.035	14.100	0.009	15.660	-0.060	11.420	0.204	16.950	-0.122	18.500	-0.205	17.260	-0.147
3c	10.850	0.255	17.070	-0.164	14.630	0.017	13.740	0.066	18.850	-0.246	15.270	-0.009	14.140	0.052
4a	-12.940	1.478	-12.220	1.433	-11.550	1.396	-13.560	1.520	-9.590	1.290	-12.690	1.456	-12.770	1.473
4b	-14.160	1.556	-13.060	1.493	-3.400	0.957	-14.370	1.569	-11.850	1.424	-14.010	1.547	-4.690	1.038
4c	-14.370	1.566	-4.310	1.019	-9.600	1.300	-14.650	1.576	-14.290	1.563	-14.680	1.586	-8.450	1.246
4d	-14.440	1.566	-4.690	1.041	-10.170	1.328	-14.700	1.572	-15.140	1.609	-14.790	1.590	-16.480	1.676

Note that several scenarios are the same since control approach and UR do not apply for cooling (i.e. 1a,1b and 1c are all the same, 2a is the same as 2d, etc.)

Heating Load Factor

Factors in the table below ($F_{load,heating}$) are used to determine the fraction of the annual heating load that is met by the ASHP unit.

Fraction of Heating Load Met by the ASHP ($F_{load,heating}$)							
Scenario	**Albany**	**Binghamton**	**Buffalo**	**Massena**	**New York**	**Poughkeepsie**	**Syracuse**
1a	1.00	1.00	1.00	0.98	1.00	0.97	1.00
1b	0.99	0.99	0.99	0.96	0.99	0.95	0.99
1c	0.86	0.86	0.89	0.69	0.96	0.82	0.90
1d	1.00	1.00	1.00	0.99	1.00	0.98	1.00
2a	0.25	0.25	0.25	0.23	0.37	0.25	0.24
2b	0.39	0.38	0.39	0.37	0.55	0.39	0.38
2c	0.56	0.55	0.56	0.55	0.76	0.54	0.55
2d	0.54	0.53	0.53	0.51	0.69	0.51	0.54
2e	0.74	0.73	0.73	0.71	0.87	0.69	0.74
2f	0.86	0.85	0.85	0.82	0.95	0.81	0.86
2g	0.98	0.97	0.97	0.94	0.99	0.92	0.98
2h	0.99	0.98	0.99	0.95	1.00	0.94	0.99
3a	0.72	0.71	0.70	0.67	0.86	0.67	0.72
3b	0.96	0.94	0.94	0.92	0.98	0.90	0.95
3c	0.97	0.96	0.96	0.94	0.99	0.92	0.98
4a	0.43	0.42	0.43	0.42	0.52	0.43	0.42
4b	0.59	0.58	0.58	0.56	0.67	0.56	0.58
4c	0.97	0.96	0.97	0.94	0.98	0.92	0.98
4d	0.99	0.99	0.99	0.96	0.99	0.95	0.99

Cooling Load Factor

Factors in the table below ($F_{load,cooling}$) are used to determine the fraction of the annual cooling load that is met by the ASHP unit. The cooling sizing is determined using assumptions about the relative size of cooling loads (BCL) and heating loads (BHL) in NY based on climate.

Fraction of Cooling Load Met by the ASHP ($F_{load,cooling}$)							
Scenario	**Albany**	**Binghamton**	**Buffalo**	**Massena**	**New York**	**Poughkeepsie**	**Syracuse**
1a	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1b	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1c	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1d	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2a	0.90	0.79	0.90	0.95	0.91	0.88	0.89
2b	0.99	0.95	0.99	1.00	0.99	0.99	0.99
2c	1.00	0.99	1.00	1.00	1.00	1.00	1.00
2d	0.90	0.79	0.90	0.95	0.91	0.88	0.89
2e	0.99	0.95	0.99	1.00	0.99	0.99	0.99
2f	1.00	0.99	1.00	1.00	1.00	1.00	1.00
2g	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2h	1.00	1.00	1.00	1.00	1.00	1.00	1.00
3a	1.00	0.99	1.00	1.00	1.00	1.00	1.00
3b	1.00	1.00	1.00	1.00	1.00	1.00	1.00
3c	1.00	1.00	1.00	1.00	1.00	1.00	1.00
4a	0.99	0.96	0.99	1.00	0.98	0.99	0.99
4b	1.00	0.99	1.00	1.00	1.00	1.00	1.00
4c	1.00	1.00	1.00	1.00	1.00	1.00	1.00
4d	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Note that several scenarios are the same since control approach and UR do not apply for cooling (i.e. 1a,1b and 1c are all the same, 2a is the same as 2d, etc.)

Operating Hours

The Building Equivalent Full Load Hours for heating (BEFLH $_{heating}$) and for cooling (BEFLH $_{cooling}$) in the tables below represent equivalent full load operating hours for HVAC equipment based on 1% design temperature, TMY3 weather data, and the design heating load. For heating, hours from the summer period (June through September) were excluded. For Cooling, the values of EFLH from Appendix G were multiplied by a factor of 1.25 to convert to BEFLH.

Single-Family Detached Cooling BEFLH$_{cooling}$ by Vintage and City

City	Old	Average	New
Albany	403	388	349
Binghamton	249	246	198
Buffalo	418	403	345
Massena	323	313	263
NYC	838	811	788
Poughkeepsie	620	588	580
Syracuse	388	370	335

Multi-Family Low-Rise Cooling BEFLH $_{cooling}$ by Vintage and City

City	Prior to 1979	From 1979 Through 2006	From 2007 Through Present
Albany	358	369	349
Binghamton	271	274	263
Buffalo	338	343	320
Massena	288	285	273
NYC	634	688	703
Poughkeepsie	496	529	526
Syracuse	331	355	371

Single-Family Detached Heating BEFLH $_{heating}$ by Vintage and City

City	Old	Average	New
Albany	1,878	1,763	1,643
Binghamton	2,060	1,935	1,804
Buffalo	2,080	1,952	1,819
Massena	1,986	1,880	1,772
NYC	1,636	1,485	1,329
Poughkeepsie	2,044	1,912	1,776
Syracuse	1,960	1,842	1,720

Multi-Family Low-Rise Heating BEFLH $_{heating}$ by Vintage and City

City	Pre-war uninsulated brick	Prior to 1979	From 1979 Through 2006	From 2007 Through present
Albany	1,889	1,751	1,720	1,239
Binghamton	2,375	2,244	2,117	1,528
Buffalo	2,178	2,072	2,066	1,501
Massena	2,436	2,220	2,254	1,639
NYC	1,698	1,287	1,229	855
Poughkeepsie	1,457	1,520	1,476	1,047
Syracuse	2,372	1,998	2,050	1,437

Example Calculation *(Not to be used as default)*

A central ducted air source heat pump is installed in a single-family, detached home located near Albany constructed in 1965. The heat pump is rated at 20 SEER, 13 EER, and 12 HSPF with a total system heating capacity at 5ºF of 60 kBTU/h. The heat pump fully replaces the existing 3-ton central air conditioner and 80 kBTU/h gas fired furnace. The building cooling load is 36 kBTU/h and building heating load is 58 kBTU/h. The system includes supplemental electric resistance heat. Annual Electric Energy Savings, Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta kWh = \left(\left(BCL \times \frac{1}{1{,}000} \times \left(\frac{1}{SEER_{baseline}} - \frac{1}{EER_{season,ee}}\right) \times BEFLH_{cooling} \times F_{load,cooling}\right) + \left(BHL \times \frac{1}{1{,}000} \times \left(\frac{F_{ElecHeat}}{COP_{season,baseline}} - \frac{1}{COP_{season,ee}}\right) \times \frac{1}{3.412} \times BEFLH_{heating} \times F_{load,heating,ElecHeat}\right) - \left(BHL \times \frac{1}{1{,}000} \times F_{ElecHeat,new} \times \frac{1}{3.412} \times BEFLH_{heating} \times \left(1 - F_{load,heating}\right)\right)\right)$$

$$\Delta kW = BCL \times \frac{1}{1{,}000} \times \left(\frac{1}{EER_{baseline}} - \frac{1}{EER_{ee}}\right) \times F_{load,cooling} \times CF$$

$$\Delta MMBtu = BHL \times \frac{1}{1{,}000{,}000} \times \frac{F_{FuelHeat}}{AFUE_{baseline}} \times BEFLH_{heating} \times F_{load,heating,FuelHeat}$$

BCL = 36,000, from application

$SEER_{baseline}$ = 14.0, from Electric Cooling and Heating System Baseline Efficiencies table based on equipment type from application

$EER_{seaons,ee}$ = c + d x SEER = -0.460 + 0.946 x 20 = 18.46

$EER_{season,ee}$ equation from Compliance Efficiency section

c and d from Coefficients for Seasonal Cooling Efficiency table based on scenario and location from application. To determine scenario, the HP Sizing Ratio is calculated: $QH_{5,max}$ / BHL= 60/58 = 1.03. Thus c and d correspond to scenario 1d based on application conditions

SEER from application

$BEFLH_{cooling}$ = 403, from Operating Hours section tables based on housing type, city, and vintage from application

$F_{load,cooling}$ = 1.00, from Cooling Load Factor table based on scenario from application

BHL = 58,000, from application

$F_{ElecHeat}$ = 0, from application
$COP_{season,baseline}$ = N/A, from application
$COP_{season,ee}$ = a + b x HSPF x 1/3.412 = -0.117 + 0.902 x 12 x 1/3.412 = 3.14
$COP_{season,ee}$ equation from Compliance Efficiency section
a and b from Coefficients for Seasonal Heating Efficiency table based on scenario and location from application
HSPF from application
$BEFLH_{heating}$ = 1,878, from Operating Hours section tables based on housing type, city, and vintage from application
$F_{load,heating,ElecHeat}$ = 1.00, from Heating Load Factor table based on scenario and existing heat system from application
$F_{ElecHeat,new}$ = 1, from application
$F_{load,heating}$ = 1.00, from Heating Load Factor table based on scenario from application
$EER_{baseline}$ = 11.8, from Electric Cooling and Heating System Baseline Efficiencies table based on equipment type from application
EER_{ee} = 13, from application
CF = 0.69, from Coincidence Factor section
$F_{FuelHeat}$ = 1, from application
$AFUE_{baseline}$ = 0.80, from Baseline Efficiencies section based on equipment type and size from application
$F_{load,heating,FuelHeat}$ = 1, from on Summary of Variables and Data Sources table based on heating system from application

$$\Delta kWh = \left(\left(36{,}000 \times \frac{1}{1{,}000} \times \left(\frac{1}{14} - \frac{1}{18.46}\right) \times 403 \times 1\right) + \left(58{,}000 \times \frac{1}{1{,}000} \times \left(0 - \frac{1}{3.14}\right) \times \frac{1}{3.412} \times 1{,}878 \times 1.00\right) - \left(58{,}000 \times \frac{1}{1{,}000} \times 1 \times \frac{1}{3.412} \times 1{,}735 \times (1 - 1.00)\right)\right) = -9{,}916\ kWh$$

$$\Delta kW = 36{,}000 \times \frac{1}{1{,}000} \times \left(\frac{1}{11.8} - \frac{1}{13}\right) \times 1 \times 0.69 = 0.19\ kW$$

$$\Delta MMBtu = 58{,}000 \times \frac{1}{1{,}000{,}000} \times \frac{1}{0.80} \times 1{,}878 \times 1 = 136\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. 10 CFR 430.32 Energy and water conservation standards and their compliance dates. Available from: http://www.ecfr.gov/cgi-bin/text-idx?SID=a9921a66f2b4f66a32ec851916b7b9d9&mc=true&node=se10.3.430_132&rgn=div8
2. BG&E: Development of Residential Load Profile for Central Air Conditioners and Heat Pumps
3. Building America House Simulation Protocols, Robert Hendron and Cheryn Engebrecht, National Renewable Energy Laboratory, October 2010 Available from: https://www1.eere.energy.gov/buildings/publications/pdfs/building_america/house_simulation_revised.pdf
4. ECCCNYS 2020, Table C403.3.2(4): Warm-Air Furnaces And Combination Warm-Air Furnaces/Air-Conditioning Units, Warm-Air Duct Furnaces And Unit Heaters, Minimum Efficiency Requirements & Table C403.2.3(5): Minimum Efficiency Requirements: Gas- And Oil-Fired Boilers.
   Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-[ce]-commercial-energy-efficiency#NYSECC2020P1_CE_Ch04_SecC402
5. Fairey, P., D. Parker, B Wilcox, M Lombardi. *Climate Impacts on Heating Seasonal Performance Factor (HSPF) and Seasonal Energy Efficiency Ratio (SEER) for Air Source Heat Pumps*, ASHRAE Transactions, 110(2): 178-88.
6. Henderson, H.I., 2020. White Paper: Savings Calculations for Residential Ground Source Heat Pumps: The Basis for Equivalent Full Load Hours (EFLH) and Seasonal Efficiency Factors. Prepared for the New York State Energy Research and Development Authority (NYSERDA) and the New York State Department of Public Service. Revised in June.
7. M. M. Straub, Using Available Information for Efficient Evaluation of Demand-Side Management Programs, Electricity Journal, September 2011
   Available from: https://www.sciencedirect.com/science/article/pii/S1040619011001941
8. *Manual J Residential Load Calculation*, Arlington, VA. Air Conditioning Contractors Association
9. *Manual S Equipment Selection*, Arlington, VA. Air Conditioning Contractors Association

Record of Revision

Record of Revision Number	Issue Date
1	10/15/2010
12-17-8	12/31/2017
9-18-4	9/28/2018
2-20-2	2/28/2020
7-20-21	7/31/2020

Return to Table of Contents

HEAT PUMP – WATER-TO-AIR GROUND SOURCE (GSHP)

Measure Description

This measure covers the installation of an ENERGY STAR® certified Ground Source Heat Pump (GSHP) system with a closed loop heat exchanger field or an open loop ground water system as permissible by local environmental review.[355] The GSHP system provides heating and cooling for space conditioning by a water-to-air heat pump via a typical air-duct distribution system in a residential home.[356] These systems can optionally have an integrated desuperheater or a dedicated Domestic Hot Water (DHW) water-to-water heat pump (WWHP) that supplements domestic hot water heating in conjunction with space conditioning. Methods for calculating annual DHW energy savings are presented separately below.

This measure applies to GSHPs in residential applications, and where each GSHP unit has its own dedicated loop pump. It does not apply to large GSHP systems with multiple heat pump units with centralized ground loop pumping.

The GSHP analysis associated with this measure is based on several assumptions consistent with best practice design for a quality GSHP installation:

- Current Residential code and Federal standard (Code of Federal Regulations 10 CFR 430.32, ECCCNYS 2020 or local legislation) applicable to the installation should be referenced for correct baseline system and efficiency values.

- Systems shall be sized in accordance with ACCA Manual S based on building loads calculated in accordance with ACCA Manual J.[357,358]

- The building peak heating load in New York typically exceeds the peak cooling load, therefore it is assumed that the GSHP runs at part-load during peak cooling hours.

- The ground loop heat exchanger is adequately sized and installed properly to allow the GSHP to meet the peak heating load without electric resistance auxiliary heat.

- The GSHP is equipped with either a two stage or variable-speed compressor system, a variable speed or constant speed ground loop circulator pump, and a variable-speed blower distribution fan.

- The GSHP efficiency is rated in accordance with ISO 13256-1, and AHRI-certified performance ratings are provided by the manufacturer showing the efficiency and capacity of the unit under full and part load conditions.

[355] This measure section does not apply to a subset of open loop systems known as standing column wells, since operating temperatures are much different in these applications.
[356] "Residential homes" means detached one- and two-family dwellings and townhouses not more than three stories above-grade in height with a separate means of egress and their accessory structures, and one-family dwellings converted to bed and breakfast dwellings.
[357] ECCCNYS 2020, Section R403.7
[358] ECCNYS 2020 requires that systems serving multiple dwelling units follow Sections C403 and C404.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Note: The algorithms below address energy impacts associated with space conditioning load only. See the *Methods for Calculating Annual Domestic Hot Water Energy Savings from an Integrated Desuperheater or Dedicated Water-to-Water Heat Pump* section of this measure for estimating DHW savings associated with these systems.

Annual Electric Energy Savings

$$\Delta kWh = \left[\frac{BCL}{1{,}000} \times \left(\frac{1}{EER_{season,baseline}} - \frac{1}{EER_{season,ee}}\right) \times BEFLH_{cooling}\right] + \left[\frac{BHL}{3{,}412} \times \left(\frac{F_{ElecHeat}}{COP_{season,baseline}} - \frac{1}{COP_{season,ee}}\right) \times BEFLH_{heating}\right]$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \frac{BCL}{1{,}000} \times \left(\frac{1}{EER_{peak,baseline}} - \frac{1}{EER_{GSHP,full,ee}}\right) \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = \frac{BHL}{1{,}000{,}000} \times \frac{F_{FuelHeat}}{AFUE_{baseline}} \times BEFLH_{heating}$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
BCL	= Building Cooling Load at design conditions (BTU/h)
BHL	= Building Heating Load at design conditions (BTU/h)
$F_{ElecHeat}$	= Electric heating factor; used to account for the presence or absence of an electric heating system
$F_{FuelHeat}$	= Fossil fuel heating factor; used to account for the presence or absence of a fossil fuel heating system
baseline	= Characteristic of baseline condition
ee	= Characteristic of energy efficient condition
EER_{season}	= Energy efficiency ratio (BTU/watt-hour) at part-load seasonally adjusted for fan and pump power
EER_{peak}	= Full load energy efficiency ratio (BTU/watt-hour)
$EER_{GSHP,full}$	= Full load energy efficiency ratio (BTU/watt-hour). Refers to Ground Loop Heat Pump (GLHP)-rated condition for closed loop GSHP systems or Ground Water Heat Pump (GWHP)-rated conditions for open loop systems.
COP_{season}	= Coefficient of performance, seasonally adjusted for fan and pump power.
AFUE	= Annual fuel utilization efficiency, seasonal efficiency for fossil fuel-fired heating equipment
$BEFLH_{cooling}$	= Cooling equivalent full-load hours based on building design load

$BEFLH_{heating}$ = Heating equivalent full-load hours based on building design load
CF = Coincidence Factor
3,412 = Conversion factor, one kWh equals 3,412 BTU
1,000 = Conversion factor, one kW equals 1,000 Watts
1,000,000 = Conversion factor, one MMBtu equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
BCL		Building cooling load at design conditions calculated in accordance with ACCA Manual J, from application.
BHL		Building heating load at design conditions calculated in accordance with ACCA Manual J, from application.
$F_{ElecHeat}$		If the baseline heating system is an electric system, set equal to 1. Otherwise, set equal to 0.
$F_{FuelHeat}$		If the baseline heating system is a fossil fuel system, set equal to 1. Otherwise, set equal to 0.
$EER_{season,baseline}$		Seasonal electric cooling energy efficiency rating of baseline equipment. See SEER values in Baseline Efficiency section below for details.
$EER_{peak,baseline}$		Electric cooling energy efficiency rating of baseline equipment. See EER values in Baseline Efficiency section below for details.
$EER_{season,ee}$		Energy efficiency ratio from the manufacturer's catalog data adjusted to account for applied fan and pump power. See Compliance Efficiency section below for details.
$EER_{GSHP,full,ee}$		Full load energy efficiency ratio at AHRI rated conditions. Corresponds to GLHP-rated condition with fluid temperature of 77ºF for closed loop systems, or GWHP-rated condition with fluid temperature of 59ºF for open loop systems.
$COP_{season,baseline}$		Electric heating energy efficiency rating of baseline equipment. See Baseline Efficiency section below for details.
$COP_{season,ee}$		Coefficient of performance from the manufacturer's catalog data adjusted to account for applied fan and pump power. See Compliance Efficiency section below for details.
$AFUE_{baseline}$		Seasonal fuel energy efficiency of the baseline equipment. See Baseline Efficiency section below for details.
$BEFLH_{cooling}$		Lookup based on building type, vintage and location from the appropriate table in the Operating Hours section below.
$BEFLH_{heating}$		Lookup based on building type, vintage and location from the appropriate table in the Operating Hours section below.
CF	0.69	

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.69.[359]

Baseline Efficiencies from which Energy Savings are Calculated

The baselines used in this measure are determined by the type of equipment that would have been installed without the influence of the program supporting the installation of this measure. This allows for an analysis that does not depend on a typical 'like-for-like' replacement scenario.

A GSHP system can be considered a normal replacement scenario for electric resistance heating (with or without a central electric cooling system), an ASHP system (that provides space heating and cooling), or a fossil fuel fired heating system (with or without a central electric cooling system). The tables below provide baseline efficiencies for electric cooling and heating and fossil fuel fired heating systems.

For scenarios where there is new construction or substantial renovation, the baseline is assumed to be a fossil fuel fired warm air furnace of the fuel type most likely to be installed at the project site without the influence of the program with a central air conditioning system.

The baseline efficiency for electric cooling and heating systems is defined by the Code of Federal Regulations as shown in the table below.

Electric Cooling and Heating System Baseline Efficiencies

Product Class	Seasonal Energy Efficiency Ratio (SEER)[360]	Energy Efficiency Ratio (EER)	Heating Seasonal Performance Factor (HSPF)[361]
Split System – Air Conditioner (<45 kBTU/h)	13.0	11.2	N/A
Split System – Air Conditioner (≥45 and <65 kBTU/h)	13.0	11.2	N/A
Single Package – Air Conditioner	14.0	11.8	N/A
Split System – Heat Pump (<45 kBTU/h)	14.0	11.8	8.2
Split System – Heat Pump (≥45 and < 65 kBTU/h)	14.0	11.8	8.2

[359] Based on BG&E 'Development of Residential Load Profile for Central Air Conditioners and Heat Pumps' research, the Maryland Peak Definition coincidence factor is 0.69. This study is not publicly available, but is referenced by M. M. Straub, Using Available Information for Efficient Evaluation of Demand-Side Management Programs, Electricity Journal, September 2011 and supported by research conducted by Cadmus on behalf of the RM Management Committee.

[360] 10 CFR 430.32(c)(1)

[361] 10 CFR 430.32(c)(1)

Product Class	Seasonal Energy Efficiency Ratio (SEER)[360]	Energy Efficiency Ratio (EER)	Heating Seasonal Performance Factor (HSPF)[361]
Single Package – Heat Pump (<65 kBTU/h)	14.0	11.8	8.0

GSHP System Baseline Efficiencies

Product Application	Full-Load Rated Heating COP	Full-Load Rated Cooling EER	Adjusted Heating Efficiency ($COP_{season,base}$)	Adjusted Cooling Efficiency ($EER_{season,base}$)
Closed Loop, GLHP-rating	3.2	14.1	2.95	12.99
Open Loop, GWHP-rating	3.7	18.0	3.05	14.71

*Equipment < 135 kBTU/h cooling capacity rated by ISO/ANSI/ASHRAE 13256-1: Baseline system is assumed to be single stage.
**Adjusted values use corrections below for pumping and distribution losses assuming a pumping power of 90 Watts per ton for closed loop and 120 Watts per ton open loop.

The baseline efficiency for fossil fuel fired heating systems serving single-family homes and individual units is defined by the Code of Federal Regulations as shown in the table below.

Fossil Fuel Fired Heating System Baseline Efficiencies: Systems Serving Single Units[362]

Equipment Type	Size Range	ECCCNYS Minimum Efficiency for Climate Zones 4, 5 and 6
Warm Air Furnace, Gas Fired	All Capacities	0.80 AFUE
Warm Air Furnace, Oil Fired	All Capacities	0.83 AFUE
Boiler, Hot Water, Gas Fired	All Capacities	0.82 AFUE
Boiler, Hot Water, Oil Fired	All Capacities	0.84 AFUE
Boiler, Steam, Gas Fired	All Capacities	0.80 AFUE
Boiler, Steam, Oil Fired	All Capacities	0.82 AFUE

The baseline efficiency for heating systems serving multiple dwelling units is defined by International Energy Conservation Code[363] and subsequently adopted by the Energy Conservation Construction Code of New York State (ECCCNYS) as shown in the table below.

[362] 10 CFR 430.32(e)
[363] ECCCNYS 2020, Table C403.3.2(4) & Table C403.3.2(5)

Fossil Fuel Fired Heating System Baseline Efficiencies: Systems Serving Multiple Dwelling Units

Equipment Type	Size Range	ECCCNYS Minimum Efficiency for Climate Zones 4, 5 and 6
Warm Air Furnace, Gas Fired	< 225 kBTU/h	0.80 AFUE
	≥ 225 kBTU/h	0.80 Et
Warm Air Furnace, Oil Fired	< 225 kBTU/h	0.83 AFUE
	≥ 225 kBTU/h	0.80 Et
Warm Air Unit Heaters, Gas Fired	All Capacities	0.80 Ec
Warm Air Unit Heaters, Oil Fired	All Capacities	0.80 Ec
Boiler, Hot Water, Gas Fired	< 300 kBTU/h	0.82 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.80 Et
	> 2,500 kBTU/h	0.82 Ec
Boiler, Hot Water, Oil Fired	< 300 kBTU/h	0.84 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.82 Et
	> 2,500 kBTU/h	0.84 Ec
Boiler, Steam, Gas Fired, All Except Natural Draft	< 300 kBTU/h	0.80 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.79 Et
	> 2,500 kBTU/h	0.79 Et
Boiler, Steam, Gas Fired, Natural Draft	< 300 kBTU/h	0.80 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.77 Et
	> 2,500 kBTU/h	0.77 Et
Boiler, Steam, Oil Fired	< 300 kBTU/h	0.82 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.81 Et
	> 2,500 kBTU/h	0.81 Et

For scenarios where the baseline heating system is electric resistance heat or an electric furnace, the baseline efficiency is assumed to be a COP of 1.0.

For scenarios where the baseline heating system is a conventional ASHP, additional consideration is given to account for the significant difference between the rating conditions for HSPF and the typical operating conditions in New York State, as shown below:

The HSPF is the AHRI-rated heating seasonal average efficiency expressed in terms of BTU/watt-hour. A seasonally adjusted $COP_{baseline}$ of a conventional air-source heat pump is used in the above equations. This adjusted baseline COP shall be calculated as:

$$COP_{season,baseline} = \frac{HSPF \times F_{HSPF}}{3.412}$$

where:

HSPF = Heating seasonal performance factor of the baseline system

F_{HSPF} = HSPF Climate Adjustment Factor, from table below

3.412 = Conversion factor, one watt-hour equals 3.412 BTU

HSPF Climate Adjustment Factor (F_{HSPF}) for Conventional ASHP Used as a Baseline

City	HSPF < 8.5	HSPF ≥ 8.5
Albany	0.70	0.67
Binghamton	0.68	0.65
Buffalo	0.73	0.70
Massena	0.59	0.56
NYC	0.80	0.78
Poughkeepsie	0.62	0.59
Syracuse	0.69	0.66

For scenarios where the baseline cooling system is a conventional ASHP, no additional consideration is given to account for the difference between the rating conditions for SEER and the typical operating conditions in New York State, because the differences between the rating conditions and the typical operating conditions are small.

For scenarios where the baseline heating and cooling system is an existing GSHP, the seasonal heating and cooling efficiencies of the baseline equipment code minimum efficiencies that have been adjusted consistent with the methodology provided for efficient equipment described in the *Compliance Efficiency from Which Incentives are Calculated* section below.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is an ENERGY STAR® certified GSHP system as defined in the Measure Description section above. If the GSHP system is closed loop, use the following formulas with the COP and EER values from the GLHP ratings. If the GSHP system is an open loop system, use the following formulas with the COP and EER values from the GWHP ratings. The formulas adjust performance for closed loop systems to an average entering water temperature of approximately 40°F for heating and 77°F for cooling. The open loop formulas adjust performance to an average entering water temperature of 50°F for both heating and cooling[364].

The formulas determine the average seasonal cooling efficiency ($EER_{season,ee}$) and the average seasonal heating efficiency ($COP_{season,ee}$) for a GSHP system with a two-stage or variable speed compressor.

Closed Loop Systems (using GLHP ratings):

$$EER_{season,ee} = \Big(\big(F_{full} \times EER_{GLHP,full} \times 1.09 \times F_{pump,full}\big) + \big(F_{part} \times EER_{GLHP,part} \times F_{pump,part}\big)\Big) \times F_{dist,c}$$

$$COP_{season,ee} = \Big(\big(F_{full} \times COP_{GLHP,full} \times 1.08 \times F_{pump,full}\big) + \big(F_{part} \times COP_{GLHP,part} \times F_{pump,part}\big)\Big) \times F_{dist,h}$$

[364] These entering temperatures were selected based on measured data from GSHP sites presented in NYSERDA Report 18-03.

Open Loop Systems (using GWHP ratings):

$$EER_{season,ee} = \Big(\big(F_{full} \times EER_{GWHP,full} \times F_{pump,full}\big) + \big(F_{part} \times EER_{GWHP,part} \times F_{pump,part}\big)\Big) \times 1.09 \times F_{dist,c}$$

$$COP_{season,ee} = \Big(\big(F_{full} \times COP_{GWHP,full} \times F_{pump,full}\big) + \big(F_{part} \times COP_{GWHP,part} \times F_{pump,part}\big)\Big) \times F_{dist,h}$$

where:

$COP_{GLHP,full}$ = Rated COP of the unit at GLHP full load heating conditions
$COP_{GLHP,part}$ = Rated COP of the unit at GLHP part load heating conditions
$EER_{GLHP,full}$ = Rated EER of the unit at GLHP full load cooling conditions
$EER_{GLHP,part}$ = Rated EER of the unit at GLHP part load cooling conditions
$COP_{GWHP,full}$ = Rated COP of the unit at GWHP full load heating conditions
$COP_{GWHP,part}$ = Rated COP of the unit at GWHP part load heating conditions
$EER_{GWHP,full}$ = Rated EER of the unit at GWHP full load cooling conditions
$EER_{GWHP,part}$ = Rated EER of the unit at GWHP part load cooling conditions
$F_{dist,c}$ = Factor to adjust the cooling efficiency to account for additional fan power
$F_{dist,h}$ = Factor to adjust the heating efficiency to account for additional fan power
F_{full} = Seasonal weighting factor for full load efficiency
F_{part} = Seasonal weighting factor for part load efficiency
$F_{pump,\ part}$ = Factor to adjust part load efficiency to account for additional pumping power
$F_{pump,full}$ = Factor to adjust full load efficiency to account for additional pumping power
1.09 = Correction for change in EER[365]
1.08 = Correction for change in COP[366]

Summary of Variables and Data Sources

Variable	Value	Source
$COP_{GLHP,full}$		The rated COP of the unit at GLHP full load (or standard) heating conditions from ASHRAE/ISO 13256-1. This value is certified by AHRI and is available in the product directory. It corresponds to an entering loop temperature of 32°F.
$COP_{GLHP,part}$		The rated COP of the unit at GLHP part load heating conditions from ASHRAE/ISO 13256-1. This value is certified by AHRI and is available in the product directory. It corresponds to an entering loop temperature of 41°F.

[365] Correction for 9% change in EER as the entering fluid temperature decreases from 77°F to 68°F. The 1% per °F was observed from published performance data as well as in the IGSHPA Design Manual. This factor also applies to the GWHP adjustment from 50°F to 59°F.
[366] Correction for 8% change in COP as the entering fluid temperature increases from 32°F to 40°F. The 1% per °F was observed from published performance data as well as in the IGSHPA Design Manual.

Variable	Value	Source
$EER_{GLHP,full}$		The rated EER of the unit at GLHP full load (or standard) cooling conditions from ASHRAE/ISO 13256-1. This value is certified by AHRI and is available in the product directory. It corresponds to an entering loop temperature of 77°F.
$EER_{GLHP,part}$		The rated EER of the unit at GLHP part load cooling conditions from ASHRAE/ISO 13256-1. This value is certified by AHRI and is available in the product directory. It corresponds to an entering loop temperature of 68°F.
$COP_{GWHP,full}$		The rated COP of the unit at GWHP full load (or standard) heating conditions from ASHRAE/ISO 13256-1. This value is certified by AHRI and is available in the product directory. It corresponds to an entering water temperature of 50°F.
$COP_{GWHP,part}$		The rated COP of the unit at GWHP part load heating conditions from ASHRAE/ISO 13256-1. This value is certified by AHRI and is available in the product directory. It corresponds to an entering water temperature of 50°F.
$EER_{GWHP,full}$		The rated EER of the unit at GWHP full load (or standard) cooling conditions from ASHRAE/ISO 13256-1. This value is certified by AHRI and is available in the product directory. It corresponds to an entering water temperature of 59°F.
$EER_{GWHP,part}$		The rated EER of the unit at GWHP part load cooling conditions from ASHRAE/ISO 13256-1. This value is certified by AHRI and is available in the product directory. It corresponds to an entering water temperature of 59°F.
$F_{dist,c}$		Factor to adjust the cooling efficiency to account for additional fan power that would be required, beyond the fan power corresponding to zero static in rated COP. Choose the appropriate factor from the Distribution Correction Factors table below.
$F_{dist,h}$		Factor to adjust the heating efficiency to account for additional fan power that would be required, beyond the fan power corresponding to zero static in rated COP. Choose the appropriate factor from the Distribution Correction Factors table below.
F_{full}	0.25	Seasonal weighting factor for full load efficiency = 0.25. Based in part on observed mix of low and high stage operation from field testing.[367]
F_{part}	0.75	Seasonal weighting factor for part load efficiency = 0.75. Based in part on observed mix of low and high stage operation from field testing.[368]
$F_{pump,full}$		Factor to adjust the full load efficiency to account for additional pumping power used by the system. Choose the appropriate factor from Pumping Power Adjustment Factor table below.

[367] New York State Energy Research and Development Authority (NYSERDA) 2017. "Analysis of Water Furnace Geothermal Heat Pump Sites in New York State with Symphony Monitoring System," NYSERDA Report Number 18-03. Prepared by CDH Energy Corp., Cazenovia, NY. nyserda.ny.gov/publications.
[368] Ibid.

Variable	Value	Source
$F_{pump,part}$		Factor to adjust the part load efficiency to account for additional pumping power used by the system. Choose the appropriate factor from Pumping Power Adjustment Factor table below.

Loop Pumping Power Correction Factor ($F_{pump,full}$ and $F_{pump,part}$)

A correction factor for pumps ($F_{pump,full}$ and $F_{pump,part}$) is required because the rated efficiency values only include the pumping energy associated with the water-side pressure drop through the heat pump unit (typically about 5-10 Watts per nominal ton). Actual pumping power is much higher. The ASHRAE GSHP Design Guide (Kavanaugh and Rafferty 2015) developed a grading system that assigns scores based on the amount of pumping power per installed ton. For instance, it gives a grade of "A" to system that uses 45 Watts per nominal ton and a grade of "B" to a system that uses 60 Watts per nominal ton.

Analysis of observed pumping power from 45 to 120 Watts/ton was performed to determine the impact of loop pumping power on efficiency. Results are shown in the Pumping Factors table below.[369]

Pumping Power Adjustment Factors

Different factors are required for different loop pumping power levels and loop pump control strategies. For part load performance there are multiple ways to control the pump at low stage:

- the pump can maintain constant flow regardless of compressor stage.
- the pump stages flow in proportion to the compressor capacity.
- the pump can be variable speed and modulate with the variable speed compressor.

A constant speed loop pump results in poor performance since the pump power becomes a relatively larger portion of total power at low stage. Variable speed pumping with a variable speed compressor results in the best performance. The penalty for constant speed pumping is highest for units with variable speed compressors. The last consideration is the low-to-high capacity ratio (CR), which can be calculated as follows:

$$CR = \frac{QC_{GLHP,part}}{QC_{GLHP,full}}$$

where:

CR = Capacity ratio of part-load cooling capacity to full-load heating capacity.

$QC_{GLHP,part}$ = Part-load cooling capacity rating from AHRI certificate.

$QC_{GLHP,full}$ = Full-load heating capacity rating from AHRI certificate.

[369] Henderson, H.I., 2020. White Paper: Savings Calculations for Residential Ground Source Heat Pumps: The Basis for Equivalent Full Load Hours (EFLH) and Seasonal Efficiency Factors. Prepared for the New York State Energy Research and Development Authority (NYSERDA) and the New York State Department of Public Service. Revised in June.

The values of QC are the rated full and part load performance values from AHRI. Units with two stage compressors typically have a value of CR of approximately 0.75. Units with variable speed compressors typically have a CR of approximately 0.40.
The table below presents the values of $F_{pump,full}$ and $F_{pump,part}$ that correspond to each loop pump arrangement (e.g. pumping control strategy, CR, and pumping power). The full load pumping factors are typically 0.86 to 0.94. Part load factors can range from 0.62 to 0.95 depending on the pumping control strategy, the capacity ratio of the heat pump, and the pumping power. The factor closest to the actual situation should be used.

Pumping Factors ($F_{pump,full}$ and $F_{pump,part}$)

Pumping Control Strategy	Capacity Ratio	Pumping Power											
		45 Watts/ton		60 Watts/ton		75 Watts/ton		90 Watts/ton		105 Watt/ton		120 Watts/ton	
		Clg	Htg	Clg	Htg	Clg	Htg	Clg	Htg	Clg	Htg	Clg	Htg
Full load ($F_{pump,full}$)		0.94	0.94	0.93	0.92	0.91	0.90	0.89	0.89	0.88	0.87	0.86	0.86
Part load – constant flow pumping ($F_{pump,part}$)	0.75	0.89	0.91	0.86	0.89	0.83	0.86	0.80	0.84	0.78	0.82	0.75	0.80
Part load – constant flow pumping ($F_{pump,part}$)	0.40	0.81	0.85	0.77	0.81	0.72	0.77	0.69	0.74	0.65	0.71	0.62	0.68
Part load – staged pumping ($F_{pump,part}$)	0.75	0.92	0.94	0.89	0.91	0.87	0.89	0.84	0.87	0.82	0.86	0.80	0.84
Part load – staged pumping ($F_{pump,part}$)	0.40	0.92	0.94	0.89	0.91	0.87	0.89	0.84	0.87	0.82	0.86	0.80	0.84
Part load – variable pumping ($F_{pump,part}$)	0.40	0.94	0.95	0.92	0.93	0.90	0.92	0.88	0.90	0.86	0.89	0.84	0.87

Distribution Power Correction

For GSHP systems with an air-duct distribution system, the fan power included in the rated efficiencies corresponds to zero external static pressure and therefore is smaller than would be expected for an actual application. The indoor fan power included in the ISO 13256-1 test procedure is estimated to be approximately 0.15 Watts/cfm for permanent split-capacitor fan motors and 0.11 Watts/cfm for electrically commutated fan motors.[370]

The purpose of the distribution (i.e., fan or pump) correction factor, $F_{dist,h}$ and $F_{dist,c}$ is to determine the equivalent amount of distribution power for the baseline system, such as a fossil fuel fired furnace or boiler, or a heat pump. The correction factor considers the differential distribution power between the GSHP and the baseline system. The Distribution Correction Factors to correct GSHP Seasonal Efficiency for typical baseline scenarios summarized in the table below:

[370] Ibid.

Distribution Correction Factors ($F_{dist,h}$ and $F_{dist,c}$)

	If baseline system is a Furnace with conventional air conditioning	If baseline system is a Boiler with conventional air conditioning	If baseline system is a Central air source heat pump
Heating ($F_{dist,h}$)	0.96	0.96	0.97
Cooling ($F_{dist,c}$)	0.95	0.95	0.95

Note: Based on furnace and boiler ancillary power of 137 Watts

Operating Hours

The Building Equivalent Full Load Hours for heating ($BEFLH_{heating}$) and for cooling ($BEFLH_{cooling}$) in the tables below represent equivalent full load operating hours for HVAC equipment based on 1% design temperature, TMY3 weather data, and the design heating load. For heating, hours from the summer period (June through September) were excluded. For Cooling, the values of EFLH from Appendix G were multiplied by a factor of 1.25 to convert to BEFLH.

Single-Family Detached Cooling $BEFLH_{cooling}$ by Vintage and City

City	Old	Average	New
Albany	403	388	349
Binghamton	249	246	198
Buffalo	418	403	345
Massena	323	313	263
NYC	838	811	788
Poughkeepsie	620	588	580
Syracuse	388	370	335

Multi-Family Low-Rise Cooling $BEFLH_{cooling}$ by Vintage and City

City	Prior to 1979	From 1979 Through 2006	From 2007 Through Present
Albany	358	369	349
Binghamton	271	274	263
Buffalo	338	343	320
Massena	288	285	273
NYC	634	688	703
Poughkeepsie	496	529	526
Syracuse	331	355	371

Single-Family Detached Heating $BEFLH_{heating}$ by Vintage and City

City	Old	Average	New
Albany	1,878	1,763	1,643
Binghamton	2,060	1,935	1,804
Buffalo	2,080	1,952	1,819
Massena	1,986	1,880	1,772
NYC	1,636	1,485	1,329
Poughkeepsie	2,044	1,912	1,776
Syracuse	1,960	1,842	1,720

Multi-Family Low-Rise Heating BEFLH $_{heating}$ by Vintage and City

City	Pre-war uninsulated brick	Prior to 1979	From 1979 Through 2006	From 2007 Through present
Albany	1,889	1,751	1,720	1,239
Binghamton	2,375	2,244	2,117	1,528
Buffalo	2,178	2,072	2,066	1,501
Massena	2,436	2,220	2,254	1,639
NYC	1,698	1,287	1,229	855
Poughkeepsie	1,457	1,520	1,476	1,047
Syracuse	2,372	1,998	2,050	1,437

Example Calculation *(Not to be used as default)*

A closed loop water-to-air GSHP is installed in a single family, detached home located near Albany and constructed in 1995. The heat pump has variable speed pump controls and a rated heating capacity of 60 kBTUh, with a full load EER of 19, part load EER of 25, full load COP of 3.5 and part load COP of 4.1. The GSHP has 60 watts/ton system pumping power. The home has a building cooling load of 36 kBTUh and the building cooling load of 58 kBTUh, and existing HVAC equipment are a split system air conditioner and a gas fired furnace. Annual Electric Energy Savings, Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta kWh = \left[\frac{BCL}{1{,}000} \times \left(\frac{1}{EER_{season,baseline}} - \frac{1}{EER_{season,ee}}\right) \times BEFLH_{cooling}\right] + \left[\frac{BHL}{3{,}412} \times \left(\frac{F_{ElecHeat}}{COP_{season,baseline}} - \frac{1}{COP_{season,ee}}\right) \times BEFLH_{heating}\right]$$

$$\Delta kW = \frac{BCL}{1{,}000} \times \left(\frac{1}{EER_{peak,baseline}} - \frac{1}{EER_{GSHP,full,ee}}\right) \times CF$$

$$\Delta MMBtu = \frac{BHL}{1{,}000{,}000} \times \frac{F_{FuelHeat}}{AFUE_{baseline}} \times BEFLH_{heating}$$

BCL = 36,000, from application

$EER_{season,baseline}$ = 13.0, from Baseline Efficiencies section based on equipment type and size from application

$EER_{season,ee}$ = ((F_{full} x $EER_{GLHP,full}$ x 1.09 x $F_{pump,full}$) + (F_{part} x $EER_{GLHP,part}$ x $F_{pump,part}$)) x $F_{dist,c}$
= ((0.25 x 19 x 1.09 x 0.93) + (0.75 x 25 x 0.92)) x 0.95 = 20.96

$EER_{season,ee}$ equation from Compliance Efficiency section based on GSHP type

F_{full} from Compliance Efficiency section's Summary of Variables and Data Sources table

$EER_{GLHP,full}$ from application

$F_{pump,full}$ from Pumping Power Adjustment Factors table based on application

F_{part} from Compliance Efficiency section's Summary of Variables and Data Sources table

$EER_{GLHP,part}$ from application

$F_{pump,part}$ from Pumping Power Adjustment Factors table based on application
$F_{dist,c}$ from Distribution Correction Factors based on application
$BEFLH_{cooling}$ = 388, from Operating Hours section tables based on housing type, city, and vintage from application
BHL = 58,000, from application
$F_{ElecHeat}$ = 0, from Summary of Variables and Data Sources table based on existing HVAC from application
$COP_{seaseason,baseline}$ = N/A
$COP_{season,ee} = ((F_{full} \times COP_{GLHP,full} \times 1.08 \times F_{pump,full}) + (F_{part} \times COP_{GLHP,part} \times F_{pump,part})) \times F_{dist,h}$
= ((0.25 x 3.5 x 1.08 x 0.92) + (0.75 x 4.1 x 0.93)) x 0.96 = 3.58
$COP_{season,ee}$ equation from Compliance Efficiency section based on GSHP type
$COP_{GLHP,full}$ from application
$F_{pump,full}$ from Pumping Power Adjustment Factors table based on application
$COP_{GLHP,part}$ from application
$F_{pump,part}$ from Pumping Power Adjustment Factors table based on application
$F_{dist,h}$ from Distribution Correction Factors based on application
$BEFLH_{heating}$ = 1,735, from Operating Hours section tables based on housing type, city, and vintage from application
$EER_{peak,baseline}$ = 11.2, from Baseline Efficiencies section based on equipment type and size from application
$EER_{GSHP,full,ee}$ = 19, from application
CF = 0.69, from Summary of Variables and Data Sources table
$F_{FuelHeat}$ = 1, from Summary of Variables and Data Sources table based on existing HVAC from application
$AFUE_{baseline}$ = 0.8, from Baseline Efficiencies section based on equipment type and size from application

$$\Delta kWh = \left[\frac{36{,}000}{1{,}000} \times \left(\frac{1}{13} - \frac{1}{20.96}\right) \times 388\right] + \left[\frac{58{,}000}{3{,}412} \times \left(0 - \frac{1}{3.58}\right) \times 1{,}735\right] = -7{,}830\ kWh$$

$$\Delta kW = \frac{36{,}000}{1{,}000} \times \left(\frac{1}{11.2} - \frac{1}{19}\right) \times 0.69 = 0.91\ kW$$

$$\Delta MMBtu = \frac{58{,}000}{1{,}000{,}000} \times \frac{1}{0.8} \times 1{,}735 = 125.79\ MMBtu$$

<u>Methods for Calculating Annual Domestic Hot Water Energy Savings from an Integrated Desuperheater or Dedicated Water-to-Water Heat Pump</u>

GSHP systems can reduce DHW energy consumption by two optional methods: 1) using a GSHP unit with an optional desuperheater or 2) installing an additional water-to-water heat pump (WWHP) dedicated to meeting the DHW load.

When a desuperheater is installed with a GSHP system, the energy consumed by a typical DHW appliance can be reduced. The waste heat from the compressor of the GSHP system is transferred through a heat exchanger to heat or preheat water that is delivered to a storage tank-type water heater. The benefit of the desuperheater varies throughout the year and depends on whether the system is operating in heating mode or cooling mode, and the duration of compressor operation. In the cooling mode, waste heat from the compressor is transferred to heat domestic hot water instead of the closed loop heat exchanger field. In the heating mode water heating is supplied at the heating COP of the heat pump. A desuperheater only heats DHW when the GSHP unit runs to meet the space heating or cooling load.

When a WWHP that is dedicated to DHW is added to the ground loop, the dedicated DHW-WWHP operates in response to the DHW loads, independent of GSHP unit operation to meet space loads. Therefore, the energy savings are more consistent across the year.

In this analysis, installation of a desuperheater is assumed to displace a percentage of the total DHW load, depending on the size of the DHW load. The dedicated WWHP more consistently displaces a larger portion of the DHW load. Electric demand impacts are not considered at this time.

$$\Delta MMBtu_{GSHP-DHW} = \frac{Q_{GSHP-DHW}}{1{,}000{,}000} \times \frac{F_{FFDHW}}{UEF_{baseline}}$$

$$\Delta kWh_{GSHP-DHW} = \frac{Q_{GSHP-DHW}}{3{,}412} \times \left(\frac{F_{EDHW}}{UEF_{baseline}} - \frac{1}{COP_{GSHP-DHW}}\right)$$

$$Q_{GSHP-DHW} = F_{GSHP-DHW} \times GPD \times 365 \times 8.33 \times \Delta T_{main}$$

For a desuperheater:

$$F_{GSHP-DHW} = F_{desup}$$

$$COP_{GSHP-DHW} = \frac{COP_{desup}}{F_{desup,htg\ mode}}$$

For a dedicated DHW-WWHP:

When DHW tank has resistance elements,

$$F_{GSHP-DHW} = 0.95$$

OR, when DHW tank is over 80 gallons and has no resistance elements[371]

[371] Based on feedback from NY-GEO on current field practices, if a DHW-WWHP is installed with a large pre-heating tank (e.g., over 80 gallons) it does not need an electric resistance element and can therefore meet 100% of the DHW load.

$$F_{GSHP-DHW} = 1.0$$

$$COP_{GSHP-DHW} = COP_{AHRI,GLHP} \times 0.9$$

where:

$\Delta MMBtu_{GSHP-DHW}$	= Fossil fuel energy displaced by a desuperheater or dedicated DHW-WWHP
$\Delta kWh_{GSHP-DHW}$	= Electricity displaced by desuperheater or dedicated DHW-WWHP operation, considering that desuperheater operation in the heating mode increases energy use
$COP_{AHRI,GLHP}$	= Rated COP for a per ISO13256-2 at GLHP conditions (32°F source, 104°F load)
COP_{desup}	= Overall COP of desuperheater (same as space heating efficiency, use $COP_{season,ee}$ as calculated in Compliance Efficiency section above)
$COP_{GSHP-DHW}$	= Overall annual COP of desuperheater or dedicated DHW-WWHP
F_{desup}	= Fraction of annual DHW load served by a desuperheater
$F_{desup,htg\ mode}$	= Fraction of desuperheater operation that occurs in heating mode
F_{EDHW}	= Factor indicating that baseline DHW system is electric
F_{FFDHW}	= Factor indicating that baseline DHW system is fossil fuel fired
$F_{GSHP-DHW}$	= Fraction of annual DHW load served by a desuperheater or dedicated DHW-WWHP
GPD	= Gallons per day per each unit
$Q_{GSHP-DHW}$	= Annual DHW load served by desuperheater or dedicated DHW-WWHP, BTU
$UEF_{baseline}$	= Uniform energy factor of baseline DHW appliance (fossil fuel or electric)
ΔT_{main}	= Average temperature difference between water heater set point temperature and the supply water temperature in water main (°F)
0.9	= Correction factor from AHRI rated conditions to 40°F source, 115°F load.
0.95	= Fraction of annual DHW load served by dedicated DHW-WWHP
8.33	= Energy required (BTU) to heat one gallon of water by one-degree Fahrenheit
365	= Days in one year
3,412	= Conversion factor, one kWh equals 3,412 BTU
1,000,000	= Conversion factor, one MMBtu equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
COP_{desup}		From application
F_{desup}		Choose annual desuperheater fraction from table as function of water use (GPD). Fraction of total DHW load met by desuperheater. If no desuperheater is present, set equal to 0.
$F_{desup,htg\ mode}$	0.72 for NY 0.86 for other cities	Fraction of desuperheater operation that occurs in the heating mode
F_{EDHW}	1 for electric DHW	Factor indicating baseline DHW is electric

Variable	Value	Notes
F_{FFDHW}	1 for fossil fuel-fired DHW	Factor indicating baseline DHW is fossil fuel-fired
GPD	17.2 × # of people	Calculated based on number of people served by the system. If unknown, use 46 GPD.
T_{main}		Supply water temperature in water main (°F). Lookup in Cold Water Inlet Temperature table below based on nearest city.
T_{set}	130	Water heater set point temperature (°F).
$UEF_{baseline}$		Uniform Energy Factor of the baseline condition. See Baseline Efficiencies section for details regarding derivation of this input.
ΔT_{main}	T_{set} - T_{main}	Average temperature difference between water heater set point temperature and the supply water temperature in water main (°F).

Desuperheater Annual Load Fraction

GPD	Fraction of DHW Load met by Desuperheater (F_{desup}, %)[372]
35	36%
45	30%
55	26%
65	22%

Note: Based on DHW set point of 130°F.

Cold Water Inlet Temperature (T_{main})

Supply water main temperatures vary according to climate and are approximately equal to the annual average outdoor temperature plus 6°F.[373] Supply main temperatures based on the annual outdoor temperature are shown below.

City	Annual average outdoor temperature[374] (°F)	T_{main} (°F)
Albany	48.3	54.3
Binghamton	46.3	52.3
Buffalo	48.3	54.3
Massena	43.5	49.5
NYC	55.4	61.4
Poughkeepsie	49.8	55.8
Syracuse	48.3	54.3

[372] Based on an analysis using results from Carlson (1997) combined with bin data for NY cities, as shown in Appendix E of the GSHP White Paper (Henderson 2020). These factors consider the net impact on DHW system, after distribution losses from desuperheater piping. A Geolink report for Albany implied a fraction of 50% with usage of 54 gal/day, ignoring distribution losses.

[373] Burch, Jay and Christensen, Craig, "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory

[374] Average annual outdoor temperatures taken from NCEI 1981-2010 climate normals.

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a minimally code compliant water heater of type (storage-type or instantaneous) equivalent to the existing water heater and with tank volume (where applicable), input capacity and draw pattern equivalent to the efficient water heater. For new construction, the baseline condition is a minimally code compliant storage-type water heater with tank volume, input capacity and draw pattern equivalent to the efficient water heater. $UEF_{baseline}$ shall be calculated as a function of qualifying equipment tank volume (vt) for storage type water heaters. A Medium draw pattern should be assumed for storage type water heaters with rated storage capacity ≤ 50 gallons and a High draw pattern should be assumed otherwise.[375]

Residential Water Heaters[376]

Product Class	Rated Storage Volume and Input Rating	Draw Pattern	$UEF_{baseline}$
Electric Storage Water Heater	≥ 20 gal and ≤ 55 gal	Very Small	$0.8808 - (0.0008 \times v_t)$
		Low	$0.9254 - (0.0003 \times v_t)$
		Medium	$0.9307 - (0.0002 \times v_t)$
		High	$0.9349 - (0.0001 \times v_t)$
	> 55 gal and ≤ 120 gal	Very Small	$1.9236 - (0.0011 \times v_t)$
		Low	$2.0440 - (0.0011 \times v_t)$
		Medium	$2.1171 - (0.0011 \times v_t)$
		High	$2.2418 - (0.0011 \times v_t)$
Gas-Fired Storage Water Heater	≥ 20 gal and ≤ 55 gal	Very Small	$0.3456 – (0.0020 \times v_t)$
		Low	$0.5982 – (0.0019 \times v_t)$
		Medium	$0.6483 – (0.0017 \times v_t)$
		High	$0.6920 – (0.0013 \times v_t)$
	> 55 gal and ≤ 100 gal	Very Small	$0.6470 – (0.0006 \times v_t)$
		Low	$0.7689 – (0.0005 \times v_t)$
		Medium	$0.7897 – (0.0004 \times v_t)$
		High	$0.8072 – (0.0003 \times v_t)$
Oil-Fired Storage Water Heater	≤ 50 gal	Very Small	$0.2509 – (0.0012 \times v_t)$
		Low	$0.5330 – (0.0016 \times v_t)$
		Medium	$0.6078 – (0.0016 \times v_t)$
		High	$0.6815 – (0.0014 \times v_t)$

*v_t = tank volume in gallons

First Hour Rating vs. Draw Pattern (Storage Type Only)[377]

First Hour Rating	Draw Pattern
< 18 gallons	Very Small
≥ 18 and < 51 gallons	Low
≥ 51 and < 75 gallons	Medium
≥ 75 gallons	High

[375] Based on review of typical usage bins for AHRI certified residential water heating equipment. (https://www.ahridirectory.org/ahridirectory/pages/home.aspx)
[376] 10 CFR 430.32(d)
[377] 10 CFR 429.17

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. 10 CFR 430.32 Energy and water conservation standards and their compliance dates. Available from: http://www.ecfr.gov/cgi-bin/text-idx?SID=a9921a66f2b4f66a32ec851916b7b9d9&mc=true&node=se10.3.430_132&rgn=div8
2. BG&E: Development of Residential Load Profile for Central Air Conditioners and Heat Pumps
3. Building America House Simulation Protocols, Robert Hendron and Cheryn Engebrecht, National Renewable Energy Laboratory, October 2010 Available from: https://www1.eere.energy.gov/buildings/publications/pdfs/building_america/house_simulation_revised.pdf
4. Carlson, S. 1997. "Geothermal Heat Pump Performance in Heating Dominated Climates." Presented at Heat Pumps in Cold Climates, 3rd International Technical Conference. August 11-12. Wolfville, Nova Scotia.
5. ECCCNYS 2020, Table C403.3.2(4): Warm-Air Furnaces And Combination Warm-Air Furnaces/Air-Conditioning Units, Warm-Air Duct Furnaces And Unit Heaters, Minimum Efficiency Requirements & Table C403.2.3(5): Minimum Efficiency Requirements: Gas- And Oil-Fired Boilers.
   Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-[ce]-commercial-energy-efficiency#NYSECC2020P1_CE_Ch04_SecC402
6. Fairey, P., D. Parker, B Wilcox, M Lombardi. *Climate Impacts on Heating Seasonal Performance Factor (HSPF) and Seasonal Energy Efficiency Ratio (SEER) for Air Source Heat Pumps*, ASHRAE Transactions, 110(2): 178-88.
7. *Guide to Geothermal Heat Pumps* (February 2011) U. S. Department of Energy, Energy Efficiency and Renewable Energy, DOE/EE-0385
8. Henderson, H.I., 2020. White Paper: Savings Calculations for Residential Ground Source Heat Pumps: The Basis for Equivalent Full Load Hours (EFLH) and Seasonal Efficiency Factors. Prepared for the New York State Energy Research and Development Authority (NYSERDA) and the New York State Department of Public Service. Revised in June.
9. International Ground Source Heat Pump Association (IGSHPA). 2011. Ground Source Heat Pump Residential and Light Commercial Design and Installation Guide. Oklahoma State University. Stillwater.

10. Kavanaugh, S and Rafferty, K (2015): *Geothermal Heating and Cooling, Design of Ground-Source Heat Pump Systems* RP-1674, Atlanta, GA. ASHRAE Inc.
11. *Manual J Residential Load Calculation*, Arlington, VA. Air Conditioning Contractors Association
12. *Manual S Equipment Selection*, Arlington, VA. Air Conditioning Contractors Association
13. M. M. Straub, Using Available Information for Efficient Evaluation of Demand-Side Management Programs, Electricity Journal, September 2011 Available from: https://www.sciencedirect.com/science/article/pii/S1040619011001941
14. Monitored data from geothermal heat pump systems installed in New York State submitted August 2015 by the New York Geothermal Energy Organization and reviewed by NYS DPS Staff.
15. New York State Energy Research and Development Authority (NYSERDA). 2017. "Analysis of Water Furnace Geothermal Heat Pump Sites in New York State with Symphony Monitoring System," NYSERDA Report Number 18-03. Prepared by CDH Energy Corp., Cazenovia, NY. nyserda.ny.gov/publications.
16. *Water Source Heat Pumps – Testing and Rating for Performance – Part 1: Water to Air and Brine to Air Heat Pumps* (2012) Arlington, VA. ANSI/ASHRAE/ISO Standard 13256-1:1998 (RA 2012), AHRI, 2012.

Record of Revision

Record of Revision Number	Issue Date
1	10/15/2010
4-16-1	3/31/2016
6-17-6	6/30/2017
3-18-11	3/29/2018
2-20-3	2/28/2020
7-20-22	7/31/2020

Return to Table of Contents

REFRIGERANT CHARGE CORRECTION & TUNE UP – AIR CONDITIONER AND HEAT PUMP

Measure Description

This measure estimates savings associated with refrigerant charge correction for unitary and split system air conditioners and heat pumps in single and multi-family residential applications. In order to be eligible for energy savings, the scope of work performed must include manufacturer recommended AC tune-up procedures including but not limited to the cleaning of the condenser coils.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

For Units with Cooling Capacity < 65,000 BTU/h

$$\Delta kWh = units \times \left\{ \left[tons/unit \times \left(\frac{12}{SEER_{baseline}} - \frac{12}{SEER_{ee}} \right) \times EFLH_{cooling} \right] + \left[(kBTU/h)_{out}/unit \times \left(\frac{1}{HSPF_{baseline}} - \frac{1}{HSPF_{ee}} \right) \times EFLH_{heating} \right] \right\}$$

For Units with Cooling Capacity ≥ 65,000 BTU/h

$$\Delta kWh = units \times \left\{ \left[tons/unit \times \left(\frac{12}{IEER_{baseline}} - \frac{12}{IEER_{ee}} \right) \times EFLH_{cooling} \right] + \left[\frac{(kBTU/h)_{out}/unit}{3.412} \times \left(\frac{1}{COP_{baseline}} - \frac{1}{COP_{ee}} \right) \times EFLH_{heating} \right] \right\}$$

Summer Peak Coincident Demand Savings

$$\Delta kW = units \times tons/unit \times \left(\frac{12}{EER_{baseline}} - \frac{12}{EER_{ee}} \right) \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
tons/unit	= Tons of air conditioning per unit, based on AHRI certification or nameplate data of condenser or matched pair (condenser and coil)

$(kBTU/h)_{out}$/unit= Output heating capacity in kBTU/h (at AHRI standard high-temperature rating conditions)

$_{baseline}$ = Characteristic of baseline condition

$_{ee}$ = Characteristic of energy efficient condition

SEER = Seasonal average energy efficiency ratio over the cooling season, BTU/watt-hour, (used for average U.S. location/region)

IEER = Integrated energy efficiency ratio in BTU/watt-hour. A weighted calculation of mechanical cooling efficiencies at full load and part load AHRI standard rating conditions (used only for units with cooing capacity ≥ 65,000BTU/h)

EER = Energy efficiency ratio under peak conditions, measurement of cooling capacity for a unit (in BTU/h) / electrical energy used (watts) (at AHRI standard rating conditions)

HSPF = Heating seasonal performance factor, total heating output (supply heat) in BTU (including electric strip heat) during the heating season divided by the total electric energy heat pump consumed in watt-hours

COP = Coefficient of performance, ratio of output energy/input energy (at AHRI standard high-temperature rating conditions)

$EFLH_{cooling}$ = Cooling equivalent full-load hours

$EFLH_{heating}$ = Heating equivalent full-load hours

CF = Coincidence factor

12 = (kBTU/h)/ton of air conditioning capacity

3.412 = Conversion factor, one watt-hour equals 3.412 BTU

Summary of Variables and Data Sources

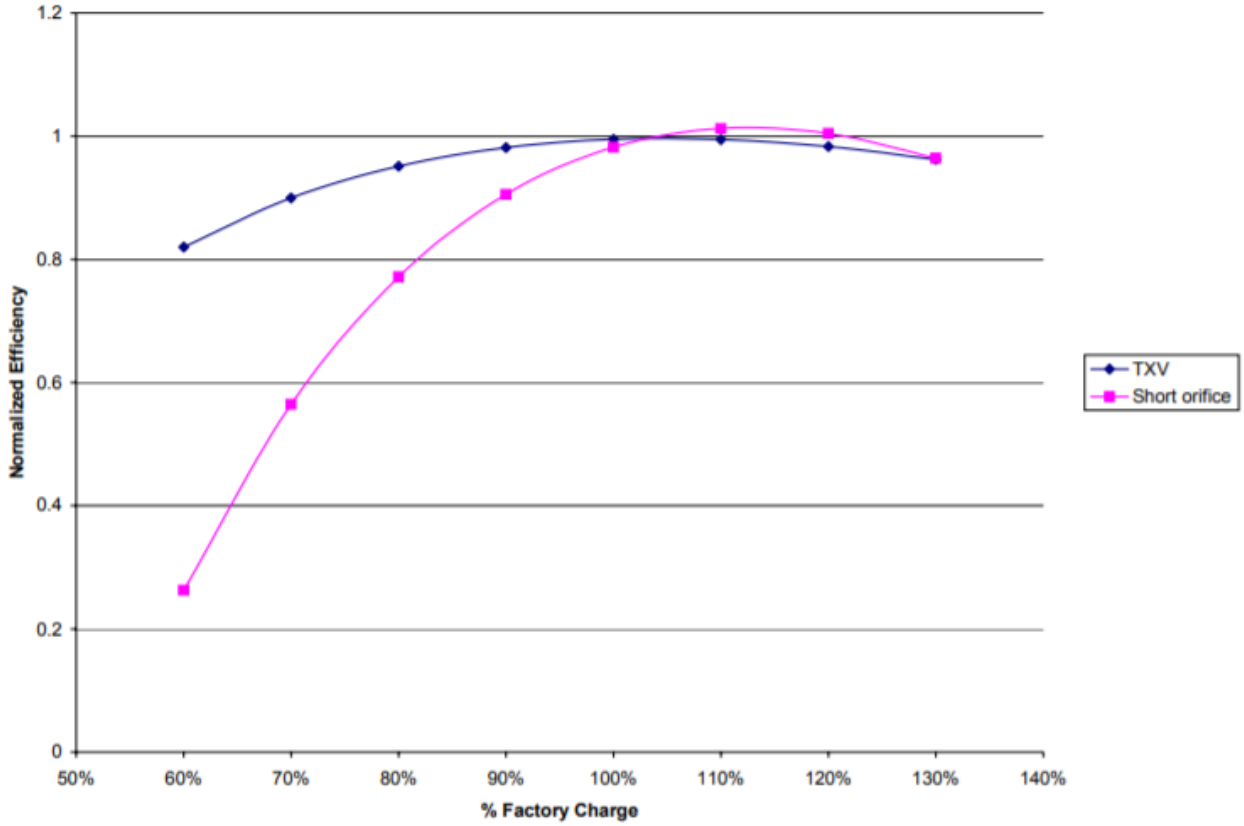
Variable	Value	Notes
tons/unit		From application.
$kBTU/h_{out}$		From application.
$SEER_{ee}$		Actual equipment nameplate SEER.
$SEER_{baseline}$		Actual equipment nameplate SEER, derated in accordance with the Baseline Efficiency section below.
$IEER_{ee}$		Actual equipment nameplate IEER.
$IEER_{baseline}$		Actual equipment nameplate IEER, derated in accordance with the Baseline Efficiency section below.
EER_{ee}		Actual equipment nameplate EER.
$EER_{baseline}$		Actual equipment nameplate EER, derated in accordance with the Baseline Efficiency section below.
$HSPF_{ee}$		Actual equipment nameplate HSPF.
$HSPF_{baseline}$		Actual equipment nameplate HSPF, derated in accordance with the Baseline Efficiency section below.
COP_{ee}		Actual equipment nameplate COP.
$COP_{baseline}$		Actual equipment nameplate COP, derated in accordance with the Baseline Efficiency section below.
$EFLH_{cooling}$		Look up based on building type, vintage and location in Appendix G.
$EFLH_{heating}$		Look up based on building type, vintage and location in Appendix G.
CF	0.69	

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.69.[378]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is equivalent to the existing condition with efficiency ratings taken from the actual equipment nameplate, derated to account for under or overcharging. The efficiency improvement resulting from refrigerant charge adjustment is dependent upon the discrepancy between the actual equipment charge before the adjustment was performed and the manufacturer's specification. The efficiency adjustment factor as a function of charge adjustment is taken from the figure or table below.[379] Note the efficiency change depends on the type of expansion valve. Use the curve or column labeled "TXV" for units with thermal expansion valves; otherwise use the curve or column labeled "Short orifice".



[378] Based on BG&E 'Development of Residential Load Profile for Central Air Conditioners and Heat Pumps' research, the Maryland Peak Definition coincidence factor is 0.69. This study is not publicly available, but is referenced by M. M. Straub, Using Available Information for Efficient Evaluation of Demand-Side Management Programs, Electricity Journal, September 2011 and supported by research conducted by Cadmus on behalf of the TRM Management Committee.

[379] Efficiency as a function of charge adjustment from Small HVAC System Design Guide, New Buildings Institute, 2003

% Factory Charge	Normalized Efficiency (Short Orifice)	Normalized Efficiency (TXV)	% Factory Charge	Normalized Efficiency (Short Orifice)	Normalized Efficiency (TXV)
60%	0.26	0.82	96%	0.96	0.99
62%	0.32	0.84	98%	0.97	0.99
64%	0.39	0.85	100%	0.98	1.00
66%	0.45	0.87	102%	0.99	1.00
68%	0.51	0.89	104%	1.00	1.00
70%	0.56	0.90	106%	1.00	1.00
72%	0.61	0.91	108%	1.00	1.00
74%	0.66	0.92	110%	1.00	1.00
76%	0.70	0.93	112%	1.00	0.99
78%	0.73	0.94	114%	1.00	0.99
80%	0.77	0.95	116%	1.00	0.99
82%	0.80	0.96	118%	1.00	0.99
84%	0.83	0.97	120%	1.00	0.99
86%	0.86	0.97	122%	1.00	0.98
88%	0.88	0.98	124%	0.99	0.98
90%	0.91	0.98	126%	0.98	0.97
92%	0.92	0.99	128%	0.97	0.97
94%	0.94	0.99	130%	0.96	0.96

If the equipment is a multi-circuit system, the overall efficiency adjustment shall be calculated as the sum of each circuit's derating factor multiplied by its percentage of the total system capacity. For example, the equation for $EER_{baseline}$ is shown below:

$$EER_{baseline} = EER_{ee} \times \sum_{n} \left(Cap_n \times F_{derate,n} \right)$$

where:

n = Each circuit

Cap = Fraction of total capacity

F_{derate} = Derating factor, normalized efficiency from figure/table above

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a residential air-cooled unitary or split system air conditioner or heat pump that has undergone a tune up involving a refrigerant charge correction. SEER, IEER, EER, HSPF, and COP values are taken from application as reported on the equipment nameplate or manufacturer specifications.

Operating Hours

For central air conditioners and heat pumps, look up EFLH data by location, building type and vintage from Appendix G. The oversizing assumptions embedded in the Appendix G data are appropriate for equipment sized to meet the peak-cooling load for central air conditioners and air source heat pumps.

Example Calculation *(Not to be used as default)*

A split system 3-ton heat pump with 36 kBTU/h heating capacity undergoes refrigerant charge correction and tune-up per manufacture recommended procedures in a single-family, detached home located near Albany constructed in 1995. The heat pump is rated at 18 SEER, 13.7 EER, and 10 HSPF and is equipped with a thermal expansion valve. It was determined that the unit was operating at 70% of factory charge prior to correction. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

$$\Delta kWh = units \times \left\{\left[tons/unit \times \left(\frac{12}{SEER_{baseline}} - \frac{12}{SEER_{ee}}\right) \times EFLH_{cooling}\right] + \left[(kBTU/h)_{out}/unit \times \left(\frac{1}{HSPF_{baseline}} - \frac{1}{HSPF_{ee}}\right) \times EFLH_{heating}\right]\right\}$$

$$\Delta kW = units \times tons/unit \times \left(\frac{12}{EER_{baseline}} - \frac{12}{EER_{ee}}\right) \times CF$$

units = 1, from application
tons/unit = 3, from application
$SEER_{baseline} = SEER_{ee} \times F_{detrate,n} = 18 \times 0.9 = 16.2$
$F_{derate,n}$ from Baseline Efficiencies table based on percentage of factory charge correction and expansion valve type from application
$SEER_{ee} = 18$, from application
$EFLH_{cooling} = 310$, from Appendix G based on housing type, building vintage, and location from application.
$(kBTU/h)_{out}/unit = 36$, from application
$HSPF_{baseline} = HSPF_{ee} \times F_{detrate,n} = 10 \times 0.9 = 9$, from Baseline Efficiencies table based on percentage of factory charge correction and expansion valve type from application
$HSPF_{ee} = 10$, from application
$EFLH_{heating} = 978$, from Appendix G based on housing type, building vintage, and location from application
$EER_{baseline} = EER_{ee} \times F_{detrate,n} = 13.7 \times 0.9 = 12.3$, from Baseline Efficiencies table based on percentage of factory charge correction and expansion valve type from application
$EER_{ee} = 13.7$, from application
CF = 0.69, from Summary of Variables and Data Sources table

$$\Delta kWh = 1 \times \left\{\left[3 \times \left(\frac{12}{16.2} - \frac{12}{18}\right) \times 310\right] + \left[36 \times \left(\frac{1}{9} - \frac{1}{10}\right) \times 978\right]\right\} = 460\ kWh$$

$$\Delta kW = 1 \times 3 \times \left(\frac{12}{12.3} - \frac{12}{13.7}\right) \times 0.69 = 0.202\ kW$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. Small HVAC System Design Guide, New Buildings Institute, White Salmon, WA for the California Energy Commission.
   Available from: https://newbuildings.org/sites/default/files/A-12_Sm_HVAC_Guide_4.7.5.pdf
2. BG&E, Development of Residential Load Profile for Central Air Conditioners and Heat Pumps

Record of Revision

Record of Revision Number	Issue Date
1	10/15/2010
6-18-3	6/26/2018

Return to Table of Contents

TUNE-UP - BOILER

Measure Description

This measure covers tune-up of residential fossil fuel-fired space heating boilers to improve seasonal heating efficiency. A tune-up involves the inspection, cleaning, and/or adjustment of boiler and appurtenances per manufacturer's recommendations. This measure addresses tune-up benefits associated with heating performance in single family or low-rise multifamily buildings only. For boiler tune-up in high-rise multifamily buildings, see Commercial Boiler Tune-Up measure.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = N/A$$

Summer Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = units \times \frac{kBTU/h_{in}}{unit} \times \frac{EFLH_{heating}}{1{,}000} \times ESF$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
$kBTU/h_{in}$	= Nameplate capacity fuel input rating (kBTU/h)
$EFLH_{heating}$	= Heating equivalent full-load hours
ESF	= Energy savings factor
1,000	= Conversion factor, one MMBtu equals 1,000 kBTU

Summary of Variables and Data Sources

Variable	Value	Notes
$kBTU/h_{in}$		From application.
$EFLH_{heating}$		Look up based on building type, vintage and location in Appendix G.
ESF	0.03	The energy savings factor for boiler tune-ups is used to estimate the annual heating energy savings.[380]

[380] Energy savings on the order of 2% - 5% were realized from a boiler tune-up program in the Pacific Northwest. Building Tune-Up and Operations Program Evaluation. Washington State University Energy Program, pg. 5.

Coincidence Factor (CF)

The prescribed value for the coincidence factor is N/A.

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a residential fossil fuel-fired space heating boiler in a single family or low-rise multifamily building that has not received a tune-up in 5 years or more.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a residential fossil fuel-fired boiler that has undergone a tune-up in accordance with the manufacturer's recommendations.

Operating Hours

Heating equivalent full-load hours were calculated from a DOE-2.2 simulation of prototypical single and multi-family residential buildings. Operating hour assumptions for the prototypical building models are described in Appendix A. The heating EFLH for residential buildings in NY are shown in Appendix G.

Example Calculation *(Not to be used as default)*

A 150 kBTU/h boiler undergoes a maintenance tune-up in a single-family, detached home located near Albany constructed in 1995. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are not applicable. Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta MMBtu = units \times \frac{kBTU/h_{in}}{unit} \times \frac{EFLH_{heating}}{1{,}000} \times ESF$$

units = 1, from Summary of Variables and Data Sources table
$kBTU/h_{in}$/unit = 150, from application
$EFLH_{heating}$ = 978, from Appendix G based on housing type, building vintage, and location from application
ESF = 0.03, from Summary of Variables and Data Sources table

$$\Delta MMBtu = 1 \times 150 \times \frac{978}{1{,}000} \times 0.03 = 4.40\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Improved boiler efficiency as a result of a boiler tune-up will reduce the run time of the distribution system's circulator pumps and boiler combustion fan if so equipped. These effects are anticipated to be small and are not currently quantified for this measure.

References

1. Dethman and Kunkle, Building Tune-Up and Operations Program Evaluation. Washington State University Energy Program, 2007. Available from: https://library.cee1.org/system/files/library/1808/990.pdf

Record of Revision

Record of Revision Number	Issue Date
6-18-15	6/26/2018

Return to Table of Contents

TUNE-UP - FURNACE

Measure Description

This measure covers tune-up of residential fossil fuel-fired furnaces to improve seasonal heating efficiency. A tune-up involves the inspection, cleaning, and or adjustment of furnace and appurtenances per manufacturer's recommendations. This measure addresses tune up benefits associated with heating performance only.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = \Delta MMBtu \times (\Delta kWh/\Delta MMBtu)$$

Summer Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = units \times \frac{kBTU/h_{in}}{unit} \times \frac{EFLH_{heating}}{1{,}000} \times ESF$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
$kBTU/h_{in}$	= Annual fuel input rating
$EFLH_{heating}$	= Heating equivalent full-load hours
ESF	= Energy savings factor
(ΔkWh/ΔMMBtu)	= Annual electric energy savings per unit annual fossil fuel energy savings
1,000	= Conversion factor, one MMBtu equals 1,000 kBTU

Summary of Variables and Data Sources

Variable	Value	Notes
$kBTU/h_{in}$		From application.
$EFLH_{heating}$		Look up based on building type, vintage and location in Appendix G.
ESF	0.05	The energy savings factor for furnace tune-ups is used to estimate the annual heating energy savings.[381]

[381] Energy savings on the order of 2% - 5% were realized from a boiler tune-up program in the Pacific Northwest. Building Tune-Up and Operations Program Evaluation. Washington State University Energy Program, p. 5.

Variable	Value	Notes
(ΔkWh/ΔMMBtu)	5.0	Savings resultant from reduced fan run time due to improved efficiency and cycling of furnace.[382]

Coincidence Factor (CF)

The prescribed value for the coincidence factor is N/A.

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a residential fossil fuel-fired furnace that has not received a tune-up in 5 years or more.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a residential fossil fuel-fired furnace that has undergone a tune-up in accordance with the manufacturer's recommendations.

Operating Hours

Heating equivalent full-load hours were calculated from a DOE-2.2 simulation of prototypical single and multi-family residential buildings. Operating hour assumptions for the prototypical building models are described in Appendix A. The heating EFLH for single and multi-family buildings in NY are shown in Appendix G.

Example Calculation *(Not to be used as default)*

A 80 kBTU/h furnace undergoes a maintenance tune-up in a single-family, detached home located near Albany constructed in 1995. Summer Peak Coincident Demand Savings are not applicable. Annual Electric Energy Savings and Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta MMBtu = units \times \frac{kBTU/h_{in}}{unit} \times \frac{EFLH_{heating}}{1{,}000} \times ESF$$

$$\Delta kWh = \Delta MMBtu \times (\Delta kWh/\Delta MMBtu)$$

units = 1, from Summary of Variables and Data Sources table
$kBTU/h_{in}$/unit = 80, from application
$EFLH_{heating}$ = 978, from Appendix G based on housing type, building vintage, and location from application
ESF = 0.05, from Summary of Variables and Data Sources table
ΔkWh/ΔMMBtu = 5.0, from Summary of Variables and Data Sources table

[382] Electricity Savings from Variable-Speed Furnaces in Cold Climates, Scott Pigg, Energy Center of Wisconsin & Tom Talerico, Glacier Consulting Group

$$\Delta MMBtu = 1 \times 80 \times \frac{978}{1{,}000} \times 0.05 = 3.91\ MMBtu$$

$$\Delta kWh = 3.91 \times 5.0 = 19.55\ kWh$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. Dethman and Kunkle, Building Tune-Up and Operations Program Evaluation. Washington State University Energy Program, 2007. Available from: https://library.cee1.org/system/files/library/1808/990.pdf
2. Electricity Savings from Variable-Speed Furnaces in Cold Climates, Scott Pigg, Energy Center of Wisconsin & Tom Talerico, Glacier Consulting Group Available from: https://aceee.org/files/proceedings/2004/data/papers/SS04_Panel1_Paper23.pdf

Record of Revision

Record of Revision Number	Issue Date
0	10/15/2010
3-18-13	3/29/2018

Return to Table of Contents

HEATING, VENTILATION AND AIR CONDITIONING (HVAC) – CONTROL

ADAPTIVE PHOTONIC CONTROL FOR HVAC FAN MOTORS

Measure Description

This measure covers the installation of adaptive photonic control systems applied to HVAC fan motors. Adaptive photonic control involves integration with an HVAC system's motors including PTACs, PTHPs, mini-splits, central air units and furnace distribution system supply fans. It enables adaptive speed control for single-speed AC fan motors using sensors by continuously adapting to end-user requirements. The controller uses photonic (opto-electronic) transducers and graphical apertures that are integrated into intelligent, signal and vector processors enabling their use as analog power controllers[383,384]. It provides an adaptive airflow solution by tracking air temperature and optimizing operation based on climate conditions. Savings accrue not only from the reduction of fan speed to match thermal delivery rates, but also through better air mixing in the space and more effective heat transfer on the coils when the system is in operation. By adjusting airflow to improve heat transfer, the controller improves whole system operating efficiency and significantly reduces compressor run times.

This measure is only applicable to adaptive photonic control integrated into single-speed AC induction fan motors rated up to 5 horsepower (HP) that do not have speed variability restriction (e.g., via centrifugal speed switch).[385,386] Savings estimated per this methodology may be claimed in retrofit applications as well as in new construction applications where electronically commutated (EC) motors are not otherwise required by federal, state, local or municipal codes or standards.

Method for Calculating Annual Energy and Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = \Delta kWh_{cooling} + \Delta kWh_{heating} + \Delta kWh_{fan}$$

$$\Delta kWh_{cooling} = units \times \frac{(W_{cooling} \times ESF)}{1{,}000} \times LF \times hrs_{cooling}$$

$$\Delta kWh_{heating} = units \times \frac{(W_{heating} \times ESF)}{1{,}000} \times LF \times hrs_{heating}$$

$$\Delta kWh_{fan} = units \times \frac{(W_{blowerfan} \times ESF)}{1{,}000} \times LF \times hrs_{fan}$$

Note: ΔkWh_{fan} is only applicable if fan is set to on position during occupancy

[383] IEEE Transactions on Industrial Electronics, 'A novel switched reluctance motor drive with optical graphical programming technology', 2000.
[384] ACHR News, Fan Coil Units Get VSD, 2005
[385] San Diego Gas & Electric, Work Paper WPSDGENRHC1051, Revision 1, Sept 2016
[386] Comfort-Plus Drive™, Variable Speed Drive for Fan Coil Units, 2005

Summer Peak Coincident Demand Savings

$$\Delta kW = units \times \frac{(W_{cooling} \times ESF)}{1{,}000} \times LF \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = units \times \frac{(kBtu/h_{in} \times ESF)}{1{,}000} \times LF \times hrs_{heating}$$

where:

$$W_{cooling} = W_{evaporator} + W_{compressor} + W_{condenser}$$

$$W_{heating} = W_{evaporator} + W_{ElecHeat}$$

$$W_{evaporator} = V_{evaporator} \times A_{evaporator} \times PF$$

$$W_{compressor} = V_{compressor} \times A_{compressor} \times PF$$

$$W_{condenser} = V_{condenser} \times A_{condenser} \times PF$$

$$hrs_{fan} = hrs - (hrs_{cooling} + hrs_{heating})$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
$\Delta kWh_{cooling}$	= Annual electric energy savings in cooling mode
$\Delta kWh_{heating}$	= Annual electric energy savings in heating mode
ΔkWh_{fan}	= Annual electric energy savings in fan only mode
units	= Number of measures installed under the program
$W_{cooling}$	= Retrofitted system peak wattage in cooling mode
$W_{heating}$	= Retrofitted system peak wattage in heating mode
$W_{evaporator}$	= Retrofitted system evaporator wattage, based on nameplate specifications
$W_{compressor}$	= Retrofitted system compressor wattage, based on nameplate specifications
$W_{condenser}$	= Retrofitted system condenser wattage, based on nameplate specifications
$W_{blowerfan}$	= Retrofitted system blower fan wattage, based on nameplate specifications
$W_{ElecHeat}$	= Retrofitted system electric resistance heating element wattage, based on nameplate specifications, where applicable
$V_{evaporator}$	= Retrofitted system evaporator voltage
$V_{compressor}$	= Retrofitted system compressor voltage
$V_{condenser}$	= Retrofitted system condenser voltage
$A_{evaporator}$	= Retrofitted system evaporator amps
$A_{compressor}$	= Retrofitted system compressor amps

$A_{condenser}$ = Retrofitted system condenser amps
PF = Power factor
$kBtu/h_{in}$ = Retrofitted system space heating input fuel rating (kBtu/h)
ESF = Energy savings factor
LF = Motor load factor
$hrs_{cooling}$ = Retrofitted system annual operating hours in cooling mode
$hrs_{heating}$ = Retrofitted system annual operating hours in heating mode
hrs_{fan} = Retrofitted system annual operating hours in fan only mode
hrs = Retrofitted system annual operating hours
CF = Coincidence factor
1,000 = Conversion factor, one kW equals 1,000 watts

Summary of Variables and Data Sources

Variable	Value	Notes
$W_{ElecHeat}$		From application.
$W_{blowerfan}$		From application.
$V_{evaporator}$		From application.
$V_{compressor}$		From application.
$V_{condenser}$		From application.
$A_{evaporator}$		From application.
$A_{compressor}$		From application.
$A_{condenser}$		From application.
PF	0.85	From Standard Handbook of Electrical Engineers[387] and the Engineering Toolbox.[388]
$kBtu/h_{in}$		From application.
ESF	0.30	Average of multiple validation tests.[389]
LF	0.9	Assumed value to reflect that motors do not typically run at 100% of rated power.
$hrs_{cooling}$		From application. If unknown, see Operating Hours section below.
$hrs_{heating}$		From application. If unknown, see Operating Hours section below.
hrs		From application.
CF	0.69	

[387] Standard Handbook for Electrical Engineers (McGraw-Hill Handbooks), Donald G. Fink, ISBN 10: 0070220050 / ISBN 13: 9780070220058, Published by McGraw-Hill Publishing Co., 1999
[388] Engineering Tool Box, Power Factors for Inductive Loads, https://www.engineeringtoolbox.com/power-factor-electrical-motor-d_654.html
[389] Aclectic, Adaptive Control Technologies, Validation Tests

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.69.[390]

Baseline Efficiencies from which Savings are Calculated

The baseline condition is a standard efficiency, single-speed AC induction motor in a direct-drive HVAC circulation (blower) fan application. Baseline wattage shall be derived from the nameplate rating of existing system components.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a single-speed AC induction motor with adaptive photonic control as described in the Measure Description section above in a direct-drive HVAC circulation (blower) fan application.

Operating Hours

Annual cooling mode, heating mode and total system operating hours shall be taken from application. If cooling and heating mode operating hours are unknown, look up from Appendix G (i.e., cooling and heating equivalent load full hours shall be used as proxy values for annual cooling mode and annual heating mode hours, respectively). Total system operating hours must be taken from application in all cases.

Example Calculation *(Not to be used as default)*

An adaptive photonic control system is installed on a home's HVAC system with central air conditioning and gas heating with 45 kBTU/h capacity.. The system's compressor is rated at 230 V and 14.1 amps, the condenser is rated at 230 V and 0.8 amps and the evaporator is rated at 115 V and 6.1 amps. The blower fan has a rated wattage of 249 W. The system runs in cooling mode for approximately 600 hours per year, in heating mode for approximately 2,000 hours per year and in fan only mode for approximately 1,200 hours per year, for a total of 3,800 hours annually. Annual Electric Energy Savings, Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta kWh = \Delta kWh_{cooling} + \Delta kWh_{heating} + \Delta kWh_{fan}$$

$$\Delta kWh_{cooling} = units \times \frac{(W_{cooling} \times ESF)}{1{,}000} \times LF \times hrs_{cooling}$$

$$\Delta kWh_{heating} = units \times \frac{(W_{heating} \times ESF)}{1{,}000} \times LF \times hrs_{heating}$$

[390] Based on BG&E 'Development of Residential Load Profile for Central Air Conditioners and Heat Pumps' research, the Maryland Peak Definition coincidence factor is 0.69. This study is not publicly available, but is referenced by M. M. Straub, Using Available Information for Efficient Evaluation of Demand-Side Management Programs, Electricity Journal, September 2011 and supported by research conducted by Cadmus on behalf of the RM Management Committee.

$$\Delta kWh_{fan} = units \times \frac{(W_{blowerfan} \times ESF)}{1{,}000} \times LF \times hrs_{fan}$$

$$\Delta kW = units \times \frac{(W_{cooling} \times ESF)}{1{,}000} \times LF \times CF$$

$$\Delta MMBtu = units \times \frac{(kBtu/h_{in} \times ESF)}{1{,}000} \times LF \times hrs_{heating}$$

units = 1, from application
$W_{cooling} = W_{evaporator} + W_{compressor} + W_{condensor}$ = 596 + 2,757 + 156 = 3,509 W
$W_{cooling}$ equation from 'where' section
$W_{evaporator} = V_{evaporator}$ x $A_{evaporator}$ x PF = 115 x 6.1 x 0.85 = 596 W
$W_{evaporator}$ equation from 'where' section
$V_{evaporator}$ from application
$A_{evaporator}$ from application
PF from Summary of Variables and Data Sources table
$W_{compressor} = V_{compressor}$ x $A_{compressor}$ x PF = 230 x 14.1 x 0.85 = 2,757 W
$W_{compressor}$ equation from 'where' section
$V_{compressor}$ from application
$A_{compressor}$ from application
$W_{condensor} = V_{condensor}$ x $A_{condensor}$ x PF = 230 x 0.8 x 0.85 = 156 W
$W_{condensor}$ equation from 'where' section
$V_{condensor}$ from application
$A_{condensor}$ from application
ESF = 0.3 from Summary of Variables and Data Sources table
LF = 0.9 from Summary of Variables and Data Sources table
$hrs_{cooling}$ = 600, from application
$W_{heating}$ = 0, from application
$W_{blowerfan}$ = 249, from application
$hrs_{fan} = hrs - (hrs_{cooling} + hrs_{heating})$ = 3,800 – (600 + 2,000) = 1,200
hrs from application
$hrs_{heating}$ from application
CF = 0.69, from Summary of Variables and Data Sources table
$kBtu/h_{in}$ = 45, from application

$$\Delta kWh_{cooling} = 1 \times \frac{(3{,}509 \times 0.3)}{1{,}000} \times 0.9 \times 600 = 568\ kWh$$

$$\Delta kWh_{fan} = 1 \times \frac{(249 \times 0.3)}{1{,}000} \times 0.9 \times 1{,}200 = 81\ kWh$$

$$\Delta kWh = 568 + 0 + 81 = 649\ kWh$$

$$\Delta kW = 1 \times \frac{(3{,}509 \times 0.3)}{1{,}000} \times 0.9 \times 0.69 = 0.65\ kW$$

$$\Delta MMBtu = 1 \times \frac{(45 \times 0.3)}{1{,}000} \times 0.9 \times 2{,}000 = 24.3\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

HVAC circulation fans with adaptive photonic controlled AC motors generate less heat during operation, resulting in decreased cooling loads and increased heating loads. These effects are captured in the prescribed methodology detailed above. The HVAC interaction factors calculated from the prototypical building DOE-2 models as a function of the building and HVAC system type are shown in Appendix D.

Ancillary Electric Savings Impacts

HVAC circulation fan with adaptive photonic controlled AC motors generate less heat during operation, resulting in decreased cooling loads and increased heating loads. These effects are captured in the prescribed methodology detailed above. The HVAC interaction factors calculated from the prototypical building DOE-2 models as a function of the building and HVAC system type are shown in Appendix D.

References

1. A novel switched reluctance motor drive with optical graphical programming technology, Clarkson University, P. Pillay; Yaguang Liu; O.G. Durham, IEEE Transactions on Industrial Electronics (Volume: 47, Issue: 4, Aug 2000).
   Available from: https://ieeexplore.ieee.org/document/857972
2. Fan Coil Units Get VSD, The Air Conditioning, Heating, Refrigeration News, 2005
   Available from: https://www.achrnews.com/articles/95898-fan-coil-units-get-vsd#:~:text=They%20are%20small%20air%2Dhandling,stacked%2C%20or%20installed%20horizontally%20overhead.
3. Guest Room PTAC/PTHP Adaptive Climate Controller, San Diego Gas & Electric, Energy Efficiency Engineering, Work Paper WPSDGENRHC1051, Revision 1, Sept 2016.
   Available from: http://www.deeresources.net/workpapers
4. Comfort-Plus Drive™, Variable Speed Drive for Fan Coil Units, Carrier Corporation, 2005
   Available from: https://dms.hvacpartners.com/docs/1003/Public/08/05-02-0501-01.pdf
5. Standard Handbook for Electrical Engineers (McGraw-Hill Handbooks), Donald G. Fink, ISBN 10: 0070220050 / ISBN 13: 9780070220058, Published by McGraw-Hill Publishing Co., 1999

6. Engineering Tool Box, Power Factors for Inductive Loads
   Available from: https://www.engineeringtoolbox.com/power-factor-electrical-motor-d_654.html
7. Multiple Validation Tests of Adaptive Photonic Technology Controller at (1) ConEdison, (2) Environmental Test Laboratory, (3) EME Consulting Engineers (NYSERDA), (4) SUNY Oneonta, (5) Tim Garrison (Third Party), (6) McQuay Cooling Tests, (7) Purdue University Tests and (8) ConEdison Tests by ERS.
   Available from: https://efbb029c-a900-4301-9ab1-40fc00b9e54e.filesusr.com/ugd/9cd7aa_186d85d0a69b4da4b69f07ea0d03eeff.pdf?index=true
8. BG&E: Development of Residential Load Profile for Central Air Conditioners and Heat Pumps

Record of Revision

Record of Revision Number	Issue Date
12-20-3	12/31/2020
3-21-21	4/9/2021

Return to Table of Contents

BOILER – ADVANCED CONTROL

Measure Description

This measure covers the installation of advanced boiler control systems in multi-family buildings with a central boiler system. An advanced boiler control system is designed for the automated control of the boiler's cycling time based on both indoor and outdoor temperatures. These systems utilize both indoor and outdoor temperature sensors along with remote monitoring to provide a real-time operating and energy consumption data on the building. Utilizing this data, the controls optimize the cycling operation of the boiler to better meet the demand for heat within the building.

These systems also have built-in communication software capable of connecting building operators to service providers in order to read, change, monitor, and analyze the system settings as well as receive diagnostic alerts in regards to equipment malfunctions, poor sensor readings, combustion inefficiencies, and other corrective actions needed. These services may be included up to a certain term, after which a service agreement is required.

In multifamily buildings, an advanced boiler control system installed with indoor temperature sensors in apartments and other heated spaces can reduce energy consumption by optimizing boiler operation based on seasonal weather variations, use patterns, and self-diagnostic functions.

This measure is only applicable to the retrofit of existing boiler control systems. An advanced boiler control system must be an upgrade over existing minimally code-compliant boiler control systems. Minimally code-compliant boiler control systems include an outdoor temperature setback control that controls the boiler's cycling time based only on the outdoor temperature. This measure must include a minimum of 25% apartment sensors as well as temperature sensors for the stack, DHW supply, outdoor weather, heating water supply or return, and condensate (steam). The advanced boiler control system must allow multiple boiler systems to have staging capability.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = N/A$$

Summer Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = units \times \frac{BTU/h_{in}}{1{,}000{,}000} \times EFLH_{heating} \times ESF$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings

units = Number of measures installed under program
BTU/h_{in} = Boiler input rating
$EFLH_{heating}$ = Heating equivalent full-load hours
ESF = Energy Savings Factor for boiler control systems
1,000,000 = Conversion factor, one MMBtu equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
BTU/h_{in}		From application, boiler input rating, in BTU/h.
$EFLH_{heating}$		Lookup based on building type and location.
ESF	0.10	Energy Savings Factor[391]

Coincidence Factor (CF)

The prescribed value for the coincidence factor is N/A.

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is an existing multi-family residential boiler with a control system based on outdoor temperature reset.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is the new installation of an advanced boiler control system with the capability of controlling an existing multi-family boiler based on indoor and outdoor temperature.

Operating Hours

Heating equivalent full-load hours were calculated from a DOE-2.2 simulation of prototypical single and multi-family residential buildings. Operating hour assumptions for the prototypical building models are described in Appendix A. The heating EFLH for residential buildings in NY are shown in Appendix G.

Example Calculation *(Not to be used as default)*

An advanced boiler control system is installed on the central boiler plant of a high-rise multifamily building with total input capacity of 4,000 kBTU/h. The building was constructed in 1975 and is located near Albany. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are not applicable. Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta MMBtu = units \times \frac{BTU/h_{in}}{1{,}000{,}000} \times EFLH_{heating} \times ESF$$

[391] Con Edison EEPS Programs – Con Ed Multifamily Program, Program Year 2017 Impact Evaluation, December 11, 2019.

units =1, from application
BTU/h_{in} = 4,000,000, from application
$EFLH_{heating}$ = 786, from Appendix G based on housing type, building vintage, and location from application
ESF = 0.10, from Summary of Variables and Data Sources table

$$\Delta MMBtu = 1 \times \frac{4{,}000{,}000}{1{,}000{,}000} \times 786 \times 0.10 = 314.4\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. Con Edison EEPS Programs – Con Ed Multifamily Program, Program Year 2017 Impact Evaluation, December 11, 2019.

Record of Revision

Record of Revision Number	Issue Date
3-20-16	03/30/2020

Return to Table of Contents

OUTDOOR TEMPERATURE SETBACK CONTROL FOR HYDRONIC BOILER

Measure Description

This measure covers the installation of outdoor temperature setback control for single and multi-family residential fossil fuel-fired boilers. Outdoor temperature setback control adjusts the hot water set point temperature of the boiler in response to outdoor air temperature. This measure is only applicable to retrofit of existing boiler systems. One outdoor temperature setback measure may be applied to each boiler.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = N/A$$

Summer Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = units \times \frac{kBTU/h_{in}}{unit} \times \frac{EFLH_{heating}}{1{,}000} \times ESF$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
$kBTU/h_{in}$	= Fuel input rating (kBTU/h)
$EFLH_{heating}$	= Heating equivalent full-load hours
ESF	= Energy savings factor
1,000	= Conversion factor, one MMBtu equals 1,000 kBTU

Summary of Variables and Data Sources

Variable	Value	Notes
$kBTU/h_{in}$		From application.
$EFLH_{heating}$		Look up based on building type, vintage and location in Appendix G.
ESF	0.05	Cadmus Group, Inc. [392]

Coincidence Factor (CF)

The prescribed value for the coincidence factor is N/A.

[392] Cadmus Group, Inc., Home Energy Services Impact Evaluation, August 2012, pg. 20

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is an existing single or multi-family residential boiler without outdoor temperature setback control.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is an existing single or multi-family residential boiler equipped with outdoor temperature setback control.

Operating Hours

Heating equivalent full-load hours were calculated from a DOE-2.2 simulation of prototypical single and multi-family residential buildings. Operating hour assumptions for the prototypical building models are described in Appendix A. The heating EFLH for residential buildings in NY are shown in Appendix G.

Example Calculation *(Not to be used as default)*

Outdoor temperature setback control is installed on a 150 kBTU/h boiler in a single-family, detached home located near Albany constructed in 1995. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are not applicable. Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta MMBtu = units \times \frac{kBTU/h_{in}}{unit} \times \frac{EFLH_{heating}}{1{,}000} \times ESF$$

units = 1, from application
$kBTU/h_{in}/unit$ = 150, from application
$EFLH_{heating}$ = 978, from Appendix G based on housing type, building vintage, and location from application
ESF = 0.05, from Summary of Variables and Data Sources table

$$\Delta MMBtu = 1 \times 150 \times \frac{978}{1{,}000} \times 0.05 = 7.34\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Lower boiler set point temperatures may cause hot water circulators to run longer cycles. This impact is anticipated to be minor and is not quantified in this measure.

References

1. Cadmus Group, Inc., Home Energy Services Impact Evaluation, August 2012
   Available from: http://ma-eeac.org/wordpress/wp-content/uploads/Home-Energy-Services-Impact-Evaluation-Report_Part-of-the-Massachusetts-2011-Residential-Retrofit-and-Low-Income-Program-Area-Evaluation.pdf

Record of Revision

Record of Revision Number	Issue Date
0	10/15/2010
6-16-4	6/30/2016
6-18-6	6/26/2018

Return to Table of Contents

STEAM TRAP – LOW PRESSURE SPACE HEATING

Measure Description

This measure covers the repair or replacement of steam traps in low-pressure (≤15 psig) steam space heating applications on existing residential steam systems served by fossil fuel-fired boilers. Steam systems distribute heat from boilers to satisfy space heating requirements. Steam distribution systems contain steam traps. Steam traps that fail may allow excess steam to escape, thus increasing the amount of steam that must be generated to meet end-use requirements. This measure is intended for the repair or replacement of steam traps only. This measure does not apply to municipal steam systems.

All traps are susceptible to wear and dirt contamination and require periodic inspection and maintenance to ensure correct operation. Faulty steam traps (leaking or blow-through) can be diagnosed with ultrasonic, temperature, or conductivity monitoring techniques. Regular steam trap maintenance and faulty steam trap replacement are steps that minimize steam production. There are three major types of steam traps that are applicable: 1) thermostatic (including float and thermostatic), 2) mechanical and 3) thermodynamic.

Method for Calculating Annual Energy and Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = N/A$$

Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = units \times Loss_{steam} \times \frac{\Delta H_{vap}}{Eff} \times \frac{hrs}{1{,}000{,}000} \times F_{CR}$$

$$Loss_{steam} = 60 \times \frac{\pi}{4} \times Dia^2 \times psia^{0.97} \times F_{Discharge} \times F_{Loss}$$

$$psia = psig + p_{atm}$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of steam traps repaired/replaced under the program
$Loss_{steam}$	= Hourly steam loss per failed trap (lb/hr)
ΔH_{vap}	= Heat of vaporization (latent heat), in BTU/lb, at system operating pressure (psig)
Eff	= Efficiency of boiler
hrs	= Annual hours trap pressurized

F_{CR} = Condensate Return Factor, used to account for the proportion of energy lost that is returned to the system via condensate line
Dia = Internal Diameter (I.D.) of steam trap orifice (inches)
psia = Absolute steam pressure (psi)
$F_{Discharge}$ = Discharge coefficient
F_{Loss} = Steam loss adjustment factor
psig = Steam gage pressure (psi)
p_{atm} = Atmospheric pressure (psi)
60 = An empirically derived constant in the Grashof's equation (lb_m/ $in^{0.06}$-$lb^{0.97}$-hr)[393]
$\pi/4$ = Orifice area development factor
$^{0.97}$ = An empirically derived constant in the Grashof equation[394]
1,000,000 = Conversion from Btu to MMBtu (100,000 Btu/MMBtu)

Summary of Variables and Data Sources

Variable	Value	Notes
$Loss_{steam}$		Calculated per the equation above, dependent upon system operating pressure (psig), steam trap orifice diameter (Dia) and steam loss adjustment factor (F_{Loss}).
ΔH_{vap}		Look up from table below based on system operating pressure (psig).
Eff		Boiler efficiency, from application. Either E_t or AFUE shall be used, based on nameplate rating metric of existing equipment or actual system efficiency as provided on the application and documented by the customer.
hrs		From application.
$F_{Discharge}$	0.7	Based on Massachusetts Steam Trap Evaluation[395]
F_{CR}	Condensate Return: 0.45 No Condensate Return: 1.00	Based on ERS memo to NYSEG/RG&E[396]
Dia		From application.
psia		Calculated per the equation above, dependent upon system operating pressure (psia).
F_{Loss}	0.37	Based on Massachusetts Steam Trap Evaluation[397]
psig		From application.
P_{atm}	14.7	Atmospheric pressure (14.7 psi).

[393] Massachusetts Program Administrators and Energy Efficiency Advisory Council, "Steam Trap Evaluation Phase 2" March 8, 2017. pg 6
[394] Ibid.
[395] Ibid, pg 7
[396] ERS Memo to NYSEG/RG&E, "Recommendations to Update Algorithms for C&I Steam Trap Repair Energy Savings in NY TRM Introduction", October 10, 2019
[397] Massachusetts Program Administrators and Energy Efficiency Advisory Council, "Steam Trap Evaluation Phase 2". March 8, 2017. Table 4-7

Heat of Vaporization (Btu/lb)[398]

Pressure (psig)	Heat of Vaporization (Btu/lb)
0	970
1	968
2	966
3	964
4	962
5	961
6	959
7	957
8	956
9	954
10	953
11	951
12	950
13	948
14	947
15	946

Coincidence Factor (CF)

The recommended value for the coincidence factor is N/A.

Baseline Efficiencies from which Savings are Calculated

The baseline condition is a leaking or blow-through steam trap on a low-pressure steam space heating system.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is an intact (replaced or repaired) steam trap on a low-pressure steam space heating system. Replaced or repaired steam traps will no longer leak or blow-through after installation.

Operating Hours

Annual pressurized hours shall be established based on actual operation.

Example Calculation *(Not to be used as default)*

Four steam traps identified during a system survey as having failed open are replaced in a multifamily building with an 80% gas fired steam boiler with condensate return system. Steam traps have 3/16" orifice diameter and the system has a steam gage pressure of 10 psi. The system is pressurized an estimated 2,500 hours per year. Annual Electric Energy Savings and

[398] Thermodynamic Properties of Steam Including Data for the Liquid and Solid Phases (1936)

Summer Peak Coincident Demand Savings are not applicable. Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta MMBtu = units \times Loss_{steam} \times \frac{\Delta H_{vap}}{Eff} \times \frac{hrs}{1{,}000{,}000} \times F_{CR}$$

$$Loss_{steam} = 60 \times \frac{\pi}{4} \times Dia^2 \times psia^{0.97} \times F_{Discharge} \times F_{Loss}$$

$$psia = psig + p_{atm}$$

units = 4, from application
Dia = 0.1875, from application
psia = psig + p_{atm} = 10 + 14.7 = 24.7
psig from application
p_{atm} from Summary of Variables and Data Sources table
$F_{Discharge}$ = 0.7, from Summary of Variables and Data Sources table
F_{loss} = 0.37, from Summary of Variables and Data Sources table
ΔH_{vap} = 953, from Heat of Vaporization table based on pressure from application
Eff = 0.80, from application
hrs = 2,500, from application
F_{CR} = 0.45, from Summary of Variables and Data Sources table based on conditions from application

$$Loss_{steam} = 60 \times \frac{\pi}{4} \times 0.1875^2 \times 24.7^{0.97} \times 0.7 \times 0.37 = 9.626$$

$$\Delta MMBtu = 4 \times 9.626 \times \frac{953}{0.80} \times \frac{2{,}500}{1{,}000{,}000} \times 0.45 = 51.6\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. ERS Memo to NYSEG/RG&E, "Recommendations to Update Algorithms for C&I Steam Trap Repair Energy Savings in NY TRM Introduction", October 10, 2019

2. Joseph Henry Keenan and Frederick G. Keyes, Thermodynamic Properties of Steam Including Data for the Liquid and Solid Phases, John Wiley and Sons, New York (1936)

Record of Revision

Record of Revision Number	Issue Date
6-18-19	6/30/2018
3-20-2	3/30/2020
3-21-22	4/9/2021

Return to Table of Contents

SUBMETERING

Measure Description

This measure covers the installation of submeters for individual apartments in multi-family buildings in order to charge tenants for electric consumption according to their metered usage. Submetering achieves savings by tying tenant electric usage to utility cost, financially encouraging tenants to consume less energy. Submeter service providers are required to comply with the NYS Public Service Law and all applicable Commission rules and regulations, including but not limited to New York State Codes, Rules and Regulations (NYCRR) Title 16 part 96.[399]

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = \frac{kWh}{SF} \times SF \times ESF$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \frac{\Delta kWh}{8{,}760} \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
kWh/SF	= Annual electric energy consumption per square foot of conditioned floor area subject to submetering
SF	= Total conditioned floor area of tenant spaces subject to submetering
ESF	= Energy savings factor
CF	= Coincidence factor
8,760	= Hours in one year

[399] New York Codes, Rules and Regulations (NYCRR) Title 16. NYS Department of Public Service Chapter II. Electric Utilities Part 96. Residential Electric Submetering.

Summary of Variables and Data Sources

Variable	Value	Notes
kWh/SF		From application. Annual energy consumption per square foot of conditioned floor area should be either site-specific and adjusted to exclude common areas or based on utility territory specific evaluation of typical tenant energy consumption. It is the responsibility of the utility to establish these values.
SF		From application.
ESF	0.10	NYSERDA Electrical Submetering Manual. [400]
CF	1.0	

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 1.0. [401]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a multifamily building that is master metered for electric service.

Compliance Efficiency from which Incentives are Calculated

The efficient condition is a multi-family building with regulation compliant electric submetering.

Operating Hours

Submetering hours are not utilized in the estimation of energy savings, but meters are assumed to be operational 8,760 hours per year.

Example Calculation *(Not to be used as default)*

Submeters are installed in a 12,000 SF multifamily building in order to charge tenants for electric consumption according to their metered usage. The building billing data reflected an annual 7 kWh/SF the prior year. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

$$\Delta kWh = \frac{kWh}{SF} \times SF \times ESF$$

$$\Delta kW = \frac{\Delta kWh}{8{,}760} \times CF$$

kWh/SF = 7, from application

[400] NYSERDA Electrical Submetering Manual, conservative end of reported 10-26% savings of residential submetering. However, given the scarcity of recent, reliable studies, it is particularly important that savings from submetering be rigorously evaluated through ex-post studies.

[401] *No source specified – update pending availability and review of applicable references.*

SF = 12,000, from application
ESF = 0.10, from Summary of Variables and Data Sources table
CF = 1, from Summary of Variables and Data Sources table

$$\Delta kWh = 7 \times 12{,}000 \times 0.1 = 8{,}400\ kWh$$

$$\Delta kW = \frac{8{,}400}{8{,}760} \times 1 = 0.96\ kW$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Submetering results in more energy conscious tenants, which may translate to indirect fossil fuel savings. However, due to the uncertainty in the reliability of indirect fossil fuel savings, these impacts have not been quantified at this time.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. New York State Codes, Rules and Regulations (NYCRR) Title 16. NYS Department of Public Service Chapter II. Electric Utilities Part 96. Residential Electric Submetering. Available from: https://www3.dps.ny.gov/W/PSCWeb.nsf/96f0fec0b45a3c6485257688006a701a/d4f1e6b0f51ac85785257687006f39cc/$FILE/16%20NYCRR%20Part%2096%20-%20Submetering%20Regulations.pdf
2. NYSERDA Electrical Submetering Manual

Record of Revision

Record of Revision Number	Issue Date
0	10/15/2010
9-18-5	9/28/2018

Return to Table of Contents

THERMOSTAT - LEARNING

Measure Description

This measure covers the installation of ENERGY STAR® qualified smart thermostats with behavioral learning capabilities applied to single-family and multi-family residential HVAC systems. Utilizing Wi-Fi connections, a smart (learning) thermostat provides and receives feedback from users to enhance energy efficiency without compromising comfort. A learning thermostat controls HVAC equipment to regulate the temperature of the room or space in which it is installed, communicates with sources external to the HVAC system for remote adjustment and has the ability to perform automatic adjustments in response to occupant behavior. Additional learning thermostat capabilities may vary, but at minimum, must meet the following criteria:

- Work as a basic thermostat in absence of connectivity to the service provider.
- Give residents some form of feedback about the energy consequences of their settings.
- Provide information about HVAC energy use, such as monthly run time.
- Provide the ability to set a schedule.
- Provide the ability to work with utility programs to prevent brownouts and blackouts, while preserving consumers' ability to override those grid requests.[402]

This measure is applicable to single and multi-family centralized heating and cooling systems. For single family applications with multiple zones, energy savings are per residence. While incentives may be provided for multiple thermostat units, the algorithms below shall apply a value of "1" to the "units" term. For multifamily applications, "tons/unit", "$(kBTU/h)_{out}$/unit" and "$(kBTU/h_{in})$/unit" terms shall be set equal to the total capacity of the central cooling/heating system divided by the total number of dwelling units served by the system. The "units" term shall be set equal to the total number of dwelling units in which learning thermostats are installed. This measure is not applicable to multifamily central heating systems with additional capacity for domestic hot water.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times \left[\left(tons/unit \times \frac{12}{Eff_{cooling}} \times EFLH_{cooling} \times ESF_{cooling} \times F_{ElecCool}\right) + \left((kBTU/h)_{out}/unit \times \frac{1}{HSPF} \times EFLH_{heating} \times ESF_{heating} \times F_{ElecHeat}\right)\right]$$

Summer Peak Coincident Demand Savings

$$\Delta kW = N/A$$

[402] ENERGY STAR® Program Requirements Product Specification for Connected Thermostat Products, Eligibility Criteria Version 1.0, January 2017

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = units \times \left((kBTU/h)_{in}/unit \times \frac{1}{1{,}000} \times EFLH_{heating} \times ESF_{heating} \times F_{FuelHeat} \right)$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of residences in which the measure is installed under the program
tons/unit	= Tons of air conditioning per residence, based on nameplate data; for multifamily buildings with centralized HVAC, this term shall be set equal to the total cooling capacity of the system divided by the total number of dwelling units it serves
$(kBTU/h)_{out}$/unit	= Output electric heating capacity in kBTU/h per residence, based on nameplate data; for multifamily buildings with centralized HVAC, this term shall be set equal to the total heating capacity of the system divided by the total number of dwelling units it serves
$(kBTU/h)_{in}$/unit	= Input heating capacity in kBTU/h per residence, based on nameplate data; for multifamily buildings with centralized HVAC, this term shall be set equal to the total heating capacity of the system divided by the total number of dwelling units it serves
$Eff_{cooling}$	= Seasonal average energy efficiency over the cooling season, BTU/watt-hour, (used for average U.S. location/region), using either SEER (<5.4 tons) or IEER (≥5.4 tons)
HSPF	= Seasonal average energy efficiency over the heating season, Heating seasonal performance factor, BTU/watt-hour, total heating output (supply heat) in BTU (including resistance heat) during the heating season / total electric energy heat pump consumed (in watt-hour); if equipment efficiency is reported in COP, convert to HSPF using the equivalency HSPF = COP x 3.412
$EFLH_{cooling}$	= Cooling equivalent full-load hours
$EFLH_{heating}$	= Heating equivalent full-load hours
ESF	= Energy savings factor
$F_{ElecCool}$	= Electric cooling factor; used to account for the presence or absence of an electric cooling system
$F_{ElecHeat}$	= Electric heating factor; used to account for the presence or absence of an electric heating system
$F_{FuelHeat}$	= Fossil fuel heating factor; used to account for the presence or absence of a fossil fuel heating system
12	= (kBTU/h)/ton of air conditioning capacity
1,000	= Conversion factor, one MMBtu equals 1,000 kBTU

Summary of Variables & Data Sources

Variable	Value	Notes
tons/unit		From application or use 3 tons as a default.[403]
$(kBTU/h)_{out}$/unit		From application or use 72 kBTU/h as a default.[404]
$(kBTU/h)_{in}$/unit		From application or use 90 kBTU/h as a default.[405]
$Eff_{cooling}$		From application or use 14 SEER, assuming a 3-ton central ASHP system.[406]
HSPF		From application or use 8.2 HSPF, assuming a 3-ton central ASHP system. [407] For electric resistance heating and electric furnaces, use 3.4 HSPF. If taken from application, COP must be converted to HSPF using the equivalency HSPF = COP x 3.412.
$EFLH_{cooling}$		Look up based on building type, vintage and city in Appendix G.
$EFLH_{heating}$		Look up based on building type, vintage and city in Appendix G.
$ESF_{cooling}$	0.10	Energy savings factor for cooling.[408]
$ESF_{heating}$	0.08	Energy savings factor for heating.[409]
$F_{ElecCool}$	Electric Cooling: 1 No Electric Cooling: 0 Unknown: 0.39	Based on EIA Residential Energy Consumption Survey (RECS) 2015 for Middle Atlantic States.[410]
$F_{ElecHeat}$	Electric Heating: 1 No Electric Heating: 0 Unknown: 0.15	Based on EIA Residential Energy Consumption Survey (RECS) 2015 for Middle Atlantic States.[411]
$F_{FuelHeat}$	Fossil Fuel Heating: 1 No Fossil Fuel Heating: 0 Unknown: 0.60	Based on EIA Residential Energy Consumption Survey (RECS) 2015 for Middle Atlantic States.[412]

[403] Assumes a 1,800 ft^2 home with 20 BTU/h-ft^2 cooling load: 1,800 ft^2 x 20 BTU/h-ft^2 x 1/12,000 ton/(BTU/h) = 3 tons
[404] Assumes a 1,800 ft^2 home with 40 BTU/h-ft^2 heating load: 1,800 ft^2 x 40 BTU/h-ft^2 x 1/(1,000 kBTU/h)/(BTU/h) = 72 kBTU/h
[405] Assumes a 1,800 ft^2 home with 40 BTU/h-ft^2 heating load and 80% AFUE: 1,800 ft^2 x 40 BTU/h-ft^2 x 1/0.80 x 1/(1,000 kBTU/h)/(BTU/h) = 90 kBTU/h
[406] 10 CFR 430.32 (c)(1)
[407] Ibid.
[408] ENERGY STAR® Program Requirements Product Specification for Connected Thermostat Products, Eligibility Criteria Version 1.0, January 2017, pg. 10
[409] Ibid.
[410] EIA Residential Energy Consumption Survey (RECS) 2015 for Middle Atlantic States, Table HC7.7 ("Unknown" calculated as the number of homes with central AC divided by the total number of homes)
[411] EIA Residential Energy Consumption Survey (RECS) 2015 for Middle Atlantic States, Table HC6.7 ("Unknown" calculated as the number of homes with electric heat divided by the total number of homes)
[412] EIA Residential Energy Consumption Survey (RECS) 2015 for Middle Atlantic States, Table HC6.7 ("Unknown" calculated as the number of homes with natural gas heat divided by the total number of homes)

Coincidence Factor (CF)

The prescribed value for the coincidence factor is N/A.

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is an HVAC system controlled by a programmable thermostat without Wi-Fi or behavioral learning capability.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is an HVAC system controlled by an ENERGY STAR® qualified Wi-Fi communicating thermostat with behavioral learning capability as defined in the Measure Description section above.

Operating Hours

Cooling and heating equivalent full-load hours were calculated from a DOE-2.2 simulation of prototypical single and multi-family residential buildings. Operating hour assumptions for the prototypical building models are described in Appendix A. The heating EFLH for single and multi-family buildings in NY are shown in Appendix G.

Example Calculation *(Not to be used as default)*

A learning thermostat is installed in single-family detached home located near Albany constructed in 1995. The home is cooled by a 2.5 ton air conditioner with an efficiency of 14 SEER and heated by an 80 kBTUh gas-fired furnace. Summer Peak Coincident Demand Savings are not applicable. Annual Electric Energy Savings and Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta kWh = units \times \left[\left(tons/unit \times \frac{12}{Eff_{cooling}} \times EFLH_{cooling} \times ESF_{cooling} \times F_{ElecCool}\right) + \left((kBTU/h)_{out}/unit \times \frac{1}{HSPF} \times EFLH_{heating} \times ESF_{heating} \times F_{ElecHeat}\right)\right]$$

$$\Delta MMBtu = units \times \left((kBTU/h)_{in}/unit \times \frac{1}{1{,}000} \times EFLH_{heating} \times ESF_{heating} \times F_{FuelHeat}\right)$$

units = 1, from application
tons/unit = 2.5, from application
$Eff_{cooling}$ = 14, from application
$EFLH_{cooling}$ = 310, from Appendix G based on housing type, building vintage, and location from application.

$ESF_{cooling}$ = 0.10, from Summary of Variables and Data Sources table
$F_{ElecCool}$ = 1, from Summary of Variables and Data Sources table based on application
$(kBTU/h)_{out}$/unit = N/A based on application
HSPF = N/A based on application
$F_{ElecHeat}$ = 0, from Summary of Variables and Data Sources table based on application
$(kBTU/h)_{in}$/unit = 80, from application
$EFLH_{heating}$ = 978, from Appendix G based on housing type, building vintage, and location from application
$ESF_{heating}$ = 0.08, from Summary of Variables and Data Sources table
$F_{FuelHeat}$ = 1, from Summary of Variables and Data Sources table based on application

$$\Delta kWh = 1 \times \left[\left(2.5 \times \frac{12}{14} \times 310 \times 0.1 \times 1\right) + (0)\right] = 66.4\ kWh$$

$$\Delta MMBtu = 1 \times \left(80 \times \frac{1}{1{,}000} \times 978 \times 0.08 \times 1\right) = 6.26\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Reduced operating hours during the heating and cooling season result in distribution blower electric savings. These effects are not quantified in the prescribed savings estimation methodology for this measure at this time.

References

1. ENERGY STAR® Program Requirements Product Specification for Connected Thermostat Products, Eligibility Criteria Version 1.0, January 2017
   Available from: https://www.energystar.gov/sites/default/files/asset/document/ENERGY%20STAR%20Program%20Requirements%20for%20Connected%20Thermostats%20Version%201.0.pdf
2. 10 CFR 430.32 Energy and water conservation standards and their compliance dates.
   Available from: http://www.ecfr.gov/cgi-bin/text-idx?SID=a9921a66f2b4f66a32ec851916b7b9d9&mc=true&node=se10.3.430_132&rgn=div8
3. EIA Residential Energy Consumption Survey (RECS) 2015 Survey Data for Middle Atlantic States.
   Available from: https://www.eia.gov/consumption/residential/data/2015/

Record of Revision

Record of Revision Number	Issue Date
3-18-17	3/29/2018

Return to Table of Contents

THERMOSTAT - PROGRAMMABLE SETBACK

Measure Description

This measure covers the installati onfo programmable setback thermostats applied to single-family and multi-family residential air conditioners, heat pumps, boilers, furnaces and electric resistance baseboard heating systems.

One programmable thermostat may be applied to each controlled HVAC system.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times \left[\left(tons/unit \times \frac{12}{Eff_{cooling}} \times EFLH_{cooling} \times ESF_{cooling}\right) + \left((kBTU/h)_{out}/unit \times \frac{1}{HSPF} \times EFLH_{heating} \times ESF_{heating}\right)\right]$$

Summer Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = units \times \left((kBTU/h)_{in}/unit \times \frac{1}{1{,}000} \times EFLH_{heating} \times ESF_{heating}\right)$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of residences in which the measure is installed under the program
tons/unit	= Tons of air conditioning per residence, based on nameplate data; for multifamily buildings with centralized HVAC, this term shall be set equal to the total cooling capacity of the system divided by the total number of dwelling units it serves
$(kBTU/h)_{out}$/unit	= Output electric heating capacity in kBTU/h per residence, based on nameplate data; for multifamily buildings with centralized HVAC, this term shall be set equal to the total heating capacity of the system divided by the total number of dwelling units it serves
$(kBTU/h)_{in}$/unit	= Input heating capacity in kBTU/h per residence, based on nameplate data; for multifamily buildings with centralized HVAC, this term shall be set equal to the total heating capacity of the system divided by the total number of dwelling units it serves
$Eff_{cooling}$	= Seasonal average energy efficiency over the cooling season, BTU/watt-hour, (used for average U.S. location/region), using either SEER (<5.4 tons) or IEER (≥5.4 tons)

HSPF = Seasonal average energy efficiency over the heating season, Heating seasonal performance factor, BTU/watt-hour, total heating output (supply heat) in BTU (including resistance heat) during the heating season / total electric energy heat pump consumed (in watt-hour); if equipment efficiency is reported in COP, convert to HSPF using the equivalency HSPF = COP x 3.412

$EFLH_{cooling}$ = Cooling equivalent full-load hours

$EFLH_{heating}$ = Heating equivalent full-load hours

ESF = Energy savings factor

12 = (kBTU/h)/ton of air conditioning capacity

1,000 = Conversion factor, one MMBtu equals 1,000 kBTU

Summary of Variables and Data Sources

Variable	Value	Notes
tons/unit		From application or use 3 tons as a default.[413]
$(kBTU/h)_{out}$/unit		From application or use 72 kBTU/h as a default.[414]
$(kBTU/h)_{in}$/unit		From application or use 90 kBTU/h as a default.[415]
$Eff_{cooling}$		From application or use 14 SEER, assuming a 3-ton central ASHP system.[416]
HSPF		From application or use 8.2 HSPF, assuming a 3-ton central ASHP system. [417] For electric resistance heating and electric furnaces, use 3.4 HSPF. If taken from application, COP must be converted to HSPF using the equivalency HSPF = COP x 3.412.
$EFLH_{cooling}$		Look up based on building type, vintage and city in Appendix G.
$EFLH_{heating}$		Look up based on building type, vintage and city in Appendix G.
$ESF_{cooling}$	0.09	Energy savings factor for cooling.
$ESF_{heating}$	0.02	Energy savings factor for heating. [418]

The nominal rating of the cooling capacity of the air conditioner or heat pump should be set equal to the rated capacity of all cooling equipment in the residence. The energy savings should be calculated based on the capacity of the HVAC system, with one thermostat controlling the system. For multifamily with central HVAC, total cooling capacity of the system should be used.

[413] Assumes a 1,800 ft^2 home with 20 BTU/h-ft^2 cooling load: 1,800 ft^2 x 20 BTU/h-ft^2 x 1/12,000 ton/(BTU/h) = 3 tons

[414] Assumes a 1,800 ft^2 home with 40 BTU/h-ft^2 heating load: 1,800 ft^2 x 40 BTU/h-ft^2 x 1/(1,000 kBTU/h)/(BTU/h) = 72 kBTU/h

[415] Assumes a 1,800 ft^2 home with 40 BTU/h-ft^2 heating load and 80% AFUE: 1,800 ft^2 x 40 BTU/h-ft^2 x 1/0.80 x 1/(1,000 kBTU/h)/(BTU/h) = 90 kBTU/h

[416] 10 CFR 430.32 (c)(1)

[417] Ibid.

[418] Opinion Dynamics: New York Statewide Residential Gas High-Efficiency Heating Equipment Programs Evaluation of 2009-2011 Programs; August 2014

The nominal rating of the heating capacity of the heat pump should be set equal to the rated capacity of all heating equipment controlled in the residence. The energy savings should be calculated based on the capacity of the HVAC system, with one thermostat controlling the system. For multifamily with central HVAC, total heating capacity of the system should be used.

Coincidence Factor (CF)

The prescribed value for the coincidence factor is N/A.

Baseline Efficiencies from which Energy Savings are Calculated

The baseline system is a standard, non-programmable thermostat for a central heating and cooling system when a programmable thermostat is not otherwise required by applicable energy conservation code. If programmable thermostats are required by code, no deemed savings exist.

The baseline efficiency for air conditioners and heat pumps should be set according to the sections on air conditioner and heat pump efficiency above. Electric resistance heating systems should use an HSPF = 3.412, which is equivalent to a coefficient of performance of 1.0.

Studies of residential heating thermostat set point behavior indicate some amount of manual setback adjustment in homes without programmable thermostats. This behavior is accounted for in the prototypical building simulation model used to calculate heating equivalent full-load hours, as described in Appendix A. An assumption of 3°F of night time setback behavior is embedded in the models.

Compliance Efficiency from which Incentives are Calculated

The energy savings factor for heating ($ESF_{heating}$) is the ratio of the energy savings resulting from installation of a programmable setback thermostat to the annual heating energy. The heating energy savings factor assumption is derived from the results of a New York State specific residential fossil fuel program evaluation conducted by Opinion Dynamics. This evaluation indicated a 2-4% reduction in total annual fossil fuel consumption resulting from installation of programmable thermostats. A conservative value of 2% of the annual heating energy consumption is assumed as deemed savings for programmable setback thermostats in residential applications.

The cooling energy savings factor ($ESF_{cooling}$) is the ratio of the energy savings resulting from installation of a programmable setback thermostat to the annual cooling energy. The cooling energy savings factor assumption is taken from the ENERGY STAR® website. The ENERGY STAR® calculator estimates an energy savings of 6% of the annual cooling energy consumption per degree of setback for programmable setback thermostats in residential applications. This measure assumes an average of 1.5 degrees of setback over the cooling season for an estimated annual cooling energy savings of 9%.

Operating Hours

Cooling and heating equivalent full-load hours were calculated from a DOE-2.2 simulation of prototypical single and multi-family residential buildings. Operating hour assumptions for the

prototypical building models are described in Appendix A. The heating EFLH for single and multi-family buildings in NY are shown in Appendix G.

Example Calculation *(Not to be used as default)*

A programmable setback thermostat is installed in single-family detached home located near Albany constructed in 1995. The home is cooled by a 2.5 ton air conditioner with an efficiency of 14 SEER and heated by an 80 kBTUh gas-fired furnace. Summer Peak Coincident Demand Savings are not applicable. Annual Electric Energy Savings and Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta kWh = units \times \left[\left(tons/unit \times \frac{12}{Eff_{cooling}} \times EFLH_{cooling} \times ESF_{cooling}\right) + \left((kBTU/h)_{out}/unit \times \frac{1}{HSPF} \times EFLH_{heating} \times ESF_{heating}\right)\right]$$

$$\Delta MMBtu = units \times \left((kBTU/h)_{in}/unit \times \frac{1}{1{,}000} \times EFLH_{heating} \times ESF_{heating}\right)$$

units = 1, from application
tons/unit = 2.5, from application
$Eff_{cooling}$ = 14, from application
$EFLH_{cooling}$ = 310, from Appendix G based on housing type, building vintage, and location from application.
$ESF_{cooling}$ = 0.09, from Summary of Variables and Data Sources table
$F_{ElecCool}$ = 1, from Summary of Variables and Data Sources table based on application
$(kBTU/h)_{out}$/unit = N/A based on application
HSPF = N/A based on application
$F_{ElecHeat}$ = 0, from Summary of Variables and Data Sources table based on application
$(kBTU/h)_{in}$/unit = 80, from application
$EFLH_{heating}$ = 978, from Appendix G based on housing type, building vintage, and location from application
$ESF_{heating}$ = 0.02, from Summary of Variables and Data Sources table
$F_{FuelHeat}$ = 1, from Summary of Variables and Data Sources table based on application

$$\Delta kWh = 1 \times \left[\left(2.5 \times \frac{12}{14} \times 310 \times 0.09 \times 1\right) + (0)\right] = 59.8\ kWh$$

$$\Delta MMBtu = 1 \times \left(80 \times \frac{1}{1{,}000} \times 978 \times 0.02 \times 1\right) = 1.56\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Reduced operating hours during the heating and cooling season result in distribution blower electric savings. These effects are not quantified in the prescribed savings estimation methodology for this measure at this time.

References

1. 10 CFR 430.32 Energy and water conservation standards and their compliance dates. Available from: http://www.ecfr.gov/cgi-bin/text-idx?SID=a9921a66f2b4f66a32ec851916b7b9d9&mc=true&node=se10.3.430_132&rgn=div8
2. For examples of studies on residential thermostat set point behavior, see the literature review conducted for the California Energy Commission project "Residential Thermostats: Comfort Controls in California Homes," CEC-500-03-026 Available from: http://eta-publications.lbl.gov/sites/default/files/lbnl-938e.pdf
3. Baseline thermostat setback assumptions taken from: Conner, C.C. and Lucas, R.L. 1990. Thermostat Related Behavior and Internal Temperatures Based on Measured Data in Residences. PNL-7465, Pacific Northwest Laboratory. Richland, WA. Available from: http://elcap.nwcouncil.org/Documents/Thermostat%20Related%20Behavior.PDF
4. Opinion Dynamics: New York Statewide Residential Gas High-Efficiency Heating Equipment Programs Evaluation of 2009-2011 Programs; August 2014 Available from: http://www.nationalfuelforthought.com/docs/psc-reports/EEPS_Opinion_Dynamics_Corporation_Residential_Rebate_Program_Statewide_Impact_Evaluation_Report_Completed_August_2014.pdf
5. Programmable thermostat savings for the cooling season taken from the ENERGY STAR® website: Available from: https://www.energystar.gov/sites/default/files/asset/document/ProgrammableThermostat_Calculator.xls

Record of Revision

Record of Revision Number	Issue Date
0	10/15/2010
1	12/31/2015
1-17-3	12/31/2016
2-17-1	2/10/2017

Return to Table of Contents

THERMOSTAT - WI-FI (COMMUNICATING)

Measure Description

This section covers Wi-Fi communicating thermostats without behavioral learning capability applied to single-family and multi-family residential air conditioners, heat pumps, boilers, furnaces and electric resistance baseboard heating systems. These communicating thermostats allow set point adjustment via a remote application.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times \left\{ (\Delta kWh/unit)_{cooling} + \left[(\Delta MMBtu/unit) \times \frac{Eff_{FuelHeat}}{COP} \times \frac{1{,}000{,}000}{3{,}412} \times F_{ElecHeat} \right] \right\}$$

Summer Peak Coincident Demand Savings

$$\Delta kW = units \times \frac{(\Delta kWh/unit)_{cooling}}{EFLH_{cooling}} \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = units \times (\Delta MMBtu/unit) \times F_{FuelHeat}$$

where:

ΔkWh	= Annual electricity energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
$(\Delta kWh/unit)_{cooling}$	= Annual electric cooling savings per unit
(ΔMMBtu/unit)	= Annual heating energy savings per unit
$Eff_{FuelHeat}$	= Efficiency of fossil fuel heating equipment (AFUE, Et, or Ec)
COP	= Coefficient of performance, ratio of output energy/input energy (at AHRI standard high-temperature rating conditions)
$F_{ElecHeat}$	= Electric heating factor; used to account for the presence or absence of an electric heating system
$F_{FuelHeat}$	= Fossil fuel heating factor; used to account for the presence or absence of a fossil fuel heating system
$EFLH_{cooling}$	= Cooling equivalent full-load hours
CF	= Coincidence factor
3,412	= Conversion factor, one kWh equals 3,412 BTU
1,000,000	= Conversion factor, one MMBtu equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
$(\Delta kWh/unit)_{cooling}$	104	Annual electric cooling savings per installed thermostat, in kWh[419]
(ΔMMBtu/unit)	6.6	Annual heating energy savings per installed thermostat, in MMBtu[420]
$Eff_{FuelHeat}$	0.8	From application. If unknown, use 0.8 based on the assumed presence of code compliant natural gas furnaces in the sites assessed in the Cadmus study.[421]
COP	Heat Pump: 2.4 Electric Resistance: 1.0	Assumed efficiency of electric heating system, based on a COP of 1.0 for electric resistance heating and a minimally code compliant, 3-ton split system HP for heat pumps.[422]
$F_{ElecHeat}$		Use a value of 1.0 if the building is electrically heated. Otherwise, use 0.0.
$F_{FuelHeat}$		Use a value of 1.0 if the building is fossil fuel heated. Otherwise, use 0.0.
$EFLH_{cooling}$		Lookup based on building type, vintage and location from Appendix G.
CF	0.69	

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.69.[423]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline efficiency is an HVAC system using fossil fuel and electricity to provide space heating and cooling controlled by a non-Wi-Fi communicating programmable thermostat.

Compliance Efficiency from which Incentives are Calculated

The compliance efficiency is an HVAC system using fossil fuel and electricity to provide space heating and cooling controlled by a Wi-Fi communicating thermostat without behavioral learning capability.

[419] Cadmus Group, Wi-Fi Programmable Controllable Thermostat Pilot Program Evaluation, September 2012, p. 18
[420] Ibid. p. 12
[421] ECCCNYS 2020, Table C403.3.2(4) and Table C403.3.2(5) and Cadmus Group, Wi-Fi Programmable Controllable Thermostat Pilot Program Evaluation, September 2012
[422] ECCCNYS 2020, Table C403.3.2(2)
[423] Based on BG&E 'Development of Residential Load Profile for Central Air Conditioners and Heat Pumps' research, the Maryland Peak Definition coincidence factor is 0.69. This study is not publicly available, but is referenced by M. M. Straub, Using Available Information for Efficient Evaluation of Demand-Side Management Programs, Electricity Journal, September 2011 and supported by research conducted by Cadmus on behalf of the RM Management Committee.

Operating Hours

HVAC system operating hours are embedded in the deemed savings values associated with Wi-Fi communicating thermostats, which are based on metering results. Cooling EFLH data by location, building type and vintage are tabulated in Appendix G.

Example Calculation *(Not to be used as default)*

A Wi-Fi thermostat is installed in single-family detached home located near Albany constructed in 1995. The home is equipped with a heat pump for heating and cooling. Annual Electric Energy Savings, Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta kWh = units \times \left\{ (\Delta kWh/unit)_{cooling} + \left[(\Delta MMBtu/unit) \times \frac{Eff_{FuelHeat}}{COP} \times \frac{1{,}000{,}000}{3{,}412} \times F_{ElecHeat} \right] \right\}$$

$$\Delta kW = units \times \frac{(\Delta kWh/unit)_{cooling}}{EFLH_{cooling}} \times CF$$

$$\Delta MMBtu = units \times (\Delta MMBtu/unit) \times F_{FuelHeat}$$

units = 1, from application
$(\Delta kWh/unit)_{cooling}$ = 104, from Summary of Variables and Data Sources table
$(\Delta MMBtu/unit)$ = 6.6, from Summary of Variables and Data Sources table
$Eff_{FuelHeat}$ = 0.8, from Summary of Variables and Data Sources table
COP = 2.4, from Summary of Variables and Data Sources table based on application equipment
$F_{ElecHeat}$ = 1, from Summary of Variables and Data Sources table based on application
$EFLH_{cooling}$ = 310, from Appendix G based on housing type, building vintage, and location from application.
CF = 0.69, from Summary of Variables and Data Sources table
$F_{FuelHeat}$ = 0, from Summary of Variables and Data Sources table based on application

$$\Delta kWh = 1 \times \left\{ 104 + \left[6.6 \times \frac{0.8}{2.4} \times \frac{1{,}000{,}000}{3{,}412} \times 1 \right] \right\} = 106\ kWh$$

$$\Delta kW = 1 \times \frac{104}{310} \times 0.69 = 0.231\ kW$$

$$\Delta MMBtu = 1 \times 6.6 \times 0 = 0\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. Cadmus Group, Inc. *"Wi-Fi Programmable Controllable Thermostat Pilot Program Evaluation"*, prepared for The Electric and Gas Program Administrators of Massachusetts, September 2012
   Available from: http://ma-eeac.org/wordpress/wp-content/uploads/Wi-Fi-Programmable-Controllable-Thermostat-Pilot-Program-Evaluation_Part-of-the-Massachusetts-2011-Residential-Retrofit-Low-Income-Program-Area-Study.pdf
2. ECCCNYS 2020 Table C403.3.2(2): Minimum Efficiency Requirements: Electrically Operated Unitary and Applied Heat Pumps, Table C403.3.2(4): Warm-Air Furnaces And Combination Warm-Air Furnaces/Air-Conditioning Units, Warm-Air Duct Furnaces And Unit Heaters, Minimum Efficiency Requirements, C403.3.2(5) Minimum Efficiency Requirements: Gas- and Oil-Fired Boilers
   Available from: https://codes.iccsafe.org/content/NYSECC2020P1
3. BG&E, Development of Residential Load Profile for Central Air Conditioners and Heat Pumps
4. M. M. Straub, Using Available Information for Efficient Evaluation of Demand-Side Management Programs, Electricity Journal, September 2011
   Available from: https://www.sciencedirect.com/science/article/pii/S1040619011001941

Record of Revision

Record of Revision Number	Issue Date
1-16-19	12/31/2015
9-17-1	9/30/2017
7-20-3	7/31/2020

Return to Table of Contents

THERMOSTATIC RADIATOR VALVE (TRV) – ONE PIPE STEAM RADIATOR

Measure Description

This measure covers the installation of thermostatic radiator valves (TRVs) on one-pipe steam radiators. TRVs are self-contained, self-operated valves that do not require ancillary power. They provide local control of room temperature by controlling the venting of air out of the radiator. TRVs are available for a variety of installation conditions utilizing either remote-mounted sensors or integral-mounted sensors by means of remote or integral set point adjustment. This measure is specifically a TRV in combination with an air vent installed at one or more radiators in a one-pipe steam space heating system.

TRVs demonstrate the greatest potential for energy savings and financial viability when overheating is exhibited in zones throughout the system and when combined with other steam system best practices improvements. Therefore, prioritization of this measure is recommended in zones that are overheated by 3°F or greater[424] and when installed as part of system inspection, balancing and commissioning including, but not limited to: burner tuning, boiler cleaning, recalibration of boiler control set points, inspection and repair/replacement of leaking inlets and air vents, installation of properly sized air vents, main line steam trap repair/replacement, recalibration of system operating pressure, insulation of bare steam lines and installation of radiator orifice plates in two-pipe systems.[425]

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = N/A$$

Summer Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = units \times (\Delta MMBtu/HDD) \times HDD_{loc}$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of TRVs installed
(ΔMMBtu/HDD)	= Annual fossil fuel energy savings per Heating Degree Day (HDD), per TRV
HDD_{loc}	= Heating Degree Days based on location

[424] NYSERDA, Thermostatic Radiator Valve (TRV) Demonstration Project, Report No. 95-14, September 1995, pg. 5-1

[425] US DOE, Thermostatic Radiator Valve Evaluation, January 2015, pg. 25 - 26

Summary of Variables and Data Sources

Variable	Value	Notes
ΔMMBtu/HDD	0.0004318	Average fuel savings per HDD per unit[426]
HDD_{loc}		Lookup based on location from Heating Degree Days section below

Heating Degree Days

For the purposes of this measure, Heating Degree Days are defined as the number of degrees that a day's average temperature is below some baseline temperature, which represents the temperature below which buildings need to be heated. The HDD values listed in the table below are based on 30-year averages of U.S annual climate normals for the period of 1981 to 2010 using base 65° F.[427]

City	HDD_{loc}
Albany	6,680
Binghamton	7,193
Buffalo	6,617
Massena	8,196
NYC	4,671
Poughkeepsie	6,210
Syracuse	6,651

Coincidence Factor (CF)

The prescribed value for the coincidence factor is N/A.

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is an existing space heating system with manual control valves at freestanding radiators, convectors, or baseboard heating units.

Compliance Efficiency from which Incentives are Calculated

The measure is defined as the existing radiator, convector, or baseboard heater unit controlled by the thermostatic radiator valve.

Operating Hours

Evaluation of savings associated with installation of TRVs is dependent upon typical heating degree days as specified in the Summary of Variables and Data Sources above.

[426] Thermostatic Radiator Valve (TRV) Demonstration Project. Prepared by NYSERDA, Project Manager Norine Karins and the EME Group Project Manager Michael McNamara. NYSERDA report 95-14. September 1995.
[427] HDD taken from NCEI 1981-2010 climate normals

Example Calculation *(Not to be used as default)*

10 thermostatic radiator valves are installed on one-pipe steam radiators in a multifamily building located near Albany. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are not applicable. Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta MMBtu = units \times (\Delta MMBtu/HDD) \times HDD_{loc}$$

units = 10, from application
(ΔMMBtu/HDD) = 0.0004318, from Summary of Variables and Data Sources table
HDD_{loc} = 6,680, from Heating Degree Days table based on location from application

$$\Delta MMBtu = 10 \times 0.0004318 \times 6{,}680 = 28.84\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. NYSERDA, Thermostatic Radiator Valve (TRV) Demonstration Project, Report No. 95-14, September 1995
   Available from: https://www.osti.gov/servlets/purl/119941
2. US DOE, Thermostatic Radiator Valve Evaluation, January 2015
   Available from: https://www.nrel.gov/docs/fy15osti/63388.pdf
3. Thermostatic Radiator Valve (TRV) Demonstration Project. Prepared by NYSERDA, Project manager Norine Karins and the EME Group project manager Michael McNamara. NYSERDA report 95-14. September 1995.
   Available from: https://www.osti.gov/servlets/purl/119941
4. NOAA National Centers for Environmental Information – NCEI 1981-2010 Normals
   Available from: http://www.ncdc.noaa.gov/cdo-web/datatools/normals

Record of Revision

Record of Revision Number	Issue Date
1-16-12	12/31/2015
6-17-7	6/30/2017
6-19-8	6/28/2019
7-21-23	8/30/2021

Return to Table of Contents

SMART THERMOSTATIC RADIATOR ENCLOSURE (TRE)

Measure Description

This measure is applicable to the installation of **S**mart Thermostatic Radiator Enclosures (TRE). Smart TREs are insulated radiator covers with integrated temperature controls and sensors. These systems allow for the control of heat energy transfer from the radiator to a room, while enabling feedback to the heating plant to optimize building-wide energy consumption. Each radiator cover incorporates a thermostatically-controlled fan, which operates based on the room temperature and the temperature set-point (set by the user and/or the designated operator). An integrated radio in the cover communicates room and radiator temperature in real-time to centralized systems and instructs the system to provide heating only when necessary.

TREs demonstrate significant savings opportunities in buildings with heating distribution imbalances and perform best when combined with other steam system best practices improvements. This measure is only applicable in buildings with one or two-pipe steam space heating. This measure is only applicable when 60% or more of a building's radiators are retrofitted with TREs to ensure the benefits of system network communication.[428]

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = -(units \times kWh_{TRE})$$

Summer Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings[429]

$$\Delta MMBtu = (F_{ratio} \times HEI + F_{lower\ bound}) \times heating_{annual}$$

$$HEI = \frac{BTU/SF}{HDD}$$

where:

ΔkWh = Annual electricity energy savings
ΔkW = Peak coincident demand electric savings
ΔMMBtu = Annual fossil fuel energy savings

[428] A majority of a building's radiators must be retrofitted with smart TREs for the system to realize the savings presented in this measure, which is dependent upon temperature and air flow communication throughout the building. While the implementation rate is typically expected to be higher, this measure is subject to diminishing returns, which become appreciable at approximately 60% implementation. For example, kitchens and bathrooms often experience unpredictable temperature loads and smart TREs in such rooms may not increase heating system efficiency.

[429] Annual Fossil Fuel Energy Savings equation developed based on a linear regression analysis comparing building heating therm savings and Heating Energy Intensity (HEI).

units = Number of TREs installed under the program
kWh_{TRE} = Annual electric consumption of smart TRE
HEI = Building Heating Energy Intensity
BTU = Annual space heating fossil fuel consumption, in BTUs
SF = Conditioned square footage of building
HDD = Heating Degree Days based on location
F_{ratio} = Factor, observed ratio of percent savings to existing building HEI`1
$F_{lower\ bound}$ = Factor, observed lower bound of percent savings[430]
$heating_{annual}$ = Annual heating consumption of building, in MMBtu

Summary of Variables and Data Sources

Variable	Value	Notes
kWh_{TRE}	7	Empirically determined consumption of smart TRE[431]
HEI		From application. Building Heating Energy Intensity is the heating energy consumed by a building in one year (in BTU) divided by the total conditioned square footage of the building divided by local annual heating degree days. Each component is further outlined below. If billing data is not available, use a value of 10.5 as a default. Default HEI was calculated by multiplying a weighted average of New York City residential building fossil fuel EUI values[432] for steam systems by 0.72 to establish space heating HEI[433], and dividing by New York City HDD.
BTU		From application, annual space heating fuel consumption, from billing data. If annual space heating fossil fuel consumption is not known, multiply total annual energy consumption (electric and fossil fuel, in BTU) by 0.61 for single family homes or 0.41 for multifamily buildings to derive default annual space heating BTU.[434] If using the default HEI value cited above, BTU is already accounted for in that value.
SF		From application, total conditioned building square footage.

[430] Value represents the y-intercept of linear regression analysis.
[431] NYSERDA ETAC-EPV-001: Radiator Labs Energy Performance Validation Project, page 2
[432] Local Law 84 data via Urban Green Council, Demystifying Steam, February 2019, Table 2: Total Building Floor Area by Heating System Type and Building Size, and Table 3: Baseline Fuel Use and Estimated Savings from Boiler and Distribution Improvements
[433] Local Law 84 and Local Law 87 as cited in Urban Green Council, Demystifying Steam, February 2019, page 22
[434] EIA Residential Energy Consumption Survey (RECS) 2015 for the Northeast, Table CE3.2. Blended averages are developed for single family data and for multifamily space heating consumption data compared to total building consumption data.

Variable	Value	Notes
HDD		If using billing data to develop HEI, look up based on location from Heating Degree Days section below. Otherwise, HDD is accounted for in the default HEI value cited above.
$heating_{annual}$		From application, annual space heating consumption of building, in MMBtu. If annual space heating consumption of building is not known, derive $heating_{annual}$ by the following methods depending on available data: 1. If total annual energy consumption is known, multiply total annual energy consumption (electric and fossil fuel, in MMBtu) by 0.61 for single family homes or 0.41 for multifamily buildings to derive $heating_{annual}$.[435] 2. If using the default HEI value cited above, multiply default HEI by conditioned square footage and by HDD (look up based on location from Heating Degree Days section below), then divide the result by 1,000,000 to derive $heating_{annual}$.[436]
F_{ratio}	0.018	Based on slope of linear regression analysis comparing building heating MMBtu savings and HEI[437]. For additional detail on the derivation of this value, refer to the "NY TRM - Smart Thermostatic Radiator Enclosure - Supplement.xlsx" workbook.
$F_{lower\ bound}$	0.020	Based on intercept of linear regression analysis comparing building heating MMBtu savings and HEI[438]. For additional detail on the derivation of this value, refer to the "NY TRM - Smart Thermostatic Radiator Enclosure - Supplement.xlsx" workbook.

Heating Degree Days

For the purposes of this measure, Heating Degree Days are defined as the number of degrees that a day's average temperature is below some baseline temperature, which represents the temperature

[435] EIA Residential Energy Consumption Survey (RECS) 2015 for the Northeast, Table CE3.2. Blended averages are developed for single family data and for multifamily space heating consumption data compared to total building consumption data.

[436] Urban Green Council, Demystifying Steam, February 2019. Typical HEI of 10.5 developed by multiplying a weighted average of fuel EUI (Table 2 of report) by 0.72 (page 22 of report) to derive space heating HEI for steam systems and dividing by NYC HDD to derive HEI in BTU/SF/HDD.

[437] Savings analysis based on "A focused Demonstration Project; the 'Cozy' by Radiator Labs" (NYSERDA, 2016) and "Radiator Labs Energy Performance Validation Project" (NYSERDA, 2018).

[438] Ibid

below which buildings need to be heated. The HDD values listed in the table below are based on 30-year averages of U.S annual climate normals for the period of 1981 to 2010 using base 65° F.[439]

City	HDD
Albany	6,680
Binghamton	7,193
Buffalo	6,617
Massena	8,196
NYC	4,671
Poughkeepsie	6,210
Syracuse	6,651

Coincidence Factor (CF)

The prescribed value for the coincidence factor is N/A.

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is an exposed radiator in a one or two-pipe space heating steam system.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a radiator equipped with a smart TRE in a one or two-pipe space heating steam system. At least 60% of the building's radiators must be retrofitted with smart TREs with radio communication capability between the heating system and individual TREs. Smart TREs must be insulation rated to R-3 and be UL certified.

Operating Hours

Operating hours are not directly applied in this methodology and are therefore not explicitly defined for this measure. However, consideration of system operating hours is embedded in normalized, location-dependent heating degree days.

Example Calculation *(Not to be used as default)*

Smart TREs are installed on 20 one-pipe steam radiators in a 20,000 SF multifamily building. A year of building billing data captures 1,170 MMBtu space heating energy consumption. National weather data reports 5,120 heating degree days over the billing period of that year. Electric Energy Savings and Summer Peak Coincident Demand Savings are not applicable. Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta kWh = -(units \times kWh_{TRE})$$

$$\Delta MMBtu = (F_{ratio} \times HEI + F_{lower\ bound}) \times heating_{annual}$$

units = 20, from application

[439] HDD taken from NCEI 1981-2010 climate normals

kWh_{TRE} = 7, from Summary of Variables and Data Sources table
F_{ratio} = 0.018, from Summary of Variables and Data Sources table
HEI = BTU/SF/HDD = 1,170,000,000 / 20,000 / 5,120 = 11.4
BTU, SF, and HDD based on application
$F_{lower,bound}$ = 0.020, from Summary of Variables and Data Sources table
$heating_{annual}$ = 1,170, from application

$$\Delta kWh = -(20 \times 7) = -140\ kWh$$

$$\Delta MMBtu = (0.018 \times 11.4 + 0.020) \times 1{,}170 = 264\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Smart TRE building implementation incorporates radio communication between radiators and the central heating system. Building wide integration enables monitoring of whole system and tracking of potential issues in real time, notifying building owners of issues with steam traps and risers, unexpected heating flow or blockage, etc. These impacts are not considered in the prescribed savings methodology for this measure.

Ancillary Electric Savings Impacts

Each radiator cover has a circulation fan that cycles on each time that the infrared thermostat indicates that heating is required. As a result, the installation of this system results in a marginal increase in electric energy use. This impact is addressed in this measure.

References

1. NYSERDA Report Number 18-12, "A Focused Demonstration Project: The "Cozy" by Radiator Labs"
   Available from: https://www.radiatorlabs.com/wp-content/uploads/2018/10/Radiator-Labs.Cozy_.NYSERDA-Report.2018.pdf
2. NYSERDA ETAC-EPV-001: Radiator Labs Energy Performance Validation Project
   Available from: https://www.radiatorlabs.com/wp-content/uploads/2016/08/RADLABS_NYSERDA_ETAC_Report_Final.pdf
3. BizEE Degree Days; Weather Data for Energy Professionals
   Available from: https://www.degreedays.net/
4. NOAA National Centers for Environmental Information – NCEI 1981-2010 Normals
   Available from: http://www.ncdc.noaa.gov/cdo-web/datatools/normals
5. Urban Green Council, Demystifying Steam, February 2019
   Available from: https://www.urbangreencouncil.org/sites/default/files/2019.02.12_demystifying_steam_report.pdf

6. EIA Residential Energy Consumption Survey (RECS) 2015 Survey Data End-Use Consumption in the Northeast
Available from:
https://www.eia.gov/consumption/residential/data/2015/index.php?view=consumption

Record of Revision

Record of Revision Number	Issue Date
12-19-5	12/23/2019

Return to Table of Contents

LIGHTING

INTERIOR AND EXTERIOR LIGHTING

Measure Description

This measure covers energy efficient lighting equipment, such as energy efficient lamps, LED lamps and improved lighting fixtures installed in interior or exterior locations. These technologies, taken separately or combined into an energy efficient lighting fixture, provide the required illumination at reduced input power.

Beginning January 2012 and phased in through January 2014, the Energy Independence and Security Act of 2007 (EISA) regulations stipulated typical screw-based general service lamps with wattages ranging from 40W to 100W to comply with new lamp wattage standards such that the range of wattages decreased to be from 29W to 72W for rated lumen output ranging from 310 to 2,600 lumens.[440] Deemed baseline values for this measure will apply wattages based on lamp type and light output (lumens).[441]

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times \frac{(W_{baseline} - W_{ee})}{1{,}000} \times hrs \times (1 + HVAC_c)$$

Summer Peak Coincident Demand Savings

$$\Delta kW = units \times \frac{(W_{baseline} - W_{ee})}{1{,}000} \times (1 + HVAC_d) \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = units \times \frac{(W_{baseline} - W_{ee})}{1{,}000} \times hrs \times HVAC_{ff}$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
W	= Rated wattage of lamp and/or fixture (Watts)
baseline	= Characteristic of baseline condition
ee	= Characteristic of energy efficient condition
hrs	= Lighting operating hours

[440] The maximum rated wattage varies for modified spectrum lamps.
[441] Energy Independence and Security Act of 2007. Pub. L. 110-140. Sec. 321. Efficient Light Bulbs H.R.6 – 86

$HVAC_c$ = HVAC interaction factor for annual electric energy consumption
$HVAC_d$ = HVAC interaction factor at utility summer peak hour
$HVAC_{ff}$ = HVAC interaction factor for annual fossil fuel consumption (MMBtu/kWh)
CF = Coincidence factor
1,000 = Conversion factor, one kW equals 1,000 Watts

Summary of Variables and Data Sources

Variable	Value	Notes
W_{ee}		Energy efficient measure Watts, from application
$W_{baseline}$		Baseline measure Watts, from application or default values from applicable table in "Baseline Efficiencies…" section below depending on program structure/delivery mechanism.
hrs		Look up in Operating Hours section below based on installation type and location. "Interior" designation extends to any covered area not adequately lit during daylight hours by sunlight, thus requiring daytime operation of lighting. "Unknown" is not a valid selection for direct install programs.
$HVAC_c$	Exterior and Unconditioned Spaces: 0	HVAC interaction factor for annual electric energy consumption (dimensionless). Vintage and HVAC type weighted average by city. See Appendix D.
$HVAC_d$	Exterior and Unconditioned Space: 0	HVAC interaction factor for peak demand at utility summer peak hour (dimensionless). Vintage and HVAC type weighted average by city. See Appendix D.
$HVAC_{ff}$	Exterior and Unconditioned Space: 0	HVAC interaction factor for annual fossil fuel energy consumption (MMBtu/kWh). Vintage and HVAC type weighted average by city. See Appendix D.
CF	Interior: 0.16 Exterior: 0	"Interior" designation extends to any covered area not adequately lit during daylight hours by sunlight, thus requiring daytime operation of lighting.

HVAC system interaction factors are defined as the ratios of the cooling energy and demand reduction and heating energy increase per unit of lighting energy reduction. Much of the input energy for lighting systems is converted to heat that must be removed by the HVAC system. Reductions in lighting heat gains due to lighting power reduction decrease the need for space cooling and increase the need for space heating.

HVAC interaction factors vary by climate, HVAC system type and building type. Prescribed values for HVAC interaction factors for lighting energy and peak demand savings are shown in Appendix D. Lighting systems in unconditioned spaces or on the building exterior will have interaction factors of 0.0.

Coincidence Factor (CF)

The prescribed value for the coincidence factor for interior lighting is 0.16.[442] This value shall also be used if the installation location is unknown.

Because exterior lighting is assumed to operate during off-peak hours only, the prescribed coincidence factor for exterior lighting is 0.0.

Baseline Efficiencies from which Energy Savings are Calculated

Rated wattage baseline values should reflect the guidance noted below based on bulb type and lumens in accordance with EISA standards. [443]

General Service Lamps

Baseline wattage for general service lamps are found in the table below. Per EISA 2007 guidelines, a general service lamp is defined as a standard incandescent or halogen type lamp that:

(1) Is intended for general service applications;
(2) Has a medium screw base;
(3) Has a lumen range of not less than 310 lumens and not more than 2,600 lumens
(4) Is capable of being operated at voltage range at least partially within 110 and 130 volts.

Certain lamp types are exempt from EISA compliance, including reflector lamps (see Reflector/Flood Lamps section below), some decorative and globe shape lamps (see Specialty Lamps section below) and three-way lamps. Baseline wattage for any of these exempt lamp types shall reflect the values in column (c) of the table below, with the exception of those lamps defined in the Specialty Lamps or Reflector/Flood Lamps sections below. All other general service lamps shall use the baseline wattage values in column (b), corresponding to the applicable lumen range identified in column (a). For standard lamps that fall outside of the prescribed lumen ranges below, the manufacturer recommended baseline wattage shall be used. For a complete list and definitions of EISA-exempt lamp types, reference Sec. 321: Efficient Light Bulbs of Public Law 110-140.[444]

Lumen Range **(a)**	**EISA 2007 Incandescent Equivalent** **$W_{baseline}$** **(b)**	**EISA-Exempt Incandescent Equivalent** **$W_{baseline}$** **(c)**
310 – 749	29	40
750 – 1,049	43	60
1,050 – 1,489	53	75
1,490 – 2,600	72	100

[442] NMR Group Inc., "Northeast Residential Lighting Hours-of-Use Study", May 5, 2014. Table 4-4: Peak Period Coincidence Factors and Confidence Intervals – Efficient Bulbs. CF referenced reflects Average Summer for NYSERDA based on ISO-NE peak period. The NYSERDA model includes UNY and DNY. The NYSERDA model does not differentiate between interior and exterior lighting. The interior lighting sample size is significantly larger than the exterior sample size. Thus, reported Coincidence Factor is appropriate for interior lighting and unknown installations.
[443] Energy Independence and Security Act of 2007. Pub. L. 110-140. Sec. 321. Efficient Light Bulbs H.R.6 – 89
[444] Energy Independence and Security Act of 2007. Pub. L. 110-140. Sec. 321. Efficient Light Bulbs H.R.6 – 82-86

Specialty Lamps

Baseline wattage for specialty lamps are found in the table below. Specialty lamps are defined as screw-base lamps that are globe, bullet, candle or decorative shaped. These can be medium base, intermediate base, or candelabra base lamps. EISA 2007 set specific limits on maximum rated wattage for incandescent intermediate and candelabra base lamps, 40W and 60W respectively. In addition, some medium screw-base specialty lamps that could be used for general service applications are specifically exempt from EISA 2007 wattage limits and include: 1) a G shape lamp with a diameter of 5 inches or more (i.e. a G40 lamp); 2) a T shape lamp that uses not more than 40 watts or has a length of more than 10 inches; (3) a B, BA, CA, F, G16–1/2, G–25, G30, S, or M–14 lamp of 40 watts or less; and 4) a silver bowl lamp.[445] Medium screw-base specialty lamps not exempt from EISA 2007 must meet the maximum wattage requirements outlined in EISA 2007. For these lamps, the baseline wattage from column (b) in the table above should be used based on the lumen output. For specialty lamps that fall outside of the prescribed lumen ranges below, the manufacturer recommended baseline wattage should be used.

Bulb Type (a)	**Base Type (b)**	**Lumen Range (c)**	**$W_{baseline}$[446] (d)**
Globe	Medium and intermediate base	90 – 179	10
		180 – 249	20
		250 – 349	25
		350 – 749	40
	Candelabra base	90 – 179	10
		180 – 249	20
		250 – 349	25
		350 – 499	40
		500 – 1,049	60
Decorative (Shapes B, BA, C, CA, DC, F, G)	Medium and intermediate base	70 – 89	10
		90 – 149	15
		150 – 299	25
		300 – 749	40
	Candelabra base	70 – 89	10
		90 – 149	15
		150 – 299	25
		300 – 449	40
		450 – 1,049	60

Reflector/Flood Lamps

Baseline wattage for reflector and flood type lamps are found in the tables below. For reflector and flood lamps that are not covered by the table below, either based on bulb type or lumen output, the manufacturer recommended baseline wattage should be used. The first part of the

[445] Ibid

[446] The baseline wattage for the specialty lamps is calculated by dividing the midpoint lumen output for the range by the mean efficacy for "General Purpose- Incandescent Omni" for Globe bulbs and "Decorative- Incandescent Omni" for Decorative bulbs found in Table C.2 (page 82) from the Energy Savings Forecast of Solid-State Lighting in General Illumination Applications Report (US DOE, 2019). The calculated baseline wattage is rounded to a standard wattage output or the maximum rated wattage for that category.

table lists the baseline wattage for the incandescent reflector lamp bulb types specifically exempted from federal standards and include 1) Lamps rated at 50 watts or less that are ER30, BR30, BR40, or ER40 lamps; 2) Lamps rated at 65 watts that are BR30, BR40, or ER40 lamps; or 3) R20 incandescent reflector lamps rated 45 watts or less. [447]

Exempt Bulb Type (a)	**Lumen Range (b)**	**$W_{baseline}$[448] (c)**
ER30, BR30, BR40, or ER40	300 – 399	40
	400 – 649	50
BR30, BR40, or ER40	650 – 1,183	65
R20	< 300	30
	300 – 450	45

Not Exempt Bulb Type (a)	**Diameter (b)**	**Lumen Range (c)**	**$W_{baseline}$[449] (d)**
All other R, PAR, ER, BR, BPAR, or similar bulb shapes, with diameter >2.25", other than those listed above	> 2.25” and ≤ 2.5”	400 – 718	40
		719 – 810	50
		811 - 1,002	55
		1,003 – 1,202	65
		1,203 – 1,516	75
		1,517 – 1,733	90
		1,734 – 2,184	100
		> 2,184	120
	> 2.5”	639 – 847	40
		848 – 956	50
		957 – 1,183	55
		1,184 – 1,419	65
		1,420 – 1,789	75
		1,790 – 2,045	90
		2,046 – 2,578	100
		> 2,578	120

[447] Electronic Code of Federal Regulations, Title 10: Energy, PART 430—ENERGY CONSERVATION PROGRAM FOR CONSUMER PRODUCTS, Subpart C—Energy and Water Conservation Standards

[448] The baseline wattage for the exempt reflector/flood lamps is calculated by dividing the midpoint lumen output for the range by the mean efficacy for “Downlights- Incandescent Directional” bulbs found in Table C.2 (page 82) from the Energy Savings Forecast of Solid-State Lighting in General Illumination Applications Report (US DOE, 2019). The calculated baseline wattage is rounded to a standard wattage output or the maximum rated wattage for that category.

[449] The baseline wattage is calculated based on the standards outlined in the Electronic Code of Federal Regulations, Title 10: Energy, PART 430—ENERGY CONSERVATION PROGRAM FOR CONSUMER PRODUCTS, Subpart C—Energy and Water Conservation Standards

Other Bulb Types (a)	Diameter (b)	Lumen Range (c)	$W_{baseline}$[450] (d)
All ER, BR, BPAR, or similar bulb shapes	≤ 2.25”	300 – 399	40
		400 – 499	50
		500 – 599	60
		600 – 1,000	65
MR16	2”	< 450	35
		450 – 600	50
		> 600	75
All other reflector lamps not included above	All	200 – 299	30
		300 – 399	40

Compliance Efficiency from which Incentives are Calculated

The compliance condition is an efficient lighting product (lamp or fixture) meeting the minimum requirements of the current effective version of ENERGY STAR® Lamps specification, ENERGY STAR® Luminaires specification or the Design Lights Consortium qualified products list.

Operating Hours

Look up operating hours from the table below, based on lamp location and city. See details below for derivation of operating hours. “Interior” designation extends to any covered area not adequately lit during daylight hours by sunlight, thus requiring daytime operation of lighting. “Unknown” is not a valid selection for direct install programs.

City	Interior	Exterior	Unknown
Albany	986	2,081	1,022
Binghamton	986	2,081	1,022
Buffalo	986	2,081	1,022
Massena	986	2,081	1,022
NYC	1,752	2,117	1,752
Poughkeepsie	986	2,081	1,022
Syracuse	986	2,081	1,022

<u>NYS cities other than NYC, Interior</u>

Hours of operation for interior lighting is estimated to be 2.7 operating hours per day or 986 (2.7 x 365) hours per year. This value is derived from on-site lighting inventories of homes in New

[450] The baseline wattage for the other reflector/flood bulb types is calculated by dividing the midpoint lumen output for the range by the mean efficacy for “Small Directional (MR16)- Halogen” for the MR16 bulbs or by “Downlights- Incandescent Directional” for all other bulbs found in Table C.2 (page 82) from the Energy Savings Forecast of Solid-State Lighting in General Illumination Applications Report (US DOE, 2019). The calculated baseline wattage is rounded to a standard wattage output or the maximum rated wattage for that category.

York, exclusive of New York City and Westchester County, and refined through a hierarchical model that drew upon loggers installed in Connecticut, Massachusetts, and Rhode Island.[451]

NYS cities other than NYC, Exterior

Hours of operation for exterior lighting is estimated to be 5.7 operating hours per day or 2,081 (5.7 x 365) hours per year. This value is derived from on-site lighting inventories of homes in New York, exclusive of New York City and Westchester County, and refined through a hierarchical model that drew upon loggers installed in Connecticut, Massachusetts, and Rhode Island. [452]

NYS cities other than NYC, Unknown

Hours of operation for lighting installed in an unknown location is estimated to be 2.8 operating hours per day or 1,022 (2.8 x 365) hours per year. This value is a weighted average of interior and exterior lighting hours derived from on-site lighting inventories of homes in New York, exclusive of New York City and Westchester County, and refined through a hierarchical model that drew upon loggers installed in Connecticut, Massachusetts, and Rhode Island.[453]

NYC, Interior

Hours of operation for exterior lighting is estimated to be 4.8 operating hours per day or 1,752 (4.8 x 365) hours per year. This value is derived from on-site lighting inventories of homes in New York City and Westchester County.[454]

NYC, Exterior

Hours of operation for exterior lighting is estimated to be 4.4 operating hours per day or 1,606 (4.4 x 365) hours per year. This value is derived from on-site lighting inventories of homes in New York City and Westchester County.[455]

NYC, Unknown

Hours of operation for lighting installed in an unknown location is estimated to be 4.8 operating hours per day or 1,752 (4.8 x 365) hours per year. This value is a weighted average of interior and

[451] NMR Group Inc., "Northeast Residential Lighting Hours-of-Use Study", May 5, 2014. Table ES-5: HOU by Area Adjusted for Snapback, Table 3-2: Sample Sizes, Overall HOU Estimates by Area and Room, and hierarchical model as described in section 2.6.3 (p. 22). HOU referenced is a weighted average of interior room types for UNY and is Snapback Adjusted.

[452] NMR Group Inc., "Northeast Residential Lighting Hours-of-Use Study", May 5, 2014. Table ES-5: HOU by Area Adjusted for Snapback and hierarchical model as described in section 2.6.3 (p. 22). HOU referenced is the value for Exterior for UNY and is Snapback Adjusted.

[453] NMR Group Inc., "Northeast Residential Lighting Hours-of-Use Study", May 5, 2014. Table ES-5: HOU by Area Adjusted for Snapback and hierarchical model as described in section 2.6.3 (p. 22). HOU referenced is the value for Household for UNY, which is a weighted average of all room types and is Snapback Adjusted.

[454] NMR Group Inc., "Northeast Residential Lighting Hours-of-Use Study", May 5, 2014. Table ES-6: HOU by Area Adjusted for Snapback and Table 3-2: Sample Sizes, Overall HOU Estimates by Area and Room. HOU referenced is a weighted average for interior room types for DNY and is Snapback Adjusted.

[455] NMR Group Inc., "Northeast Residential Lighting Hours-of-Use Study", May 5, 2014. Table ES-6: HOU by Area Adjusted for Snapback. HOU referenced is the value for Exterior for DNY and is Snapback Adjusted.

exterior lighting hours derived from on-site lighting inventories of homes in New York City and Westchester County.[456]

Example Calculation *(Not to be used as default)*

An existing residential customer replaces twenty 60-watt incandescent lamps with 10-watt LED lamps throughout the interior of their home located near Albany. The home has a central AC and gas-furnace. Annual Electric Energy Savings, Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta kWh = units \times \frac{(W_{baseline} - W_{ee})}{1{,}000} \times hrs \times (1 + HVAC_c)$$

$$\Delta kW = units \times \frac{(W_{baseline} - W_{ee})}{1{,}000} \times (1 + HVAC_d) \times CF$$

$$\Delta MMBtu = units \times \frac{(W_{baseline} - W_{ee})}{1{,}000} \times hrs \times HVAC_{ff}$$

units = 20, from application
$W_{baseline}$ = 60, from application
W_{ee} = 10, from application
hrs = 986, from Operating Hours section table based on lamp location and city from application
$HVAC_c$ = 0.043, from Appendix D based on building type, HVAC type, and location from application
$HVAC_d$ = 0.073, from Appendix D based on building type, HVAC type, and location from application
CF = 0.16, from Summary of Variables and Data Sources table based on lamp location from application
$HVAC_{ff}$ = -0.003, from Appendix D based on building type, HVAC type, and location from application

$$\Delta kWh = 20 \times \frac{(60 - 10)}{1{,}000} \times 986 \times (1 + 0.043) = 1{,}028\ kWh$$

$$\Delta kW = 20 \times \frac{(60 - 10)}{1{,}000} \times (1 + 0.073) \times 0.16 = 0.17\ kW$$

$$\Delta MMBtu = 20 \times \frac{(60 - 10)}{1{,}000} \times 986 \times (-0.003) = -2.96\ MMBtu$$

[456] NMR Group Inc., "Northeast Residential Lighting Hours-of-Use Study", May 5, 2014. Table ES-6: HOU by Area Adjusted for Snapback. HOU referenced is the value for Household for DNY, which is a weighted average of all room types and is Snapback Adjusted. The study's sample size included far more interior to exterior lights, thus a weighted distribution heavily favors the interior lighting hours.

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Reduction in lighting power increases space heating requirements in conditioned spaces. Interactive HVAC impacts are addressed in prescribed energy savings calculation methodology.

Ancillary Electric Savings Impacts

Reduction in lighting power decreases cooling requirements in conditioned spaces. Interactive HVAC impacts are addressed in prescribed energy savings calculation methodology.

References

1. Energy Independence and Security Act of 2007. Pub. L. 110-140. Sec. 321. Efficient Light Bulbs H.R.6 – 82-86
   Available from: https://www.gpo.gov/fdsys/pkg/BILLS-110hr6enr/pdf/BILLS-110hr6enr.pdf
2. NMR Group Inc., "Northeast Residential Lighting Hours-of-Use Study", May 5, 2014.
   Available from: https://neep.org/sites/default/files/resources/Northeast-Residential-Lighting-Hours-of-Use-Study-Final-Report1.pdf
3. Coincidence Factor Study Residential and Commercial & Industrial Lighting Measures - For use as an Energy Efficiency Measures/Programs Reference Document for the ISO Forward Capacity Market (FCM), prepared for the New England State Program Working Group by RLW Analytics Inc., Spring 2007.
   Available from:
   https://www.puc.nh.gov/Electric/Monitoring%20and%20Evaluation%20Reports/National%20Grid/116_RLW_CF%20Res%20C&I%20ltg.pdf
4. Energy Savings Forecast of Solid-State Lighting in General Illumination Applications, US Department of Energy, December 2019, p. 82.
   Available from: https://www.energy.gov/sites/prod/files/2020/02/f72/2019_ssl-energy-savings-forecast.pdf
5. Electronic Code of Federal Regulations, Title 10: Energy, PART 430—ENERGY CONSERVATION PROGRAM FOR CONSUMER PRODUCTS, Subpart C—Energy and Water Conservation Standards
   Available from: https://www.ecfr.gov/cgi-bin/text-idx?c=ecfr&SID=1ae0322478999c2c4ff2c83d9ce4c04a&rgn=div8&view=text&node=10:3.0.1.4.18.3.9.2&idno=10l

Record of Revision

Record of Revision Number	Issue Date
1	10/15/2010
7-13-2	7/31/2013
6-15-3	6/1/2015
1-16-3	12/31/2015
1-17-4	12/31/2016
9-17-2	9/30/2017
12-19-6	12/23/2019
12-19-7	12/23/2019
12-20-13	12/31/2020
7-21-9	8/30/2021

Return to Table of Contents

LIGHTING - CONTROL

(place-holder)

Return to Table of Contents

MOTORS AND DRIVES

POOL CIRCULATOR TIMER

Measure Description

This measure covers the installation of multi-speed timer control on pool water circulation pumps in residential inground swimming pools. Pool circulator timers, also known as pool pump controls, adjust the operating speed of pool pumps automatically based on a set operating schedule. This measure is only applicable to pool pump control systems that meet or exceed CEE Tier 1 standards. In order for a pool pump control system to meet CEE Tier 1 standards, the system must have the ability to operate a pool pump at two or more speeds based on user presets, a default filtration speed that (when no auxiliary pool loads are operating) is no more than one-half of the motor's maximum rotation speed, and a default setting that returns the pool pump to the lowest user preset speed within one cycle or 24 hours.[457]

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times \frac{60 \times days}{1{,}000} \times \left\{ \left[\frac{GPM_{HS} \times \left(hrs_{baseline,HS} - hrs_{ee,HS} \right)}{EF_{HS}} \right] + \left[\frac{GPM_{LS} \times \left(hrs_{baseline,LS} - hrs_{ee,LS} \right)}{EF_{\mathrm{LS}}} \right] \right\}$$

Summer Peak Coincident Demand Savings

$$\Delta kW = units \times \frac{1}{1{,}000} \times \left(\frac{GPM_{HS}}{EF_{HS}} - \frac{GPM_{LS}}{EF_{\mathrm{LS}}} \right) \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

where:

ΔkWh	= Annual electricity energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
days	= Number of operating days per day
HS	= High speed operation
LS	= Low speed operation

[457] Consortium for Energy Efficiency, High Efficiency Residential Swimming Pool Initiative; Pool Pump Control Specification

GPM = Gallons per minute
baseline = Characteristic of baseline condition
ee = Characteristic of energy efficient condition
hrs = Hours of operation per day
EF = Energy factor (Gal/Wh)
CF = Coincidence factor
60 = Minutes in one hour
1,000 = Conversion factor, one kW equals 1,000 watts

Summary of Variables and Data Sources

Variable	Value	Notes
GPM_{HS}		From application, or look up in Gallons per Minute and Energy Factor table below.
GPM_{LS}		From application, or look up in Gallons per Minute and Energy Factor table below.
$hrs_{baseline,LS}$		From application. If unknown, use 10 as default.
$hrs_{baseline,HS}$		From application. If unknown, use 2 as default.[458]
$hrs_{ee,HS}$		From application.
$hrs_{ee,LS}$		From application.
EF_{HS}		From application, or look up in Gallons per Minute and Energy Factor Table below.
EF_{LS}		From application, or look up in Gallons per Minute and Energy Factor Table below.
days		From application. If unknown, use 122 as default, based on 4 months of operation per year.
CF	0.362	

Gallons per Minute and Energy Factor

Default values for WEF, EF, and GPM are found in the table below, based on nameplate horsepower.[459] Pump Performance Curve C is assumed for ENERGY STAR pumps. The pump curve compares the total head in feet of water to the flow rate of the water for a given pump at a given motor speed.

Pump Type and Variable	Nameplate Horsepower at High Speed				
	1.65 hhp (3 HP)	1.25 hhp (2.5 HP)	1.18 hhp (2 HP)	0.95 hhp (1.65 HP)	0.72 hhp (1-1.4 HP)
EF_{HS}	2.0	2.2	2.3	2.3	2.5
GPM_{HS}	102	93	89	78	76
EF_{LS}	6.1	6.0	6.5	6.7	6.8
GPM_{LS}	51.0	45.7	44.8	41.8	40.3

[458] Cal TF Workpaper, "SWRE002-01 VSD for Pool and Spa Pump", pg 14.
[459] Savings Calculator for ENERGY STAR® Certified Inground Pool Pumps (accessed 7/14/2020). Single speed conventional pump Energy Factor and Glow rate used as a proxy for high speed. Variable-speed pump Low Energy Factor and Low Flow used as a proxy for low speed.

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.362.[460]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition for this measure is a multi or variable speed pool pump without a CEE Tier 1 certified pool circulator timer.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a multi or variable speed pool pump equipped with a CEE Tier 1 certified pool circulator timer.

Operating Hours

Hour of operation shall be taken from application, or using defaults recommended above based on 12 hours of operation per day and 122 days per year. It is assumed that a pool is in use for 4 months per year given New York's average climate.[461]

Example Calculation *(Not to be used as default)*

An existing residential customer installs a CEE Tier 1 pool circulator timer on a 2 hp inground pool pump at their home near NYC. Prior to installation, the pump operated at high speed for 3 hours and low speed for 9 hours per day. Following installation, the pump operates on high speed for 2 hours and low speed for 10 hours per day. The pool is in use 124 days per year. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

$$\Delta kWh = units \times \frac{60 \times days}{1{,}000} \times \left\{ \left[\frac{GPM_{HS} \times \left(hrs_{baseline,HS} - hrs_{ee,HS} \right)}{EF_{HS}} \right] + \left[\frac{GPM_{LS} \times \left(hrs_{baseline,LS} - hrs_{ee,LS} \right)}{EF_{\mathrm{LS}}} \right] \right\}$$

$$\Delta kW = units \times \frac{1}{1{,}000} \times \left(\frac{GPM_{HS}}{EF_{HS}} - \frac{GPM_{LS}}{EF_{\mathrm{LS}}} \right) \times CF$$

units = 1, from application
GPM_{HS} = 89, from Gallons per minute and Energy Factor table
GPM_{LS} = 44.8, from Gallons per minute and Energy Factor table
$hrs_{baseline,HS}$ = 3, from application

[460] Standards Driven Market Transformation; 20 Year Multifaceted Intervention Leads to DOE Pool Pump Standard, ACEEE, pg 5-6

[461] It is assumed that 50% of pools are unheated and operate for 3 months per year and the other 50% of pools are heated and operate for 5 months per year, giving an average of 4 months of usage per year

$hrs_{baseline,LS}$ = 9, from application
$hrs_{ee,HS}$ = 2, from application
$hrs_{ee,LS}$ = 10, from application
EF_{HS} = 2.3, from Gallons per minute and Energy Factor table
EF_{LS} = 6.5, from Gallons per minute and Energy Factor table
days = 124, from application
CF = 0.362, from Summary of Variables and Data sources table

$$\Delta kWh = 1 \times \frac{60 \times 124}{1{,}000} \times \left\{\left[\frac{89 \times (3-2)}{2.3}\right] + \left[\frac{44.8 \times (9-10)}{6.5}\right]\right\} = 236.62\ kWh$$

$$\Delta kW = 1 \times \frac{1}{1{,}000} \times \left(\frac{89}{2.3} - \frac{44.8}{6.5}\right) \times 0.362 = 0.012\ kW$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. Consortium for Energy Efficiency, High Efficiency Residential Swimming Pool Initiative; Pool Pump Control Specification.
   Available from: https://library.cee1.org/system/files/library/9988/cee_residential_pool_pump_control_specification_29414.pdf
2. Southern California Technical Forum, SWRE002-01 VSD for Pool and Spa Pump, July 5, 2020
   Available from: http://deeresources.net/workpapers
3. Standards Driven Market Transformation; 20 Year Multifaceted Intervention Leads to DOE Pool Pump Standard, ACEEE, pg 5-6
   Available from: https://www.aceee.org/files/proceedings/2016/data/papers/5_761.pdf
4. Savings Calculator for ENERGY STAR® Certified Inground Pool Pumps, April 2020
   Available from: https://www.energystar.gov/productfinder/product/certified-pool-pumps/results#

Record of Revision

Record of Revision Number	Issue Date
7-20-4	7/31/2020

Return to Table of Contents

POOL PUMP

Measure Description

This measure covers the installation of ENERGY STAR® qualified multi-speed and variable frequency drive (VFD) residential inground pool pumps. Pool pump speeds vary based on the pump's operation. Filtration, for example, only requires half the flow rate of running a pool cleaner. Conventional pool pumps, with only one speed, are set to run at the higher speeds required of the pool cleaner and waste energy during filtration operation by running faster than necessary. An ENERGY STAR® certified pool pump can run at different speeds and be programmed to match the pool operation with its appropriate pool pump speed. The energy saved is considerable; reducing pump speed by one-half allows the pump to use just one-eighth as much energy.[462] After January 1, 2019, all pool pumps must be rated according to Weighted Energy Factor (WEF).[463] Pool pumps that have earned this label use up to 70% less energy than non-qualified models.[464]

This measure is applicable to multi-speed and VFD inground or self-priming pool pumps with a total horsepower rating between 1 and 3 HP. While single-speed pumps, non-self-priming pumps, and pressure cleanser booster pumps are eligible under ENERGY STAR® qualified product criteria, there was a critical lack of information regarding ENERGY STAR® calculations and assumptions pertaining to this equipment available at the time of publication of this measure. The measure scope will be expanded as more information becomes available. This measure is not applicable to community pools in multifamily housing complexes.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times \frac{days}{1{,}000} \times V_{pool} \times N_{turnover} \times \left[\frac{1}{EF_{baseline}} - \frac{1}{WEF_{ee}}\right]$$

Summer Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

Note: Although pump hp is not applied directly within algorithms, it must be known to establish baseline and compliance efficiency values.

where:

ΔkWh = Annual electric energy savings
ΔkW = Peak coincident demand electric savings

[462] ENERGY STAR® Pool Pumps
[463] ENERGY STAR® Pool Pumps Version 2 and Version 3 Specification Cover Letter, April 2018
[464] ENERGY STAR® Pool Pump Fact Sheet, January 2018

ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
days	= Number of operating days per year
baseline	= Characteristic of baseline condition
ee	= Characteristic of energy efficient condition
WEF	= Weighted Energy factor (kgal/kWh)
EF	= Energy factor (kgal/kWh)
V_{pool}	= Volume of pool, in gallons
$N_{turnover}$	= Number of turnovers per day, where a turnover is a full cycling of pool water through the pool filter
hp	= Horsepower of qualifying pump motor
1,000	= Conversion factor, one kgal equals 1,000 gallons

Summary of Variables and Data Sources

Variable	Value	Notes
V_{pool}		From application. If unknown, assume 22,000.[465]
$N_{turnover}$		From application. If unknown, use 2 per day.[466]
WEF_{ee}		From application, or look up in Compliance Efficiency section below, based on nameplate hp.
hp		From application
$EF_{baseline}$		Look up in Baseline Efficiencies section below, based on nameplate hp.
days		From application. If unknown, use 122. [467]

Default Values

The table below contains values for annual electric energy savings and Summer Peak Coincident Demand Savings. These values were established by using the assumed values from the Summary of Variables and Data Sources table above. Default values additionally assume a 22,000-gallon pool, a 1.5 hp baseline pump performing 2 turnovers per day lasting 9.4 hours, and a 1.0 hp qualifying pump performing 2 turnover per day lasting 12 hours each. [468]

Pump Type	Rated in WEF	
	ΔkWh	ΔkW
Multi-speed or VFD	1,744	0.216

Coincidence Factor (CF)

The prescribed value for the coincidence factor is N/A.

[465] Savings Calculator for ENERGY STAR® Certified Inground Pool Pumps (accessed 7/14/2020)
[466] CEE^{SM} High Efficiency Residential Swimming Pool Initiative, January 2013, pg 33
[467] Ibid
[468] CEE^{SM} High Efficiency Residential Swimming Pool Initiative, January 2013, pg 33

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a non-ENERGY STAR® qualified single-speed pool pump. The values for baseline EF are found in the table below, based on nameplate horsepower. Pump Performance Curve C is assumed for pool pumps. The pump curve compares the total head in feet of water to the flow rate of the water for a given pump at a given motor speed.

Pump Type and Variable	Nameplate Horsepower						
	0.5	**0.75**	**1**	**1.5**	**2**	**2.5**	**3**
$EF_{baseline}$	3.4	3.3	2.5	2.3	2.3	2.2	2.0

Compliance Efficiency from which Incentives are Calculated

The compliance condition is an ENERGY STAR® qualified multi or variable speed self-priming, inground pool pump. Self-priming pool pumps must have a WEF (in kgal/kWh) equal to or greater than the equation below for pumps on curve C.[469]

$$WEF \geq -230 \times ln(hhp) + 6.59$$

where:

hhp = hydraulic horsepower, equal to or greater than 0.711

<u>Multi-Speed and Variable Frequency Drive Pool Pumps</u>[470]

Typical WEF for ENERGY STAR® multi-speed and variable frequency drive pool pumps are found in the table below, based on nameplate horsepower. Pump Performance Curve C is assumed for ENERGY STAR pumps. The pump curve compares the total head in feet of water to the flow rate of the water for a given pump at a given motor speed.

Pump Type and Variable	Nameplate Horsepower at High Speed				
	1-1.4 HP (0.72 hhp)	**1.65 HP (0.95 hhp)**	**2 HP (1.18 hhp)**	**2.5 HP (1.25 hhp)**	**3 HP (1.65 hhp)**
WEF_{ee}	8.7	8.9	9.3	7.4	7.1

Operating Hours

Based on New York's average climate, it is assumed that a pool is in use for 4 months per year.[471] While in use, the energy efficient pump cycles through pool water at a default rate of 12 hours per turnover.

[469] ENERGY STAR® Program Requirements Product Specification for Pool Pumps, Eligibility Criteria Version 2.0, January 2019

[470] Ibid

[471] It is assumed that 50% of pools are unheated and operate for 3 months per year and the other 50% of pools are heated and operate for 5 months per year, giving an average of 4 months of usage per year

Example Calculation *(Not to be used as default)*

An ENERGY STAR® qualified variable frequency drive (VFD) residential inground 2 hp pool pump is installed at a single family home near Albany. The pump has a WEF of 9.3 and conducts one turnover per day. The pool is 21,000 gallons and operational for 122 days per year. Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings are calculated as below.

$$\Delta kWh = units \times \frac{days}{1{,}000} \times V_{pool} \times N_{turnover} \times \left[\frac{1}{EF_{baseline}} - \frac{1}{WEF_{ee}}\right]$$

units = 1, from application
days = 122, from application
V_{pool} = 21,000, from application
WEF_{ee} = 9.3, from application
$N_{turnover}$ = 1, from application
$EF_{baseline}$ = 2.3, from Baseline Efficiency from which Incentives are Calculated section

$$\Delta kWh = 1 \times \frac{122}{1{,}000} \times 21{,}000 \times 1 \times \left[\frac{1}{2.3} - \frac{1}{9.3}\right] = 838.43\ kWh$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. ENERGY STAR® Program Requirements Product Specification for Pool Pumps, Eligibility Criteria Version 2.0, January 2019
   Available from:
   https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Final%20Version%202.0%20Pool%20Pumps%20Specification.pdf
2. 10 CFR Appendix B to Subpart Y of Part 431 – Uniform Test Method for the Measurement of Energy Efficiency of Dedicated-Purpose Pool Pumps
   Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=1e172a51fbd7c0fa1753866066133e14&mc=true&node=pt10.3.431&rgn=div5#ap10.3.431_1466.b

3. ENERGY STAR® Pool Pumps Version 2 and Version 3 Specification Cover Letter, April 30, 2018
   Available from:
   https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Pool%20Pumps%20Version%202%20and%20Version%203%20Specification%20Cover%20Letter.pdf
4. ENERGY STAR® Pool Pump Fact Sheet, January 2018
   Available from:
   https://www.energystar.gov/sites/default/files/asset/document/PoolPumps_FactSheet_012318_0.pdf
5. Savings Calculator for ENERGY STAR® Certified Inground Pool Pumps, May 2020
   Available from:
   https://www.energystar.gov/productfinder/downloads/Pool_Pump_Calculator_2020.05.05_FINAL.xlsx
6. CEE℠ High Efficiency Residential Swimming Pool Initiative, Consortium for Energy Efficiency, January 2013
   Available from:
   https://library.cee1.org/system/files/library/9986/CEE_Res_SwimmingPoolInitiative_01Jan2013_Corrected.pdf

Record of Revision

Record of Revision Number	Issue Date
6-18-20	6/30/2018
9-18-6	9/28/2018
12-20-4	12/31/2020

Return to Table of Contents

OTHER

HEAT PUMP POOL HEATER

Measure Description

This measure is applicable to electric heat pump pool heaters in residential applications. Heat pumps capture heat and move it from one place to another. The saving equations presented herein comprise three aspects of pool heating: convective heat loss via pool surface area due to water and air temperature differential, initial heat of full pool volume for seasonal pool use and reheat of pool refill on year round pools, and the heating of added pool water to offset water loss through evaporation.[472] If baseline equipment is a fossil fuel-fired pool heater, electric energy impacts result in a penalty.

This measure is only applicable to inground pools and is not applicable to spas. This measure is not applicable to community pools in multifamily housing complexes. For community pools, refer to the Commercial Heat Pump Pool Heater measure in this TRM.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = \frac{\left(BTU_{Surface} + BTU_{Reheat} + BTU_{Evap}\right)}{3{,}412} \times \left(\frac{F_{elec,baseline}}{COP_{baseline}} - \frac{1}{COP_{ee}}\right)$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \frac{\Delta kWh}{hrs} \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = \frac{\left(BTU_{Surface} + BTU_{Reheat} + BTU_{Evap}\right)}{1{,}000{,}000} \times \frac{F_{fuel,baseline}}{E_{t,baseline}}$$

where:

$$BTU_{Surface} = \left(T_{pool} - T_{amb}\right) \times A_{pool} \times U \times \left[hrs - \left(hrs_{cover} \times ESF_{cover,surface}\right)\right]$$

$$BTU_{Reheat} = V_{pool} \times 8.33 \times \left(T_{pool} - T_{main}\right) \times F_{Reheat}$$

[472] ASHRAE Handbook: HVAC Applications, 2019, pg 51.25. ASHRAE states that except in aboveground pools and rare cases where cold groundwater flows past the pool walls, conductive losses through pool walls are small and can be ignored. ASRHAE additionally indicates that radiation losses that occur due to sky temperature differentials at night may be offset by solar heat gains of an unshaded pool during the day.

$$BTU_{Evap} = 0.1 \times AF \times A_{pool} \times (P_{\omega} - P_{dp}) \times (T_{pool} - T_{main}) \times [hrs - (hrs_{cover} \times ESF_{cover,evap})]$$

where:

ΔkWh	= Annual electricity energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
$BTU_{Surface}$[473]	= Annual heating energy load contributed by convection and radiation heat losses via pool surface, (BTU)
BTU_{Reheat}[474]	= Annual heating energy load contributed by heating the full volume of pool water, (BTU)
BTU_{Evap}[475]	= Annual heating energy load contributed by evaporation, (BTU)
$F_{elec,baseline}$	= Baseline electric pool heater factor; used to account for the presence or absence of an electric pool heater
$F_{fuel,baseline}$	= Baseline fossil fuel pool heater factor; used to account for the presence or absence of a fossil fuel pool heater
$COP_{baseline}$	= Coefficient of performance, ratio of output energy/input energy of baseline electric resistance pool heater, if present
COP_{ee}	= Coefficient of performance, ratio of output energy/input energy of heat pump pool heater
$E_{t,baseline}$	= Thermal efficiency of baseline fossil fuel-fired pool heater, if present
T_{pool}	= Pool temperature set point, (ºF)
T_{amb}	= Average temperature of surrounding ambient air, (ºF)
T_{main}	= Supply water temperature in water main, (ºF)
A_{pool}	= Surface area of pool, (ft^2)
V_{pool}	= Volume of pool water, (gallons)
F_{Reheat}	= Factor capturing annual number of times full pool volume is heated to the desired temperature, whether as the result of refill or heating of pool water from ground water temperature at start of season
U	= Surface heat loss coefficient, (BTU/hr-ft^2-ºF)
AF	= Activity Factor, consideration of activity within pool
P_{ω}	= Saturation vapor pressure taken at surface water temperature, (in. Hg)
P_{dp}	= Saturation pressure at dew point, (in. Hg)
hrs	= Total annual swimming season hours
hrs_{cover}	= Total annual hours pool covered during the swimming season
$ESF_{cover,surface}$	= Energy Savings Factor of pool cover to insulate from convective and radiation heat losses
$ESF_{cover,evap}$	= Energy Savings Factor of pool cover to insulate from evaporative heat loss
CF	= Coincidence factor

[473] ASHRAE Handbook: HVAC Applications, 2019, Ch 51 Service Water Heating, Swimming Pools/Health Clubs, eqn. 15
[474] Ibid, eqn. 14
[475] ASHRAE Handbook: HVAC Applications, 2019, Ch 6 Indoor Swimming Pools, eqn. 3, multiplied by required heating temperature difference

0.1 = Simplified empirically derived evaporation factor considering latent heat and air flow[476]; assumes 1,000 BTU/lb of latent heat required to change water to vapor at surface water temperature and air velocity over water surface ranging from 10 to 30 fpm, (lb/hr-ft^2-in. hg)
8.33 = Energy required (BTU) to heat one gallon of water by one degree Fahrenheit
3,412 = Conversion factor, one kWh equals 3,412 BTU
1,000,000 = Conversion factor, one MMBtu equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
$F_{elec,baseline}$		If baseline system is an electric resistance pool heater, set equal to 1. Otherwise, set equal to 0.
$F_{fuel,baseline}$		If baseline system is a fossil fuel-fired pool heater, set equal to 1. Otherwise, set equal to 0.
$COP_{baseline}$		If baseline pool heater is electric, assume 1.0.
COP_{ee}		From application.
$E_{t,baseline}$		From application. If unknown, use 0.82 as default.[477]
T_{pool}		From application.
T_{amb}		Indoor pool ambient temperature shall come from application. For outdoor pool ambient temperature, lookup in Outdoor Pool table in the Air Temperature and Pressure section below based on nearest city.
T_{main}		Supply water temperature in water main (ºF). Lookup in Cold Water Inlet Temperature table below based on nearest city.
A_{pool}		Pool surface area, from application.[478] Assistance in determining the area of common pool shapes as follows: Elliptical: 3.14 x short radius x long radius Kidney Shaped: 0.45 x length x (width at one end x width at other end) Oval: 3.14 x radius^2 + (length of straight sides x width) Rectangular: length x width
V_{pool}		Volume of water, from application.

[476] Simplified constant presented in ASHRAE Handbook: HVAC Application 2019 Ch 6 based on empirically derived eqn (2) constants and ASHRAE's variable assumptions
[477] 10 CFR 430.32 (k)(2)
[478] Guidance for determining surface area of common pool shapes can be found at ASHRAE Handbook: HVAC Applications, 2019, pg 51.25

Variable	Value	Notes
F_{Reheat}		From application. If pool is filled by delivery service providing preheated water, set F_{Reheat} equal to 0. Otherwise F_{Reheat} shall default to 1.[479]
U	Indoor pool: 3.9 Outdoor pool, sheltered: 5.3 Outdoor pool, unsheltered: 6.6	Surface heat loss coefficient (BTU/hr-ft^2-ºF).[480]
AF	0.5	Activity Factor considers activity level of the pool, allowing for splashing and a limited area of wetted deck.[481]
P_{ω}		Lookup from Saturation Vapor Pressure section below based on pool water temperature. Linear interpolation and extrapolation of the data in the table is acceptable for pool templates not provided.
P_{dp}		Lookup from indoor or outdoor pool tables in Air Temperature and Pressure section below based on ambient temperature and relative humidity (RH) or city, respectively. Linear interpolation and extrapolation of the data in the table is acceptable for pool templates not provided.
hrs		From application. Hours shall reflect the total annual hours through the swimming season (number of days between season opening and season closing x 24).
hrs_{cover}		From application. Hours shall reflect the total hours pool covered during the swimming season. Set equal to 0 if pool is left uncovered throughout swimming season.
$ESF_{cover,surface}$	0.8	Based on cost savings from DOE for gas and heat pump pool heater savings[482]
$ESF_{cover,evap}$	0.95	Effectiveness of Pool Covers to Reduce Evaporation from Swimming Pools. [483]
CF	Outdoor pool: 0 Indoor pool: 0.8	

[479] The water temperature of an undrained pool between swim seasons is assumed to have reached the water main temperature by the beginning of the next swim season. If the pool remains open throughout the year, it is assumed the pool undergoes one effective full pool volume reheat from water main temperature for cleaning and other maintenance (CDC, Healthy Swimming, Operating Public Swimming Pools).
[480] ASHRAE Handbook: HVAC Applications, 2019, Ch 51, eqn. 15. Surface heat loss coefficient adjusted from ASHRAE Handbook rolled up surface heat transfer conservations by discounting contribution of evaporation (50-60%) and applying the following assumption for wind velocity: Indoor pools experience average wind speeds less than 3.5 mph (10.5x0.5x0.75), outdoor sheltered pools experience wind speeds between 3.5 and 5 mph (10.5x0.5), and outdoor unsheltered pools experience wind speeds above 5 mph (10.5x0.5x1.25).
[481] ASHRAE Handbook, Applications, 2019, Ch 6, Table 1
[482] U.S. D.O.E., Swimming Pool Covers
[483] National Plasterers Council, Effectiveness of Pool Covers to Reduce Evaporation from Swimming Pools, prepared by California Polytechnic State University, January 2016

Cold Water Inlet Temperature (T_{main})
Supply water main temperatures vary according to climate, and are approximately equal to the annual average outdoor temperature plus 6°F.[484] Supply main temperatures based on the annual outdoor temperature are shown below.

City	Annual average outdoor temperature[485] (°F)	T_{main} (°F)
Albany	48.3	54.3
Binghamton	46.3	52.3
Buffalo	48.3	54.3
Massena	43.5	49.5
NYC	55.4	61.4
Poughkeepsie	49.8	55.8
Syracuse	48.3	54.3

Saturation Vapor Pressure (P_ω)
Lookup saturation vapor pressure taken at surface water temperature for indoor and outdoor pools from the table below, based on pool temperature.[486]

Pool Temperature, T_{pool} (°F)	P_ω (in. Hg)
72	0.79
74	0.85
76	0.91
78	0.97
80	1.03
82	1.10
84	1.18

Ambient Air Temperature and Pressure (T_{amb} and P_{dp})
Indoor pools shall apply ambient air temperature from application based on facility set point temperature. Lookup saturation vapor pressure based on facility set point temperature and relative humidity (RH) from the table below, based on psychrometric analysis. Interpolation may be performed for indoor pool ambient temperatures not listed.

Indoor Pool T_{amb} (°F)	Indoor Pool, P_{dp} (in. Hg)		
	RH 50%	RH 55%	RH 60%
72	0.40	0.44	0.47
74	0.42	0.47	0.51
76	0.45	0.50	0.54
78	0.48	0.53	0.58

[484] Burch, Jay and Christensen, Craig, "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory
[485] Average annual outdoor temperatures taken from NCDC 1981-2010 climate normals
[486] ASHRAE Handbook: Fundamentals 2017, Ch 1 Psychrometrics, Table 3 Thermodynamic Properties of Water at Saturation

Indoor Pool T_{amb} (°F)	Indoor Pool, P_{dp} (in. Hg)		
	RH 50%	RH 55%	RH 60%
80	0.52	0.56	0.62
82	0.55	0.61	0.66
84	0.59	0.65	0.71
86	0.63	0.69	0.75

For outdoor pools, lookup T_{amb} and P_{dp} from the table below based on location. Ambient temperature averages for outdoor pools apply a 4-month swimming season[487].

City	Outdoor Pool T_{amb}[488] (°F)	Outdoor Pool P_{dp} (in. Hg)
Albany	67.8	0.48
Binghamton	65.0	0.44
Buffalo	67.3	0.47
Massena	64.6	0.47
NYC	73.4	0.53
Poughkeepsie	68.6	0.54
Syracuse	67.5	0.48

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0 for outdoor pools and is 0.8 for indoor pools.[489]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition for this measure is an electric resistance or fossil fuel-fired pool heater.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is an AHRI-certified heat pump pool heater.

Operating Hours

The annual operating hours shall be taken from application based on the number of total hours of residence's swimming season and total hours pool is covered during the swimming season.

Example Calculation *(Not to be used as default)*

A gas pool heater is replaced with a heat pump pool heater at a single family home located near Albany. The swimming season spans 3 months (2,208 hours) per year and the pool is left uncovered at night. The pool is 15 ft by 30 ft and has a volume of 17,600 gallons, and is

[487] It is assumed that 50% of pools are unheated and operate for 3 months per year and the other 50% of pools are heated and operate for 5 months per year, giving an average of 4 months of usage per year; June 1 through Sept 30

[488] Average ambient temperatures taken from NCDC 1981-2010 climate normals, averaged from June 1 through Sept 30

[489] *No source specified – update pending availability and review of applicable references.*

sheltered from winds by the house and backyard trees. The pool temperature is maintained at 80ºF. The replaced gas pool heater has an efficiency of 0.84 and the heat pump pool heater has an efficiency of 5.0 COP. Annual Electric Energy Savings, Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta kWh = \frac{\left(BTU_{Surface} + BTU_{Reheat} + BTU_{Evap}\right)}{3{,}412} \times \left(\frac{F_{elec,baseline}}{COP_{baseline}} - \frac{1}{COP_{ee}}\right)$$

$$\Delta kW = \frac{\Delta kWh}{hrs} \times CF$$

$$\Delta MMBtu = \frac{\left(BTU_{Surface} + BTU_{Reheat} + BTU_{Evap}\right)}{1{,}000{,}000} \times \frac{F_{fuel,baseline}}{E_{t,baseline}}$$

where:

$$BTU_{Surface} = \left(T_{pool} - T_{amb}\right) \times A_{pool} \times U \times \left[hrs - \left(hrs_{cover} \times ESF_{cover,surface}\right)\right]$$

$$BTU_{Reheat} = V_{pool} \times 8.33 \times \left(T_{pool} - T_{main}\right) \times F_{Reheat}$$

$$BTU_{Evap} = 0.1 \times AF \times A_{pool} \times \left(P_{\omega} - P_{dp}\right) \times \left(T_{pool} - T_{main}\right) \times \left[hrs - \left(hrs_{cover} \times ESF_{cover,evap}\right)\right]$$

T_{pool} = 80, from application
T_{amb} = 67.8, from Ambient Air Temperature and Pressure section based on location from application
A_{pool} = width x length = 15’ x 30’ = 450’
Width and length from application
U = 5.3, from Summary of Variables and Data Sources table based on conditions from application
hrs = 2,208, from application
hrs_{cover} = 0, from application
$ESF_{cover,surface}$ = 0.8, from Summary of Variables and Data Sources table
V_{pool} = 17,600, from application
T_{main} = 54.3, from Cold Water Inlet Temperature table based on location from application
F_{Reheat} = 1, from Summary of Variables and Data Sources table
AF = 0.5, from Summary of Variables and Data Sources table
P_{ω} = 1.03, from Saturation Vapor Pressure section based on pool temperature from application
P_{dp} = 0.48, from Ambient Air Temperature and Pressure section based on location from application
$ESF_{cover,evap}$ = 0.95, from Summary of Variables and Data Sources table
$F_{elec,baseline}$ = 0, from Summary of Variables and Data Sources table based on application
COP_{ee} = 5.0, from application
CF = 0, from Summary of Variables and Data Sources table based on application
$F_{fuel,baseline}$ = 1, from Summary of Variables and Data Sources table based on application

$E_{t,baseline}$ = 0.84, from application

$$BTU_{Surface} = (80 - 67.8) \times 450 \times 5.3 \times [2{,}208 - (0)] = 64{,}246{,}176\ Btu$$

$$BTU_{Reheat} = 17{,}600 \times 8.33 \times (80 - 54.3) \times 1 = 3{,}767{,}826\ Btu$$

$$BTU_{Evap} = 0.1 \times 0.5 \times 450 \times (1.03 - 0.48) \times (80 - 54.3) \times [2{,}208 - (0)] = 702{,}227\ Btu$$

$$\Delta kWh = \frac{(64{,}246{,}176 + 3{,}767{,}826 + 702{,}227)}{3{,}412} \times \left(0 - \frac{1}{5}\right) = -4{,}028\ kWh$$

$$\Delta kW = \frac{-4{,}028}{2{,}208} \times 0 = 0\ kW$$

$$\Delta MMBtu = \frac{(64{,}246{,}176 + 3{,}767{,}826 + 702{,}227)}{1{,}000{,}000} \times \frac{1}{0.84} = 81.8\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Higher efficiency heat pump pool heaters may require fewer pool water circulations through the pool pump, alleviating some of the pool pump energy load. This energy impact is not considered in the methodology for this measure.

References

1. 2019 ASHRAE Handbook – HVAC Applications, Chapter 6: Indoor Swimming Pools
2. 2019 ASHRAE Handbook – HVAC Applications, Chapter 51: Service Water Heating
3. 2017 ASHRAE Handbook – Fundamentals, Chapter 1, Psychrometrics
4. 10 CFR 430.32 Energy and water conservation standards and their compliance dates
   Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=840d2f09fea283237b0f345001c03a28&mc=true&node=pt10.3.430&rgn=div5#se10.3.430_132
5. U.S. D.O.E., Swimming Pool Covers.
   Available from: https://www.energy.gov/energysaver/swimming-pool-covers

6. Burch, Jay and Craig Christensen; "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory
Available from:
http://citeseerx.ist.psu.edu/viewdoc/download;jsessionid=05D73BA6EF5ECCF71969D083FB317991?doi=10.1.1.515.6885&rep=rep1&type=pdf
7. NOAA National Center for Environmental Information – NCEI 1981 – 2010 Annual/Seasonal Climate Normals
Available from: https://www.ncdc.noaa.gov/cdo-web/datatools/normals
8. National Plasterers Council, Effectiveness of Pool Covers to Reduce Evaporation from Swimming Pools, prepared by California Polytechnic State University, January 2016
Available from:
https://cdn.ymaws.com/www.npconline.org/resource/resmgr/Docs/Evaporation_Study_Report.pdf

Record of Revision

Record of Revision Number	Issue Date
7-21-10	8/30/2021

Return to Table of Contents

POOL HEATER

Measure Description

This measure covers the installation of high efficiency fossil fuel pool heaters in residential applications.[490] Fossil fuel-fired pool heaters are designed for heating non-potable water and employ fossil fuel burners. High-efficiency fossil fuel heaters can have thermal efficiency ratings as high as 95%. Pool heaters must have a thermal efficiency rating of 84% or greater to qualify for estimated energy savings using this measure.[491]

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = N/A$$

Summer Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = units \times ((MMBtu/kBTU/h_{in})_{baseline} - (MMBtu/kBTU/h_{in})_{ee}) \times kBTU/h_{in}$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
$_{baseline}$	= Characteristic of baseline condition
$_{ee}$	= Characteristic of energy efficient condition
$(MMBtu/kBTU/h_{in})$	= Annual fossil fuel consumption per pool heater heating capacity
$kBTU/h_{in}$	= Pool heater input heating capacity, in kBTU/h

Summary of Variables and Data Sources

Variable	Value	Notes
$(MMBtu/kBTU/h_{in})_{baseline}$	0.146	From the annual energy consumption table below, based on a thermal efficiency rating of 82%.

[490] Similar to other measures in the NY TRM, this measure will continue to be reviewed for accuracy and for potential updates, based on up-take in programs, changes in codes and standards, and the availability of other measure-specific information.
[491] 10 CFR 430.32.(k)(1)

Variable	Value	Notes
$(MMBtu/kBTU/h_{in})_{ee}$		Look up from energy consumption table below based on thermal efficiency rating of efficient pool heater. Interpolation may be performed for pool heater efficiencies not listed, above 84%.
$kBTU/h_{in}$		Pool heater input capacity as indicated on equipment nameplate, from application.

Annual Energy Consumption[492]

Thermal Efficiency (%)	Annual Fossil Fuel Consumption ($MMBtu/kBTU/h_{in}$)
82 (baseline)	1.46
84	1.38
86	1.34
90	1.28
95	1.22

Coincidence Factor (CF)

The prescribed value for the coincidence factor is N/A.

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a fossil fuel-fired pool heater with a thermal efficiency of 82% as mandated by federal standards.[493]

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a fossil fuel-fired pool heater that has a thermal efficiency of 84% or greater.[494]

Operating Hours

Pool heater run hours are embedded in the values found in the Annual Energy Consumption table provided above. The derivation assumes a 250-kBTU/h pool heater, 26.5% of heaters equipped with a pilot with an input rate of 1-kBTU/h, an average pilot operating hours of 4,464 hours per year, and a distribution range of pool operational hours from 235 to 8,760 per year. [495]

[492] US DOE, Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters, Chapter 7, Table 7.4.2: Annual Energy Consumption for Gas-Fired Pool Heaters. The derivation assumes a 250-kBTU/h pool heater and 26.5% of heaters equipped with a pilot with an input rate of 1-kBTU/h.
[493] 10 CFR 430.32.(k)(1)
[494] Compliance requirement based on SoCal Gas minimum thermal efficiency to qualify for incentive (accessed 11/27/2018)
[495] A continuously burning pilot is prohibited by the Code of Federal Regulations. However, removing the 26.5% of pool heaters with a pilot from the analyzed population, assuming these are distributed across efficiency levels, will not change nominal savings.

Example Calculation *(Not to be used as default)*

A fossil fuel fired pool heater with an efficiency rating of 90% and an input capacity of 100 kBTU/h is installed in a residential pool. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are not applicable. Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta MMBtu = units \times ((MMBtu/kBTU/h_{in})_{baseline} - (MMBtu/kBTU/h_{in})_{ee}) \times kBTU/h_{in}$$

$(MMBtu/kBTU/h_{in})_{baseline}$ = 1.46, from Summary of Variables and Data Sources table
$(MMBtu/kBTU/h_{in})_{ee}$ = 1.28, from Annual Energy Consumption table based on thermal efficiency from application
$kBTU/h_{in}$ = 100 $kBTU/h_{in}$, from application

$$\Delta MMBtu = 1 \times (1.46 - 1.28) \times 100 = 18\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Analysis of baseline and high-efficiency fossil fuel pool heaters conducted using the DOE test procedure suggests that auxiliary and stand-by electric loads are slightly higher for more efficient equipment.[496] The magnitude of these effects is considered negligible relative to anticipated fossil fuel savings and electric impacts have thus been excluded from the prescribed methodology.

References

1. 10 CFR 430.32 Energy and water conservation standards and their compliance dates. Available from: https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=e2b12730e1b0fd7608318eb139d57b10&mc=true&n=pt10.3.430&r=PART&ty=HTML#se10.3.430_132

[496] US DOE, Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters, Chapter 7, Table 7.4.2: Annual Energy Consumption for Gas-Fired Pool Heaters

2. Department of Energy; Notice of Proposed Rulemaking Technical Support Document Energy Conservation Program for Consumer Products: Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters, Chapter 7: Energy Use Characterization, November 23, 2009
   Available from: https://www.regulations.gov/contentStreamer?documentId=EERE-2006-STD-0129-0170&attachmentNumber=8&contentType=pdf
3. SoCal Gas, Pool Heater List (accessed November 27, 2018)
   Available from: https://www.socalgas.com/pool-heater-list

Record of Revision

Record of Revision Number	Issue Date
12-18-8	12/28/2018
12-19-8	12/23/2019

Return to Table of Contents

SOLAR POOL HEATER

Measure Description

This measure covers the installation of solar pool heating systems utilizing glazed or unglazed solar thermal collectors. Solar thermal collectors absorb sunlight, convert solar energy directly into heat and transfer heat to filtered pool water pumped through the system. Thermal collectors shall be permanently installed on a roof or raised frame.

Solar pool heaters may be installed to partially or fully offset energy consumption of traditional heaters. This measure only applies to solar pool heaters installed in place of or to supplement fossil fuel pool heaters for inground swimming pools. Installed thermal collector area must be 50-100% of pool surface area.[497] This methodology assumes that thermal collectors experience minimal shading between the hours of 10AM and 4PM during the summer months. Qualifying thermal collectors must be rated by Solar Rating & Certification Corporation (SRCC) and be OG-100 certified.[498]

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

For Single Speed Pool Pumps

$$\Delta kWh = \frac{60 \times days}{1{,}000} \times \frac{GPM}{EF} \times (hrs_{baseline} - hrs_{ee})$$

For Multi-Speed or Variable Frequency Drive Pool Pumps

$$\Delta kWh = \frac{60 \times days}{1{,}000} \times \left(\frac{F_{HS} \times GPM_{HS} + F_{LS} \times GPM_{LS}}{WEF}\right) \times (hrs_{baseline} - hrs_{ee})$$

Summer Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = \frac{CR \times SF \times days \times (1 - F_{derate})}{E_{t,baseline} \times 1{,}000{,}000}$$

where:

ΔkWh = Annual electricity energy savings
ΔkW = Peak coincident demand electric savings

[497] US DOE "Solar Swimming Pool Heaters".
[498] Solar Rating & Certification Corporation Directory: http://solar-rating.org/programs/og-100-program/. The Solar Rating & Certification Corporation (ICC-SRCC) is an ISO/IEC 17065-accredited third-party certification body with programs for the certification and performance rating of solar heating and cooling products. The OG-100 Solar Thermal Collector Certification Program provides certification for solar thermal collectors to the current ICC 901/SRCC 100 Solar Thermal Collector standard.

ΔMMBtu	= Annual fossil fuel energy savings
$_{baseline}$	= Characteristic of baseline condition
$_{ee}$	= Characteristic of energy efficient condition
$_{HS}$	= High speed operation
$_{LS}$	= Low speed operation
CR	= Collector Rating (Btu/ft^2-day)
SF	= Square Footage of thermal collectors (ft^2)
days	= Annual days pool heater is used
F_{derate}	= Derating factor
F	= Weighting factor
$hrs_{baseline}$	= Annual pool pump operating hours with fossil fuel-fired pool heater
hrs_{ee}	= Annual pool pump operating hours with solar pool heater
EF	= Energy factor (kgal/kWh)
WEF	= Weighted Energy factor (kgal/kWh)
GPM	= Gallons per minute
$E_{t,baseline}$	= Thermal efficiency of baseline pool heater
60	= Conversion factor, minutes per hour
1,000	= Conversion factor, one kW equals 1,000 watts
1,000,000	= Conversion factor, one MMBtu equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
CR		From application, as rated by Solar Rating & Certification Corporation. Value shall reflect scenario A (Pool Heating – Warm Climate) and Medium Radiation (1,500 Btu/ft^2-day).[499]
SF		From application.
days		From application. If unknown, use 122 as default, based on 4 months of operation per year.
F_{HS}	0.2	Code of Federal Regulations. [500]
F_{LS}	0.8	Code of Federal Regulations. [501]
F_{derate}	0.06	Derating factor considers approximate shading (3% deration) and operational availability (3% deration).[502]
$hrs_{baseline}$		From application. If unknown, use 9.4[503] as default for a single-speed pump, based on a 1.5 HP pump, 22,000 gallon pool, and assuming two turnovers per day for baseline condition.[504]
hrs_{ee}		From application.

[499] Solar Rating & Certification Corporation Directory; scenario selected based on review of NASA Open Data Portal, Prediction of Worldwide Energy Resources (POWER), suggesting that this is the most appropriate selection across NY cities.
[500] 10 CFR Appendix B to Subpart Y of Part 431 – Uniform Test Method for the Measurement of Energy Efficiency of Dedicated-Purpose Pool Pumps
[501] Ibid
[502] NREL "PVWatts Version 5 Manual" Table 6.
[503] Savings Calculator for ENERGY STAR® Certified Inground Pool Pumps (accessed 7/14/2020)
[504] CEE^{SM} High Efficiency Residential Swimming Pool Initiative, January 2013, pg 33

Variable	Value	Notes
GPM		Look up in Baseline Efficiencies section below, based on pool pump type (single speed, multi-speed, or variable frequency drive) and nameplate hp.
EF		Look up in Baseline Efficiencies section below, based on nameplate hp.
WEF		Look up in Baseline Efficiencies section below, based on nameplate hp.
$E_{t,baseline}$		From application. If unknown, apply 0.86 as default in partial displacement of pool heater load scenarios and 0.82 as default in complete replacement of pool heater load scenarios. [505]

Coincidence Factor (CF)

The prescribed coincidence factor for this measure is N/A.

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition for this measure is a standard efficiency fossil fuel-fired pool heater. The values for baseline EF, WEF and GPM are found in the table below, based on pump type and nameplate horsepower. Pump Performance Curve C is assumed for all pumps. The pump curve compares the total head in feet of water to the flow rate of the water for a given pump at a given motor speed.

Single Speed Pool Pumps[506]

Pump Type and Variable	Nameplate Horsepower					
	3	2.5	2	1.5	1	0.75
EF	2.0	2.2	2.3	2.3	2.5	3.3
GPM	102	93	89	78	76	65

Multi-Speed and Variable Frequency Drive Pool Pumps[507]

Pump Type and Variable	Nameplate Horsepower at High Speed				
	1.65 hhp (3 HP)	1.25 hhp (2.5 HP)	1.18 hhp (2 HP)	0.95 hhp (1.65 HP)	0.72 hhp (1-1.4 HP)
WEF	3.6	4.0	4.1	4.6	4.9
GPM_{HS}	102.0	90.0	89.7	78.0	70.0
GPM_{LS}	51.0	45.7	44.8	41.8	40.3

Compliance Efficiency from which Incentives are Calculated

The compliance condition for this measure is a thermal collector installed to offset or replace the consumption of a traditional fossil fuel-fired pool heater for an inground swimming pool.

[505] 10 CFR 430.32 (k)(2)
[506] Savings Calculator for ENERGY STAR® Certified Inground Pool Pumps (accessed 7/14/2020)
[507] Ibid

Qualifying thermal collectors must be rated by Solar Rating & Certification Corporation's OG-100 program.

Operating Hours

The annual operating days shall be taken from application. If actual operating days are unknown, 122 days may be used as a default, assuming 4 months of operation per year.

Example Calculation *(Not to be used as default)*

An existing residential customer near Syracuse replaces their gas fired inground pool heater with a solar pool heating system comprising 470 SF of glazed thermal collectors. The pool is equipped with a 2 hp single speed pool pump that operates for 10 hours per day. The pump runtime is reduced to 8 hours per day post installation. The pool heater is in operation for 120 days per year. The Solar Pool Heater has a Collector Rating (CR) of 850 Btu/ft^2-day. Summer Peak Coincident Demand Savings are not applicable. Annual Electric Energy Savings and Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta kWh = \frac{60 \times days}{1{,}000} \times \frac{GPM}{EF} \times (hrs_{baseline} - hrs_{ee})$$

$$\Delta MMBtu = \frac{CR \times SF \times days \times (1 - F_{derate})}{E_{t,baseline} \times 1{,}000{,}000}$$

Days = 120, from application
SF = 470, from application
GPM = 89 gallons/min, from Single Speed Pool Pumps table in Baseline Efficiencies from which Energy Savings are Calculated section
EF = 2.3, from Single Speed Pool Pumps table in Baseline Efficiencies from which Energy Savings are Calculated section
$Hrs_{baseline}$ = 10 hours, from application
Hrs_{ee} = 8 hours, from application
F_{derate} = 0.06, from Summary of Variables and Data sources table
$E_{t,baseline}$ = 0.82, from Summary of Variables and Data sources table
CR = 850, from application

$$\Delta kWh = \frac{60 \times 120}{1{,}000} \times \frac{89}{2.3} \times (10 - 8) = 557.2\ kWh$$

$$\Delta MMBtu = \frac{850 \times 470 \times 120 \times (1 - 0.06)}{0.82 \times 1{,}000{,}000} = 54.96\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Addition of a thermal collector will require additional run time of pool pump. This additional electric consumption is considered in the ΔkWh equation above.

References

1. Department of Energy, Solar Swimming Pool Heaters
   Available from: https://www.energy.gov/energysaver/solar-swimming-pool-heaters
2. Solar Rating & Certification Corporation directory
   Available from: http://solar-rating.org/directories/certified-companies/
3. National Renewable Energy Laboratory, PVWatts Version 5 Manual, September 2014
   Available from: https://www.nrel.gov/docs/fy14osti/62641.pdf
4. NOAA National Centers for Environmental Information – NCEI 1981-2010 Climate Normals
   Available from: https://www.ncdc.noaa.gov/cdo-web/datatools/normals
5. NASA's Open Data Portal, Prediction of Worldwide Energy Resources (POWER)
   Available from: https://data.nasa.gov/Earth-Science/Prediction-Of-Worldwide-Energy-Resources-POWER-/wn3p-qsan
6. Savings Calculator for ENERGY STAR® Certified Inground Pool Pumps, April 2020
   Available from: https://www.energystar.gov/productfinder/product/certified-pool-pumps/results#
7. CEE℠ High Efficiency Residential Swimming Pool Initiative, Consortium for Energy Efficiency, January 2013
   Available from: https://library.cee1.org/system/files/library/9986/CEE_Res_SwimmingPoolInitiative_01Jan2013_Corrected.pdf
8. 10 CFR 430.32 Energy and water conservation standards and their compliance dates
   Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=840d2f09fea283237b0f345001c03a28&mc=true&node=pt10.3.430&rgn=div5#se10.3.430_132
9. 10 CFR Appendix B to Subpart Y of Part 431 – Uniform Test Method for the Measurement of Energy Efficiency of Dedicated-Purpose Pool Pumps
   Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=1e172a51fbd7c0fa1753866066133e14&mc=true&node=pt10.3.431&rgn=div5#ap10.3.431_1466.b

Record of Revision

Record of Revision Number	Issue Date
3-20-1	3/30/2020
7-21-11	8/30/2021

Return to Table of Contents

COMMERCIAL AND INDUSTRIAL MEASURES

AGRICULTURAL EQUIPMENT

HIGH SPEED FAN

Measure Description

This measure is applicable to the installation of high speed, high efficiency fans installed in agricultural applications. For the purposes of this measure, a high speed fan shall consist of the blade and motor assembly. Ventilation, exhaust and circulating high speed fans improve animal comfort, control moisture and maintain indoor air quality for livestock and other agricultural applications. Variable frequency drives (VFD) may be installed along with high speed fans to increase energy savings and the associated savings are quantified by this methodology. If VFD savings are claimed via this measure, additional savings may not be claimed for VFDs utilizing a separate methodology. Qualifying fans must be rated by an Air Movement and Control Association (AMCA) accredited laboratory such as Bioenvironmental and Structural Systems (BESS) Laboratories.[508] An alternative energy savings approach is provided for circulating fans when manufacturer ratings are in lbf/kW.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times \frac{\left[\left(\frac{CFM_{baseline}}{\left(\frac{CFM}{Watt}\right)_{baseline}}\right) - \left(\frac{CFM_{ee}}{\left(\frac{CFM}{Watt}\right)_{ee}} \times F_{VFD,ee}\right)\right]}{1{,}000} \times hrs$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \frac{\Delta kWh}{hrs} \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

where:

ΔkWh	= Annual electricity energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings

[508] BESS Laboratories is a research, product testing, and educational laboratory at the University of Illinois.

units = Number of fans installed under the program
baseline = Characteristic of baseline condition
ee = Characteristic of energy efficient condition
CFM = Air flow, measured in cubic feet per minute
CFM/watt = Ventilating efficiency ratio, rated at 0.01'' static pressure in cubic feet per minute per watt
F_{VFD} = Factor to account for reduced consumption resultant from VFD control
hrs = Annual hours of operation
CF = Coincidence Factor
1,000 = Conversion factor, one kW equals 1,000 Watts

Alternative Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings for Circulating Fans when Manufacturer Ratings are in lbf/kW

Annual Electric Energy Savings

$$\Delta kWh = units \times \left[\left(\frac{lbf_{baseline}}{\left(\frac{lbf}{kW}\right)_{baseline}}\right) - \left(\frac{lbf_{ee}}{\left(\frac{lbf}{kW}\right)_{ee}} \times F_{VFD,ee}\right)\right] \times hrs$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \frac{\Delta kWh}{hrs} \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

where:

ΔkWh = Annual electricity energy savings
ΔkW = Peak coincident demand electric savings
ΔMMBtu = Annual fossil fuel energy savings
units = Number of fans installed under the program
baseline = Characteristic of baseline condition
ee = Characteristic of energy efficient condition
lbf = Thrust, in pounds-force
lbf/kW = Thrust efficiency ratio, in pounds-force per kilowatt
F_{VFD} = Factor to account for reduced consumption resultant from VFD control
hrs = Annual hours of operation
CF = Coincidence Factor
1,000 = Conversion factor, one kW equals 1,000 watts

Summary of Variables and Data Sources

Variable	Value	Notes
$CFM_{baseline}$		From application, look up from BESS Labs database based on manufacturer and model number. If unknown, or for new installations, use CFM_{ee} as the default value.
CFM_{ee}		From application.
$(CFM/watt)_{baseline}$		From application, look up from BESS Labs database based on manufacturer and model number. If not tested by BESS Labs, look up from Baseline Efficiencies section below based on fan diameter.
$(CFM/watt)_{ee}$		From application, look up from BESS Labs database based on manufacturer and model number or as rated by other third-party accredited laboratory
$lbf_{baseline}$		From application, look up from BESS Labs database based on manufacturer and model number. If unknown, or for new installations, use lbf_{ee} as the default value.
lbf_{ee}		From application.
$(lbf/kW)_{baseline}$		From application, look up from BESS Labs database based on manufacturer and model number. If not tested by BESS Labs, look up from Baseline Efficiencies section below based on fan diameter.
$(lbf/kW)_{ee}$		From application, look up from BESS Labs database based on manufacturer and model number or as rated by other third-party accredited laboratory
$F_{VFD,ee}$	No VFD: 1.00 VFD (Greenhouse): 0.64 VFD (Poultry/Livestock): 0.75	Adjustment to efficient condition consumption to account for VFD control, based on presence of VFDs and fan application.[509]
hrs		From application. If unavailable, lookup in Operating Hours section below.
CF	1.0	

[509] Teitel, M. & Levi, Asher & Zhao, Yun & Barak, Moti & Bar-lev, Eli & Shmuel, David. (2008). Energy saving in agricultural buildings through fan motor control by variable frequency drives. Energy and Buildings. 40. 953-960. 10.1016/j.enbuild.2007.07.010.

Coincidence Factor (CF)

The prescribed coincidence factor for this measure is 1.0.[510]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition for this measure is a standard efficiency exhaust, ventilation or circulating fan. Baseline fan airflow (CFM) for exhaust and ventilation fans or thrust (lbf) for circulating fans and fan efficiency shall come from application. If unavailable, look up from the table below based on fan type and diameter.[511]

Fan Diameter	Circulating, Ventilation and Exhaust Fans (CFM/W)	Circulating Fans (lbf/kW)
24" – 35"	9.4	10.5
36" - 47"	12.2	12.9
48" - 52"	15.1	19.8
53"+	16.7	20.8

Compliance Efficiency from which Incentives are Calculated

The compliance condition for this measure is a high speed exhaust, ventilation or circulating fan that meets or exceeds the minimum efficiency requirements from the table below, based on fan type and diameter.[512]

Fan Diameter	Circulating, Ventilation and Exhaust Fans (CFM/W)	Circulating Fans (lbf/kW)
24" – 35"	14.0	15.0
36" - 47"	17.0	20.0
48" - 52"	19.9	24.2
53"+	22.0	24.6

Operating Hours

Fan operating hours shall come from application. If operating hours are unknown, the prescribed hours shall come from the lookup table below based on location. Default hours are developed from NOAA hourly normals by summing annual hours dry bulb temperature is above 50ºF.[513]

[510] It is assumed that fans will always be running during the peak hour.
[511] Default baseline efficiency was determined by calculating the 10th percentile of the efficiencies of all fans in the active BESS Labs database for the respective fan diameter ranges. Many low efficiency fans are often not tested by BESS Labs, therefore the average tested fan is more efficient than the average market available fan. Ventilation and exhaust fan CFM and circulating fan lbf represent the averages of each diameter range, regardless of fan efficiency. The database includes single and three phase fans at four voltages.
[512] Minimum qualifying fan efficiency is equivalent to the 75th percentile of all BESS Labs tested in the respective fan diameters. The database includes single and three phase fans at four voltages.
[513] NOAA National Centers for Environmental information – NCEI 2010 Hourly Normals

City	Circulating Fan Hours	Exhaust/Ventilation Fan Hours[514]
Albany	4,238	6,570
Binghamton	3,969	6,570
Buffalo	4,189	6,570
Massena*	4,156	6,570
NYC	5,162	6,570
Poughkeepsie**	4,722	6,570
Syracuse	4,179	6,570

*Massena hourly normals are approximated from Rochester airport data due to limited available data
** Poughkeepsie hourly normals are approximated from Long Island ISLIP airport data due to limited available data

Example Calculation *(Not to be used as default)*

A poultry farm near Poughkeepsie replaces two circulating fans rated at 2,500 CFM and 15 CFM/W with high speed fans rated at 2,000 CFM and 20 CFM/W equipped with VFD control. The fans run for 4,300 hours per year. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

$$\Delta kWh = units \times \frac{\left[\left(\frac{CFM_{baseline}}{\left(\frac{CFM}{Watt}\right)_{baseline}}\right) - \left(\frac{CFM_{ee}}{\left(\frac{CFM}{Watt}\right)_{ee}} \times F_{VFD,ee}\right)\right]}{1{,}000} \times hrs$$

$$\Delta kW = \frac{\Delta kWh}{hrs} \times CF$$

units = 2, from application
$CFM_{baseline}$ = 2,500 CFM, from application
$(CFM/Watt)_{baseline}$ = 15 CFM/W, from application
CFM_{ee} = 2,000 CFM, from application
$(CFM/Watt)_{ee}$ = 20 CFM/W, from application
$F_{VFD,ee}$ = 0.75, from Summary of Variables and Data sources table
CF = 1, from Summary of Variables and Data sources table
hrs = 4,300 hours, from application

$$\Delta kWh = 2 \times \frac{\left[\left(\frac{2{,}500}{15}\right) - \left(\frac{2{,}000}{20} \times 0.75\right)\right]}{1{,}000} \times 4{,}300 = 788\ kWh$$

$$\Delta kW = \frac{788}{4{,}300} \times 1 = 0.18\ kW$$

[514] Exhaust/Ventilation fans are assumed to operate 75% of total annual hours (8,760 x 0.75 = 6,570).

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. Teitel, M. & Levi, Asher & Zhao, Yun & Barak, Moti & Bar-lev, Eli & Shmuel, David. (2008). Energy saving in agricultural buildings through fan motor control by variable frequency drives. Energy and Buildings. 40. 953-960. 10.1016/j.enbuild.2007.07.010. Available from: https://www.researchgate.net/publication/223846494_Energy_saving_in_agricultural_buildings_through_fan_motor_control_by_variable_frequency_drives
2. Agricultural Ventilation Fans, Bioenvironmental and Structural Systems Laboratory, University of Illinois, Department of Agricultural and Biological Engineering, Accessed September 26, 2019
   Available from: http://www.bess.illinois.edu/current.asp
3. Circulating Fans, Bioenvironmental and Structural Systems Laboratory, University of Illinois, Department of Agricultural and Biological Engineering, Accessed September 26, 2019
   Available from: http://bess.illinois.edu/
4. NOAA National Centers for Environmental Information
   Available from: https://www.ncdc.noaa.gov/cdo-web/search?datasetid=NORMAL_HLY

Record of Revision

Record of Revision Number	Issue Date
3-20-3	3/30/2020
7-21-12	8/30/2021

Return to Table of Contents

MILK PRE-COOLER HEAT EXCHANGER

Measure Description

This measure addresses the potential refrigeration energy savings of adding a heat exchanger, i.e., a milk pre-cooler, ahead of the milk storage tank to decrease the cooling load. A pre-cooler can reduce the milk temperature from 100°F to within the 55 – 70°F range before it enters the bulk storage tank. The dairy farm site must have an adequate supply of water since milk plate coolers require up to twice the amount of water as compared to processed milk to be effective. Sites may use the warm water leaving the heat exchanger for other purposes such as either watering cows or wash-down. Due to the indirect benefits[515] associated with the warm water discharge from the plate coolers, and because it is typical for the water to be repurposed, the measure analysis assumes that there are no negative water impacts. Typically, the plate cooler discharge water is not redirected to the existing hot water heater. Hence, there are no interactive domestic hot water savings attributable to the installation of a milk pre-cooler heat exchanger.

Additional savings may be claimed with the installation of a variable speed drive (VSD) control on either a new or existing milk transfer pump. By reducing the speed of the milk transfer pump motor, a VSD control reduces the milk's flowrate through the pre-cooler increasing the amount of time the milk is in the heat exchanger. The reduced milk flowrate yields an increase in milk cooling through the heat exchanger further reducing the refrigeration load in the bulk storage tank. This results in more heat transfer between the warm milk and the cold ground water used in the plate heat exchanger pre-cooler. The primary electric energy savings are realized by the reduced load on the primary milk cooling system.

The measure's savings do not apply to systems where the source water for the milk pre-cooler heat exchanger is mechanically cooled.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = \frac{lbs_{milk} \times cows \times \Delta T \times 0.93}{EER \times 1{,}000}$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \frac{\left(\frac{lbs_{milk} \times cows \times \Delta T \times 0.93}{EER \times 1{,}000}\right)}{hrs} \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

[515] It is less stressful (metabolically) for cows to drink warmed water, and research has shown that cows will drink more water if it is warmer, leading to increased milk production. "Massachusetts Farm Energy Best Management Practices for Dairy Farms", United States Department of Agriculture (USDA), Natural Resource Conservation Service (NRCS), 2012.

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
lbs_{milk}	= Average pounds of milk produced per cow per year
cows	= Number of milking cows on farm
ΔT	= Change in milk temperature attributable to the pre-cooler
EER	= Energy efficiency ratio under peak conditions of existing compressor (BTU/watt-hour)
hrs	= Hours per year that raw milk is being cooled
0.93	= Specific heat of milk (Btu/lb·˚F)[516]
1,000	= Conversion factor, one kW equals 1,000 watts
CF	= Coincidence factor

Summary of Variables and Data Sources

Variable	Value	Notes
lbs_{milk}	23,888	Assumed value based on 2018 NYS Agricultural Statistics.[517]
cows		From application
ΔT		From application, if unknown use 30˚F as default.[518]. If a VSD is installed on an existing milk pre-cooler heat exchanger, use 11.7°F as default. If a VSD is installed on a new milk pre-cooler heat exchanger, use 41.7°F as default.[519]
EER		From application, if unknown use 8.0 as default [520]
hrs		From application, if unknown use 2,920 as default [521]
CF	0.4	

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.4.[522]

[516] Specific heat of whole milk, Table 3: Unfrozen Composition Data, Initial Freezing Point, and Specific Heat of Foods, 2014 ASHRAE Handbook - Refrigeration. Page 19.5.

[517] 2018 – 2019 Agricultural Statistics Annual Bulletin: New York, Milk Production, Disposition, and Income — New York: 2014-2018, pg. 19

[518] The efficacy of a milk plate cooler is sourced from Sanford, Scott (University of Wisconsin–Madison). "Energy Efficiency for Dairy Enterprises." Presentation to Agricultural and Life Sciences Program staff. December 2014. It was assumed that there is a 25°F of milk temperature difference for a single pass plate cooler and a 35°F of temperature difference for a double/multi-pass plate cooler. An average of 30°F between the two types was used.

[519] Sanford, Scott (University of Wisconsin–Madison). "Well Water Precoolers." Publication A37843. October 2003. It was determined that a plate cooler alone can reduce milk temperature to 68 ˚F and a plate cooler paired with a milk transfer pump VSD can reduce milk temperature to 56.3 ˚F. The additional benefits of the milk transfer pump VSD over the plate cooler is 11.7 ˚F.

[520] Average efficiency of an existing compressor on a dairy farm. Massachusetts Farm Energy: Best Management Practices for Dairy Farms, USDA NRCS, 2012 (page 19).

[521] Dairy Farm Energy Management Guide: California, Ludington, Johnson, Kowalski, & Mage, Southern California Edison, 2004. Assuming raw milk for pasturing must be cooled within 4 hours, 2 milking per day.

[522] Regional Technical Forum (RTF) as part of the Northwest Power & Conservation Council, Deemed Measures List. Agricultural: Variable Frequency Drives-Dairy, FY2012, V1.2.

Baseline Efficiencies from which Savings are Calculated

The baseline conditions assume that no previous pre-cooler heat exchanger was installed, and the entire milk cooling load is on the milk bulk tank.

Compliance Efficiency from which Incentives are Calculated

The measure entails installation of a heat exchanger to decrease the cooling requirement of the primary milk bulk tank refrigeration system. The heat exchanger fluid medium used for heat rejection is either well or ground water as this produces the largest temperature differential for energy savings. For water requirements, the water supply system must have capacity to keep up with the existing farm water demands and additional demands of the pre-cooler. To minimize the volume of water used for pre-cooling, a solenoid valve should be installed on the water supply line to the pre-cooler and be actuated only when the milk pump is in operation. A bypass line around the solenoid valve or a time delay relay can also be used to provide additional cooling of the residual milk in the pre-cooler between pumping cycles. A storage tank will be necessary for used cooling water storage until it is re-used for watering cows, cleanup or another purpose on the farm.

Operating Hours

Raw milk for pasteurizing must be cooled within four hours. Most dairies milk twice per day which equates to a total of 2,920 hours annually for raw milk cooling.

Example Calculation *(Not to be used as default)*

A milk pre-cooler is installed on an 80 cow dairy farm near Poughkeepsie. The heat exchanger will run for 3,000 hours per year to cool raw milk. The pre-cooler is estimated to reduce the milk temperature by 35°F. The approximate efficiency of the refrigeration compressor is 9.0 EER. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

$$\Delta kWh = \frac{lbs_{milk} \times cows \times \Delta T \times 0.93}{EER \times 1{,}000}$$

$$\Delta kW = \frac{\left(\frac{lbs_{milk} \times cows \times \Delta T \times 0.93}{EER \times 1{,}000}\right)}{hrs} \times CF$$

lbs_{milk} = 23,888, from Summary of Variables and Data Sources
Cows = 80, from application
ΔT = 35°F, from application
EER = 9.0, from application
hrs = 3000 hours, from application
CF = 0.4, from Summary of Variables and Data Sources

$$\Delta kWh = \frac{23{,}888 \times 80 \times 35 \times 0.93}{9.0 \times 1{,}000} = 6{,}911.6\ kWh$$

$$\Delta kW = \frac{\left(\frac{23{,}888 \times 80 \times 35 \times 0.93}{9.0 \times 1{,}000}\right)}{3{,}000} \times 0.4 = 0.921\ kW$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. "Massachusetts Farm Energy Best Management Practices for Dairy Farms", United States Department of Agriculture (USDA), Natural Resource Conservation Service (NRCS), 2012.
   Available from: https://massfarmenergy.com/wp-content/uploads/2014/03/Dairy%20Farms%20Best%20Practices.pdf
2. Sanford, Scott (University of Wisconsin–Madison). "Energy Efficiency for Dairy Enterprises." Presentation to Agricultural and Life Sciences Program staff. December 2014.
   Available from: https://aeeibse.wp.prod.es.cloud.vt.edu/wp-content/uploads/2018/01/EC-for-Dairy-Enterprises-Nov-2017.pdf
3. Unfrozen Composition Data, Initial Freezing Point, and Specific Heat of Foods, 2014 ASHRAE Handbook - Refrigeration. Page 19.5, Table 3.
4. USDA, National Agricultural Statistics Service, "2018 – 2019 Agricultural Statistics Annual Bulletin: New York", 2019
   Available from:
   https://www.nass.usda.gov/Statistics_by_State/New_York/Publications/Annual_Statistical_Bulletin/2019/2018-2019%20NY%20Annual%20Bulletin.pdf
5. Energy Conservation in Agriculture: Well Water Precoolers, A3784-03, Scott Sanford, University of Wisconsin Extension, 2003, page 6.
   Available from: https://cdn.shopify.com/s/files/1/0145/8808/4272/files/A3784-03.pdf
6. Dairy Farm Energy Management Guide: California, Ludington, Johnson, Kowalski, & Mage, Southern California Edison, 2004.
   Available from:
   http://www.energy.wsu.edu/EnergyLibrary/AgricultureMatters/CatalogItemDetail.aspx?id=429

Record of Revisions

Record of Revision Number	Issue Date
7-20-5	7/31/2020

Return to Table of Contents

REFRIGERATION HEAT RECOVERY – DAIRY FARMS

Measure Description

This measure covers the installation of a heat recovery system on bulk tank compressors on dairy farms. Heat recovery systems recover waste heat from bulk tank compressors used in milk cooling processes. This waste heat is used to pre-heat water before it is transferred to a water heater, thus reducing the load of the water heater. Hot water is used in various farm applications such as cleaning and livestock watering.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

There are two methods of calculating savings. One is to calculate the amount of energy that can be recovered by the heat recovery system in the milk cooling process. This method is reflected in the ΔBTU_{milk} equation. The second method is to calculate the energy required to heat the water in the storage tank to 120°F.[523] This method is reflected in the $\Delta BTU_{hru,}$ equation. The smaller of the two shall be selected. If ΔBTU_{milk} is smaller than $\Delta BTU_{hru,}$ this implies that the energy recovered by the heat recovery system is not sufficient to fully heat the water to 120°F, and therefore represents the upper limit of savings. If ΔBTU_{hru} is smaller than ΔBTU_{milk} this implies the energy required to heat the water to 120°F is less than the energy that is recovered by the heat recovery system, and therefore represents the upper limit of savings.

Annual Electric Energy Savings (Electric Water Heating Equipment Only)

$$\Delta kWh = \frac{MIN[\Delta BTU_{milk}, \Delta BTU_{hru}]}{3{,}412 \times E_{t,elec}}$$

Summer Peak Coincident Demand Savings (Electric Water Heating Equipment Only)

$$\Delta kW = \frac{\Delta kWh}{hrs} \times CF$$

Annual Fossil Fuel Energy Savings (Fossil Fuel Water Heating Equipment Only)

$$\Delta MMBtu = \frac{MIN[\Delta BTU_{milk}, \Delta BTU_{hru}]}{1{,}000{,}000 \times E_{t,fuel}}$$

where:

$$\Delta BTU_{milk} = lbs_{milk} \times cows \times \Delta T_{milk} \times 0.93 \times ESF$$

$$\Delta BTU_{hru} = v_{hru} \times \Delta T_{water} \times 8.33 \times 365 \times cows$$

where:

ΔkWh = Annual electricity energy savings
ΔkW = Peak coincident demand electric savings

[523] DeLaval. "Dairy Farm Energy Efficiency". A heat recovery system is capable of heating water up to 120°F.

$\Delta MMBtu$ = Annual fossil fuel energy savings
ΔBTU_{milk} = Energy that is recoverable from the milk cooling process, in BTU
ΔBTU_{hru} = Energy required to heat water in the storage tank unit to 120°F, in BTU
lbs_{milk} = Average pounds of milk produced per cow per year
cows = Number of milking cows on farm
ΔT_{milk} = Difference in temperature between the milk entering the bulk tank and final stored temperature of cooled milk (°F)
ESF = Energy savings factor
ΔT_{water} = Change in water temperature attributable to heat recovery system (°F)
v_{hru} = Volume of hot water for washing and cleaning per day per cow, in gallons
E_t = Water heater thermal efficiency
hrs = Operating hours per year
CF = Coincidence factor
0.93 = Specific heat of milk (BTU/lb-°F)[524]
8.33 = Energy required (BTU's), to heat one gallon of water by one degree Fahrenheit
3,412 = Conversion factor, one kWh equals 3,412 BTU
1,000,000 = Conversion factor, one MMBtu equals 1,000,000 BTU
365 = Days in one year

Summary of Variables and Data Sources

Variable	Value	Notes
lbs_{milk}	23,888	Assumed value based on 2018 NYS Agricultural Statistics.[525]
cows		From application.
ΔT_{milk}	No Pre-Cooler: 60 Standard Pre-Cooler: 30 Variable Speed Pre-Cooler: 18.3	Sanford, Scott (University of Wisconsin–Madison). "Well Water Precoolers." [526]
ESF	0.4	Assumed value based on midpoint of range identified in reference literature.[527]

[524] 2018 ASHRAE Handbook – Refrigeration, Specific heat of whole milk, Table 3: Unfrozen Composition Data, Initial Freezing Point, and Specific Heat of Foods
[525] 2018 – 2019 Agricultural Statistics Annual Bulletin: New York, Milk Production, Disposition, and Income — New York: 2014-2018, pg. 19
[526] Sanford, Scott (University of Wisconsin–Madison). "Well Water Precoolers." Publication A37843. October 2003. It was determined that a plate cooler alone can reduce milk temperature to 68 ˚F and a plate cooler paired with a milk transfer pump VSD can reduce milk temperature to 56.3 ˚F. The additional benefits of the milk transfer pump VSD over the plate cooler is 11.7 ˚F. Milk is stored at 38°F, therefore 56.3°F-38°F=18.3°F.
[527] DeLaval. "Dairy Farm Energy Efficiency". A heat recovery system can recover 20%-60% of the energy required in the milk cooling process.

Variable	Value	Notes
ΔT_{water}	T_{set} - T_{main}	Lookup T_{main} value based on location in Cold Water Inlet Temperature table below. For a fully condensing RHR system, T_{set} =120°F. For a desuperheater RHR condenser a T_{set} of 95°F to 115°F should be selected.[528]
V_{hru}		From application. If unknown use 6.3 gallons/cow/day.[529]
milkings		From application or use 2 as default value.[530]
$E_{t,elec}$	0.98	Thermal efficiency of electric water heater.[531]
$E_{t,fuel}$	0.80	Thermal efficiency of fossil fuel water heater.[532]
hrs		From application, if unknown use 2,920 as default [533]
CF	0.8	

Cold Water Inlet Temperature (T_{main})

Supply water main temperatures vary according to climate, and are approximately equal to the annual average outdoor temperature plus 6°F.[534] Supply main temperatures based on the annual outdoor temperature are shown below.

City	Annual average outdoor temperature[535] (°F)	T_{main} (°F)
Albany	48.3	54.3
Binghamton	46.3	52.3
Buffalo	48.3	54.3
Massena	43.5	49.5
NYC	55.4	61.4
Poughkeepsie	49.8	55.8
Syracuse	48.3	54.3

[528] DeLaval. "Dairy Farm Energy Efficiency." April 20, 2011
[529] Michigan State University "Water use on dairy farms"
[530] According to USDA's "Milk Cost-of-Production Estimates-2016 Base", only 6.61% of cows are milked more than twice a day in New York state. Therefore, it is assumed that cows are milked twice per day.
[531] Per 10 CFR 430 Subpart B Appendix E – Uniform Test Method for Measuring the Energy Consumption of Water Heaters: *6.3.2 Recovery Efficiency*
[532] Per 10 CFR 431.110 (a)
[533] Dairy Farm Energy Management Guide: California, Ludington, Johnson, Kowalski, & Mage, Southern California Edison, 2004. Assuming raw milk for pasturing must be cooled within 4 hours, 2 milking per day.
[534] Burch, Jay and Christensen, Craig, "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory
[535] Average annual outdoor temperatures taken from NCEI 1981-2010 climate normals

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.8.[536]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition for this measure is a dairy farm without a heat recovery system.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a dairy farm with a heat recovery system

Operating Hours

Raw milk for pasteurizing must be cooled within four hours. Most dairies milk twice per day which equates to a total of 2,920 hours annually for raw milk cooling. The heat recovery system operates during the cooling process; therefore, the operating hours are assumed to be the same for the purposes of estimating peak demand savings.

Example Calculation *(Not to be used as default)*

A refrigeration heat recovery system is installed on an 80 cow dairy farm with electric water heating near Syracuse. The Refrigeration Heat Recovery (RHR) system aims to recover heat in the milk cooling process and would operate during the milk cooling process for 3,000 hours per year. The system includes a standard pre-cooler. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

$$\Delta kWh = \frac{MIN[\Delta BTU_{milk}, \Delta BTU_{hru}]}{3{,}412 \times E_{t,elec}}$$

$$\Delta kW = \frac{\Delta kWh}{hrs} \times CF$$

where:

$$\Delta BTU_{milk} = lbs_{milk} \times cows \times \Delta T_{milk} \times 0.93 \times ESF$$

$$\Delta BTU_{hru} = v_{hru} \times \Delta T_{water} \times 8.33 \times 365 \times cows$$

lbs_{milk} = 23,888 lbs, from Summary of Variables and Data Sources
ESF = 0.4, from Summary of Variables and Data Sources
ΔT_{milk} = 30, from Summary of Variables and Data Sources
cows = 80, from application
v_{hru} = 6.3 gallons/cow/day, default from Summary of Variables and Data Sources
$T_{water} = T_{set} - T_{main} = 120 - 54.3 = 65.7$
T_{set} = 120F, from Summary of Variables and Data Sources

[536] *No source specified – update pending availability and review of applicable references.*

T_{main} = 54.3, from Cold Water Inlet Temperature table based on City
hrs = 3,000, from application
$E_{t,elec}$ = 0.98, from Summary of Variables and Data Sources
CF = 0.8, from Summary of variables and Data Sources

$$\Delta BTU_{milk} = 23{,}888 \times 80 \times 30 \times 0.93 \times 0.4 = 21{,}327{,}206.4$$

$$\Delta BTU_{hru} = 6.3 \times 65.7 \times 8.33 \times 365 \times 80 = 110{,}677{,}812.76$$

As per the measure direction, the smaller of the ΔBTU_{milk} and ΔBTU_{hru} would be selected.

$$\Delta kWh = \frac{21{,}327{,}206.4}{3{,}412 \times 0.98} = 6{,}378.21\ kWh$$

$$\Delta kW = \frac{6{,}378.21}{3{,}000} \times 0.8 = 1.7\ kW$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. DeLaval. "Dairy Farm Energy Efficiency." April 20, 2011.
   Available from: http://www.milkproduction.com/Library/Scientific-articles/Management/Dairy-farm-energy-efficiency/2018 ASHRAE Handbook - Refrigeration
2. USDA, National Agricultural Statistics Service, "2018 – 2019 Agricultural Statistics Annual Bulletin: New York", 2019
   Available from:
   https://www.nass.usda.gov/Statistics_by_State/New_York/Publications/Annual_Statistical_Bulletin/2019/2018-2019%20NY%20Annual%20Bulletin.pdf

3. Sanford, Scott (University of Wisconsin–Madison). "Energy Efficiency for Dairy

Enterprises." Presentation to Agricultural and Life Sciences Program staff. December 2014.
Available from: https://aeeibse.wp.prod.es.cloud.vt.edu/wp-content/uploads/2018/01/EC-for-Dairy-Enterprises-Nov-2017.pdf

4. U.S. Department of Agriculture Economic Research Service. "Milk Cost of Production Estimates."
Available from: https://www.ers.usda.gov/data-products/milk-cost-of-production-estimates.aspx
5. Michigan State University "Water Use on Dairy Farms"
Available from:
https://www.canr.msu.edu/news/water_use_on_dairy_farms#:~:text=There%20were%20854%2D1005%20total,gallons%20per%20cow%20per%20day.
6. 10 CFR 430 Subpart B – Test Procedures, Appendix E – Uniform Test Method for Measuring the Energy Consumption of Water Heaters
Available from: https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=9624a8ba0987aaae248454c49194a661&mc=true&n=pt10.3.430&r=PART&ty=HTML#ap10.3.430_127.e
7. 10 CFR 431.110 Energy conservation standards and their effective dates
Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=64f994924a5f31b841cab23a6d543f85&mc=true&node=pt10.3.431&rgn=div5#se10.3.431_1110
8. Dairy Farm Energy Management Guide: California, Ludington, Johnson, Kowalski, & Mage, Southern California Edison, 2004.
Available from:
http://www.energy.wsu.edu/EnergyLibrary/AgricultureMatters/CatalogItemDetail.aspx?id=429
9. Burch, Jay and Christensen, Craig, "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory
Available from:
http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.515.6885&rep=rep1&type=pdf
10. NOAA National Centers for Environmental Information – NCDC 1981-2010 Climate Normals
Available from: https://www.ncdc.noaa.gov/cdo-web/datatools/normals

Record of Revision

Record of Revision Number	Issue Date
7-20-6	7/31/2020

Return to Table of Contents

SCROLL COMPRESSOR – DAIRY FARMS

Measure Description

This measure covers the replacement of reciprocating compressors with scroll compressors in milk cooling dairy farm applications. A scroll compressor is a device used to compress refrigerant and is more efficient and reliable than traditional reciprocating compressors. Scroll compressors are now the predominant compressor type sold on the market in these applications; therefore, this measure is only applicable in retrofit scenarios.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = \frac{BTU/h_{ee}}{BTU/h_{total}} \times lbs_{milk} \times cows \times \Delta T \times 0.93 \times \left[\left(\frac{1}{EER_{baseline} \times 1{,}000}\right) - \left(\frac{1}{EER_{ee} \times 1{,}000}\right)\right]$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \frac{\Delta kWh}{8{,}760} \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

where:

$$EER_{ee} = \frac{BTU/h_{ee}}{W_{ee}}$$

$$EER_{baseline} = \frac{BTU/h_{baseline}}{W_{baseline}}$$

where:

ΔkWh	= Annual electricity energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
BTU/h_{total}	= Total cooling capacity of compressors on dairy farm
lbs_{milk}	= Average pounds of milk produced per cow per year
cows	= Number of milking cows on farm
ΔT	= Difference in temperature between the milk entering the bulk tank and final stored temperature of cooled milk (°F)
$EER_{baseline}$	= Energy efficiency ratio of reciprocating compressor based on nameplate BTU/h and wattage

EER_{ee} = Energy efficiency ratio of scroll compressor based on nameplate BTU/h and wattage
$BTU/h_{baseline}$ = Nameplate BTU/h of existing reciprocating compressor
BTU/h_{ee} = Nameplate BTU/h of installed scroll compressor
$W_{baseline}$ = Nameplate wattage of existing reciprocating compressor
W_{ee} = Nameplate wattage of installed scroll compressor
CF = Coincidence factor
0.93 = Specific heat of milk (BTU/lb-°F)[537]
1,000 = Conversion factor, one kW equals 1,000 watts
8,760 = Hours in one year

Summary of Variables and Data Sources

Variable	Value	Notes
BTU/h_{ee}		From application
BTU/h_{total}		From application
lbs_{milk}	23,888	Assumed value based on 2018 NYS Agricultural Statistics.[538]
cows		From application
ΔT	No Pre-Cooler: 60 Standard Pre-Cooler: 30 Variable Speed Pre-Cooler: 18.3	Sanford, Scott (University of Wisconsin–Madison). "Well Water Precoolers." [539]
$W_{baseline}$		From application
W_{ee}		From application
EER_{ee}		From application, calculate based on equation above.[540]
$EER_{baseline}$		From application, calculate based on equation above. If unknown, assume $EER_{baseline} = 0.85 \times EER_{ee}$.[541]
CF	1.0	

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 1.0.[542]

[537] 2018 ASHRAE Handbook – Refrigeration, Specific heat of whole milk, Table 3: Unfrozen Composition Data, Initial Freezing Point, and Specific Heat of Foods
[538] 2018 – 2019 Agricultural Statistics Annual Bulletin: New York, Milk Production, Disposition, and Income — New York: 2014-2018, pg. 19
[539] Sanford, Scott (University of Wisconsin–Madison). "Well Water Precoolers." Publication A37843. October 2003. It was determined that a plate cooler alone can reduce milk temperature to 68 ˚F and a plate cooler paired with a milk transfer pump VSD can reduce milk temperature to 56.3 ˚F. The additional benefits of the milk transfer pump VSD over the plate cooler is 11.7 ˚F. Milk is stored at 38°F, therefore 56.3°F-38°F=18.3°F.
[540] Equation given by Massachusetts Farm Energy: Best Management Practices for Dairy Farms, USDA NRCS, 2012
[541] Massachusetts Farm Energy: Best Management Practices for Dairy Farms, USDA NRCS, 2012 (page 31). It is assumed that scroll compressors are 15% more efficient than reciprocating compressors.
[542] *No source specified – update pending availability and review of applicable references.*

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition for this measure is a dairy operation using a reciprocating compressor for milk cooling.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is the replacement of a reciprocating compressor with a scroll compressor for milk cooling.

Operating Hours

Hours of operation are embedded in other assumptions used in this methodology. Assumed hours of operation for derivation of kW savings are 8,760 to provide a conservative estimate of peak demand impacts.

Example Calculation *(Not to be used as default)*

A reciprocating compressor with 24,000 BTU/h capacity and full load wattage of 3,500 W is replaced with a scroll compressor with 22,000 BTU/h capacity and full load wattage of 2,075 W on an 80 cow dairy farm near Syracuse. The system is equipped with a standard pre-cooler. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

$$\Delta kWh = \frac{BTU/h_{ee}}{BTU/h_{total}} \times lbs_{milk} \times cows \times \Delta T \times 0.93 \times \left[\left(\frac{1}{EER_{baseline} \times 1{,}000}\right) - \left(\frac{1}{EER_{ee} \times 1{,}000}\right)\right]$$

$$\Delta kW = \frac{\Delta kWh}{8{,}760} \times CF$$

where:

$$EER_{ee} = \frac{BTU/h_{ee}}{W_{ee}}$$

$$EER_{baseline} = \frac{BTU/h_{baseline}}{W_{baseline}}$$

lbs_{milk} = 23,888 lbs, from Summary of Variables and Data Sources
cows = 80, from application
ΔT = 30, from Summary of Variables and Data sources table based on standard pre-cooler
BTU/h_{ee} = 22,000 BTU/h, from application
$BTU/h_{baseline}$ = 24,000 BTU/h, from application
BTU/h_{total} = 22,000 BTU/h, from application

$W_{baseline}$ = 3,500 watts, from application
W_{ee} = 2,075 watts, from application
CF = 1, from Summary of Variables and Data sources table

$$EER_{ee} = \frac{22{,}000}{2{,}075} = 10.6$$

$$EER_{baseline} = \frac{24{,}000}{3{,}500} = 6.9$$

$$\Delta kWh = \frac{22{,}000}{22{,}000} \times 23{,}888 \times 80 \times 30 \times 0.93 \times \left[\left(\frac{1}{6.9 \times 1{,}000}\right) - \left(\frac{1}{10.6 \times 1{,}000}\right)\right] = 2{,}697\ kWh$$

$$\Delta kW = \frac{2{,}697}{8{,}760} \times 1 = 0.31\ kW$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. 2018 ASHRAE Handbook - Refrigeration
2. USDA, National Agricultural Statistics Service, "2018 – 2019 Agricultural Statistics Annual Bulletin: New York", 2019
   Available from:
   https://www.nass.usda.gov/Statistics_by_State/New_York/Publications/Annual_Statistical_Bulletin/2019/2018-2019%20NY%20Annual%20Bulletin.pdf
3. Sanford, Scott (University of Wisconsin–Madison). "Energy Efficiency for Dairy Enterprises." Presentation to Agricultural and Life Sciences Program staff. December 2014.
   Available from: https://aeeibse.wp.prod.es.cloud.vt.edu/wp-content/uploads/2018/01/EC-for-Dairy-Enterprises-Nov-2017.pdf

4. "Massachusetts Farm Energy Best Management Practices for Dairy Farms", United States Department of Agriculture (USDA), Natural Resource Conservation Service (NRCS), 2012.
Available from: https://massfarmenergy.com/wp-content/uploads/2014/03/Dairy%20Farms%20Best%20Practices.pdf

Record of Revision

Record of Revision Number	Issue Date
7-20-7	7/31/2020

Return to Table of Contents

AGRICULTURAL EQUIPMENT – CONTROL

ENGINE BLOCK HEATER TIMER

Measure Description

This measure covers the installation of timers used to control engine block heaters on existing farm equipment engines such as tractors, skid steers, trucks, and generators. Engine block heaters are used to warm an engine prior to use and are generally used during cold weather. For convenience, engine block heaters without automation are typically left running longer than necessary. Timers limit energy consumption by pre-warming equipment only as required.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times \frac{W_{heater}}{1{,}000} \times (hrs_{baseline} - hrs_{ee}) \times days$$

Summer Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of engine block heaters connected to timers under the program
W_{heater}	= Wattage of engine block heater under control
baseline	= Characteristic of baseline condition
ee	= Characteristic of energy efficient condition
hrs	= Hours of use per day
days	= Days of use per year
1,000	= Conversion factor, one kW equals 1,000 watts

Summary of Variables and Data Sources

Variable	Value	Notes
W_{heater}		From application, if unknown use a default value of 1,000 W.[543]
$hrs_{baseline}$		From application, if unknown use a default value of 10 hrs.[544]

[543] 2018 FFA to Farm Engine Block Heater Timer Fundraiser Fact Sheet
[544] Ibid.

Variable	Value	Notes
hrs_{ee}		From application, if unknown use a default value of 2 hrs.[545]
days		From application, if unknown use a default value of 90 days.[546]

Coincidence Factor (CF)

The prescribed value for the coincidence factor is N/A.

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is an engine block heater without a timer that is manually controlled.

Compliance Efficiency from which Incentives are Calculated

The energy efficient condition is an engine block heater controlled by a timer.

Operating Hours

Timer on hours are set by the customer. If timer set hours are unknown, assume 2 hours per day. If days of use per year are unknown, assume 90.

Example Calculation *(Not to be used as default)*

A 1,100 W tractor engine block heater is equipped with timer control on a farm near Syracuse to limit energy consumption during pre-warming by reducing daily run hours from 11 to 2.25. The heater operates 92 days per year. Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings are calculated as below.

$$\Delta kWh = units \times \frac{W_{heater}}{1{,}000} \times (hrs_{baseline} - hrs_{ee}) \times days$$

units= 1, from application
W_{heater} = 1,100 W, from application
$hrs_{baseline}$ = 11 hours, from application
hrs_{ee} = 2.25 hours, from application
days = 92 days, from application

$$\Delta kWh = 1 \times \frac{1{,}100}{1{,}000} \times (11 - 2.25) \times 92 = 885.5\ kWh$$

[545] Ibid.
[546] Energy Efficiency in New York State Agriculture: Summary of Energy Efficiency Programs and Research Opportunities, NYSERDA, C-4

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. 2018 FFA to Farm Engine Block Heater Timer Fundraiser Fact Sheet, Focus on Energy
   Available from: https://focusonenergy.com/sites/default/files/inline-files/EBHT_Flyer_030418_1.pdf
2. Energy Efficiency in New York State Agriculture: Summary of Energy Efficiency Programs and Research Opportunities, NYSERDA
   Available from: https://www.nyserda.ny.gov/-/media/Files/Publications/Research/Other-Technical-Reports/energy-efficiency-in-new-york-state-agriculture.pdf

Record of Revisions

Record of Revision Number	Issue Date
7-13-28	7/31/2013
9-18-7	9/28/2018

Return to Table of Contents

VARIABLE SPEED DRIVE VACUUM PUMP – DAIRY FARMS

Measure Description

Milking vacuum systems consume large amounts of electricity on dairy farms. A conventional system runs a vacuum pump motor at full speed and a mechanical vacuum regulator creates an intentional air leak or "bleed" to regulate the system pressure regardless of the amount of milk being pumped. When the system requires a higher level of vacuum, the regulator closes and the vacuum level increases.[547]

This measure modifies the milking vacuum system and installs a variable speed drive (VSD) to control the vacuum pump motor. The VSD controls the speed of the vacuum pump motor, slowing it down when the milking units are attached to the udders, reducing electrical power demand and saving electricity usage. A milking vacuum system controlled with a VSD consists of three main parts: a three-phase electric motor, a VSD unit, and a differential pressure transducer. The VSD modulates the vacuum pump motor speed based on the control signal from the differential pressure transducer. The baseline for this measure reflects a standard vacuum pump motor operating at constant speed. If the motor is being replaced as part of this measure, the "New Motor" efficiency in the Standard Motor Efficiency table below shall be used. Otherwise, the "Existing Motor" efficiency shall be used.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = \left[\left(\frac{hp \times LF \times 0.746}{Eff}\right) - (0.05 \times 2 \times MU + 1.7729)\right] \times hrs$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \left[\left(\frac{hp \times LF \times 0.746}{Eff}\right) - (0.05 \times 2 \times MU + 1.7729)\right] \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
hp	= Rated horsepower of vacuum pump motor
LF	= Average load factor for a constant speed vacuum pump
0.746	= Conversion factor (kW/hp), 746 watts equals one electric horsepower

[547] Evaluation, Measurement and Verification Report, California Multi Measure Farm Program 1354-04 and 1360-04, prepared for the California Public Utilities Commission and EnSave, Inc., by kW Engineering, CALMAC ID: ENS0002.01, March 15, 2007, pages 3 -4.

Eff	= Rated pump motor efficiency
0.05	= Regression coefficient for the average speed of a VSD and processed milk units[548]
2	= Air flow rate of milking unit (CFM)[549]
1.7729	= Regression constant for the average speed of a VSD and processed milk units[550]
MU	= Number of milk extraction units equipped with a vacuum pump processed per day
hrs	= Annual hours of pump operation

Summary of Variables and Data Sources

Variable	Value	Notes
hp		From application.
LF		From application, if unknown use 0.75 as default value.
Eff		From application, if unknown use default values listed in Standard Motor Efficiency table below.
MU		From application, if unknown use 32 as default value.[551]
hrs		From application, if unknown use 1,232 as default value based on USDA data. [552]
CF	0.4	

Standard Motor Efficiency

Motor Classification	Size (hp)	Existing Motor[553]	New Motor[554]
Milk: Vacuum Pump with Adjustable Speed Drive Package – 7.5 HP	7.5	89.5%	91.7%
Milk: Vacuum Pump with Adjustable Speed Drive Package – 10 HP	10	89.5%	91.7%
Milk: Vacuum Pump with Adjustable Speed Drive Package – 15 HP	15	91.0%	92.4%
Milk: Vacuum Pump with Adjustable Speed Drive Package – 30 HP	30	92.4%	93.6%

[548] Sanford, Scott (University of Wisconsin–Madison). "Milking System Air Consumption When Using a Variable Speed Vacuum Pump", Figure 2. The regression coefficient of 0.0018 LPM is converted into 0.05 CFM.
[549] Ibid. An air leakage rate of 2 CFM is chosen as a conservative estimate for which to perform regression analysis.
[550] Ibid
[551] "Milking System Air Consumption When Using a Variable Speed Vacuum Pump", ASAE 033014, July 2003
[552] The default value for the average number of milking cows per farm is sourced from the 2017 U.S. Census of Agriculture, New York State Summary Highlights, Full Report, Volume 1, Chapter 2, U.S. State Level. Average number of cows per farm = 628,245 cows / 4,648 farms. Assuming 5 hours per cow in a stall daily, 16 stalls per farm, and 2 milking sessions per day for each cow.
[553] The Energy Independence and Security Act of 2007 (EISA), 1800 RPM, TEFC assumed as typical for Dairy vacuum pump motors, see https://www.baldor.com/catalog#category=84, as an example
[554] US Department of Energy, Office of Energy Efficiency & Renewable Energy, "Premium Efficiency Motor Selection and Application Guide: A Handbook for Industry". Table 2-1. 1800 RPM, TEFC assumed as typical for Dairy vacuum pump motors, see https://www.baldor.com/catalog#category=84, as an example

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.4.[555]

Baseline Efficiencies from which Savings are Calculated

The baseline condition is a constant speed dairy vacuum pump that is controlled with a mechanical vacuum regulator.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a dairy vacuum pump with a variable speed drive installed.

Operating Hours

Milking typically occurs twice per day for each cow, which can take up to 5 hours each. Assuming 16 stalls and the average number of cows per farm in the state on New York based on USDA 2017 census data, operation is 1,232 hours annually.

Example Calculation *(Not to be used as default)*

A 10 hp variable speed vacuum pump with a 0.75 load factor and rated efficiency of 93% is installed on a dairy farm near Albany. The pump operates for 1,300 hours annually. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

$$\Delta kWh = \left[\left(\frac{hp \times LF \times 0.746}{Eff}\right) - (0.05 \times 2 \times MU + 1.7729)\right] \times hrs$$

$$\Delta kW = \left[\left(\frac{hp \times LF \times 0.746}{Eff}\right) - (0.05 \times 2 \times MU + 1.7729)\right] \times CF$$

hp = 10 hp, from application
LF = 0.75, from application
Eff = 93% , from Standard Motor Efficiency table
MU = 32, default from Summary of Variables and Data Sources
hrs = 1,300 hours, from application
CF = 0.4, from Summary of Variables and Data Sources table

$$\Delta kWh = \left[\left(\frac{10 \times 0.75 \times 0.746}{0.93}\right) - (0.05 \times 2 \times 32 + 1.7729)\right] \times 1{,}300 = 1{,}356\ kWh$$

$$\Delta kW = \left[\left(\frac{10 \times 0.75 \times 0.746}{0.93}\right) - (0.05 \times 2 \times 32 + 1.7729)\right] \times 0.4 = 0.42\ kW$$

[555] Regional Technical Forum (RTF) as part of the Northwest Power & Conservation Council, Deemed Measures List. Agricultural: Variable Frequency Drives-Dairy, FY2012, V1.2.

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. Sanford, Scott (University of Wisconsin–Madison). "Milking System Air Consumption When Using a Variable Speed Vacuum Pump." Paper presented at the ASAE Annual International Meeting, Las Vegas, Nevada, July 27–30, 2003.
   Available from: https://milkquality.webhosting.cals.wisc.edu/wp-content/uploads/sites/212/2011/10/milking-system-air-consumption-variable-speed.pdf
2. 2017 U.S. Census of Agriculture, New York State Summary Highlights, Full Report, Volume 1, Chapter 2, U.S. State Level.
   Available from:
   https://www.nass.usda.gov/Publications/AgCensus/2017/Full_Report/Volume_1,_Chapter_1_State_Level/New_York/
3. The Energy Independence and Security Act of 2007 (EISA)
   Available from: https://www.govinfo.gov/content/pkg/PLAW-110publ140/pdf/PLAW-110publ140.pdf
4. US Department of Energy, Office of Energy Efficiency & Renewable Energy, "Premium Efficiency Motor Selection and Application Guide: A Handbook for Industry"
   Available from:
   https://www.energy.gov/sites/prod/files/2014/04/f15/amo_motors_handbook_web.pdf
5. List of Deactivated UES Measures from the Regional Technical Forum (RTF) as part of the Northwest Power & Conservation Council, Deemed Measures List. Agricultural: Variable Frequency Drives-Dairy, FY2012, V1.2.
   Available from: https://rtf.nwcouncil.org/deactivated-measures

Record of Revisions

Record of Revision Number	Issue Date
7-20-8	7/31/2020

Return to Table of Contents

APPLIANCE

CLOTHES DRYER

Measure Description

This measure covers residential grade clothes dryers meeting the criteria established under the ENERGY STAR® Program, Version 1.1, effective May 5, 2017 installed in small commercial settings.[556] ENERGY STAR® clothes dryers have a higher combined energy factor (CEF), and save energy through a combination of more efficient drying and reduced runtime of the drying cycle. More efficient drying is achieved through increased insulation, modifying operating conditions, improving air circulation, and improved efficiency of motors. Reduced dryer runtime is achieved through automatic termination of the dryer cycles based on temperature and moisture sensors. Clothes dryers originally qualified for the ENERGY STAR® label in May 2014. Clothes dryers that have earned this label are approximately 20% more efficient than non-qualified models.[557]

The algorithms, inputs, and savings presented below assume a normal replacement scenario.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times Cycles_{annual} \times Load \times \left(\frac{F_{elec,baseline}}{CEF_{baseline}} - \frac{F_{elec,ee}}{CEF_{ee}}\right)$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \frac{\Delta kWh}{hrs} \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = units \times Cycles_{annual} \times Load \times \left(\frac{F_{fuel,baseline}}{CEF_{baseline}} - \frac{F_{fuel,ee}}{CEF_{ee}}\right) \times \frac{3{,}412}{1{,}000{,}000}$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
$Cycles_{annual}$	= Number of dryer cycles per year
Load	= Average total weight (lbs) of clothes per drying cycle

[556] ENERGY STAR® Program Requirements Product Specification for Clothes Dryers, Eligibility Criteria Version 1.1, May 2017

[557] Efficiency of ENERGY STAR® products: https://www.energystar.gov/products/appliances/clothes_dryers

baseline	= Characteristic of baseline condition
ee	= Characteristic ofeenergy efficient condition
F_{elec}	= Percentage of energy consumed that is derived from electricity
F_{fuel}	= Percentage of energy consumed that is derived from fossil fuel
CEF	= Combined energy factor (lb/kWh)
hrs	= Annual run hours of clothes dryer
CF	= Coincidence Factor
3,412	= Conversion factor, one kWh equals 3,412 BTU
1,000,000	= Conversion factor, one MMBtu equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
$Cycles_{annual}$		From application, or lookup based on efficient dryer type in table below.[558]
Load		Lookup based on efficient dryer type in table below.[559]
$F_{elec,baseline}$		Lookup based on efficient dryer type in table below.[560]
$F_{elec,ee}$		Lookup based on efficient dryer type in table below.[561]
$F_{fuel,baseline}$		Lookup based on efficient dryer type in table below.[562]
$F_{fuel,ee}$		Lookup based on efficient dryer type in table below.[563]
$CEF_{baseline}$		Lookup based on efficient dryer type in table below.[564]
CEF_{ee}		Lookup based on efficient dryer type in table below.[565]
hrs		From application, or lookup based on efficient dryer type in table below.[566]
CF	0.042	

Key Variables Lookup Table

Variable	Dryer Type				
	Vented Gas Dryer	*Ventless or Vented Electric, Standard ≥ 4.4 ft^3*	*Ventless or Vented Electric, Compact (120V) < 4.4 ft^3*	*Vented Electric, Compact (240V) < 4.4 ft^3*	*Ventless Electric, Compact (240V) < 4.4 ft^3*
$Cycles_{annual}$	283	283	283	283	283
Load	8.45	8.45	3.00	3.00	3.00
$F_{elec,baseline}$	0.05	1.00	1.00	1.00	1.00

558 Savings calculator for ENERGY STAR® Qualified Appliances (accessed 10/18/2017)
559 Ibid.
560 ENERGY STAR® Program Requirements Product Specification for Clothes Dryers, Eligibility Criteria Version 1.1, May 2017
561 Ibid.
562 Ibid.
563 Ibid.
564 10 CFR 430.32 (h)(3)
565 ENERGY STAR® Program Requirements Product Specification for Clothes Dryers, Eligibility Criteria Version 1.1, May 2017
566 Savings calculator for ENERGY STAR® Qualified Appliances (accessed 10/18/2017)

Variable	Dryer Type				
	Vented Gas Dryer	*Ventless or Vented Electric, Standard ≥ 4.4 ft^3*	*Ventless or Vented Electric, Compact (120V) < 4.4 ft^3*	*Vented Electric, Compact (240V) < 4.4 ft^3*	*Ventless Electric, Compact (240V) < 4.4 ft^3*
$F_{elec,ee}$	0.05	1.00	1.00	1.00	1.00
$F_{fuel,baseline}$	0.95	0.00	0.00	0.00	0.00
$F_{fuel,ee}$	0.95	0.00	0.00	0.00	0.00
$CEF_{baseline}$	3.30	3.73	3.61	3.27	2.55
CEF_{ee}	3.48	3.93	3.80	3.45	2.68
hrs	290	290	290	290	290

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.042.[567]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a standard efficiency, residential grade clothes dryer with operating specifications as defined in the Key Variables Lookup Table above.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a residential grade clothes dryer appearing on the ENERGY STAR® qualified products list.

Operating Hours

Operating hours for residential clothes dryers are provided in the Key Variables Lookup Table above. In the absence of justifiable default operating characteristics for residential grade clothes dryers installed in small commercial facilities, residential values are assumed.

Example Calculation *(Not to be used as default)*

A small business owner in Albany replaces an existing electric clothes dryer with an ENERGY STAR ® qualified ventless electric, compact clothes dryer. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

$$\Delta kWh = units \times Cycles_{annual} \times Load \times \left(\frac{F_{elec,baseline}}{CEF_{baseline}} - \frac{F_{elec,ee}}{CEF_{ee}}\right)$$

[567] Based on metered data from Navigant Consulting, "EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (6/1/2012 – 5/31/2013) Appliance Rebate Program." March 2014, page 36. This report is not publicly available, but is referenced by the Mid-Atlantic Technical Reference Manual, Version 9.0, October 2019

$$\Delta kW = \frac{\Delta kWh}{hrs} \times CF$$

units = 1, from application
$Cycles_{annual}$ = 283, from Key Variables Lookup table
Load = 3, from Key Variables Lookup table
$F_{elec,baseline}$ = 1, from Key Variables Lookup table
$F_{elec,ee}$ = 1, from Key Variables Lookup table
$CEF_{baseline}$ = 2.55, from Key Variables Lookup table
CEF_{ee} = 2.68, from Key Variables Lookup table
hrs = 290, from Key Variables Lookup table
CF = 0.042, from Summary of Variables and Data Sources

$$\Delta kWh = 1 \times 283 \times 3 \times \left(\frac{1}{2.55} - \frac{1}{2.68}\right) = 16.15kWh$$

$$\Delta kW = \frac{\Delta kWh}{hrs} \times CF = 0.002kW$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

A clothes dryer releases heat to the surrounding environment. Conventional vented dryers also vent air outside the building. The associated HVAC impact of dryers depends upon a number of variables including climate and placement of a dryer (i.e., in a conditioned or unconditioned space). It is an area of ongoing research.[568] These impacts are excluded from the methodology prescribed herein until they can be quantified and substantiated through independent research.

Ancillary Electric Savings Impacts

See Ancillary Fossil Fuel Savings Impacts section above.

References

1. ENERGY STAR® Program Requirements Product Specification for Clothes Dryers, Eligibility Criteria Version 1.1, May 2017
   Available from:
   https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Final%20Version%201.1%20Clothes%20Dryers%20Specification%20-%20Program%20Commitment%20Criteria%20and%20Eligibility%20Criteria.pdf

[568] ENERGY STAR® Market & Industry Scoping Report: Residential Clothes Dryers, November 2011

2. Savings calculator for ENERGY STAR® Qualified Appliances
   Available from:
   https://www.energystar.gov/sites/default/files/asset/document/appliance_calculator.xlsx
3. 10 CFR 430.32 Energy and water conservation standards and their compliance dates.
   Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=39bdf94d4be5c5dac50be36d83225fe4&mc=true&node=pt10.3.430&rgn=div5#se10.3.430_13
4. ENERGY STAR® Market & Industry Scoping Report: Residential Clothes Dryers, November 2011
   Available from:
   https://www.energystar.gov/sites/default/files/asset/document/ENERGY_STAR_Scoping_Report_Residential_Clothes_Dryers.pdf

Record of Revision

Record of Revision Number	Issue Date
12-17-15	12/31/2017
12-18-4	12/28/2018

Return to Table of Contents

CLOTHES WASHER

Measure Description

This measure is applicable to commercial grade clothes washers meeting the criteria established under the ENERGY STAR® Program, Version 8.0, effective February 5, 2018, installed in commercial settings.[569] ENERGY STAR® clothes washers have a higher Modified Energy Factor (MEF) and a lower Integrated Water Factor (IWF), saving energy and water with greater tub capacities and sophisticated wash and rinse systems. Rather than filling the tub with water, efficient wash cycles are achieved by spinning or flipping clothes through a stream of water. Efficient rinse cycles are achieved through high-pressure spraying instead of soaking clothes. Reduced dryer load represents additional energy savings associated with the thorough removal of water from the clothes in the washer. Clothes washers originally qualified for the ENERGY STAR® label in 1997. Clothes washers that have earned this label use approximately 25% less energy and 33% less water than comparable non-qualified models.[570]

This measure addresses installation of soft-mounted[571] front-loading clothes washers.[572] This measure applies to commercial equipment installed in multifamily common areas, coin laundries, hospitals, hotels and motels.

The algorithms, inputs, and savings presented below assume a normal replacement scenario.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times Cycles_{daily} \times days \times capacity \times \left(\frac{1}{MEF_{baseline}} - \frac{1}{MEF_{ee}}\right) \times \left[F_{washer} + (F_{wh} \times ElecSF_{wh}) + (F_{dryer} \times ElecSF_{dryer})\right]$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \frac{\Delta kWh}{days \times 24} \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = units \times Cycles_{daily} \times days \times capacity \times \left(\frac{1}{MEF_{baseline}} - \frac{1}{MEF_{ee}}\right) \times \left[\frac{(F_{wh}}{E_{t,fuel}} \times FuelSF_{wh}) + (F_{dryer} \times FuelSF_{dryer} \times 1.12)\right] \times \frac{3{,}412}{1{,}000{,}000}$$

[569] ENERGY STAR® Program Requirements Product Specification for Clothes Washers, Eligibility Criteria Version 8.0, February 2018
[570] Efficiency of ENERGY STAR® products: https://www.energystar.gov/products/appliances/clothes_washers
[571] Soft-mounted washing machines are built in a cradle that contains springs and shock absorbers to isolate the drum from the frame of the washer.
[572] Per 10 CFR 431.110 (a)

where:

ΔkWh	= Annual electricity energy savings
ΔkW	= Peak coincident demand electric savings
$\Delta MMBtu$	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
$Cycles_{daily}$	= Number of dryer cycles per day
$ElecSF_{wh}$	= Electric Savings Factor for water heaters
$ElecSF_{dryer}$	= Electric Savings Factor for dryers
$FuelSF_{wh}$	= Fossil Fuel Savings Factor for water heaters
$FuelSF_{dryer}$	= Fossil Fuel Savings Factor for dryers
$MEF_{baseline}$	= Baseline Modified Energy Factor
MEF_{ee}	= Energy Efficient Modified Energy Factor
F_{washer}	= Percentage of savings attributable to washer
F_{wh}	= Percentage of savings attributable to water heater
F_{dryer}	= Percentage of savings attributable to dryer
capacity	= Clothes Washer rated capacity (cu.ft.)
days	= Number of operating days per year
$E_{t,fuel}$	= Water heater thermal efficiency
CF	= Coincidence Factor
1.12	= Gas dryer correction factor[573]
24	= Hours in one day
3,412	= Conversion factor, one kWh equals 3,412 BTU
1,000,000	= Conversion factor, one MMBtu equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
$MEF_{baseline}$		Lookup based on Equipment class in the table in Baseline Efficiency section below.
MEF_{ee}		From application.
F_{washer}	0.08	Calculated from conventions drawn from ENERGY STAR and 10 CFR[574]
F_{wh}	0.33	Calculated from conventions drawn from ENERGY STAR and 10 CFR[575]
F_{dryer}	0.59	Calculated from conventions drawn from ENERGY STAR and 10 CFR[576]

[573] A gas dryer correction factor corrects for the differential in typical efficiency between electric and gas dryers. U.S. Department of Energy (DOE). 2012. Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Clothes Washers
[574] Calculated based on defaults from ENERGY STAR and 10 CFR 431.156
[575] Calculated based on defaults from ENERGY STAR and 10 CFR 431.156
[576] Calculated based on defaults from ENERGY STAR and 10 CFR 431.156

Variable	Value	Notes
$ElecSF_{wh}$	Electric WH: 1.0 Fossil Fuel WH: 0 Unknown: 0.43	Based on EIA Commercial Energy Consumption Survey (CBECS) 2012 for Middle Atlantic States.[577]
$ElecSF_{dryer}$	Electric Dryer: 1.0 Gas Dryer: 0 Unknown: 0.43	Based on EIA Commercial Energy Consumption Survey (CBECS) 2012 for Middle Atlantic States.[578]
$FuelSF_{wh}$	Electric WH: 0 Fossil Fuel WH: 1.0 Unknown: 0.57	Based on EIA Commercial Energy Consumption Survey (CBECS) 2012 for Middle Atlantic States.[579]
$FuelSF_{dryer}$	Electric Dryer: 0 Gas Dryer: 1.0 Unknown: 0.57	Based on EIA Commercial Energy Consumption Survey (CBECS) 2012 for Middle Atlantic States.[580]
$E_{t,fuel}$	0.80	Thermal efficiency of fossil fuel water heater.[581]
$Cycles_{daily}$	Laundromat: 4.3 Multi-family: 3.4 Hospital/Hotel/Motel: 10.4	State of the Self-Service Industry Laundry Report.[582] ACEEE White Paper.[583] Laundry Planning Guide, EDRO.[584]
Capacity		From application.
days		From application.
CF	1.0	

Integrated Water Factor, IWF[585] (gal/ft^3/cycle) is the quotient of the total weighted per-cycle water consumption for all wash cycles in gallons divided by the cubic foot (or liter) capacity of the clothes washer. A lower value reflects a more efficient clothes washer[586]. Manufacturers must submit their water consumption factors with their ENERGY STAR® certified commercial clothes washers.

Modified energy factor (ft^3/kWh/cycle), is the quotient of the cubic foot (or liter) capacity of the clothes container divided by the total clothes washer energy consumption per cycle, with such energy consumption expressed as the sum of the machine electrical energy consumption, the hot

[577] EIA Commercial Energy Consumption Survey (CBECS) 2012 for Middle Atlantic States, Table B4. Census region and division, number of buildings ("Unknown" calculated as the number of homes with electric water heating divided by the total number of homes with electric, fuel oil or gas water heating.)
[578] Ibid, water heater values are applied as proxy.
[579] EIA Commercial Energy Consumption Survey (CBECS) 2012 for Middle Atlantic States, Table B4. Census region and division, number of buildings ("Unknown" calculated as the number of homes with gas or fuel water heating divided by the total number of homes with electric, fuel oil or gas water heating.)
[580] Ibid, water heater values are applied as proxy.
[581] Per 10 CFR 431.110 (a)
[582] '2014-2015 State of the Self-Service Laundry Industry Report' Carlo Calma April 2015.
[583] Saving Energy and Water through State Programs for Clothes Washer Replacement in the Great Lakes region
[584] Laundry Planning Guide, EDRO, January 2015.
[585] 10 CFR 430 Subpart B, Appendix J2
[586] ENERGY STAR® Program Requirements Product Specification for Clothes Washers, Eligibility Criteria Version 8.0, February 2018

water energy consumption, and the energy required for removal of the remaining moisture in the wash load.

Coincidence Factor (CF)

The recommended value for the coincidence factor is 1.0.[587]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline equipment class should be determined based on existing conditions and the baseline MEF should be based on that equipment class. If unknown or for new construction/installation, a front-loading baseline should be assumed, as specified in the Code of Federal Regulations.[588]

Equipment Class	Modified Energy Factor (MEFJ2)	Integrated Water Factor (IWF)
Front-Loading	2.00	4.1

Compliance Efficiency from which Incentives are Calculated

The compliance condition is an ENERGY STAR® qualified clothes washer. The equipment must be a soft-mounted front-loading commercial clothes washer with a MEF of 2.20 and IWF ≤ 4.0 with a volume lesser than or equal to 8.0 cubic feet.

Operating Hours

Equipment operating days per year shall be taken from application. This assumption is applied to produce conservative demand savings estimates.

Example Calculation *(Not to be used as default)*

A laundromat replaces 20 electric clothes washers with ENERGY STAR® qualified electric soft-mounted front-loading clothes washers with 5 cu.ft. capacity, Modified Energy Factor of 2.45 and IWF of 3.8. The laundromat is open 250 days per year. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

$$\Delta kWh = units \times Cycles_{daily} \times days \times capacity \times \left(\frac{1}{MEF_{baseline}} - \frac{1}{MEF_{ee}}\right) \times \left[F_{washer} + (F_{wh} \times ElecSF_{wh}) + (F_{dryer} \times ElecSF_{dryer})\right]$$

$$\Delta kW = \frac{\Delta kWh}{days \times 24} \times CF$$

units = 20, from application
$Cycles_{daily}$ = 4.3, from Summary of Variables and Data Sources table
days = 250, from application

[587] A conservative approach that suggests savings are equally likely to occur at any time throughout the year.
[588] 10 CFR 431.156

Capacity = 5, from application
$MEF_{baseline}$ = 2.00, from application
MEF_{ee} = 2.45, from Compliance Efficiency section
F_{washer} = 0.08, from Summary of Variables and Data Sources table
F_{wh} = 0.33, from Summary of Variables and Data Sources table
F_{dryer} = 0.59, from Summary of Variables and Data Sources table
$ElecSF_{dryer}$ = 1, from Summary of Variables and Data Sources table
$ElecSF_{wh}$ = 1, from Summary of Variables and Data Sources table
CF = 1.0, from Summary of Variables and Data Sources table

$$\Delta kWh = 20 \times 4.3 \times 250 \times 5 \times \left(\frac{1}{2.00} - \frac{1}{2.45}\right) \times [0.08 + (0.33 \times 1) + (0.59 \times 1)]$$
$$= 9{,}872\ kWh$$

$$\Delta kW = \frac{9{,}872}{250 \times 24} \times 1 = 1.65\ kW$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

High efficiency clothes washers more effectively remove moisture from clothing during spin cycles. This reduces the amount of time necessary for drying cycles and leads to energy savings. Clothes dryer energy savings are considered in overall energy savings calculations above.

Ancillary Electric Savings Impacts

High efficiency clothes washers more effectively remove moisture from clothing during spin cycles. This reduces the amount of time necessary for drying cycles and leads to energy savings. Clothes dryer energy savings are considered in overall energy savings calculations above.

References

1. ENERGY STAR® Program Requirements Product Specification for Clothes Washers, Eligibility Criteria Version 8.0, February 2018
   Available from:
   https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Final%20Version%208.0%20Clothes%20Washer%20Partner%20Commitments%20and%20Eligibility%20Criteria.pdf
2. ENERGY STAR® Certified Products, Appliances, Clothes Washers
   Available from: https://www.energystar.gov/products/appliances/clothes_washers/

3. Purchase energy-saving products, Savings Calculator for ENERGY STAR® Qualified Appliances (last updated October 2016)Available from: https://www.energystar.gov/buildings/facility-owners-and-managers/existing-buildings/save-energy/purchase-energy-saving-products
4. 10 CFR 430 Subpart B, Appendix J2 - Uniform Test Method for Measuring the Energy Consumption of Automatic and Semi-automatic Clothes Washers
   Available from: https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=6dc64a198ad50a16b0ff6af63189872b&mc=true&n=pt10.3.430&r=PART&ty=HTML#ap10.3.430_127.j2
5. ENERGY STAR® Clothes Washers Key Product Criteria
   Available from: https://www.energystar.gov/products/appliances/clothes_washers/key_product_criteria/
6. EIA Commercial Energy Consumption Survey (CBECS) 2012 Survey Data for Middle Atlantic States.
   Available from: https://www.eia.gov/consumption/commercial/data/2012/bc/cfm/b4.php
7. '2014-2015 State of the Self-Service Laundry Industry Report' Carlo Calma April 2015.
   Available from: https://americancoinop.com/articles/2014-2015-state-self-service-laundry-industry-report-conclusion
8. Saving Energy and Water through State Programs for Clothes Washer Replacement in the Great Lakes region
   Available from: https://www.aceee.org/files/pdf/white-paper/great-lakes-clothes-washers.pdf
9. 10 CFR 431.110 Energy conservation standards and their effective dates
   Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=64f994924a5f31b841cab23a6d543f85&mc=true&node=pt10.3.431&rgn=div5#se10.3.431_1110
10. Laundry Planning Guide, EDRO, January 2015.
    Available from: https://docuri.com/download/guide-to-the-installation-of-pv-systems-2nd-edition_59a8da23f581719e12aed728_pdf
11. U.S. Department of Energy (DOE). 2012. Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Clothes Washers. Prepared by Navigant Consulting, Inc. and Ernest Orlando Lawrence Berkeley National Laboratory.
    Available from: https://www.federalregister.gov/documents/2012/05/31/2012-12320/energy-conservation-program-energy-conservation-standards-for-residential-clothes-washers

Record of Revision

Record of Revision Number	Issue Date
3-21-9	4/9/2021

Return to Table of Contents

COMBINATION OVEN

Measure Description

This measure covers the installation of ENERGY STAR® qualified gas or electric commercial combination ovens.[589] Though not eligible for ENERGY STAR® qualifications, electric combination ovens with capacities of 21 pans or greater aligning with California Technical Forum Workpaper assumptions for energy efficient products per the compliance efficiencies section below are also included in the measure.[590] A combination oven combines the function of hot air convection, saturated and superheating steam heating, and combination convection/steam mode for moist heating. The oven is used for steaming, baking, roasting, re-thermalizing, and proofing of various food products.

A combination oven can also be referred to as a combi, combo, or combination oven/steamer. Combination ovens come in a range of sizes based on their capacity to accommodate 12 x 20 x 2 1/2 inch hotel pans. This measure includes half size and full size combination ovens. Measure calculations are based on oven pan capacity of full size, 2 1/2 inch hotel pans.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings (Electric Equipment Only)

$$\Delta kWh = units \times days \times \frac{\left(\Delta BTU_{preheat} + \Delta BTU_{idle,c} + \Delta BTU_{idle,s} + \Delta BTU_{cooking,c} + \Delta BTU_{cooking,s}\right)}{3{,}412}$$

Summer Peak Coincident Demand Savings (Electric Equipment Only)

$$\Delta kW = \frac{\Delta kWh}{(days \times hrs)} \times CF$$

Annual Fossil Fuel Energy Savings (Fossil Fuel Equipment Only)

$$\Delta MMBtu = units \times days \times \frac{\left(\Delta BTU_{preheat} + \Delta BTU_{idle,c} + \Delta BTU_{idle,s} + \Delta BTU_{cooking,c} + \Delta BTU_{cooking,s}\right)}{1{,}000{,}000}$$

where:

$$\Delta BTU_{preheat} = N_{preheat} \times \left(BTU_{preheat,baseline} - BTU_{preheat,ee}\right)$$

[589] ENERGY STAR® Program Requirements Product Specification for Commercial Ovens, Eligibility Criteria Version 2.2, March 2015
[590] Cal TF Workpaper SWFS003 Revision 1

$$\Delta BTU_{idle,c} = \left[BTUh_{idle,c,baseline} \times \left(hrs - N_{preheat} \times hrs_{preheat} - \frac{lbs}{(lbs/hr)_{c,baseline}}\right) - BTUh_{idle,c,ee} \times \left(hrs - N_{preheat} \times hrs_{preheat} - \frac{lbs}{(lbs/hr)_{c,ee}}\right)\right] \times (1 - F_s)$$

$$\Delta BTU_{idle,s} = \left[BTU/h_{idle,s,baseline} \times \left(hrs - N_{preheat} \times hrs_{preheat} - \frac{lbs}{(lbs/hr)_{s,baseline}}\right) - BTU/h_{idle,s,ee} \times \left(hrs - N_{preheat} \times hrs_{preheat} - \frac{lbs}{(lbs/hr)_{s,ee}}\right)\right] \times F_s$$

$$\Delta BTU_{cooking,c} = lbs \times Q_{food,c} \times \left(\frac{1}{Eff_{c,baseline}} - \frac{1}{Eff_{c,ee}}\right) \times (1 - F_s)$$

$$\Delta BTU_{cooking,s} = lbs \times Q_{food,s} \times \left(\frac{1}{Eff_{s,baseline}} - \frac{1}{Eff_{s,ee}}\right) \times F_s$$

NOTE: $\Delta BTU_{preheat}$, ΔBTU_{idle} and $\Delta BTU_{cooking}$ terms can be calculated per the equations above using any combination of actual qualifying equipment specifications and assumed values as defined in the Baseline Efficiencies, Compliance Efficiency and Operating Hours sections below, or looked up from the Default Values table below.

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
$\Delta BTU_{preheat}$	= Daily preheat energy savings
ΔBTU_{idle}	= Daily idle energy savings
$\Delta BTU_{cooking}$	= Daily cooking energy savings
units	= Number of measures installed under the program
days	= Operating days per year
hrs	= Daily operating hours
baseline	= Characteristic of baseline condition
ee	= Characteristic of energy efficient condition
c	= Convection mode
s	= Steam mode
$BTU_{preheat}$	= Equipment preheat energy (BTU)
$N_{preheat}$	= Number of preheats per day
$hrs_{preheat}$	= Preheat duration (hours)
BTU/h_{idle}	= Equipment idle energy rate (BTU/h)
(lbs/hr)	= Equipment production capacity (lbs/hr)
lbs	= Total daily food production
Q_{food}	= Heat to food (BTU/lb)
Eff	= Equipment convection/steam mode cooking efficiency
F_s	= Steam mode time factor
CF	= Coincidence factor
3,412	= Conversion factor, one kW equals 3,412 BTU/h

1,000,000 = Conversion factor, one MMBtu equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
$\Delta BTU_{preheat}$		Calculate based on calculations above or look up in Default Values table below.
$\Delta BTU_{idle,c}$		Calculate based on calculations above or look up in Default Values table below.
$\Delta BTU_{idle,s}$		Calculate based on calculations above or look up in Default Values table below.
$\Delta BTU_{cooking,c}$		Calculate based on calculations above or look up in Default Values table below.
$\Delta BTU_{cooking,s}$		Calculate based on calculations above or look up in Default Values table below.
days		From application or look up based on facility type in Operating Hours section below.
hrs		From application or look up based on facility type in Operating Hours section below.
$N_{preheat}$	1	Pacific Gas and Electric. [591]
$BTU_{preheat,baseline}$		Look up based on qualifying equipment type in Baseline Efficiencies section below.
$BTU_{preheat,ee}$		From application or look up based on qualifying equipment type in Compliance Efficiency section below.
$BTU/h_{idle,c,baseline}$		Look up based on qualifying equipment type in Baseline Efficiencies section below.
$BTU/h_{idle,s,baseline}$		Look up based on qualifying equipment type in Baseline Efficiencies section below.
$BTU/h_{idle,c,ee}$		From application or look up based on qualifying equipment type in Compliance Efficiency section below.
$BTU/h_{idle,s,ee}$		From application or look up based on qualifying equipment type in Compliance Efficiency section below.
$hrs_{preheat}$	0.25	Pacific Gas and Electric. [592]
$(lbs/hr)_{c,baseline}$		Look up based on qualifying equipment type in Baseline Efficiencies section below.
$(lbs/hr)_{s,baseline}$		Look up based on qualifying equipment type in Baseline Efficiencies section below.
$(lbs/hr)_{c,ee}$		From application or look up based on qualifying equipment type in Compliance Efficiency section below
$(lbs/hr)_{s,ee}$		From application or look up based on qualifying equipment type in Compliance Efficiency section below

[591] Cal TF Workpaper SWFS003 Revision 1, pg. 8
[592] Ibid.

Variable	Value	Notes
lbs	< 15 Pans: 200 15-28 Pans: 250 ≥ 29 Pans: 400	From application or use values provided[593]
$Q_{food,c}$	250	Convection mode heat to food (BTU/lb) [594]
$Q_{food,s}$	105	Steam mode heat to food (BTU/lb) [595]
$Eff_{c,baseline}$		Look up based on qualifying equipment type in Baseline Efficiencies section below.
$Eff_{s,baseline}$		Look up based on qualifying equipment type in Baseline Efficiencies section below.
$Eff_{c,ee}$		From application or look up based on qualifying equipment type in Compliance Efficiency section below.
$Eff_{s,ee}$		From application or look up based on qualifying equipment type in Compliance Efficiency section below.
F_s	0.50	ENERGY STAR®.[596]
CF	0.9	

Default Values

The table below contains values and simplified calculations for $\Delta BTU_{preheat}$, ΔBTU_{idle} and $\Delta BTU_{cooking}$ terms that may be used in the formulation of estimated savings in lieu of utilizing the calculations prescribed above for these terms. These values were established by performing those calculations using assumed values from the Common Variables, Baseline Efficiencies and Compliance Efficiency sections below.

Equipment	$\Delta BTU_{preheat}$	$\Delta BTU_{idle,c}$	$\Delta BTU_{idle,s}$	$\Delta BTU_{cooking,c}$	$\Delta BTU_{cooking,s}$
Combi Electric Oven, < 15 Pans[597]	5,118	36 x hrs -1,986	5,612 x hrs - 11,848	1,827	2,338
Combi Electric Oven, 15 - 20 Pans[598]	5,971	309 x hrs -1,481	9,227 x hrs - 10,865	2,284	2,922
Combi Electric Oven, 21 - 28 Pans	5,971	2,133 x hrs - 7,997	11,089 x hrs - 25,519	3,434	6,563
Combi Electric Oven, > 28 Pans	8,974	2,133 x hrs - 5,162	15,354 x hrs - 23,579	5,495	10,500
Combi Gas Oven, < 15 Pans[599]	5,000	911 x hrs -1,641	5,073 x hrs - 5,887	3,434	1,313
Combi Gas Oven, 15 - 28 Pans[600]	6,000	1,182 x hrs - 2,942	7,026 x hrs - 11,564	4,293	1,642
Combi Gas Oven, 29 Pans[601]	8,000	507 x hrs -3,076	6,126 x hrs - 15,924	6,868	2,627

[593] Ibid.
[594] ENERGY STAR® Commercial Food Service Equipment Calculator (accessed 2/26/2018)
[595] Ibid.
[596] Ibid.
[597] Assumes 10 pans
[598] Assumes 20 pans
[599] Assumes 10 pans
[600] Assumes 20 pans
[601] Assumes 29 pans

Equipment	$\Delta BTU_{preheat}$	$\Delta BTU_{idle,c}$	$\Delta BTU_{idle,s}$	$\Delta BTU_{cooking,c}$	$\Delta BTU_{cooking,s}$
Combi Gas Oven, ≥ 30 Pans[602]	8,000	788 x hrs -1,030	14,395 x hrs - 14,021	6,868	2,627

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.9.[603]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a combination oven as defined in the Measure Description section above with operating characteristics per the table below. Values are as reported from referenced ENERGY STAR® Commercial Food Service Calculator[604] unless otherwise noted. Preheat energy rates and all values for electric combi-ovens with capacities greater than 21 pans are reported from referenced FSTC calculators.

Equipment	$BTU_{preheat, baseline}$ (BTU)	$BTU/h_{idle, c,baseline}$ (BTU/h)	$BTU/h_{idle, s,baseline}$ (BTU/h)	$(lbs/hr)_{c,baseline}$	$(lbs/hr)_{s,baseline}$	$Eff_{c,baseline}$	$Eff_{s,baseline}$
Combi Electric Oven, < 15 Pans	10,236[605]	4,504	17,947	79	126	0.72	0.49
Combi Electric Oven, 15 - 20 Pans	12,795[606]	7,779	29,719	166	295	0.72	0.49
Combi Electric Oven, 21 - 28 Pans[607]	12,795	12,795	42,650	100	150	0.65	0.40
Combi Electric Oven, > 28 Pans[608]	19,210	17,913	61,416	275	350	0.65	0.40
Combi Gas Oven, < 15 Pans	18,000[609]	8,747	18,656	125	195	0.52	0.39
Combi Gas Oven, 15 - 28 Pans	22,000[610]	10,788	24,562	176	211	0.52	0.39
Combi Gas Oven, 29 Pans	32,000[611]	10,788	24,562	176	211	0.52	0.39
Combi Gas Oven, ≥ 30 Pans	32,000[612]	13,000	43,300	392	579	0.52	0.39

[602] Assumes 40 pans
[603] Cal TF Workpaper SWFS003 Revision 1, pg. 11
[604] ENERGY STAR® Commercial Food Service Equipment Calculator (accessed 2/26/2018)
[605] Cal TF Workpaper SWFS003 Revision 1, pg 8
[606] Cal TF Workpaper SWFS003 Revision 1, pg. 9
[607] Ibid.
[608] Ibid.
[609] Cal TF Workpaper SWFS003 Revision 1, pg. 13
[610] Cal TF Workpaper SWFS003 Revision 1, pg. 14
[611] Ibid.
[612] Ibid.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is ENERGY STAR® food service equipment as defined in the Measure Description section above. Operating characteristics shall be taken from application. When unavailable, default characteristics shall be taken from the table below. Values are as reported from the referenced ENERGY STAR® Commercial Food Service Calculator[613], unless otherwise noted. Preheat energy rates and all values for electric combi ovens with capacity greater than 21 pans are reported from referenced Cal TF workpaper.

Equipment	$BTU_{preheat,ee}$ (BTU)	$BTU/h_{idle,c,ee}$ (BTU/h)	$BTU/h_{idle,s,ee}$ (BTU/h)	$(lbs/hr)_{c,ee}$	$(lbs/hr)_{s,ee}$	$Eff_{c,ee}$	$Eff_{s,ee}$
Combi Electric Oven, < 15 Pans	5,118[614]	273 x no. pans + 1,702	454 x no. pans + 2,184	119	177	0.76	0.55
Combi Electric Oven, 15 - 20 Pans	6,824[615]	273 x no. pans + 1,702	454 x no. pans + 2,184	201	349	0.76	0.55
Combi Electric Oven, 21 - 28 Pans[616]	6,824	8,530	20,472	125	200	0.70	0.50
Combi Electric Oven, > 28 Pans[617]	10,236	13,648	30,708	325	400	0.70	0.50
Combi Gas Oven, < 15 Pans	13,000[618]	150 x no. pans + 5,425	200 x no. pans + 6,511	124	172	0.56	0.41
Combi Gas Oven, 15 - 28 Pans	16,000[619]	150 x no. pans + 5,425	200 x no. pans + 6,511	210	277	0.56	0.41
Combi Gas Oven, 29 Pans	24,000[620]	150 x no. pans + 5,425	200 x no. pans + 6,511	210	277	0.56	0.41
Combi Gas Oven, ≥ 30 Pans	24,000[621]	150 x no. pans + 5,425	200 x no. pans + 6,511	394	640	0.56	0.41

Operating Hours

Equipment operating hours per day and days per year shall be taken from the application if known. Default operating hours per day and days per year are provided below, established based on a weighted average of values associated with similar facility types, as reported by the California Energy Commission.[622]

Facility Type	Hours/Day	Days/Year
Community College	11	283
Fast Food	14	363
Full Service Restaurant	12	321

[613] ENERGY STAR® Commercial Food Service Equipment Calculator (accessed 2/26/2018)
[614] Cal TF Workpaper SWFS003 Revision 1, pg. 8
[615] Cal TF Workpaper SWFS003 Revision 1, pg. 9
[616] Ibid.
[617] Ibid.
[618] Cal TF Workpaper SWFS003 Revision 1, pg. 13
[619] Cal TF Workpaper SWFS003 Revision 1, pg. 14
[620] Ibid.
[621] Ibid.
[622] California Energy Commission, Characterizing the Energy Efficiency Potential of Gas-Fired Commercial Foodservice Equipment, Appendix E

Facility Type	Hours/Day	Days/Year
Grocery	12	365
Hospital	11	365
Hotel	20	365
Miscellaneous	9	325
Motel	20	365
Primary School	5	180
Secondary School	8	180
Small Office	12	250
University	11	283

Example Calculation *(Not to be used as default)*

An ENERGY STAR® qualified gas fired combination oven with 18 pan capacity is installed in the kitchen of a hotel located near Albany that operates year round. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are not applicable. Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta MMBtu = units \times days \times \frac{\left(\Delta BTU_{preheat} + \Delta BTU_{idle,c} + \Delta BTU_{idle,s} + \Delta BTU_{cooking,c} + \Delta BTU_{cooking,s}\right)}{1{,}000{,}000}$$

$$\Delta BTU_{preheat} = N_{preheat} \times \left(BTU_{preheat,baseline} - BTU_{preheat,ee}\right)$$

$$\Delta BTU_{idle,c} = \left[BTUh_{idle,c,baseline} \times \left(hrs - N_{preheat} \times hrs_{preheat} - \frac{lbs}{(lbs/hr)_{c,baseline}}\right) - BTUh_{idle,c,ee} \times \left(hrs - N_{preheat} \times hrs_{preheat} - \frac{lbs}{(lbs/hr)_{c,ee}}\right)\right] \times (1 - F_s)$$

$$\Delta BTU_{idle,s} = \left[BTU/h_{idle,s,baseline} \times \left(hrs - N_{preheat} \times hrs_{preheat} - \frac{lbs}{(lbs/hr)_{s,baseline}}\right) - BTU/h_{idle,s,ee} \times \left(hrs - N_{preheat} \times hrs_{preheat} - \frac{lbs}{(lbs/hr)_{s,ee}}\right)\right] \times F_s$$

$$\Delta BTU_{cooking,c} = lbs \times Q_{food,c} \times \left(\frac{1}{Eff_{c,baseline}} - \frac{1}{Eff_{c,ee}}\right) \times (1 - F_s)$$

$$\Delta BTU_{cooking,s} = lbs \times Q_{food,s} \times \left(\frac{1}{Eff_{s,baseline}} - \frac{1}{Eff_{s,ee}}\right) \times F_s$$

units = 1, from application
days = 365 days a year, from Operating Hours section based on facility type

hrs = 20 hours a day, from Operating Hours section based on facility type
hrspreheat = 0.25, from Summary of Variables and Data Sources
lbs = 250, from Summary of Variables and Data Sources based on number of pans
$N_{preheat}$ = 1, from Summary of Variables and Data Sources
$BTU_{preheat,baseline}$ = 12,795 BTU, from Baseline Efficiency section from which Energy Savings are calculated
$BTU_{preheat,ee}$ = 6,824 BTU, from Compliance Efficiency section from which Energy Savings are calculated
$BTU_{idle,c,baseline}$ = 7,779 BTU, from Baseline Efficiency section from which Energy Savings are calculated
$BTU_{idle,c,ee}$ = 273 x no. of pans + 1,702 = 273 x 18 + 1,702 = 6,616
no. of pans =18, from application
$(lbs/hr)_{c,baseline}$ = 166 lbs, from Baseline Efficiency section from which Energy Savings are calculated
$(lbs/hr)_{c,ee}$ = 201, from Compliance Efficiency section from which Energy Savings are calculated
F_s = 0.50, from Summary of Variables and Data Sources
$BTU/h_{idle,s,baseline}$ = 29,719 from Baseline Efficiency section from which Energy Savings are calculated
$BTU/h_{idle,s,ee}$ = 454 x no. of pans + 2,184 = 454 x 18 + 2,184 = 10,356
no. of pans =18, from application
$(lbs/hr)_{s,baseline}$ = 295 lbs from Baseline Efficiency section from which Energy Savings are calculated
$(lbs/hr)_{s,ee}$ = 349, from Compliance Efficiency section from which Energy Savings are calculated
$Q_{food,c}$ = 250, from Summary of Variables and Data Sources
$Eff_{c,baseline}$ = 0.72, from Baseline Efficiency section from which Energy Savings are calculated
$Eff_{c,ee}$ = 0.76, from Compliance Efficiency section from which Energy Savings are calculated
$Q_{food,s}$ = 150, from Summary of Variables and Data Sources
$Eff_{s,baseline}$ = 0.49, from Baseline Efficiency section from which Energy Savings are calculated
$Eff_{s,ee}$ = 0.55, from Compliance Efficiency section from which Energy Savings are calculated

$$\Delta BTU_{preheat} = 1 \times (12{,}795 - 6{,}824) = 5{,}971$$

$$\Delta BTU_{idle,c} = \left[7{,}779 \times \left(20 - 1 \times 0.25 - \frac{250}{166}\right) - 6{,}616 \times \left(20 - 1 \times 0.25 - \frac{250}{201}\right)\right] \times (1 - 0.50) = 145{,}207.3$$

$$\Delta BTU_{idle,s} = \left[29{,}719 \times \left(20 - 1 \times 0.25 - \frac{250}{295}\right) - 10{,}356 \times \left(20 - 1 \times 0.25 - \frac{250}{349}\right)\right] \times 0.50 = 182{,}326$$

$$\Delta BTU_{cooking,c} = 250 \times 150 \times \left(\frac{1}{0.72} - \frac{1}{0.76}\right) \times (1 - 0.50) = 1{,}370.61$$

$$\Delta BTU_{cooking,s} = 250 \times 150 \times \left(\frac{1}{0.49} - \frac{1}{0.55}\right) \times 0.50 = 8{,}348.8$$

$$\Delta MMBtu = 1 \times 365 \times \frac{(5{,}971 + 145{,}207.3 + 182{,}326 + 1{,}370.61 + 8{,}348.8)}{1{,}000{,}000}$$
$$= 125.28\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

More efficient food service equipment rejects less heat into the condition space than standard equipment, increasing space heating requirements while decreasing cooling load. However, no relevant studies have been performed to date that would allow quantification of these impacts. Until additional information is available, these impacts are excluded from the prescribed formulation of savings.

Ancillary Electric Savings Impacts

More efficient food service equipment rejects less heat into the condition space than standard equipment, increasing space heating requirements while decreasing cooling load. However, no relevant studies have been performed to date that would allow quantification of these impacts. Until additional information is available, these impacts are excluded from the prescribed formulation of savings.

References

1. ENERGY STAR® Program Requirements Product Specification for Commercial Ovens, Eligibility Criteria, Version 2.2, March 2015.
   Available from:
   https://www.energystar.gov/sites/default/files/Commercial%20Ovens%20Final%20Version%202.2%20Specification.pdf
2. California Technical Forum, Workpaper SWFS003 Revision 1, October 2018
   Available from: deeresources.net/workpapers
3. ENERGY STAR® Commercial Food Service Calculator (accessed February 26, 2018)
   Available from:
   https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator.xlsx
4. California Energy Commission, Energy Research and Development Division, Characterizing the Energy Efficiency Potential of Gas-Fired Commercial Foodservice Equipment, October 2014.
   Available from: http://www.energy.ca.gov/2014publications/CEC-500-2014-095/CEC-500-2014-095.pdf

Record of Revision

Record of Revision Number	Issue Date
3-18-19	3/29/2018
3-20-5	3/30/2020

Return to Table of Contents

CONVEYOR BROILER

Measure Description

This measure covers the installation of efficient fossil fuel-fired conveyor broilers. Conveyor broilers are broilers fitted with a belt that transports food between a set of two or more heating radiants that are above and below the belt, while consistently cooking the food. They are less labor intensive than standard broilers while allowing high production output. Qualifying conveyor broilers must have a catalyst and an input rate less than 80 kBTU/h or a dual stage or modulating fuel valve with a capability of throttling the input rate below 80 kBTU/h.

Fossil fuel-fired conveyor broilers may also be equipped with an electric bun grill and/or electric heating/warming elements. Fossil fuel-fired conveyor broilers are only eligible for electric savings when equipped with an electric bun grill and/or electric heating/warming elements.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings (Use only when efficient measure includes electric equipment as described in Measure Description)

$$\Delta kWh = units \times (\Delta kWh/unit)$$

Summer Peak Coincident Demand Savings (Use only when efficient measure includes electric equipment as described in Measure Description)

$$\Delta kW = units \times (\Delta kW/unit)$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = units \times (\Delta MMBtu/unit)$$

where:

ΔkWh = Annual electricity energy savings
ΔkW = Peak coincident demand electric savings
ΔMMBtu = Annual fossil fuel energy savings
(ΔkWh/unit) = Annual electric energy savings per unit
(ΔkW/unit) = Peak coincident demand electric savings per unit
(ΔMMBtu/unit) = Annual fossil fuel energy savings per unit

Summary of Variables and Data Sources

Variable	Value	Notes
(ΔkWh/unit)		Look up from table below based on belt width.
(ΔkW/unit)		Look up from table below based on belt width.
(ΔMMBtu/unit)		Look up from table below based on belt width.

Unit Energy Savings[623]

Belt Width (inches)	ΔkWh/unit	ΔkW/unit	ΔMMBtu/unit
< 20 inches	7,144	1.48	114.5
≥ 20 inches and ≤ 28 inches	6,403	0.88	193.3
> 28 inches	23,849	3.29	316.1

Coincidence Factor (CF)

The prescribed value for the coincidence factor is N/A. Peak coincidence is embedded in ΔkW/unit value above.

Baseline Efficiencies from which Energy Savings are Calculated

The baseline case for this measure is an automatic conveyor broiler capable of maintaining a temperature above 600°F with a tested idle rate greater than 40 kBTU/h for a belt width narrower than 20", greater than 60 kBTU/h for a belt width between 20" and 28", greater than 70 kBTU/h for a belt width wider than 28".

Compliance Efficiency from which Incentives are Calculated

The compliance case is an automatic conveyor broiler with a catalyst and an input rate less than 80 kBTU/h, or a dual stage or modulating fuel valve with the capability of throttling the input rate below 80 kBTU/h. The compliance broiler must be of similar size or smaller than the baseline condition.

Operating Hours

Operating hours are embedded into the unit energy savings above. Market analysis found that conveyor broilers are mostly installed in quick service restaurants and are turned on an hour prior to their opening, resulting in an average operation of 18.3 hours per day.[624]

Example Calculation *(Not to be used as default)*

A restaurant in Syracuse installs a gas-fired conveyor broiler with 24 inch belt width. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are not applicable. Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta MMBtu = units \times (\Delta MMBtu/unit)$$

units = 1, from application
ΔMMBtu/unit = 193.3, from Unit Energy Savings table based on belt width

$$\Delta MMBtu = 1 \times (193.3) = 193.3\ MMBtu$$

[623] Southern California Gas Company, Work Paper WPSCGNRCC171226A Commercial Conveyor Broilers, pg 2
[624] Technical Support Document: 50% Energy Savings for Quick-Service Restaurants. Hours of operation and daily energy use were collected from field monitoring data conducted by PG&E and SoCalGas from four quick service restaurant chains. Average hours from Figure 2.7 as cited in SoCalGas WPSCGNRCC171226A workpaper.

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

More efficient food service equipment rejects less heat into the condition space than standard equipment, increasing space heating requirements while decreasing cooling load. However, no relevant studies have been performed to date that would allow quantification of these impacts. Until additional information is available, these impacts are excluded from the prescribed formulation of savings.

Ancillary Electric Savings Impacts

More efficient food service equipment rejects less heat into the condition space than standard equipment, increasing space heating requirements while decreasing cooling load. However, no relevant studies have been performed to date that would allow quantification of these impacts. Until additional information is available, these impacts are excluded from the prescribed formulation of savings

References

1. Southern California Gas Company, Work Paper WPSCGNRCC171226A Commercial Conveyor Broilers, Revision 01, March 21, 2019
   Available from: http://deeresources.net/workpapers
2. Technical Support Document: 50% Energy Savings for Quick-Service Restaurants, Available from:
   http://www.pnl.gov/main/publications/external/technical_reports/PNNL-19809.pdf

Record of Revision

Record of Revision Number	Issue Date
12-19-9	12/23/2019

Return to Table of Contents

DISHWASHER

Measure Description

This measure covers the installation of ENERGY STAR® qualified electric commercial dishwashers.[625] A dishwasher is a machine designed to clean and sanitize plates, pots, pans, glasses, cups, bowls, utensils, and trays by applying sprays of detergent solution (with or without blasting media granules) and a sanitizing rinse. ENERGY STAR® rated machines consume less water and use less energy while idling between wash cycles. Commercial dishwashers that have earned the label are about 40% more energy efficient than comparable un-qualified models.[626]

This measure applies to stationary rack machines and conveyor machines operating at low or high temperatures. This measure is not applicable to flight machines, which are custom-built, continuous conveyor machines designed for use in large institutions.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times [(\Delta kWh_{wh} \times ElecSF_{wh}) + (\Delta kWh_{booster} \times ElecSF_{booster}) + \Delta kWh_{idle}]$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \frac{\Delta kWh}{hrs} \times F_{peak} \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = units \times [(\Delta MMBtu_{wh} \times FuelSF_{wh}) + (\Delta MMBtu_{booster} \times FuelSF_{booster})]$$

where:

ΔkWh = Annual electric energy savings
ΔkW = Peak coincident demand electric savings
$\Delta MMBtu$ = Annual fossil fuel energy savings
units = Number of measures installed under the program
ΔkWh_{wh} = Annual electric water heating energy savings
$\Delta kWh_{booster}$ = Annual electric booster water heater energy savings
ΔkWh_{idle} = Annual electric dishwasher idle energy savings
$ElecSF_{wh}$ = Electric Savings Factor for water heaters
$ElecSF_{booster}$ = Electric Savings Factor for booster water heaters
$\Delta MMBtu_{wh}$ = Annual fossil fuel water heating energy savings
$\Delta MMBtu_{booster}$ = Annual fossil fuel booster water heater energy savings
$FuelSF_{wh}$ = Fossil Fuel Savings Factor for water heaters
$FuelSF_{booster}$ = Fossil Fuel Savings Factor for booster water heaters

[625] ENERGY STAR® Program Requirements Product Specification for Commercial Dishwashers Eligibility Criteria Version 2.0, February 2013
[626] Efficiency of ENERGY STAR® products: https://www.energystar.gov/products/commercial_food_service_equipment/commercial_dishwashers

hrs = Annual hours of operation
F_{peak} = Peak operation factor; binary variable to indicate whether equipment operates during electric system peak (summer weekday hour ending at 5PM)
CF = Coincidence factor

Summary of Variables and Data Sources

Variable	Value	Notes
ΔkWh_{wh}		Look up based on Dishwasher Type in Default Values table below.
$\Delta kWh_{booster}$		Look up based on Dishwasher Type in Default Values table below.
ΔkWh_{idle}		Look up based on Dishwasher Type in Default Values table below.
$ElecSF_{wh}$	Electric WH: 1 Fossil Fuel WH: 0	
$ElecSF_{booster}$	Electric Booster: 1 Fossil Fuel Booster: 0	
$\Delta MMBtu_{wh}$		Look up based on Dishwasher Type in Default Values table below.
$\Delta MMBTu_{booster}$		Look up based on Dishwasher Type in Default Values table below.
$FuelSF_{wh}$	Electric WH: 0 Fossil Fuel WH: 1	
$FuelSF_{booster}$	Electric Booster: 0 Fossil Fuel Booster: 1	
hrs		From application. Default values use 6,570 which assumes 18 hours of run time per day, 365 days per year
F_{peak}	Peak Operation: 1 No Peak Operation: 0	From application.
CF	0.9	

Default Values[627]

Dishwasher Type	Elec. DHW (ΔkWh_{wh})	Fossil Fuel DHW ($\Delta MMBtu_{wh}$)	Elec. Booster ($\Delta kWh_{booster}$)	Fossil Fuel Booster ($\Delta MMBtu_{booster}$)	Dishwasher (ΔkWh_{idle})
Low Temp, Under Counter	2,540	10.6	N/A	N/A	0

[627] Deemed savings based on default values listed in Savings Calculator for ENERGY STAR® Commercial Kitchen Equipment (accessed 2/4/2018)

Dishwasher Type	Elec. DHW (ΔkWh_{wh})	Fossil Fuel DHW ($\Delta MMBtu_{wh}$)	Elec. Booster ($\Delta kWh_{booster}$)	Fossil Fuel Booster ($\Delta MMBtu_{booster}$)	Dishwasher (ΔkWh_{idle})
Low Temp, Stationary Single Tank Door	16,153	67.5	N/A	N/A	0
Low Temp, Single Tank Conveyor	13,042	54.5	N/A	N/A	584
Low Temp, Multi-Tank Conveyor	18,811	78.6	N/A	N/A	0
High Temp, Under Counter	1,082	4.5	618	2.6	1,471
High Temp, Stationary Single Tank Door	7,023	29.4	4,013	16.8	827
High Temp, Single Tank Conveyor	4,264	17.8	2,436	10.2	2,511
High Temp, Multi-Tank Conveyor	16,178	67.6	9,244	38.6	1,986
High Temp, Pot, Pan, and Utensil	2,107	8.8	1,204	5.0	0

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.9.[628]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a commercial dishwasher as defined in the Measure Description section above with type equivalent to the efficient case. Baseline specifications for idle energy rate, measured in kW, and water consumption, measured in gallons per rack (GPR), used in the formulation of default savings values are provided in the table below.[629]

[628] PG&E Work Paper PGECOFST126 Revision 0, Table 10, pg. 18
[629] Savings Calculator for ENERGY STAR® Commercial Kitchen Equipment (accessed 2/4/2018)

Machine Type	High Temp		Low Temp	
	Idle Energy Rate (kW)	Water Consumption (GPR)	Idle Energy Rate (kW)	Water Consumption (GPR)
Under Counter	≤ 0.76	≤ 1.09	≤ 0.50	≤ 1.73
Stationary Single Tank Door	≤ 0.87	≤ 1.29	≤ 0.60	≤ 2.10
Single Tank Conveyor	≤ 1.93	≤ 0.87	≤ 1.60	≤ 1.31
Multiple Tank Conveyor	≤ 2.59	≤ 0.97	≤ 2.00	≤ 1.04
Pot, Pan, Utensil	≤ 1.20	≤ 0.70	N/A	N/A

Compliance Efficiency from which Incentives are Calculated

The compliance condition is an ENERGY STAR® rated commercial dishwasher as defined in the Measure Description section above. Compliance specifications for idle energy rate, measure in kW, and water consumption, measured in gallons per rack (GPR) used in the formulation of default savings values are provided in the table below.[630]

Machine Type	High Temp		Low Temp	
	Idle Energy Rate (kW)	Water Consumption (GPR)	Idle Energy Rate (kW)	Water Consumption (GPR)
Under Counter	≤ 0.50	≤ 0.86	≤ 0.50	≤ 1.19
Stationary Single Tank Door	≤ 0.70	≤ 0.89	≤ 0.60	≤ 1.18
Single Tank Conveyor	≤ 1.50	≤ 0.70	≤ 1.50	≤ 0.79
Multiple Tank Conveyor	≤ 2.25	≤ 0.54	≤ 2.00	≤ 0.54
Pot, Pan, Utensil	≤ 1.20	≤ 0.58	N/A	N/A

Operating Hours

Operating hours shall come from application. Default savings assumes that dishwashers are available for operation 18 hours per day, 365 days per year.[631]

Example Calculation *(Not to be used as default)*

An ENERGY STAR® qualified electric high temp under counter dishwasher is installed in a hotel in NYC that operates for 6,000 hours a year including peak hours. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

[630] Savings Calculator for ENERGY STAR® Commercial Kitchen Equipment (accessed 2/4/2018)
[631] Savings Calculator for ENERGY STAR® Commercial Kitchen Equipment (accessed 2/4/2018)

$$\Delta kWh = units \times [(\Delta kWh_{wh} \times ElecSF_{wh}) + (\Delta kWh_{booster} \times ElecSF_{booster}) + \Delta kWh_{idle}]$$

$$\Delta kW = \frac{\Delta kWh}{hrs} \times F_{peak} \times CF$$

units = 1, from application
ΔkWh_{wh} = 1,082, from Default Values table based on dishwasher type
$\Delta kWh_{booster}$ = 618, from Default Values table based on dishwasher type
ΔkWh_{idle} = 1,471, from Default Values table based on dishwasher type
$ElecSF_{wh}$ = 1, from Summary of Variables and Data Sources table based on type of fuel
$ElecSF_{booster}$ = 1, from Summary of Variables and Data Sources table based on type of fuel
hrs = 6,000, from application
F_{peak} = 1, from application
CF = 0.9, from Summary of Variables and Data Sources table

$$\Delta kWh = 1 \times [(1{,}082 \times 1) + (618 \times 1) + 1{,}471] = 3{,}171\ kWh$$

$$\Delta kW = \frac{3{,}171}{6{,}000} \times 1 \times 0.9 = 0.475\ kW$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. ENERGY STAR® Program Requirements for Commercial Dishwashers Eligibility Criteria Version 2.0, February 2013
   Available From:
   https://www.energystar.gov/ia/products/commercial_food_service/comm_dishwashers/Final_Comm_Dish_Spec.pdf

2. ENERGY STAR® Certified Products, Commercial Food Service Equipment, Commercial Dishwashers

Available from:
https://www.energystar.gov/products/commercial_food_service_equipment/commercial_dishwashers

3. Pacific Gas & Electric Company, Work Paper PGECOFST126 Energy Efficient Door-Type Commercial Dishwashers, Revision 0, November 2015
   Available from: www.deeresources.net/workpapers
4. Savings calculator for ENERGY STAR® Commercial Kitchen Equipment, accessed February 4, 2018
   Available from:
   http://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator.xlsx

Record of Revision

Record of Revision Number	Issue Date
6-18-18	6/26/2018

Return to Table of Contents

ELECTRIC DECK OVEN

Measure Description

This measure covers the installation of efficient electric deck ovens. Commercial deck ovens cook food directly placed on the floor of a heater chamber. The bottom of each compartment is called a deck and heat is typically supplied by burners or elements located beneath the deck. The oven ceiling, floor, and walls are designed to absorb heat quickly and radiate that heat back slowly and evenly.[632] Deck ovens are available in various sizes measured by the surface area of the oven cavity floor. Sizes range from approximately 1,000 in^2 to 2,200 in^2. Deck ovens are typically stackable to allow for multiple ovens on a single floor space.[633]

Qualifying deck ovens must be rated according to ASTM Standard Test Method for Performance of Deck Ovens F1965-99,[634] and must meet or exceed a minimum of 60% cooking efficiency.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times days \times \frac{\left(\Delta BTU_{preheat} + \Delta BTU_{idle} + \Delta BTU_{cooking}\right)}{3{,}412}$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \frac{\Delta kWh}{(days \times hrs)} \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

where:

$$\Delta BTU_{preheat} = N_{preheat} \times \left(BTU_{preheat,baseline} - BTU_{preheat,ee}\right)$$

$$\Delta BTU_{idle} = \left(BTU/h_{idle,baseline} - BTU/h_{idle,ee}\right) \times \left[hrs - \left(N_{preheat} \times hrs_{preheat}\right) - \left(\frac{lbs}{lbs/hr}\right)\right]$$

$$\Delta BTU_{cooking} = lbs \times Q_{food} \times \left(\frac{1}{Eff_{baseline}} - \frac{1}{Eff_{ee}}\right)$$

[632] ENERGY STAR Program requirements for Commercial ovens, Version 2.2
[633] Cal TF Workpaper SWFS009-01 Revision 1, pg 2.
[634] American Society for Testing and Materials (ASTM). 2010. ASTM F1965-17, Standard Test Method for the Performance of Deck Ovens, West Conshohocken, PA: ASTM International.

NOTE: $\Delta BTU_{preheat}$, ΔBTU_{idle} and $\Delta BTU_{cooking}$ terms can be calculated per the equations above using any combination of actual qualifying equipment specifications and assumed values as defined in the Baseline Efficiencies, Compliance Efficiency and Operating Hours sections below, or looked up from the Default Values table below.

where:

ΔkWh	= Annual electricity energy savings
ΔkW	= Peak coincident demand electric savings
$\Delta MMBtu$	= Annual fossil fuel energy savings
$\Delta BTU_{preheat}$	= Daily preheat energy savings
ΔBTU_{idle}	= Daily idle energy savings
$\Delta BTU_{cooking}$	= Daily cooking energy savings
units	= Number of units installed
days	= Operating days per year
hrs	= Daily operating hours
$_{baseline}$	= Characteristic of baseline condition
$_{ee}$	= Characteristic of energy efficient condition
$BTU_{preheat}$	= Equipment preheat energy (BTU)
$N_{preheat}$	= Number of preheats per day
$hrs_{preheat}$	= Preheat duration (hours)
BTU/h_{idle}	= Equipment idle energy rate (BTU/h)
lbs/hr	= Equipment production capacity (lbs/hr)
lbs	= Total daily food production
Q_{food}	= Heat to food (BTU/lb)
Eff	= Equipment convection/steam mode cooking efficiency
CF	= Coincidence factor
3,412	= Conversion factor, one kW equals 3,412 BTU/h

Summary of Variables and Data Sources

Variable	Value	Notes
$\Delta BTU_{preheat}$		Calculate based on calculations above or look up in Default Values table below.
$\Delta BTU_{idle,}$		Calculate based on calculations above or look up in Default Values table below.
$\Delta BTU_{cooking}$		Calculate based on calculations above or look up in Default Values table below.
days		From application or look up based on facility type in Operating Hours section below.
hrs		From application or look up based on facility type in Operating Hours section below.
$N_{preheat}$	1	California Technical Forum Workpaper. [635]
$BTU_{preheat,baseline}$		Look up in Baseline Efficiencies section below.
$BTU_{preheat,ee}$		From application or look up in Compliance Efficiency section below.

[635] Cal TF Workpaper SWFS009-01 Revision 1, pg. 8

Variable	Value	Notes
$BTU/h_{idle,baseline}$		Look up in Baseline Efficiencies section below.
$BTU/h_{idle,ee}$		From application or look up in Compliance Efficiency section below
$hrs_{preheat}$	0.50	California Technical Forum[636]
lbs	200	From application or use value provided.[637]
lbs/hr		From application. If unknown, use 60 as default.
$Eff_{,baseline}$		Look up in Baseline Efficiencies section below.
Eff_{ee}		From application or look up in Compliance Efficiency section below.
Q_{food}	250	Heat to food (BTU/lb)[638]
CF	0.9	

Default Values

The table below contains values and simplified calculations for $\Delta BTU_{preheat}$, ΔBTU_{idle} and $\Delta BTU_{cooking}$ terms that may be used in the formulation of estimated savings in lieu of utilizing the calculations prescribed above for these terms. These values were established by performing those calculations using assumed values from the Summary of Variables and Data Sources above and Baseline Efficiencies and Compliance Efficiency sections below.

Equipment	$\Delta BTU_{preheat}$	ΔBTU_{idle}	$\Delta BTU_{cooking}$
Deck Oven, Electric	11,942	2,047 x hrs – 7,848	41,667

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.9.[639]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is an electric oven as defined in the Measure Description section above with operating characteristics per the table below.[640]

Equipment	$BTU_{preheat,baseline}$ (BTU)	$BTU/h_{idle,baseline}$ (BTU/h)	lbs/hr	$Eff_{baseline}$
Deck Oven, Electric	22,178	6,483	60	0.40

Compliance Efficiency from which Incentives are Calculated

The compliance condition is an electric deck oven meeting or exceeding a minimum of 60% cooking efficiency. Operating characteristics shall be taken from application. When unavailable,

[636] Ibid, pg. 8
[637] Ibid, pg. 8
[638] Ibid, pg. 8
[639] Ibid, pg. 9
[640] Ibid, pg. 3

default characteristics shall be taken from the table below. Performance specifications are as reported from the referenced California Technical Forum workpaper.[641]

Equipment	$BTU_{preheat,ee}$ (BTU)	$BTU/h_{idle,ee}$ (BTU/h)	lbs/hr	Eff_{ee}
Deck Oven, Electric	10,236	4,436	60	0.60

Operating Hours

Equipment operating hours per day and days per year shall be taken from the application if known. Default operating hours per day and days per year are provided below, established based on a weighted average of values associated with similar facility types, as reported by the California Energy Commission.[642]

Facility Type	Hours/Day	Days/Year
Community College	11	283
Fast Food	14	363
Full Service Restaurant	12	321
Grocery	12	365
Hospital	11	365
Hotel	20	365
Miscellaneous	9	325
Motel	20	365
Primary School	5	180
Secondary School	8	180
Small Office	12	250
University	11	283

Example Calculation *(Not to be used as default)*

Two electric deck ovens are installed in a secondary school in Syracuse. The electric deck ovens have 250 lb/day cooking capacity with 65 lbs/hr output. The ovens consume 11 kBTU while preheating and their idle energy rate is 4,879 BTU/h. The deck ovens have an efficiency rating of 65%. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

$$\Delta kWh = units \times days \times \frac{\left(\Delta BTU_{preheat} + \Delta BTU_{idle} + \Delta BTU_{cooking}\right)}{3{,}412}$$

$$\Delta kW = \frac{\Delta kWh}{(days \times hrs)} \times CF$$

[641] Cal TF workpaper SWFS009-01, pg. 3

[642] California Energy Commission, Characterizing the Energy Efficiency Potential of Gas-Fired Commercial Foodservice Equipment, Appendix E

$$\Delta BTU_{preheat} = N_{preheat} \times \left(BTU_{preheat,baseline} - BTU_{preheat,ee}\right)$$

$$\Delta BTU_{idle} = \left(BTU/h_{idle,baseline} - BTU/h_{idle,ee}\right) \times \left[hrs - \left(N_{preheat} \times hrs_{preheat}\right) - \left(\frac{lbs}{lbs/hr}\right)\right]$$

$$\Delta BTU_{cooking} = lbs \times Q_{food} \times \left(\frac{1}{Eff_{baseline}} - \frac{1}{Eff_{ee}}\right)$$

units = 2, from application
days = 8, from Operating Hours section based on facility type
hrs = 180, from Operating Hours section based on facility type
$N_{preheat}$ = 1, from Summary of Variables and Data Sources table
$BTU_{preheat,baseline}$ = 22,178 BTU, from Baseline Efficiencies from which energy savings are calculated
$BTU_{preheat,ee}$ = 11,000 BTU, from application
$BTU/h_{idle,baseline}$ = 6,483 BTU/h, from Baseline Efficiencies from which energy savings are calculated
$BTU/h_{idle,ee}$ = 4,879 BTU/h, from application
$hrs_{preheat}$ = 0.50, from Summary of Variables and Data Sources table
lbs = 250, from application
lbs/hr = 65, from application
Q_{food} = 250 BTU/lb, from Summary of Variables and Data Sources table
$Eff_{baseline}$ = 0.40, from Baseline Efficiencies from which energy savings are calculated
Eff_{ee} = 0.65, from application
CF = 0.9, from Summary of Variables and Data Sources table

$$\Delta BTU_{preheat} = 1 \times (22{,}178 - 11{,}000) = 11{,}178$$

$$\Delta BTU_{idle} = (6{,}483 - 4{,}879) \times \left[180 - (1 \times 0.5) - \left(\frac{250}{65}\right)\right] = 281{,}749$$

$$\Delta BTU_{cooking} = 250 \times 250 \times \left(\frac{1}{0.4} - \frac{1}{0.7}\right) = 66{,}964$$

$$\Delta kWh = 2 \times 8 \times \frac{(11{,}178 + 281{,}749 + 66{,}964)}{3{,}412} = 1{,}688\ kWh$$

$$\Delta kW = \frac{1688}{(8 \times 180)} \times 0.9 = 1.06\ kW$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

More efficient food service equipment rejects less heat into the condition space than standard equipment, increasing space heating requirements while decreasing cooling load. However, no relevant studies have been performed to date that would allow quantification of these impacts. Until additional information is available, these impacts are excluded from the prescribed formulation of savings.

Ancillary Electric Savings Impacts

More efficient food service equipment rejects less heat into the condition space than standard equipment, increasing space heating requirements while decreasing cooling load. However, no relevant studies have been performed to date that would allow quantification of these impacts. Until additional information is available, these impacts are excluded from the prescribed formulation of savings.

References

1. ENERGY STAR® Program Requirements Product Specification for Commercial Ovens, Eligibility Criteria, Version 2.2, October 2015
   Available from:
   https://www.energystar.gov/products/commercial_food_service_equipment/commercial_ovens/partners
2. California Technical Forum, Workpaper SWFS009-01, January 2020
   Available from: deeresources.net/workpapers
3. American Society for Testing and Materials (ASTM). 2010. ASTM F1965-17, Standard Test Method for the Performance of Deck Ovens, West Conshohocken, PA: ASTM International
4. California Energy Commission, Energy Research and Development Division, Characterizing the Energy Efficiency Potential of Gas-Fired Commercial Foodservice Equipment, October 2014

Record of Revision

Record of Revision Number	Issue Date
12-20-5	12/31/2020

Return to Table of Contents

FIREPLACE

Measure Description

This measure covers the installation of direct-vented, gas fireplaces with fireplace efficiency (FE) greater than or equal to 70% tested in accordance with the Canadian Standards Association (CSA) CSA-P.4 method and electric, intermittent pilot lights. This measure is only applicable to the installation of gas fireplaces for use as a supplemental heat source.

This analysis leverages the DOE Technical Support Document (TSD) for baseline fireplaces and pilot lights and a survey of US utilities for efficient fireplaces.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times \Delta kWh_{PilotLight}$$

Summer Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = units \times \left[\frac{kBTUh_{out}}{1{,}000} \times \left(\frac{1}{FE_{baseline}} - \frac{1}{FE_{ee}}\right) \times hrs + \Delta MMBtu_{PilotLight}\right]$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
$\Delta kWh_{PilotLight}$	= Change in electric consumption of pilot light
$kBTUh_{out}$	= Output capacity of fireplace in kBTU/h
baseline	= Characteristic of baseline condition
ee	= Characteristic of energy efficient condition
FE	= Rated efficiency of fireplace
hrs	= Annual operating hours of fireplace
$\Delta MMBtu_{PilotLight}$	= Change in fossil fuel consumption of pilot light
1,000	= Conversion factor, one MMBtu equals 1,000 kBTU

Summary of Variables and Data Sources

Variable	Value	Notes
$\Delta kWh_{PilotLight}$	-13.6	Baseline direct, vented gas fireplaces with a standing pilot light consumes no electric energy but consumes gas energy. Intermittent pilot lights consume electricity but save gas.[643]
$kBTUh_{out}$		From application
$FE_{baseline}$	0.64	Average efficiency of baseline fireplace[644]
FE_{ee}		From application.
hrs		From application. If unknown, facility open hours during the heating season may be used as a default.
$\Delta MMBtu_{PilotLight}$	3.49	Average MMBtu savings from switching from baseline, standing pilot light to intermittent pilot light[645]

Coincidence Factor (CF)

The prescribed coincidence factor for this measure is N/A. While there is an electric energy penalty due to the intermittent pilot light, there are no recommended demand savings due to fireplaces being operated during the heating season.[646]

Baseline Efficiencies from which Savings are Calculated

The baseline fireplace, as defined by DOE, is a direct-vented, gas fireplace with an FE of 64% and a standing pilot light.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a direct-vented gas fireplace with an FE of 70% or greater tested in accordance with the Canadian Standards Association (CSA) CSA-P.4 method and an intermittent pilot light.

Operating Hours

Operating hours of baseline and energy efficient fireplaces shall come from application.

[643] DOE Technical Support Document, Table 7.4.1: Average Annual Energy Consumption and Savings for Hearth Products
[644] DOE Technical Support Document, page 7-7.
[645] DOE Technical Support Document, Table 7.4.1: Average Annual Energy Consumption and Savings for Hearth Products
[646] Technical Support Document: Energy Conservation Program for Consumer Products: Energy Conservation Standards for Hearth Products. Chapters 7 and 8. The most common form of electronic ignition system found in hearth products is the intermittent pilot ignition. In an intermittent pilot ignition, the pilot light is only lit when there is a call for heat, and the pilot light is automatically extinguished after the burner is turned off. In order to ignite the pilot light, these systems require an outside power source, often supplied by either a battery or an electrical connection.

Example Calculation *(Not to be used as default)*

A commercial building in NYC installs a 90 kBTU/h direct vented gas fireplace with 80% efficiency that operates for 157 hours per year. The intermittent pilot light in the efficient fireplace consumes electricity but the fireplace saves gas. Summer Peak Coincident Demand Savings are not applicable. Annual Electric Energy Savings and Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta kWh = units \times \Delta kWh_{PilotLight}$$

$$\Delta MMBtu = units \times \left[\frac{kBTUh_{out}}{1{,}000} \times \left(\frac{1}{FE_{baseline}} - \frac{1}{FE_{ee}}\right) \times hrs + \Delta MMBtu_{PilotLight}\right]$$

units = 1, from application
$\Delta kWh_{PilotLight}$ = -13.6, from Summary of Variables and Data Sources
$\Delta MMBtu_{PilotLight}$ = 3.49, from Summary of Variables and Data Sources
$kBTUh_{out}$ = 90kBTU/h, from application
$FE_{basline}$ = 0.64, from Summary of Variables and Data Sources
FE_{ee} = 0.80, from application
hrs = 157, from application

$$\Delta kWh = 1 \times -13.6 = -13.6\ kWh$$

$$\Delta MMBtu = 1 \times \left[\frac{90}{1{,}000} \times \left(\frac{1}{0.64} - \frac{1}{0.80}\right) \times 157 + 3.49\right] = 7.90\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. Technical Support Document: Energy Conservation Program for Consumer Products: Energy Conservation Standards for Hearth Products. Chapters 7 and 8. Department of Energy (DOE). January 30, 2015.
   Available from: https://www.regulations.gov/document?D=EERE-2014-BT-STD-0036-0002.

2. A survey of US utilities offering rebates for high efficiency fireplaces and/or fireplaces with intermittent pilot lights found the minimum qualifying FE to be 70%. Utilities and organizations include Energy Trust of Oregon, CenterPoint Energy, Puget Sound Energy, Minnesota Energy Resources, and Dominion Energy Utah. Retrieved using *E-Source*.

Record of Revision

Record of Revision Number	Issue Date
7-20-9	7/31/2020

Return to Table of Contents

ICE MAKER

Measure Description

This measure covers the installation of ENERGY STAR® qualified ice makers. Ice makers are factory-made assemblies consisting of a condensing unit and ice-making section operating as an integrated unit, with means for making and harvesting ice. This measure includes batch-type (cube type) and continuous-type (flake or nugget type) ice makers. Batch-type ice makers have distinct freezing and harvesting periods whereas continuous-type ice makers produce ice through a continuous freezing and harvesting process. Ice makers that have earned the ENERGY STAR® label use approximately 11% less energy and 25% less water than comparable non-qualified models.[647]

This measure covers ice making head, remote condensing, and self-contained air-cooled ice makers. Water-cooled ice makers, ice and water dispensing systems, and air-cooled remote condensing units that are designed only for connection to remote rack compressors are not eligible for energy savings.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times (kWh_{baseline} - kWh_{ee}) \times 365 \times Cycle \times (IHR/100)$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \frac{\Delta kWh}{8{,}760 \times Cycle} \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
baseline	= Characteristic of baseline condition
ee	= Characteristic of energy efficient condition
kWh	= Daily electric energy consumption per 100 pounds of ice
Cycle	= Compressor duty cycle
IHR	= Rated Ice Harvest Rate (lbs/day) of the energy efficient ice maker
CF	= Coincidence factor
365	= Days in one year
100	= Factor to convert IHR to units of 100 lbs/day

[647] ENERGY STAR® Ice Machine Key Product Criteria

8,760 = Hours in one year

Summary of Variables and Data Sources

Variable	Value	Notes
$kWh_{baseline}$		Look up based on efficient Equipment Type and Ice Harvest Rate from Baseline Efficiency section below.
kWh_{ee}		From application. If unknown, look up based on efficient Equipment Type and Ice Harvest Rate from Compliance Efficiencies section below.
IHR		Rated capacity of efficient ice maker from application.
Cycle	0.75	Compressor duty cycle. [648]
CF	0.9	

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.9.[649]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a commercial ice maker as defined in the Measure Description section above with Equipment Type and Ice Harvest Rate equivalent to the efficient case. Baseline daily energy use per 100 lbs of ice shall be established based on efficient equipment Ice Harvest Rate in accordance with current federal standards for batch type[650] and continuous type[651] ice makers, as specified in the Code of Federal Regulations and provided in the table below.

Equipment Type	Ice Harvest Rate (IHR)	Maximum Daily Energy Use per 100 lbs ($kWh_{baseline}$)
Batch Type, Ice-Making Head	< 300	10 - 0.01233 x IHR
Batch Type, Ice-Making Head	≥ 300 and < 800	7.05 - 0.0025 x IHR
Batch Type, Ice-Making Head	≥ 800 and < 1,500	5.55 - 0.00063 x IHR
Batch Type, Ice-Making Head	≥ 1500 and < 4,000	4.61
Batch Type, Remote Condensing	< 988	7.97 - 0.00342 x IHR
Batch Type, Remote Condensing	≥ 988 and < 4,000	4.59
Batch Type, Self-Contained	< 110	14.79 - 0.0469 x IHR
Batch Type, Self-Contained	≥ 110 and < 200	12.42 - 0.02533 x IHR
Batch Type, Self-Contained	≥ 200 and < 4,000	7.35
Continuous Type, Ice-Making Head	< 310	9.19 - 0.00629 x IHR
Continuous Type, Ice-Making Head	≥ 310 and < 820	8.23 - 0.0032 x IHR
Continuous Type, Ice-Making Head	≥ 820 and < 4,000	5.61
Continuous Type, Remote Condensing	< 800	9.7 - 0.0058 x IHR

[648] PG&E Work Paper SWFS006-01, pg 9
[649] PG&E Work Paper SWFS006-01, pg 12
[650] 10 CFR 431.136 (c)
[651] 10 CFR 431.136 (d)

Equipment Type	Ice Harvest Rate (IHR)	Maximum Daily Energy Use per 100 lbs ($kWh_{baseline}$)
Continuous Type, Remote Condensing	≥ 800 and < 4,000	5.06
Continuous Type, Self-Contained	< 200	14.22 - 0.03 x IHR
Continuous Type, Self-Contained	≥ 200 and < 700	9.47 - 0.00624 x IHR
Continuous Type, Self-Contained	≥ 700 and < 4,000	5.1

Compliance Efficiency from which Incentives are Calculated

The compliance condition is an ENERGY STAR® qualified commercial ice maker as defined in the Measure Description above. Efficient condition daily energy use per 100 pounds of ice are established based on efficient equipment Ice Harvest Rate in accordance with ENERGY STAR® maximum qualifying specifications, as shown in the table below.[652]

Equipment Type	Ice Harvest Rate (IHR)	Maximum Daily Energy Use per 100 lbs (kWh_{ee})	Potable Water Use (gal/100 lbs ice)
Batch Type, Ice-Making Head	< 300	9.20 - 0.01134 x IHR	≤ 20.0
Batch Type, Ice-Making Head	≥ 300 and < 800	6.49 - 0.0023 x IHR	≤ 20.0
Batch Type, Ice-Making Head	≥ 800 and < 1,500	5.11 - 0.00058 x IHR	≤ 20.0
Batch Type, Ice-Making Head	≥ 1500 and < 4,000	4.24	≤ 20.0
Batch Type, Remote Condensing	< 988	7.17 - 0.00308 x IHR	≤ 20.0
Batch Type, Remote Condensing	≥ 988 and < 4,000	4.13	≤ 20.0
Batch Type, Self-Contained	< 110	12.57 - 0.0399 x IHR	≤ 25.0
Batch Type, Self-Contained	≥ 110 and < 200	10.56 - 0.0215 x IHR	≤ 25.0
Batch Type, Self-Contained	≥ 200 and < 4,000	6.25	≤ 25.0
Continuous Type, Ice-Making Head	< 310	7.90 - 0.005409 x IHR	≤ 15.0
Continuous Type, Ice-Making Head	≥ 310 and < 820	7.08 - 0.002752 x IHR	≤ 15.0
Continuous Type, Ice-Making Head	≥ 820 and < 4,000	4.82	≤ 15.0
Continuous Type, Remote Condensing	< 800	7.76 - 0.00464 x IHR	≤ 15.0

[652] ENEGY STAR® Program Requirements Product Specification for Automatic Commercial Ice Makers, Eligibility Criteria Version 3.0, January 2018

Equipment Type	Ice Harvest Rate (IHR)	Maximum Daily Energy Use per 100 lbs (kWh_{ee})	Potable Water Use (gal/100 lbs ice)
Continuous Type, Remote Condensing	≥ 800 and < 4,000	4.05	≤ 15.0
Continuous Type, Self-Contained	< 200	12.37 - 0.0261 x IHR	≤ 15.0
Continuous Type, Self-Contained	≥ 200 and < 700	8.24 - 0.005429 x IHR	≤ 15.0
Continuous Type, Self-Contained	≥ 700 and < 4,000	4.44	≤ 15.0

Operating Hours

Commercial ice makers are assumed to be available for operation 24 hours per day, 365 days per year with a compressor duty cycle of 0.75.[653]

Example Calculation *(Not to be used as default)*

An ENERGY STAR® qualified continuous-type ice making head ice machine with ice harvest rate of 500 lb/day is installed in a hotel in NYC. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

$$\Delta kWh = units \times (kWh_{baseline} - kWh_{ee}) \times 365 \times Cycle \times (IHR/100)$$

$$\Delta kW = \frac{\Delta kWh}{8{,}760 \times Cycle} \times CF$$

units = 1, from application

$kWh_{baseline}$ = 8.23 – 0.0032 x IHR = 8.32 – 0.0032 x 500 = 6.62kWh

$kWh_{baseline}$ equation based on Maximum Daily Energy use per 100lbs based on baseline equipment type

IHR = 500, from application

kWh_{ee} = 7.08 – 0.002752 x IHR =7.08 – 0.002752 x 500 = 5.704 kWh

kWh_{ee} equation based on Maximum Daily Energy use per 100lbs based on ENERGY STAR® qualified equipment type

IHR = 500, from application

cycle = 0.75, from Summary of Variables and Data Sources

IHR = 500, from application

CF = 0.9, from Summary of Variables and Data Sources

$$\Delta kWh = 1 \times (6.63 - 5.704) \times 365 \times 0.75 \times \left(\frac{500}{100}\right) = 1{,}267.46\ kWh$$

[653] PG&E Work Paper SWFS006-01, pg 9

$$\Delta kW = \frac{1{,}267.46}{8{,}760 \times 0.75} \times 0.9 = 0.173\ kW$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Efficient ice makers reject less heat than standard equipment, increasing space heating requirements while decreasing cooling load, when located inside a conditioned area. However, this interactivity is considered negligible for the installation of an air-cooled ice maker and is not included in the energy savings calculation.

Ancillary Electric Savings Impacts

Efficient ice makers reject less heat than standard equipment, increasing space heating requirements while decreasing cooling load, when located inside a conditioned area. However, this interactivity is considered negligible for the installation of an air-cooled ice maker and is not included in the energy savings calculation.

References

1. ENERGY STAR® Program Requirements Product Specification for Automatic Commercial Ice Makers Eligibility Criteria Version 3.0, January 2018
   Available from:
   https://www.energystar.gov/sites/default/files/asset/document/Final%20V3.0%20ACIM%20Specification%205-17-17_1_1.pdf
2. ENERGY STAR® Certified Products, Commercial Ice Makers
   Available from:
   https://www.energystar.gov/products/commercial_food_service_equipment/commercial_ice_makers
3. Pacific Gas & Electric Work Paper SWFS006-01 Commercial Ice Machines, January, 2020.
   Available from: www.deeresources.net/workpapers
4. 10 CFR 431.136 Energy conservation standards and their effective dates
   Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=39bdf94d4be5c5dac50be36d83225fe4&mc=true&node=pt10.3.430&rgn=div5#_top

Record of Revision

Record of Revision Number	Issue Date
6-18-19	6/26/2018

Return to Table of Contents

INFRARED CHARBROILER

Measure Description

This measure covers the installation of infrared charbroilers. A charbroiler, also known as a chargrill or simply a broiler, contains a heat source underneath a sturdy grate to cook food. An infrared charbroiler operates through radiant rather than a combination of convective and radiant heat transfer.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = N/A$$

Summer Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = units \times days \times \frac{\left(\Delta BTU_{preheat} + \Delta BTU_{cooking}\right)}{1{,}000{,}000}$$

where:

$$\Delta BTU_{preheat} = \left(BTU/h_{preheat,baseline} - BTU/h_{preheat,ee}\right) \times N_{preheat} \times hrs_{preheat}$$

$$\Delta BTU_{cooking} = \left(BTU/h_{cooking,baseline} - BTU/h_{cooking,ee}\right) \times Cycle \times hrs_{cooking}$$

$$hrs_{cooking} = hrs - \left(hrs_{preheat} \times N_{preheat}\right)$$

where:

ΔkWh	= Annual electricity energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
$\Delta BTU_{preheat}$	= Daily preheat energy savings
$\Delta BTU_{cooking}$	= Daily cooking energy savings
units	= Number of measures installed under the program
days	= Operating days per year
$_{baseline}$	= Characteristic of baseline condition
$_{ee}$	= Characteristic of energy efficient condition
$BTU/h_{preheat}$	= Equipment preheat energy rate (BTU/h)
$N_{preheat}$	= Number of preheats per day
$BTU/h_{cooking}$	= Equipment cooking energy rate (BTU/h)
Cycle	= Duty cycle
hrs	= Daily operating hours

$hrs_{preheat}$ = Preheat duration (hours)
$hrs_{cooking}$ = Daily operating hours excluding preheat time
1,000,000 = Conversion factor, one MMBtu equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
$BTU/h_{preheat,baseline}$	64,000	FSTC Gas Broiler Life-Cycle Cost Calculator[654]
$BTU/h_{preheat,ee}$	54,000	FSTC Gas Broiler Life-Cycle Cost Calculator[655]
$N_{preheat}$	1	Pacific Gas and Electric.[656]
hrs		From application. Otherwise, look up based on facility type in the Hours/Day column of the Operating Hours table below.
$hrs_{preheat}$	0.25	FSTC Gas Broiler Life-Cycle Cost Calculator[657]
$hrs_{cooking}$	$= hrs - (hrs_{preheat} \times N_{preheat})$	
$BTU/h_{cooking,baseline}$	140,000	FSTC Gas Broiler Life-Cycle Cost Calculator[658]
$BTU/h_{cooking,ee}$	105,000	FSTC Gas Broiler Life-Cycle Cost Calculator[659]
Cycle	0.8	FSTC Gas Broiler Life-Cycle Cost Calculator[660]
days		From application or look up based on facility type in the Days/Year column of the Operating Hours table below.

Coincidence Factor (CF)

The prescribed coincidence factor is N/A

Baseline Efficiencies from which Energy Savings are Calculated

The baseline case for this measure is a charbroiler that contains a heat source underneath a sturdy grate to cook food with a combination of radiant, conductive, and convective heat.

[654] FSTC Gas Broiler Life-Cycle Cost Calculator, referenced by the the Illinois TRM Version 7.0, pg 68
[655] Ibid
[656] Ibid
[657] Ibid
[658] Ibid
[659] Ibid
[660] Ibid

Compliance Efficiency from which Incentives are Calculated

The compliance case is a charbroiler with infrared heating elements.

Coincidence Factor (CF)

The prescribed value for the coincidence factor is N/A.

Operating Hours

Equipment operating hours per day and days per year shall be taken from the application if known. Default operating hours per day and days per year are provided below, established based on a weighted average of values associated with similar facility types, as reported by the California Energy Commission.[661]

Facility Type	Hours/Day	Days/Year
Community College	11	283
Fast Food	14	363
Full Service Restaurant	12	321
Grocery	12	365
Hospital	11	365
Hotel	20	365
Miscellaneous	9	325
Motel	20	365
Primary School	5	180
Secondary School	8	180
Small Office	12	250
University	11	283

Example Calculation *(Not to be used as default)*

An infrared charbroiler is installed in a hotel kitchen in NYC. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are not applicable. Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta MMBtu = units \times days \times \frac{\left(\Delta BTU_{preheat} + \Delta BTU_{cooking}\right)}{1{,}000{,}000}$$

where:

$$\Delta BTU_{preheat} = \left(BTU/h_{preheat,baseline} - BTU/h_{preheat,ee}\right) \times N_{preheat} \times hrs_{preheat}$$

$$\Delta BTU_{cooking} = \left(BTU/h_{cooking,baseline} - BTU/h_{cooking,ee}\right) \times Cycle \times hrs_{cooking}$$

[661] California Energy Commission, Characterizing the Energy Efficiency Potential of Gas-Fired Commercial Foodservice Equipment, Appendix E

$$hrs_{cooking} = hrs - (hrs_{preheat} \times N_{preheat})$$

units = 1, from application
days = 356 days/year, from Operating Hours section based on facility type
$BTU/h_{preheat,baseline}$ = 64,000 BTU/h, from Summary of Variables and Data Sources
$BTU/h_{preheat,ee}$ = 54,000 BTU/h, from Summary of Variables and Data Sources
$N_{preheat}$ = 1, from Summary of Variables and Data Sources
$hrs_{preheat}$ = 0.25, from Summary of Variables and Data Sources
$BTU/h_{cooking,baseline}$ = 140,000 BTU/h, from Summary of Variables and Data Sources
$BTU/h_{cooking,ee}$ = 105,000 BTU/h, from Summary of Variables and Data Sources
Cycle = 0.8, from Summary of Variables and Data Sources
hrs = 20 hours/day, from Operating Hours section based on facility type

$$\Delta BTU_{preheat} = (64{,}000 - 54{,}000) \times 1 \times 0.25 = 2{,}500$$

$$hrs_{cooking} = 20 - (0.25 \times 1) = 19.75$$

$$\Delta BTU_{cooking} = (140{,}000 - 105{,}000) \times 0.8 \times 19.75 = 553{,}000$$

$$\Delta MMBtu = 1 \times 365 \times \frac{(2{,}500 + 553{,}000)}{1{,}000{,}000} = 202.8\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

More efficient food service equipment rejects less heat into the condition space than standard equipment, increasing space heating requirements while decreasing cooling load. However, no relevant studies have been performed to date that would allow quantification of these impacts. Until additional information is available, these impacts are excluded from the prescribed formulation of savings.

Ancillary Electric Savings Impacts

More efficient food service equipment rejects less heat into the condition space than standard equipment, increasing space heating requirements while decreasing cooling load. However, no relevant studies have been performed to date that would allow quantification of these impacts. Until additional information is available, these impacts are excluded from the prescribed formulation of savings.

References

1. 2019 Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 7.0. September 13, 2018 (accessed July 28, 2019) Available from: http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_7/Final/2019_IL-TRM_Version_7.0_dated_Sept-13-2018_Final_Volumes_1-4_Compiled.pdf
2. California Energy Commission, Energy Research and Development Division, Characterizing the Energy Efficiency Potential of Gas-Fired Commercial Foodservice Equipment, October 2014.
   Available from: http://www.energy.ca.gov/2014publications/CEC-500-2014-095/CEC-500-2014-095.pdf

Record of Revision

Record of Revision Number	Issue Date
12-19-10	12/23/2019

Return to Table of Contents

INFRARED SALAMANDER BROILER

Measure Description

This measure covers the installation of fossil fuel-fired, commercial standalone infrared salamander broilers. Infrared broilers operate through radiant rather than convective heat transfer. Salamander broilers are used for broiling, browning, caramelizing, glazing, grilling, and toasting. Also known as back shelf broilers, they are particularly common for searing proteins such as beef and chicken.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = N/A$$

Summer Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = units \times \frac{(kBTU/h_{baseline} - kBTU/h_{ee}) \times cycle \times hrs}{1{,}000}$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of infrared salamander broilers installed under the program
kBTU/h	= Heating capacity input rating
$_{baseline}$	= Characteristic of baseline condition
$_{ee}$	= Characteristic of energy efficient condition
cycle	= Broiler duty cycle
hrs	= Operating hours per year
1,000	= Conversion factor, one MMBtu equals 1,000 kBTU

Summary of Variables and Data Sources

Variable	Value	Notes
$kBTU/h_{baseline}$		From application, or use 38.5 as default[662]
$kBTU/h_{ee}$		From application.
cycle		From application, or use 0.7 as default[663]

[662] Derived by taking the average rated salamander broiler from FSTC Commercial Cooking Appliance Technology Assessment, Table 4-3.
[663] FSTC Commercial Cooking Appliance Technology Assessment, Table 4-3.

Variable	Value	Notes
hrs		From application, or use 2,496 as default[664]

Coincidence Factor (CF)

The prescribed value for the coincidence factor is N/A.

Baseline Efficiencies from which Energy Savings are Calculated

The baseline case for this measure is an existing fossil fuel-fired salamander broiler without infrared burners.

Compliance Efficiency from which Incentives are Calculated

The compliance case is the installation of a fossil fuel-fired salamander broiler with infrared burners.

Operating Hours

The annual operating hours for infrared salamander broilers will be site-specific and taken from the application. If unknown, the annual operating hours of infrared salamander broilers are assumed to be 2,496.[665]

Example Calculation *(Not to be used as default)*

Two standalone gas-fired infrared salamander broilers with 44 kBTU/h capacity each are installed in a restaurant in Albany, replacing conventional gas-fired broilers with 48k BTU/h capacity. The infrared broilers operate for 2,700 hours per year. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are not applicable. Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta MMBtu = units \times \frac{(kBTU/h_{baseline} - kBTU/h_{ee}) \times cycle \times hrs}{1{,}000}$$

units = 2, from application
$kBTU/h_{baseline}$ = 48 kBTU/h, from application
$kBTU/h_{ee}$ = 44 kBTU/h, from application
cycle = 0.7, default value from Summary of Variables and Data Sources
hrs = 2,700 hours, from application

$$\Delta MMBtu = 2 \times \frac{(48 - 44) \times 0.7 \times 2{,}700}{1{,}000} = 15.12\ MMBtu$$

[664] Typical operating hours based on broiler operating schedule of 8 hours per day, 6 days per week, 52 weeks per year, provided in Food Service Technology Center Broiler Technical Assessment, Table 4.3
[665] Ibid

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

More efficient food service equipment rejects less heat into the condition space than standard equipment, increasing space heating requirements while decreasing cooling load. However, no relevant studies have been performed to date that would allow quantification of these impacts. Until additional information is available, these impacts are excluded from the prescribed formulation of savings.

Ancillary Electric Savings Impacts

More efficient food service equipment rejects less heat into the condition space than standard equipment, increasing space heating requirements while decreasing cooling load. However, no relevant studies have been performed to date that would allow quantification of these impacts. Until additional information is available, these impacts are excluded from the prescribed formulation of savings.

References

1. Food Service Technology Center, Commercial Cooking Appliance Technology Assessment, prepared for Enbridge Gas Distribution and Pacific Gas and Electric Company, by Fisher-Nickel Inc., 2002
   Available from:
   https://fishnick.com/equipment/techassessment/Appliance_Tech_Assessment.pdf

Record of Revision

Record of Revision Number	Issue Date
12-19-11	12/23/2019

Return to Table of Contents

INSULATED HOLDING CABINET

Measure Description

This measure covers the installation of ENERGY STAR® qualified electric commercial hot food holding cabinets.[666] A food holding cabinet is a fully enclosed compartment designed to maintain the temperature of hot food that has been cooked in a separate appliance. Half-size, full-size and large-size holding cabinets are included in this measure. Half-size holding cabinets are defined as any holding cabinet with an internal measured volume of less than 15ft^3. Full-size holding cabinets are defined as any holding cabinet with an internal measured volume of greater than or equal to 15ft^3 and less than or equal to 28ft^3. Large-size holding cabinets are defined as any holding cabinet with an internal measure volume of greater than 28ft^3. This measure does not include cook-and-hold or re-therm equipment.[667]

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times hrs \times days \times \frac{\Delta W_{idle}}{1{,}000}$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \frac{\Delta kWh}{(hrs \times days)} \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

where:

$$\Delta W_{idle} = W_{idle,baseline} - W_{idle,ee}$$

NOTE: ΔW_{idle} term can be calculated per the equation above using actual qualifying equipment specifications or looked up from the Default Values table below.

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
ΔW_{idle}	= Daily idle energy savings
units	= Number of measures installed under the program
hrs	= Daily operating hours

[666] ENERGY STAR® Program Requirements for Commercial Hot Food Holding Cabinets, Eligibility Criteria Version 2.0, July 2011
[667] PG&E Work Paper PGECOFST105 Revision 5, pg. 1

days = Operating days per year
v = Volume of holding cabinet (ft^3)
baseline = Characteristic of baseline condition
ee = Characteristic of energy efficient condition
W_{idle} = Equipment idle energy rate by volume (W)
CF = Coincidence factor
1,000 = Conversion factor, one kW equals 1,000 watts

Summary of Variables and Data Sources

Variable	Value	Notes
ΔW_{idle}		Calculate based on calculations above or look up in Default Values table below.
days		From application or look up based on facility type in Operating Hours section below.
hrs		From application or look up based on facility type in Operating Hours section below.
v	Large-Size: 35 Full-Size: 25 Half-Size: 10	From application or use default values provided.[668]
$W_{idle,baseline}$	40v	Equipment idle energy rate by volume (W).[669]
$W_{idle,ee}$	Large-Size: 3.8v + 203.5 Full-Size: 2v + 254 Half-Size: 21.5v	From application or use default value provided.[670]
CF	0.9	

Default Values

The table below contains ΔW_{idle} values that may be used in the formulation of estimated savings in lieu of utilizing the calculation prescribed above for this term. These values were established by performing that calculation using default values from the Summary of Variables and Data Sources above.

Equipment	ΔW_{idle}
Insulated Holding Cabinet, Large-Size	1,064
Insulated Holding Cabinet, Full-Size	696
Insulated Holding Cabinet, Half-Size	185

[668] PG&E Work Paper PGECOFST105 Revision 5, Table 6, pg. 5
[669] ENERGY STAR® Program Requirements for Commercial Hot Food Holding Cabinets, Eligibility Criteria Version 2.0, July 2011, where v is holding cabinet volume (ft^3)
[670] Ibid, where v is holding cabinet volume (ft^3)

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.9.[671]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is an insulated holding cabinet as defined in the Measure Description above with operating characteristics per the Summary of Variables and Data Sources table above.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is ENERGY STAR® food service equipment as defined in the Measure Description section above. Operating characteristics shall be taken from application. When unavailable, default characteristics shall be taken from the Summary of Variables and Data Sources table above.

Operating Hours

Equipment operating hours per day and days per year shall be taken from the application if known. Default operating hours per day and days per year are provided below, established based on a weighted average of values associated with similar facility types, as reported by the California Energy Commission.[672]

Facility Type	hours/day	days/year
Community College	11	283
Fast Food Restaurant	14	363
Full Service Restaurant	12	321
Grocery	12	365
Hospital	11	365
Hotel	20	365
Miscellaneous	9	325
Motel	20	365
Primary School	5	180
Secondary School	8	180
Office	12	250
University	11	283

Example Calculation *(Not to be used as default)*

An ENERGY STAR ® qualified electric half-size food holding cabinet with a volume of 12ft^3 is installed for use in a grocery store in NYC. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

[671] PG&E Work Paper PGECOFST105 Revision 5, pg. 7

[672] California Energy Commission, Characterizing the Energy Efficiency Potential of Gas-Fired Commercial Foodservice Equipment, Appendix E

$$\Delta kWh = units \times hrs \times days \times \frac{\Delta W_{idle}}{1{,}000}$$

$$\Delta W_{idle} = W_{idle,baseline} - W_{idle,ee}$$

$$\Delta kW = \frac{\Delta kWh}{(hrs \times days)} \times CF$$

units = 1, from application
hrs = 12 hours/day, from Operating Hours section based on facility type
days = 365 days/year, from Operating Hours section based on facility type
$W_{idle,baseline}$ = 40 x v = 40 x 12 = 480
$W_{idle,baseline}$ equation from Summary of Variables and Data Sources
v =12ft^3, from application
$W_{idle,ee}$ = 21.5 x v =21.5 x 12 = 258
$W_{idle,ee}$ equation from Summary of Variables and Data Sources
v =12ft^3, from application
CF = 0.9, from Summary of Variables and Data Sources

$$\Delta W_{idle} = 480 - 258 = 222$$

$$\Delta kWh = 1 \times 12 \times 365 \times \frac{222}{1{,}000} = 972.36\ kWh$$

$$\Delta kW = \frac{972.36}{(12 \times 365)} \times 0.9 = 0.20\ kW$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

More efficient food service equipment rejects less heat into the conditioned space than standard equipment, increasing space heating requirements while decreasing cooling load. However, no relevant studies have been found to date that would allow quantification of these impacts. Until additional information is available, these impacts are excluded from the prescribed formulation of savings.

Ancillary Electric Savings Impacts

More efficient food service equipment rejects less heat into the conditioned space than standard equipment, increasing space heating requirements while decreasing cooling load. However, no relevant studies have been found to date that would allow quantification of these impacts. Until additional information is available, these impacts are excluded from the prescribed formulation of savings.

References

1. ENERGY STAR® Program Requirements for Commercial Hot Food Holding Cabinets, Eligibility Criteria Version 2.0, July 2011.
   Available from:
   https://www.energystar.gov/sites/default/files/specs/private/Commercial_HFHC_Program_Requirements_2.0.pdf
2. Pacific Gas & Electric Company, Work Paper PGECOFST105 Insulated Holding Cabinet-Electric, Revision 5, July 2016.
3. California Energy Commission, Energy Research and Development Division, Characterizing the Energy Efficiency Potential of Gas-Fired Commercial Foodservice Equipment, October 2014.
   Available from: http://www.energy.ca.gov/2014publications/CEC-500-2014-095/CEC-500-2014-095.pdf

Record of Revision

Record of Revision Number	Issue Date
3-18-20	3/29/2018

Return to Table of Contents

OVEN, STEAMER, FRYER AND GRIDDLE

Measure Description

This measure covers the installation of ENERGY STAR® qualified commercial kitchen equipment that meet the descriptions below. Unless otherwise noted, presented baseline, compliance, and default values are determined from ENERGY STAR® Commercial Food Service Equipment Calculator.[673]

- Convection Ovens[674] - This measure includes gas and electric commercial convection ovens. A convection oven forces hot dry air over the surface of a food product. A full size convection oven can accommodate standard full size sheet pans measuring 18 x 26 x 1 inch. A half size convection oven can accommodate half size sheet pans measuring 18 x 13 x 1 inch. Though not eligible for ENERGY STAR® qualification, this measure includes half size gas convection ovens. Half size gas convection ovens must have an idle rate of 8,500 BTU/h or less, per assumed efficiency of qualified equipment by Pacific Gas & Electric workpaper.[675]
- Rack Ovens[676] - This measure includes gas commercial rack ovens. A rack oven is a high capacity oven in which a rack is wheeled into the oven and can be rotated during the baking process. Rack ovens range in capacity from mini rack ovens to quadruple rack ovens. Single and double rack ovens are included in this measure.
- Steamers[677] - This measure includes gas and electric commercial steamers, also known as compartment steamers. A steamer is a device that contains one or more food steaming compartments in which the energy in the steam is transferred to the food by direct contact. To calculate the savings for this measure, the number of pans must be known. Countertop, wall-mounted, and floor models mounted on a stand, pedestal, or cabinet-style base are included. Commercial steamer microwave ovens are not included in this measure.
- Fryers[678] - This measure includes gas and electric commercial deep-fat fryers. A deep-fat fryer is an appliance in which oils are placed to such a depth that the cooking food is essentially supported by displacement of the cooking fluid rather than by the bottom of the vessel. Depending on the fryer type, heat is delivered to the cooking fluid by means of an immersed electric element or band-wrapped vessel (electric fryers), or by heat transfer from gas burners through either the walls of the fryer or through tubes passing through the cooking fluid (gas fryers). Standard fryers and large vat fryers are included in this measure.
- Griddles[679] - This measure includes single-sided gas and electric commercial griddles. A single-sided commercial griddle is a commercial appliance designed for cooking food in oil or its own juices by direct contact with either a flat, smooth, hot surface or a hot

[673] ENERGY STAR® Commercial Food Service Equipment Calculator (accessed 2/26/2018)
[674] ENERGY STAR® Program Requirements Product Specification for Commercial Ovens, Eligibility Criteria, Version 2.2., March 2015
[675] PG&E Work Paper PGECOFST101 Revision 6, Table 12, pg. 18
[676] ENERGY STAR® Program Requirements Product Specification for Commercial Ovens, Eligibility Criteria, Version 2.2., March 2015
[677] ENREGY STAR® Program Requirements for Commercial Steam Cookers, Eligibility Criteria Version 1.2, August 2003
[678] ENERGY STAR® Program Requirements Product Specification for Commercial Fryers, Eligibility Criteria Final Draft Version 3.0. October 2016
[679] ENERGY STAR® Program Requirements for Commercial Griddles, Eligibility Criteria Version 1.2, January 2011

channeled cooking surface where plate temperature is thermostatically controlled. To calculate the energy savings in this measure, the griddle dimensions must be known. This measure does not include double-sided gas or electric commercial griddles.

- Gas Conveyor Ovens - Though not eligible for ENERGY STAR® qualification, this measure additionally covers the installation of energy efficient gas conveyor ovens. Conveyor ovens cook food by carrying it on a moving belt through a heated chamber. Qualifying conveyor ovens have baking efficiencies greater than or equal to 42% and idle energy rates less than or equal to 57,000 BTU/h, per assumed efficiency of qualified equipment by Pacific Gas and Electric workpaper.[680]

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings (Electric Equipment Only)

$$\Delta kWh = units \times days \times \frac{\left(\Delta BTU_{preheat} + \Delta BTU_{idle} + \Delta BTU_{cooking}\right)}{3{,}412}$$

Summer Peak Coincident Demand Savings (Electric Equipment Only)

$$\Delta kW = \frac{\Delta kWh}{(days \times hrs)} \times CF$$

Annual Fossil Fuel Energy Savings (Fossil Fuel Equipment Only)

$$\Delta MMBtu = units \times days \times \frac{\left(\Delta BTU_{preheat} + \Delta BTU_{idle} + \Delta BTU_{cooking}\right)}{1{,}000{,}000}$$

where:

$$\Delta BTU_{preheat} = N_{preheat} \times \left(BTU_{preheat,baseline} - BTU_{preheat,ee}\right)$$

$$\Delta BTU_{idle} = BTU/h_{idle,baseline} \times \left[hrs - N_{preheat} \times hrs_{preheat} - \left(\frac{lbs}{(lbs/hr)_{baseline}}\right)\right] - BTU/h_{idle,ee} \times \left[hrs - N_{preheat} \times hrs_{preheat} - \left(\frac{lbs}{(lbs/hr)_{ee}}\right)\right]$$

$$\Delta BTU_{cooking} = lbs \times Q_{food} \times \left(\frac{1}{Eff_{baseline}} - \frac{1}{Eff_{ee}}\right)$$

NOTE: $\Delta BTU_{preheat}$, ΔBTU_{idle} and $\Delta BTU_{cooking}$ terms can be calculated per the equations above using either actual qualifying equipment specs or default values as defined in the Common Variables, Baseline Efficiencies, Compliance Efficiency and Operating Hours sections below, or looked up from the Default Values table below.

[680] PG&E Work Paper PGECOFST117 Revision 5, Table 9, pg. 11-12, where 1 pizza equals 0.76 lbs

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
$\Delta MMBtu$	= Annual fossil fuel energy savings
$\Delta BTU_{preheat}$	= Daily preheat energy savings
ΔBTU_{idle}	= Daily idle energy savings
$\Delta BTU_{cooking}$	= Daily cooking energy savings
units	= Number of measures installed under the program
days	= Operating days per year
hrs	= Daily operating hours
$_{baseline}$	= Characteristic of baseline condition
$_{ee}$	= Characteristic of energy efficient condition
$BTU_{preheat}$	= Equipment preheat energy (BTU)
$N_{preheat}$	= Number of preheats per day
$hrs_{preheat}$	= Preheat duration (hours)
BTU/h_{idle}	= Equipment idle energy rate (BTU/h)
(lbs/hr)	= Equipment production capacity (lbs/hr)
lbs	= Total daily food production
Q_{food}	= Heat to food (BTU/lb)
Eff	= Equipment convection/steam mode cooking efficiency
CF	= Coincidence factor
3,412	= Conversion factor, one kW equals 3,412 BTU/h
1,000,000	= Conversion factor, one MMBtu equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
$\Delta BTU_{preheat}$		Calculate based on calculations above or look up in Default Values table below.
ΔBTU_{idle}		Calculate based on calculations above or look up in Default Values table below.
$\Delta BTU_{cooking}$		Calculate based on calculations above or look up in Default Values table below.
days		From application or look up based on facility type in Operating Hours section below.
hrs		From application or look up based on facility type in Operating Hours section below.
$N_{preheat}$	1	Pacific Gas and Electric. [681]
$BTU_{preheat,baseline}$		Look up based on qualifying equipment type in Baseline Efficiencies section below.
$BTU_{preheat,ee}$		From application or look up based on qualifying equipment type in Compliance Efficiency section below.
$BTU/h_{idle,baseline}$		Look up based on qualifying equipment type in Baseline Efficiencies section below.

[681] Shared assumption from all PG&E Work Papers referenced in this measure

Variable	Value	Notes
$BTU/h_{idle,ee}$		From application or look up based on qualifying equipment type in Compliance Efficiency section below.
$hrs_{preheat}$		Look up based on qualifying equipment type in Common Variables table below.
$(lbs/hr)_{baseline}$		Look up based on qualifying equipment type in Baseline Efficiencies section below.
$(lbs/hr)_{ee}$		From application or look up based on qualifying equipment type in Compliance Efficiency section below
Lbs		From application or look up based on qualifying equipment type in Common Variables table below.
Q_{food}		Look up based on qualifying equipment type in Common Variables table below.
$Eff_{baseline}$		Look up based on qualifying equipment type in Baseline Efficiencies section below.
Eff_{ee}		From application or look up based on qualifying equipment type in Compliance Efficiency section below.
CF	0.9	

Default Values

The table below contains values and simplified calculations for $\Delta BTU_{preheat}$, ΔBTU_{idle} and $\Delta BTU_{cooking}$ terms that may be used in the formulation of estimated savings in lieu of utilizing the calculations prescribed above for these terms. These values were established by performing those calculations using assumed values from the Common Variables, Baseline Efficiencies and Compliance Efficiency sections below.

Equipment	$\Delta BTU_{preheat}$	ΔBTU_{idle}	$\Delta BTU_{cooking}$
Convection Oven, Electric, Full Size	1,706	1,365 x hrs - 1,858	3,250
Convection Oven, Electric, Half Size	341	102 x hrs - 1,011	1,553
Convection Oven, Gas, Full Size	8,000	3,100 x hrs - 5,014	2,470
Convection Oven, Gas, Half Size	5,500	3,500 x hrs - 12,087	27,778
Conveyor Oven, Gas	17,000	13,000 x hrs - 55,144	124,405
Rack Oven, Gas, Double Rack	15,000	35,000 x hrs – 179,550	423,077
Rack Oven, Gas, Single Rack	6,000	18,000 x hrs - 89,017	187,500
Steamer, Electric[682]	0	14,581 x hrs – 11,229	19,385
Steamer, Gas[683]	11,000	27,378 x hrs – 23,977	42,368
Fryer, Electric, Standard	1,706	1,365 x hrs - 3,941	10,988
Fryer, Electric, Large Vat	1,194	853 x hrs - 2,005	15,268
Fryer, Gas, Standard	2,500	5,000 x hrs - 15,481	73,286
Fryer, Gas, Large Vat	5,000	4,000 x hrs - 8,636	73,286
Griddle, Electric[684]	6,834	1,638 x hrs - 7,451	5,220

[682] Assumes 6 pans
[683] Assumes 6 pans
[684] Assumes 3-foot griddle width, 2-foot griddle depth

Equipment	$\Delta BTU_{preheat}$	ΔBTU_{idle}	$\Delta BTU_{cooking}$
Griddle, Gas[685]	6,000	5,100 x hrs - 49,875	23,438

Common Variables[686]

Equipment	Value		
	$hrs_{preheat}$	lbs	Q_{food} (BTU/lb)
Convection Oven, Electric, Full Size	0.25[687]	100	250
Convection Oven, Electric, Half Size	0.25[688]	100	250
Convection Oven, Gas, Full Size	0.25[689]	100	250
Convection Oven, Gas, Half Size	0.25[690]	100	250
Conveyor Oven, Gas	0.25[691]	190	250
Rack Oven, Gas, Double Rack	0.33[692]	1,200[693]	250
Rack Oven, Gas, Single Rack	0.33[694]	600	250
Steamer, Electric	0.25[695]	100	105
Steamer, Gas	0.25[696]	100	105
Fryer, Electric, Standard	0.25[697]	150	570
Fryer, Electric, Large Vat	0.25[698]	150	570
Fryer, Gas, Standard	0.25[699]	150	570
Fryer, Gas, Large Vat	0.25[700]	150	570
Griddle, Electric	0.25[701]	100	475
Griddle, Gas	0.25[702]	100	475

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.9.[703]

[685] Assumes 3-foot griddle width, 2-foot griddle depth
[686] ENERGY STAR® Commercial Food Service Equipment Calculator (accessed 2/26/2018), unless otherwise noted
[687] PG&E Work Paper PGECOFST101 Revision 6, Table 10, pg. 15
[688] PG&E Work Paper PGECOFST101 Revision 6, Table 9, pg. 14
[689] PG&E Work Paper PGECOFST101 Revision 6, Table 13, pg. 18
[690] PG&E Work Paper PGECOFST101 Revision 6, Table 12, pg. 18
[691] PG&E Work Paper PGECOFST117 Revision 5, Table 9, pg. 11-12, where 1 pizza equals 0.76 lbs
[692] PG&E Work Paper PGECOFST109 Revision 6, Table 7, pg. 12
[693] Ibid
[694] PG&E Work Paper PGECOFST109 Revision 6, Table 7, pg. 12
[695] PG&E Work Paper PGECOFST104 Revision 6, Table 11, pg. 13
[696] PG&E Work Paper PGECOFST104 Revision 6, Table 12, pg. 15
[697] PG&E Work Paper PGECOFST102 Revision 6, Table 10, pg. 7
[698] PG&E Work Paper PGECOFST102 Revision 6, Table 10, pg. 7
[699] PG&E Work Paper PGECOFST102 Revision 6, Table 11, pg. 10
[700] PG&E Work Paper PGECOFST102 Revision 6, Table 11, pg. 10
[701] Cal TF Work Paper SWFS004 Revision 1,pg. 7
[702] Cal TF Work Paper SWFS004 Revision 1,pg. 10
[703] Shared assumption from all PG&E Work Papers referenced in this measure

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is food service equipment as defined in the Measure Description above with operating characteristics per the table below. Values are as reported from referenced ENERGY STAR® Commercial Food Service Equipment Calculator unless otherwise noted.[704] Preheat energy and all values for half size gas convection ovens and conveyor ovens are reported from referenced FSTC sources.

Equipment	$BTU_{preheat,baseline}$ (BTU)	$BTU/h_{idle,baseline}$ (BTU/h)	$(lbs/hr)_{baseline}$	$Eff_{baseline}$
Convection Oven, Electric, Full Size	5,118[705]	6,824	90	0.65
Convection Oven, Electric, Half Size	3,412[706]	3,514	45	0.68
Convection Oven, Gas, Full Size	19,000[707]	15,100	83	0.44
Convection Oven, Gas, Half Size[708]	13,000	12,000	45	0.30
Conveyor Oven, Gas[709]	35,000	70,000	114	0.20
Rack Oven, Gas, Double Rack	100,000[710]	65,000	250	0.30
Rack Oven, Gas, Single Rack	50,000[711]	43,000	130	0.30
Steamer, Electric	5,118[712]	2,047 + 3,767 x no. pans[713]	23.3 x no. pans	0.26
Steamer, Gas	20,000[714]	9,000 + 6,524 x no. pans[715]	23.3 x no. pans	0.15
Fryer, Electric, Standard	8,189[716]	4,094	65	0.75
Fryer, Electric, Large Vat	10,577[717]	4,606	100	0.70
Fryer, Gas, Standard	18,500[718]	14,000	60	0.35
Fryer, Gas, Large Vat	27,000[719]	16,000	100	0.35
Griddle, Electric	2,275 x griddle area[720]	1,365 x griddle area	5.83 x griddle area	0.65
Griddle, Gas	3,500 x griddle area[721]	3,500 x griddle area	4.17 x griddle area	0.32

[704] ENERGY STAR® Commercial Food Service Equipment Calculator (accessed 2/26/2018)
[705] PG&E Work Paper PGECOFST101 Revision 6, Table 10, pg. 15
[706] PG&E Work Paper PGECOFST101 Revision 6, Table 9, pg. 14
[707] PG&E Work Paper PGECOFST101 Revision 6, Table 13, pg. 18
[708] PG&E Work Paper PGECOFST101 Revision 6, Table 12, pg. 18
[709] PG&E Work Paper PGECOFST117 Revision 5, Table 9, pg. 11-12, where 1 pizza equals 0.76 lbs
[710] PG&E Work Paper PGECOFST109 Revision 6, Table 7, pg. 12
[711] Food Service Technology Center: Gas Rack Oven Life-Cycle Cost Calculator
[712] PG&E Work Paper PGECOFST104 Revision 6, Table 11, pg. 13
[713] Represents energy rate when steamers are in idle mode and in constant steam mode: $(1 – Ts)*BTU/h_{idle,baseline} + Ts*(lb/hr)_{baseline}*Q_{food}/Eff_{baseline}$, where Ts (time in constant steam mode) = 40% of non-cook time and $BTU/h_{idle,baseline}$ = 3,412 BTU/h for baseline electric steamers
[714] PG&E Work Paper PGECOFST104 Revision 6, Table 11, pg. 13
[715] Represents energy rate when steams are in idle mode and in constant steam mode: $(1 – Ts)*BTU/h_{idle,baseline} + Ts*(lb/hr)_{baseline}*Q_{food}/Eff_{baseline}$, where Ts (time in constant steam mode) = 40% of non-cook time and $BTU/h_{idle,baseline}$ = 15,000 BTU/h for baseline gas steamers
[716] PG&E Work Paper PGECOFST102 Revision 6, Table 10, pg. 7
[717] Food Service Technology Center: Electric Fryer Life-Cycle Cost Calculator
[718] PG&E Work Paper PGECOFST102 Revision 6, Table 11, pg. 10
[719] Food Service Technology Center: Gas Fryer Life-Cycle Cost Calculator
[720] Cal TF Work Paper SWFS004 Revision 1,pg. 7
[721] Cal TF Work Paper SWFS004 Revision 1,pg. 10

Compliance Efficiency from which Incentives are Calculated

The compliance condition is ENERGY STAR® food service equipment or, in the case of conveyor ovens and half size gas convection ovens, equipment aligning with FSTC assumptions for energy efficient products meeting the minimum performance specifications listed in the table below. Operating characteristics shall be taken from application. When unavailable, default characteristics shall be taken from the table below. Values are as reported from the ENERGY STAR® Commercial Food Service Equipment Calculator, unless otherwise noted.[722] Preheat energy and all values for half size gas convection ovens and conveyor ovens are reported from referenced FSTC sources.

Equipment	$BTU_{preheat,ee}$ (BTU)	$BTU/h_{idle,ee}$ (BTU/h)	$(lbs/hr)_{ee}$	Eff_{ee}
Convection Oven, Electric, Full Size	3,412[723]	5,459	90	0.71
Convection Oven, Electric, Half Size	3,071[724]	3,412	50	0.71
Convection Oven, Gas, Full Size	11,000[725]	12,000	86	0.46
Convection Oven, Gas, Half Size[726]	7,500	8,500	55	0.45
Conveyor Oven, Gas[727]	18,000	57,000	167	0.42
Rack Oven, Gas, Double Rack	85,000[728]	30,000	250	0.52
Rack Oven, Gas, Single Rack	44,000[729]	25,000	130	0.48
Steamer, Electric	5,118[730]	1,678 x no. pans*[731]	16.7 x no. pans	0.50
Steamer, Gas	9,000[732]	3,463 x no. pans*[733]	20.0 x no. pans	0.38
Fryer, Electric, Standard	6,483[734]	2,730	70	0.83
Fryer, Electric, Large Vat	9,383[735]	3,753	110	0.80
Fryer, Gas, Standard	16,000[736]	9,000	65	0.50
Fryer, Gas, Large Vat	22,000[737]	12,000	110	0.50

[722] ENERGY STAR® Commercial Food Service Equipment Calculator (accessed 2/26/2018)
[723] PG&E Work Paper PGECOFST101 Revision 6, Table 10, pg. 15
[724] PG&E Work Paper PGECOFST101 Revision 6, Table 9, pg. 14
[725] PG&E Work Paper PGECOFST101 Revision 6, Table 13, pg. 18
[726] PG&E Work Paper PGECOFST101 Revision 6, Table 12, pg. 18
[727] PG&E Work Paper PGECOFST117 Revision 5, Table 9, pg. 11-12, where 1 pizza equals 0.76 lbs
[728] PG&E Work Paper PGECOFST109 Revision 6, Table 7, pg. 12
[729] Food Service Technology Center: Gas Rack Oven Life-Cycle Cost Calculator
[730] PG&E Work Paper PGECOFST104 Revision 6, Table 11, pg. 13
[731] Represents energy rate when steamer are in idle mode and in constant steam mode: $(1 – Ts)*BTU/h_{idle,ee} + Ts*(lb/hr/pan)*Q_{food}/Eff_{ee}$, where Ts (time in constant steam mode) = 40% of non-cook time and $BTU/h_{idle,ee}$ = 455 BTU/h x no. of pans for compliance electric steamers
[732] PG&E Work Paper PGECOFST104 Revision 6, Table 11, pg. 13
[733] Represents energy rate when steamers are in idle mode and in constant steam mode: $(1 – Ts)*BTU/h_{idle,ee}+ Ts*(lb/hr/pan)*Q_{food}/Eff_{ee}$, where Ts (time in constant steam mode) = 40% of non-cook time and $BTU/h_{idle,ee}$ = 2,088 BTU/h x no. of pans for compliance gas steamers
[734] PG&E Work Paper PGECOFST102 Revision 6, Table 10, pg. 7, preheat energy assumes 15min
[735] Food Service Technology Center: Electric Fryer Life-Cycle Cost Calculator, preheat energy assumes 20min
[736] PG&E Work Paper PGECOFST102 Revision 6, Table 11, pg. 10, preheat energy assumes 15min
[737] Food Service Technology Center: Gas Fryer Life-Cycle Cost Calculator, preheat energy assumes 20min

Equipment	$BTU_{preheat,ee}$ (BTU)	$BTU/h_{idle,ee}$ (BTU/h)	$(lbs/hr)_{ee}$	Eff_{ee}
Griddle, Electric	1,136 x griddle area[738]	1,092 x griddle area	6.67 x griddle area	0.70
Griddle, Gas	2,500 x griddle area[739]	2,650 x griddle area	7.5 x griddle area	0.38

* For steamers with greater than 6 pans, assume no. pans equals 6 for steamer idle energy rate

Operating Hours

Equipment operating hours per day and days per year shall be taken from the application if known. Default operating hours per day and days per year are provided below, established based on a weighted average of values associated with similar facility types, as reported by the California Energy Commission.[740]

Facility Type	hours/day	days/year
Community College	11	283
Fast Food Restaurant	14	363
Full Service Restaurant	12	321
Grocery	12	365
Hospital	11	365
Hotel	20	365
Miscellaneous	9	325
Motel	20	365
Primary School	5	180
Secondary School	8	180
Office	12	250
University	11	283

Example Calculation *(Not to be used as default)*

A full-size electric convection oven with 90 lb/hr capacity, 3,470 $BTU_{preheat}$, 5,500 BTU/h_{idle} and 72% efficiency is installed in a restaurant in NYC, which operates for 12 hours a day for 320 days per year. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

$$\Delta kWh = units \times days \times \frac{\left(\Delta BTU_{preheat} + \Delta BTU_{idle} + \Delta BTU_{cooking}\right)}{3{,}412}$$

$$\Delta kW = \frac{\Delta kWh}{(days \times hrs)} \times CF$$

[738] Cal TF Work Paper SWFS004 Revision 1,pg. 7
[739] Cal TF Work Paper SWFS004 Revision 1,pg. 10
[740] California Energy Commission, Characterizing the Energy Efficiency Potential of Gas-Fired Commercial Foodservice Equipment, Appendix E

where:

$$\Delta BTU_{preheat} = N_{preheat} \times \left(BTU_{preheat,baseline} - BTU_{preheat,ee}\right)$$

$$\Delta BTU_{idle} = BTU/h_{idle,baseline} \times \left[hrs - N_{preheat} \times hrs_{preheat} - \left(\frac{lbs}{(lbs/hr)_{baseline}}\right)\right] - BTU/h_{idle,ee} \times \left[hrs - N_{preheat} \times hrs_{preheat} - \left(\frac{lbs}{(lbs/hr)_{ee}}\right)\right]$$

$$\Delta BTU_{cooking} = lbs \times Q_{food} \times \left(\frac{1}{Eff_{baseline}} - \frac{1}{Eff_{ee}}\right)$$

units = 1, from application
days = 320 days/year, from application
$N_{preheat}$ = 1, from
$BTU_{preheat,baseline}$ = 5,118 BTU, from Baseline Efficiencies from which Energy Savings are calculated
$BTU_{preheat,ee}$ = 3,470 BTU, from application
$BTU/h_{idle,baseline}$ = 6,824 BTU, from Baseline Efficiencies from which Energy Savings are calculated
$BTU/h_{idle,ee}$ = 5,500 BTU, from application
$Hrs_{preheat}$ = 0.25, from Common Variables table based on equipment type
Hrs = 12 hours/day, from application
Lbs = 250 lbs, from Common Variables table based on equipment type
$(Lbs/hr)_{baseline}$ =90 lbs/hr, from Baseline Efficiencies from which Energy Savings are calculated
(lbs/hr)ee = 90, from application
Q_{food} = 250 BTU/lb, from Common Variables table based on equipment type
$Eff_{baseline}$ = 0.65, from Baseline Efficiencies from which Energy Savings are calculated
Eff_{ee} = 0.72, from application
CF = 0.9, from Summary of Variables and Data Sources

$$\Delta BTU_{preheat} = 1 \times (5{,}118 - 3{,}470) = 1{,}648$$

$$\Delta BTU_{idle} = 6{,}824 \times \left[12 - 1 \times 0.25 - \left(\frac{250}{90}\right)\right] - 5{,}500 \times \left[12 - 1 \times 0.25 - \left(\frac{250}{90}\right)\right] = 11{,}879$$

$$\Delta BTU_{cooking} = 250 \times 250 \times \left(\frac{1}{0.65} - \frac{1}{0.72}\right) = 9{,}348$$

$$\Delta kWh = 1 \times 320 \times \frac{(1{,}648 + 11{,}879 + 9{,}348)}{3{,}412} = 2{,}145\ kWh$$

$$\Delta kW = \frac{2{,}145}{(320 \times 12)} \times 0.9 = 0.50\ kW$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

More efficient food service equipment rejects less heat into the condition space than standard equipment, increasing space heating requirements while decreasing cooling load. However, no relevant studies have been performed to date that would allow quantification of these impacts. Until additional information is available, these impacts are excluded from the prescribed formulation of savings.

Ancillary Electric Savings Impacts

More efficient food service equipment rejects less heat into the condition space than standard equipment, increasing space heating requirements while decreasing cooling load. However, no relevant studies have been performed to date that would allow quantification of these impacts. Until additional information is available, these impacts are excluded from the prescribed formulation of savings.

References

1. ENERGY STAR® Program Requirements Product Specification for Commercial Ovens, Eligibility Criteria Version 2.2, October 2015
   Available from:
   https://www.energystar.gov/sites/default/files/Commercial%20Ovens%20Final%20Version%202.2%20Specification.pdf
2. ENERGY STAR® Program Requirements Product Specification for Commercial Steam Cookers, Eligibility Criteria Version 1.2, August 2003
   Available from:
   https://www.energystar.gov/sites/default/files/specs/private/Commercial_Steam_Cookers_Program_Requirements%20v1_2.pdf
3. ENERGY STAR® Program Requirements Product Specification for Commercial Fryers Eligibility Criteria Final Draft Version 3.0, October 2016
   Available from:
   https://www.energystar.gov/sites/default/files/Commercial%20Fryers%20Final%20Draft%20V3.0%20Specification.pdf
4. ENERGY STAR® Program Requirements Product Specification for Commercial Griddles, Eligibility Criteria Version 1.2, January 2011
   Available from:
   https://www.energystar.gov/ia/partners/product_specs/program_reqs/Commercial_Griddles_Program_Requirements.pdf

5. ENERGY STAR® Commercial Food Service Calculator (accessed February 26, 2018) Available from: https://www.energystar.gov/buildings/facility-owners-and-managers/existing-buildings/save-energy/purchase-energy-saving-products
6. Pacific Gas & Electric Company, Work Paper PGECOFST101 Commercial Convection Oven-Electric and Gas, Revision 6, August 2016
7. Pacific Gas & Electric Company, Work Paper PGECOFST117 Commercial Conveyor Oven-Gas, Revision 5, May 2014
8. Pacific Gas & Electric Company, Work Paper PGECOFST109 Commercial Rack Oven-Gas, Revision 1, October 2018
9. Pacific Gas & Electric Company, Work Paper PGECOFST104 Commercial Steam Cooker-Electric and Gas, Revision 6, June 2016
10. Pacific Gas & Electric Company, Work Paper PGECOFST102 Commercial Fryer-Electric and Gas, Revision 6, June 2016
11. California Technical Forum, Commercial Griddle-Electric and Gas, Revision 1, October 2018
12. Food Service Technology Center: Gas Rack Oven Life-Cycle Cost Calculator Available from: https://caenergywise.com/calculators/natural-gas-rack-ovens/#calc
13. Food Service Technology Center: Electric Fryer Life-Cycle Cost Calculator Available from: https://caenergywise.com/calculators/electric-fryers/#calc
14. Food Service Technology Center: Gas Fryer Life-Cycle Cost Calculator Available from: https://caenergywise.com/calculators/natural-gas-fryers/#calc
15. California Energy Commission, Energy Research and Development Division, Characterizing the Energy Efficiency Potential of Gas-Fired Commercial Foodservice Equipment, October 2014 Available from: http://www.energy.ca.gov/2014publications/CEC-500-2014-095/CEC-500-2014-095.pdf

Record of Revision

Record of Revision Number	Issue Date
3-18-18	3/29/2018
3-20-4	3/30/2020

Return to Table of Contents

REFRIGERATORS AND FREEZERS

Measure Description

This measure covers the installation of ENERGY STAR® compliant commercial refrigerators and freezers operating with an integral compressor and condenser. Eligible equipment includes commercial standard and hybrid refrigerators, freezers, and refrigerator-freezers. This measure is only applicable to horizontal or vertical self-contained equipment with solid or transparent doors.

This measure also covers the installation of ENERGY STAR® laboratory grade refrigerators and freezers. These products are used to store non-volatile reagents and biological specimens at stable temperatures in lab settings including hospitals, clinics, university and government research laboratories, and pharmaceuticals. Eligible equipment include general purpose and high performance laboratory grade refrigerators and freezers and ultra-low temperature freezers. A general purpose laboratory grade refrigerator is a product that cannot support a maximum peak variation in temperature equal to or less than 6 °C at set point temperatures between 0 °C and 12 °C (32 °F and 53.6 °F). A high performance laboratory grade refrigerator is a product that is designed to support a maximum peak variation in temperature no greater than 6 °C. A general purpose laboratory grade freezer is a product that cannot support a maximum peak variation in temperature equal to or less than 10 °C at set point temperatures between -40 °C and 0 °C (-40 °F and 32 °F). A high performance laboratory grade freezer product that is designed to support a maximum peak variation in temperature no greater than 10 °C. An ultra-low temperature freezer is a freezer designed for laboratory application that is capable of maintaining set point storage temperatures between -70 °C and -80 °C (-94 °F and -112 °F).[741]

Method for Calculating Annual Energy and Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times (kWh_{baseline} - kWh_{ee}) \times (1 + HVAC_c)$$

Peak Coincident Demand Savings

$$\Delta kW = units \times \left[\frac{kWh_{baseline} - kWh_{ee}}{8{,}760}\right] \times (1 + HVAC_d) \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = units \times (kWh_{baseline} - kWh_{ee}) \times HVAC_{ff}$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program

[741] ENERGY STAR® Refrigerators & Freezers Key Product Criteria, ENERGY STAR® Program Requirements for Laboratory Grade Refrigerators and Freezers.

$_{baseline}$	= Characteristic of aseline condition
$_{ee}$	= Characteristic of energy efficient condition
kWh	= Annual electric energy consumption
$HVAC_c$	= HVAC interaction factor for annual electric energy consumption
$HVAC_d$	= HVAC interaction factor at utility summer peak hour
$HVAC_{ff}$	= HVAC interaction factor for annual fossil fuel consumption (MMBtu/kWh)
CF	= Coincidence factor
8,760	= Hours in one year

Summary of Variables and Data Sources

Variable	Value	Notes
$kWh_{baseline}$		See Baseline Efficiencies section below.
kWh_{ee}		From application.
$HVAC_c$		HVAC interaction factor for annual electric energy consumption (dimensionless), from Appendix D based on facility type, location and HVAC type.
$HVAC_d$		HVAC interaction factor for peak demand at utility summer peak hour (dimensionless), from Appendix D based on facility type, location and HVAC type.
$HVAC_{ff}$		HVAC interaction factor for annual fossil fuel energy consumption (MMBtu/kWh), from Appendix D based on facility type, location and HVAC type.
CF	1.0	

Coincidence Factor (CF)

The recommended value for the coincidence factor is 1.0. [742]

Baseline Efficiencies from which Savings are Calculated

The baseline condition is a minimally code compliant commercial standard or hybrid refrigerator, refrigerator-freezer or freezer as defined in the Measure Description section above. Baseline annual electric consumption (kWh/yr) shall align with federally mandated maximum energy use associated with the Product Class and the chilled or frozen compartment volume (V) of the qualifying equipment.[743] Volume specification shall be taken from ENERGY STAR® qualified products listing or specification sheet of the proposed equipment. Baseline maximum daily energy consumption (kWh/day) for solid door and glass door commercial refrigerators and freezers of all volumes are calculated as shown in the table below.[744] For commercial refrigeration equipment with two or more compartments (i.e., hybrid refrigerators, hybrid freezers, hybrid refrigerator-freezers, and non-hybrid refrigerator-freezers), the maximum daily energy consumption for each model shall be the sum of the MDEC values for all of its compartments.[745] Multiply by 365 to

[742] *No source specified – update pending availability and review of applicable references.*
[743] 10 CFR Appendix A to Subpart C of Part 431 – Uniform Test Method for the Measurement of Energy Consumption of Commercial Refrigerators, Freezers, and Refrigerator-Freezers
[744] 10 CFR 431.66(e)(1)
[745] 10 CFR 431.66(e)(2)

derive annual energy consumption.

Type (Closed)	Maximum Daily Energy Consumption (kWh/day)			
	Refrigerator		Freezer	
	Solid Door	Glass Door	Solid Door	Glass Door
Vertical	≤ 0.05×V + 1.36	≤ 0.10×V + 0.86	≤ 0.22×V + 1.38	≤ 0.29×V + 2.95
Horizontal	≤ 0.05×V + 0.91	≤ 0.06×V + 0.37	≤ 0.06×V + 1.12	≤ 0.08×V + 1.23

Ultra-Low Temperature (ULT) Freezers @ -75 °C Energy Consumption[746]

Maximum Daily Energy Consumption (kWh/day)
ULT Freezer
2.51-0.06×V+0.10×1 (assumed frequency of door opening, moderate)

Compliance Efficiency from which Incentives are Calculated

The compliance condition is an ENERGY STAR® qualified commercial refrigerator, refrigerator-freezer or freezer, general purpose or high performance laboratory grade refrigerator or freezer or ultra low-temperature laboratory grade freezer as defined in the Measure Description section above. ENERGY STAR® rated refrigerators must meet the specifications in the tables below for maximum daily energy consumption (kWh/day).[747] Annual electric energy consumption of the qualifying equipment shall come from application. If unknown, use maximum energy consumption based on qualifying equipment volume from the tables below. Volume specification shall be taken from ENERGY STAR® qualified products listing or specification sheet of the proposed equipment. Multiply by 365 to derive annual energy consumption (kWh/year).

Vertical Closed Energy Consumption

Volume (ft^3)	Maximum Daily Energy Consumption (kWh/day)			
	Refrigerator		Freezer	
	Solid Door	Glass Door	Solid Door	Glass Door
0 < V < 15	≤ 0.022×V+0.97	≤ 0.095×V+0.445	≤ 0.210×V+0.900	≤ 0.232×V+2.36
15 ≤ V < 30	≤ 0.066×V+0.31	≤ 0.050×V+1.120	≤ 0.120×V+2.248	≤ 0.232×V+2.36
30 ≤ V < 50	≤ 0.040×V+1.09	≤ 0.076×V+0.340	≤ 0.285×V-2.703	≤ 0.232×V+2.36
50 ≤ V	≤ 0.024×V+1.89	≤ 0.105×V-1.111	≤ 0.142×V+4.445	≤ 0.232×V+2.36

Horizontal Closed Energy Consumption

Volume (ft^3)	Maximum Daily Energy Consumption (kWh/day)			
	Refrigerator		Freezer	
	Solid Door	Glass Door	Solid Door	Glass Door
All volumes	≤ 0.05×V+0.28	≤ 0.05×V+0.28	≤ 0.057×V+0.55	≤ 0.057×V+0.55

[746] ULT Freezers Base Case Investigation, Eversource Energy
[747] ENERGY STAR® Program Requirements Product Specification for Commercial Refrigerators and Freezers, Eligibility Criteria Version 4.0

Laboratory Grade Refrigerators Energy Consumption[748]

Applications	Volume	Maximum Daily Energy Consumption (kWh/day)
General Purpose	0 ≤ V < 25	≤ 0.124×V+2.0
	25 ≤ V	≤ 0.121×V+2.07
High performance	0 ≤ V < 25	≤ 0.184×V+3.5
	25 ≤ V < 44	≤ 0.153×V+4.28
	44 ≤ V	≤ 0.125×V+5.5

Laboratory Grade Freezers Energy Consumption[749]

Applications	Volume	Maximum Daily Energy Consumption (kWh/day)
General Purpose	0 ≤ V < 15	≤ 0.033×V+2.0
	15 ≤ V < 30	≤ 0.05×V+1.75
	30 ≤ V	≤ 0.188×V-2.375
High performance	0 ≤ V < 22	≤ 0.09×V+10
	22 ≤ V	≤ 0.426×V+2.63

Laboratory Grade Ultra-Low Temperature (ULT) Freezers @ -75 °C Energy Consumption

Maximum Daily Energy Consumption (kWh/day)
0.55×V

Operating Hours

Refrigeration products are assumed to be plugged into an electrical outlet 8,760 hours per year. Compressor cycling is inherent in the specified annual energy consumption of baseline and qualifying equipment.

Example Calculation *(Not to be used as default)*

An ENERGY STAR® qualified commercial glass door vertical refrigerator with 25 ft^3 internal volume and rated daily energy consumption of 2.05 kWh is installed in a grocery store in Albany. The building has central air conditioning and gas heat. Annual Electric Energy Savings, Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta kWh = units \times (kWh_{baseline} - kWh_{ee}) \times (1 + HVAC_c)$$

$$\Delta kW = units \times \left[\frac{kWh_{baseline} - kWh_{ee}}{8{,}760}\right] \times (1 + HVAC_d) \times CF$$

$$\Delta MMBtu = units \times (kWh_{baseline} - kWh_{ee}) \times HVAC_{ff}$$

[748] ENERGY STAR® Program Requirements for Laboratory Grade Refrigerators and Freezers
[749] Ibid.

units = 1, from application
$kWh_{baseline}$ = (0.10 x V + 0.86) x 365 = (0.10 x 25 + 0.86) x 365 = 1,226 kWh
$kWh_{baseline}$ equation from Baseline Efficiency section based on equipment type and volume
V = 25, from application
kWh_{ee} = 2.05 x 365 = 748 kWh, from application
HVACc = 0.120, from Appendix D based on location, HVAC configuration, and facility type
HVACd = 0.200, from Appendix D based on location, HVAC configuration, and facility type
HVACff = -0.002, from Appendix D based on location, HVAC configuration, and facility type
CF = 1.0, from Summary of Variables and Data Sources

$$\Delta kWh = 1 \times (1{,}226 - 748) \times (1 + 0.120) = 535\ kWh$$

$$\Delta kW = 1 \times \left[\frac{1{,}226 - 748}{8{,}760}\right] \times (1 + 0.200) \times 1.0 = 0.065\ kW$$

$$\Delta MMBtu = 1 \times (1{,}226 - 748) \times -0.002 = -0.96\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

High-efficiency refrigeration products reject less heat into the conditioned space than standard equipment, increasing space heating requirements while decreasing cooling load. The HVAC interaction factors calculated from the prototypical building DOE-2 models as a function of facility type, location and HVAC system type are shown in Appendix D.

Ancillary Electric Savings Impacts

High-efficiency refrigeration products reject less heat into the conditioned space than standard equipment, increasing space heating requirements while decreasing cooling load. The HVAC interaction factors calculated from the prototypical building DOE-2 models as a function of facility type, location and HVAC system type are shown in Appendix D.

References

1. ENERGY STAR® Refrigerators & Freezers Key Product Criteria, March 27, 2017 Available from: https://www.energystar.gov/products/commercial_food_service_equipment/commercial_refrigerators_freezers/key_product_criteria

2. 10 CFR Appendix A to Subpart C of Part 431 – Uniform Test Method for the Measurement of Energy Consumption of Commercial Refrigerators, Freezers, and Refrigerator-Freezers
   Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=fa8761ce7ff31d0c22aaf4e1c4992575&mc=true&node=pt10.3.431&rgn=div5#ap10.3.431_166.a
3. 10 CFR 431.66 Energy conservation standards and their effective dates.
   Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=4892a800dfd3976a79848bb42372bfda&mc=true&node=pt10.3.431&rgn=div5#se10.3.431_166
4. ENERGY STAR® Program Requirements Product Specification for Commercial Refrigerators and Freezers, Eligibility Criteria Version 4.0
   Available from: https://www.energystar.gov/sites/default/files/asset/document/Commercial%20Refrigerators%20and%20Freezers%20V4%20Spec%20Final%20Version_0.pdf
5. ENERGY STAR® Program Requirements for Laboratory Grade Refrigerators and Freezers.
   Available from: https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20V1.1%20Lab%20Grade%20Refrigerator%20and%20Freezer%20Program%20Requirements.pdf
6. Ultra-low Freezer base case investigations, Eversouce Energy, October 2, 2017

Record of Revision

Record of Revision Number	Issue Date
1	10/15/2010
9-18-7	9/30/2018
3-21-10	4/9/2021

Return to Table of Contents

APPLIANCE – CONTROL

ADVANCED POWER STRIP (APS)

Measure Description

This measure covers the installation of Tier 1 Advanced Power Strips (APS) in office workstations. The Tier 1 APS makes use of a control outlet to disconnect the controlled plugs when the load on the control outlet (usually a computer) is reduced below a threshold. In this case, the reduction below threshold of the control plug happens when the computer shuts down or enters standby mode. Therefore, the overall load of a centralized group of equipment (e.g. monitors and other peripherals for the computer) can be reduced.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings[750]

Annual Electric Energy Savings

$$\Delta kWh = units \times \begin{bmatrix} \Delta kW_{wkday} \times \left(hrs_{wkday} - hrs_{wkday-open}\right) \\ + \\ \Delta kW_{wkend} \times \left(hrs_{wkend} - hrs_{wkend-open}\right) \end{bmatrix} \times \frac{8{,}760}{168}$$

Summer Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
ΔkW_{wkday}	= Average power reduction during weekday off hours
ΔkW_{wkend}	= Average power reduction during weekend off hours
hrs_{wkday}	= Total hours during the work week (Monday 7:30 AM to Friday 5:30 PM)
hrs_{wkend}	= Total hours during the weekend (Friday 5:30 PM to Monday 7:30 AM)
$hrs_{wkday,open}$	= Hours the office is open during the work week
$hrs_{wkend,open}$	= Hours the office is open during the weekend
8,760	= Hours in one year
168	= Hours in one week

[750] Savings algorithm reconstructed from weekday and weekend savings information in Sheppy *et. al*, and verified against savings in Acker *et. al* and savings in: BPA, "Smart Power Strip Energy Savings Evaluation: Ross Complex," (2011). Office stations are assumed to have zero or minimal standby losses during normal operating hours.

Summary of Variables and Data Sources

Variable	Value	Notes
ΔkW_{wkday}	0.0315	Deemed value from IDL and NREL/NAVFAC study, determined by reduction in off-hours demand. See Deemed Savings Background section below for additional detail.
ΔkW_{wkend}	0.0067	Deemed value from IDL and NREL/NAVFAC study, determined by reduction in off-hours demand. See Deemed Savings Background section below for additional detail.
hrs_{wkday}	106	
$hrs_{wkday,open}$		From application. If unknown, use 50 hours.[751]
hrs_{wkend}	62	
$hrs_{wkend,open}$		From application. If unknown, use 0 hours.[752]

Deemed Savings Background

Since the introduction of the Tier 1 APS for commercial applications, three studies of its performance in commercial office settings have been conducted. Their ex-post estimates for savings are in relative agreement, between 134 and 149 kWh. The three studies are:

1. A University of Idaho Integrated Design Lab (IDL) project studying 49 load-sensing power strips in a large, private office building. Baseline data was gathered for one year and post-period data was gathered for 3 months. The study broke out findings into weekday, weekend, and holiday categories.[753]
2. A National Renewable Energy Laboratory (NREL) and Naval Facilities Engineering Command (NAVFAC) joint APS evaluation, with 100 load-sensing power strips. Whole building load shapes were monitored pre and post. This study had five weeks of baseline data and six weeks of treatment data.[754]
3. A Bonneville Power Administration APS evaluation at the Ross Complex, in which 48 strips were installed for a pre- and post-treatment period of three weeks each. Data for this study was measured at the individual power strip level.[755]

The calculation for energy savings uses the detailed breakdowns of energy savings from the IDL study and the assumption that savings only occur outside of normal business hours. The value of 31.5 watts reduced during off-hours on weekdays was calculated with data from the IDL study and aligns with the graphically shown load reduction in the NREL/NAVFAC study. The same method was performed for the weekends to obtain the wattage reduced. The number from the IDL study of 6.7 watts reduced on weekends is more conservative than the NREL/NAVFAC results and is used for this calculation.

[751] Assumes an office operating schedule of M - F, 7:30AM – 5:30PM
[752] Assumes an office operating schedule of M - F, 7:30AM – 5:30PM
[753] Acker *et al*
[754] Sheppy *et al*
[755] BPA, "Smart Power Strip Energy Savings Evaluation," Ross Complex, Vancouver, WA (2011)

Coincidence Factor (CF)

The prescribed value for the coincidence factor is N/A. The majority of kWh savings are assumed to occur during off-hours, so no Summer Peak Coincident Demand Savings are deemed.

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is an office workstation with no plug load control system.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is an office workstation with a tier 1 plug load control advanced power strip.

Operating Hours

The annual operating hours of the measure, assuming that the APS is operating when it is reducing load, can be calculated by:

$$hours = \begin{bmatrix} (hrs_{wkday} - hrs_{wkday-open}) \\ + \\ (hrs_{wkend} - hrs_{wkend-open}) \end{bmatrix} \times \frac{8{,}760}{168}$$

Which is equal to 6,153 hours, assuming that the office is open for 50 hours on weekdays and 0 hours on weekends. Alternatively, the operating hours of the workstation standby loads are reduced by this amount, to 2,607 hours from 8,760 hours.

Example Calculation *(Not to be used as default)*

10 Tier 1 advanced power strips are installed in an office in NYC, which is open for 55 hours Monday – Friday and 0 hours on weekends. Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings are calculated as below.

$$\Delta kWh = units \times \begin{bmatrix} \Delta kW_{wkday} \times (hrs_{wkday} - hrs_{wkday-open}) \\ + \\ \Delta kW_{wkend} \times (hrs_{wkend} - hrs_{wkend-open}) \end{bmatrix} \times \frac{8{,}760}{168}$$

Units = 10, from application
ΔkW_{wkday} = 0.0315, from Summary of Variables and Data Sources
ΔkW_{wkend} =0.0067, from Summary of Variables and Data Sources
Hrs_{wkday} =106, from Summary of Variables and Data Sources
$Hrs_{wkday,open}$ = 55, from application
Hrs_{wkend} = 62, from Summary of Variables and Data Sources
$Hrs_{wkend,open}$ = 0, from application

$$\Delta kWh = 10 \times \begin{bmatrix} 0.0315 \times (106 - 55) \\ + \\ 0.0067 \times (62 - 0) \end{bmatrix} \times \frac{8{,}760}{168} = 838\ kWh$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. Acker, Brad et. al, "Office Space Plug Load Profiles and Energy Saving Interventions," IDL, 2012 ACEEE Summer Study on Energy Efficiency in Buildings (2012) Available from: https://fortress.wa.gov/ga/apps/SBCC/File.ashx?cid=5572
2. Sheppy, M. et al, "Reducing Plug Loads in Office Spaces" Hawaii and Guam Energy Improvement Technology Demonstration Project, NREL/NAVFAC (January 2014) Available from: https://www.nrel.gov/docs/fy14osti/60382.pdf
3. Bonneville Power Administration, "Smart Power Strip Energy Savings Evaluation," Ross Complex, Vancouver, WA (2011) Available from: http://studylib.net/doc/8460015/smart-strip-energy-savings-evaluation-%E2%80%93-ross-complex--van...

Record of Revision

Record of Revision Number	Issue Date
12-17-16	12/31/2017

Return to Table of Contents

VENDING MACHINE AND NOVELTY COOLER CONTROL

Measure Description

This measure covers the installation of time clocks or occupancy sensors on refrigerated vending machines and novelty coolers to reduce compressor run time and lighting hours while ensuring units maintain desired product temperatures during occupied hours. The time clock control mechanism is a programmed-schedule time clock that is assumed to be set to turn the equipment off coincident with the facility closing time and turn equipment on one hour before opening time to allow the products to return to the desired sale temperature.

The occupancy sensor control mechanism uses an infrared sensor to turn off the vending machine when the surrounding area is unoccupied. The device also monitors the ambient temperature and powers up the machine as required to keep products cool. Additionally, the sensor monitors the electrical current used by the machine to ensure it is not turned off during a compressor cycle to prevent a high head pressure start from occurring.

This measure is only applicable to vending machines without a low power mode. A low power mode is a state in which a vending machine's lighting, refrigeration, and/or other energy using systems are automatically adjusted (without user intervention) such that they consume less energy than they consume in an active vending environment.[756] This measure is only applicable to vending machines and novelty coolers containing non-perishable products.

This measure also covers the installation of time clocks or occupancy sensors on non-refrigerated (snack) vending machines. In this case, savings are derived from a reduction in lighting hours during unoccupied hours.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

Refrigerated Vending Machine and Novelty Cooler

$$\Delta kWh = units \times (kW/unit) \times \left[hrs_{off} + F_{control} \times ESF \times \left(8{,}760 - hrs_{off}\right)\right] \times Cycle$$

Non-Refrigerated (Snack) Vending Machine

$$\Delta kWh = units \times (kW/unit) \times \left[hrs_{off} + F_{control} \times ESF \times \left(8{,}760 - hrs_{off}\right)\right]$$

Summer Peak Coincident Demand savings

$$\Delta kW = Negligible$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

[756] 10 CFR 431 Subpart Q, Appendix B 1.2 Definitions

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
(kW/unit)	= Vending machine power (kW), based on nameplate Volts, Amps, Phase and Power Factor
hrs_{off}	= Unit off hours per year
$F_{control}$	= Control type factor, used to include additional savings for occupancy sensor controls
ESF	= Energy Savings Factor, associated with occupancy sensor controls
Cycle	= Compressor duty cycle
8,760	= Hours in one year

Summary of Variables and Data Sources

Variable	Value	Notes
(kW/unit)	Refrigerated Vending Machine and Novelty Cooler: $= \frac{Volts \times Amps \times \sqrt{Phase} \times PF}{1{,}000}$ Non-Refrigerated (Snack) Vending Machine: 0.02	Refrigerated vending machine and novelty cooler power is based on nameplate Volts, Amps, Phase and Power Factor. If power factor is unknown, use a default value of 0.55.[757] Non-refrigerated machine power reflects typical per unit lighting wattage.[758]
hrs_{off}		From application. Off hours are equivalent to daily facility closed hours minus one multiplied by facility operating days. If building operating hours are unknown, look up in Operating Hours section below based on facility type. hrs_{off} is equivalent for time clock and occupancy sensor controls.
$F_{control}$		Use a value of 1.0 if Occupancy Sensor control type. Use a value of 0 if Time Clock control type.
ESF	0.1	Energy savings of occupancy sensing control during building operating hours, estimated from lighting occupancy sensor controls in open office space[759]

[757] Analysis of Cooler Control Energy Conservation Measures: Final Report, Select Energy Services, Inc., March 2004
[758] Southern California Edison, Work Paper SCE17CS005 Revision 1, Beverage Merchandise Controller, July 2018, pg 9
[759] DOE, Wireless Sensors for Lighting Energy Savings, March 2016, page 1

Variable	Value	Notes
Cycle	0.45	Compressor average duty cycle. [760]

Coincidence Factor (CF)

The prescribed value for the coincidence factor is N/A.

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a vending machine or novelty cooler containing non-perishable products without time clock or occupancy IR sensing/load sensing control.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is the installation of time clock or occupancy IR sensing/load sensing control installed on a vending machine or novelty cooler containing non-perishable products where controls were not previously installed.

Operating Hours

Novelty coolers and refrigerated vending machines are assumed to be connected 24 hours per day, 365 days per year. In the baseline case, these units operate during all hours and cycle according to the duty cycle cited above.

With time clock control, units are automatically shut off when the facility closes and turned back on one hour prior to the facility opening to allow the system to return the contents to their desired temperature. Energy savings are calculated based on the system off hours due to installed time clock control. If unknown, use the default off hours based on building type from the table below. This table was developed by subtracting the default lighting hours in the C&I Interior Lamps and Fixtures measure in this TRM from 8,760, and subtracting 365 from the result (assumes 365 days of facility operation). Facilities expected to operate 24/7 are excluded.

Facility Type	hrs_{off} (hrs/yr)	Facility Type	hrs_{off} (hrs/yr)
Auto Related[a]	5,585	Manufacturing Facility	5,538
Bakery	5,541	Medical Offices	4,647
Banks	4,647	Motion Picture Theatre	6,441
Church	6,440	Museum	4,647
College– Cafeteria[b]	5,682	Nursing Homes	2,555
College – Classes	5,809	Office (General Office Types)[b]	5,382
College - Dormitory	5,329	Parking Garages	4,027
Commercial Condos[c]	5,295	Parking Lots	4,295
Convenience Stores	2,019	Penitentiary	2,918
Convention Center	6,441	Performing Arts Theatre	5,809
Court House	4,647	Post Office	4,647

[760] Ibid, Table 5-5

Facility Type	hrs_{off} (hrs/yr)	Facility Type	hrs_{off} (hrs/yr)
Dining: Bar Lounge/Leisure	4,213	Pump Stations	6,446
Dining: Cafeteria / Fast Food	1,939	Refrigerated Warehouse	5,793
Dining: Family	4,213	Religious Building	6,440
Entertainment	6,443	Restaurants	4,213
Exercise Center	2,559	Retail	4,932
Fast Food Restaurants	2,019	School / University	6,208
Fire Station (Unmanned)	6,442	Schools (Jr./Sr. High)	6,208
Food Stores	4,340	Schools (Preschool/Elementary)	6,208
Gymnasium	5,809	Schools (Technical/Vocational)	6,208
Industrial - 1 Shift	5,538	Small Services	4,645
Industrial - 2 Shift	3,665	Sports Arena	6,441
Industrial - 3 Shift	1,764	Town Hall	4,647
Laundromats	4,339	Transportation	1,939
Library	4,647	Warehouse (Not Refrigerated)	5,793
Light Manufacturers[b]	5,782	Waste Water Treatment Plant	1,764
Lodging (Hotels/Motels)	5,331	Workshop	4,645
Mall Concourse	3,562		

[a] New car showrooms and Big Box retail stores with evening and/or weekend hours should use the Facility Type "Retail" for vending machine and novelty cooler off hours
[b] Lighting operating hours data from the 2008 California DEER Update study
[c] Lighting operating hours data for offices used

With occupancy sensor control, units shut off after a period of time of consistent inoccupancy. The cumulative annual off hours are estimated by summing time clock control off hours and 10% of remaining on hours, as outlined in the equations above. hrs_{off} for occupancy sensors shall come from application or lookup in table above if unknown.

Example Calculation *(Not to be used as default)*

A time clock is installed on a refrigerated vending machine with a rated wattage of 400 W in a fitness center in NYC. Prior to installation, the vending machine was operating 24 hours per day, 365 days a year. Following installation of the time clock, the annual operating hours of the vending machine are reduced by 3,000 hours per year. Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings are calculated as below.

$$\Delta kWh = units \times (kW/unit) \times \left[hrs_{off} + F_{control} \times ESF \times \left(8{,}760 - hrs_{off}\right)\right] \times Cycle$$

units = 1, from application
(kW/unit) = 0.40, from application
hrs_{off} = 3,000, from application
$F_{control}$ = 0, from Summary of Variables and Data Sources (Control Type = Time Clock)

ESF = 0.1, from Summary of Variables and Data Sources
Cycle = 0.45, from Summary of Variables and Data Sources

$$\Delta kWh = 1 \times 0.40 \times [3{,}000 + 0 \times 0.1 \times (8{,}760 - 3{,}000)] \times 0.45 = 540\ kWh$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Reduced refrigeration system run hours during facility operation will result in a slight increase in space heating requirements and a slight decrease in space cooling requirements. These effects are not considered in the prescribed savings methodology.

Ancillary Electric Savings Impacts

Reduced refrigeration system run hours during facility operation will result in a slight increase in space heating requirements and a slight decrease in space cooling requirements. These effects are not considered in the prescribed savings methodology.

References

1. 10 CFR 431 Subpart Q, Appendix B, 1.2 Definitions
   Available from: https://www.govinfo.gov/content/pkg/CFR-2017-title10-vol3/xml/CFR-2017-title10-vol3-part431.xml#seqnum431.292
2. VendingSolutions, Vending Machine Knowledge Base
   Available from: https://www.vendingsolutions.com/faq
3. Analysis of Cooler Control Energy Conservation Measures: Final Report, Select Energy Services, Inc., March 2004
   Available from: https://forum.cee1.org/system/files/library/1220/392.pdf
4. Sothern California Edison, Workpaper SCE17CS005, Revision 1, Beverage Merchandise Controller, July 23, 2018
   Available from: http://deeresources.net/workpapaers
5. Department of Energy, Wireless Sensors for Lighting Energy Savings, Wireless Occupancy Sensors for Lighting Controls: An Applications Guide for Federal Facility Managers, December 2019
   Available from:
   https://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/wireless_occupancy_sensor_guide.pdf

6. Analysis of NREL Cold-Drink Vending Machines for Energy Savings, NREL, June 2003 Available from: https://www.researchgate.net/profile/Michael_Deru/publication/242168498_Analysis_of_NREL_Cold-Drink_Vending_Machines_for_Energy_Savings/links/54bd240d0cf218da939190ab/Analysis-of-NREL-Cold-Drink-Vending-Machines-for-Energy-Savings.pdf?origin=publication_detail

Record of Revision

Record of Revision Number	Issue Date
1	10/15/2010
6-18-7	6/26/2018
3-19-8	3/29/2019
9-19-3	9/27/2019

Return to Table of Contents

APPLIANCE RECYCLING

AIR CONDITIONER – ROOM (RAC) RECYCLING

Measure Description

Room (Window) Air Conditioners, a consumer (appliance) product, other than a "packaged terminal air conditioner," which is powered by a single-phase electric current and is an encased assembly designed as a unit for mounting in a window or through the wall for the purpose of providing delivery of conditioned air to an enclosed space. It includes a prime source of refrigeration and may include a means for ventilating and heating [761]. Minimum energy conservation standards for these appliances have been established by the Code for Federal Regulations 10 CFR 430.32(b). As this standard continues to be revised, and by association ENERGY STAR® standards continue to increase, operational savings attributable to new RAC may justify early retirement before the full useful life has been exhausted. In order to realize the anticipated savings, a currently functioning appliance of equivalent cooling capacity and type having been manufactured before June 2014 must be properly disposed of when a new appliance is supplied to the customer.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings, Method using EER

$$\Delta kWh = units \times \frac{Capacity}{1{,}000} \times \left(\frac{1}{EER_{baseline}} - \frac{1}{EER_{ee}}\right) \times EFLH_{cooling}$$

Annual Electric Energy Savings, Alternate Method using CEER[762]

$$\Delta kWh = units \times \frac{Capacity}{1{,}000} \times \left(\frac{1}{CEER_{baseline}} - \frac{1}{CEER_{ee}}\right) \times EFLH_{cooling}$$

Summer Peak Coincident Demand Savings, Method using EER

$$\Delta kW = units \times \frac{Capacity}{1{,}000} \times \left(\frac{1}{EER_{baseline}} - \frac{1}{EER_{ee}}\right) \times CF$$

Summer Peak Coincident Demand Savings, Alternate Method using CEER

$$\Delta kW = units \times \frac{Capacity}{1{,}000} \times \left(\frac{1}{CEER_{baseline}} - \frac{1}{CEER_{ee}}\right) \times CF$$

[761] ENERGY STAR® Program Requirements, Product Specification for Room Air Conditioners, Eligibility Criteria Version 4.0, February 2015

[762] When available the Combined Energy Efficiency Ratio should be used for the purpose of calculating annual electric energy savings.

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures recycled under the program
Capacity	= Cooling output rating, in BTU/h
$EFLH_{cooling}$	= Cooling Equivalent Full-Load Hours
CF	= Coincidence Factor
CEER	= Combined Energy Efficiency Ratio
EER	= Energy Efficiency Ratio
$_{baseline}$	= Characteristic of baseline condition
$_{ee}$	= Characteristic of energy efficient condition
1,000	= Conversion factor, one kW equals 1,000 watts

Packaged Terminal Air Conditioner (PTAC) is defined as a wall sleeve and a separate unencased combination of heating and cooling assemblies specified by the builder and intended for mounting through the wall.

RAC with louvered sides have exterior side vents to facilitate airflow over the outdoor coil.

RAC with reverse cycle are appliances that may reverse the refrigeration cycle so as to serve as heating equipment, also known as a heat pump.

Summary of Variables and Data Sources

Variable	Value	Notes
Capacity		From application.
$EFLH_{cooling}$		Cooling equivalent full-load hours by building type, see Appendix G.
$CEER_{baseline}$		From application, or lookup from table below based on unit capacity when unknown.
$CEER_{ee}$		From application.
$EER_{baseline}$		From application, or lookup from table below based on unit capacity when unknown.
EER_{ee}		From application.
CF	NYC: 0.703 Outside of NYC: 0.305	

Coincidence Factor (CF)

The prescribed coincidence factor for this measure is 0.703 for NYC and 0.305 outside of NYC.[763]

Baseline Efficiencies from which Energy Savings are Calculated[764]

Baseline efficiency assumptions for normal replacement of units manufactured between the years 2000 – 2014 are shown below. Baseline efficiency of air conditioners manufactured after June 2014 will be the compliance efficiency.

Room Air Conditioners

Capacity (BTU/h)	with Louvered Sides ($EER_{baseline}$)	Capacity (BTU/h)	without Louvered Sides ($EER_{baseline}$)
< 6,000	≥ 9.7	< 6,000	≥ 9.0
6,000 – 7,999	≥ 9.7	6,000 – 7,999	≥ 9.0
8,000 – 13,999	≥ 9.8	8,000 – 10,999	≥ 8.5
14,000 – 19,999	≥ 9.7	11,000 – 13,999	≥ 8.5
20,000– 27,999	≥ 8.5	14,000– 19,999	≥ 8.5
≥ 28,000	≥ 8.5	≥ 20,000	≥ 8.5

Room Air Conditioners – Casement

Capacity (BTU/h)	Casement Only ($EER_{baseline}$)	Casement - Slider ($EER_{baseline}$)
All	≥ 8.7	≥ 9.5

Room Air Conditioners with Reverse Cycle (Heat Pumps)

Capacity (BTU/h)	with Louvered Sides ($EER_{baseline}$)	Capacity (BTU/h)	without Louvered Sides ($EER_{baseline}$)
≤ 19,999	≥ 9.0	≤ 13,999	≥ 8.5
≥ 20,000	≥ 8.5	≥ 14,000	≥ 8.0

Compliance Efficiency from which Incentives are Calculated[765]

Units will be treated as early retirement and total lifetime energy savings will be calculated based on remaining years of useful life (RUL) of the existing baseline unit. Units greater than 9 years old will be considered normal replacements and will be given incremental savings. Incremental savings are defined as the difference between the annual kWh consumption of minimally compliant with Federal appliance standards and the annual kWh consumption of the new unit.

Room Air Conditioners

Capacity (BTU/h)	with Louvered Sides (EER_{ee})	Capacity (BTU/h)	without Louvered Sides (EER_{ee})
< 6,000	≥ 11.0	< 6,000	≥ 10.0
6,000 – 7,999	≥ 11.0	6,000 – 7,999	≥ 10.0

[763] C&I Unitary HVAC Load Shape Project Final Report, KEMA, 2011, Table 0-6: NY - Inland and NY - Urban/Coastal

[764] 10 CFR 430.32(b) Baseline EER based on manufactured dates between 10/1/2000 and 5/31/2014.

[765] 10 CFR 430.32(b) Compliance EER based on manufactured dates after 6/1/2014.

Capacity (BTU/h)	with Louvered Sides (EER_{ee})	Capacity (BTU/h)	without Louvered Sides (EER_{ee})
8,000 – 13,999	≥ 10.9	8,000 – 10,999	≥ 9.6
14,000 – 19,999	≥ 10.7	11,000 – 13,999	≥ 9.5
20,000– 27,999	≥ 9.4	14,000– 19,999	≥ 9.3
≥ 28,000	≥ 9.0	≥ 20,000	≥ 9.4

Room Air Conditioners – Casement

Capacity (BTU/h)	Casement Only (EER_{ee})	Casement - Slider (EER_{ee})
All	≥ 9.5	≥ 10.4

Room Air Conditioners with Reverse Cycle (Heat Pumps)

Capacity (BTU/h)	with Louvered Sides (EER_{ee})	Capacity (BTU/h)	without Louvered Sides (EER_{ee})
≤ 19,999	≥ 9.8	≤ 13,999	≥ 9.3
≥ 20,000	≥ 9.3	≥14,000	≥ 8.7

Operating Hours

Reference Appendix G for applicable EFLH value for specific building use type and geographic location.

Example Calculation *(Not to be used as default)*

Six room air conditioners with louvered sides and capacity of 7,829 BTU/h each, manufactured in 2012 are replaced and recycled by a primary school near Albany. The recycled units have a rated EER of 9.8 and are replaced with new units with EER of 11.3. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

$$\Delta kWh = units \times \frac{Capacity}{1{,}000} \times \left(\frac{1}{EER_{baseline}} - \frac{1}{EER_{ee}}\right) \times EFLH_{cooling}$$

$$\Delta kW = units \times \frac{Capacity}{1{,}000} \times \left(\frac{1}{EER_{baseline}} - \frac{1}{EER_{ee}}\right) \times CF$$

Units = 1, from application
Capacity = 7,829 BTU/h, from application
$EER_{baseline}$ = 9.8, from application
EER_{ee} = 11.2, from application
$EFLH_{cooling}$ = 297 hours, from Appendix G based on building type from Small Commercial Cooling EFLH table
CF = 0.305, from Summary of Variables and Data Sources

$$\Delta kWh = 6 \times \frac{7{,}829}{1{,}000} \times \left(\frac{1}{9.8} - \frac{1}{11.2}\right) \times 297 = 178\ kWh$$

$$\Delta kW = 6 \times \frac{7{,}829}{1{,}000} \times \left(\frac{1}{9.8} - \frac{1}{11.2}\right) \times 0.305 = 0.183\ kW$$

Effective Useful Life (EUL)

For equipment 9 years old or older:
See Appendix P.

Remaining Useful Life (RUL)

For equipment less than 9 years old:
Years: 9 – (Current Year – Year Manufactured)

1. *Subtract the year of manufacture from the current year*
2. *Subtract the result of step (1) from 9*

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. CFR 10-430.32 Energy and water conservation standards and their compliance dates. Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=39bdf94d4be5c5dac50be36d83225fe4&mc=true&node=pt10.3.430&rgn=div5#se10.3.430_132
2. C&I Unitary HVAC Load Shape Project Final Report, KEMA, August 2, 2011, Table 0-6; (accessed March 21, 2017)
   Available from:
   http://www.neep.org/sites/default/files/resources/NEEP_HVAC_Load_Shape_Report_Final_August2.pdf
3. ENERGY STAR® Program Requirements, Product Specification for Room Air Conditioners, Eligibility Criteria, Version 4.0, February 2015
   Available from:
   https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Final%20Version%204.0%20Room%20Air%20Conditioners%20Specification.pdf
4. California Public Utilities Commission: Database for Energy Efficient Resources (DEER) – 2014, Updated-EULrecords_02-05-2014; EUL ID: HV-RAC-ES
   Available from: http://deeresources.com/files/deerchangelog/deerchangelog.html

Record of Revision

Record of Revision Number	Issue Date
1-16-15	12/31/2015
4-16-2	3/31/2015
6-17-8	6/30/2017

Return to Table of Contents

BUILDING SHELL

AIR CURTAIN

Measure Description

This measure is applicable to the installation of air curtains, which act as air barriers between environments. Also known as air doors, air curtains act as a controlled barrier for environmental and thermal separation between conditioned and unconditioned air when a building's doors are opened. They reduce cross mitigation of warm, lighter air flowing through the upper part of the opening and cold, heavier air flowing through the lower part of the opening while allowing an uninterrupted flow of traffic and unobstructed vision through the opening.

Qualifying air curtains must cover the entire door opening and operate only during the cooling and heating seasons. This measure is only applicable to entryways with overhead doors between indoor conditioned and outdoor unconditioned spaces.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times \left(\Delta kWh_{cooling} + \Delta kWh_{heating}\right)$$

$$\Delta kWh_{cooling} = \left\{\left[\frac{\Delta(kBTU/h)_{cooling}}{Eff_{ElecCool}}\right] - (hp_{curtain} \times 0.746)\right\} \times hrs \times days_{cooling}$$

$$\Delta kWh_{heating} = \left\{\left[\frac{\Delta(kBTU/h)_{heating}}{Eff_{ElecHeat}}\right] \times F_{ElecHeat} - (hp_{curtain} \times 0.746)\right\} \times hrs \times days_{heating}$$

Summer Peak Coincident Demand Savings

$$\Delta kW = units \times \frac{\Delta kWh_{cooling}}{days_{cooling} \times 24} \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = units \times \left[\frac{\Delta(kBTU/h)_{heating}}{Eff_{FuelHeat} \times 1{,}000}\right] \times F_{FuelHeat} \times hrs \times days_{heating}$$

where:

$$\Delta(kBTU/h)_{cooling} = \frac{4.5 \times Q_{A,cooling} \times \left(H_{outdoor,cooling} - H_{indoor,cooling}\right)}{1{,}000} \times Eff_{curtain}$$

$$Q_{A,cooling} = \sqrt{{Q_{wind,cooling}}^2 + {Q_{thermal,cooling}}^2}$$

$$Q_{wind,cooling} = MPH_{cooling} \times ht \times l \times F_{opening} \times 88$$

$$Q_{thermal,cooling} = 60 \times ht \times l \times F_{discharge} \times \sqrt{32.2 \times ht \times \frac{\left(T_{outdoor,cooling} - T_{indoor,cooling}\right)}{\left(T_{outdoor,cooling} + 459.67\right)}}$$

$$\Delta(kBTU/h)_{heating} = \frac{1.08 \times Q_{A,heating} \times \left(T_{indoor,heating} - T_{outdoor,heating}\right)}{1{,}000} \times Eff_{curtain}$$

$$Q_{A,heating} = \sqrt{{Q_{wind,heating}}^2 + {Q_{thermal,heating}}^2}$$

$$Q_{wind,heating} = MPH_{heating} \times ht \times l \times F_{opening} \times 88$$

$$Q_{thermal,heating} = 60 \times ht \times l \times F_{discharge} \times \sqrt{32.2 \times ht \times \frac{\left(T_{indoor,heating} - T_{outdoor,heating}\right)}{\left(T_{indoor,heating} + 459.67\right)}}$$

where:

ΔkWh	= Annual electricity energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
heating	= Property of heating season
cooling	= Property of cooling season
Δ(kBTU/h)	= Change in rate of heat transfer through doorway
$Eff_{ElecCool}$	= Seasonal average energy efficiency of electric cooling equipment, BTU/watt-hour, using either SEER (<65,000 BTU/h) or IEER (≥65,000 BTU/h)
$Eff_{ElecHeat}$	= Seasonal average energy efficiency of electric heating equipment. Heating Seasonal Performance Factor, BTU/watt-hour, total heating output (supply heat) in BTU (including resistance heating) during the heating season / total electric energy heat pump consumed (in watt-hour); if equipment efficiency is reported in COP, convert to HSPF using the equivalency HSPF = COP x 3.412
$Eff_{FuelHeat}$	= Fossil fuel heating system efficiency
$F_{ElecHeat}$	= Electric heating factor, used to include electric heating system impacts as applicable
$F_{FuelHeat}$	= Fossil fuel heating factor, used to include fossil fuel heating system impacts as applicable

$hp_{curtain}$ = Horsepower of air curtain motor
hrs = Daily run hours of air curtains
days = Days of operation of air curtains
CF = Coincident factor
Q_A = Total air flow entering doorway, in Cubic Feet per Minute
H_{indoor} = Average indoor enthalpy
$H_{outdoor}$ = Average outdoor enthalpy
T_{indoor} = Average indoor set temperature
$T_{outdoor}$ = Average outdoor temperature
$Eff_{curtain}$ = Effectiveness of air curtain
Q_{wind} = Air flow entering doorway due to wind
$Q_{thermal}$ = Air flow entering doorway due to thermal factors
MPH = Wind speed, in miles per hour
ht = height of doorway, in feet
l = length of doorway, in feet
$F_{opening}$ = Effectiveness of opening factor
$F_{discharge}$ = Discharge coefficient for opening
0.746 = Conversion factor (kW/hp), 746 watts equals one electric horsepower
24 = Hours in one day
1,000 = Conversion factor, one MMBtu equals 1,000 kBTU
4.5 = Density of inlet air at 70ºF x 60 min/hr, in lb-min/ft^3-hr
1.08 = Specific heat of air x density of inlet air at 70ºF x 60 min/hr, in BTU/h-ºF-CFM
1,000 = Conversion factor, on kBTU equals 1,000 BTU
88 = Conversion factor, one mile per hour equals 88 feet per minute
60 = Conversion factor, one minute equals 60 seconds
32.2 = Gravitational Constant, in ft/s^2
459.67 = Conversion factor, Fahrenheit to Rankine

Summary of Variables and Data Sources

Variable	Value	Notes
$\Delta(kBTU/h)_{cooling}$		Calculate per prescribed algorithms above. Using suggested default values in this methodology, there is a fixed linear relationship between $\Delta(kBTU/h)_{cooling}$ and the area of the entryway served by the air curtain. As such, a simplified approach for establishing default $\Delta(kBTU/h)_{cooling}$ values based on location and entryway area (A = ht x l) in ft^2 are provided in the Default Values table below.
$\Delta(kBTU/h)_{heating}$		Calculate per prescribed algorithms above. Using suggested default values in this methodology, there is a fixed linear relationship between $\Delta(kBTU/h)_{heating}$ and the area of the entryway served by the air curtain. As such, a simplified approach for establishing default $\Delta(kBTU/h)_{heating}$ values based on location and entryway area (A = ht x l) in ft^2 are provided in the Default Values table below.
$Eff_{ElecCool}$		From application. SEER or IEER shall be used, based on nameplate rating metric of existing equipment.

Variable	Value	Notes
$Eff_{ElecHeat}$		From application. HSPF shall be used, based on nameplate rating metric of existing equipment. If equipment is rated in COP, convert to HSPF using the equivalency HPSF = COP x 3.412.
$Eff_{FuelHeat}$		From application. E_c, E_t, or AFUE shall be used, based on nameplate rating metric of existing equipment.
$F_{ElecHeat}$		Use a value of 1.0 if the building is electrically heated. Otherwise, use 0.0.
$F_{FuelHeat}$		Use a value of 1.0 if the building is fossil fuel heated. Otherwise use 0.0.
$hp_{curtain}$		From application
hrs		From application
$days_{cooling}$		From application, or lookup based on location and season in table below.
$days_{heating}$		From application, or lookup based on location and season in table below.
CF	0.8	
$H_{indoor,cooling}$	34.6	Based on 85°F and 50% RH
$H_{outdoor,cooling}$		Lookup from Climate Data table below based on location[766]
$T_{indoor,cooling}$		From application or use 85°F as a default.[767]
$T_{outdoor,cooling}$		Lookup from Climate Data table below based on location[768]
$T_{indoor,heating}$		From application or use 60°F as a default.[769]
$T_{outdoor,heating}$		Lookup from Climate Data table below based on location[770]
$Eff_{curtain}$	0.7	Curtain effectiveness, based on midpoint of expected range (0.6 – 0.8)[771]
$MPH_{cooling}$		Lookup from Climate Data table below based on location[772]
$MPH_{heating}$		Lookup from Climate Data table below based on location[773]
ht		From application
l		From application
$F_{opening}$	0.3	Assumes diagonal wind[774]

[766] NCEI 1981-2010 Annual/Seasonal Climate Normals
[767] ECCNYS 2020; Table C403.4.1.4 Heated or Cooled Vestibules (Mandatory)
[768] NCEI 1981-2010 Annual/Seasonal Climate Normals
[769] ECCCNYS 2020; Table C403.4.1.4 Heated or Cooled Vestibules (Mandatory)
[770] NCEI 1981-2010 Annual/Seasonal Climate Normals
[771] 2019 ASHARE Handbook – HVAC Applications, Chapter 58, page 58.34
[772] Ibid
[773] Ibid
[774] 2017 ASHRAE Handbook – Fundamentals, Chapter 16, page 16.14

Variable	Value	Notes
$F_{discharge}$	0.4	The discharge coefficient accounts for all viscous effects such as surface drag and interfacial mixing through the door, dependent on number of entry points into the conditioned space.[775] A single entrance is assumed for simplicity. Effects of indoor and outdoor temperature differential are expected to have negligible impact on this factor and are therefore ignored.

Default Values[776]

City	$\Delta(kBTU/h)_{cooling}$	$\Delta(kBTU/h)_{heating}$
Albany	4.12A - 0.48	2.57A - 1.06
Binghamton	3.68A - 0.16	2.82A - 0.95
Buffalo	4.92A - 0.14	3.15A - 0.76
Massena	3.72A - 0.36	2.41A - 0.95
NYC	7.00A - 0.56	2.43A - 0.35
Poughkeepsie	3.15A - 0.66	1.25A - 0.76
Syracuse	4.16A - 0.42	2.68A - 0.93

Climate Data[777,778,779,780]

City	$T_{outdoor, cooling}$ (ºF)	$T_{outdoor, heating}$ (ºF)	$H_{outdoor,cooling}$ (BTU/lb)	$MPH_{cooling}$ (mph)	$MPH_{heating}$ (mph)
Albany	87.3	45.5	36.2	6.43	8.46
Binghamton	86.1	45.5	35.3	7.23	9.41
Buffalo	86.0	46.0	35.3	8.67	10.99
Massena	86.8	46.3	35.9	6.23	8.41
NYC	88.7	50.1	37.3	9.70	12.09
Poughkeepsie	86.9	49.7	35.9	4.30	5.70
Syracuse	87.2	45.8	36.1	6.77	9.14

[775] 2017 ASHRAE Handbook – Fundamentals, Chapter 16, page 16.14. equation 39
[776] "A" represents the area of the doorway in ft^2 (A = ht x l).
[777] NCEI 1981-2010 Annual/Seasonal Climate Normals
[778] 2017 ASHRAE Handbook – Fundamentals, Chapter 14, Climate Data Tables
[779] The cooling season is defined as the date range over which the outdoor air temperature is above 85°F for at least one hour in a day. The cooling season is defined as the date range over which the outdoor air temperature is below 60°F for at least one hour in a day. Temperature values are based on the 90th percentile hourly temperature during the cooling and heating seasons.
[780] Enthalpy values are based on psychrometric analysis of air at average dry bulb and wet bulb temperatures across the cooling season when the outdoor dry bulb temperature is above the assumed balance point of 65F.
MPH values reflect the average monthly values throughout the respective season (cooling/heating) identified by the ASHRAE Handbook.

Days of Operation[781]

City	Heating Season Days	Cooling Season Days
Albany	227	72
Binghamton	227	7
Buffalo	203	45
Massena	209	68
NYC	180	98
Poughkeepsie	205	58
Syracuse	217	70

Coincidence Factor (CF)

The prescribed coincidence factor for this measure is 0.8.[782]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition for this measure is an entryway with overhead doors and no air curtains installed.

Compliance Efficiency from which Incentives are Calculated

The compliance condition for this measure is an air curtain over an entryway with overhead doors between conditioned and unconditioned spaces. Qualifying air curtains must cover the entire door opening. Air curtains shall operate only during the cooling and heating seasons.

Operating Hours

Air curtain operating hours shall be based on application. Default values for number of operating days in cooling and heating seasons are provided in the Summary of Variables and Data Sources table above.

Example Calculation *(Not to be used as default)*

An air curtain with a 1/4 hp fan motor is installed in the 7 x 3 ft entryway of a small grocery store near Albany. The store has central AC with a SEER of 13 and gas heating with 82% AFUE. The door is used for 12 hours per day, 227 days per year in the heating season and 72 days per year in the cooling season. The average heating season setpoint temperature is 66°F and the average cooling season setpoint temperature is 74°F. Annual Electric Energy Savings, Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta kWh = units \times \left(\Delta kWh_{cooling} + \Delta kWh_{heating}\right)$$

[781]Derived from NCEI 1981-2010 Annual/Seasonal Climate Normals. Heating Season Days reflect the number of days in the year on which the 90th percentile hourly temperature falls below 60°F for at least one hour. Similarly, Cooling Season Days reflect the number of days in the year on which the 90th percentile hourly temperature falls above 85°F for at least one hour

[782] *No source specified – update pending availability and review of applicable references.*

$$\Delta kW = units \times \frac{\Delta kWh_{cooling}}{days_{cooling} \times 24} \times CF$$

$$\Delta MMBtu = units \times \left[\frac{\Delta(kBTU/h)_{heating}}{Eff_{FuelHeat} \times 1{,}000}\right] \times F_{FuelHeat} \times hrs \times days_{heating}$$

where:

$$\Delta kWh_{cooling} = \left\{\left[\frac{\Delta(kBTU/h)_{cooling}}{Eff_{ElecCool}}\right] - (hp_{curtain} \times 0.746)\right\} \times hrs \times days_{cooling}$$

$$\Delta(kBTU/h)_{cooling} = \frac{4.5 \times Q_{A,cooling} \times \left(H_{outdoor,cooling} - H_{indoor,cooling}\right)}{1{,}000} \times Eff_{curtain}$$

$$Q_{A,cooling} = \sqrt{{Q_{wind,cooling}}^2 + {Q_{thermal,cooling}}^2}$$

$$Q_{wind,cooling} = MPH_{cooling} \times ht \times l \times F_{opening} \times 88$$

$$Q_{thermal,cooling} = 60 \times ht \times l \times F_{discharge} \times \sqrt{32.2 \times ht \times \frac{\left(T_{outdoor,cooling} - T_{indoor,cooling}\right)}{\left(T_{outdoor,cooling} + 459.67\right)}}$$

$$\Delta kWh_{heating} = \left\{\left[\frac{\Delta(kBTU/h)_{heating}}{Eff_{ElecHeat}}\right] \times F_{ElecHeat} - (hp_{curtain} \times 0.746)\right\} \times hrs \times days_{heating}$$

$$\Delta(kBTU/h)_{heating} = \frac{1.08 \times Q_{A,heating} \times \left(T_{indoor,heating} - T_{outdoor,heating}\right)}{1{,}000} \times Eff_{curtain}$$

$$Q_{A,heating} = \sqrt{{Q_{wind,heating}}^2 + {Q_{thermal,heating}}^2}$$

$$Q_{wind,heating} = MPH_{heating} \times ht \times l \times F_{opening} \times 88$$

$$Q_{thermal,heating} = 60 \times ht \times l \times F_{discharge} \times \sqrt{32.2 \times ht \times \frac{(T_{indoor,heating} - T_{outdoor,heating})}{(T_{indoor,heating} + 459.67)}}$$

$hp_{curtain}$ = 0.25, from application
$Eff_{ElecCool}$ = 13, from application
$Eff_{FuelHeat}$ = 0.82, from application
$F_{FuelHeat}$ = 1.0, from Summary of Variables and Data Sources table
hrs = 12, from application
$days_{heating}$ = 227, from application
$days_{cooling}$ = 72, from application
CF = 0.8, from Summary of Variables and Data Sources table
$H_{indoor,cooling}$ = 34.6, from Summary of Variables and Data Sources table
$H_{outdoor,cooling}$ = 36.2, from Climate Data table based on location
$T_{indoor,cooling}$ = 74°F, default value from Summary of Variables and Data Sources table
$T_{outdoor,cooling}$ = 87.3°F, from Climate Data table based on location
$T_{indoor,heating}$ = 66°F, default value from Summary of Variables and Data Sources table
$T_{outdoor,heating}$ = 45.5°F, from Climate Data table based on location
$Eff_{curtain}$ = 0.7, from Summary of Variables and Data Sources table
$MPH_{cooling}$ = 6.43, from Climate Data table based on location
$MPH_{heating}$ = 8.46, from Climate Data table based on location
ht = 7 ft, from application
l = 3 ft, from application
$F_{opening}$ = 0.3, from Summary of Variables and Data Sources table
$F_{discharge}$ = 0.4, from Summary of Variables and Data Sources table
CF = 0.8, from Summary of Variables and Data Sources table

$$Q_{wind,cooling} = 6.43 \times 7 \times 3 \times 0.3 \times 88 = 3{,}565$$

$$Q_{thermal,cooling} = 60 \times 7 \times 3 \times 0.4 \times \sqrt{32.2 \times 7 \times \frac{(87.3 - 74)}{(87.3 + 459.67)}} = 1{,}180$$

$$Q_{A,cooling} = \sqrt{3{,}565^2 + 1{,}180^2} = 3{,}755$$

$$\Delta(kBTU/h)_{cooling} = \frac{4.5 \times 3{,}755 \times (36.2 - 34.6)}{1{,}000} \times 0.7 = 18.93$$

$$\Delta kWh_{cooling} = \left\{\left[\frac{18.93}{13}\right] - (0.25 \times 0.746)\right\} \times 12 \times 72 = 1{,}097$$

$$Q_{wind,heating} = 8.46 \times 7 \times 3 \times 0.3 \times 88 = 4{,}690$$

$$Q_{thermal,heating} = 60 \times 7 \times 3 \times 0.4 \times \sqrt{32.2 \times 7 \times \frac{(66 - 45.5)}{(66 + 459.67)}} = 1{,}494$$

$$Q_{A,heating} = \sqrt{4{,}690^2 + 1{,}494^2} = 4{,}922$$

$$\Delta(kBTU/h)_{heating} = \frac{1.08 \times 4{,}922 \times (66 - 45.5)}{1{,}000} \times 0.7 = 76.28$$

$$\Delta kWh_{heating} = \left\{\left[\frac{76.28}{N/A}\right] \times 0 - (0.25 \times 0.746)\right\} \times 12 \times 227 = -508$$

$$\Delta kWh = 1 \times (936 + (-508)) = 428\ kWh$$

$$\Delta kW = 1 \times \frac{428}{72 \times 24} \times 0.8 = 0.2\ kW$$

$$\Delta MMBtu = 1 \times \left[\frac{76.28}{0.82 \times 1{,}000}\right] \times 1 \times 12 \times 227 = 253.4\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

In addition to cooling and heating savings, installation of an air curtain results in increased electric load due to added fan power.

References

1. NOAA National Center for Environmental Information – NCEI 1981 – 2010 Annual/Seasonal Climate Normals
   Available from: https://www.ncdc.noaa.gov/cdo-web/datatools/normals
2. ECCCNYS 2020 Table C403.4.1.4 Heated or Cooled Vestibules (Mandatory)
   Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-[ce]-commercial-energy-efficiency#NYSECC2020P1_CE_Ch04_SecC403
3. 2019 ASHRAE Handbook – HVAC Applications, Chapter 58: Room Air Distribution
4. 2017 ASHRAE Handbook – Fundamentals, Chapter 16: Ventilation and Infiltration
5. 2017 ASHRAE Handbook – Fundamentals, Chapter 14: Climate Design Information

Record of Revision

Record of Revision Number	Issue Date
3-20-6	3/30/2020

Return to Table of Contents

AIR LEAKAGE SEALING

Measure Description

This measure covers methods of sealing air leakage paths to reduce the natural air infiltration rate of a building through the installation of products and repairs to the building envelope, including, but not limited to, caulking, gasketing, and weather stripping. Sealing the thermal envelope reduces passive convective heat transfer between conditioned and unconditioned spaces or outside air, thereby reducing heating and cooling loads and improving occupant comfort. This measure is only applicable as a retrofit in existing buildings. This measure is not applicable to gut rehab/major renovation projects, which entail whole-building envelope alterations that trigger more stringent code provisions, limiting potential incremental savings.

The exterior envelope, as well as interior walls/partitions between conditioned and unconditioned spaces should be inspected and all gaps sealed. At a minimum, the following items shall be inspected, and sealing measures may be implemented based upon inspection results:

- Caulk and weather strip doors and windows that leak air
- Repair or replace doors leading from conditioned to unconditioned space
- Seal air leaks between unconditioned (including unconditioned basement and attics) and conditioned spaces, to include, but not limited to, plumbing, ducting, electrical wiring, wall top plates, chimneys, flues, and dropped soffits.
- Use foam sealant on larger gaps around windows, baseboards, and other places where air leakage, either infiltration or exfiltration may occur.

In cases where blower door testing is conducted before and after implementation of air sealing treatments, those measurements shall be utilized in the estimation of energy impacts via the method below. A blower door test is performed to measure the leakage rate by depressurizing the building to a standard pressure difference of 75 Pascals or 0.3 inches of water. The flowrate indicates the leakage rate, or infiltration and exfiltration rate, of the building shell.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = \Delta kWh_{cooling} + \Delta kWh_{heating}$$

$$\Delta kWh_{cooling} = \frac{\left[\frac{(CFM_{75}/SF)_{baseline} - (CFM_{75}/SF)_{ee}}{F_{n,cooling} \times F_h}\right] \times SF \times LM \times 1.08 \times CDD \times 24}{Eff_{ElecCool} \times 1{,}000}$$

$$\Delta kWh_{heating} = \frac{\left[\frac{(CFM_{75}/SF)_{baseline} - (CFM_{75}/SF)_{ee}}{F_{n,heating} \times F_h}\right] \times SF \times 1.08 \times HDD \times 24 \times F_{ElecHeat}}{HSPF \times 1{,}000}$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \frac{\left[\frac{(CFM_{75}/SF)_{baseline} - (CFM_{75}/SF)_{ee}}{F_{n,cooling} \times F_h}\right] \times SF \times LM \times 1.08}{EER \times 1{,}000} \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = \frac{\left[\frac{(CFM_{75}/SF)_{baseline} - (CFM_{75}/SF)_{ee}}{F_{n,heating} \times F_h}\right] \times SF \times 1.08 \times HDD \times 24 \times F_{FuelHeat}}{Eff_{FuelHeat} \times 1{,}000{,}000}$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
$\Delta kWh_{cooling}$	= Annual electric cooling energy savings
$\Delta kWh_{heating}$	= Annual electric heating energy savings
$_{baseline}$	= Characteristic of baseline condition
$_{ee}$	= Characteristic of energy efficient condition
(CFM_{75}/SF)	= Infiltration rate (cubic foot per minute per building square foot) at a negative pressure differential of 75 Pa or 0.3 inches of water[783]
$F_{n,cooling}$	= Infiltration-Leakage Ratio, used to convert pressurized blower door testing results to natural infiltration rates, climate zone factor during cooling season
$F_{n,heating}$	= Infiltration-Leakage Ratio, used to convert pressurized blower door testing results to natural infiltration rates, climate zone factor during heating season
F_h	= Infiltration-Leakage Ratio, used to convert pressurized blower door testing results to natural infiltration rates, building height factor
LM	= Latent Multiplier, used to convert the sensible cooling savings calculated to a value representing sensible and latent cooling loads
SF	= Square footage of the above- and below-grade building envelope[784] (ft^2)
CDD	= Cooling Degree Day
HDD	= Heating Degree Day
$Eff_{ElecCool}$	= Seasonal average energy efficiency of electric cooling equipment, BTU/watt-hour, using either SEER (<65,000 BTU/h) or IEER (>65,000 BTU/h)
HSPF	= Seasonal average energy efficiency of electric heating equipment. Heating Seasonal Performance Factor, BTU/watt-hour, total heating output (supply heat) in BTU (including resistance heating) during the heating season / total electric energy heat pump consumed (in watt-hour); if equipment efficiency is reported in COP, convert to HSPF using the equivalency HSPF = COP x 3.412
EER	= Energy efficiency ratio under peak conditions (BTU/watt-hour)
$Eff_{FuelHeat}$	= Efficiency of fossil fuel heating equipment (AFUE, E_t, or E_c)

[783] ECCCNYS 2020 C402.5 Air leakage – thermal envelope (Mandatory)
[784] ECCCNYS 2020 C406.9 Reduced air infiltration

$F_{ElecHeat}$ = Electric heating factor; used to account for the presence or absence of an electric heating system
$F_{FuelHeat}$ = Fossil fuel heating factor; used to account for the presence or absence of a fossil fuel heating system
CF = Coincidence factor
1.08 = Specific heat of air x density of inlet air @ 70ºF x 60 min/hr, in BTU/h-ºF-CFM[785]
24 = Hours in a day
1,000 = Conversion factor, one kW equals 1,000 Watts
1,000,000 = Conversion factor, one MMBtu equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
$(CFM_{75}/SF)_{baseline}$		From application, results from blower door test. If pre-implementation blower door test results are unavailable, use 0.40 CFM_{75}/SF as default.[786]
$(CFM_{75}/SF)_{ee}$		From application, results from blower door test. If post -implementation blower door test results are unavailable, use 0.25 CFM_{75}/SF as default.[787,788,789]
SF		From application.
$F_{n,cooling}$		Look up in Infiltration-Leakage Ratio, Climate Zone table below based on location and building shielding class, as defined below.
$F_{n,heating}$		Look up in Infiltration-Leakage Ratio, Climate Zone table below based on location and building shielding class, as defined below.

[785] The sensible heat constant at standard conditions of 1.08 is applied in accordance with standard HVAC industry practice. While the underlying assumptions are not representative characteristics of a NY heating season, the impacts to this value due to average heating season temperature and NY mean elevation offset such that the NY heating season specific value is approximately 1.08.
[786] ECCCNYS 2020 C402.5 Air leakage – thermal envelope (Mandatory)
[787] ECCCNYS 2020 C406.9 Reduced air infiltration
[788] U.S. Army Corps of Engineers Air Leakage Test Protocol for Building Envelopes, Version 3, May 11, 2012, p. 7
[789] NIST, Analysis of U.S. Commercial Building Envelope Air Leakage Database to Support Sustainable Building Design. Analysis of air sealing in commercial buildings demonstrates buildings exceeding ECCCNYS Additional Efficiency Packages requirements.

Variable	Value	Notes
F_h	$= N_{stories}{}^{-0.3}$	Based on the number of conditioned stories in the building, from application.[790] The selected value should reflect the number of stories located inside the conditioned envelope of the building. Unconditioned basements and attics should not be included. Upper levels without full height perimeter walls shall be considered as half-stories (0.5).
LM		Look up in the Latent Multiplier table below, based on location.
CDD		From application. If unknown, lookup based on location in Heating and Cooling Degree Days table in the Operating Hours section below.
HDD		From application. If unknown, lookup based on location in Heating and Cooling Degree Days table in the Operating Hours section below.
$Eff_{ElecCool}$		From application. SEER or IEER shall be used, based on nameplate rating metric of existing equipment.
HSPF		From application. HSPF shall be used, based on nameplate rating metric of existing equipment. If equipment is rated in COP, convert to HSPF using the equivalency HPSF = COP x 3.412
EER		From application. If unknown, baseline EER is established as follows[791]: $EER = (1.12 \times \mathrm{Eff}_{\mathrm{ElecCool}}) - \left(0.02 \times \mathrm{Eff}_{\mathrm{ElecCool}}{}^{2}\right)$
$Eff_{heating}$		From application. E_c, E_t, or AFUE shall be used, based on nameplate rating metric of existing equipment.
$F_{ElecHeat}$		Use a value of 1.0 if the building is electrically heated. Otherwise, use 0.0.
$F_{FuelHeat}$		Use a value of 1.0 if the building is fossil fuel heated. Otherwise use 0.0.
CF	NYC: 0.822 Outside of NYC: 0.477	

<u>Infiltration-Leakage Ratio, Climate Zone</u>

The Infiltration-Leakage Ratio, Climate Zone converts pressurized blower door testing results to natural infiltration rates with consideration for climate zone. Look up $F_{n,cooling}$ and $F_{n,heating}$ in the

[790] LBL, Exegesis of Proposed ASHRAE Standard 119: Air Leakage Performance for Detached Single-Family Residential Buildings, M. Sherman, July 1986, p. 12

[791] DOE, Building America House Simulation Protocols, October 2010

tables below based on climate zone and shielding class, as defined below, based on application.[792]
Shielding Class[793]:

(1) No shielding on any side
(2) A few nearby obstructions
(3) A collection of obstructions within 25 feet
(4) Substantial number of obstructions shield most of the perimeter – typical suburban setting
(5) Building surrounded by large structures – typical urban setting

Shielding Class	$F_{n,cooling}$						
	Albany	Binghamton	Buffalo	Massena	NYC	Poughkeepsie	Syracuse
1	12	11	10	11	9	11	12
2	14	13	11	12	10	13	14
3	16	15	13	15	12	15	16
4	20	19	17	19	16	19	20
5	34	32	29	32	27	33	34

Shielding Class	$F_{n,heating}$						
	Albany	Binghamton	Buffalo	Massena	NYC	Poughkeepsie	Syracuse
1	12	10	9	10	8	10	11
2	13	11	10	11	9	11	12
3	15	13	12	13	10	13	15
4	19	17	15	17	13	17	18
5	28	26	24	26	22	26	27

Latent Multiplier[794]

The Latent Multiplier converts the sensible cooling load savings captured in the savings equation to a savings capturing both latent and sensible load savings. The multiplier accommodates for the energy savings impacts associated with decreased humidity influx in a building with improved air sealing. During the cooling season, humidity poses an additional load on the cooling system. The Latent Multiplier is the ratio of total heat load (latent and sensible) to sensible heat load. Set indoor conditions are taken as 75ºF and 50% rh.

[792] Infiltration-Leakage Ratio is calculated based on the derivation for air flow rate as outlined in ASHRAE Handbook – Fundamentals, 2017, Chapter 16 Ventilation and Infiltration, Section 10 Simplified Models of Residential Ventilation and Infiltration, p. 16.24: Airflow Rate (CFM) = Effective Air Leakage Area Conversion Factor * SQRT(Stack Coefficient * | Temperature Difference | + Wind Coefficient * (Wind Velocity)^2). Stack Coefficient and Wind Coefficient values are applied from Table 4 Basic Model Stack Coefficient C_s and Table 6 Basic Model Wind Coefficient C_w. Hourly wind speeds and ambient air temperatures are downloaded from NCEI. Effective Air Leakage Area Conversion Factor is calculated as outlined in Computing Manual J Infiltration Loads Based Upon a Target Envelope Leakage Requirement (ACCA, October 2016) Sections 2 and 5. At a pressurization of 75 CFM and assuming sea level, Equivalent Leakage Ratio = (0.2835*(4)^0.65)/(75)^0.65 = 0.042. Applying a building balance point of 65, hourly Normalized Airflow Rates are calculated for the heating season (below 65F) and the cooling season (above 65F). The inverse of the average of the hourly airflow rates are applied as the seasonal factors, $F_{n,cooling}$ and $F_{n,heating}$, as outlined in Infiltration Factor Calculation Methodology, Bruce Harley, Senior Manager, Applied Building Science, CLEAResult, 11/18/2015, as published in a IL TRM Memo, November 25, 2015.

[793] ASHRAE Handbook – Fundamentals, 2017. Chapter 16 Ventilation and Infiltration, Section 10 Simplified Models of Residential Ventilation and Infiltration, Table 5 Local Shelter Classes

[794] ASHRAE Journal, Dehumidification and Cooling Loads From Ventilation Air, Lewis Harriman, November 1997

Location	Latent Load	Sensible Load	Latent Multiplier (LM)
Albany	2.3	0.4	6.8
Binghamton	2.2	0.1	23.0
Buffalo	1.9	0.2	10.5
Massena	2.1	0.2	11.5
NYC	2.6	0.5	6.2
Poughkeepsie*	3.0	0.6	6.0
Syracuse	2.1	0.3	8.0

*Poughkeepsie data is approximated from Hartford, Connecticut due to limited available data

Coincidence Factor (CF)

The prescribed coincidence factor for this measure is 0.822 for NYC and 0.477 outside of NYC.[795]

Baseline Efficiencies from which Energy Savings are Calculated

Baseline flow rate CFM_{75}/SF shall come from blower door testing. If pre-implementation blower-door results are unavailable, use default of 0.4 CFM_{75}/SF.[796]

Compliance Efficiency from which Incentives are Calculated

The compliance condition is the application of air leakage sealing treatments to an existing building envelope (excluding gut rehab/major renovations) such that the exterior envelope, as well as interior walls/partitions between conditioned and unconditioned spaces have been inspected and all gaps sealed. At a minimum, the following items shall be inspected, and sealing measures may be implemented based upon inspection results:

- Caulk and weather strip doors and windows that leak air
- Repair or replace doors leading from conditioned to unconditioned space
- Seal air leaks between unconditioned (including unconditioned basement and attics) and conditioned spaces, to include, but not limited to, plumbing, ducting, electrical wiring, wall top plates, chimneys, flues, and dropped soffits.
- Use foam sealant on larger gaps around windows, baseboards, and other places where air leakage, either infiltration or exfiltration may occur.

Operating Hours

Effective heating and cooling hours associated with benefits of air sealing are established via the Heating and Cooling Degree Days table below.

[795] C&I Unitary HVAC Load Shape Project Final Report, KEMA, 2011, Table 0-5: NY - Inland and NY - Urban/Coastal
[796] ECCCNYS 2020 C402.5 Air leakage – thermal envelope (Mandatory)

Heating and Cooling Degree Days[797]

City	HDD	CDD
Albany	6,680	597
Binghamton	7,193	382
Buffalo	6,617	544
Massena	8,196	363
NYC	4,671	1,160
Poughkeepsie	6,210	671
Syracuse	6,651	570

Example Calculation *(Not to be used as default)*

Caulking was performed to seal air leakage in a 3 story, 15,000 square foot commercial building located near Albany after a blower door test was conducted. The building has central air conditioning with an IEER of 13 and EER of 10.8 and a gas heating system with 82% thermal efficiency. The building is surrounded by multiple structures of equal or greater height. The pre-implementation blower-door test results yielded a $(CFM_{75}/SF)_{baseline}$ of 0.44 whereas the post-implementation blower door test results yielded $(CFM_{75}/SF)_{ee}$ of 0.27. Annual Electric Energy Savings, Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta kWh = \Delta kWh_{cooling} + \Delta kWh_{heating}$$

$$\Delta kWh_{cooling} = \frac{\left[\frac{(CFM_{75}/SF)_{baseline} - (CFM_{75}/SF)_{ee}}{F_{n,cooling} \times F_h}\right] \times SF \times LM \times 1.08 \times CDD \times 24}{Eff_{ElecCool} \times 1{,}000}$$

$$\Delta kWh_{heating} = \frac{\left[\frac{(CFM_{75}/SF)_{baseline} - (CFM_{75}/SF)_{ee}}{F_{n,heating} \times F_h}\right] \times SF \times 1.08 \times HDD \times 24 \times F_{ElecHeat}}{HSPF \times 1{,}000}$$

$$\Delta kW = \frac{\left[\frac{(CFM_{75}/SF)_{baseline} - (CFM_{75}/SF)_{ee}}{F_{n,cooling} \times F_h}\right] \times SF \times LM \times 1.08}{EER \times 1{,}000} \times CF$$

$$\Delta MMBtu = \frac{\left[\frac{(CFM_{75}/SF)_{baseline} - (CFM_{75}/SF)_{ee}}{F_{n,heating} \times F_h}\right] \times SF \times 1.08 \times HDD \times 24 \times F_{FuelHeat}}{Eff_{FuelHeat} \times 1{,}000{,}000}$$

$(CFM_{75}/SF)_{baseline}$ = 0.44, from application
$(CFM_{75}/SF)_{ee}$ = 0.27, from application
SF = 15,000, from application

[797] HDD/CDD taken from NCEI 1981-2010 climate normal climate normal using a 65ºF balance point.

LM = 6.8, from Latent Multiplier table
CDD = 602, from application
HDD = 6,682, from application
$F_{n,cooling}$ = 34, from Infiltration-Leakage Ratio, Climate Zone table based on Shielding Class (5) and City
$F_{n,heating}$ = 28, from Infiltration-Leakage Ratio, Climate Zone table based on Shielding class and City
$F_h = N_{stories}^{-0.3} = 3^{-0.3} = 0.719$
$N_{stories}$ = 3, from application
$Eff_{ElecCool}$ = 13, from application
EER = 10.8, from application
$Eff_{FuelHeat}$ = 0.82, from application
$F_{ElecHeat}$= 0, from Summary of Variables and Data Sources, since building is fossil fuel heated
$F_{FuelHeat}$ = 1, from Summary of Variables and Data Sources, since building is fossil fuel heated
CF = 0.477, from Summary of Variables and Data Sources, based on location

$$\Delta kWh_{cooling} = \frac{\left[\frac{0.44 - 0.27}{34 \times 0.719}\right] \times 15{,}000 \times 6.8 \times 1.08 \times 602 \times 24}{13 \times 1{,}000} = 851$$

$$\Delta kWh_{heating} = \frac{\left[\frac{0.44 - 0.27}{28 \times 0.719}\right] \times 15{,}000 \times 1.08 \times 6{,}682 \times 24 \times 0}{N/A \times 1{,}000} = 0$$

$$\Delta kWh = 851 + 0 = 851\ kWh$$

$$\Delta kW = \frac{\left[\frac{0.44 - 0.27}{34 \times 0.719}\right] \times 15{,}000 \times 6.8 \times 1.08}{10.8 \times 1{,}000} \times 0.477 = 0.034\ kW$$

$$\Delta MMBtu = \frac{\left[\frac{0.44 - 0.27}{28 \times 0.719}\right] \times 15{,}000 \times 1.08 \times 6{,}682 \times 24 \times 1}{0.82 \times 1{,}000{,}000} = 26.75\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. ECCCNYS 2020 Section C402.5 Air leakage – thermal envelope (Mandatory)
   Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-ce-commercial-energy-efficiency#NYSECC2020P1_CE_Ch04_SecC402
2. ECCCNYS 2020 Section C406.9 Reduced air infiltration
   Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-ce-commercial-energy-efficiency#NYSECC2020P1_CE_Ch04_SecC406
3. US Army Corps of Engineers Air Leakage Test Protocol for Building Envelopes, Version 3, May 11, 2012
   Available from:
   https://www.wbdg.org/FFC/ARMYCOE/usace_airleakagetestprotocol.pdf
4. National Institute of Standards and Technology, Analysis of U.S. Commercial Building Envelope Air Leakage Database to Support Sustainable Building Design
   Available from: https://tsapps.nist.gov/publication/get_pdf.cfm?pub_id=914293
5. Lawrence Berkley Laboratory, University of California, Exegesis of Proposed ASHRAE Standard 119: Air Leakage Performance for Detached Single-Family Residential Buildings, M. Sherman, July 1986
   Available from: https://escholarship.org/uc/item/4268v5z5
6. Building America House Simulation Protocols, Robert Hendron and Cheryn Engebrecht, National Renewable Energy Laboratory, October 2010
   Available from:
   https://www1.eere.energy.gov/buildings/publications/pdfs/building_america/house_simulation_revised.pdf
7. 2017 ASHRAE Handbook – Fundamentals, Chapter 16: Ventilation and Infiltration
8. NOAA National Centers for Environmental Information – NCEI 1981-2010 Climate Normals
   Available from: https://www.ncdc.noaa.gov/cdo-web/datatools/normals
9. Air Conditioning Contractors of America, Technical Reference Note, Computing Manual J Infiltration Loads Based Upon a Target Envelope Leakage Requirement, Note 2016-1, October 2016
   Available from: https://higherlogicdownload.s3.amazonaws.com/ACCA/c6b38bda-2e04-4f93-bd51-7a80525ad936/UploadedImages/Infiltration%20per%20Blower%20Door%20Test%20Oct2016.pdf
10. Infiltration Factor Calculation Methodology, Bruce Harley, Senior Manager, Applied Building Science, CLEAResult. As captured in Appendix A of the Illinois Technical Advisory Committee's Memorandum, TRM Version 5 Draft 1 Review – Second Measure Group, November 25, 2015
    Available from:
    https://s3.amazonaws.com/ilsag/IL_TAC_Second_Measure_Group_Draft_Memo_11-25-2015.pdf

11. ASHRAE Journal, Dehumidification and Cooling Loads From Ventilation Air, Lewis Harriman, November 1997
    Available from: https://energy.mo.gov/sites/energy/files/harriman-dehumidification-and-cooling-loads-from-ventilation-air.pdf
12. C&I Unitary HVAC Load Shape Project Final Report, KEMA, August 2, 2011, Table 0-5; (accessed March 21, 2017).
    Available from: https://neep.org/sites/default/files/resources/NEEP_HVAC_Load_Shape_Report_Final_August2.pdf
13. ECCCNYS 2020 Section C402.5.1 Air Barrier Testing
    Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-[ce]-commercial-energy-efficiency#NYSECC2020P1_CE_Ch04_SecC403
14. NYSMC 2020; Section 401.2 Ventilation Required
    Available from: https://codes.iccsafe.org/content/NYSMC2020P1/chapter-4-ventilation
15. National Institute of Standards and Technology, Investigation of the Impact of Commercial Building Envelope Airtightness on HVAC Energy Use, Emmerich et al, 2005
    Available from: https://tsapps.nist.gov/publication/get_pdf.cfm?pub_id=860985
16. National Institute of Standards and Technology, Analysis of the NIST Commercial and Institutional Building Envelope Leakage Database, Emmerich et al, 2013
    Available from: https://tsapps.nist.gov/publication/get_pdf.cfm?pub_id=913709

Record of Revision

Record of Revision Number	Issue Date
3-21-11	4/9/2021

Return to Table of Contents

COOL ROOF

Measure Description

This measure covers the installation of roofing material with reduced solar absorptance. Cool roofs reduce heat gains and alleviate cooling HVAC loads. State regulations require a minimum three-year aged solar reflectance of 0.55 and thermal emittance of 0.75 and a solar reflectance index of 64.[798] In currently available system models, the cool roof (qualifying) is assumed to have a solar absorptance of 0.3 compared to a standard roof (baseline) with solar absorptance of 0.8. Due to negative impacts on space heating, this measure is applicable to buildings with air conditioning and gas heat only.

This measure is only applicable to existing buildings constructed before 2012 that have not undergone roof improvements since 2012.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = kSF \times \left(\frac{\Delta kWh}{1{,}000SF}\right)$$

Summer Peak Coincident Demand Savings

$$\Delta kW = kSF \times \left(\frac{\Delta kW}{1{,}000SF}\right) \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = kSF \times \left(\frac{\Delta MMBtu}{1{,}000SF}\right)$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
kSF	= Thousand square feet of installed cool roof
(ΔkWh/1,000SF)	= Annual electric energy savings per thousand square feet of cool roof
(ΔkW/1,000SF)	= Peak coincident demand electric savings per thousand square feet of cool roof
(ΔMMBtu/1,000SF)	= Annual fossil fuel energy savings per thousand square feet of cool roof
CF	= Coincidence factor

[798] ECCCNYS 2020 Table C402.3: Minimum Roof Reflectance and Emittance Options

Summary of Variables and Data Sources

Variable	Value	Notes
kSF		From application.
ΔkWh/1,000SF		Look up based on building type and city in Appendix I.
ΔkW/1,000SF		Look up based on building type and city in Appendix I.
ΔMMBtu/1,000SF		Look up based on building type and city in Appendix I.
CF	0.8	

Unit energy and demand savings were calculated from a DOE-2.2 simulation of a series of prototypical small commercial buildings. The prototype building characteristics are described in Appendix A. The unit energy and demand savings by building type and city are shown in Appendix I.

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.8.[799]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a roof without reduced solar absorptance, which is assumed to have a solar absorptance of 0.8.[800]

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a roof installed with reduced solar absorptance. Qualifying roofs shall have a minimum of three-year aged solar reflectance of 0.55 and thermal emittance of 0.75 and a three-year aged solar reflectance index of 64.[801]

Look up compliance cool roof efficiency from Appendix I based on building type and location. Models for cool roof efficiency congruent with state code are currently under development; available roof efficiencies assume a solar absorptance of 0.3.[802]

Operating Hours

HVAC system operating hours are embedded into the deemed savings shown in Appendix I and vary by building type. See Appendix A for details on prototype building simulation parameters.

Example Calculation *(Not to be used as default)*

A 2,500 square foot cool roof is installed on an assembly building in Albany constructed in 2010. The installed cool roof has a solar absorptance of 0.56, thermal emittance of 0.77 and solar reflectance index of 68. The building is equipped with central air conditioning and gas heat. Annual Electric Energy Savings, Summer Peak Coincident Demand Savings and Annual

[799] *No source specified – update pending availability and review of applicable references.*
[800] California Title 24 Standards
[801] ECCCNYS 2020, Table C402.3: Minimum Roof Reflectance and Emittance Options
[802] California Title 24 Standards

Fossil Fuel Energy Savings are calculated as below.

$$\Delta kWh = kSF \times \left(\frac{\Delta kWh}{1{,}000SF}\right)$$

$$\Delta kW = kSF \times \left(\frac{\Delta kW}{1{,}000SF}\right) \times CF$$

$$\Delta MMBtu = kSF \times \left(\frac{\Delta MMBtu}{1{,}000SF}\right)$$

kSF = 2.5, from application.
ΔkWh/1,000SF = 138, based on building type and city in Appendix I.
ΔkW/1,000SF = 0.128, based on building type and city in Appendix I.
ΔMMBtu/1,000SF = -1.60, based on building type and city in Appendix I.
CF = 0.8, from Summary of Variables and Data Sources table

$$\Delta kWh = 2.5 \times (138) = 345\ kWh$$

$$\Delta kW = 2.5 \times (0.128) \times 0.8 = 0.256\ kW$$

$$\Delta MMBtu = 2.5 \times (-1.60) = -4\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Reducing roofing material solar absorptance increases space heating requirements. The fossil fuel impacts are detailed above.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. ECCCNYS 2020 Table C402.3 Minimum Roof Reflectance and Emittance Options Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-cecommercial-energy-efficiency
2. Roof absorptivity assumptions taken from California Title 24 Standards for conventional and cool roofs

Record of Revisions

Record of Revision Number	Issue Date
1	10/15/2010
9-18-9	9/28/2018

Return to Table of Contents

INSULATION - HOT WATER AND STEAM PIPE

Measure Description

This measure covers the installation of fiberglass or rigid foam/cellular glass pipe insulation in space heating hot water/steam and domestic hot water (DHW) distribution systems on piping with a nominal diameter between 0.50″ and 8.00″. Estimation of energy savings depend on the type and size of the pipe, type and thickness of the insulation, supply temperature of the heating medium and ambient temperature.

This measure is applicable in retrofit applications and must be installed by a qualified contractor complying with all relevant construction and safety codes and standards. All insulation materials installed under this measure are to be tested in accordance with all pertinent federal testing standards (ASTM) and must be rated for the temperature range of the heating medium conveyed by the affected system. Service hot water pipe insulation for non-recirculating systems is limited to insulation of hot water distribution pipe in unconditioned spaces only. Space heating pipe insulation is limited to insulation installed in unheated spaces only.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = \frac{(UA/L)_{baseline} - (UA/L)_{ee}}{E_{t,elec} \times 3{,}412} \times l \times \Delta T_{amb} \times hrs \times ElecSF$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \frac{\Delta kWh}{8{,}760} \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = \frac{(UA/L)_{baseline} - (UA/L)_{ee}}{E_{t,fuel} \times 1{,}000{,}000} \times l \times \Delta T_{amb} \times hrs \times FuelSF$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
baseline	= Characteristic of baseline condition
ee	= Characteristic of energy efficient condition
(UA/L)	= Overall heat transfer coefficient per unit length (BTU/h-°F-ft)
E_t	= Thermal efficiency of hot water or steam system
l	= Length of installed insulation (ft) in unconditioned spaces
ΔT_{amb}	= Temperature difference between hot water or steam in pipe and surrounding ambient air temperature (°F)
hrs	= Annual operating hours

ElecSF = Electric Savings Factor for water heaters: Adjustment to electric water heating energy savings based on water heating fuel
FuelSF = Fossil fuel Savings Factor for water heaters: Adjustment to fossil fuel water heating energy savings based on water heating fuel
CF = Coincidence factor
3,412 = Conversion factor, one kWh equals 3,412 BTU
1,000,000 = Conversion factor, one MMBtu equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
$(UA/L)_{baseline}$		Lookup from Baseline Efficiencies section below, based on pipe diameter.
$(UA/L)_{ee}$		Lookup from Compliance Efficiency section below, based on pipe diameter and insulation type and thickness.
$E_{t,elec}$	DHW: 0.98	From application. If unknown, use default thermal efficiency of typical electric storage type water heater provided.[803]
$E_{t,fuel}$	DHW: 0.80 HW and Steam Boilers: See Boiler Efficiencies section below	From application. If unknown, use default efficiency of typical gas storage type water heater and boiler efficiencies provided. [804]
l		From application.
ΔT_{amb}	$T_{pipe} - T_{amb}$	
T_{pipe}	DHW: 125 HW Boiler: 160 Steam Boiler: 212	Average temperature of hot water in distribution system piping (°F). [805]
T_{amb}	DHW: 70 Space Heat: 50	Surrounding average ambient air temperature (°F). [806,807]
ElecSF	Electric WH: 1.0 Fossil Fuel WH: 0 Unknown WH: 0.45 Space Heat: 0	Based on EIA Commercial Buildings Energy Consumption Survey (CBECS) 2012 for Middle Atlantic States.[808]

[803] Per 10 CFR 431 Subpart G, Appendix B 5.7.1
[804] Per 10 CFR 431.110 (a)
[805] 10 CFR Appendix E to Subpart B of Part 430—Uniform Test Method for Measuring the Energy Consumption of Water Heaters, Section 2. Test Conditions, 2.5 Set Point Temperature.
[806] Average annual ambient temperature in unconditioned spaces
[807] Average ambient temperature based on typical heating season conditions of unconditioned basements
[808] EIA Commercial Building Energy Consumption Survey (CBECS) 2012 for Middle Atlantic States, Table B4, Water-heating energy sources ("Unknown" calculated as the number of buildings with electric water heating divided by the total number of buildings with electric or gas water heating)

Variable	Value	Notes
FuelSF	Electric WH: 0 Fossil Fuel WH: 1.0 Unknown WH: 0.55 Space Heat: 1.0	Based on EIA Commercial Buildings Energy Consumption Survey (CBECS) 2012 for Middle Atlantic States.[809]
hrs	DHW: 8,760 Space Heat: $EFLH_{heating}$ (Appendix G)	See Operating Hours section below.
CF	Electric DHW: 1.0 Hot Water: N/A	

Boiler Efficiency

Efficiency for commercial boilers is defined by the Code of Federal Regulations (CFR) and subsequently adopted by the Energy Conservation Construction Code of New York State[810] as shown below.

Equipment Type	Size Range	ECCCNYS Minimum Efficiency for Climate Zones 4, 5 and 6
Boiler, Hot Water, Gas Fired	< 300 kBTU/h	0.82 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.80 Et
	> 2,500 kBTU/h	0.82 Ec
Boiler, Hot Water, Oil Fired	< 300 kBTU/h	0.84 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.82 Et
	> 2,500 kBTU/h	0.84 Ec
Boiler, Steam, Gas Fired, All Except Natural Draft	< 300 kBTU/h	0.80 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.79 Et
	> 2,500 kBTU/h	0.79 Et
Boiler, Steam, Gas Fired, Natural Draft	< 300 kBTU/h	0.80 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.77 Et
	> 2,500 kBTU/h	0.77 Et
Boiler, Steam, Oil Fired	< 300 kBTU/h	0.82 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.81 Et
	> 2,500 kBTU/h	0.81 Et

Coincidence Factor (CF)

The prescribed value for the coincidence factor for domestic water heating is 1.0.[811]
The prescribed value for the coincidence factor for hot water heating is N/A.

[809] EIA Commercial Building Energy Consumption Survey (CBECS) 2012 for Middle Atlantic States, Table B4, Water-heating energy sources ("Unknown" calculated as the number of buildings with gas water heating divided by the total number of buildings with electric or gas water heating)
[810] ECCCNYS 2020, Table C403.3.2(5)
[811] *No source specified – update pending availability and review of applicable references.*

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is bare copper or steel domestic hot water or space heating piping. Prescribed $(UA/L)_{baseline}$ values are provided in the table below based on the diameter of pipe, pipe material, and application. CPVC, PEX and HDPE piping were not considered.[812] Pipe wall resistance and exterior film resistance were not considered in the derivation of the values below. Calculations were developed with NAIMA's 3E Plus software program.[813]

Pipe Diam. (in)	$(UA/L)_{baseline}$				
	Bare Copper Piping			Bare Steel Piping	
	Domestic Hot Water	Hot Water Heat	Steam Heat	Hot Water Heat	Steam Heat
0.50	0.44	0.48	0.53	0.53	0.59
0.75	0.54	0.58	0.64	0.65	0.72
1.00	0.65	0.70	0.78	0.79	0.88
1.25	0.80	0.86	0.96	0.97	1.09
1.50	0.90	0.97	1.09	1.10	1.23
2.00	1.10	1.19	1.33	1.34	1.51
2.50	1.31	1.42	1.58	1.60	1.80
3.00	1.57	1.70	1.90	1.92	2.16
3.50	1.77	1.92	2.15	2.18	2.45
4.00	1.98	2.14	2.40	2.43	2.73
5.00	2.41	2.61	2.92	2.97	3.34
6.00	2.84	3.07	3.45	3.50	3.94
8.00	3.64	3.94	4.42	4.50	5.06

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a length of service hot water or space heating hot water/steam distribution piping insulated in accordance with ECCCNYS[814]. Minimum required insulation thicknesses per material conductivity are outlined in the table below based on fluid operating temperature and pipe diameter ranges.

Fluid Operating Temperature Range and Usage (°F)	Conductivity BTU-in/h-SF-F	Mean Rating Temperature	Nominal Pipe or Tube Size (in)				
			< 1	≥ 1 and < 1.5	≥ 1.5 and < 4	≥ 4 and < 8	8
201-250	0.27-0.30	150	2.5	2.5	2.5	3.0	3.0
141-200	0.25-0.29	125	1.5	1.5	2.0	2.0	2.0
105-140	0.21-0.28	100	1.0	1.0	1.5	1.5	1.5
40-60	0.21-0.27	75	0.5	0.5	1.0	1.0	1.0

[812] These piping materials were found to have limited savings potential through preliminarily modeling in 3E Plus® Version 4.1
[813] Insulation Institute, 3E Plus® Version 4.1
[814] ECCCNYS 2020, Table C403.11.3 Minimum Pipe Insulation Thickness

Fluid Operating Temperature Range and Usage (°F)	Conductivity BTU-in/h-SF-F	Mean Rating Temperature	Nominal Pipe or Tube Size (in)				
			< 1	≥ 1 and < 1.5	≥ 1.5 and < 4	≥ 4 and < 8	8
< 40	0.20-0.26	50	0.5	1.0	1.0	1.0	1.5

For piping smaller than 1.5 inches and located in partitions within conditioned spaces, reduction of these thicknesses by 1 inch shall be permitted, before thickness adjustment if necessary, but not to a thickness less than 1 inch. For insulation outside the stated conductivity range, use the following equation to adjust the minimum required thickness from the table above:

$$T = r \times [(1 + t/r) \times K/k \ - 1]$$

where:

T = minimum insulation thickness
r = actual outside radius of pipe
t = insulation thickness listed in the table for applicable fluid temperature
K = conductivity of alternate material at mean rating temperature indicated for the applicable fluid temperature
k = the upper value of the conductivity range listed in the table for the applicable fluid temperature

The R-value is the thermal resistance of the insulating material, which is derived by dividing the thickness of the material by the material's thermal conductivity, or k-value. Thermal transmittance, or the material's U-factor, is the inverse of the R-value.

The $(UA/L)_{ee}$ values associated with fiberglass and rigid foam/cellular glass insulation of various thicknesses provided in the table below shall be used to establish the compliance condition heat transfer coefficient. Pipe diameter and insulation type and thickness shall be taken from the application. The values below were calculated assuming a k-value of 0.25 BTU-in/hr-°F-SF for fiberglass and 0.35 BTU-in/ hr-°F-SF for rigid foam/cellular glass insulation at 100°F. Pipe wall resistance and exterior film resistance were not considered in the derivation of the values below. Calculations were developed with NAIMA's 3E Plus software program.[815]

Pipe Diam. (in)	$(UA/L)_{ee}$											
	Fiberglass						Rigid Foam/Cellular Glass					
	0.5 in	1 in	1.5 in	2 in	2.5 in	3 in	0.5 in	1 in	1.5 in	2 in	2.5 in	3 in
0.50	0.13	0.09	0.08	0.07	0.06	0.06	0.15	0.12	0.10	0.09	0.09	0.08
0.75	0.14	0.11	0.09	0.08	0.07	0.07	0.17	0.13	0.11	0.10	0.10	0.09
1.00	0.17	0.12	0.10	0.09	0.08	0.07	0.19	0.15	0.13	0.12	0.11	0.10
1.25	0.20	0.14	0.11	0.10	0.09	0.08	0.23	0.17	0.15	0.13	0.12	0.11
1.50	0.22	0.15	0.12	0.11	0.10	0.09	0.25	0.19	0.16	0.14	0.13	0.12
2.00	0.26	0.18	0.14	0.12	0.11	0.10	0.29	0.22	0.18	0.16	0.14	0.13
2.50	0.30	0.20	0.16	0.14	0.12	0.11	0.34	0.25	0.20	0.18	0.16	0.15
3.00	0.35	0.24	0.18	0.16	0.14	0.12	0.39	0.29	0.23	0.20	0.18	0.16

[815] Insulation Institute, 3E Plus® Version 4.1

Pipe Diam. (in)	$(UA/L)_{ee}$											
	Fiberglass						Rigid Foam/Cellular Glass					
	0.5 in	1 in	1.5 in	2 in	2.5 in	3 in	0.5 in	1 in	1.5 in	2 in	2.5 in	3 in
3.50	0.40	0.26	0.20	0.17	0.15	0.13	0.44	0.32	0.26	0.22	0.20	0.18
4.00	0.44	0.29	0.22	0.18	0.16	0.14	0.48	0.35	0.28	0.24	0.21	0.19
5.00	0.52	0.34	0.26	0.22	0.19	0.17	0.58	0.41	0.33	0.28	0.25	0.22
6.00	0.61	0.39	0.30	0.25	0.21	0.19	0.67	0.47	0.37	0.32	0.28	0.25
8.00	0.77	0.49	0.37	0.30	0.26	0.23	0.84	0.59	0.46	0.39	0.34	0.30

Service hot water pipe insulation for non-recirculating systems is limited to insulation of hot water distribution pipe in unconditioned spaces. Space heating pipe insulation is limited to insulation installed in unheated spaces only.

Operating Hours

Domestic hot water heaters are assumed to be available for operation 8,760 hours per year.

Operating hours for water and steam boiler space heating systems are prescribed by equivalent full-load hours. Equipment heating EFLH shall be taken from the application. If unknown, default EFLH by facility type, system type and location can be found in Appendix G.

Example Calculation *(Not to be used as default)*

1.0-inch fiberglass insulation is installed on 20 feet of bare 1.25" copper piping located in unconditioned spaces used for distribution of electrically heated domestic hot water in a commercial building. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

$$\Delta kWh = \frac{(UA/L)_{baseline} - (UA/L)_{ee}}{E_{t,elec} \times 3{,}412} \times l \times \Delta T_{amb} \times hrs \times ElecSF$$

$$\Delta kW = \frac{\Delta kWh}{8{,}760} \times CF$$

$(UA/L)_{baseline}$ = 0.80, from baseline efficiency based on pipe material, size, and application
$(UA/L)_{ee}$ = 0.14, from compliance efficiency based on pipe material, size, and application
$E_{t,elec}$ = 0.98; from Summary of Variables and Data Sources table
l = 20, from application.
$\Delta T_{amb} = T_{pipe} - T_{amb}$ = 125-70= 55, from Summary of Variables and Data Sources table based on pipe application
ElecSF = 1.0, from Summary of Variables and Data Sources table
hrs = 8,760, from Summary of Variables and Data Sources table
CF = 1.0, from Summary of Variables and Data Sources table

$$\Delta kWh = \frac{0.80 - 0.14}{1.0 \times 3{,}412} \times 20 \times 55 \times 8{,}760 \times 1.0 = 1{,}864\ kWh$$

$$\Delta kW = \frac{1{,}864}{8{,}760} \times 1.0 = 0.21\ kW$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. 10 CFR 431 Subpart G – Commercial Water Heaters, Hot Water Supply Boilers and Unfired Hot Water Storage Tanks, Appendix B - Uniform Test Method for Measuring the Standby Loss of Electric Storage Water Heaters and Storage-Type Instantaneous Water Heaters
   Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=e0518d0e0befdd3d0f69d20f62691096&mc=true&node=pt10.3.431&rgn=div5#ap10.3.431_1110.b
2. 10 CFR 431.110 Energy Conservation Standards and Their Effective Dates
   Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=e0518d0e0befdd3d0f69d20f62691096&mc=true&node=pt10.3.431&rgn=div5#se10.3.431_1110
3. 10 CFR Appendix E to Subpart B of Part 430—Uniform Test Method for Measuring the Energy Consumption of Water Heaters, Section 2. Test Conditions, 2.5 Set Point Temperature.
   Available from: https://www.govinfo.gov/content/pkg/CFR-2013-title10-vol3/pdf/CFR-2013-title10-vol3-part430.pdf
4. EIA Commercial Building Energy Consumption Survey (CBECS) 2012 Survey Data for Middle Atlantic States, May 2016
   Available from: https://www.eia.gov/consumption/commercial/data/2012/bc/cfm/b4.php
5. ECCCNYS 2020 Table C404.2 Minimum Performance of Water-heating Equipment & Table C403.11.3 Minimum Pipe Insulation Thickness
   Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-ce-commercial-energy-efficiency
6. 3E Plus, NAIMA, Insulation Institute, Version 4.1
   Available from: https://insulationinstitute.org/tools-resources/free-3e-plus/

Record of Revision

Record of Revision Number	Issue Date
12-18-9	12/28/2018
12-20-6	12/31/2020

Return to Table of Contents

INSULATION - OPAQUE SHELL

Measure Description

This measure covers the installation of wall and ceiling insulation to reduce the thermal conductance of the building envelope. Energy and demand savings are realized through reductions in the building's heating and cooling loads. Existing (baseline) and installed (qualifying) shell R-values must be captured in order to estimate energy savings. This measure is only applicable as a retrofit in existing buildings. This measure is not applicable to gut rehab/major renovation projects which entail whole-building envelope alterations that trigger more stringent code provisions, limiting potential incremental savings.

For applications involving both wall and ceiling insulation, evaluate each component separately via the method below and sum together to determine total estimated energy savings.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = \Delta kWh_{cooling} + \Delta kWh_{heating}$$

$$\Delta kWh_{cooling} = \frac{\left(\frac{1}{R_{baseline}} - \frac{1}{R_{baseline} + \Delta R}\right) \times A \times \left(1 - F_{framing}\right) \times CDD \times 24 \times F_{ElecCool}}{1{,}000 \times Eff_{ElecCool}}$$

$$\Delta kWh_{heating} = \frac{\left(\frac{1}{R_{baseline}} - \frac{1}{R_{baseline} + \Delta R}\right) \times A \times \left(1 - F_{framing}\right) \times HDD \times 24 \times F_{ElecHeat}}{1{,}000 \times HSPF}$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \frac{\left(\frac{1}{R_{baseline}} - \frac{1}{R_{baseline} + \Delta R}\right) \times A \times \left(1 - F_{framing}\right) \times F_{ElecCool}}{1{,}000 \times EER} \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = \frac{\left(\frac{1}{R_{baseline}} - \frac{1}{R_{baseline} + \Delta R}\right) \times A \times \left(1 - F_{framing}\right) \times HDD \times 24 \times F_{FuelHeat}}{1{,}000{,}000 \times Eff_{FuelHeat}}$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
$\Delta kWh_{cooling}$	= Annual electric cooling energy savings

$\Delta kWh_{heating}$ = Annual electric heating energy savings
$R_{baseline}$ = R-value of existing insulation (ft^2-F°-h/BTU)
ΔR = Difference in R-value between installed insulation and existing insulation (ft^2-F°-h/BTU)
A = Area of insulated surfaces (SF)
$F_{framing}$ = Framing factor
$F_{ElecCool}$ = Electric cooling factor; used to account for the presence or absence of an electric cooling system
CDD = Cooling Degree Days - The number of degrees that a day's average temperature is above some baseline temperature, which represents the temperature above which buildings need to be cooled. The baseline temperature is typically 65°F, but may vary based on application.
HDD = Heating Degree Days - The number of degrees that a day's average temperature is below some baseline temperature, which represents the temperature below which buildings need to be heated. The baseline temperature is typically 65°F, but may vary based on application.
$F_{ElecHeat}$ = Electric heating factor, used to account for the presence or absence of an electric heating system
$F_{FuelHeat}$ = Fossil fuel heating factor, used to account for the presence or absence of a fossil fuel heating system
$Eff_{ElecCool}$ = Seasonal average energy efficiency of electric cooling equipment, BTU/watt-hour, using either SEER (<65,000 BTU/h) or IEER (≥65,000 BTU/h)
HSPF = Seasonal average energy efficiency of electric heating equipment. Heating Seasonal Performance Factor, BTU/watt-hour, total heating output (supply heat) in BTU (including resistance heating) during the heating season / total electric energy heat pump consumed (in watt-hour); if equipment efficiency is reported in COP, convert to HSPF using the equivalency HSPF = COP x 3.412
EER = Energy efficiency ratio under peak conditions (BTU/watt-hour)
$Eff_{FuelHeat}$ = Efficiency of fossil fuel heating equipment (AFUE, Et, or Ec)
CF = Coincidence factor
24 = Hours in one day
1,000 = Conversion factor, one kW equals 1,000 watts
1,000,000 = Conversion factor, one MMBtu equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
$R_{baseline}$		From application. If unknown, lookup in Baseline Efficiency section below, based on building vintage and building envelope component.
ΔR		From application.
A		From application.

Variable	Value	Notes
$F_{framing}$	Walls: 0.25 Ceilings: 0.07	Thermal Design and Code Compliance[816] California Energy Commission, 2013 Building Energy Efficiency Standards[817]
$F_{ElecCool}$		If an electric cooling system is present, set equal to 1. Otherwise, set equal to 0.
CDD		From application. If unknown, lookup based on location in Heating and Cooling Degree Days table below.
HDD		From application. If unknown, lookup based on location in Heating and Cooling Degree Days table below.
$F_{ElecHeat}$		Use a value of 1.0 if the building is electrically heated. Otherwise, use 0.0.
$F_{FuelHeat}$		Use a value of 1.0 if the building is fossil fuel heated. Otherwise, use 0.0.
$Eff_{ElecCool}$		From application. SEER or IEER shall be used, based on nameplate rating metric of existing equipment.
HSPF		From application. HSPF shall be used, based on nameplate rating metric of existing equipment. If equipment is rated in COP, convert to HSPF using the equivalency HPSF = COP x 3.412.
EER		From application.
$Eff_{FuelHeat}$		From application. E_c, E_t, or AFUE shall be used, based on nameplate rating metric of existing equipment.
CF	NYC: 0.822 Outside of NYC: 0.477	

Coincidence Factor (CF)

The prescribed coincidence factor for this measure is 0.822 for NYC and 0.477 outside of NYC.[818]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a building envelope with insufficient insulation (i.e., not compliant with all applicable construction code requirements). R-value of existing insulation shall come from application. If unknown, lookup wall and ceiling R-values based on vintage and building type from Appendix A.

[816] Thermal Design and Code Compliance for Cold-Formed Steel Walls, 2015, American Iron and Steel Institute, pg 17

[817] California Energy Commission, 2013 Building Energy Efficiency Standards, Appendix JA4(2). 7.25 percent of the attic insulation above the framing members is assumed to be at half depth, due to decreased depth of insulation at the eaves. This assumption was derived using the parallel path method as documented in the 2009 ASHRAE Handbook of Fundamentals.

[818] C&I Unitary HVAC Load Shape Project Final Report, KEMA, 2011, Table 0-5: NY - Inland and NY - Urban/Coastal

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a commercial opaque building shell with increased insulation meeting or exceeding applicable construction code requirements. The installed R-value must be captured and included in the program application.

Opaque shell insulation improvements performed under this measure shall be installed such that that all altered envelope components comply with all federal, state, local and municipal codes and standards applicable to alterations to existing buildings, including but not limited to Section C503.1 of ECCCNYS 2020[819] requiring all existing ceiling, wall, and floor cavities exposed during construction to be filled with insulation. Thermal envelope components not altered as part of this measure (e.g. continuous insulation in wood-framed buildings) are not required to meet code for compliance.

Operating Hours

Effective heating and cooling hours associated with benefits of opaque shell insulation are established via the Heating and Cooling Degree Days section below.

Heating and Cooling Degree Days[820]

City	HDD	CDD
Albany	6,680	597
Binghamton	7,193	382
Buffalo	6,617	544
Massena	8,196	363
NYC	4,671	1,160
Poughkeepsie	6,210	671
Syracuse	6,651	570

Example Calculation *(Not to be used as default)*

Insulation is added to the ceiling/roof assembly of an existing auto-repair facility constructed in 1975 in Poughkeepsie to increase the overall insulation value from R-13.5 to R-30. The insulated surface is 2,000 square feet. The facility is equipped with a heat pump which is rated at 15 SEER,12 EER and 11 HSPF. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

$$\Delta kWh = \Delta kWh_{cooling} + \Delta kWh_{heating}$$

$$\Delta kWh_{cooling} = \frac{\left(\frac{1}{R_{baseline}} - \frac{1}{R_{baseline} + \Delta R}\right) \times A \times \left(1 - F_{framing}\right) \times CDD \times 24 \times F_{ElecCool}}{1{,}000 \times Eff_{ElecCool}}$$

[819] ECCCNYS 2020, Section C503 Building Thermal Envelope
[820] HDD/CDD taken from NCEI 1981-2010 climate normal using a 65 °F balance point.

$$\Delta kWh_{heating} = \frac{\left(\frac{1}{R_{baseline}} - \frac{1}{R_{baseline} + \Delta R}\right) \times A \times \left(1 - F_{framing}\right) \times HDD \times 24 \times F_{ElecHeat}}{1{,}000 \times HSPF}$$

$$\Delta kW = \frac{\left(\frac{1}{R_{baseline}} - \frac{1}{R_{baseline} + \Delta R}\right) \times A \times \left(1 - F_{framing}\right) \times F_{ElecCool}}{1{,}000 \times EER} \times CF$$

$R_{baseline}$ = 13.5, from application.
ΔR = 30 - 13.5 = 16.5, from application.
A = 2,000, from application.
$F_{framing}$ = 0.07, from Summary of Variables and Data Sources
$F_{ElecCool}$ = 1, from Summary of Variables and Data Sources.
CDD = 671, from Operating Hours section based on city
HDD = 6,210, from Operating Hours section based on city
$F_{ElecHeat}$ = 1, from Summary of Variables and Data Sources
$Eff_{ElecCool}$ = 15 SEER, from application
HSPF = 11, from application
EER = 12, from application.
CF = 0.477, from Summary of Variables and Data Sources

$$\Delta kWh_{cooling} = \frac{\left(\frac{1}{13.5} - \frac{1}{13.5 + 16.5}\right) \times 2{,}000 \times (1 - 0.07) \times 671 \times 24 \times 1.0}{1{,}000 \times 15} = 81$$

$$\Delta kWh_{heating} = \frac{\left(\frac{1}{13.5} - \frac{1}{13.5 + 16.5}\right) \times 2{,}000 \times (1 - 0.07) \times 6{,}210 \times 24 \times 1.0}{1{,}000 \times 11} = 1{,}026$$

$$\Delta kWh = 81 + 1{,}026 = 1{,}107\ kWh$$

$$\Delta kW = \frac{\left(\frac{1}{13.5} - \frac{1}{13.5 + 16.5}\right) \times 2{,}000 \times (1 - 0.07) \times 1.0}{1{,}000 \times 12} \times 0.477 = 0.003\ kW$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. Thermal Design and Code Compliance for Cold-Formed Steel Walls, 2015- American Iron and Steel Institute.
   Available from:
   http://www.steelframing.org/PDF/energy/thermal_design_guide_2015_edition.pdf
2. Title 24, Part 6, 2013 Building Energy Efficiency Standards, California Energy Commission.
   Available from: https://energycodeace.com/site/custom/public/reference-ace-2013/index.html#!Documents/ja42roofsandceilings.htm
3. C&I Unitary HVAC Load Shape Project Final Report, KEMA, August 2, 2011, Table 0-5; (accessed March 21, 2017).
   Available from:
   https://neep.org/sites/default/files/resources/NEEP_HVAC_Load_Shape_Report_Final_August2.pdf
4. ECCCNYS 2020 Section C402 Building Thermal Envelope
   Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-ce-commercial-energy-efficiency#NYSECC2020P1_CE_Ch04_SecC402
5. ECCCNYS 2020 Section C503 Alterations
   Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-5-ce-existing-buildings
6. NOAA National Centers for Environmental Information – NCEI 1981-2010 Climate Normals
   Available from: https://www.ncdc.noaa.gov/cdo-web/datatools/normals

Record of Revision

Record of Revision Number	Issue Date
3-21-12	4/9/2021

Return to Table of Contents

WINDOW - FILM

Measure Description

This measure covers the installation of window films with reduced solar heat gain coefficient applied to single pane clear glass. Windows with lower solar heat gain coefficient lead to less required cooling loads within a conditioned space.

Due to negative impacts on space heating, this measure is applicable to buildings with electric AC and gas heat only. This measure is applicable to uncovered, single pane clear glass windows in existing buildings only.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = \frac{SF}{100} \times (\Delta kWh/100\ SF)$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \frac{SF}{100} \times (\Delta kW/100\ SF) \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = \frac{SF}{100} \times \frac{(\Delta therms/100\ SF)}{10}$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
SF	= Total aperture area of window glazing treated (ft^2)
(ΔkWh/100 SF)	= Annual electricity energy savings per 100 SF of window glazing area
(ΔkW/100 SF)	= Peak coincident demand electric savings per 100 SF of window glazing area
(Δtherms/100 SF)	= Annual fossil fuel energy savings per 100 SF of window glazing area
CF	= Coincidence factor
100	= Conversion to 100 square feet
10	= Conversion factor, one MMBtu equals 10 therms

Summary of Variables and Data Sources

Variable	Value	Notes
SF		From application.
ΔkWh/100 SF		Lookup based on building type and location from the Window Film section of Appendix F.

Variable	Value	Notes
ΔkW/100 SF		Lookup based on building type and location from the Window Film section of Appendix F.
Δtherms/100 SF		Lookup based on building type and location from the Window Film section of Appendix F.
CF	NYC: 0.822 Outside of NYC: 0.477	

Unit energy and demand savings were calculated from a DOE-2.2 simulation of prototypical small commercial buildings. The prototype building characteristics are described in Appendix A. The unit energy and demand savings by building types across different cities in NY are shown in the Window Film section of Appendix F.

Coincidence Factor (CF)

The prescribed coincidence factor for this measure is 0.822 for NYC and 0.477 outside of NYC.[821]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is an existing, untreated, single pane clear glass window with an assumed solar heat gain coefficient of 0.87 and U-value of 1.2 BTU/h- ft^2- °F.[822]

Compliance Efficiency from which Incentives are Calculated

The compliance condition is an existing window with added film with a solar heat gain coefficient of 0.40 or less.

Operating Hours

The energy savings for windows are dependent on the HVAC system operating hours and thermostat set points. See Appendix A for the modeling assumptions for each building prototype.

Example Calculation *(Not to be used as default)*

Window film is installed on 500 square feet of the single-pane clear glass windows of a small office building in NYC. The building is equipped with central air conditioning and gas heat. Annual Electric Energy Savings, Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta kWh = \frac{SF}{100} \times (\Delta kWh/100\ SF)$$

[821] C&I Unitary HVAC Load Shape Project Final Report, KEMA, 2011, Table 0-5: NY - Inland and NY - Urban/Coastal
[822] ASHRAE 2013 Handbook of Fundamentals

$$\Delta kW = \frac{SF}{100} \times (\Delta kW/100\ SF) \times CF$$

$$\Delta MMBtu = \frac{SF}{100} \times \frac{(\Delta therms/100\ SF)}{10}$$

SF = 500, from application.
ΔkWh/100 SF = 592, from Appendix F based on Facility Type, City and HVAC System
ΔkW/100 SF = 0.178, from Appendix F based on Facility Type, City and HVAC System
Δtherms/100 SF = -58.3, from Appendix F based on Facility Type, City and HVAC System
CF = 0.822 from Summary of Variables and Data Sources

$$\Delta kWh = \frac{500}{100} \times 592 = 2{,}960\ kWh$$

$$\Delta kW = \frac{500}{100} \times 0.178 \times 0.822 = 0.73\ kW$$

$$\Delta MMBtu = \frac{500}{100} \times \frac{(-58.3)}{10} = -29.15\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. ASHRAE 2013 Handbook of Fundamentals by American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE). Atlanta, GA, 2013.
2. C&I Unitary HVAC Load Shape Project Final Report, KEMA, August 2, 2011, Table 0-5; (accessed March 21, 2017).
   Available from:
   http://www.neep.org/sites/default/files/resources/NEEP_HVAC_Load_Shape_Report_Final_August2.pdf

Record of Revision

Record of Revision Number	Issue Date
1	10/15/2010
9-18-10	9/28/2018
9-19-4	9/27/2019

Return to Table of Contents

WINDOW - GLAZING

Measure Description

This measure covers the installation of high efficiency windows with reduced thermal conductance and solar heat gain coefficient. For the purposes of this measure, a window is defined as an assembled unit consisting of a frame/sash component holding one or more pieces of glazing functioning to admit light and/or air into an enclosure and designed for a vertical installation in an external wall of a commercial building.[823]

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = \frac{SF}{100} \times (\Delta kWh/100\ SF) \times \frac{SEER_{baseline}}{SEER_{part}}$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \frac{SF}{100} \times (\Delta kW/100\ SF) \times \frac{EER_{baseline}}{EER_{part}} \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = units \times \frac{SF}{100} \times \frac{(\Delta therms/100\ SF)}{10} \times \frac{Eff_{baseline}}{Eff_{part}}$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
SF	= Total glazing area of installed windows (ft^2)
(ΔkWh/100 SF)	= Annual electricity energy savings per 100 SF of window glazing area
(ΔkW/100 SF)	= Peak coincident demand electric savings per 100 SF of window glazing area
(Δtherms/100 SF)	= Annual fossil fuel energy savings per 100 SF of window glazing area
baseline	= Characteristic of baseline condition
part	= Actual efficiency of heating and cooling participant systems in place
SEER	= Seasonal average energy efficiency ratio over the cooling season, BTU/watt-hour, (used for average U.S. location/region)
EER	= Energy efficiency ratio under peak conditions
Eff	= Seasonal energy efficiency for fossil fuel heating equipment
CF	= Coincidence factor
100	= Conversion from SF to 100 SF

[823] ENERGY STAR® Product Specification Residential Windows, Doors, and Skylights, Eligibility Criteria, V6.0, January 2014

10 = Conversion factor, one MMBtu equals 10 therms

Summary of Variables and Data Sources[824]

Variable	Value	Notes
SF		From application
(ΔkWh/100 SF)		Lookup from Appendix F based on Facility Type, City and HVAC System.
(ΔkW/100 SF)		Lookup from Appendix F based on Facility Type, City and HVAC System.
(Δtherms/100 SF)		Lookup from Appendix F based on Facility Type, City and HVAC System.
$EER_{baseline}$	11.2	EER used in the simulations[825]
EER_{part}		EER of cooling systems within participant population, defaults to $EER_{baseline}$ (no adjustment)
$SEER_{baseline}$	14	SEER used in the simulations[826]
$SEER_{part}$		SEER of cooling system within participant population, defaults to $SEER_{baseline}$ (no adjustment)
$Eff_{baseline}$	0.80	Efficiency (AFUE) used in the simulations[827]
Eff_{part}		Efficiency (AFUE, E_t, or E_c) of heating system within participant population, defaults to $Eff_{baseline}$ (no adjustment)
CF	NYC: 0.822 Outside of NYC: 0.477	

Unit energy and demand savings calculated from the building prototype simulation models are shown in Appendix F. The savings are tabulated by location, building type, and HVAC system type. Savings are derived from a baseline set by the assumed window and operating characteristics listed for each building prototype in Appendix A and using the compliance window characteristics below for the efficient case.

Coincidence Factor (CF)

The prescribed coincidence factor for this measure is 0.822 for NYC and 0.477 outside of NYC.[828]

[824] Due to schedule of revisions, values specified here may not align with those presented throughout appendices.
[825] ECCCNYS 2020, Table C403.3.2(1) – Assumes a 5-ton packaged AC.
[826] Ibid.
[827] ECCCNYS 2020, Table C403.3.2 (5) – Assumes a 150 kBTU/h gas boiler.
[828] C&I Unitary HVAC Load Shape Project Final Report, KEMA, 2011, Table 0-5: NY - Inland and NY - Urban/Coastal

Baseline Efficiencies from which Energy Savings are Calculated

The baseline is described by the assumed window and operating characteristics listed for each building prototype in Appendix A. Energy savings are estimated based on the characteristics of this baseline and an efficient case window as defined in the Compliance Efficiency section below.

Compliance Efficiency from which Incentives are Calculated

The minimum compliance condition for this measure is a window meeting the current ENERGY STAR® specifications. These specifications, which are used to derive savings prescribed by this measure, are listed below[829]:

U-Factor (BTU/h-ft^2-^{o}F)	Solar Heat Gain Coefficient (SHGC)
≤0.27	Any
0.28	≥0.32
0.29	≥0.37
0.30	≥0.42

Operating Hours

The energy savings for windows are dependent on the HVAC system operating hours and thermostat set points. See Appendix A for the modeling assumptions for each building prototype.

Example Calculation *(Not to be used as default)*

A small office in Albany, NY installs high efficiency windows with reduced thermal conductance and solar heat gain covering 600 SF of area of the external wall of the building The building is equipped with an air source heat pump with a SEER of 14.6 and EER of 11.9. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

$$\Delta kWh = \frac{SF}{100} \times (\Delta kWh/100\ SF) \times \frac{SEER_{baseline}}{SEER_{part}}$$

$$\Delta kW = \frac{SF}{100} \times (\Delta kW/100\ SF) \times \frac{EER_{baseline}}{EER_{part}} \times CF$$

SF = 600, from application
(ΔkWh/100 SF) = 829, from Appendix F based on Facility Type, City and HVAC System.
(ΔkW/100 SF) = 0.156, from Appendix F based on Facility Type, City and HVAC System.
(Δtherms/100 SF) = 0, from Appendix F based on Facility Type, City and HVAC System.
$EER_{baseline}$ = 11.2; from Summary of Variables and Data Sources
EER_{part} = 11.9, from application

[829] ENERGY STAR® Product Specification Residential Windows, Doors, and Skylights, Eligibility Criteria, V6.0, January 2014

$SEER_{baseline}$ = 14; from Summary of Variables and Data Sources
$SEER_{part}$ = 14.6, from application
CF = 0.477, from Summary of Variables and Data Sources

$$\Delta kWh = \frac{600}{100} \times 829 \times \frac{14}{14.6} = 4{,}770\ kWh$$

$$\Delta kW = \frac{600}{100} \times 0.156 \times \frac{11.2}{11.9} \times 0.477 = 0.42\ kW$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. ENERGY STAR® Product Specification Residential Windows, Doors, and Skylights, Eligibility Criteria, Version 6.0, January 2014
   Available from:
   https://www.energystar.gov/sites/default/files/ES_Final_V6_Residential_WDS_Spec.pdf
2. ECCCNYS 2020 Table C403.3.2(1): Minimum Efficiency Requirements: Electrically Operated Unitary Air Conditioners And Condensing Units & Table C403.3.2(5): Minimum Efficiency Requirements: Gas- And Oil-Fired Boilers.
   Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-ce-commercial-energy-efficiency
3. Window properties for baseline windows taken from 2013 ASHRAE Handbook of Fundamentals Chapter 15. The 2013 ASHRAE Handbook of Fundamentals is used in the prototype simulations and therefore is not updated to the current version.
4. C&I Unitary HVAC Load Shape Project Final Report, KEMA, August 2, 2011, Table 0-5; (accessed March 21, 2017).
   Available from:
   http://www.neep.org/sites/default/files/resources/NEEP_HVAC_Load_Shape_Report_Final_August2.pdf

Record of Revision

Record of Revision Number	Issue Date
1	10/15/2010
6-17-9	6/30/2017
9-19-5	9/30/2019
12-19-12	12/23/2019

Return to Table of Contents

COMPRESSED AIR

AIR COMPRESSOR

Measure Description

This measure covers the installation of oil-flooded, rotary screw air compressors with variable frequency drives or variable displacement controls and properly sized air receivers in commercial and industrial compressed air systems (single compressor systems only). Inlet valve modulation, which modulates the compressor by throttling the air inlet and load/unload control, which switches the compressor to unload when the cut-out pressure set point is reached, are inefficient means of compressed air system control under part load conditions. Variable frequency drives modulate the frequency and speed of the compressor motor, which reduces input power. Variable displacement controls change the compressor capacity by varying the amount of the compressor used to compress air. Both represent a significant improvement in part load operating efficiency and savings over the baseline condition.[830]

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times hp_{comp} \times (\Delta kW/hp) \times hrs$$

Summer Peak Coincident Demand Savings

$$\Delta kW = units \times hp_{comp} \times (\Delta kW/hp) \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
hp_{comp}	= Horsepower of air compressor
(ΔkW/hp)	= Demand electric savings per horsepower
hrs	= Annual operating hours of air compressor
CF	= Coincidence factor

[830] The Impact Evaluation of Custom Compressed Air, conducted by DNV GL for Niagara Mohawk Power Corporation d/b/a National Grid (approved March 2017), was reviewed for findings relevant to this measure. The findings of this report, which quantifies kWh and peak summer kW savings and associated realization rates for custom compressed air measures at 25 unique sites, do not directly inform the algorithms, key inputs or default values found in this energy savings estimation methodology. As such, no changes have been applied as a result of this review.

Summary of Variables and Data Sources

Variable	Value	Notes
hp_{comp}		From application
(ΔkW/hp)		Lookup in table below based on compressor size and control strategy.[831]
hrs		From application
CF	0.8	

Air Compressor Savings (ΔkW/hp)

Control Type	Compressor hp	ΔkW/hp
Variable Frequency Drive	≥ 15 and < 75	0.189
Variable Frequency Drive	≥ 75	0.216
Variable Displacement	≥ 50 and < 75	0.125
Variable Displacement	≥ 75	0.141

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.8.[832]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is an oil-flooded, rotary screw compressor utilized in a single compressor system meeting the requirements of ISO Standard 8573.1 with load/unload control and blow down capability.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is an oil-flooded, rotary screw compressor utilized in a single compressor system meeting the requirements of ISO Standard 8573.1 with variable speed drive or variable displacement capacity control and a properly sized air receiver. Flow controller must be used to maintain 5-10 psi pressure difference between receiver and distribution system.

Operating Hours

The operating hours of compressed air systems vary widely and shall be defined by the application.

[831] For equipment with < 75 hp: Energy saving factors from Impact Evaluation of Prescriptive Chiller and Compressed Air Installations, DNV-GL, prepared by KEMA, Inc. for Massachusetts Energy Efficiency Advisory Council, October 2015
For equipment with ≥ 75 hp: Energy savings factors were developed by using U.S. Dept. of Energy part load data for different compressor control types as well as load profiles from 50 facilities employing air compressors. This data suggests an average 17% load reduction compared to baseline for Variable Displacement and an average 26% load reduction compared to baseline for Variable Frequency Drives and an average 90% operating efficiency for new compressor equipment. ΔkW/hp values were derived using these assumptions in the form: % Savings x 0.746\System Efficiency.
[832] *No source specified – update pending availability and review of applicable references.*

Example Calculation *(Not to be used as default)*

A 50 hp oil-flooded, rotary screw compressor in an auto repair shop in Albany is replaced with a variable frequency drive compressor and new air receiver. The auto-repair shop runs the air compressor for approximately 800 hours per year. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

$$\Delta kWh = units \times hp_{comp} \times (\Delta kW/hp) \times hrs$$

$$\Delta kW = units \times hp_{comp} \times (\Delta kW/hp) \times CF$$

hp_{comp} = 50, from application
(ΔkW/hp) = 0.189, from air compressor savings table based on compressor size and control strategy.
Hrs = 800, from application
CF = 0.8, from Summary of Variables and Data sources

$$\Delta kWh = 1 \times 50 \times 0.189 \times 800 = 7{,}560\ kWh$$

$$\Delta kW = 1 \times 50 \times 0.189 \times 0.8 = 7.56\ kW$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. "Improving Compressed Air System Performance": A sourcebook for Industry, U.S. Dept. of Energy, November 2003.
   Available from:
   https://www1.eere.energy.gov/manufacturing/tech_assistance/pdfs/compressed_air_sourcebook.pdf

2. Impact Evaluation of Prescriptive Chiller and Compressed Air Installations, DNV-GL, prepared by KEMA, Inc. for Massachusetts Energy Efficiency Advisory Council, October 2015
   Available from: https://ma-eeac.org/wp-content/uploads/MA30-Prescriptive-Chiller-and-CAIR-Report_FINAL_151026.pdf
3. Impact Evaluation of Custom Compressed Air, DNV GL, March 2017
   Available from: http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7BE21FC3D0-70BC-426E-B35B-85E082640361%7D

Record of Revisions

Record of Revision Number	Issue Date
1	10/15/2010
12-17-9	12/31/2017
3-19-9	3/29/2019
6-19-9	6/28/2019

Return to Table of Contents

COMPRESSED AIR HEAT RECOVERY

Measure Description

This measure covers the installation of a compressed air heat recovery system on an air-cooled compressor system. The mechanical work of an air compressor yields large amounts of waste heat. This waste heat can be used for either space heat, domestic hot water, or process heating applications depending on the temperature of the waste heat stream. A heat recovery system is an equipment add-on retrofit to either an air-cooled or water-cooled air compressor system. With air-cooled compressor systems, typical retrofits require ductwork and fans for heat recovery. For water-cooled air compressor systems, either a water-to-air or water-to-water heat exchanger is necessary. Water-cooled air compressor systems are not addressed by this measure.

This measure only considers waste heat recovery for space heating. This measure is applicable in retrofit applications only and is not applicable to backup or redundant units.

Method for Calculating Annual Energy and Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = \left(\frac{hp_{comp} \times LF \times RE \times hrs \times 0.746}{COP_{heating}} \times F_{ElecHeat}\right) - \left(\frac{hp_{fan} \times 0.746 \times hrs}{Eff_{fan}}\right)$$

Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = \frac{hp_{comp} \times LF \times RE \times hrs \times 0.746}{Eff_{heating}} \times F_{FuelHeat} \times \frac{3{,}412}{1{,}000{,}000}$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
hp_{comp}	= Compressor motor horsepower
hp_{fan}	= Distribution fan motor horsepower
LF	= Average load factor of the compressor motor
RE	= Recovery efficiency based on brake horsepower
hrs	= Annual heating hours coincident with compressor operation
$COP_{heating}$	= Coefficient of performance, ratio of output energy/input energy (at AHRI standard high-temperature rating conditions)
$Eff_{heating}$	= Efficiency of fossil fuel heating system
$F_{ElecHeat}$	= Electric heating factor; used to account for the presence or absence of an electric heating system

$F_{FuelHeat}$ = Fossil fuel heating factor; used to account for the presence or absence of a fossil fuel heating system
Eff_{fan} = Motor efficiency of fan
0.746 = Conversion factor (kW/hp), 746 watts equals one horsepower
3,412 = Conversion factor, one kWh equals 3,412 BTU
1,000,000 = Conversion factor, one MMBtu equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
hp_{comp}		From application.
hp_{fan}		From application. If unknown assume 1.0 hp or if no fan is in use, use 0 hp. If a fan is already used to exhaust the heat outside, the value will be the difference in hp between the two fans or 0 if the same.
LF		From application. If unknown use 0.92.[833]
RE		From application. If unknown use 0.8.[834]
hrs		From application. If unknown, lookup in Operating hours section below based on location and facility type.[835]
$COP_{heating}$		From application. If unknown use 3.2 for heat pumps. For electric resistance heating, use a value of 1.0.
$Eff_{heating}$		From application. If unknown use a value of 0.8.
$F_{ElecHeat}$		If a central electric heating system is present, set equal to 1. Otherwise, set equal to 0.
$F_{FuelHeat}$		If a central fossil fuel heating system is present, set equal to 1. Otherwise, set equal to 0.
Eff_{fan}		From application. Value should be based on the rated NEMA Premium efficiency of the motor installed. If unknown assume 0.86 for a 1 horsepower fan motor.[836] Calculation assumes fan is fully loaded when on.

Coincidence Factor (CF)

Compressed air heat recovery savings described by this measure offset facility space heating load only. As a result, no summer peak demand savings shall be claimed and the prescribed value for the coincidence factor is N/A.

[833] Cascade Energy. "Proposed Standard Savings Estimation Protocol for Ultra-Premium Efficiency Motors." Table 6: Load Factor by Nameplate hp and End Use. November 5, 2012. Assumes 30 hp air compressor.
[834] "Compressed Air Challenge™, Heat Recovery with Compressed Air Systems." Compressed Air Systems Fact Sheet #10.
[835] Cadmus. Focus on Energy Evaluated Deemed Savings Changes. August 31, 2017.
[836] U.S. Department of Energy. "Premium Efficiency Motor Selection and Application Guide". Table 2-1. EISA Mandatory Minimum Full-Load Efficiency Standards, % (for motors rated 600 V or less). February 2014.

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is an air-cooled air compressor without a heat recovery system in a building with electric or fossil fuel space heating.

Compliance Efficiency from which Incentives are Calculated

The energy efficient condition is an air-cooled air compressor with a heat recovery system in a building with electric or fossil fuel space heating.

Operating Hours

Operating hours to be used in this measure reflect hours when operation of air compressor is coincident with heating hours. Hours shall come from application. If unknown, look up in table below based on facility type and average run hours.

Facility Type[837]	Albany	Binghamton	Buffalo	Massena*	NYC	Poughkeepsie**	Syracuse
Single Shift	1,501	1,552	1,541	1,529	1,444	1,495	1,513
Two Shift	2,856	2,940	2,925	2,903	2,760	2,874	2,880
Three Shift	4,080	4,164	4,149	4,127	3,984	4,098	4,104
Continuous	5,676	5,785	5,769	5,743	5,552	5,704	5,711

*Massena hourly normals are approximated from Rochester airport data due to limited available data
** Poughkeepsie hourly normals are approximated from Long Island ISLIP airport data due to limited available data

Example Calculation *(Not to be used as default)*

A two-shift industrial process facility in Albany installs a heat recovery system with a ¾ hp, 88% efficient distribution fan on an existing 50 hp air-cooled compressor system. The building is equipped with central air conditioning and gas heat with 82% thermal efficiency. The average compressor motor load factor is 90% and the recovery efficiency of the heat recovery system is 82%. Summer Peak Coincident Demand Savings are not applicable. Annual Electric Energy Savings and Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta kWh = \left(\frac{hp_{comp} \times LF \times RE \times hrs \times 0.746}{COP_{heating}} \times F_{ElecHeat}\right) - \left(\frac{hp_{fan} \times 0.746 \times hrs}{Eff_{fan}}\right)$$

$$\Delta MMBtu = \frac{hp_{comp} \times LF \times RE \times hrs \times 0.746}{Eff_{heating}} \times F_{FuelHeat} \times \frac{3{,}412}{1{,}000{,}000}$$

hp_{comp} = 50, from application.
LF = 0.90, from application
RE = 0.82, from application
hrs = 2,856, from Operating Hours section based on location and facility type
$F_{ElecHeat}$ =0, from Summary of Variables and Data sources
hp_{fan} = 0.75, from application
Eff_{fan} = 0.88, from application

[837] Compressor Run Hours is determined by breaking the hours in Single Shift 7am-3pm M-F, Two Shift 7am-11pm M-F, Three Shift 24 hours M-F and Continuous 24/7.

$Eff_{heating}$ = 0.82, from application
$F_{FuelHeat}$ =1, from Summary of Variables and Data sources

$$\Delta kWh = \left(\frac{50 \times 0.90 \times 0.82 \times 2{,}856 \times 0.746}{N/A} \times 0\right) - \left(\frac{0.75 \times 0.746 \times 2{,}856}{0.88}\right)$$
$$= -1{,}815\ kWh$$

$$\Delta MMBtu = \frac{50 \times 0.90 \times 0.82 \times 2{,}856 \times 0.746}{0.82} \times 1 \times \frac{3{,}412}{1{,}000{,}000} = 327.13\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Compressed Air Heat Recovery may lead to increased electric consumption resulting from the addition of fan power for heat recovery. These impacts are addressed in the prescribed methodology.

References

1. Cascade Energy. "Proposed Standard Savings Estimation Protocol for Ultra-Premium Efficiency Motors." Table 6: Load Factor by Nameplate hp and End Use. November 5, 2012.
   Available from: https://rtf.nwcouncil.org/meeting/rtf-meeting-november-14-2012
2. "Compressed Air Challenge™, Heat Recovery with Compressed Air Systems." Compressed Air Systems Fact Sheet #10.
   Available from:
   https://www.compressedairchallenge.org/data/sites/1/media/library/factsheets/factsheet10.pdf
3. Cadmus. Focus on Energy Evaluated Deemed Savings Changes. August 31, 2017.
   Available from:
   https://www.focusonenergy.com/sites/default/files/FoE_Deemed%20Savings%20Report_%20CY%2017_v1.7.pdf
4. U.S. Department of Energy. "Premium Efficiency Motor Selection and Application Guide". Table 2-1. EISA Mandatory Minimum Full-Load Efficiency Standards, % (for motors rated 600 V or less). February 2014.
   Available from:
   https://www.energy.gov/sites/prod/files/2014/04/f15/amo_motors_handbook_web.pdf

5. U.S. Department of Energy. "Evaluation of the Compressed Air Challenge® Training Program". March 2004.
Available from:
https://www.compressedairchallenge.org/data/sites/1/media/library/evaluation/Evaluation.pdf

Record of Revisions

Record of Revision Number	Issue Date
3-20-7	3/30/2020

Return to Table of Contents

COMPRESSED AIR FLOW CONTROLLER

Measure Description

This measure covers the installation of a pressure/flow controller on an existing compressed air system. Pressure/flow controller equipment is also referred to as demand valves, precision flow controllers, pilot-operated regulators and precision pressure regulators. Compressed air flow controllers are precision pressure regulators that allow airflow to fluctuate while maintaining a constant pressure in the compressed air distribution system. They are installed between the compressed air dry storage tank and the end use distribution system allowing the controller to supply the process peak demands for compressed air and allowing the air compressor system to operate at a more efficient load point than at peak demand load requirements. The pressure/flow controller allows the compressed air system to reduce peak demand, run compressors closer to their best operating performance load, reduce system pressure to required minimum levels, and allow some compressors to unload and turn-off during either low or no demand conditions.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = 0.746 \times LF \times ESF \times hrs \times \sum \frac{hp_{comp}}{Eff}$$

Summer Peak Coincident Demand Savings

$$\Delta kW = 0.746 \times LF \times ESF \times CF \times \sum \frac{hp_{comp}}{Eff}$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

where:

$$ESF = \Delta P \times 0.005$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
LF	= Load Factor of the compressed air system
hrs	= Hours of operation per year
ESF	= Energy savings factor
hp_{comp}	= Horsepower of each air compressor motor
Eff	= Efficiency of each air compressor motor
ΔP	= Average pre- and post-treatment measured system pressure differential, in psi
0.005	= Savings factor per change in psi
0.746	= Conversion factor (kW/hp), 746 watts equals one horsepower

Summary of Variables and Data Sources

Variable	Value	Notes
LF		From application. If unknown use 0.92 as default value.[838]
ESF		Calculate based on the equation in Method for Calculating Savings above. If actual measured system pressure differential (ΔP) is unavailable, use ESF of 0.05 [839]
ΔP		From application, average pre- and post-treatment measured system pressure differential, in psi.
hrs		From application. If unknown, lookup in Operating Hours section below based on facility type.
hp_{comp}		From application.
Eff		From application. If unknown lookup based on horsepower, RPM, and TEFC/ODP [in] Motor Efficiency table below.
CF	Single shift: 0 Two shift, three shift or continuous operation: 0.8	Based on facility operation schedule.

Motor Efficiency[840]

HP	Open Drip Proof			Totally Enclosed Fan Cooled		
RPM	1200	1800	3600	1200	1800	3600
1	0.825	0.855	0.770	0.825	0.855	0.770
1.5	0.865	0.865	0.840	0.875	0.865	0.840
2	0.875	0.865	0.855	0.885	0.865	0.855
3	0.885	0.895	0.855	0.895	0.895	0.865
5	0.895	0.895	0.865	0.895	0.895	0.885
7.5	0.902	0.910	0.885	0.910	0.917	0.895
10	0.917	0.917	0.895	0.910	0.917	0.902
15	0.917	0.930	0.902	0.917	0.924	0.910
20	0.924	0.930	0.910	0.917	0.930	0.910
25	0.930	0.936	0.917	0.930	0.936	0.917
30	0.936	0.941	0.917	0.930	0.936	0.917
40	0.941	0.941	0.924	0.941	0.941	0.924
50	0.941	0.945	0.930	0.941	0.945	0.930
60	0.945	0.950	0.936	0.945	0.950	0.936
75	0.945	0.950	0.936	0.945	0.954	0.936
100	0.950	0.954	0.936	0.950	0.954	0.941

[838] Cascade Energy. Proposed Standard Savings Estimation Protocol for Ultra-Premium Efficiency Motors. November 5, 2012. Table 6: Load Factor by nameplate hp and end use load

[839] United States Department of Energy. *Improving Compressed Air System Performance: A Sourcebook for Industry.* p. 34. March 2016. For every 2 psi reduced in the system, 1% of energy is saved. Assumes 10 psi reduction.

[840] Cascade Energy. Proposed Standard Savings Estimation Protocol for Ultra-Premium Efficiency Motors. November 5, 2012. Table 3: NEMA premium efficient motor standards.

HP	Open Drip Proof			Totally Enclosed Fan Cooled		
RPM	1200	1800	3600	1200	1800	3600
125	0.950	0.954	0.941	0.950	0.954	0.950
150	0.954	0.958	0.941	0.958	0.958	0.950
200	0.954	0.958	0.950	0.958	0.962	0.954
250	0.958	0.958	0.953	0.955	0.955	0.958
300	0.958	0.958	0.955	0.955	0.958	0.958
350	0.958	0.958	0.955	0.955	0.958	0.958
400	0.958	0.958	0.958	0.955	0.958	0.958
450	0.958	0.960	0.960	0.955	0.958	0.958
500	0.958	0.960	0.960	0.955	0.960	0.958

Coincidence Factor (CF)

The prescribed value for the coincidence factor is based on facility operating hours. Apply a coincidence factor of 0.8 for facilities operating two shift, three shift, or continuous operating schedules. Coincidence factor is 0.0 for facilities operating single shift schedules.

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a compressed air system with a total capacity greater than or equal to 50 hp without a pressure/flow controller installed.

Compliance Efficiency from which Incentives are Calculated

The energy efficient condition is a compressed air system greater than or equal to 50 hp equipped with a flow/pressure controller.

Operating Hours

Operating hours shall come from application. If unknown, the default hours based on number of shifts provided in the table below may be used.

Shift	Hours
Single Shift 7AM – 3 PM, weekdays, minus 10 federal holidays and three 8-hour shifts of scheduled down time	1,976
Two Shifts 7AM – 11 PM, weekdays, minus 10 federal holidays and six 8-hour shifts of scheduled down time	3,952
Three Shifts 24 hours per day, weekdays, minus 10 federal holidays and nine 8-hour shifts of scheduled down time	5,928
Four Shifts or Continual Operation 24 hours per day, 7 days a week minus 10 federal holidays and 55 8-hour shifts of scheduled down time	8,320

Example Calculation *(Not to be used as default)*

A flow controller is installed on an existing 150 hp compressed air system in a two-shift industrial process facility near Albany. The average compressed air system motor efficiency is 94%, the load factor is 90% and it operates 4,000 hours per year. The resultant change in pressure as a result of controller installation is 10 psi. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

$$\Delta kWh = 0.746 \times LF \times ESF \times hrs \times \sum \frac{hp_{comp}}{Eff}$$

$$\Delta kW = 0.746 \times LF \times ESF \times CF \times \sum \frac{hp_{comp}}{Eff}$$

$$ESF = \Delta P \times 0.005$$

LF = 0.90, from application
ΔP = 10 psi, from application
hrs = 4,000, from application
hp_{comp} = 150 hp, from application
Eff = 0.94, from application
CF = 0.8, from Summary of Variables and Data Sources

$$ESF = 10 \times 0.005 = 0.05$$

$$\Delta kWh = 0.746 \times 0.90 \times 0.05 \times 4{,}000 \times \sum \frac{150}{0.94} = 21{,}428\ kWh$$

$$\Delta kW = 0.746 \times 0.90 \times 0.05 \times 0.8 \times \sum \frac{150}{0.94} = 4.29\ kW$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. Cascade Energy. Proposed Standard Savings Estimation Protocol for Ultra-Premium Efficiency Motors. November 5, 2012.
   Available from: https://nwcouncil.app.box.com/s/fkxkcwm1is88dnttb8ve7eb5rhs9qhmv
2. United States Department of Energy. Improving Compressed Air System Performance: A Sourcebook for Industry. Third Edition. p. 34. March 1, 2016
   Available from:
   https://www.energy.gov/sites/prod/files/2016/03/f30/Improving%20Compressed%20Air%20Sourcebook%20version%203.pdf

Record of Revisions

Record of Revision Number	Issue Date
7-20-10	7/31/2020

Return to Table of Contents

COMPRESSED AIR - LOW PRESSURE DROP FILTERS

Measure Description

This measure applies to the installation of a low pressure drop filter on a large existing compressed air system. Typical coalescing oil filters operate with a pressure drop in the range of 2 to 10 pounds-per-square-inch differential (psid). In contrast, a low pressure drop filter exhibits close to a 0.5 psid pressure drop, increasing over time to 3 psid at which point filter replacement is recommended. The reduced pressure drop allows the compressed air system to operate more efficiently.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings[841]

Annual Electric Energy Savings

$$\Delta kWh = 0.746 \times LF \times (ESF/psid) \times \Delta psid \times hrs \times \sum \frac{hp_{comp}}{Eff}$$

Summer Peak Coincident Demand Savings

$$\Delta kW = 0.746 \times LF \times (ESF/psid) \times \Delta psid \times CF \times \sum \frac{hp_{comp}}{Eff}$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
LF	= Load Factor of the compressed air system
hrs	= Hours of operation per year
(ESF/psid)	= Percent savings per psid pressure drop reduction
Δpsid	= Reduction in pressure drop resulting from low pressure drop filters, in psid
hp_{comp}	= Horsepower of each air compressor motor
Eff	= Efficiency of each air compressor motor
0.746	= Conversion factor (kW/hp), 746 watts equals one horsepower

[841] The use of the sigma operator is intended to address multi-compressor systems. In those cases, the sum of each compressor's hp rating divided by its efficiency shall be input. For single compressor systems, the sigma operator can be ignored.

Summary of Variables and Data Sources

Variable	Value	Notes
LF		From application. If unknown use 0.92 as default value.[842]
(ESF/psid)	0.005	Sullair Corporation.[843]
Δpsid		From application. If unknown use 4 psid as default value.[844]
hrs		From application. If unknown, lookup in Operating Hours section below based on facility type.
hp_{comp}		From application.
Eff		From application. If unknown lookup based on horsepower, RPM, and TEFC/ODP [in] Motor Efficiency table below.
CF	Single shift: 0 Two shift, three shift or continuous operation: 0.8	Based on facility operation schedule.

Motor Efficiency[845]

HP	Open Drip Proof			Totally Enclosed Fan Cooled		
RPM	1200	1800	3600	1200	1800	3600
1	0.825	0.855	0.770	0.825	0.855	0.770
1.5	0.865	0.865	0.840	0.875	0.865	0.840
2	0.875	0.865	0.855	0.885	0.865	0.855
3	0.885	0.895	0.855	0.895	0.895	0.865
5	0.895	0.895	0.865	0.895	0.895	0.885
7.5	0.902	0.910	0.885	0.910	0.917	0.895
10	0.917	0.917	0.895	0.910	0.917	0.902
15	0.917	0.930	0.902	0.917	0.924	0.910
20	0.924	0.930	0.910	0.917	0.930	0.910
25	0.930	0.936	0.917	0.930	0.936	0.917
30	0.936	0.941	0.917	0.930	0.936	0.917
40	0.941	0.941	0.924	0.941	0.941	0.924
50	0.941	0.945	0.930	0.941	0.945	0.930
60	0.945	0.950	0.936	0.945	0.950	0.936
75	0.945	0.950	0.936	0.945	0.954	0.936
100	0.950	0.954	0.936	0.950	0.954	0.941
125	0.950	0.954	0.941	0.950	0.954	0.950
150	0.954	0.958	0.941	0.958	0.958	0.950
200	0.954	0.958	0.950	0.958	0.962	0.954

[842] Cascade Energy. Proposed Standard Savings Estimation Protocol for Ultra-Premium Efficiency Motors. November 5, 2012. Table 6: Load Factor by nameplate hp and end use load
[843] Sullair Corporation. Compressed Air Filtration and Mist Eliminators Datasheet. Every 2 psi pressure drop = 1% energy reduction in compressor horsepower. Therefore, 1 psi = 0.5% savings in lost compressor power.
[844] Ibid.
[845] Cascade Energy. Proposed Standard Savings Estimation Protocol for Ultra-Premium Efficiency Motors. November 5, 2012. Table 3: NEMA premium efficient motor standards.

HP	Open Drip Proof			Totally Enclosed Fan Cooled		
RPM	1200	1800	3600	1200	1800	3600
250	0.958	0.958	0.953	0.955	0.955	0.958
300	0.958	0.958	0.955	0.955	0.958	0.958
350	0.958	0.958	0.955	0.955	0.958	0.958
400	0.958	0.958	0.958	0.955	0.958	0.958
450	0.958	0.960	0.960	0.955	0.958	0.958
500	0.958	0.960	0.960	0.955	0.960	0.958

Coincidence Factor (CF)

The prescribed value for the coincidence factor is based on facility operating hours. Apply a coincidence factor of 0.8 for facilities operating two shift, three shift, or continuous operating schedules. Coincidence factor is 0.0 for facilities operating single shift schedules.

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a compressed air system with a total capacity greater than or equal to 50 hp with a standard coalescing filter.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a compressed air system with a total capacity greater than or equal to 50 hp with a low pressure drop filter. The initial pressure differential of the filter must be <1 psid.

Operating Hours

Operating hours shall come from application. If unknown, the default hours based on number of shifts provided in the table below may be used.

Shift	Hours
Single Shift 7AM – 3 PM, weekdays, minus 10 federal holidays and three 8-hour shifts of scheduled down time	1,976
Two Shifts 7AM – 11 PM, weekdays, minus 10 federal holidays and six 8-hour shifts of scheduled down time	3,952
Three Shifts 24 hours per day, weekdays, minus 10 federal holidays and nine 8-hour shifts of scheduled down time	5,928
Four Shifts or Continual Operation 24 hours per day, 7 days a week minus 10 federal holidays and 55 8-hour shifts of scheduled down time	8,320

Example Calculation *(Not to be used as default)*

Low pressure drop filters are installed on a 200 hp compressed air system in a two-shift industrial process facility. The average compressed air system motor efficiency is 94%, the load factor is 90% and it operates 4,000 hours per year. As a result of filter replacement, the measured pressure drop across the filters decreased by 5 psi. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

$$\Delta kWh = 0.746 \times LF \times (ESF/psid) \times \Delta psid \times hrs \times \sum \frac{hp_{comp}}{Eff}$$

$$\Delta kW = 0.746 \times LF \times \left(\frac{ESF}{psid}\right) \times \Delta psid \times CF \times \sum \frac{hp_{comp}}{Eff}$$

LF = 0.90, from application
(ESF/psid) = 0.005, from Summary of Variables and Data Sources
Δpsid = 5, from application
hrs = 4,000, from application
hp_{comp} = 200 hp, from application.
Eff = 0.94 From application
CF = 0.8, from Summary of Variables and Data Sources based on operating hours

$$kWh = 0.746 \times 0.90 \times 0.005 \times 5 \times 4{,}000 \times \sum \frac{200}{0.94} = 14{,}285\ kWh$$

$$\Delta kW = 0.746 \times 0.90 \times 0.005 \times 5 \times 0.8 \times \sum \frac{200}{0.94} = 2.86\ kW$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. Cascade Energy. Proposed Standard Savings Estimation Protocol for Ultra-Premium Efficiency Motors. November 5, 2012.
   Available from: https://nwcouncil.app.box.com/s/fkxkcwm1is88dnttb8ve7eb5rhs9qhmv
2. Sullair Corporation. Compressed Air Filtration and Mist Eliminators Datasheet.
   Available from:
   http://www.amcompair.com/products/brochures/sullair_brochures/_Sullair%20filtration.pdf.

Record of Revisions

Record of Revision Number	Issue Date
7-20-11	7/31/2020

Return to Table of Contents

ENGINEERED AIR NOZZLE

Measure Description

This measure covers the installation of engineered nozzles used in compressed air systems, for the purposes of equipment cleaning, cooling, drying, etc. Unlike standard air nozzles, engineered nozzles entrain compressed air with surrounding air to provide effective air nozzle action while reducing compressed air requirement.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times (CFM_{baseline} - CFM_{ee}) \times (kW/CFM) \times hrs$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \frac{\Delta kWh}{hrs} \times F_{peak} \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
$CFM_{baseline}$	= Open nozzle flow
CFM_{ee}	= Engineered nozzle flow
kW/CFM	= Air compressor kW per CFM air delivery at 100 psi
hrs	= Annual hours of use of compressed air
F_{peak}	= Peak operation factor; binary variable to indicate whether equipment operates during electric system peak (summer weekday hour ending at 5 PM)
CF	= Coincidence factor

Summary of Variables and Data Sources

Variable	Value	Notes
$CFM_{baseline}$	CFM = 14.485 x D^2 x (psig + 14.7)	From application, where: D = Diameter of open air nozzle orifice in inches psig = Air pressure at nozzle[846]
CFM_{ee}		From application

[846] Compressed Air Best Practices, Compressed Air Savings with Nozzles and Blowers. The constant 14.485 is a derived constant to satisfy the equation assuming air at standard temperature and pressure. The constant 14.7 converts gauge pressure (psig) into absolute pressure (psia).

Variable	Value	Notes
kW/CFM		Look up from Air Compressor Efficiency table below based on air compressor type
hrs		From application. If unknown, assume compressed air application (i.e. operation of nozzle) represents 5% of the total operating hours of the air compressor system.[847]
F_{peak}	Peak Operation: 1 No Peak Operation: 0	From application.
CF	0.8	

Air Compressor Efficiency[848]

Air Compressor Type	kW/CFM
Single-Acting, Air-Cooled Reciprocating	0.22
Double-Acting Water-Cooled Reciprocating	0.15
Lubricant-Injected Rotary Screw Compressor	0.15
Lubricant-Free Rotary Screw Compressor	0.17
Centrifugal Air Compressor	0.16
VSD Compressor	0.14[849]

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.8.[850]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a modulating compressor with blow down system with an open/standard nozzle.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a modulating compressor with blow down system installed with an engineered nozzle, also known as an air entraining nozzle, as defined in the Measure Description section above.

[847] Assume 5% based on an average of 3 seconds per minute. Assumes 50% handheld air guns and 50% stationary air nozzles. Manual air guns tend to be used less than stationary air nozzles, and a conservative estimate of 1 second of blow-off per minute of compressor runtime is assumed. Stationary air nozzles are commonly more wasteful, as they are often mounted on machine tools and can be manually operated, resulting in the possibility of a long-term open blow situation. An assumption of 5 seconds of blow-off per minute of compressor runtime is used.
[848] Improving Compressed Air System Performance: A Sourcebook for Industry, pg 46, 47.
[849] Compressed Air Best Practices, VSD Compressor Control. Calculated based on operating point conditions and assuming a main-drive motor with a typical efficiency of 92%.
[850] *No source specified – update pending availability and review of applicable references.*

Operating Hours

Nozzles are assumed to be in use 5% of the time the compressed air system is operating, if actual hours of use are not known. Compressor system operating hours shall be taken from application.

Example Calculation *(Not to be used as default)*

An engineered air nozzle with a rated air consumption of 10 CFM at 100 psi is fitted in replacement of a standard air nozzle with a 1/8" diameter orifice on a VSD air compressor system used for equipment cleaning at a pressure of 100 psi. The equipment is in use for 250 hours per year during off peak hours. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

$$\Delta kWh = units \times (CFM_{baseline} - CFM_{ee}) \times (kW/CFM) \times hrs$$

$$\Delta kW = \frac{\Delta kWh}{hrs} \times F_{peak} \times CF$$

$CFM_{baseline}$ = 14.485 x D^2 x (psig + 14.7) = 14.485 x $(0.125)^2$ x (100 + 14.7) = 25.96

$CFM_{baseline}$ equation from Summary of Variables and Data Sources table

D = 0.125, from application

psig = 100, from application

CFM_{ee} = 10, from application

kW/CFM = 0.14, from Air Compressor Efficiency table based on air compressor type

hrs = 250 hours, from application.

F_{peak} = 0, from Summary of Variables and Data Sources table as there is no peak operation

CF = 0.8, from Summary of Variables and Data Sources table

$$\Delta kWh = 1 \times (25.96 - 10) \times 0.14 \times 250 = 559\ kWh$$

$$\Delta kW = \frac{559}{250} \times 0 \times 0.8 = 0\ kW$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. Compressed Air Best Practices, Compressed Air Savings with Nozzles and Blowers
   Available from: https://www.airbestpractices.com/system-assessments/end-uses/compressed-air-savings-nozzles-or-blowers
2. Compressed Air Best Practices, VSD Compressor Control
   Available from: https://www.airbestpractices.com/technology/compressor-controls/vsd-compressor-control

Record of Revision

Record of Revision Number	Issue Date
1	10/15/2010
9-18-11	9/28/2018

Return to Table of Contents

NO AIR LOSS WATER DRAIN

Measure Description

This measure covers the installation of a no air loss water drain in a compressed air system. No-loss drains monitor condensate levels and allow water to drain from the compressed air system without compressed air loss. No loss drains decrease air demand and increase overall efficiency.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times CFM_{drain} \times \Delta CFM \times (kW/CFM) \times hrs$$

Peak Coincident Demand Energy Savings

$$\Delta kW = units \times CFM_{drain} \times \Delta CFM \times (kW/CFM) \times F_{peak} \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
CFM_{drain}	= Full flow rated capacity of drain, in cubic feet per minute
ΔCFM	= Average cubic foot per minute saved per CFM of capacity of drain
kW/CFM	= Air compressor kW per CFM air delivery at 100 psi
hrs	= Annual operating hours
F_{peak}	= Peak operation factor; binary variable to indicate whether equipment operates during electric system peak (summer weekday hour ending at 5PM)
CF	= Coincidence factor

Summary of Variables and Data Sources

Variable	Value	Notes
CFM_{drain}		From application, if unknown, use 103.9 as default[851]
ΔCFM	0.049	DNV-GL[852]

[851] Based on an orifice size of 1/4 inch and a typical system pressure of 100 psi. Orifice sizes for timed drains range from 5/32 in. to 9/16 in. with the most common size being 7/16 in; 1/4 in. is considered a reasonably conservative estimate of average size. 100 psi is a conservative estimate of average system pressure; most systems are run at higher pressure than 100 psi. 103.9 is derived using the equation CFM = 14.485 x D^2 x (psig + 14.7), where 14.485 is a derived constant to satisfy the equation assuming air at standard temperature and pressure, D is the orifice diameter in inches, psig is the air pressure at the nozzle (gauge pressure), and 14.7 converts gauge pressure into absolute pressure.

[852] Impact Evaluation of Prescriptive Chiller and Compressed Air Installations, DNV GL, October 2015, p 45

Variable	Value	Notes
kW/CFM		Look up from Air Compressor Efficiency table below based on air compressor type
hrs		From application
F_{peak}	Peak Operation: 1 No Peak Operation: 0	From application
CF	0.8	

Air Compressor Efficiency[853]

Air Compressor Type	kW/CFM
Single-Acting, Air-Cooled Reciprocating	0.22
Double-Acting Water-Cooled Reciprocating	0.15
Lubricant-Injected Rotary Screw Compressor	0.15
Lubricant-Free Rotary Screw Compressor	0.17
Centrifugal Air Compressor	0.16
VSD Compressor[854]	0.14

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.8.[855]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a compressed air system with an electronic solenoid and timed drain.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a load/unload with storage, VSD, or variable displacement compressed air system with a no air loss water drain.

Operating Hours

Hours of operation shall be taken from application.

Example Calculation *(Not to be used as default)*

A no air loss water drain with a rated capacity of 105 CFM is installed in a single-acting air-cooled reciprocating air compressor system that is in operation for 800 hours per year, including some hours that overlap with system peak. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

$$\Delta kWh = units \times CFM_{drain} \times \Delta CFM \times (kW/CFM) \times hrs$$

[853] Improving Compressed Air System Performance: A Sourcebook for Industry, pg 46, 47.
[854] Compressed Air Best Practices, VSD Compressor Control. Calculated based on operating point conditions and assuming a main-drive motor with a typical efficiency of 92%.
[855] *No source specified – update pending availability and review of applicable references.*

$$\Delta kW = units \times CFM_{drain} \times \Delta CFM \times (kW/CFM) \times F_{peak} \times CF$$

CFM_{drain} = 105 CFM, from application
ΔCFM = 0.049, from Summary of Variables and Data Sources table
kW/CFM = 0.22, from Air Compressor Efficiency table based on air compressor type
hrs = 800 hours, from application
F_{peak} = 1, from Summary of Variables and Data Sources table
CF = 0.8, from Summary of Variables and Data Sources table

$$\Delta kWh = 1 \times 105 \times 0.049 \times 0.22 \times 800 = 906\ kWh$$

$$\Delta kW = 1 \times 105 \times 0.049 \times 0.22 \times 1 \times 0.8 = 0.91\ kW$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. Impact Evaluation and Prescriptive Chiller and Compressed Air Installations, DNV-GL, prepared by KEMA, Inc. for Massachusetts Energy Efficiency Advisory Council. October 2015.
   Available from: https://ma-eeac.org/wp-content/uploads/MA30-Prescriptive-Chiller-and-CAIR-Report_FINAL_151026.pdf
2. Improving Compressed Air System Performance: A Sourcebook for Industry Third Edition, Department of Energy
   Available from:
   https://www.energy.gov/sites/prod/files/2016/03/f30/Improving%20Compressed%20Air%20Sourcebook%20version%203.pdf
3. Compressed Air Best Practices, VSD Compressor Control
   Available from: https://www.airbestpractices.com/technology/compressor-controls/vsd-compressor-control

Record of Revision

Record of Revision Number	Issue Date
1	10/15/2010
9-18-12	9/28/2018

Return to Table of Contents

REFRIGERATED AIR DRYER

Measure Description

This measure covers the installation of a cycling or variable frequency drive (VFD)-controlled refrigerated air dryer on a compressed air system with a non-cycling air dryer. High efficiency air dryers utilize a refrigeration system to condense and remove moisture from a compressed air system. As demand requires, cycling refrigerated air dryer systems cool a medium that cools the compressed air. VFD-controlled refrigerated air dryer systems use a variable speed drive as required by the demand. Both systems save energy by dismissing the need for the system to run continuously at full speed.

This measure is applicable to single compressor systems only.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times CFM_{dryer} \times (\Delta kW/CFM) \times hrs$$

Summer Peak Coincident Demand Savings

$$\Delta kW = units \times CFM_{dryer} \times (\Delta kW/CFM) \times F_{peak} \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
CFM_{dryer}	= Full flow rated capacity of refrigerated air dryer, in cubic feet per minute
ΔkW/CFM	= kW reduction per full flow rated CFM
hrs	= Annual operating hours of dryer
F_{peak}	= Peak operation factor; binary variable to indicate whether equipment operates during electric system peak (summer weekday hour ending at 5PM)
CF	= Coincidence factor

Summary of Variables and Data Sources

Variable	Value	Notes
CFM_{dryer}		From application.
ΔkW/CFM	0.00554	DNV-GL.[856]

[856] Impact Evaluation of Prescriptive Chiller and Compressed Air Installations, DNV GL, October 2015, Table 1-10: Dryer kW per CFM Saved

Variable	Value	Notes
hrs		From application.
F_{peak}	Peak Operation: 1 No Peak Operation: 0	From application.
CF	0.8	

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.8.[857]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a compressed air system equipped with a non-cycling air dryer.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a compressed air system with a cycling or VFD-controlled refrigerated air dryer.

Operating Hours

Hours of operation shall be taken from application.

Example Calculation *(Not to be used as default)*

A VFD refrigerated air dryer with a rated capacity of 150 CFM is installed on a compressed air system that is in operation 800 hours per year, including some hours that overlap with system peak. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

$$\Delta kWh = units \times CFM_{dryer} \times (\Delta kW/CFM) \times hrs$$

$$\Delta kW = units \times CFM_{dryer} \times (\Delta kW/CFM) \times F_{peak} \times CF$$

units = 1, from application
CFM_{dryer} = 150 CFM, from application
ΔkW/CFM = 0.00554, from Summary of Variables and Data Sources table
hrs = 800 hours, from application
F_{peak} = 1, from Summary of Variables and Data Sources table
CF = 0.8, from Summary of Variables and Data Sources table

$$\Delta kWh = 1 \times 150 \times 0.00554 \times 800 = 665\ kWh$$

$$\Delta kW = 1 \times 150 \times 0.00554 \times 1 \times 0.8 = 0.66\ kW$$

[857] *No source specified – update pending availability and review of applicable references.*

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. Impact Evaluation of Prescriptive Chiller and Compressed Air Installations, DNV-GL, prepared by KEMA, Inc. for Massachusetts Energy Efficiency Advisory Council, October 2015
   Available from: https://ma-eeac.org/wp-content/uploads/MA30-Prescriptive-Chiller-and-CAIR-Report_FINAL_151026.pdf

Record of Revision

Record of Revision Number	Issue Date
1	10/15/2010
6-18-8	6/26/2018

Return to Table of Contents

DOMESTIC HOT WATER

INDIRECT WATER HEATER

Measure Description

This measure covers the installation of a fossil fuel fired indirect water heater in which the stored water is heated via hot water or steam produced by a fossil fuel boiler rather than direct input from electric elements or fossil fuel burners. In such a system, a heat exchanger separates the potable water in the water heater from the boiler water. This measure applies to small commercial indirect systems comprising a boiler with input heating capacity less than 300,000 BTU/h and greater than or equal to 4,000 BTU/h per gallon of stored water.[858]

This measure estimates savings associated with the delivery of potable hot water only and assumes the installation of zone priority controls to interrupt demand for space heating until domestic hot water demand is met. Larger equipment as well as equipment where zone priority control is not feasible shall be treated under a custom application.

The baseline assumption for indirect water heaters is a minimally code compliant tank type water heater or an indirect system with a minimally code compliant boiler, based on actual existing conditions. For new construction, a tank type baseline shall be assumed.

Method for Calculating Annual Energy and Peak Coincidence Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = N/A$$

Summer Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = units \times \left[\frac{GPD \times 365 \times 8.33 \times \Delta T_{main}}{1{,}000{,}000} \times \left(\frac{1}{Eff_{baseline}} - \frac{1}{Eff_{ee}}\right) + \left(\frac{UA_{baseline}}{Eff_{baseline}} - \frac{UA_{ee}}{Eff_{ee}}\right) \times \frac{\Delta T_{amb}}{1{,}000{,}000} \times 8{,}760\right]$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program

[858] 10 CFR 431.102

GPD	= Gallons per day
ΔT_{main}	= Average temperature difference between water heater set point temperature and the supply water temperature in water main (°F)
ΔT_{amb}	= Average temperature difference between water heater set point temperature and the surrounding ambient air temperature (°F)
baseline	= Characteristic of baseline condition
ee	= Characteristic of energy efficient condition
Eff	= Efficiency
UA	= Overall heat loss coefficient (BTU/h-°F)
365	= Days in one year
8.33	= Energy required (BTU) to heat one gallon of water by one degree Fahrenheit
1,000,000	= Conversion factor, one MMBtu equals 1,000,000 BTU
8,760	= Hours in one year

Summary of Variables and Data Sources

Variable	Value	Notes
GPD		From application, or lookup/calculate based on building type, square footage and occupancy from GPD table below.
ΔT_{main}	$T_{set} - T_{main}$	Average temperature difference between water heater set point temperature and the supply water temperature in water main (°F).
ΔT_{amb}	$T_{set} - T_{amb}$	Average temperature difference between water heater set point temperature and the surrounding ambient air temperature (°F).
T_{set}		Water heater set point temperature (°F), per application or use 140°F as a default.[859]
T_{main}		Supply water temperature in water main (°F). Lookup in Cold Water Inlet Temperature table below based on nearest city. (°F).
T_{amb}	70	Surrounding ambient air temperature (°F).[860]
$Eff_{baseline}$		Efficiency of baseline condition. Lookup in Baseline Efficiencies section below.
Eff_{ee}		Efficiency of energy efficient indirect-system boiler (AFUE) from application.
$UA_{baseline}$		Overall heat loss coefficient of the baseline condition (BTU/h-°F). Calculate based on baseline standby loss per the Baseline Heat Loss Coefficient section below.

[859] Per OSHA recommendations for prevention of Legionella bacterial growth (https://www.osha.gov/SLTC/legionnairesdisease/control_prevention.html)

[860] Water heaters are generally located in conditioned or partially conditioned spaces with a typical average temperature of 65°F to 70°F to avoid freezing. A value of 70°F is used for the purposes of estimating tank/ambient air temperature differential, which aligns with standby loss specification testing standards.

Variable	Value	Notes
UA_{ee}		Overall heat loss coefficient of the energy efficient measure (BTU/h-°F). Calculate based on energy efficient standby loss per the Qualifying Heat Loss Coefficient section below.

Gallons per Day (GPD)

The average daily hot water usage, expressed in gallons per day, for several commercial facility types is tabulated below. Daily hot water usage can be calculated based on the GPD and site-specific metric in the Rate column, or default values can be referenced directly from the GPD column.

Building Type	GPD	Rate	Notes/Assumptions	Source
Assembly	239	7.02 GPD per 1,000 SF	Assumes 10% hot water, 34,000 SF	EIA[861]: Public Assembly
Auto Repair	25	4.89 GPD per 1,000 SF	Assumes 10% hot water, 5,150 SF	EIA: Other
Big Box Retail	448	3.43 GPD per 1,000 SF	Assumes 10% hot water, 130,500 SF	EIA: Mercantile
Community College	1,520	1.9 GPD per person	Assumes 800 students	NREL[862]: School with Showers
Dormitory	8,600	17.2 GPD per resident	Assumes 500 residents	Water Research Foundation[863]
Elementary School	250	0.5 GPD per student	Assumes 500 students	NREL: School
Fast Food Restaurant	500	500 GPD per restaurant		FSTC[864]: Quick Service
Full-Service Restaurant	2,500	2,500 GPD per restaurant		FSTC: Full Service
Grocery	172	3.43 GPD per 1,000 SF	Assumes 10% hot water, 50,000 SF	EIA: Mercantile
High School	1,520	1.9 GPD per person	Assumes 800 students	NREL: School with Showers
Hospital	16,938	54.42 GPD per 1,000 SF	Assumes 40% hot water, 250,000 SF	EIA: Health Care, Inpatient
Hotel	9,104	45.52 GPD per 1,000 SF	Assumes 40% hot water, 200,000 SF	EIA: Lodging
Large Office	550	1.1 GPD per person	Assumes 500 people	NREL: Office
Large Retail	446	3.43 GPD per 1,000 SF	Assumes 10% hot water, 130,000 SF	EIA: Mercantile
Light Industrial	489	4.89 GPD per 1,000 SF	Assumes 10% hot water, 100,000 SF	EIA: Other
Motel	1,366	45.52 GPD per 1,000 SF	Assumes 40% hot water, 30,000 SF	EIA: Lodging
Multifamily High-Rise	4,600	46 GPD per unit	Assumes 100 units	Water Research Foundation
Multifamily Low-Rise	552	46 GPD per unit	Assumes 12 units	Water Research Foundation
Refrigerated Warehouse	86	0.93 GPD per 1,000 SF	Assumes 10% hot water, 92,000 SF	EIA: Warehouse and Storage
Religious	77	7.02 GPD per 1,000 SF	Assumes 10% hot water, 11,000 SF	EIA: Public Assembly
Small Office	110	1.1 GPD per person	Assumes 100 people	NREL: Office
Small Retail	27	3.43 GPD per 1,000 SF	Assumes 10% hot water, 8,000 SF	EIA: Mercantile
University	1,000	0.5 GPD per student	Assumes 2,000 students	NREL: School
Warehouse	465	0.93 GPD per 1,000 SF	Assumes 10% hot water, 500,000 SF	EIA: Warehouse and Storage
Other	Calculate	4.89 GPD per 1,000 SF	Assumes 10% hot water	EIA: Other

Cold Water Inlet Temperature (T_{main})

Supply water main temperatures vary according to climate and are approximately equal to the annual average outdoor temperature plus 6°F.[865] Supply main temperatures based on the annual outdoor temperature are shown below.

[861] U.S. Energy Information Administration, 2012 Commercial Buildings Energy Consumption Survey: Water Consumption in Large Buildings, Table WD1. Daily water consumption in large commercial buildings, 2012

[862] National Renewable Energy Laboratory, Saving Energy in Commercial Buildings: Domestic Hot Water Assessment Guidelines, Table 1. Hot Water Use By Building Type, June 2011

[863] Water Research Foundation: Residential End Uses of Water, Version 2, April 2016

[864] Improving Commercial Kitchen Hot Water System Perofmrance, Design Guide – Energy Efficient Heating, Delivery and Use, Table 1. Typical hot water system cost for restaurants, March 2010

[865] Burch, Jay and Christensen, Craig, "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory

City	Annual average outdoor temperature[866] (°F)	T_{main} (°F)
Albany	48.3	54.3
Binghamton	46.3	52.3
Buffalo	48.3	54.3
Massena	43.5	49.5
NYC	55.4	61.4
Poughkeepsie	49.8	55.8
Syracuse	48.3	54.3

Baseline Heat Loss Coefficient ($UA_{baseline}$)

$UA_{baseline}$ is calculated from the assumed equipment standby loss specification ($SL_{baseline}$), which is determined per minimum effective federal standards for commercial gas storage type water heaters (see Baseline Standby Losses section below).[867]

$$UA_{baseline} = \frac{SL_{baseline}}{70}$$

where:

$SL_{baseline}$ = Standby heat loss (BTU/h) specification. For the baseline condition ($SL_{baseline}$), use the intermediate standby loss equation from the Baseline Standby Losses section below.

70 = Temperature difference associated with standby loss specification (°F)[868]

Baseline Standby Losses ($SL_{baseline}$)

Standby losses ($SL_{baseline}$) for commercial gas storage type water heaters:[869]

$$SL_{baseline} = \frac{Q_{baseline}}{800} + 110\sqrt{v_{baseline}}$$

where:

$v_{baseline}$ = Baseline tank volume (gal), equal to the storage capacity of the efficient equipment

$Q_{baseline}$ = Baseline input capacity (BTU/h), equal to the input capacity of the efficient equipment

Qualifying Heat Loss Coefficient (UA_{ee})

Indirect water heater storage tanks are tested and rated for standby losses (in °F/hr or BTU/h) at standard testing conditions in accordance with testing standards.[870]

[866] Average annual outdoor temperatures taken from NCEI 1981-2010 climate normals
[867] 10 CFR 429, 430, and 431 Docket No. EERE-2015-BT-TP-0007, Energy Conservation Program for Consumer Products and Certain Commercial and Industrial Equipment: Test Procedures for Consumer and Commercial Water Heaters
[868] Ibid.
[869] Ibid.
[870] GAMA Testing Standard: Performance of Indirect-Fired Water Heaters, March 2003

For equipment with standby losses rated in °F/hr, the qualifying equipment standby loss specification (SL_{ee}) shall be used in the formula below, along with tank volume (v_{ee}) to establish the qualifying equipment heat loss coefficient (UA_{ee}).

$$UA_{ee} = \frac{SL_{ee}}{70} \times v_{ee} \times 8.33$$

where:

UA_{ee}	= Overall heat loss coefficient (BTU/h-°F) of the energy efficient condition
SL_{ee}	= Standby loss specification (°F/hr) of the energy efficient condition
v_{ee}	= Rated storage capacity (gallons) of the energy efficient condition
70	= Temperature difference associated with standby loss specification (°F)[871]
8.33	= Energy required (BTU) to heat one gallon of water by one degree Fahrenheit

For equipment with standby losses rated in BTU/h, the qualifying equipment standby loss specification (SL_{ee}) shall be used in the formula below to establish the qualifying equipment heat loss coefficient (UA_{ee})

$$UA_{ee} = \frac{SL_{ee}}{70}$$

where:

UA_{ee}	= Overall heat loss coefficient (BTU/h-°F) of the energy efficient condition
SL_{ee}	= Standby loss specification (BTU/h) of the energy efficient condition
70	= Temperature difference associated with standby loss specification (°F)[872]

Coincidence Factor (CF)

The prescribed value for the coincidence factor is N/A.

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a minimally code compliant fossil fuel storage type or indirect water heater (based on actual existing conditions) with efficiency per the Energy Conservation Construction Code of New York State[873] as shown in the table below. Heat loss coefficient of the baseline condition shall be established as indicated in the Baseline Heat Loss Coefficient section above. Measure is only applicable to small commercial (<300,000 BTU/h) equipment in applications with zone priority control. Baseline tank volume and input capacity shall be set equal to the energy efficient condition. For new construction, a tank type baseline shall be assumed.

[871] 10 CFR 429, 430, and 431 Docket No. EERE-2015-BT-TP-0007, Energy Conservation Program for Consumer Products and Certain Commercial and Industrial Equipment: Test Procedures for Consumer and Commercial Water Heaters
[872] Ibid.
[873] ECCCNYS 2020, Table C403.3.3(5) and Table C404.2

Equipment Type/Size	Efficiency
Tank Type: All Sizes	0.80 E_t
Gas-Fired Hot Water Boiler: < 300,000 BTU/h	0.82 AFUE
Oil-Fired Hot Water Boiler: < 300,000 BTU/h	0.84 AFUE
Gas-Fired Steam Boiler, All Except Natural Draft: < 300,000 BTU/h	0.80 AFUE
Gas-Fired Steam Boiler, Natural Draft: < 300,000 BTU/h	0.80 AFUE
Oil-Fired Steam Boiler: < 300,000 BTU/h	0.82 AFUE

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a small commercial (<300,000 BTU/h) fossil fuel-fired indirect water heater as defined in the Measure Description section. The efficiency of the compliant equipment must exceed the efficiency of the baseline equipment.

Operating Hours

Water heater run hours are not utilized in the estimation of energy or demand savings, but water heater is assumed to be available for operation 8,760 hours per year. Additionally, it is assumed standby losses are incurred 8,760 hours per year.

Example Calculation *(Not to be used as default)*

A gas-fired storage type water heater is replaced with an indirect water heater tank with an input capacity of 150 kBtu/h and storage capacity of 60 gallons in a commercial facility located near Albany. The building's hot water demand is 200 gallons per day and water heater set point temperature is 145ºF. The boiler has a 90% energy efficiency rating and a standby loss rating of 0.56 ºF/hr. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are not applicable. Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta MMBtu = units \times \left[\frac{GPD \times 365 \times 8.33 \times \Delta T_{main}}{1{,}000{,}000} \times \left(\frac{1}{Eff_{baseline}} - \frac{1}{Eff_{ee}}\right) + \left(\frac{UA_{baseline}}{Eff_{baseline}} - \frac{UA_{ee}}{Eff_{ee}}\right) \times \frac{\Delta T_{amb}}{1{,}000{,}000} \times 8{,}760\right]$$

units =1
GPD = 200, from application
$\Delta T_{main} = T_{set} - T_{main} = 145 - 54.3 = 90.7$
T_{set} from application
T_{main} from Cold Water Inlet Temperature table based on location from application
$\Delta T_{amb} = T_{set} - T_{amb} = 145 - 70 = 75$
T_{amb} from Summary of Variables and Data Sources table
$Eff_{baseline}$ = 0.82, from Baseline Efficiency section based on application
Eff_{ee} = 0.9, from application
$UA_{baseline} = SL_{baseline} / 70 = 962 / 70 = 13.74$

$UA_{baseline}$ equation from Baseline Heat Loss Coefficient section
$SL_{baseline} = Q_{baseline} / 800 + 100 \times (v_{baseline})^{1/2} = 150{,}000 / 800 + 100 \times (60)^{1/2} = 962$
$SL_{baseline}$ equation from Baseline Standby Losses section
$Q_{baseline}$ from application based on efficient equipment
$v_{baseline}$ from application based on efficient equipment
$UA_{ee} = SL_{ee} / 70 \times v_{ee} \times 8.33 = 0.56 / 70 \times 60 \times 8.33 = 4.00$
UA_{ee} equation from Qualifying Heat Loss Coefficient section
SL_{ee} from application
v_{ee} from application

$$\Delta MMBtu = 1 \times \left[\frac{200 \times 365 \times 8.33 \times 90.7}{1{,}000{,}000} \times \left(\frac{1}{0.82} - \frac{1}{0.9}\right) + \left(\frac{13.74}{0.82} - \frac{4.00}{0.9}\right) \times \frac{75}{1{,}000{,}000} \times 8{,}760\right] = 14.07\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Reduction in standby heat losses will have a negligible impact on space heating when the water heater is located in a conditioned space. Consideration of these effects is not included in this methodology.

Ancillary Electric Savings Impacts

Reduction in standby heat losses will have a negligible impact on space heating when the water heater is located in a conditioned space. Consideration of these effects is not included in this methodology.

References

1. 10 CFR 431.102 Definitions concerning commercial water heaters, hot water supply boilers, unfired hot water storage tanks, and commercial heat pump water heaters. Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=d294d58298d519e0a50d8a28c654ebb5&mc=true&node=pt10.3.431&rgn=div5#se10.3.431_1102
2. 10 CFR Appendix E to Subpart B of Part 430—Uniform Test Method for Measuring the Energy Consumption of Water Heaters, Section 2. Test Conditions, 2.5 Set Point Temperature.
   Available from: https://www.govinfo.gov/content/pkg/CFR-2013-title10-vol3/pdf/CFR-2013-title10-vol3-part430.pdf

3. OSHA Legionnaire's Disease eTool: Section II: C-1. Domestic Hot-Water Systems
Available from:
https://www.osha.gov/SLTC/legionnairesdisease/control_prevention.htmlU.S. Energy Information Administration, 2012 Commercial Buildings Energy Consumption Survey: Water Consumption in Large Buildings, Table WD1. Daily water consumption in large commercial buildings, 2012
Available from: https://www.eia.gov/consumption/commercial/reports/2012/water/
4. National Renewable Energy Laboratory, Saving Energy in Commercial Buildings: Domestic Hot Water Assessment Guidelines, Table 1. Hot Water Use By Building Type, June 2011
Available from: https://www.nrel.gov/docs/fy11osti/50118.pdf
5. Water Research Foundation: "Residential End Uses of Water, Version 2: Executive Report", April 2016
Available from: https://www.circleofblue.org/wp-content/uploads/2016/04/WRF_REU2016.pdf
6. Improving Commercial Kitchen Hot Water System Perofmrance, Design Guide – Energy Efficient Heating, Delivery and Use, Table 1. Typical hot water system cost for restaurants, March 2010
Available from: https://caenergywise.com/design-guides/Water_Heating_Design_Guide.pdf
7. Burch, Jay and Craig Christensen; "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory.
Available from:
https://www.energystar.gov/ia/partners/prod_development/new_specs/downloads/water_heaters/AlgorithmForMainsWaterTemperature.pdf
8. NOAA National Centers for Environmental Information – NCEI 1981-2010 Climate Normals
Available from: https://www.ncdc.noaa.gov/cdo-web/datatools/normals
9. 10 CFR 429, 430, and 431 Docket No. EERE-2015-BT-TP-0007, Energy Conservation Program for Consumer Products and Certain Commercial and Industrial Equipment: Test Procedures for Consumer and Commercial Water Heaters
Available from:
https://energy.gov/sites/prod/files/2016/08/f33/Water%20Heaters%20Test%20Procedure%20SNOPR.pdf
10. GAMA Testing Standard: Performance of Indirect-Fired Water Heaters, March 2003
Available from:
http://www.ahrinet.org/App_Content/ahri/files/standards%20pdfs/Indirect-Fired%20Water%20Heater%20Testing%20Standard03.pdf
11. ECCCNYS 2020 Table C403.3.2(5): Minimum Efficiency Requirements: Gas- And Oil-Fired Boilers & Table C404.2: Minimum Performance of Water Heating Equipment
Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-ce-commercial-energy-efficiency

Record of Revision

Record of Revision Number	Issue Date
1	10/15/2010
3-18-14	3/29/2018

Return to Table of Contents

INSTANTANEOUS WATER HEATER

Measure Description

This measure covers the installation of high-efficiency fossil fuel and electric instantaneous water heaters, which heat water but contain no more than one gallon of water per 4,000 BTU/h of input. It is applicable to fossil fuel-fired instantaneous water heaters with a rated input greater than 200,000 BTU/h and electric instantaneous water heaters with a rated input greater than 12 kW.[874] This measure applies to potable hot water delivery only; it is not applicable to hot water heaters used for process loads or space heating.

This measure applies to replacement of existing storage type water heaters using the same heating fuel (fossil fuel or electric) as the efficient case. For new construction, this measure assumes baseline to be a standard efficiency water heater using the same heating fuel (fossil fuel or electric) as the efficient case.

This measure applies to commercial grade water heaters only. For residential-duty water heaters installed in commercial settings, the Residential Storage Tank and Instantaneous Domestic Water Heater methodology detailed in this document shall be employed utilizing typical GPD values as defined in the "Gallons per Day (GPD)" section below.

Method for Calculating Annual Energy and Peak Coincidence Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times \left[\frac{GPD \times 365 \times 8.33 \times \Delta T_{main}}{3{,}412} \times \left(\frac{1}{E_{t,baseline}} - \frac{1}{E_{t,ee}}\right) + \frac{UA_{baseline} \times \Delta T_{amb} \times 8{,}760}{E_{t,baseline} \times 3{,}412}\right]$$

Summer Peak Coincident Demand Savings

$$\Delta kW = units \times \frac{UA_{baseline} \times \Delta T_{amb}}{3{,}412} \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = units \times \left[\frac{GPD \times 365 \times 8.33 \times \Delta T_{main}}{1{,}000{,}000} \times \left(\frac{1}{E_{t,baseline}} - \frac{1}{E_{t,ee}}\right) + \frac{UA_{baseline} \times \Delta T_{amb} \times 8{,}760}{E_{t,baseline} \times 1{,}000{,}000}\right]$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
GPD	= Gallons per day
ΔT_{main}	= Average temperature difference between water heater set point temperature and the supply water temperature in water main (°F)
ΔT_{amb}	= Average temperature difference between water heater set point temperature and

[874] 10 CFR 431.102

the surrounding ambient air temperature (°F)

$_{baseline}$ = Characteristic of baseline condition

$_{ee}$ = Characteristic of energy efficient condition

E_t = Thermal efficiency

UA = Overall heat loss coefficient (BTU/h-°F)

CF = Coincidence factor

365 = Days in one year

8.33 = Energy required (BTU) to heat one gallon of water by one degree Fahrenheit

3,412 = Conversion factor, one kWh equals 3,412 BTU

1,000,000 = Conversion factor, one MMBtu equals 1,000,000 BTU

8,760 = Hours in one year

Summary of Variables and Data Sources

Variable	Value	Notes
GPD		From application, or lookup based on building type in GPD table below.
ΔT_{main}	T_{set} - T_{main}	Average temperature difference between water heater set point temperature and the supply water temperature in water main (°F)
ΔT_{amb}	T_{set} - T_{amb}	Average temperature difference between water heater set point temperature and the surrounding ambient air temperature (°F)
T_{set}		Water heater set point temperature (°F). From application, or use 140°F.[875]
T_{main}		Supply water temperature in water main (°F). Lookup in Cold Water Inlet Temperature table below based on nearest city.
T_{amb}	70	Surrounding ambient air temperature (°F). [876]
$E_{t,baseline}$	Electric: 0.98 Fossil Fuel: 0.80	Thermal efficiency of the baseline condition[877,878]
$E_{t,ee}$		Thermal efficiency for energy efficient measure, from application
$UA_{baseline}$		Overall heat loss coefficient of the baseline condition, calculate based on baseline standby loss per the Overall Heat Loss Coefficient section below.
CF	0.8	

[875] Per OSHA recommendations for prevention of Legionella bacterial growth (https://www.osha.gov/SLTC/legionnairesdisease/control_prevention.html

[876] Water heaters are generally located in conditioned or partially conditioned spaces with a typical average temperature of 65°F to 70°F to avoid freezing. A value of 70°F is used for the purposes of estimating tank/ambient air temperature differential, which aligns with standby loss specification testing standards.

[877] Fuel: 10 CFR 431.110 (a)

[878] Electric: Per 10 CFR 430 Subpart B Appendix E – Uniform Test Method for Measuring the Energy Consumption of Water Heaters: *6.3.2 Recovery Efficiency*

Gallons per Day (GPD)

The average daily hot water usage, expressed in gallons per day, for several commercial facility types is tabulated below. Daily hot water usage can be calculated based on the GPD and site-specific metric in the Rate column, or default values can be referenced directly from the GPD column.

Building Type	GPD	Rate	Notes/Assumptions	Source
Assembly	239	7.02 GPD per 1,000 SF	Assumes 10% hot water, 34,000 SF	EIA[879]: Public Assembly
Auto Repair	25	4.89 GPD per 1,000 SF	Assumes 10% hot water, 5,150 SF	EIA: Other
Big Box Retail	448	3.43 GPD per 1,000 SF	Assumes 10% hot water, 130,500 SF	EIA: Mercantile
Community College	1,520	1.9 GPD per person	Assumes 800 students	NREL[880]: School with Showers
Dormitory	8,600	17.2 GPD per resident	Assumes 500 residents	Water Research Foundation[881]
Elementary School	250	0.5 GPD per student	Assumes 500 students	NREL: School
Fast Food Restaurant	500	500 GPD per restaurant		FSTC[882]: Quick Service
Full-Service Restaurant	2,500	2,500 GPD per restaurant		FSTC: Full Service
Grocery	172	3.43 GPD per 1,000 SF	Assumes 10% hot water, 50,000 SF	EIA: Mercantile
High School	1,520	1.9 GPD per person	Assumes 800 students	NREL: School with Showers
Hospital	16,938	54.42 GPD per 1,000 SF	Assumes 40% hot water, 250,000 SF	EIA: Health Care, Inpatient
Hotel	9,104	45.52 GPD per 1,000 SF	Assumes 40% hot water, 200,000 SF	EIA: Lodging
Large Office	550	1.1 GPD per person	Assumes 500 people	NREL: Office
Large Retail	446	3.43 GPD per 1,000 SF	Assumes 10% hot water, 130,000 SF	EIA: Mercantile
Light Industrial	489	4.89 GPD per 1,000 SF	Assumes 10% hot water, 100,000 SF	EIA: Other
Motel	1,366	45.52 GPD per 1,000 SF	Assumes 40% hot water, 30,000 SF	EIA: Lodging
Multifamily High-Rise	4,600	46 GPD per unit	Assumes 100 units	Water Research Foundation
Multifamily Low-Rise	552	46 GPD per unit	Assumes 12 units	Water Research Foundation
Refrigerated Warehouse	86	0.93 GPD per 1,000 SF	Assumes 10% hot water, 92,000 SF	EIA: Warehouse and Storage
Religious	77	7.02 GPD per 1,000 SF	Assumes 10% hot water, 11,000 SF	EIA: Public Assembly
Small Office	110	1.1 GPD per person	Assumes 100 people	NREL: Office
Small Retail	27	3.43 GPD per 1,000 SF	Assumes 10% hot water, 8,000 SF	EIA: Mercantile
University	1,000	0.5 GPD per student	Assumes 2,000 students	NREL: School
Warehouse	465	0.93 GPD per 1,000 SF	Assumes 10% hot water, 500,000 SF	EIA: Warehouse and Storage
Other	Calculate	4.89 GPD per 1,000 SF	Assumes 10% hot water	EIA: Other

Cold Water Inlet Temperature (T_{main})

Supply water main temperatures vary according to climate, and are approximately equal to the annual average outdoor temperature plus 6°F.[883] Supply main temperatures based on the annual outdoor temperature are shown below.

City	Annual average outdoor temperature[884] (°F)	T_{main} (°F)
Albany	48.3	54.3
Binghamton	46.3	52.3
Buffalo	48.3	54.3
Massena	43.5	49.5

[879] U.S. Energy Information Administration, 2012 Commercial Buildings Energy Consumption Survey: Water Consumption in Large Buildings, Table WD1. Daily water consumption in large commercial buildings, 2012

[880] National Renewable Energy Laboratory, Saving Energy in Commercial Buildings: Domestic Hot Water Assessment Guidelines, Table 1. Hot Water Use By Building Type, June 2011

[881] Water Research Foundation: Residential End Uses of Water, Version 2, April 2016

[882] Food Service Technology Center, Design Guide – Energy Efficient Heating, Delivery and Use, Table 1. Typical hot water system cost for restaurants, March 2010

[883] Burch, Jay and Christensen, Craig, "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory

[884] Average annual outdoor temperatures taken from NCEI 1981-2010 climate normals

City	Annual average outdoor temperature[884] (°F)	T_{main} (°F)
NYC	55.4	61.4
Poughkeepsie	49.8	55.8
Syracuse	48.3	54.3

Overall Heat Loss Coefficient ($UA_{baseline}$)

Tank overall heat loss coefficient is calculated from the equipment standby loss specification. To calculate $UA_{baseline}$, use the appropriate intermediate standby loss equation from the Baseline Standby Losses section below.

$$UA = \frac{SL}{70}$$

where:

SL = Standby heat loss (BTU/h). For the baseline condition ($SL_{baseline}$), use the appropriate intermediate standby loss equation from the Baseline Standby Losses section below.

70 = Temperature difference associated with standby loss specification (°F)[885]

Baseline Standby Losses ($SL_{baseline}$)

Standby losses ($SL_{baseline}$) for large electric storage type water heaters (> 12kW and > 20 gallons):[886]

$$SL_{baseline} = \frac{\left(0.30 + \frac{27}{v_{baseline}}\right)}{100} \times 70 \times v_{baseline} \times 8.33$$

where:

$v_{baseline}$ = Baseline tank volume (gal). If unknown, assume 150 gallons.

70 = Temperature difference associated with standby loss specification (°F)[887]

8.33 = Energy required (BTU) to heat one gallon of water by one degree Fahrenheit

Standby losses ($SL_{baseline}$) for large oil and gas storage type water heaters (> 75,000 BTU/h input capacity (Q) and storage size > 1 gallon per 4000 BTU/h):[888]

$$SL_{baseline} = \frac{Q_{baseline}}{800} + 110\sqrt{v_{baseline}}$$

[885] 10 CFR 429, 430, and 431 Docket No. EERE-2015-BT-TP-0007, Energy Conservation Program for Consumer Products and Certain Commercial and Industrial Equipment: Test Procedures for Consumer and Commercial Water Heaters

[886] Ibid.

[887] 10 CFR 429, 430, and 431 Docket No. EERE-2015-BT-TP-0007, Energy Conservation Program for Consumer Products and Certain Commercial and Industrial Equipment: Test Procedures for Consumer and Commercial Water Heaters

[888] Ibid.

where:

$V_{baseline}$ = Baseline tank volume (gal). If unknown, assume 150 gallons.

$Q_{baseline}$ = Baseline input capacity (BTU/h). If unknown, assume 200,000 BTU/h.

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.8[889]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a standard efficiency fossil fuel or electric storage type water heater (fuel type equivalent to the efficient case) with tank volume and input capacity equivalent to those of the existing equipment, UA value calculated as prescribed above and a thermal efficiency of 0.80 (fossil fuel) or 0.98 (electric). For new construction, assume the baseline condition consists of a 100-gallon storage type water heater with an input capacity of 200,000 BTU/h.[890]

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a fossil fuel or electric instantaneous water heater as defined in the Measure Description section above. Fossil fuel tankless water heaters must meet the minimum qualifying efficiency for ENERGY STAR® certification of a thermal efficiency greater than or equal to 0.94.[891] Electric tankless water heaters must meet or exceed the efficiency of the baseline condition with a thermal efficiency greater than or equal to 0.98.

Effective Useful Life (EUL)

See Appendix P.

Operating Hours

Water heater run hours are not utilized in the estimation of energy or demand savings, but water heater is assumed to be available for operation 8,760 hours per year. Additionally, it is assumed standby losses are incurred 8,760 hours per year in the baseline case.

Example Calculation *(Not to be used as default)*

A 250 kBTU/h, 150 gallon gas-fired storage tank water heater in a commercial facility located near Albany is replaced with a 380 kBTU/h gas-fired instantaneous water heater with a 95% rated thermal efficiency. The facility has a hot water demand of 1,000 gallons per day and a hot water set point temperature of 145ºF. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are not applicable. Annual Fossil Fuel Energy Savings are calculated as below.

[889] *No source specified – update pending availability and review of applicable references.*

[890] Based on the average storage size and capacity of AHRI-certified commercial storage type water heaters per the ARHI Directory (https://www.ahridirectory.org/Search/SearchHome)

[891] ENERGY STAR® Commercial Water Heater Key Product Criteria

$$\Delta MMBtu = units \times \left[\frac{GPD \times 365 \times 8.33 \times \Delta T_{main}}{1{,}000{,}000} \times \left(\frac{1}{E_{t,baseline}} - \frac{1}{E_{t,ee}}\right) + \frac{UA_{baseline} \times \Delta T_{amb} \times 8{,}760}{E_{t,baseline} \times 1{,}000{,}000}\right]$$

GPD = 1,000, from application

$\Delta T_{main} = T_{set} - T_{main} = 145 - 54.3 = 90.7$

T_{set} from application

T_{main} from Cold Water Inlet Temperature table based on location from application

$E_{t,baseline} = 0.8$, from Summary of Variables and Data Sources table based on type from application

$E_{t,ee} = 0.95$, from application

$UA_{baseline} = SL_{baseline} / 70 = 1{,}537 / 70 = 21.96$

$UA_{baseline}$ equation from Overall Heat Loss Coefficient section

$SL_{baseline} = Q_{baseline} /800 + 100 \times (v_{baseline})^{1/2} = 250{,}000/800 + 100 \times (150)^{1/2} = 1{,}537$

$SL_{baseline}$ equation from Baseline Standby Losses section based on equipment type from application

$Q_{baseline}$ from application

$v_{baseline}$ from application

$\Delta T_{amb} = T_{set} - T_{amb} = 145 - 70 = 75$

T_{amb} from Summary of Variables and Data Sources table

$$\Delta MMBtu = 1 \times \left[\frac{1{,}000 \times 365 \times 8.33 \times 90.7}{1{,}000{,}000} \times \left(\frac{1}{0.8} - \frac{1}{0.95}\right) + \frac{21.96 \times 75 \times 8{,}760}{0.8 \times 1{,}000{,}000}\right] = 72.5\ MMBtu$$

Ancillary Fossil Fuel Savings Impacts

Reduction in standby heat losses will have a negligible impact on space heating when the water heater is located in a conditioned space. Consideration of these effects is not included in this methodology.

Ancillary Electric Savings Impacts

Reduction in standby heat losses will have a negligible impact on space heating and cooling when the water heater is located in a conditioned space. Consideration of these effects is not included in this methodology.

References

1. 10 CFR 431.102 Definitions concerning commercial water heaters, hot water supply boilers, unfired hot water storage tanks, and commercial heat pump water heaters. Available from: https://www.govinfo.gov/content/pkg/CFR-2013-title10-vol3/pdf/CFR-2013-title10-vol3-part431.pdf

2. 10 CFR Appendix E to Subpart B of Part 430—Uniform Test Method for Measuring the Energy Consumption of Water Heaters, Section 2. Test Conditions, 2.5 Set Point Temperature.
   Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=2c2e82b00e0ba6b6305499302e81fa2a&mc=true&node=ap10.3.430_127.e&rgn=div9
3. OSHA Legionnaire's Disease eTool: Section II: C-1. Domestic Hot-Water Systems
   Available from:
   https://www.osha.gov/SLTC/legionnairesdisease/control_prevention.html
4. 10 CFR 431.110 Energy conservation standards and their effective dates
   Available from: https://www.govinfo.gov/content/pkg/CFR-2013-title10-vol3/pdf/CFR-2013-title10-vol3-part431.pdf
5. U.S. Energy Information Administration, 2012 Commercial Buildings Energy Consumption Survey: Water Consumption in Large Buildings, Table WD1. Daily water consumption in large commercial buildings, 2012
   Available from: https://www.eia.gov/consumption/commercial/reports/2012/water/
6. National Renewable Energy Laboratory, Saving Energy in Commercial Buildings: Domestic Hot Water Assessment Guidelines, Table 1. Hot Water Use By Building Type, June 2011
   Available from: https://www.nrel.gov/docs/fy11osti/50118.pdf
7. Water Research Foundation: "Residential End Uses of Water, Version 2: Executive Report", April 2016
   Available from: : https://www.circleofblue.org/wp-content/uploads/2016/04/WRF_REU2016.pdf
8. Improving Commercial Kitchen Hot Water System Performance, Design Guide – Energy Efficient Heating, Delivery and Use, Table 1. Typical hot water system cost for restaurants, March 2010
   Available from: https://caenergywise.com/design-guides/Water_Heating_Design_Guide.pdf
9. Burch, Jay and Craig Christensen; "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory.
   Available from:
   https://www.energystar.gov/ia/partners/prod_development/new_specs/downloads/water_heaters/AlgorithmForMainsWaterTemperature.pdf
10. NOAA National Centers for Environmental Information – NCEI 1981-2010 Climate Normals
    Available from: https://www.ncdc.noaa.gov/cdo-web/datatools/normals
11. 10 CFR 429, 430, and 431 Docket No. EERE-2015-BT-TP-0007, Energy Conservation Program for Consumer Products and Certain Commercial and Industrial Equipment: Test Procedures for Consumer and Commercial Water Heaters
    Available from:
    https://energy.gov/sites/prod/files/2016/08/f33/Water%20Heaters%20Test%20Procedure%20SNOPR.pdf

12. ENERGY STAR® Commercial Water Heater Key Product Criteria
Available from:
https://www.energystar.gov/products/water_heaters/commercial_water_heaters/key_product_criteria

Record of Revision

Record of Revision Number	Issue Date
6-18-20	6/26/2018
3-21-13	4/9/2021

Return to Table of Contents

STORAGE TANK WATER HEATER

Measure Description

This measure covers the installation of fossil fuel and electric storage tank water heaters designed to heat and store water at a thermostatically controlled temperature. This measure applies to potable hot water delivery only; it is not applicable to hot water heaters used for process loads or space heating.

Storage type units include commercial fossil fuel storage water heaters with a nominal input of greater than 75,000 BTU/h and less than 4,000 BTU/h per gallon of stored water and commercial electric storage water heaters with a nominal input of greater than 12 kilowatts and less than 4,000 BTU/h per gallon of stored water.[892]

This measure applies to replacement of existing storage type water heaters using the same heating fuel (fossil fuel or electric) as the efficient case. For new construction, this measure assumes baseline to be a standard efficiency water heater using the same heating fuel (fossil fuel or electric) as the efficient equipment.

This measure applies to commercial grade water heaters only. For residential-duty water heaters installed in commercial settings, the Residential Storage Tank and Instantaneous Domestic Water Heater methodology detailed in this document shall be employed utilizing typical GPD values as defined in the "Gallons per Day (GPD)" section below.

Method for Calculating Annual Energy and Peak Coincidence Demand Savings

Annual Electric Energy Savings (Electric Equipment Only)

$$\Delta kWh = units \times \frac{GPD \times 365 \times 8.33 \times \Delta T_{main}}{3{,}412} \times \left(\frac{1}{E_{t,baseline}} - \frac{1}{E_{t,ee}}\right)$$

Summer Peak Coincident Demand Savings (Electric Equipment Only)

$$\Delta kW = units \times \frac{(UA_{baseline} - UA_{ee}) \times \Delta T_{amb}}{3{,}412} \times CF$$

Annual Fossil Fuel Energy Savings (Fossil Fuel Equipment Only)

$$\Delta MMBtu = units \times \frac{GPD \times 365 \times 8.33 \times \Delta T_{main}}{1{,}000{,}000} \times \left(\frac{1}{E_{t,baseline}} - \frac{1}{E_{t,ee}}\right)$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings

[892] 10 CFR 431.102

units = Number of measures installed under the program
GPD = Gallons per day
ΔT_{main} = Average temperature difference between water heater set point temperature and the supply water temperature in water main (°F)
ΔT_{amb} = Average temperature difference between water heater set point temperature and the surrounding ambient air temperature (°F)
$_{baseline}$ = Characteristic of baseline condition
$_{ee}$ = Characteristic of energy efficient condition
E_t = Thermal efficiency
UA = Overall heat loss coefficient (BTU/h-°F)
CF = Coincidence factor
365 = Days in one year
8.33 = Energy required (BTU) to heat one gallon of water by one degree Fahrenheit
3,412 = Conversion factor, one kWh equals 3,412 BTU
1,000,000 = Conversion factor, one MMBtu equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
GPD		From application, or lookup/calculate based on building type, square footage and occupancy from GPD table below.
ΔT_{main}	T_{set} - T_{main}	Average temperature difference between water heater set point temperature and the supply water temperature in water main (°F)
ΔT_{amb}	T_{set} - T_{amb}	Average temperature difference between water heater set point temperature and the surrounding ambient air temperature (°F)
T_{set}		Water heater set point temperature (°F), per application or use 140°F as a default.[893]
T_{main}		Supply water temperature in water main (°F). Lookup in Cold Water Inlet Temperature table below based on nearest city.
T_{amb}	70	Surrounding ambient air temperature (°F).[894]
$E_{t,baseline}$	Electric: 0.98 Fossil Fuel: 0.80	Thermal efficiency of the baseline condition[895,896]
$E_{t,ee}$		Thermal efficiency for energy efficient measure, from application

[893] Per OSHA recommendations for prevention of Legionella bacterial growth (https://www.osha.gov/SLTC/legionnairesdisease/control_prevention.html)
[894] Water heaters are generally located in conditioned or partially conditioned spaces with a typical average temperature of 65°F to 70°F to avoid freezing. A value of 70°F is used for the purposes of estimating tank/ambient air temperature differential, which aligns with standby loss specification testing standards.
[895] Fuel: 10 CFR 431.110 (a)
[896] Electric: Per 10 CFR 430 Subpart B Appendix E – Uniform Test Method for Measuring the Energy Consumption of Water Heaters: *6.3.2 Recovery Efficiency*

Variable	Value	Notes
$UA_{baseline}$		Overall heat loss coefficient of the baseline condition (BTU/h-°F). Calculate based on baseline standby loss per the Overall Heat Loss Coefficient section below.
UA_{ee}		Overall heat loss coefficient of the energy efficient measure (BTU/h-°F). Calculate based on energy efficient standby loss per the Overall Heat Loss Coefficient section below.
CF	0.8	

Gallons per Day (GPD)

The average daily hot water usage, expressed in gallons per day, for several commercial facility types is tabulated below. Daily hot water usage can be calculated based on the GPD and site-specific metric in the Rate column, or default values can be referenced directly from the GPD column.

Building Type	GPD	Rate	Notes/Assumptions	Source
Assembly	239	7.02 GPD per 1,000 SF	Assumes 10% hot water, 34,000 SF	EIA[897]: Public Assembly
Auto Repair	25	4.89 GPD per 1,000 SF	Assumes 10% hot water, 5,150 SF	EIA: Other
Big Box Retail	448	3.43 GPD per 1,000 SF	Assumes 10% hot water, 130,500 SF	EIA: Mercantile
Community College	1,520	1.9 GPD per person	Assumes 800 students	NREL[898]: School with Showers
Dormitory	8,600	17.2 GPD per resident	Assumes 500 residents	Water Research Foundation[899]
Elementary School	250	0.5 GPD per student	Assumes 500 students	NREL: School
Fast Food Restaurant	500	500 GPD per restaurant		FSTC[900]: Quick Service
Full-Service Restaurant	2,500	2,500 GPD per restaurant		FSTC: Full Service
Grocery	172	3.43 GPD per 1,000 SF	Assumes 10% hot water, 50,000 SF	EIA: Mercantile
High School	1,520	1.9 GPD per person	Assumes 800 students	NREL: School with Showers
Hospital	16,938	54.42 GPD per 1,000 SF	Assumes 40% hot water, 250,000 SF	EIA: Health Care, Inpatient
Hotel	9,104	45.52 GPD per 1,000 SF	Assumes 40% hot water, 200,000 SF	EIA: Lodging
Large Office	550	1.1 GPD per person	Assumes 500 people	NREL: Office
Large Retail	446	3.43 GPD per 1,000 SF	Assumes 10% hot water, 130,000 SF	EIA: Mercantile
Light Industrial	489	4.89 GPD per 1,000 SF	Assumes 10% hot water, 100,000 SF	EIA: Other
Motel	1,366	45.52 GPD per 1,000 SF	Assumes 40% hot water, 30,000 SF	EIA: Lodging
Multifamily High-Rise	4,600	46 GPD per unit	Assumes 100 units	Water Research Foundation
Multifamily Low-Rise	552	46 GPD per unit	Assumes 12 units	Water Research Foundation
Refrigerated Warehouse	86	0.93 GPD per 1,000 SF	Assumes 10% hot water, 92,000 SF	EIA: Warehouse and Storage
Religious	77	7.02 GPD per 1,000 SF	Assumes 10% hot water, 11,000 SF	EIA: Public Assembly
Small Office	110	1.1 GPD per person	Assumes 100 people	NREL: Office
Small Retail	27	3.43 GPD per 1,000 SF	Assumes 10% hot water, 8,000 SF	EIA: Mercantile
University	1,000	0.5 GPD per student	Assumes 2,000 students	NREL: School
Warehouse	465	0.93 GPD per 1,000 SF	Assumes 10% hot water, 500,000 SF	EIA: Warehouse and Storage
Other	Calculate	4.89 GPD per 1,000 SF	Assumes 10% hot water	EIA: Other

[897] U.S. Energy Information Administration, 2012 Commercial Buildings Energy Consumption Survey: Water Consumption in Large Buildings, Table WD1. Daily water consumption in large commercial buildings, 2012
[898] National Renewable Energy Laboratory, Saving Energy in Commercial Buildings: Domestic Hot Water Assessment Guidelines, Table 1. Hot Water Use By Building Type, June 2011
[899] Water Research Foundation: Residential End Uses of Water, Version 2, April 2016
[900] Food Service Technology Center, Design Guide – Energy Efficient Heating, Delivery and Use, Table 1. Typical hot water system cost for restaurants, March 2010

Cold Water Inlet Temperature (T_{main})

Supply water main temperatures vary according to climate, and are approximately equal to the annual average outdoor temperature plus 6°F.[901] Supply main temperatures based on the annual outdoor temperature are shown below.

City	Annual average outdoor temperature[902] (°F)	T_{main} (°F)
Albany	48.3	54.3
Binghamton	46.3	52.3
Buffalo	48.3	54.3
Massena	43.5	49.5
NYC	55.4	61.4
Poughkeepsie	49.8	55.8
Syracuse	48.3	54.3

Overall Heat Loss Coefficient ($UA_{baseline}$ and UA_{ee})

Tank overall heat loss coefficient is calculated from the equipment standby loss specification. For UA_{ee}, the manufacturer specified standby loss shall be applied directly to the UA formula below. To calculate $UA_{baseline}$, use the appropriate intermediate standby loss equation from the Baseline Standby Losses section below.

$$UA = \frac{SL}{70}$$

where:

SL = Standby heat loss (BTU/h), from application for the energy efficient measure (SL_{ee}). For the baseline condition ($SL_{baseline}$), use the appropriate intermediate standby loss equation from the Baseline Standby Losses section below.

70 = Temperature difference associated with standby loss specification (°F)[903]

Baseline Standby Losses ($SL_{baseline}$)

Standby losses ($SL_{baseline}$) for commercial electric storage type water heaters:[904]

$$SL_{baseline} = \frac{\left(0.30 + \frac{27}{v_{baseline}}\right)}{100} \times 70 \times v_{baseline} \times 8.33$$

where:

$v_{baseline}$ = Baseline tank volume (gal), equal to the storage capacity of the efficient equipment

[901] Burch, Jay and Christensen, Craig, "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory

[902] Average annual outdoor temperatures taken from NCEI 1981-2010 climate normals

[903] 10 CFR 429, 430, and 431 Docket No. EERE-2015-BT-TP-0007, Energy Conservation Program for Consumer Products and Certain Commercial and Industrial Equipment: Test Procedures for Consumer and Commercial Water Heaters

[904] Ibid.

70 = Temperature difference associated with standby loss specification (°F)[905]
8.33 = Energy required (BTU) to heat one gallon of water by one degree Fahrenheit

Standby losses ($SL_{baseline}$) for commercial gas storage type water heaters:[906]

$$SL_{baseline} = \frac{Q_{baseline}}{800} + 110\sqrt{v_{baseline}}$$

where:
$v_{baseline}$ = Baseline tank volume (gal), equal to the storage capacity of the efficient equipment
$Q_{baseline}$ = Baseline input capacity (BTU/h), equal to the input capacity of the efficient equipment

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.8[907]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition for replacement measures is a standard efficiency fossil fuel or electric storage type water heater (based on proposed conditions) with tank volume and input capacity equivalent to the efficient case, UA value calculated as prescribed above and a thermal efficiency of 0.80 (fossil fuel) or 0.98 (electric).

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a fossil fuel or electric storage type water heater as defined in the Measure Description section above, which exceeds the efficiency of the baseline equipment.

Operating Hours

Water heater run hours are not utilized in the estimation of energy or demand savings, but water heater is assumed to be available for operation 8,760 hours per year. Additionally, it is assumed standby losses are incurred 8,760 hours per year.

Example Calculation *(Not to be used as default)*

A gas storage tank water heater is installed in a commercial facility located near Albany. The facility has a hot water demand of 500 gallons per day. The storage tank water heater has a storage capacity of 100 gallons, an input capacity of 200 kBTU/h and an efficiency rating of 97%. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are not applicable. Annual Fossil Fuel Energy Savings are calculated as below.

[905] 10 CFR 429, 430, and 431 Docket No. EERE-2015-BT-TP-0007, Energy Conservation Program for Consumer Products and Certain Commercial and Industrial Equipment: Test Procedures for Consumer and Commercial Water Heaters
[906] 10 CFR 429, 430, and 431 Docket No. EERE-2015-BT-TP-0007, Energy Conservation Program for Consumer Products and Certain Commercial and Industrial Equipment: Test Procedures for Consumer and Commercial Water Heaters
[907] *No source specified – update pending availability and review of applicable references.*

$$\Delta MMBtu = units \times \frac{GPD \times 365 \times 8.33 \times \Delta T_{main}}{1{,}000{,}000} \times \left(\frac{1}{E_{t,baseline}} - \frac{1}{E_{t,ee}}\right)$$

units = 1
GPD = 500, from application
$\Delta T_{main} = T_{set} - T_{main} = 145 - 54.3 = 90.7$
T_{set} from application
T_{main} from Cold Water Inlet Temperature table based on location from application
$E_{t,baseline}$ = 0.8, from Summary of Variables and Data Sources table based on type from application
$E_{t,ee}$ = 0.97, from application

$$\Delta MMBtu = 1 \times \frac{500 \times 365 \times 8.33 \times 90.7}{1{,}000{,}000} \times \left(\frac{1}{0.8} - \frac{1}{0.97}\right) = 30.2\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Reduction in standby heat losses will have a negligible impact on space heating when the water heater is located in conditioned space. Consideration of these effects is not included in this methodology.

Ancillary Electric Savings Impacts

High-efficiency water heaters may incorporate a draft fan, which increases electricity consumption. Additionally, reduction in standby heat losses will have a negligible impact on space heating and cooling when the water heater is located in conditioned space. Consideration of these effects is not included in this methodology.

References

1. 10 CFR 431.102 Definitions concerning commercial water heaters, hot water supply boilers, unfired hot water storage tanks, and commercial heat pump water heaters. Available from: https://www.govinfo.gov/content/pkg/CFR-2013-title10-vol3/pdf/CFR-2013-title10-vol3-part431.pdf
2. 10 CFR Appendix E to Subpart B of Part 430—Uniform Test Method for Measuring the Energy Consumption of Water Heaters, Section 2. Test Conditions, 2.5 Set Point Temperature.
   Available from: https://www.govinfo.gov/content/pkg/CFR-2013-title10-vol3/pdf/CFR-2013-title10-vol3-part430.pdf

3. OSHA Legionnaire's Disease eTool: Section II: C-1. Domestic Hot-Water Systems
Available from:
https://www.osha.gov/SLTC/legionnairesdisease/control_prevention.html
4. 10 CFR 431.110 Energy conservation standards and their effective dates
Available from: https://www.govinfo.gov/content/pkg/CFR-2013-title10-vol3/pdf/CFR-2013-title10-vol3-part431.pdf
5. U.S. Energy Information Administration, 2012 Commercial Buildings Energy Consumption Survey: Water Consumption in Large Buildings, Table WD1. Daily water consumption in large commercial buildings, 2012
Available from: https://www.eia.gov/consumption/commercial/reports/2012/water/
6. National Renewable Energy Laboratory, Saving Energy in Commercial Buildings: Domestic Hot Water Assessment Guidelines, Table 1. Hot Water Use By Building Type, June 2011
Available from: https://www.nrel.gov/docs/fy11osti/50118.pdf
7. Water Research Foundation: "Residential End Uses of Water, Version 2: Executive Report", April 2016
Available from: : https://www.circleofblue.org/wp-content/uploads/2016/04/WRF_REU2016.pdf
8. Improving Commercial Kitchen Hot Water System Perofmrance, Design Guide – Energy Efficient Heating, Delivery and Use, Table 1. Typical hot water system cost for restaurants, March 2010
Available from: https://caenergywise.com/design-guides/Water_Heating_Design_Guide.pdf
9. Burch, Jay and Craig Christensen; "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory.
Available from:
https://www.energystar.gov/ia/partners/prod_development/new_specs/downloads/water_heaters/AlgorithmForMainsWaterTemperature.pdf
10. NOAA National Centers for Environmental Information – NCEI 1981-2010 Climate Normals
Available from: https://www.ncdc.noaa.gov/cdo-web/datatools/normals
11. 10 CFR 429, 430, and 431 Docket No. EERE-2015-BT-TP-0007, Energy Conservation Program for Consumer Products and Certain Commercial and Industrial Equipment: Test Procedures for Consumer and Commercial Water Heaters
Available from:
https://energy.gov/sites/prod/files/2016/08/f33/Water%20Heaters%20Test%20Procedure%20SNOPR.pdf

Record of Revision

Record of Revision Number	Issue Date
1	10/15/2010
12-17-10	12/31/2017

Return to Table of Contents

DOMESTIC HOT WATER (DHW) – CONTROL

CENTRAL DOMESTIC HOT WATER (DHW) CONTROL

Measure Description

This measure is applicable to the installation of temperature modulation and demand controls on central domestic hot water (DHW) systems with recirculation. Temperature modulation controls reduce circulator pump energy and recirculation heat losses by modulating DHW system supply temperatures according to a set schedule, activating recirculation when supply water drops below the set point. Demand controls limit energy consumption by activating recirculation loops based on demand. DHW demand controls must monitor calls for hot water and return water temperature, activating recirculation when demand is detected or return water has dropped below a prescribed temperature. Temperature modulation and demand controls achieve savings without significant interruptions to instantaneous hot water availability.

This measure is not applicable to new construction or gut rehab installations.[908] This measure is not applicable in facilities where twenty-four-hour recirculation and delivered hot water temperature is required by code. DHW demand control systems shall be installed by a qualified contractor complying with all relevant construction and safety codes and standards.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = \Delta kWh_{pump} + \Delta kWh_{HW}$$

$$\Delta kWh_{pump} = \frac{hp \times 0.746}{Eff_{pump}} \times LF \times hrs_{recirc,baseline} \times ESF_{pump}$$

$$\Delta kWh_{HW} = \frac{GPD \times 365 \times 8.33 \times \Delta T_{main}}{3{,}412} \times \frac{F_{DHW,elec}}{E_{t,elec}} \times \frac{hrs_{recirc,baseline}}{8{,}760} \times ESF_{HW}$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \frac{\Delta kWh}{hrs_{recirc,baseline}} \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = \frac{GPD \times 365 \times 8.33 \times \Delta T_{main}}{1{,}000{,}000} \times \frac{F_{DHW,fuel}}{E_{t,fuel}} \times \frac{hrs_{recirc,baseline}}{8{,}760} \times ESF_{HW}$$

[908] ECCCNYS 2020 C404.7 and NYSPC 607.2

where:

ΔkWh	= Annual electricity energy savings
ΔkW	= Peak coincident demand electric savings
$\Delta MMBtu$	= Annual fossil fuel energy savings
hp	= Total recirculation system pump horsepower
Eff	= Efficiency
$_{pump}$	= Property of circulator pump
LF	= Load Factor
$hrs_{recirc,baseline}$	= Annual hours of operation of recirculation system in the baseline condition
ESF	= Energy savings factor
GPD	= Gallons per day
ΔT_{main}	= Average temperature difference between water heater set point temperature and the supply water temperature in water main (ºF)
E_t	= Thermal efficiency
$_{elec}$	= Property of electrical central DHW system
$_{fuel}$	= Property of fossil fuel central DHW system
$_{HW}$	= Hot water
$F_{DHW,elec}$	= Electric water heating factor
$F_{DHW,fuel}$	= Fossil fuel water heating factor
CF	= Coincidence Factor
0.746	= Conversion factor (kW/hp), 746 watts equals one electric horsepower
8.33	= Energy required (BTU) to heat one gallon of water by one degree Fahrenheit
8,760	= Hours in one year
365	= Days in one year
3,412	= Conversion factor, one kWh equals 3,412 BTU
1,000,000	= Conversion factor, one MMBtu equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
hp		From application.
Eff_{pump}	PSC Pump: 0.60 ECM Pump: 0.80	PSC pump efficiency[909] ECM pump efficiency[910] If unknown, use a value of 0.80.
LF	0.9	Assumed value to reflect that motors do not typically run at 100% of rated power.
$hrs_{recirc,baseline}$		From application.
GPD		From application, or lookup/calculate based on building type, square footage and occupancy from GPD table below.

[909] US DOE, Energy Savings Potential and Opportunities for High-Efficiency Electric Motors in Residential and Commercial Equipment, Table 2.1 Summary of Single-Phase AC Induction Motor Characteristics - Efficiency of the baseline condition is taken as the average full load efficiency rating range for a PSC motor.
[910] ACHR News, Comparing Motor Technologies, December 2009

Variable	Value	Notes
ΔT_{main}	$T_{set} - T_{main}$	Average temperature difference between water heater set point temperature and the supply water temperature in water main (ºF)
T_{set}		Water heater set point temperature (ºF), per application of use 140ºF as default.[911]
T_{main}		Supply water temperature in water main (ºF). Lookup in Cold Water Inlet Temperature table below based on nearest city.
$E_{t,elec}$	0.98	Thermal efficiency of electric water heater.[912]
$E_{t,fuel}$	0.80	Thermal efficiency of fossil fuel water heater.[913]
ESF_{pump}	0.87	Minnesota Department of Commerce[914]
ESF_{HW}		Lookup based on control type in the Energy Savings Factor section below.
$F_{DHW,elec}$		Use a value of 1.0 if the water was previously heated with electricity or if it is a new construction home with no gas access. Otherwise, use 0.0.
		Use a value of 1.0 if the water was previously heated directly with fossil fuels or if it is a new construction home with gas access. Otherwise, use 0.0.
CF	0.8	

Gallons per Day (GPD)

The average daily hot water usage, expressed in gallons per day, for several commercial facility types is tabulated below. Daily hot water usage can be calculated based on the GPD and site-specific metric in the Rate column, or default values can be referenced directly from the GPD column.

Building Type	GPD	Rate	Notes/Assumptions	Source
Assembly	239	7.02 GPD per 1,000 SF	Assumes 10% hot water, 34,000 SF	EIA[915]: Public Assembly
Auto Repair	25	4.89 GPD per 1,000 SF	Assumes 10% hot water, 5,150 SF	EIA: Other
Big Box Retail	448	3.43 GPD per 1,000 SF	Assumes 10% hot water, 130,500 SF	EIA: Mercantile
Community College	1,520	1.9 GPD per person	Assumes 800 students	NREL[916]: School with Showers
Dormitory	8,600	17.2 GPD per resident	Assumes 500 residents	Water Research Foundation[917]
Elementary School	250	0.5 GPD per student	Assumes 500 students	NREL: School
Fast Food Restaurant	500	500 GPD per restaurant		FSTC[918]: Quick Service

[911] 10 CFR Appendix E to Subpart B of Part 430—Uniform Test Method for Measuring the Energy Consumption of Water Heaters, Section 2. Test Conditions, 2.5 Set Point Temperature.
[912] Per 10 CFR 430 Subpart B Appendix E – Uniform Test Method for Measuring the Energy Consumption of Water Heaters: *6.3.2 Recovery Efficiency*
[913] Per 10 CFR 431.110(a)
[914] Center for Energy and Environment, Evaluation of New DHW System Controls in Hospitality and Commercial Buildings, Prepared for Minnesota Department of Commerce, Division of Energy Resources, June 30, 2018, pg 12
[915] U.S. Energy Information Administration, 2012 Commercial Buildings Energy Consumption Survey: Water Consumption in Large Buildings, Table WD1. Daily water consumption in large commercial buildings, 2012
[916] National Renewable Energy Laboratory, Saving Energy in Commercial Buildings: Domestic Hot Water Assessment Guidelines, Table 1. Hot Water Use By Building Type, June 2011
[917] Water Research Foundation: Residential End Uses of Water, Version 2, April 2016
[918] Food Service Technology Center, Design Guide – Energy Efficient Heating, Delivery and Use, Table 1. Typical hot water system cost for restaurants, March 2010

Building Type	GPD	Rate	Notes/Assumptions	Source
Full-Service Restaurant	2,500	2,500 GPD per restaurant		FSTC: Full Service
Grocery	172	3.43 GPD per 1,000 SF	Assumes 10% hot water, 50,000 SF	EIA: Mercantile
High School	1,520	1.9 GPD per person	Assumes 800 students	NREL: School with Showers
Hospital	16,938	54.42 GPD per 1,000 SF	Assumes 40% hot water, 250,000 SF	EIA: Health Care, Inpatient
Hotel	9,104	45.52 GPD per 1,000 SF	Assumes 40% hot water, 200,000 SF	EIA: Lodging
Large Office	550	1.1 GPD per person	Assumes 500 people	NREL: Office
Large Retail	446	3.43 GPD per 1,000 SF	Assumes 10% hot water, 130,000 SF	EIA: Mercantile
Light Industrial	489	4.89 GPD per 1,000 SF	Assumes 10% hot water, 100,000 SF	EIA: Other
Motel	1,366	45.52 GPD per 1,000 SF	Assumes 40% hot water, 30,000 SF	EIA: Lodging
Multifamily High-Rise	4,600	46 GPD per unit	Assumes 100 units	Water Research Foundation
Multifamily Low-Rise	552	46 GPD per unit	Assumes 12 units	Water Research Foundation
Refrigerated Warehouse	86	0.93 GPD per 1,000 SF	Assumes 10% hot water, 92,000 SF	EIA: Warehouse and Storage
Religious	77	7.02 GPD per 1,000 SF	Assumes 10% hot water, 11,000 SF	EIA: Public Assembly
Small Office	110	1.1 GPD per person	Assumes 100 people	NREL: Office
Small Retail	27	3.43 GPD per 1,000 SF	Assumes 10% hot water, 8,000 SF	EIA: Mercantile
University	1,000	0.5 GPD per student	Assumes 2,000 students	NREL: School
Warehouse	465	0.93 GPD per 1,000 SF	Assumes 10% hot water, 500,000 SF	EIA: Warehouse and Storage
Other	Calculate	4.89 GPD per 1,000 SF	Assumes 10% hot water	EIA: Other

Cold Water Inlet Temperature (T_{main})

Supply water main temperatures vary according to climate, and are approximately equal to the annual average outdoor temperature plus 6°F.[919] Supply main temperatures based on the annual outdoor temperature are shown below.

City	Annual average outdoor temperature[920] (°F)	T_{main} (°F)
Albany	48.3	54.3
Binghamton	46.3	52.3
Buffalo	48.3	54.3
Massena	43.5	49.5
NYC	55.4	61.4
Poughkeepsie	49.8	55.8
Syracuse	48.3	54.3

Energy Savings Factor

The hot water energy savings factor (ESF_{HW}) is dependent on the installed control type.

Control Type	ESF_{HW}	Notes
Demand Control	0.07	NREL[921]
Temperature Modulation	0.02	NREL[922]
Demand Control and Temperature Modulation	0.15	NREL[923]

[919] Burch, Jay and Christensen, Craig, "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory

[920] Average annual outdoor temperatures taken from NCEI 1981-2010 climate normals

[921] NREL, Control Strategies to Reduce the Energy Consumption of Central Domestic Hot Water Systems, June 2016

[922] Ibid

[923] Ibid

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.8. [924]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition for this measure is a central DHW recirculation system running in continuous operation.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a central DHW recirculation system with a control system that regulates circulator pump operation based on demand, temperature or both. Recirculation system controls must be installed by a qualified contractor complying with all relevant construction and safety codes and standards.

Operating Hours

Baseline recirculation hours drive savings and shall come from application.

Example Calculation *(Not to be used as default)*

Temperature modulation and demand controls are installed on a gas fired, central domestic hot water system with recirculation in a commercial facility located near Albany. The recirculation pump is run by a 1/4 horsepower EC motor and is in continuous operation year round. The facility has a demand of 750 gallons of water per day and a hot water set point temperature of 145ºF. Annual Electric Energy Savings, Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta kWh = \Delta kWh_{pump} + \Delta kWh_{HW}$$

$$\Delta kWh_{pump} = \frac{hp \times 0.746}{Eff_{pump}} \times LF \times hrs_{recirc,baseline} \times ESF_{pump}$$

$$\Delta kWh_{HW} = \frac{GPD \times 365 \times 8.33 \times \Delta T_{main}}{3{,}412} \times \frac{1}{E_{t,elec}} \times \frac{hrs_{recirc,baseline}}{8{,}760} \times ESF_{HW}$$

$$\Delta kW = \frac{\Delta kWh}{hrs_{recirc,baseline}} \times CF$$

$$\Delta MMBtu = \frac{GPD \times 365 \times 8.33 \times \Delta T_{main}}{1{,}000{,}000} \times \frac{1}{E_{t,fuel}} \times \frac{hrs_{recirc,baseline}}{8{,}760} \times ESF_{HW}$$

hp = 0.25, from application

[924] *No source specified – update pending availability and review of applicable references.*

Eff_{pump} = 0.8, from Summary of Variables and Data Sources table based on pump type from application
LF = 0.9, from Summary of Variables and Data Sources table
$hrs_{recirc,baseline}$ = 8,760, from application
ESF_{pump} = 0.87, from Summary of Variables and Data Sources table
GPD = 750, from application
$\Delta T_{main} = T_{set} - T_{main} = 145 - 54.3 = 90.7$
T_{set} from application
T_{main} from Cold Water Inlet Temperature table based on location from application
$E_{t,fuel}$ = 0.80, from Summary of Variables and Data Sources table based on equipment from application
ESF_{HW} = 0.15, based on Energy Savings Factor table based on application
CF = 0.8

$$\Delta kWh_{pump} = \frac{0.25 \times 0.746}{0.8} \times 0.9 \times 8{,}760 \times 0.87 = 1{,}599\ kWh$$

$$\Delta kWh = \Delta kWh_{pump} + 0 = 1{,}599 + 0 = 1{,}599\ kWh$$

$$\Delta kW = \frac{1{,}599}{8{,}760} \times 0.8 = 0.146\ kW$$

$$\Delta MMBtu = \frac{750 \times 365 \times 8.33 \times 90.7}{1{,}000{,}000} \times \frac{1}{0.8} \times \frac{8{,}760}{8{,}760} \times 0.15 = 38.8\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. ECCCNYS 2020, C404.7 Demand recirculation controls
   Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-ce-commercial-energy-efficiency

2. NYSPC 2020, 607.2.1.2 Demand recirculation controls for distribution system
   Available from: https://codes.iccsafe.org/content/NYSPC2020P1/chapter-6-water-supply-and-distribution
3. Energy Savings Potential and Opportunities for High-Efficiency Electric Motors in Residential and Commercial Equipment, Building Technologies Office, US Department of Energy. December 2013. Available from: https://www.energy.gov/sites/prod/files/2014/02/f8/Motor%20Energy%20Savings%20Potential%20Report%202013-12-4.pdf
4. ACHR News, Comparing Motor Technologies, December 2009
   Available from: https://www.achrnews.com/articles/112674-comparing-motor-technologies
5. Center for Energy and Environment, Evaluation of New DHW System Controls in Hospitality and Commercial Buildings, Prepared for Minnesota Department of Commerce, Division of Energy Resources. June 30, 2018.
   Available from: http://mn.gov/commerce-stat/pdfs/card-dhw-system-controls.pdf
6. NREL, Control Strategies to Reduce the Energy Consumption of Central Domestic Hot Water Systems, Jordan Dentz et al. June 2016.
   Available from: https://www.nrel.gov/docs/fy16osti/64541.pdf
7. 10 CFR Appendix E to Subpart B of Part 430—Uniform Test Method for Measuring the Energy Consumption of Water Heaters, Section 2. Test Conditions, 2.5 Set Point Temperature.
   Available from: https://www.govinfo.gov/content/pkg/CFR-2013-title10-vol3/pdf/CFR-2013-title10-vol3-part430.pdf
8. U.S. Energy Information Administration, 2012 Commercial Buildings Energy Consumption Survey: Water Consumption in Large Buildings, Table WD1. Daily water consumption in large commercial buildings, 2012
   Available from: https://www.eia.gov/consumption/commercial/reports/2012/water/
9. National Renewable Energy Laboratory, Saving Energy in Commercial Buildings: Domestic Hot Water Assessment Guidelines, Table 1. Hot Water Use By Building Type, June 2011
   Available from: https://www.nrel.gov/docs/fy11osti/50118.pdf
10. 10 CFR 431.102 Definitions concerning commercial water heaters, hot water supply boilers, unfired hot water storage tanks, and commercial heat pump water heaters.
    Available from: https://www.govinfo.gov/content/pkg/CFR-2013-title10-vol3/pdf/CFR-2013-title10-vol3-part431.pdf
11. Water Research Foundation: "Residential End Uses of Water, Version 2: Executive Report", April 2016
    Available from: https://www.circleofblue.org/wp-content/uploads/2016/04/WRF_REU2016.pdf
12. Improving Commercial Kitchen Hot Water System Perofmrance, Design Guide – Energy Efficient Heating, Delivery and Use, Table 1. Typical hot water system cost for restaurants, March 2010
    Available from: https://caenergywise.com/design-guides/Water_Heating_Design_Guide.pdf

13. Burch, Jay and Craig Christensen; "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory.
Available from:
https://www.energystar.gov/ia/partners/prod_development/new_specs/downloads/water_heaters/AlgorithmForMainsWaterTemperature.pdf
14. NOAA National Centers for Environmental Information – NCEI 1981-2010 Climate Normals
Available from: https://www.ncdc.noaa.gov/cdo-web/datatools/normals

Record of Revision

Record of Revision Number	Issue Date
3-20-8	3/30/2020

Return to Table of Contents

DRAIN WATER HEAT RECOVERY (DWHR)

Measure Description

This measure covers the installation of drain water heat recovery systems on a main waste drain in commercial applications. Drain water heat recovery (DWHR) systems are drainage heat exchangers that recover heat from drain greywater to preheat cold water entering the water heater. By preheating cold water entering the storage tank, the water heater consumes less energy to heat the water to the desired temperature.

This measure is only applicable to buildings with storage type water heaters.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings (Electric Water Heating Only)

$$\Delta kWh = units \times \frac{GPD \times 365 \times 8.33 \times \Delta T_{main}}{3{,}412} \times \frac{1}{E_{t,elec}} \times ESF$$

Summer Peak Coincident Demand Savings (Electric Water Heating Only)

$$\Delta kW = units \times \frac{UA \times \Delta T_{amb}}{3{,}412} \times \frac{1}{E_{t,elec}} \times ESF \times CF$$

Annual Fossil Fuel Energy Savings (Fossil Fuel Water Heating Only)

$$\Delta MMBtu = units \times \frac{GPD \times 365 \times 8.33 \times \Delta T_{main}}{1{,}000{,}000} \times \frac{1}{E_{t,fuel}} \times ESF$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
GPD	= Gallons per day
ΔT_{main}	= Average temperature difference between water heater set point temperature and the supply water temperature in water main (°F)
ΔT_{amb}	= Average temperature difference between water heater set point temperature and the surrounding ambient air temperature (°F)
UA	= Overall heat loss coefficient (BTU/h-°F)
ESF	= Energy savings factor
E_t	= Water heater thermal efficiency
CF	= Coincidence factor
365	= Days in one year
8.33	= Energy required (BTU) to heat one gallon of water by one degree Fahrenheit
3,412	= Conversion factor, one kWh equals 3,412 BTU
1,000,000	= Conversion factor, one MMBtu equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
GPD		From application, or lookup/calculate based on building type, square footage and occupancy from GPD table below.
ΔT_{main}	T_{set} - T_{main}	Average temperature difference between water heater set point temperature and the supply water temperature in water main (°F)
ΔT_{amb}	= T_{set} - T_{amb}	Average temperature difference between water heater set point temperature and the surrounding ambient air temperature (°F).
T_{set}		From application.
T_{main}		Supply water temperature in water main (°F). Lookup in Cold Water Inlet Temperature table below based on nearest city.
T_{amb}	70	Surrounding ambient air temperature (°F).[925]
$E_{t,elec}$	0.98	From application. If unknown, use default thermal efficiency of typical electric storage type water heater provided.[926]
$E_{t,fuel}$	0.80	From application. If unknown, use default efficiency of typical gas storage type water heater.[927]
UA	7.85	Overall heat loss coefficient of the baseline condition (BTU/h-°F).[928]
ESF	0.25	Oak Ridge National Laboratory. [929]
CF	0.8	

Cold Water Inlet Temperature (T_{main})

Supply water main temperatures vary according to climate and are approximately equal to the annual average outdoor temperature plus 6°F.[930] Supply main temperatures based on the annual

[925] Water heaters are generally located in conditioned or partially conditioned spaces with a typical average temperature of 65°F to 70°F to avoid freezing. A value of 70°F is used for the purposes of estimating tank/ambient air temperature differential, which aligns with standby loss specification testing standards.
[926] Per 10 CFR 431 Subpart G, Appendix B 5.7.1
[927] Per 10 CFR 431.110 (a)
[928] Based on computation of heat loss coefficients via conversion equations found in 10 CFR 429, 430, and 431 Docket No. EERE-2015-BT-TP-0007, Energy Conservation Program for Consumer Products and Certain Commercial and Industrial Equipment: Test Procedures for Consumer and Commercial Water Heaters. Heat loss coefficient was equated for two minimally code compliant gas storage water heaters found to be the most typical in terms of storage and input capacity, representing storage type water heaters of between 20 and 55 gallon capacity (40 gallon, 40,000 BTU/h assumed) and between 55 and 120 gallon capacity (75 gallon, 76,000 BTU/h assumed). Results of heat loss coefficient evaluation at these two data points agreed to within 0.3%, so the lower of the two was selected to represent the $UA_{baseline}$ term.
[929] GFX Evaluation, Oak Ridge National Laboratory, August 2000, lower end of the energy savings range (25-30%). Savings are assumed to be comparable to residential application.
[930] Burch, Jay and Christensen, Craig, "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory

outdoor temperature are shown below.

City	Annual average outdoor temperature[931] (°F)	T_{main} (°F)
Albany	48.3	54.3
Binghamton	46.3	52.3
Buffalo	48.3	54.3
Massena	43.5	49.5
NYC	55.4	61.4
Poughkeepsie	49.8	55.8
Syracuse	48.3	54.3

Gallons per Day (GPD)

The average daily hot water usage, expressed in gallons per day, for several commercial facility types is tabulated below. Daily hot water usage can be calculated based on the GPD and site-specific metric in the Rate column, or default values can be referenced directly from the GPD column.

Building Type	GPD	Rate	Notes/Assumptions	Source
Assembly	239	7.02 GPD per 1,000 SF	Assumes 10% hot water, 34,000 SF	EIA[932]: Public Assembly
Auto Repair	25	4.89 GPD per 1,000 SF	Assumes 10% hot water, 5,150 SF	EIA: Other
Big Box Retail	448	3.43 GPD per 1,000 SF	Assumes 10% hot water, 130,500 SF	EIA: Mercantile
Community College	1,520	1.9 GPD per person	Assumes 800 students	NREL[933]: School with Showers
Dormitory	8,600	17.2 GPD per resident	Assumes 500 residents	Water Research Foundation[934]
Elementary School	250	0.5 GPD per student	Assumes 500 students	NREL: School
Fast Food Restaurant	500	500 GPD per restaurant		FSTC[935]: Quick Service
Full-Service Restaurant	2,500	2,500 GPD per restaurant		FSTC: Full Service
Grocery	172	3.43 GPD per 1,000 SF	Assumes 10% hot water, 50,000 SF	EIA: Mercantile
High School	1,520	1.9 GPD per person	Assumes 800 students	NREL: School with Showers
Hospital	16,938	54.42 GPD per 1,000 SF	Assumes 40% hot water, 250,000 SF	EIA: Health Care, Inpatient
Hotel	9,104	45.52 GPD per 1,000 SF	Assumes 40% hot water, 200,000 SF	EIA: Lodging
Large Office	550	1.1 GPD per person	Assumes 500 people	NREL: Office
Large Retail	446	3.43 GPD per 1,000 SF	Assumes 10% hot water, 130,000 SF	EIA: Mercantile
Light Industrial	489	4.89 GPD per 1,000 SF	Assumes 10% hot water, 100,000 SF	EIA: Other
Motel	1,366	45.52 GPD per 1,000 SF	Assumes 40% hot water, 30,000 SF	EIA: Lodging
Multifamily High-Rise	4,600	46 GPD per unit	Assumes 100 units	Water Research Foundation
Multifamily Low-Rise	552	46 GPD per unit	Assumes 12 units	Water Research Foundation
Refrigerated Warehouse	86	0.93 GPD per 1,000 SF	Assumes 10% hot water, 92,000 SF	EIA: Warehouse and Storage
Religious	77	7.02 GPD per 1,000 SF	Assumes 10% hot water, 11,000 SF	EIA: Public Assembly
Small Office	110	1.1 GPD per person	Assumes 100 people	NREL: Office
Small Retail	27	3.43 GPD per 1,000 SF	Assumes 10% hot water, 8,000 SF	EIA: Mercantile
University	1,000	0.5 GPD per student	Assumes 2,000 students	NREL: School
Warehouse	465	0.93 GPD per 1,000 SF	Assumes 10% hot water, 500,000 SF	EIA: Warehouse and Storage
Other	Calculate	4.89 GPD per 1,000 SF	Assumes 10% hot water	EIA: Other

[931] Average annual outdoor temperatures taken from NCEI 1981-2010 climate normals

[932] U.S. Energy Information Administration, 2012 Commercial Buildings Energy Consumption Survey: Water Consumption in Large Buildings, Table WD1. Daily water consumption in large commercial buildings, 2012

[933] National Renewable Energy Laboratory, Saving Energy in Commercial Buildings: Domestic Hot Water Assessment Guidelines, Table 1. Hot Water Use By Building Type, June 2011

[934] Water Research Foundation: Residential End Uses of Water, Version 2, April 2016

[935] Food Service Technology Center, Design Guide – Energy Efficient Heating, Delivery and Use, Table 1. Typical hot water system cost for restaurants, March 2010

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.8.[936]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a storage type water heater without a DWHR system in a commercial application.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a storage type water heater equipped with DWHR on the main waste drainage line in a commercial application. DWHR units shall comply with CSA B55.2 and shall be tested in accordance with CSA B55.1. Potable water-side pressure loss of DWHR units shall be less than 3 psi.[937]

Operating Hours

Water heater run hours are not utilized in the estimation of energy or demand savings, but water heater is assumed to be available for operation 8,760 hours per year. Additionally, it is assumed standby losses are incurred 8,760 hours per year.

Example Calculation *(Not to be used as default)*

A drainwater heat recovery system is installed in a small commercial facility located near Albany. The facility has an electric water heater with a demand of 300 gallons of water per day and a set point temperature of 140ºF. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

$$\Delta kWh = units \times \frac{GPD \times 365 \times 8.33 \times \Delta T_{main}}{3{,}412} \times \frac{1}{E_{t,elec}} \times ESF$$

$$\Delta kW = units \times \frac{UA \times \Delta T_{amb}}{3{,}412} \times \frac{1}{E_{t,elec}} \times ESF \times CF$$

units =1, from application
GPD = 300, from application
$\Delta T_{main} = T_{set} - T_{main} = 140 - 54.3 = 85.7$
T_{set} from application
T_{main} from Cold Water Inlet Temperature table based on location from application
$E_{t,elec} = 0.98$, from Summary of Variables and Data Sources table
ESF = 0.25, from Summary of Variables and Data Sources table
UA = 7.85, from Summary of Variables and Data Sources table
$\Delta T_{amb} = T_{set} - T_{amb} = 140 - 70 = 70$

[936] *No source specified – update pending availability and review of applicable references.*
[937] ECCCNYS 2020, Section R403.5.4 Drain Water Recovery Units

T_{amb} from Summary of Variables and Data Sources table
CF = 0.8, from Summary of Variables and Data Sources table

$$\Delta kWh = 1 \times \frac{300 \times 365 \times 8.33 \times 85.7}{3{,}412} \times \frac{1}{0.98} \times 0.25 = 5{,}844\ kWh$$

$$\Delta kW = 1 \times \frac{7.85 \times 70}{3{,}412} \times \frac{1}{0.98} \times 0.25 \times 0.8 = 0.0329\ kW$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. 10 CFR 430.2 Definitions.
   Available from: https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=78ea8c7c6bf5379d6e0fd2b41e335739&mc=true&n=pt10.3.430&r=PART&ty=HTML#se10.3.430_12
2. 10 CFR 430.32 Energy and water conservation standards and their compliance dates.
   Available from: http://www.ecfr.gov/cgi-bin/text-idx?SID=a9921a66f2b4f66a32ec851916b7b9d9&mc=true&node=se10.3.430_132&rgn=div8
3. 10 CFR 431.110 Energy conservation standards and their effective dates.
   Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=a69096e892b13c204bbe6da3a92f8111&mc=true&node=se10.3.431_1110&rgn=div8
4. GFX Evaluation, Oak Ridge National Laboratory, August 2000
   Available from: http://gfxtechnology.com/Duluth-Triplex.pdf
5. 10 CFR 429, 430, and 431 Docket No. EERE-2015-BT-TP-0007, Energy Conservation Program for Consumer Products and Certain Commercial and Industrial Equipment: Test Procedures for Consumer and Commercial Water Heaters
   Available from: https://energy.gov/sites/prod/files/2016/08/f33/Water%20Heaters%20Test%20Procedure%20SNOPR.pdf

6. AHRI Directory of Certified Product Performance
   Available from: https://www.ahridirectory.org/ahridirectory/pages/home.aspx
7. Burch, Jay and Craig Christensen; "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory.
   Available from:
   http://citeseerx.ist.psu.edu/viewdoc/download;jsessionid=05D73BA6EF5ECCF71969D083FB317991?doi=10.1.1.515.6885&rep=rep1&type=pdf
8. NOAA National Centers for Environmental Information – NCEI 1981-2010 Climate Normals
   Available from: https://www.ncdc.noaa.gov/cdo-web/datatools/normals
9. 10 CFR 429.17 Water heaters.
   Available from: : https://www.ecfr.gov/cgi-bin/text-idx?rgn=div5&node=10:3.0.1.4.17#se10.3.429_117
10. ECCCNYS 2020 Section R403.5.4 Drain Water Heat Recovery Units
    Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-re-residential-energy-efficiency
11. 10 CFR 431 Subpart G – Commercial Water Heaters, Hot Water Supply Boilers and Unfired Hot Water Storage Tanks, Appendix B - Uniform Test Method for Measuring the Standby Loss of Electric Storage Water Heaters and Storage-Type Instantaneous Water Heaters
    Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=e0518d0e0befdd3d0f69d20f62691096&mc=true&node=pt10.3.431&rgn=div5#ap10.3.431_1110.b

Record of Revision

Record of Revision Number	Issue Date
3-21-14	4/9/2021

Return to Table of Contents

LOW-FLOW - FAUCET AERATOR

Measure Description

This measure covers the installation of low-flow faucet aerators in commercial and industrial applications. A faucet aerator is a water saving device that attaches to a preinstalled faucet and reduces water flow while maintaining appropriate water pressure. Retrofitting existing code compliant aerators in locations where service water is supplied by electric or fossil fuel-fired hot water heaters with more energy efficient aerators reduces hot water consumption resulting in corresponding energy savings. This measure is not applicable to public lavatories.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times \frac{\left(GPM_{baseline} \times Flow_{r,baseline} - GPM_{ee} \times Flow_{r,ee}\right) \times \Delta T_{main} \times 8.33}{3{,}412} \times 60 \times hrs \times days \times \frac{1}{E_{t,elec}}$$

Summer Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = units \times \frac{\left(GPM_{baseline} \times Flow_{r,baseline} - GPM_{ee} \times Flow_{r,ee}\right) \times \Delta T_{main} \times 8.33}{1{,}000{,}000} \times 60 \times hrs \times days \times \frac{1}{E_{t,fuel}}$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
baseline	= Characteristic of baseline condition
ee	= Characteristic of energy efficient condition
GPM	= Gallons per minute
$Flow_r$	= Flow rate restricted
ΔT_{main}	= Average temperature difference between faucet operating temperature and the supply water temperature in water main (°F)
hrs	= Operating hours per day
days	= Operating days per year
E_t	= Water heater thermal efficiency
8.33	= Energy required (BTU) to heat one gallon of water by one degree Fahrenheit
60	= Conversion factor, minutes in one hour

3,412 = Conversion factor, one kWh equals 3,412 BTU
1,000,000 = Conversion factor, one MMBtu equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
$GPM_{baseline}$	Kitchen Sink: 2.2 Private Lavatory: 1.5	Maximum flow rate defined by NYS[938] plumbing code. For municipalities subject to EPA WaterSense (i.e., WaterSense Partners[939]), maximum standard flow rate under that program supersede federal standard values.
GPM_{ee}		From application, or use minimum program compliant flowrate if unknown.
$Flow_{r,baseline}$	0.83	American Council for an Energy-Efficient Economy. [940]
$Flow_{r,ee}$	0.95	American Council for an Energy-Efficient Economy. [941]
hrs	0.25	Based on an assumed 30 uses per day, 30 seconds per use.[942]
days		Facility annual operating days, from application or look up based on facility type in Operating Hours section below.
ΔT_{main}	$T_{faucet} - T_{main}$	Average temperature difference between faucet operating temperature and the supply water temperature in water main (°F).
T_{faucet}	Lavatory: 86 Kitchen: 93 Unknown: 88	Faucet operating temperature (°F).[943] Unknown is derived from the calculated weighted average based on statewide average assumptions: ((1*93)+(3*86))/(1+3)=88.
T_{main}		Supply water temperature in water main (°F). Lookup in Cold Water Inlet Temperature table below based on nearest city.
$E_{t,elec}$	0.98	Thermal efficiency of electric water heater.[944]
$E_{t,fuel}$	0.80	Thermal efficiency of fossil fuel water heater. [945]

[938] 2020 NYS Plumbing Code, Table 604.4
[939] Find Water Sense Partners at the Environmental Protection Agency website: https://www.epa.gov/watersense/partners-directory
[940] Energy Related Water Fixture Measurements: Securing the Baseline for Northwest Single Family Homes, American Council for an Energy-Efficient Economy, August 2008, pg. 1-265
[941] Ibid.
[942] FEMP, Domestic Water Conservation Technologies, pg. 35
[943] Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, Directed to Michigan Evaluation Working Group. Table 93 "HEI Updated PY2014 Variable Assumptions"
[944] Per 10 CFR 430 Subpart B Appendix E – Uniform Test Method for Measuring the Energy Consumption of Water Heaters: *6.3.2 Recovery Efficiency*
[945] Per 10 CFR 431.110 (a)

Cold Water Inlet Temperature (T_{main})

Supply water main temperatures vary according to climate and are approximately equal to the annual average outdoor temperature plus 6°F.[946] Supply main temperatures based on the annual outdoor temperature are shown below.

City	Annual average outdoor temperature[947] (°F)	T_{main} (°F)
Albany	48.3	54.3
Binghamton	46.3	52.3
Buffalo	48.3	54.3
Massena	43.5	49.5
NYC	55.4	61.4
Poughkeepsie	49.8	55.8
Syracuse	48.3	54.3

Coincidence Factor

The prescribed value for the coincidence factor is N/A.

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a kitchen sink or private lavatory faucet aerator as defined in the Measure Description section above with flow rate equivalent to maximum code compliant GPM per application.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a low-flow kitchen sink or private lavatory faucet aerator as defined in the Measure Description section above which exceeds the efficiency of the baseline equipment.

Operating Hours

Faucets are assumed to be used 30 times per day with an average of 30 seconds per use.[948] Days of operation shall be taken from application. If unknown, default operating days per year are provided below, established based on a weighted average of values associated with similar facility types, as reported by the California Energy Commission.[949]

Facility Type	Days/Year
Community College	283
Fast Food	363
Full Service Restaurant	321

[946] Burch, Jay and Christensen, Craig, "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory

[947] Average annual outdoor temperatures taken from NCEI 1981-2010 climate normals

[948] FEMP, Domestic Water Conservation Technologies, pg. 35

[949] California Energy Commission, Characterizing the Energy Efficiency Potential of Gas-Fired Commercial Foodservice Equipment, Appendix E.

Facility Type	Days/Year
Grocery	365
Hospital	365
Hotel	365
Miscellaneous	325
Motel	365
Primary School	180
Secondary School	180
Small Office	250
University	283

Example Calculation *(Not to be used as default)*

Twenty 0.5 GPM low-flow faucet aerators are installed on lavatory sinks in a commercial facility located near Albany. Hot water is provided by a 100 gallon gas-fired storage tank water heater. The facility is open 300 days per year. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are not applicable. Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta MMBtu = units \times \frac{\left(GPM_{baseline} \times Flow_{r,baseline} - GPM_{ee} \times Flow_{r,ee}\right) \times \Delta T_{main} \times 8.33}{1{,}000{,}000} \times 60 \times hrs \times days \times \frac{1}{E_{t,fuel}}$$

units = 20, from application
$GPM_{baseline}$ = 1.5, from Summary of Variables and Data Sources table based on location from application
$Flow_{r,baseline}$ = 0.83, from Summary of Variables and Data Sources table
GPM_{ee} =0.5, from application
$Flow_{r,ee}$ = 0.95, from Summary of Variables and Data Sources table
$\Delta T_{main} = T_{faucet} - T_{main} = 86 - 54.3 = 31.7$
T_{faucet} = 86, from Summary of Variables and Data Sources table based on location from application
T_{main} from Cold Water Inlet Temperature table based on location from application
hrs = 0.25, from Summary of Variables and Data Sources table
days = 300, from application
$E_{t,fuel}$ = 0.80, from Summary of Variables and Data Sources table

$$\Delta MMBtu = 20 \times \frac{(1.5 \times 0.83 - 0.5 \times 0.95) \times 31.7 \times 8.33}{1{,}000{,}000} \times 60 \times 0.25 \times 300 \times \frac{1}{0.80} = 22.9\ MMBtu$$

Effective Useful Life

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. NYS 2020 Plumbing Code Table 604.4, Maximum Flow Rates and Consumption for Plumbing Fixtures and Fixture Fittings
   Available from: https://codes.iccsafe.org/content/NYSPC2020P1/chapter-6-water-supply-and-distribution
2. Energy-related Water Fixture Measurements: Securing the Baseline for Northwest Single Family Homes, American Council for an Energy-Efficient Economy, August 2008
   Available from: http://www.seattle.gov/light/conserve/reports/paper_10.pdf
3. Federal Energy Management Program, Domestic Water Conservation Technologies, October 2002
   Available from: https://www1.eere.energy.gov/femp/pdfs/22799.pdf
4. Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, Directed to Michigan Evaluation Working Group
   Available from: http://www.oracle.com/us/industries/utilities/cadmus-indianapolis-power-light-3697534.pdf
5. 10 CFR 430 Subpart B – Test Procedures, Appendix E – Uniform Test Method for Measuring the Energy Consumption of Water Heaters
   Available from: https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=9624a8ba0987aaae248454c49194a661&mc=true&n=pt10.3.430&r=PART&ty=HTML#ap10.3.430_127.e
6. 10 CFR 431.110 Energy conservation standards and their effective dates
   Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=64f994924a5f31b841cab23a6d543f85&mc=true&node=pt10.3.431&rgn=div5#se10.3.431_1110
7. Burch, Jay and Christensen, Craig, "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory
   Available from:
   https://energy.mo.gov/sites/energy/files/algorithmformainswatertemperature.pdf
8. NOAA National Centers for Environmental Information – NCEI 1981-2010 Climate Normals
   Available from: https://www.ncdc.noaa.gov/cdo-web/datatools/normals

9. California Energy Commission, Energy Research and Development Division, Characterizing the Energy Efficiency Potential of Gas-Fired Commercial Foodservice Equipment, October 2014.
Available from: http://www.energy.ca.gov/2014publications/CEC-500-2014-095/CEC-500-2014-095.pdf

Record of Revision

Record of Revision Number	Issue Date
1	10/15/2010
6-18-9	6/26/2018

Return to Table of Contents

LOW-FLOW - PRE-RINSE SPRAY VALVE (PRSV)

Measure Description

This measure covers the retrofit of pre-rinse spray valves, often used in commercial and institutional kitchens. Pre-rinse spray valves (PRSV) are handheld devices that are designed to remove food waste from dishes prior to dishwashing. Retrofitting existing standard flow PRSVs in locations where service water is supplied by electric or natural gas fired hot water heaters with new low-flow PRSVs reduces hot water consumption resulting in corresponding energy savings.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings (Electric Water Heating Equipment Only)

$$\Delta kWh = units \times \frac{(GPM_{baseline} - GPM_{ee}) \times 60 \times hrs \times \Delta T_{main} \times 8.33}{3{,}412} \times \frac{1}{Eff_{elec}}$$

Summer Peak Coincident Demand Savings (Electric Water Heating Equipment Only)

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings (Fossil Fuel Water Heating Equipment Only)

$$\Delta MMBtu = units \times \frac{(GPM_{baseline} - GPM_{ee}) \times 60 \times hrs \times \Delta T_{main} \times 8.33}{1{,}000{,}000} \times \frac{1}{Eff_{fuel}}$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
baseline	= Characteristic of baseline condition
ee	= Characteristic of energy efficient condition
GPM	= Gallons per minute
hrs	= Annual operating hours of PRSV
ΔT_{main}	= Average temperature difference between PRSV operating temperature and the supply water temperature in water main (°F)
Eff	= Water heating process efficiency
8.33	= Energy required (BTU) to heat one gallon of water by one degree Fahrenheit
3,412	= Conversion factor, one kWh equals 3,412 BTU
1,000,000	= Conversion factor, one MMBtu equals 1,000,000 BTU
60	= Minutes in one hour

Summary of Variables and Data Sources

Variable	Value	Notes
$GPM_{baseline}$	≤ 5.0 ozf: 1.00 > 5.0 and ≤ 8.0 ozf: 1.20 > 8.0 ozf: 1.28	Current federal standard based on spray force product class in ounce-force, ofz.[950] For municipalities subject to EPA WaterSense (i.e., WaterSense Partners[951]), maximum standard flowrate under that program supersede federal standard values.
GPM_{ee}		From application.
hrs		Lookup in operating hours table below based on facility type. If unknown, use 365 as default
ΔT_{main}	$T_{PRSV} - T_{main}$	Average temperature difference between PRSV operating temperature and the supply water temperature in water main (°F).
T_{PRSV}		PRSV operating temperature (°F), from application. If unknown, assume 120°F.[952]
T_{main}		Supply water temperature in water main (°F). Lookup in Cold Water Inlet Temperature table below based on nearest city.
Eff_{elec}	0.90	Process efficiency of electric water heater.[953] The temperature differential is derived from the average main temperature and the operating temperature at the PRSV. Therefore, process efficiency of delivery of hot water to the PRSV, rather than rated water heater efficiency, is used.
Eff_{fuel}	0.60	Process efficiency of fossil fuel water heater.[954] The temperature differential is derived from the average main temperature and the operating temperature at the PRSV. Therefore, process efficiency of delivery of hot water to the PRSV, rather than rated water heater efficiency, is used.

Cold Water Inlet Temperature (T_{main})

Supply water main temperatures vary according to climate and are approximately equal to the annual average outdoor temperature plus 6°F.[955] Supply main temperatures based on the annual outdoor temperature are shown below.

[950] 10 CFR 431.266(b)
[951] Find Water Sense Partners at the Environmental Protection Agency website: https://www.epa.gov/watersense/partners-directory
[952] CEE Commercial Kitchens Initiative Program Guidance on Pre-Rinse Spray Valves, 2005, pg. 3
[953] EPA Water Sense Pre-Rinse Spray Valves Field Study Report, February 2011, pg. 30
[954] EPA Water Sense Pre-Rinse Spray Valves Field Study Report, February 2011, pg. 30
[955] Burch, Jay and Christensen, Craig, "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory

City	Annual average outdoor temperature[956] (°F)	Average Main Temperature T_{main} (°F)
Albany	48.3	54.3
Binghamton	46.3	52.3
Buffalo	48.3	54.3
Massena	43.5	49.5
NYC	55.4	61.4
Poughkeepsie	49.8	55.8
Syracuse	48.3	54.3

Coincidence Factor (CF)

The prescribed coincidence factor for this measure is N/A.

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a PRSV as defined in the Measure Description section above with flow rate equivalent to current federal standard. For municipalities subject to EPA WaterSense (i.e., WaterSense Partners[957]), maximum standard flowrate under that program supersede federal standard values.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a PRSV as defined in the Measure Description section above, whose flow rate is less than that of the baseline condition.

Operating Hours

Annual operating hours of pre-rinse spray valves based on facility type are listed in the table below.[958]

Type of Facility	hrs (Hours/Year)
Quick-Service Restaurant	365
Casual Dining Restaurant	730
Cafeteria	1460

Example Calculation *(Not to be used as default)*

A 0.8 GPM PRSV is installed in the kitchen in a casual dining restaurant located near Albany. The exit temperature of the PRSV is 125ºF at 6 ounce-force, and the facility has an electric storage type water heater. Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings are calculated as below.

[956] Average annual outdoor temperatures taken from NCEI 1981-2010 climate normals
[957] Find Water Sense Partners at the Environmental Protection Agency website: https://www.epa.gov/watersense/partners-directory
[958] CEE Commercial Kitchens Initiative Program Guidance on Pre-Rinse Spray Valves, 2005, pg. 3

$$\Delta kWh = units \times \frac{(GPM_{baseline} - GPM_{ee}) \times 60 \times hrs \times \Delta T_{main} \times 8.33}{3{,}412} \times \frac{1}{Eff_{elec}}$$

$GPM_{baseline}$ = 1.20, from Summary of Variables and Data Sources table based on faucet set points from application
GPM_{ee} = 0.8, from application
hrs = 730, from operating hours table based on facility type from application
$\Delta T_{main} = T_{PRSV} - T_{main}$ = 125 – 54.3 = 70.7
T_{PRSV} = from application. If unknown, assume 120°F
T_{main} from Cold Water Inlet Temperature table based on location from application
Eff_{elec} = 0.90, from Summary of Variables aand Data Sources table

$$\Delta kWh = 1 \times \frac{(1.2 - 0.8) \times 60 \times 730 \times 70.7 \times 8.33}{3{,}412} \times \frac{1}{0.9} = 3{,}360\ kWh$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. 10 CFR 431.266 Energy conservation standards and their effective dates
   Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=fa5acd7c1276f26b10eb66f5c415baae&mc=true&node=pt10.3.431&rgn=div5#se10.3.431_1266
2. US EPA, WaterSense® Pre-Rinse Spray Valves Field Study Report, February 1, 2011
   Available from: https://www.epa.gov/sites/production/files/2017-01/documents/ws-products-support-statement-prsv.pdf
3. Burch, Jay and Craig Christensen; "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory.
   Available from:
   https://www.energystar.gov/ia/partners/prod_development/new_specs/downloads/water_heaters/AlgorithmForMainsWaterTemperature.pdf

4. NOAA National Centers for Environmental Information – NCEI 1981-2010 Climate Normals
   Available from: https://www.ncdc.noaa.gov/cdo-web/datatools/normals
5. CEE Commercial Kitchens Initiative Program Guidance on Pre-Rinse Spray Valves
   Available from:
   https://library.cee1.org/system/files/library/4252/PRSV%20Program%20Guidance.pdf

Record of Revision

Record of Revision Number	Issue Date
1-16-18	12/31/2015
3-18-10	3/29/2018

Return to Table of Contents

LOW-FLOW - SALON VALVE

Measure Description

This measure covers the retrofit of salon valves, often used at hair salons and at pet grooming facilities, with low-flow spray heads. Salon valves are handheld devices that are designed to wash and rinse hair. Retrofitting existing standard-flow salon valves in locations where service water is supplied by electric or natural gas fired hot water heaters with new low-flow heads reduces hot water consumption, which results in corresponding energy savings.

Due to limited information regarding the typical operating characteristics of low-flow salon valves, this measure relies on commercial showerhead and pre-rinse spray valve research to establish an approach that estimates the savings associated with low-flow salon valve devices.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings (Electric Water Heating Equipment Only)

$$\Delta kWh = units \times \frac{(GPM_{baseline} - GPM_{ee}) \times F_{throttle} \times min_{valve} \times hrs \times \Delta T_{main} \times 8.33}{3{,}412} \times \frac{1}{Eff_{elec}}$$

Summer Peak Coincident Demand Savings (Electric Water Heating Equipment Only)

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings (Fossil Fuel Water Heating Equipment Only)

$$\Delta MMBtu = units \times \frac{(GPM_{baseline} - GPM_{ee}) \times F_{throttle} \times min_{valve} \times hrs \times \Delta T_{main} \times 8.33}{1{,}000{,}000} \times \frac{1}{Eff_{fuel}}$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
$_{baseline}$	= Characteristic of baseline condition
$_{ee}$	= Characteristic of energy efficient condition
GPM	= Gallons per minute
$F_{throttle}$	= Throttle factor
min_{valve}	= Minutes of operation of salon valve per hour
hrs	= Annual operating hours of facility
ΔT_{main}	= Average temperature difference between salon valve operating temperature and the supply water temperature in water main (°F)

Eff = Water heating process efficiency
8.33 = Energy required (BTU) to heat one gallon of water by one degree Fahrenheit
3,412 = Conversion factor, one kWh equals 3,412 BTU
1,000,000 = Conversion factor, one MMBtu equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
$GPM_{baseline}$	NYS: 2.0 NYC: 2.0 WaterSense®: See Notes	Current international plumbing code standard as adopted by New York State[959]. For municipalities subject to EPA WaterSense® (i.e., WaterSense Partners[960]), showerheads under that program shall follow code-compliant values.[961]
GPM_{ee}		From application.
$F_{throttle}$	0.9	Used in LBNL study to adjust for occupant reduction in flowrate[962]
min_{valve}	20	One shampoo cycle lasts 5 minutes and occurs an average of 4 times per washing station per hour, based on market research.
hrs		From application. If unknown, use 2,080.[963]
ΔT_{main}	$T_{valve} - T_{main}$	Average temperature difference between valve operating temperature and the supply water temperature in water main (°F).
T_{valve}		Salon valve operating temperature (°F), from application. If unknown, assume 105°F.[964]
T_{main}		Supply water temperature in water main (°F). Lookup in Cold Water Inlet Temperature table below based on nearest city.
Eff_{elec}	0.90	Process efficiency of electric water heater.[965] The temperature differential is derived from the average main temperature and the operating temperature at the valve. Therefore, process efficiency of delivery of hot water to the valve, rather than rated water heater efficiency, is used.

[959] 2020 NYS Plumbing Code, Table 604.4
[960] Find Water Sense Partners at the Environmental Protection Agency website: https://www.epa.gov/watersense/partners-directory
[961] EPA WaterSense® Specification for Showerheads, Version 1.1, July 26, 2011
[962] LBNL: Potential Water and Energy Savings from Showerheads, March 2006
[963] Based on market research, assumes 5 minutes of water used per shampoo and 4 shampoos per hour where facility operating hours are 8 hours per day, 5 days per week.
[964] Average temperature at showerhead; conservative assumption based on NYS plumbing code, EPA MFHR program and ASSE 1070-2014
[965] EPA Water Sense Pre-Rinse Spray Valves Field Study Report, February 2011, pg. 30

Variable	Value	Notes
Eff_{fuel}	0.60	Process efficiency of fossil fuel water heater.[966] The temperature differential is derived from the average main temperature and the operating temperature at the valve. Therefore, process efficiency of delivery of hot water to the valve, rather than rated water heater efficiency, is used.

Cold Water Inlet Temperature (T_{main})

Supply water main temperatures vary according to climate and are approximately equal to the annual average outdoor temperature plus 6°F.[967] Supply main temperatures based on the annual outdoor temperature are shown below.

City	Annual average outdoor temperature[968] (°F)	Average Main Temperature T_{main} (°F)
Albany	48.3	54.3
Binghamton	46.3	52.3
Buffalo	48.3	54.3
Massena	43.5	49.5
NYC	55.4	61.4
Poughkeepsie	49.8	55.8
Syracuse	48.3	54.3

Coincidence Factor (CF)

The prescribed coincidence factor for this measure is N/A.

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a salon valve as defined in the Measure Description section above with flow rate equivalent to maximum code compliance. For municipalities subject to EPA WaterSense (i.e., WaterSense Partners), maximum standard flowrates under that program supersede code compliant values.[969]

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a salon valve as defined in the Measure Description section above with flow rate less than the specified baseline value (< 2.0 gpm) or less than the more restrictive codes or guidelines of local governments, municipalities or entities which, for example, participate in the US EPA Water Sense® Partnership Program.

[966] EPA Water Sense Pre-Rinse Spray Valves Field Study Report, February 2011, pg. 30
[967] Burch, Jay and Christensen, Craig, "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory
[968] Average annual outdoor temperatures taken from NCEI 1981-2010 climate normals.
[969] Find Water Sense Partners at the Environmental Protection Agency website: https://www.epa.gov/watersense/partners-directory

Operating Hours

Based on market research, one shampoo cycle lasts 5 minutes and occurs an average of 4 times per washing station per hour, resulting in 20 minutes of valve operation per hour. Total annual hours of usage are based on the hours of operation of the facility, from application. If unknown, assume 2,080 annual hours, based on 8 hours per day, 5 days per week.

Example Calculation *(Not to be used as default)*

A salon located near Albany installs two 1.5 GPM low-flow salon valves. The salon is open for 2,200 hours annually. Domestic hot water is provided by a gas-fired storage tank water heater. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are not applicable. Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta MMBtu = units \times \frac{(GPM_{baseline} - GPM_{ee}) \times F_{throttle} \times min_{valve} \times hrs \times \Delta T_{main} \times 8.33}{1{,}000{,}000} \times \frac{1}{Eff_{fuel}}$$

units = 2, from application
$GPM_{baseline}$ = 2.0, from Summary of Variables and Data Sources table
GPM_{ee} = 1.5, from application
$F_{throttle}$ = 0.9, from Summary of Variables and Data Sources table
min_{valve} = 20, from Summary of Variables and Data Sources table
hrs = 2,200, from application
$\Delta T_{main} = T_{valve} - T_{main}$ = 105ºF - 54.3 ºF = 50.7ºF
T_{valve} =105ºF, default from Summary of Variables and Data Sources table
T_{main} = 54.3, from Cold Water Inlet Temperature table based on location from application
Eff_{fuel} = 0.60, from Summary of Variables and Data Sources table

$$\Delta MMBtu = 2 \times \frac{(2 - 1.5) \times 0.9 \times 20 \times 2{,}200 \times 50.7 \times 8.33}{1{,}000{,}000} \times \frac{1}{0.6} = 27.9\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this

measure algorithm in future revisions to the TRM.

References

1. NYS Plumbing Code 2020, Chapter 6
   Available from: https://codes.iccsafe.org/content/NYSPC2020P1/chapter-6-water-supply-and-distribution
2. EPA WaterSense® Specification for Showerheads, Version 1.1, July 26, 2018
   Available from: https://www.epa.gov/sites/production/files/2018-07/documents/ws-products-specification-showerheads-v1-1.pdf
3. Lawrence Berkeley National Laboratory (LBNL): "Potential Water and Energy Savings from Showerheads", March 2006
   Available from: http://www.map-testing.com/assets/files/Biermayer,%20P.%20(2006)%20Potential%20Water%20and%20Energy%20Savings%20from%20Showerheads.pdf
4. US EPA, WaterSense® Pre-Rinse Spray Valves Field Study Report, February 1, 2011
   Available from: https://www.epa.gov/sites/production/files/2017-01/documents/ws-products-support-statement-prsv.pdf
5. Burch, Jay and Craig Christensen; "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory.
   Available from:
   https://www.energystar.gov/ia/partners/prod_development/new_specs/downloads/water_heaters/AlgorithmForMainsWaterTemperature.pdf
6. NOAA National Centers for Environmental Information – NCEI 1981-2010 Climate Normals
   Available from: https://www.ncdc.noaa.gov/cdo-web/datatools/normals
7. CEE Commercial Kitchens Initiative Program Guidance on Pre-Rinse Spray Valves
   Available from:
   https://library.cee1.org/system/files/library/4252/PRSV%20Program%20Guidance.pdf

Record of Revision

Record of Revision Number	Issue Date
12-18-10	12/28/2018

Return to Table of Contents

LOW-FLOW - SHOWERHEAD

Measure Description

A low flow showerhead is a water saving showerhead with rated gallons per minute (gpm) less than maximum allowable flowrate as mandated by federal, state, local and municipal codes and standards. New York State construction code dictate a maximum flowrate of 2.0 gpm for showerheads. This is a retrofit direct install measure or a new installation.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times H_2O_{savings} \times (T_{shower} - T_{main}) \times \frac{8.33}{3{,}412} \times \frac{1}{E_{t,elec}}$$

Summer Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = units \times H_2O_{savings} \times (T_{shower} - T_{main}) \times \frac{8.33}{1{,}000{,}000} \times \frac{1}{E_{t,fuel}}$$

Note: to estimate the annual gallons of water saved from installation of measure

$$H_2O_{savings} = (GPM_{baseline} - GPM_{ee}) \times Throttle_{fac} \times \frac{minutes}{use} \times \frac{uses}{day} \times 365\,\frac{days}{yr}$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
$H_2O_{savings}$	= Reduction of hot water usage per facility per year
units	= Number of measures installed under the program
$_{baseline}$	= Characteristic of baseline condition
$_{ee}$	= Characteristic of energy efficient condition
GPM	= Gallons per minute
E_t	= Thermal efficiency of water heater
$Throttle_{fac}$	= Throttle factor
T_{shower}	= Temperature (°F) at showerhead
T_{main}	= Temperature (°F) of supply water from main
8.33	= Energy required (BTU) to heat one gallon of water by one degree Fahrenheit
3,412	= Conversion factor, one kW equals 3,412 BTU/h
1,000,000	= Conversion factor, one MMBtu equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
$GPM_{baseline}$	2.0	Gallons per minute for baseline[970]
GPM_{ee}		Gallons per minute for energy efficient measure, from application.
$Throttle_{fac}$	0.9	Used in LBNL study to adjust for occupant reduction in flow rate[971]
minutes/use	8.2	Average shower duration per LBNL study.[972]
uses/day		From application.
$E_{t,fuel}$	0.80	Assumed typical fossil fuel water heater recovery efficiency (standard efficiency)
	0.94	Assumed typical fossil fuel water heater recovery efficiency (ENERGY STAR® qualified)
$E_{t,elec}$	0.98	Assumed typical electric water heater recovery efficiency.
T_{main}		Average inlet water temperature (°F) by location is shown below.
T_{shower}	105	Average temperature (°F) at showerhead; conservative assumption based on NYS plumbing code, EPA MFHR program and ASSE 1070-2014

Cold Water Inlet Temperature (T_{main})

Supply water main temperatures vary according to climate, and are approximately equal to the annual average outdoor temperature plus 6°F.[973] Supply main temperatures based on the annual outdoor temperature are shown below.

City	Annual average outdoor temperature[974] (°F)	T_{main} (°F)
Albany	48.3	54.3
Binghamton	46.3	52.3
Buffalo	48.3	54.3
Massena	43.5	49.5
NYC	55.4	61.4
Poughkeepsie	49.8	55.8
Syracuse	48.3	54.3

Coincidence Factor (CF)

The prescribed value for the coincidence factor is N/A.

970 2020 NYS Plumbing Code, Table 604.4
971 LBNL: Potential Water and Energy Savings from Showerheads, March 2006
972 Ibid.
973 Burch, Jay and Christensen, Craig, "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory
974 Average annual outdoor temperatures taken from NCEI 1981-2010 climate normals

Baseline Efficiencies from which Energy Savings are Calculated

The Summary of Variables and Data Sources provides the baseline (standard) water flow, water heating efficiency and related input assumptions. Assumptions regarding average duration of use and number of uses per day are also presented.

Compliance Efficiency from which Incentives are Calculated

Compliance flow rate is less than the specified baseline value (<2.0 gpm) or less than the more restrictive codes or guidelines of local governments, municipalities or entities which, for example, participate in the US EPA Water Sense® Partnership Program. [975]

Operating Hours

Assumed duration of shower and assumed number of showers per day as listed above in Summary of Variables and Data Sources.

Example Calculation *(Not to be used as default)*

Eight 1.5 GPM low-flow showerheads are installed in a fitness center locker room located near Albany. Each showerhead is used an average of 3 times per day. A standard efficiency gas-fired storage water heater provides domestic hot water to the building. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are not applicable. Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta MMBtu = units \times H_2O_{savings} \times (T_{shower} - T_{main}) \times \frac{8.33}{1{,}000{,}000} \times \frac{1}{E_{t,fuel}}$$

$$H_2O_{savings} = (GPM_{baseline} - GPM_{ee}) \times Throttle_{fac} \times \frac{minutes}{use} \times \frac{uses}{day} \times 365\,\frac{days}{yr}$$

$GPM_{baseline}$= 2.0, from Summary of Variables and Data Sources table
GPM_{ee}= 1.5, from application
$Throttle_{fac}$= 0.9, from Summary of Variables and Data Sources table
minutes/use= 8.2, from Summary of Variables and Data Sources table
uses/day = 3, from application
$E_{t,fuel}$ = 0.80, from Summary of Variables and Data Sources table based on hot water heating from application
T_{main} = 54.3, from Cold Water Inlet Temperature table based on location from application
T_{shower} = 105, from Summary of Variables and Data Sources table

$$H_2O_{savings} = (2 - 1.5) \times 0.9 \times 8.2 \times 3 \times 365 = 4{,}040$$

$$\Delta MMBtu = 8 \times 4{,}040 \times (105 - 54.3) \times \frac{8.33}{1{,}000{,}000} \times \frac{1}{0.8} = 17.1\ MMBtu$$

[975] Find Water Sense Partners at the Environmental Protection Agency website: https://www.epa.gov/watersense/partners-directory

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. Burch, Jay and Craig Christensen; "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory.
   Available from:
   https://www.energystar.gov/ia/partners/prod_development/new_specs/downloads/water_heaters/AlgorithmForMainsWaterTemperature.pdf
2. NOAA National Centers for Environmental Information – NCEI 1981-2010 Climate Normals
   Available from: https://www.ncdc.noaa.gov/cdo-web/datatools/normals
3. NYS 2020 Plumbing Code Table 604.4 Maximum Flow Rates and Consumption for Plumbing Fixtures and Fixture Fittings
   Available from: https://codes.iccsafe.org/content/NYSPC2020P1/chapter-6-water-supply-and-distribution
4. Lawrence Berkeley National Laboratory (LBNL): "Potential Water and Energy Savings from Showerheads", March 2006
   Available from: http://www.map-testing.com/assets/files/Biermayer,%20P.%20(2006)%20Potential%20Water%20and%20Energy%20Savings%20from%20Showerheads.pdf
5. EPA WaterSense® Specification for Showerheads, Version 1.1, July 26, 2018
   Available from: https://www.epa.gov/sites/production/files/2018-07/documents/ws-products-specification-showerheads-v1-1.pdf

Record of Revision

Record of Revision Number	Issue Date
1	10/15/2010
6-13-8	6/30/2013
6-15-1	6/1/2015
6-17-10	6/30/2017

Return to Table of Contents

HEATING, VENTILATION AND AIR CONDITIONING (HVAC)

AIR CONDITIONER AND HEAT PUMP – PACKAGED TERMINAL

Measure Description

This measure covers the installation of high efficiency packaged terminal conditioners heat pumps in commercial applications.

Packaged Terminal Air Conditioner (PTAC)

A wall sleeve and a separate un-encased combination of heating and cooling assemblies specified by the manufacturer and intended for mounting through the wall. It includes refrigeration components, separable outdoor louvres, forced ventilation, and heating availability by purchaser's choice of, at least, hot water, steam, or electrical resistance heat.

Note: *Models designated as "cooling only" units need not include heating elements if the physical characteristics and arrangement of the refrigeration system are identical to those of models with heating availability.*[976]

Packaged Terminal Heat Pump (PTHP)

A separate un-encased refrigeration system installed in a cabinet having a function and configuration similar to that of a packaged terminal air-conditioner. It uses reverse cycle refrigeration as its prime heat source and should have other supplementary heat source(s) available to purchasers with the choice of, at least, hot water, steam, or electric resistance heat.[977,978]

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times \left[\begin{array}{c} \left(\frac{kBTU/h_{cooling}}{unit} \times \left(\frac{F_{ElecCool}}{EER_{baseline}} - \frac{1}{EER_{ee}} \right) \times EFLH_{cooling} \right) \\ + \\ \left(\frac{kBTU/h_{heating}}{unit \times 3.412} \times \left(\frac{F_{ElecHeat}}{COP_{baseline}} - \frac{1}{COP_{ee}} \right) \times EFLH_{heating} \right) \end{array} \right]$$

Summer Peak Coincident Demand Savings

$$\Delta kW = units \times \left[\frac{kBTU/h_{cooling}}{unit} \times \left(\frac{F_{CEC}}{EER_{baseline}} - \frac{1}{EER_{ee}} \right) \times CF \right]$$

976 AHRI Standard 310/380 – 2014

977 Ibid.

978 Replacement unit shall be factory labeled as follows: "MANUFACTURED FOR REPLACEMENT APPLICATIONS ONLY: NOT TO BE INSTALLED IN NEW CONSTRUCTION PROJECTS." Replacement efficiencies apply only to units with existing sleeves less than 16 inches (406 mm) in height and less than 42 inches (1067 mm) in width.

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = units \times \left(\frac{kBTU/h_{heating}}{unit} \times \frac{F_{FuelHeat}}{Eff_{heating,baseline}} \times \frac{EFLH_{heating}}{1{,}000} \right)$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
$_{baseline}$	= Characteristic of baseline condition
$_{ee}$	= Characteristic of energy efficient condition
$kBTU/h_{cooling}$	= Output cooling capacity in kBTU/h (at AHRI standard rating conditions)
$kBTU/h_{heating}$	= Output heating capacity in kBTU/h (at AHRI standard high-temperature rating conditions)
$F_{ElecCool}$	= Electric cooling factor; used to account for the presence or absence of an electric cooling system
$F_{ElecHeat}$	= Electric heating factor; used to account for the presence or absence of an electric heating system
$F_{FuelHeat}$	= Fossil fuel heating factor; used to account for the presence or absence of a fossil fuel heating system
EER	= Energy efficiency ratio, measurement of cooling capacity for a unit (in BTU/hour) / electrical energy used (watts) (at AHRI standard rating conditions)
COP	= Coefficient of performance, ratio of output energy/input energy (at AHRI standard high-temperature rating conditions)
$Eff_{heating}$	= Fossil fuel heating energy efficiency rating of equipment.
$EFLH_{cooling}$	= Cooling equivalent full-load hours
$EFLH_{heating}$	= Heating equivalent full-load hours
CF	= Coincidence factor
3.412	= Conversion factor, one watt-hour equals 3.412 BTU
1,000	= Conversion factor, one MMBtu equals 1,000 kBTU

Summary of Variables and Data Sources

Variable	Value	Notes
$kBTU/h_{cooling}$		From application
$kBTU/h_{heating}$		From application
$F_{ElecCool}$		If an electric cooling system is present, set equal to 1. Otherwise, set equal to 0.
$F_{ElecHeat}$		If a an electric heating system is present, set equal to 1. Otherwise, set equal to 0.
$F_{FuelHeat}$		If a fossil fuel-fired heating system is present, set equal to 1. Otherwise, set equal to 0.
$EER_{baseline}$		Calculate from Baseline Efficiencies table below based on equipment type, size category and capacity.
EER_{ee}		From application

Variable	Value	Notes
$COP_{baseline}$		Calculate from Baseline Efficiencies table below based on equipment type, size category and capacity.
COP_{ee}		From application
$Eff_{heating,baseline}$		From Fossil Fuel Fired Heating System Baseline Efficiencies table below.
$EFLH_{cooling}$		From application. If unknown, lookup based on building type and location from Appendix G.
$EFLH_{heating}$		From application. If unknown, lookup based on building type and location from Appendix G.
CF	0.8	

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.8.[979]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline for a non-fuel switching normal replacement at end of the appliance effective useful life (EUL), in new construction, or substantial renovation scenarios is the minimally-compliant state or municipal energy code or federal standard, that is applicable to the measure or system being installed. The baseline efficiencies are calculated based on rated equipment input capacity in BTU/h and are defined by International Energy Conservation Code[980] and subsequently adopted by the Energy Conservation Construction Code of New York State (ECCCNYS) as shown below. The formulas in the rightmost column shall be used to establish the baseline efficiency in the units specified (EER or COP).

[979] *No source specified – update pending availability and review of applicable references.*
[980] ECCCNYS 2020, Table C403.3.2(3)

Electric Cooling and Heating System Baseline Efficiencies

Equipment Type	Size Category (Input)	Subcategory or Rating Condition	Minimum Efficiency ECCCNYS[981]
PTAC (Cooling Mode) Standard Size	All Capacities	95°F db Outdoor Air	EER = 14.0 - (0.300 × Cap/1,000)
PTAC (Cooling Mode) Replacements/ Nonstandard Size[982]	All Capacities	95°F db Outdoor Air	EER = 10.9 - (0.213 × Cap/1,000)
PTHP (Cooling Mode) Standard Size	All Capacities	95°F db Outdoor Air	EER = 14.0 - (0.300 × Cap/1,000)
PTHP (Cooling Mode) Replacements/ Nonstandard Size	All Capacities	95°F db Outdoor Air	EER = 10.8 - (0.213 × Cap/1,000)
PTHP (Heating Mode) Standard Size	All Capacities	—	NYS: COP = 3.2 – (0.026 × Cap/1,000) NYC: COP = 3.7 – (0.052 × Cap/1,000)
PTHP (Heating Mode) Replacements/ Nonstandard Size	All Capacities	—	COP = 2.9 - (0.026 × Cap/1,000)

The baseline for a fuel switching installation at the end of the appliance effective useful life is the minimally-compliant, state or municipal energy code or federal standard, that is applicable to the measure or system, similar to the existing measure or system, that the consumer would have installed without the influence of the energy efficiency program. The baseline efficiency for commercial furnaces, boilers, and unit heaters is defined by the Code of Federal Regulations (CFR) and subsequently adopted by the Energy Conservation Construction Code of New York State as shown below.

[981] "Cap" = The rated cooling capacity of the project in BTU/h. If the unit's capacity is less than 7,000 BTU/h, use 7,000 BTU/h in the calculation. If the unit's capacity is greater than 15,000 BTU/h, use 15,000 BTU/h in the calculations."

[982] Replacement/Nonstandard size units must be factory labeled as follows: "MANUFACTURED FOR REPLACEMENT APPLICATIONS ONLY; NOT TO BE INSTALLED IN NEW CONSTRUCTION PROJECTS." Replacement/Nonstandard size efficiencies apply only to units being installed in existing sleeves having an external wall opening of less than 16 in. high or less than 42 in. wide and having a cross-sectional area less than 670 in.

Fossil Fuel Fired Heating System Baseline Efficiencies[983]

Equipment Type	Size Range	ECCCNYS Minimum Efficiency for Climate Zones 4, 5 and 6
Warm Air Furnace, Gas Fired	< 225 kBTU/h	0.80 AFUE
	≥ 225 kBTU/h	0.80 Et
Warm Air Furnace, Oil Fired	< 225 kBTU/h	0.83 AFUE
	≥ 225 kBTU/h	0.80 Et
Warm Air Unit Heaters, Gas Fired	All Capacities	0.80 Ec
Warm Air Unit Heaters, Oil Fired	All Capacities	0.80 Ec
Boiler, Hot Water, Gas Fired	< 300 kBTU/h	0.82 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.80 Et
	> 2,500 kBTU/h	0.82 Ec
Boiler, Hot Water, Oil Fired	< 300 kBTU/h	0.84 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.82 Et
	> 2,500 kBTU/h	0.84 Ec
Boiler, Steam, Gas Fired, All Except Natural Draft	< 300 kBTU/h	0.80 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.79 Et
	> 2,500 kBTU/h	0.79 Et
Boiler, Steam, Gas Fired, Natural Draft	< 300 kBTU/h	0.80 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.77 Et
	> 2,500 kBTU/h	0.77 Et
Boiler, Steam, Oil Fired	< 300 kBTU/h	0.82 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.81 Et
	> 2,500 kBTU/h	0.81 Et

The baseline for a system being installed prior to the end of useful life of the existing on-site equipment may be considered as an Early Replacement; consistent with methods described in Appendix M, *Guidelines for Early Replacement* of this TRM. The non-fuel switching and fuel switching baselines detailed above shall be considered where applicable when calculating Remaining Useful Life (RUL).

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a high efficiency packaged terminal air conditioner or heat pump system as defined in the Measure Description section above meeting or exceeding an efficiency rating of 10% better than code, as outlined in the Baseline Efficiencies section.

Operating Hours

Equipment heating and cooling equivalent full load hours shall be taken from the application. If unknown, default EFLH by facility type and location can be found in Appendix G.

[983] ECCCNYS 2020, Table C403.3.2(4) and Table C403.3.2(5)

Example Calculation *(Not to be used as default)*

A hotel near Albany replaces twenty existing PTAC units equipped with electric resistance heating with PTHP replacement units with 12,000 BTU/h cooling, 10,800 BTU/h heating, EER rating of 12 and a COP rating of 3.4. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

$$\Delta kWh = units \times \left[\begin{array}{c}\left(\frac{kBTU/h_{cooling}}{unit} \times \left(\frac{F_{ElecCool}}{EER_{baseline}} - \frac{1}{EER_{ee}}\right) \times EFLH_{cooling}\right) \\ + \\ \left(\frac{kBTU/h_{heating}}{unit \times 3.412} \times \left(\frac{F_{ElecHeat}}{COP_{baseline}} - \frac{1}{COP_{ee}}\right) \times EFLH_{heating}\right)\end{array}\right]$$

$$\Delta kW = units \times \left[\frac{kBTU/h_{cooling}}{unit} \times \left(\frac{F_{CEC}}{EER_{baseline}} - \frac{1}{EER_{ee}}\right) \times CF\right]$$

units = 20
($kBTU/h_{cooling}$)/unit = 12, from application
$F_{ElecCool}$ = 1, based on application
$EER_{baseline}$ = 10.8 – (0.213 x Cap/1,000) = 10.8 – (0.213 x 12,000/1,000) = 8.24
$EER_{baseline}$ equation from Electric Cooling and Heating System Baseline Efficiencies based on equipment type of compliance equipment from application
Cap = 12,000, from application
EER_{ee} = 12, from application
$EFLH_{cooling}$ = 2,945, from Appendix G based on housing type, building vintage, and location from application
($kBTU/h_{heating}$)/unit = 10.8, from application
$F_{ElecHeat}$ = 1, based on application
$COP_{baseline}$ = 2.9 – (0.026 x Cap/1,000) = 2.9 – (0.026 x 12,000/1,000) = 2.59
$COP_{baseline}$ equation from Electric Cooling and Heating System Baseline Efficiencies based on equipment type of compliance equipment from application
Cap = 12,000, from application
COP_{ee} = 3.4, from application
$EFLH_{heating}$ = 962, from Appendix G based on housing type, building vintage, and location from application
CF = 0.8, from Summary of Variables and Data Sources table

$$\Delta kWh = 20 \times \left[\left(12 \times \left(\frac{1}{8.24} - \frac{1}{12}\right) \times 2{,}945\right) + \left(\frac{10.8}{3.412} \times \left(\frac{1}{2.59} - \frac{1}{3.4}\right) \times 962\right)\right] = 32{,}482\ kWh$$

$$\Delta kW = 20 \times \left[12 \times \left(\frac{1}{8.24} - \frac{1}{12}\right) \times 0.8\right] = 7.30\ kW$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. AHRI Standard 310/380 – 2014: Standard for Packaged Terminal Air-Conditioners and Heat Pumps
   Available from:
   http://www.ahrinet.org/App_Content/ahri/files/STANDARDS/AHRI/AHRI_Standard_310_380-2014_CSA_C744-14.pdf
2. ECCCNYS 2020 Table C403.3.2(3): Minimum Efficiency Requirements: Electrically Operated Unitary Packaged Terminal Air Conditioners, Packaged Terminal Heat Pumps, Single-Package Vertical Air Conditioners, Single Vertical Heat Pumps, Room Air Conditioners and Room Air Conditioner Heat Pumps, Table C403.2.3(4): Warm-Air Furnaces And Combination Warm-Air Furnaces/Air-Conditioning Units, Warm-Air Duct Furnaces And Unit Heaters, Minimum Efficiency Requirements & Table C403.2.3(5): Minimum Efficiency Requirements: Gas- And Oil-Fired Boilers.
   Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-ce-commercial-energy-efficiency

Record of Revision

Record of Revision Number	Issue Date
1	10/15/2010
1-17-6	12/31/2016
12-17-14	12/31/2017
2-20-7	2/28/2020

Return to Table of Contents

AIR CONDITIONER AND HEAT PUMP - UNITARY & APPLIED

Measure Description

This measure covers installation of high-efficiency unitary air conditioners and unitary and applied heat pumps in commercial applications including high rise multifamily buildings of four or more stories[984] or with an occupied floor located more than 75 feet above the lowest level of fire department vehicle access[985]. The baseline case shall be minimally code compliant equipment of the same type and capacity as in the efficient case, which shall be sized in accordance with federal, state, local and municipal codes and standards.

Unitary Air Conditioner

One or more factory-made assemblies, which normally include a cooling coil, an air moving device, a compressor(s) and condenser combination, and may include a heating function as well. The functions of commercial and industrial Unitary Air Conditioners, either alone or in combination with a heating plant, are to provide air circulation, cooling, and dehumidification, and may include the functions of heating, humidifying, outdoor air ventilation, and air cleaning.[986]

Unitary and Applied Heat Pump

One or more factory-made assemblies, which normally include an indoor conditioning coil, an air moving device, compressor(s), and an outdoor coil(s), including means to provide a heating function and may or may not include a cooling function. Such equipment may be provided in one assembly by a single manufacturer (unitary) or separate assemblies designed to be used together (applied). Commercial and industrial unitary and applied heat pumps shall provide the function of heating and may include the function of air circulation, air cooling, dehumidifying or humidifying, outdoor air ventilation, and air cleaning.[987]

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

For Units with Cooling Capacity <65,000 BTU/h

$$\Delta kWh = units \times \left[\frac{tons}{unit} \times \left(\frac{12}{SEER_{baseline}} - \frac{12}{SEER_{ee}}\right) \times EFLH_{cooling} + \frac{kBTU/h}{unit} \times \left(\frac{1}{HSPF_{baseline}} - \frac{1}{HSPF_{ee}}\right) \times EFLH_{heating}\right]$$

[984] ECCCNYS Capter 2 Definitions
[985] NYBC 2020; Chapter 2 Definitions: High-Rise Building
[986] AHRI Standard 340/360 – 2015 & AHRI Standard 210/240 with Addenda 1 and 2 – 2012
[987] Ibid.

<u>For Units with Cooling Capacity ≥ 65,000 BTU/h</u>

$$\Delta kWh = units \times \left[\frac{tons}{unit} \times \left(\frac{12}{IEER_{baseline}} - \frac{12}{IEER_{ee}}\right) \times EFLH_{cooling} + \frac{(kBTU/h)/unit}{3.412} \times \left(\frac{1}{COP_{baseline}} - \frac{1}{COP_{ee}}\right) \times EFLH_{heating}\right]$$

Summer Peak Coincident Demand Savings

$$\Delta kW = units \times \left[\frac{tons}{unit} \times \left(\frac{12}{EER_{baseline}} - \frac{12}{EER_{ee}}\right) \times CF_{cooling}\right]$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
tons	= Output cooling capacity in tons (at AHRI standard rating conditions)
kBTU/h	= Output heating capacity in kBTU/h (at AHRI standard high-temperature rating conditions)
baseline	= Characteristic of baseline condition
ee	= Characteristic of energy efficient condition
SEER	= Seasonal energy efficiency ratio in BTU/watt-hour. Total cooling output of an air conditioner during its normal annual usage period for cooling in BTU, divided by the total electric energy input during the same period in watt-hours (used only for units with cooling capacity <65,000 BTU/h).
IEER	= Integrated energy efficiency ratio in BTU/watt-hour. A weighted calculation of mechanical cooling efficiencies at full load and part load AHRI standard rating conditions (used only for units with cooling capacity ≥65,000 BTU/h)[988]
EER	= Energy efficiency ratio under peak conditions in BTU/watt-hour. Measurement of the cooling capacity for a unit in BTU/h divided by the connected electric power of the unit in watts (at AHRI standard rating conditions)
HSPF	= Heating seasonal performance factor, total heating output (supply heat) in BTU (including electric strip heat) during the heating season divided by the total electric energy heat pump consumed in watt-hours (used only for units with cooling capacity <65,000 BTU/h)
COP	= Coefficient of performance, ratio of output energy/input energy (at AHRI standard high-temperature rating conditions) (used only for units with cooling capacity ≥65,000 BTU/h)

[988] AHRI Standard 340/360 – 2015 & AHRI Standard 210/240 with Addenda 1 and 2 – 2012

$EFLH_{cooling}$ = Cooling equivalent full-load hours
$EFLH_{heating}$ = Heating equivalent full-load hours
CF = Coincidence factor
12 = (kBTU/h)/ton of air conditioning capacity
3.412 = Conversion factor, one watt/h equals 3.412 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
tons		From application
kBTU/h		From application
$SEER_{baseline}$		Lookup from Baseline Efficiencies table below based on equipment type, size category and applicable code.
$SEER_{ee}$		From application
$HSPF_{baseline}$		Lookup from Baseline Efficiencies table below based on equipment type, size category and applicable code.
$HSPF_{ee}$		From application
$IEER_{baseline}$		Lookup from Baseline Efficiencies table below based on equipment type, size category and applicable code.
$IEER_{ee}$		From application
$COP_{baseline}$		Lookup from Baseline Efficiencies table below based on equipment type, size category and applicable code.
COP_{ee}		From application
$EER_{baseline}$		Lookup from Baseline Efficiencies table below based on equipment type, size category and applicable code.
EER_{ee}		From application
$EFLH_{heating}$		From application. If unknown, lookup based on building type and location from Appendix G.
$EFLH_{cooling}$		From application. If unknown, lookup based on building type and location from Appendix G.
CF	0.8	

The **SEER** is an estimate of the seasonal energy efficiency for an average US city for small units <65,000 BTU/h cooling output.

The **EER** is the rated full-load efficiency of the unit. It is used to estimate the efficiency of the unit under peak summer conditions.

The **IEER** is a weighted calculation of mechanical cooling efficiencies at full load and part load AHRI Standard Rating Conditions. Larger units are rated in IEER.

The **COP** is a ratio of the heating capacity in watts to the power input value in watts at any given set of AHRI Standard Rating Conditions.

The **HSPF** is the average space heating system efficiency during the space heating season in BTU/watt-hour for small units <65,000 BTU/h cooling output.

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.8.[989]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is defined as minimally code compliant equipment of type and cooling and heating capacities equivalent to the efficient case. The baseline efficiencies for unitary air conditioning and unitary and applied heat pump equipment are specified in the table below, as defined by International Energy Conservation Code and subsequently adopted by the Energy Conservation Construction Code of New York State[990] (ECCCNYS). EER requirements are not specified by state or city code for equipment with <65,000 BTU/h cooling capacity. For this equipment, baseline EER are established as follows[991]:

$$EER = (1.12 \times SEER) - (0.02 \times SEER^2)$$

Resultant values from application of this equation to equipment with <65,000 BTU/h cooling capacity are tabulated in the baseline efficiencies table below.

Federal energy conservation standards[992] effective January 1, 2018 for small, large and very large package air conditioning and heating equipment are more stringent than NYS and NYC codes. These cases are denoted with footnotes in the table below.

Unitary Air Conditioners				
Equipment Type	**Size Category (Cooling Capacity)**	**Heating Section Type**	**Subcategory or Rating Condition**	**Baseline Efficiency**
Air conditioners (air cooled)	< 65,000 BTU/h (single phase)	All	Split System	11.2 EER 13.0 SEER
			Single Package	11.8 EER 14.0 SEER
Through-the-wall (air cooled)	≤ 30,000 BTU/h (single phase)	All	Split System	10.6 EER 12.0 SEER
			Single Package	10.6 EER 12.0 SEER
Small-duct high-velocity (air cooled)	< 65,000 BTU/h (single phase)	All	Split System	9.9 EER 11.0 SEER

989 *No source specified – update pending availability and review of applicable references.*
990 ECCCNYS 2020, Table C403.2.3(1) & Table C403.2.3(2)
991 DOE, Building America House Simulation Protocols, October 2010
992 10 CFR 431.97 (Table 3)

Unitary Air Conditioners				
Equipment Type	**Size Category (Cooling Capacity)**	**Heating Section Type**	**Subcategory or Rating Condition**	**Baseline Efficiency**
Air conditioners (air cooled)	≥ 65,000 BTU/h and < 135,000 BTU/h[993]	Electric Resistance (or None)	Split System and Single Package	11.2 EER 12.9 IEER
		All Other	Split System and Single Package	11.0 EER 12.7 IEER
	≥ 135,000 BTU/h and < 240,000 BTU/h	Electric Resistance (or None)	Split System and Single Package	11.0 EER 12.4 IEER
		All Other	Split System and Single Package	10.8 EER 12.2 IEER
	≥ 240,000 BTU/h and < 760,000 BTU/h	Electric Resistance (or None)	Split System and Single Package	10.0 EER 11.6 IEER
		All Other	Split System and Single Package	9.8 EER 11.4 IEER
	≥ 760,000 BTU/h	Electric Resistance (or None)	Split System and Single Package	9.7 EER 11.2 IEER
		All Other	Split System and Single Package	9.5 EER 11.0 IEER

[993] For equipment with ≥65,000 BTU/h and <135,000 BTU/h cooling capacity, IEER values are taken from 10 CFR 431.97 (Table 3)

Unitary and Applied Heat Pumps				
Equipment Type	**Size Category (Cooling Capacity)**	**Heating Section Type**	**Subcategory or Rating Condition**	**Baseline Efficiency**
Cooling				
Air cooled (cooling mode)	< 65,000 BTU/h (single phase)	All	Split System	11.8 EER 14.0 SEER
			Single Package	11.8 EER 14.0 SEER
Through-the-wall (air cooled)	≥ 30,000 BTU/h (single phase)	All	Split System	10.6 EER 12.0 SEER
			Single Package	10.6 EER 12.0 SEER
Single-duct high-velocity (air cooled)	< 65,000 BTU/h (single phase)	All	Split System	9.9 EER 11.0 SEER
Air cooled (cooling mode)	≥ 65,000 BTU/h and < 135,000 BTU/h[994]	Electric Resistance (or None)	Split System and Single Package	11.0 EER 12.2 IEER
		All other	Split System and Single Package	10.8 EER 12.0 IEER
	≥ 135,000 BTU/h and < 240,000 BTU/h	Electric Resistance (or None)	Split System and Single Package	10.6 EER 11.6 IEER
		All other	Split System and Single Package	10.4 EER 11.4 IEER
	≥ 240,000 BTU/h[995]	Electric Resistance (or None)	Split System and Single Package	9.5 EER 10.6 IEER
		All other	Split System and Single Package	9.3 EER 10.4 IEER
Heating				
Air cooled (heating mode)	< 65,000 BTU/h (single phase)	—	Split System	8.2 HSPF
		—	Single Package	8.0 HSPF
Through-the-wall (air cooled, heating mode)	≥ 30,000 BTU/h (single phase)	—	Split System	7.4 HSPF
		—	Single Package	7.4 HSPF
Small-duct high velocity (air cooled, heating mode)	< 65,000 BTU/h (single phase)	—	Split System	6.8 HSPF

[994] For equipment with ≥65,000 BTU/h and <135,000 BTU/h cooling capacity, IEER values are taken from 10 CFR 431.97 (Table 3)
[995] For equipment with ≥240,000 BTU/h cooling capacity, IEER values are taken from 10 CFR 431.97 (Table 3)

Unitary and Applied Heat Pumps				
Equipment Type	**Size Category (Cooling Capacity)**	**Heating Section Type**	**Subcategory or Rating Condition**	**Baseline Efficiency**
Air cooled (heating mode)	≥ 65,000 BTU/h and < 135,000 BTU/h	—	47ºF db/43ºF wb Outdoor Air	3.3 COP
			17ºF db/15ºF wb Outdoor Air	2.25 COP
	≥ 135,000 BTU/h	—	47ºF db/43ºF wb Outdoor Air	3.2 COP
			17ºF db/15ºF wb Outdoor Air	2.05 COP

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a high efficiency unitary air conditioning or unitary/applied heat pump system as defined in the Measure Description section. The efficiency of the compliant equipment must exceed the efficiency of the baseline equipment.

Operating Hours

Equipment heating and cooling equivalent full load hours shall be taken from the application. If unknown, default EFLH by facility type and location can be found in Appendix G.

Example Calculation *(Not to be used as default)*

A commercial facility installs a 10 ton air cooled split system air conditioner. The system has a rated IEER of 13.5 and EER of 11.5. The facility has an estimated cooling EFLH of 500 hours. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

$$\Delta kWh = units \times \left[\frac{tons}{unit} \times \left(\frac{12}{IEER_{baseline}} - \frac{12}{IEER_{ee}}\right) \times EFLH_{cooling} + \frac{(kBTU/h)/unit}{3.412} \times \left(\frac{1}{COP_{baseline}} - \frac{1}{COP_{ee}}\right) \times EFLH_{heating}\right]$$

$$\Delta kW = units \times \left[\frac{tons}{unit} \times \left(\frac{12}{EER_{baseline}} - \frac{12}{EER_{ee}}\right) \times CF_{cooling}\right]$$

units = 1, from application
tons/unit = 10, from application
$IEER_{baseline}$ = 12.0, from Baseline Efficiencies table based on equipment type and size from application
$IEER_{ee}$ = 13.5, from application
$EER_{baseline}$ = 10.8, from Baseline Efficiencies based on equipment type and size from application

EER_{ee} = 11.5, from application
CF = 0.8, from Summary of Variables and Data Sources table

$$\Delta kWh = 1 \times \left[10 \times \left(\frac{12}{12.0} - \frac{12}{13.5}\right) \times 500 + 0\right] = 556\ kWh$$

$$\Delta kW = 1 \times \left[10 \times \left(\frac{12}{10.8} - \frac{12}{11.5}\right) \times 0.8\right] = 0.541\ kW$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. ECCCNYS 2020 Chapter 2: Definitions
   Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-2-ce-definitions

2. 2020 Building Code of New York State
   Available from: https://codes.iccsafe.org/content/NYSBC2020P1
3. AHRI Standard 340/360, 2015 Standard for Performance Rating of Commercial and Industrial Unitary Air-Conditioning and Heat Pump Equipment
   Available from:
   http://ahrinet.org/App_Content/ahri/files/STANDARDS/AHRI/AHRI_Standard_340-360_2015.pdf
4. AHRI Standard 210/240 with Addenda 1 and 2, 2008 Standard for Performance Rating of Unitary Air-Conditioning & Air Source Heat Pump Equipment, December 2012
   Available from:
   http://www.ahrinet.org/App_Content/ahri/files/standards%20pdfs/ANSI%20standards%20pdfs/ANSI.AHRI%20Standard%20210.240%20with%20Addenda%201%20and%202.pdf
5. C&I Unitary HVAC Load Shape Project Final Report, KEMA, August 2, 2011, Table 0-6 & Table 0-7
   Available from:
   http://www.neep.org/sites/default/files/resources/NEEP_HVAC_Load_Shape_Report_Final_August2.pdf

6. ECCCNYS 2020 Table C403.3.2(3): Minimum Efficiency Requirements: Electrically Operated Unitary Packaged Terminal Air Conditioners, Packaged Terminal Heat Pumps, Single-Package Vertical Air Conditioners, Single Vertical Heat Pumps, Room Air Conditioners and Room Air Conditioner Heat Pumps
   Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-[ce]-commercial-energy-efficiency#NYSECC2020P1_CE_Ch04_SecC403
7. Building America House Simulation Protocols, Robert Hendron and Cheryn Engebrecht, National Renewable Energy Laboratory, October 2010
   Available from: https://www.nrel.gov/docs/fy11osti/49246.pdf
8. 10 CFR 431.97: Energy Efficiency Standards and Their Compliance Dates, Table 3: Updates to the Minimum Cooling Efficiency Standards for Air Conditioning and Heating Equipment
   Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=69945fdbe7327d148adc5e11b79bda36&node=se10.3.431_197&rgn=div8

Record of Revision

Record of Revision Number	Issue Date
1	10/15/2010
1-17-5	12/31/2016
12-17-2	12/31/2017
12-18-5	12/28/2018

Return to Table of Contents

BOILER, FURNACE AND UNIT HEATER

Measure Description

This measure covers high-efficiency fossil fuel-fired boilers, furnaces and unit heaters used for space heating installed in all buildings except low-rise residential (single and multifamily) applications. The baseline case shall be minimally code compliant equipment of the same type and capacity as in the efficient case, which shall be sized in accordance with federal, state, local and municipal codes and standards

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = N/A$$

Summer Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = units \times \frac{kBTU/h_{in}}{unit} \times \left(\frac{Eff_{ee}}{Eff_{baseline}} - 1\right) \times \frac{EFLH_{heating}}{1{,}000}$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
$kBTU/h_{in}$	= Fuel Input Rating per unit
Eff_{ee}	= Efficiency of energy efficient condition
$Eff_{baseline}$	= Efficiency of baseline condition
$EFLH_{heating}$	= Heating equivalent full-load hours
1,000	= Conversion factor, one MMBtu equals 1,000 kBTU

Summary of Variables and Data Sources

Variable	Value	Notes
$(kBTU/h)_{in}$/unit		Nameplate input rating of the efficient unit, from application.
$Eff_{baseline}$		Lookup based on equipment type, size and applicable energy conservation code from the Baseline Efficiency section below.
Eff_{ee}		From application.
$EFLH_{heating}$		From application. If unknown, lookup based on building type and location from Appendix G.

Efficiency is expressed as the ratio of the fuel input relative to the output heating capacity. The efficiency of furnaces, boilers and unit heaters is customarily evaluated on the basis of one or more of three standards, namely Thermal Efficiency (E_t), Combustion Efficiency, (E_c) and Annual Fuel Utilization Efficiency (AFUE).

Presently, the AFUE value is only applicable to smaller units (<300 kBTU/h for boilers and <225 kBTU/h for furnaces). For larger units, use thermal and combustion efficiencies referenced on manufacturer's nameplate data in accordance with nationally recognized standards and testing agencies.

Coincidence Factor (CF)

The prescribed value for the coincidence factor is N/A.

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a minimally code compliant system of type and capacity equivalent to the efficient condition. The baseline efficiency for commercial furnaces, boilers, and unit heaters is defined by the Code of Federal Regulations (CFR) and subsequently adopted by the Energy Conservation Construction Code of New York State[996] as shown below.

Equipment Type	Size Range	ECCCNYS Minimum Efficiency for Climate Zones 4, 5 and 6
Warm Air Furnace, Gas Fired	< 225 kBTU/h	0.80 AFUE
	≥ 225 kBTU/h	0.80 Et
Warm Air Furnace, Oil Fired	< 225 kBTU/h	0.83 AFUE
	≥ 225 kBTU/h	0.80 Et
Warm Air Unit Heaters, Gas Fired	All Capacities	0.80 Ec
Warm Air Unit Heaters, Oil Fired	All Capacities	0.80 Ec
Boiler, Hot Water, Gas Fired	< 300 kBTU/h	0.82 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.80 Et
	> 2,500 kBTU/h	0.82 Ec
Boiler, Hot Water, Oil Fired	< 300 kBTU/h	0.84 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.82 Et
	> 2,500 kBTU/h	0.84 Ec
Boiler, Steam, Gas Fired, All Except Natural Draft	< 300 kBTU/h	0.80 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.79 Et
	> 2,500 kBTU/h	0.79 Et
Boiler, Steam, Gas Fired, Natural Draft	< 300 kBTU/h	0.80 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.77 Et
	> 2,500 kBTU/h	0.77 Et

[996] ECCCNYS 2020, Table C403.3.2(4) and Table C403.2.3(5)

Equipment Type	Size Range	ECCCNYS Minimum Efficiency for Climate Zones 4, 5 and 6
Boiler, Steam, Oil Fired	< 300 kBTU/h	0.82 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.81 Et
	> 2,500 kBTU/h	0.81 Et

Compliance Efficiency From Which Incentives are Calculated

The compliance condition is a fossil fuel-fired boiler, furnace or unit heater used for space heating as defined in the Measure Description section above. The efficiency of the compliant equipment must exceed the efficiency of the baseline equipment.

Operating Hours

Heating equivalent full-load hours were calculated from a DOE-2.2 simulation of prototypical commercial buildings. Operating hour assumptions for the prototypical building models are described in Appendix A. The heating EFLH for commercial buildings in NY are shown in Appendix G.

Example Calculation *(Not to be used as default)*

A warm air, gas fired furnace is installed in a small commercial facility located near Albany. The 120 kBTU/h furnace has a rated efficiency of 92% AFUE. The facility has an estimated heating EFLH of 1,000 hours. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are not applicable. Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta MMBtu = units \times \frac{kBTU/h_{in}}{unit} \times \left(\frac{Eff_{ee}}{Eff_{baseline}} - 1\right) \times \frac{EFLH_{heating}}{1{,}000}$$

units = 1, from application
$kBTU/h_{in}$ = 120, from application
Eff_{ee} = 0.92, from application
$Eff_{baseline}$ = 0.80, from Baseline Efficiencies section based on equipment type and size from application
$EFLH_{heating}$ = 1,000, from application

$$\Delta MMBtu = 1 \times 120 \times \left(\frac{0.92}{0.80} - 1\right) \times \frac{1{,}000}{1{,}000} = 18.0\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

High efficiency furnaces may be packaged with high efficiency cooling equipment and/or electronically commutated blower motors, which may provide electricity savings. Draft fans, when present, will increase electricity consumption. These ancillary impacts are not included in the savings estimation approach detailed above.

References

1. ECCCNYS 2020 Table C403.3.2(4): Warm-Air Furnaces And Combination Warm-Air Furnaces/Air-Conditioning Units, Warm-Air Duct Furnaces And Unit Heaters, Minimum Efficiency Requirements & Table C403.2.3(5): Minimum Efficiency Requirements: Gas- And Oil-Fired Boilers.
   Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-[ce]-commercial-energy-efficiency#NYSECC2020P1_CE_Ch04_SecC402

Record of Revision

Record of Revision Number	Issue Date
1	10/15/2010
6-15-7	6/1/2015
1-16-4	12/31/2015
12-17-13	12/31/2017

Return to Table of Contents

BOILER AND FURNACE - COMBINATION ("COMBI") BOILER AND FURNACE

Measure Description

This measure covers the installation of fossil fuel combination (or "combi") boilers and furnaces, which are defined as high-efficiency, instantaneous water heaters with a heating designation. Combi-boilers are all-in-one high-efficiency space heating systems with integrated capability for providing instantaneous domestic hot water, while combi-furnaces supply both domestic tankless hot water and forced air heating. These units realize energy savings through increased thermal efficiency and by taking cold water straight from the main supply and heating it as needed, which eliminates the need for a separate hot water storage tank and avoids standby losses. Qualifying equipment must be in accordance with ASHRAE Standard 124-2007 (RA 2016).[997] This measure only applies to systems with modulating/staging capability and no water storage tank.

This measure only captures the fossil fuel savings impacts of combi-boilers and combi-furnaces. While electric combi-boilers exist, more investigation and research is required before an approach for estimating associated energy savings can be developed.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = N/A$$

Summer Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = \Delta MMBtu_{SH} + \Delta MMBtu_{DHW}$$

$$\Delta MMBtu_{SH} = units \times \frac{kBTU/h_{in}}{unit} \times \left(\frac{Eff_{ee}}{Eff_{baseline}} - 1\right) \times \frac{EFLH_{heating}}{1{,}000}$$

$$\Delta MMBtu_{DHW} = units \times \left[\frac{GPD \times 365 \times 8.33 \times \Delta T_{main}}{1{,}000{,}000} \times \left(\frac{1}{E_{t,baseline}} - \frac{1}{Eff_{ee}}\right) + \frac{UA_{baseline}}{E_{t,baseline}} \times \frac{\Delta T_{amb}}{1{,}000{,}000} \times 8{,}760\right]$$

[997] ASHRAE Standard 124-2007 (RA 2016) – Methods of Testing for Rating Combination Space-Heating and Water-Heating Appliances (ANSI Approved)

where:

ΔkWh = Annual electric energy savings
ΔkW = Peak coincident demand electric savings
$\Delta MMBtu$ = Annual fossil fuel energy savings
$\Delta MMBtu_{SH}$ = Annual space heating savings associated with installation of a high-efficiency combi-boiler or combi-furnace
$\Delta MMBtu_{DHW}$ = Annual domestic hot water savings associated with installation of a high-efficiency combi-boiler or combi-furnace
units = Number of measures installed under the program
$kBTU/h_{in}$ = Space heating fuel input rating
$_{baseline}$ = Characteristic of baseline condition
$_{ee}$ = Characteristic of energy efficient condition
Eff = Energy efficiency (0-100%)
$EFLH_{heating}$ = Heating equivalent full-load hours
GPD = Gallons per day
ΔT_{main} = Average difference between the cold inlet temperature and the hot water delivery temperature (°F)
E_t = Water heating designation thermal efficiency
UA = Overall heat loss coefficient (BTU/h-°F)
ΔT_{amb} = Average temperature difference between water heater set point temperature and the surrounding ambient air temperature (°F)
8.33 = Energy required (BTU), to heat one gallon of water by one degree Fahrenheit
365 = Days in one year
1,000 = Conversion factor, one MMBtu equals 1,000 kBTU
8,760 = Hours in one year
1,000,000 = Conversion factor, one MMBtu equals 1,000,000 BTU

Summary of Variables & Data Sources

Variable	Value	Notes/References
$kBTUh_{in}$		Nominal heating input capacity is the nameplate input rating of the unit in kBTU/hr, from application.
$Eff_{baseline}$		See Baseline Efficiencies section below.
Eff_{ee}		From application.
$EFLH_{heating}$		Lookup based on building type and location in Appendix G.
GPD		From application, or lookup/calculate based on building type, square footage and occupancy from GPD table below.
ΔT_{main}	T_{set} - T_{main}	Average temperature difference between water heater set point temperature and the supply water temperature in water main (°F).
ΔT_{amb}	T_{set} - T_{amb}	Average temperature difference between water heater set point temperature and the surrounding ambient air temperature (°F).

Variable	Value	Notes/References
T_{set}		Water heater set point temperature (°F). From application. If unknown use 140°F [998]
T_{main}		Supply water temperature in water main (°F). Lookup in Cold Water Inlet Temperature table below based on nearest city.
T_{amb}	70	Surrounding ambient air temperature (°F).[999]
$E_{t,baseline}$	0.80	Water heating designation thermal efficiency of the baseline condition.[1000]
$UA_{baseline}$	7.85	Overall heat loss coefficient of the baseline condition (BTU/h-°F).[1001]

Gallons per Day (GPD)

The average daily hot water usage, expressed in gallons per day, for several commercial facility types is tabulated below. Daily hot water usage can be calculated based on the GPD and site-specific metric in the Rate column, or default values can be referenced directly from the GPD column.

Building Type	GPD	Rate	Notes/Assumptions	Source
Assembly	239	7.02 GPD per 1,000 SF	Assumes 10% hot water, 34,000 SF	EIA[1002]: Public Assembly
Auto Repair	25	4.89 GPD per 1,000 SF	Assumes 10% hot water, 5,150 SF	EIA: Other
Big Box Retail	448	3.43 GPD per 1,000 SF	Assumes 10% hot water, 130,500 SF	EIA: Mercantile
Community College	1,520	1.9 GPD per person	Assumes 800 students	NREL[1003]: School with Showers
Dormitory	8,600	17.2 GPD per resident	Assumes 500 residents	Water Research Foundation[1004]
Elementary School	250	0.5 GPD per student	Assumes 500 students	NREL: School
Fast Food Restaurant	500	500 GPD per restaurant		FSTC[1005]: Quick Service
Full-Service Restaurant	2,500	2,500 GPD per restaurant		FSTC: Full Service
Grocery	172	3.43 GPD per 1,000 SF	Assumes 10% hot water, 50,000 SF	EIA: Mercantile
High School	1,520	1.9 GPD per person	Assumes 800 students	NREL: School with Showers
Hospital	16,938	54.42 GPD per 1,000 SF	Assumes 40% hot water, 250,000 SF	EIA: Health Care, Inpatient
Hotel	9,104	45.52 GPD per 1,000 SF	Assumes 40% hot water, 200,000 SF	EIA: Lodging
Large Office	550	1.1 GPD per person	Assumes 500 people	NREL: Office

[998] Per OSHA recommendations for prevention of Legionella bacterial growth (https://www.osha.gov/SLTC/etools/hospital/hazards/leg/leg.html)

[999] Water heaters are generally located in conditioned or partially conditioned spaces with a typical average temperature of 65°F to 70°F to avoid freezing. A value of 70°F is used for the purposes of estimating tank/ambient air temperature differential, which aligns with standby loss specification testing standards.

[1000] 10 CFR 431.110 (a)

[1001] Based on computation of heat loss coefficients via conversion equations found in 10 CFR 429, 430, and 431 Docket No. EERE-2015-BT-TP-0007, Energy Conservation Program for Consumer Products and Certain Commercial and Industrial Equipment: Test Procedures for Consumer and Commercial Water Heaters. Heat loss coefficient was calculated for a minimally code compliant fuel storage water heater found to be the most typical in terms of storage and input capacity, representing storage type water heaters of between 20 and 55 gallon capacity (40 gallon, 40,000 Btu/h assumed). Results of heat loss coefficient evaluation for this assumed baseline is used to represent the $UA_{baseline}$ term.

[1002] U.S. Energy Information Administration, 2012 Commercial Buildings Energy Consumption Survey: Water Consumption in Large Buildings, Table WD1. Daily water consumption in large commercial buildings, 2012

[1003] National Renewable Energy Laboratory, Saving Energy in Commercial Buildings: Domestic Hot Water Assessment Guidelines, Table 1. Hot Water Use By Building Type, June 2011

[1004] Water Research Foundation: Residential End Uses of Water, Version 2, April 2016

[1005] Food Service Technology Center, Design Guide – Energy Efficient Heating, Delivery and Use, Table 1. Typical hot water system cost for restaurants, March 2010

Building Type	GPD	Rate	Notes/Assumptions	Source
Large Retail	446	3.43 GPD per 1,000 SF	Assumes 10% hot water, 130,000 SF	EIA: Mercantile
Light Industrial	489	4.89 GPD per 1,000 SF	Assumes 10% hot water, 100,000 SF	EIA: Other
Motel	1,366	45.52 GPD per 1,000 SF	Assumes 40% hot water, 30,000 SF	EIA: Lodging
Multifamily High-Rise	4,600	46 GPD per unit	Assumes 100 units	Water Research Foundation
Multifamily Low-Rise	552	46 GPD per unit	Assumes 12 units	Water Research Foundation
Refrigerated Warehouse	86	0.93 GPD per 1,000 SF	Assumes 10% hot water, 92,000 SF	EIA: Warehouse and Storage
Religious	77	7.02 GPD per 1,000 SF	Assumes 10% hot water, 11,000 SF	EIA: Public Assembly
Small Office	110	1.1 GPD per person	Assumes 100 people	NREL: Office
Small Retail	27	3.43 GPD per 1,000 SF	Assumes 10% hot water, 8,000 SF	EIA: Mercantile
University	1,000	0.5 GPD per student	Assumes 2,000 students	NREL: School
Warehouse	465	0.93 GPD per 1,000 SF	Assumes 10% hot water, 500,000 SF	EIA: Warehouse and Storage
Other	Calculate	4.89 GPD per 1,000 SF	Assumes 10% hot water	EIA: Other

Cold Water Inlet Temperature (T_{main})

Supply water main temperatures vary according to climate and are approximately equal to the annual average outdoor temperature plus 6°F.[1006] Supply main temperatures based on the annual outdoor temperature are shown below.

City	Annual average outdoor temperature[1007] (°F)	T_{main} (°F)
Albany	48.3	54.3
Binghamton	46.3	52.3
Buffalo	48.3	54.3
Massena	43.5	49.5
NYC	55.4	61.4
Poughkeepsie	49.8	55.8
Syracuse	48.3	54.3

Coincidence Factor (CF)

The prescribed value for the coincidence factor is N/A.

Baseline Efficiencies from which Energy Savings are Calculated

Space Heating Component

The baseline condition for the space heating component of combi-boilers and combi-furnaces shall be consistent with code requirements for commercial fossil fuel-fired furnaces and boilers defined by the Code of Federal Regulations (CFR) and subsequently adopted by the Energy Conservation Construction Code of New York State. The table below establishes the prescribed baseline efficiency values for combi-furnaces and combi-boilers by input capacity. For combi-furnaces < 225 kBTU/h, selection of efficiency rating (AFUE or E_t) should align with the rating specification of the qualifying equipment.

[1006] Burch, Jay and Christensen, Craig, "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory

[1007] Average annual outdoor temperatures taken from NCDC 1981-2010 climate normals

Equipment Type	Size Range	ECCCNYS Minimum Efficiency for Climate Zones 4, 5 and 6
Warm Air Furnace, Gas Fired	< 225 kBTU/h	0.80 AFUE or 0.80 E_t
	≥ 225 kBTU/h	0.80 Et
Warm Air Furnace, Oil Fired	< 225 kBTU/h	0.83 AFUE or 0.80 E_t
	≥ 225 kBTU/h	0.80 Et
Warm Air Unit Heaters, Gas Fired	All Capacities	0.80 Ec
Warm Air Unit Heaters, Oil Fired	All Capacities	0.80 Ec
Boiler, Hot Water, Gas Fired	< 300 kBTU/h	0.82 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.80 Et
	> 2,500 kBTU/h	0.82 Ec
Boiler, Hot Water, Oil Fired	< 300 kBTU/h	0.84 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.82 Et
	> 2,500 kBTU/h	0.84 Ec
Boiler, Steam, Gas Fired, All Except Natural Draft	< 300 kBTU/h	0.80 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.79 Et
	> 2,500 kBTU/h	0.79 Et
Boiler, Steam, Gas Fired, Natural Draft	< 300 kBTU/h	0.80 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.77 Et
	> 2,500 kBTU/h	0.77 Et
Boiler, Hot Water, Oil Fired	< 300 kBTU/h	0.82 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.81 Et
	> 2,500 kBTU/h	0.81 Et
Boiler, Steam, Oil Fired	< 300 kBTU/h	0.82 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.81 Et
	> 2,500 kBTU/h	0.81 Et

Domestic Hot Water Component

The baseline condition is a standard efficiency storage type water heater with a thermal efficiency of 80%[1008] and heat loss coefficient of 7.85 BTU/hr-°F.[1009]

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a combi-boiler unit with a heating designation efficiency of 90% AFUE, E_t or E_c or greater or a combi-furnace unit with a heating designation efficiency of 92%

[1008] 10 CFR 431.110 (a)

[1009] Based on computation of heat loss coefficients via conversion equations found in 10 CFR 429, 430, and 431 Docket No. EERE-2015-BT-TP-0007, Energy Conservation Program for Consumer Products and Certain Commercial and Industrial Equipment: Test Procedures for Consumer and Commercial Water Heaters. Heat loss coefficient was calculated for a minimally code compliant gas storage water heater found to be the most typical in terms of storage and input capacity, representing storage type water heaters of between 20 and 55 gallon capacity (40 gallon, 40,000 Btu/h assumed). Results of heat loss coefficient evaluation for this assumed baseline is used to represent the $UA_{baseline}$ term.

AFUE or E_t or greater. Qualifying systems must be equipped with modulating/staging capability and no water storage tank. Units shall be in accordance with ASHRAE Standard 124-2007 (RA 2016).[1010]

Operating Hours

Heating equivalent full-load hours were calculated from a DOE-2.2 simulation of prototypical commercial buildings. Operating hour assumptions for the prototypical building models are described in Appendix A. The heating EFLH for commercial buildings in NY are shown in Appendix G.

Domestic hot water heaters are assumed to be available for operation 8,760 hours per year, and it is assumed standby losses in the baseline case are incurred 8,760 hours per year.

Example Calculation *(Not to be used as default)*

A "combi" boiler with 199 kBTU/h and 95% AFUE is installed in a small office building located near Albany. The conditions prior to installation include a gas-fired warm air furnace and gas-fired storage type water heater. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are not applicable. Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta MMBtu = \Delta MMBtu_{SH} + \Delta MMBtu_{DHW}$$

$$\Delta MMBtu_{SH} = units \times \frac{kBTU/h_{in}}{unit} \times \left(\frac{Eff_{ee}}{Eff_{baseline}} - 1\right) \times \frac{EFLH_{heating}}{1{,}000}$$

$$\Delta MMBtu_{DHW} = units \times \left[\frac{GPD \times 365 \times 8.33 \times \Delta T_{main}}{1{,}000{,}000} \times \left(\frac{1}{E_{t,baseline}} - \frac{1}{Eff_{ee}}\right) + \frac{UA_{baseline}}{E_{t,baseline}} \times \frac{\Delta T_{amb}}{1{,}000{,}000} \times 8{,}760\right]$$

units = 1, from application
$(kBTU/h_{in})/unit$ = 199, from application
Eff_{ee} = 0.9, from application
$Eff_{baseline}$ = 0.80, from Baseline Efficiencies section based on equipment type and size from application
$EFLH_{heating}$ = 747, from Appendix G based on HVAC system, building type, and location from application
GPD = 110, from Gallons per Day table based on building type from application
$\Delta T_{main} = T_{set} - T_{main} = 140 - 54.3 = 85.7$
T_{set} from Summary of Variables and Data Sources table

[1010] ASHRAE Standard 124-2007 (RA 2016) – Methods of Testing for Rating Combination Space-Heating and Water-Heating Appliances (ANSI Approved)

T_{main} from Cold Water Inlet Temperature lookup table based on location from application

$UA_{baseline}$ = 7.85, from Summary of Variables and Data Sources table

$E_{t,baseline}$ = 0.8, from Summary of Variables and Data Sources table

$\Delta T_{amb} = T_{set} - T_{amb} = 140 - 70 = 70$

T_{set} from Summary of Variables and Data Sources table

T_{amb} from Summary of Variables and Data Sources table

$$\Delta MMBtu_{SH} = 1 \times 199 \times \left(\frac{0.95}{0.80} - 1\right) \times \frac{747}{1{,}000} = 27.9\ MMBtu$$

$$\Delta MMBtu_{DHW} = 1 \times \left[\frac{110 \times 365 \times 8.33 \times 85.7}{1{,}000{,}000} \times \left(\frac{1}{0.8} - \frac{1}{0.95}\right) + \frac{7.85}{0.8} \times \frac{70}{1{,}000{,}000} \times\ 8{,}760\right] = 11.7\ MMBtu$$

$$\Delta MMBtu = 27.9 + 11.7 = 39.6\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

High efficiency furnaces may be packaged with high efficiency cooling equipment and/or electronically commutated blower motors, which may provide electricity savings. Draft fans, when present, will increase electricity consumption.

References

1. ASHRAE Standard 124-2007 (RA 2016) – Methods of Testing for Rating Combination Space-Heating and Water-Heating Appliances (ANSI Approved)
2. 10 CFR 431.110 Energy conservation standards and their effective dates Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=64f994924a5f31b841cab23a6d543f85&mc=true&node=pt10.3.431&rgn=div5#se10.3.431_1110

3. 10 CFR 430 Appendix E to Subpart B of Part 430 Uniform Test Method for Measuring the Energy Consumption of Water Heaters, Section 2. Test Conditions, 2.5 Set Point Temperature.
   Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=80dfa785ea350ebeee184bb0ae03e7f0&mc=true&node=ap10.3.430_127.e&rgn=div9
4. 10 CFR 429, 430, and 431 Docket No. EERE-2015-BT-TP-0007, Energy Conservation Program for Consumer Products and Certain Commercial and Industrial Equipment: Test Procedures for Consumer and Commercial Water Heaters
   Available from: https://energy.gov/sites/prod/files/2016/08/f33/Water%20Heaters%20Test%20Procedure%20SNOPR.pdf
5. AHRI Directory of Certified Product Performance
   Available from: https://www.ahridirectory.org/ahridirectory/pages/home.aspx
6. U.S. Energy Information Administration, 2012 Commercial Buildings Energy Consumption Survey: Water Consumption in Large Buildings, Table WD1. Daily water consumption in large commercial buildings, 2012
   Available from: https://www.eia.gov/consumption/commercial/reports/2012/water/
7. National Renewable Energy Laboratory, Saving Energy in Commercial Buildings: Domestic Hot Water Assessment Guidelines, Table 1. Hot Water Use By Building Type, June 2011
   Available from: https://www.nrel.gov/docs/fy11osti/50118.pdf
8. Water Research Foundation: "Residential End Uses of Water, Version 2: Executive Report", April 2016
   Available from: https://www.waterrf.org/research/projects/residential-end-uses-water-version-2
9. Food Service Technology Center, Design Guide – Energy Efficient Heating, Delivery and Use, Table 1. Typical hot water system cost for restaurants, March 2010
10. Burch, Jay and Craig Christensen; "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory.
    Available from: http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.515.6885
11. NOAA National Centers for Environmental Information – NCEI 1981-2010 Climate Normals
    Available from: https://www.ncdc.noaa.gov/cdo-web/datatools/normals
12. ECCCNYS 2020 Table C403.3.2(4): Warm-Air Furnaces And Combination Warm-Air Furnaces/Air-Conditioning Units, Warm-Air Duct Furnaces And Unit Heaters, Minimum Efficiency Requirements & Table C403.2.3(5): Minimum Efficiency Requirements: Gas- And Oil-Fired Boilers.
    Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-[ce]-commercial-energy-efficiency#NYSECC2020P1_CE_Ch04_SecC402

Record of Revision

Record of Revision Number	Issue Date
3-19-12	3/29/2019

Return to Table of Contents

BOILER ECONOMIZER

Measure Description

This measure covers the installation of a boiler economizer. Also known as stack economizers and feedwater economizers, boiler economizers are designed to recover heat from hot flue gases. Recovered heat is used to pre-heat boiler feedwater, reducing heating requirements. Condensing and conventional economizers are the two principal types of boiler economizers. Conventional, or non-condensing economizers are typically air-to-water heat exchangers and operate above the dew point of the flue gas to avoid condensation.[1011] Condensing economizers are designed to allow condensing of the exhaust gas components and reduce the flue gas temperature below its dew point. Condensing economizers recapture latent heat, resulting in improved effectiveness of waste heat recovery.[1012] This measure is applicable to the installation of condensing and non-condensing economizers on boilers serving space heating loads and process loads and is restricted to non-condensing, forced draft burner boilers.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = N/A$$

Summer Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = units \times (kBTU/h_{in})/unit \times \frac{ESF \times hrs}{1{,}000}$$

where:

$$ESF = \frac{(T_{baseline} - T_{ee})}{40} \times TRE$$

where:

ΔkWh	= Annual electricity energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
$(kBTU/h_{in})/unit$	= Fuel input rating per boiler, based on nameplate data
ESF	= Energy Savings Factor[1013]
hrs	= System full load operating hours (see Summary of Variables and Data Sources for details)

[1011] US DOE, Improving Steam System Performance: A Sourcebook for Industry, Second Edition
[1012] US DOE, Steam Tip Sheet #26B, Considerations When Selecting a Condensing Economizer
[1013] US DOE, Steam Tip Sheet #3, Use Feedwater Economizers for Waste Heat Recovery

baseline	= Characteristic of baseline condition
ee	= Characteristic of energy efficient condition
T	= Full-fire boiler flue gas temperature as it exits the stack, in ºF
TRE	= Temperature Reduction Efficiency; percentage efficiency increases for stack temperature reduction, per 40ºF reduction in net stack temperature
40	= Stepped reduction in net stack temperature, in ºF
1,000	= Conversion factor, one MMBTU equals to 1,000 kBTU

Summary of Variables and Data Sources

Variable	Value	Notes
(kBTU/h_{in})/unit		Nominal heating input capacity is the nameplate input rating of the unit in kBTU/h, from application.
$T_{baseline}$		From application. If unknown, use a default of 420ºF for hot water boilers and 500ºF for steam boilers.[1014]
T_{ee}		From application. If unknown, lookup from the Compliance Efficiency section below based on boiler and economizer.
TRE		From application. If unknown, use default of 0.01.[1015]
hrs		For space heating boilers, use $EFLH_{heating}$, lookup based on building type and location in Appendix G. For process loads, input value from application.

Coincidence Factor (CF)

The prescribed coincidence factor for this measure is N/A.

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a non-condensing, forced draft burner boiler serving space heating or process loads without a stack economizer.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a non-condensing, forced draft burner boiler serving space heating or process loads with a non-condensing or condensing stack economizer.

[1014] Assumes hot water boiler efficiency of 82% and steam boiler efficiency of 80% based on ECCCNYS 2020, Table C403.3.2(5)
[1015] US DOE, Steam Tip Sheet #3, Use Feedwater Economizers for Waste Heat Recovery

Equipment Type	Energy Efficient Boiler Flue Gas Temperature (T_{ee})	
	Conventional Economizer[1016,1017]	Condensing Economizer[1018,1019]
Hot Water Boiler	335°F	247.5°F
Steam Boiler	375°F	287.5°F

Operating Hours

For boilers serving space heating loads, equipment heating and cooling equivalent full load hours shall be taken from the application. If unknown, default EFLH by facility type and location can be found in Appendix G.

For boilers serving process loads, operating hours shall come from application.

Example Calculation *(Not to be used as default)*

A 23,500 MBh firetube steam boiler at a hospital near albany is equipped with a stack economizer, reducing the flue gas temperature from 480ºF to 315ºF The heating EFLH of the facility is estimated at 2,500 hours. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are not applicable. Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta MMBtu = units \times (kBTU/h_{in})/unit \times \frac{ESF \times hrs}{1{,}000}$$

units = 1, from application
$(kBTU/h_{in})$/unit = 23,500, from application
ESF = $((T_{baseline} - T_{ee}) / 40) \times TRE = (480 - 315) / 40) \times 0.01 = 0.04125$
ESF equation from where section of algorithms
$T_{baseline}$ from application
T_{ee} from application
TRE = 0.01, from Summary of Variables and Data Sources table
hrs = 2,500, from application

$$\Delta MMBtu = 1 \times 23{,}500 \times \frac{0.04125 \times 2{,}500}{1{,}000} = 2{,}423\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

[1016] As cited in U.S. DOE, Steam Tip Sheet #26A, Consider Installing a Condensing Economizer, the minimum stack temperature for a non-condensing economizer is 250°F. The average temperature drop is assumed to be halfway between the baseline and efficient temperature minimum: (420°F + 250°F) / 2 = 335°F
[1017] Ibid, the minimum stack temperature for a non-condensing economizer is 250°F: (500°F + 250°F) / 2 = 375°F
[1018] Ibid, the minimum stack temperature for a condensing economizer is 75°F: (420°F + 75°F) / 2 = 247.5°F
[1019] Ibid, the minimum stack temperature for a condensing economizer is 75°F: (500°F + 75°F) / 2 = 287.5°F

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. U.S. Department of Energy, Energy Efficiency and Renewable Energy. Improving Steam System Performance: A Sourcebook for Industry, Second Edition. October 2012. Available from: https://www.nrel.gov/docs/fy13osti/51710.pdf
2. U.S. Department of Energy, Energy Efficiency and Renewable Energy. Steam Tip Sheet #26A, *Consider Installing a Condensing Economizer*. January 2012. Available from: https://www.energy.gov/sites/prod/files/2014/05/f16/steam26a_condensing.pdf
3. U.S. Department of Energy, Energy Efficiency and Renewable Energy. Steam Tip Sheet #26B, *Considerations when Selecting a Condensing Economizer*. January 2012. Available from: https://www.energy.gov/sites/prod/files/2014/05/f16/steam26b_condensing.pdf
4. U.S. Department of Energy, Energy Efficiency and Renewable Energy. Steam Tip Sheet #3, *Use Feedwater Economizers for Waste Heat Recovery*. January 2012. Available from: https://www.energy.gov/sites/prod/files/2014/05/f16/steam3_recovery.pdf
5. ECCCNYS 2020 Table C403.3.2(5): Minimum Efficiency Requirements: Gas- And Oil-Fired Boilers & Table C404.2: Minimum Performance of Water Heating Equipment Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-ce-commercial-energy-efficiency

Record of Revision

Record of Revision Number	Issue Date
12-20-8	12/31/2020

Return to Table of Contents

CHILLER - AIR AND WATER COOLED

Measure Description

This measure applies to constant and variable speed electric air-cooled and water-cooled chillers in commercial buildings with built-up HVAC systems.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times tons/unit \times (IPLV_{baseline} - IPLV_{ee}) \times EFLH_{cooling}$$

Summer Peak Coincident Demand Savings

$$\Delta kW = units \times tons/unit \times (FL_{baseline} - FL_{ee}) \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
tons/unit	= Tons of air conditioning per unit, based on nameplate data
$_{baseline}$	= Characteristic of baseline condition
$_{ee}$	= Characteristic of energy efficient condition
IPLV	= Integrated part-load value (in kW/Ton)
FL	= Full-load chiller efficiency under peak conditions
$EFLH_{cooling}$	= Cooling equivalent full-load hours
CF	= Coincidence factor

Summary of Variables and Data Sources

Variable	Value	Notes
tons		From application
$FL_{baseline}$		Full-load efficiency of baseline chiller under peak conditions, lookup based on chiller type and size from Baseline Efficiencies tables below. Use Path A values for constant speed chillers and Path B values for variable speed chillers (based on proposed case).
FL_{ee}		Full-load efficiency of energy efficiency chiller, from application.

Variable	Value	Notes
$IPLV_{baseline}$		Integrated part-load value (kW/ton) of baseline chiller, lookup based on chiller type and size from Baseline Efficiencies tables below. Use Path A values for constant speed chillers and Path B values for variable speed chillers (based on proposed case).
$IPLV_{ee}$		Integrated part-load value (kW/ton) for energy efficient measure, from application.
$EFLH_{cooling}$		Cooling equivalent full-load hours, lookup by city, building type and HVAC type from Appendix G.
CF	0.8	

The rated full-load kW/ton (FL) at AHRI rating conditions is used to define the efficiency under peak conditions. The IPLV as defined by AHRI is used to define the annual average efficiency. Note, chiller full-load efficiency or IPLV may also be expressed as coefficient of performance (COP). To convert chiller efficiency from COP to kW/ton, use the following equation:
kW/ton = 3.517 / COP.

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.8. [1020]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline full load and IPLV kW/Ton values listed in the tables below, per the 2020 Energy Conservation Construction Code of New York State[1021] and shall be used. Path A values shall be used for proposed constant speed chillers and Path B values for proposed variable speed chillers.

Path A – Constant Speed Chillers

Equipment Type	Size Category	ECCCNYS Maximum Full Load (kW/Ton)	ECCCNYS Maximum IPLV (kW/Ton)
Air-Cooled Chillers	< 150 Tons	1.188	0.876
	≥ 150 Tons	1.188	0.857
Water-Cooled, Positive Displacement	< 75 Tons	0.750	0.600
	≥ 75 Tons and < 150 Tons	0.720	0.560
	≥ 150 Tons and < 300 Tons	0.660	0.540
	≥ 300 Tons and < 600 Tons	0.610	0.520
	≥ 600 Tons	0.560	0.500
Water Cooled, Centrifugal	< 150 Tons	0.610	0.550
	≥ 150 Tons and < 300 Tons	0.610	0.550
	≥ 300 Tons and < 400 Tons	0.560	0.520
	≥ 400 Tons and < 600 Tons	0.560	0.500
	≥ 600 Tons	0.560	0.500

[1020] *No source specified – update pending availability and review of applicable references.*
[1021] ECCCNYS 2020, Table C403.3.2(7)

Path B – Variable Speed Chillers

Equipment Type	Size Category	ECCCNYS Maximum Full Load (kW/Ton)	ECCCNYS Maximum IPLV (kW/Ton)
Air-Cooled Chillers	< 150 Tons	1.237	0.759
	≥ 150 Tons	1.237	0.745
Water-Cooled, Positive Displacement	< 75 Tons	0.780	0.500
	≥ 75 Tons and < 150 Tons	0.750	0.490
	≥ 150 Tons and < 300 Tons	0.680	0.440
	≥ 300 Tons and < 600 Tons	0.625	0.410
	≥ 600 Tons	0.585	0.380
Water Cooled, Centrifugal	< 150 Tons	0.695	0.440
	≥ 150 Tons and < 300 Tons	0.635	0.400
	≥ 300 Tons and < 400 Tons	0.595	0.390
	≥ 400 Tons and < 600 Tons	0.585	0.380
	≥ 600 Tons	0.585	0.380

Compliance Efficiency from which Incentives are Calculated

Compliance condition is a constant or variable speed electric air-cooled or water-cooled chiller which exceeds the baseline efficiency.

Operating Hours

Cooling equivalent full-load hours (EFLH) were calculated from a DOE-2.2 simulation of prototypical large office building. The prototype building characteristics are described in Appendix A. The $EFLH_{cooling}$ for built-up HVAC systems in commercial buildings by climate zone and building type are shown in Appendix G.

Example Calculation *(Not to be used as default)*

Two 300-ton variable speed water-cooled centrifugal chillers are installed in a new construction hotel building located near Albany. The chillers have rated IPLV efficiency of 0.350 kW/ton and full load efficiency of 0.520 kW/ton. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

$$\Delta kWh = units \times tons/unit \times (IPLV_{baseline} - IPLV_{ee}) \times EFLH_{cooling}$$

$$\Delta kW = units \times tons/unit \times (FL_{baseline} - FL_{ee}) \times CF$$

units = 2, from application
tons/unit = 300, from application
$IPLV_{baseline}$ = 0.390, from Baseline Efficiencies section tables based on chiller type and size from application

$IPLV_{ee}$ = 0.350, from application
$EFLH_{cooling}$ = 2,702, from Appendix G based on building type and location from application
$FL_{baseline}$ = 0.595, from Baseline Efficiencies section tables based on chiller type and size from application
FL_{ee} = 0.520, from application
CF = 0.8, from Summary of Variables and Data Sources table

$$\Delta kWh = 2 \times 300 \times (0.390 - 0.350) \times 2{,}702 = 64{,}848\ kWh$$

$$\Delta kW = 2 \times 300 \times (0.595 - 0.520) \times 0.8 = 36.0\ kW$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. ECCCNYS 2020 Table C403.3.2(7): Water Chilling Packages – Efficiency Requirements Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-[ce]-commercial-energy-efficiency#NYSECC2020P1_CE_Ch04_SecC403

Record of Revision

Record of Revision Number	Issue Date
1	10/15/2010
9-17-3	9/30/2017

Return to Table of Contents

CHILLER - COOLING TOWER

Measure Description

This measure covers the installation of close approach cooling towers applied to water-cooled chillers used for space cooling. Electric consumption and summer peak coincident demand savings are achieved through the installation of an over-sized cooling tower designed to provide an approach of ≤ 6°F at standard rating conditions. This measure addresses approach temperature only, which is defined as the difference between the cold water temperature (cooling tower outlet) and ambient wet bulb temperature. Changes in condenser water set point control strategies are not included.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times tons \times (\Delta kWh/ton)$$

Summer Peak Coincident Demand Savings

$$\Delta kW = units \times tons \times (\Delta kW/ton) \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
tons	= Size of cooling system (in tons) being retrofitted with a close approach tower
(ΔkWh/ton)	= Annual electric energy savings per ton of cooling
(ΔkW/ton)	= Electric demand savings per ton of cooling
CF	= Coincidence factor

Summary of Variables and Data Sources

Variable	Value	Notes
tons		From application
(ΔkWh/ton)		Annual electric energy savings per ton of cooling system retrofitted with close approach tower. Look up in Appendix J based on building type, HVAC type and location.
(ΔkW/ton)		Electric demand savings per ton of cooling system retrofitted with close approach tower. Look up in Appendix J based on building type, HVAC type and location
CF	0.8	

Unit energy savings were calculated from a DOE-2.2 simulation of commercial buildings with built-up HVAC systems. The prototype building characteristics are described in Appendix A. The unit energy savings by building type across different cities in NY are shown in Appendix J.

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.8.[1022]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a standard cooling tower with a 10°F approach temperature under standard rating conditions.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a close approach cooling tower with a 6°F approach temperature under standard rating conditions.

Operating Hours

The HVAC system operating hours vary by building type. Operating hour assumptions for the prototypical building models are described in Appendix A.

Example Calculation *(Not to be used as default)*

A close approach cooling tower is installed to remove heat from a 300-ton chiller plant serving a dormintory building located near Albany. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

$$\Delta kWh = units \times tons \times (\Delta kWh/ton)$$

$$\Delta kW = units \times tons \times (\Delta kW/ton) \times CF$$

units = 1, from application
Tons = 300, from application
(ΔkWh/ton) = 6.7, from Appendix J based on building type and location from application
(ΔkW/ton) = 0.003, from Appendix J based on building type and location from application
CF = 0.8, from Summary of Variables and Data Sources table

$$\Delta kWh = 1 \times 300 \times 6.7 = 2{,}010\ kWh$$

$$\Delta kW = 1 \times 300 \times 0.003 \times 0.9kW$$

[1022] *No source specified – update pending availability and review of applicable references.*

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

N/A

Record of Revision

Record of Revision Number	Issue Date
1	10/15/2010
12-17-12	12/31/2017

Return to Table of Contents

DUCT SEALING AND INSULATION

Measure Description

This measure covers the installation of sealing and insulation of the space heating and air conditioning distribution system (including air handlers, filter boxes and building cavities used as ducts before code change) in the unconditioned spaces of commercial facilities. Duct sealing and insulation reduces air and thermal leakage into unconditioned and outdoor spaces, improving system efficiency. Sealing and insulation installed under this measure shall meet or exceed all applicable construction code requirements. This measure is only applicable in existing buildings. This excludes gut rehab projects, which shall be considered new construction. Only ductwork located outside of the thermal envelope is eligible for energy savings.

This measure is to be implemented with a visual inspection and an outdoor duct leakage test on the distribution system pre- and post-implementation.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

For AC and HP Units with Capacity <65,000 BTU/h

$$\Delta kWh = \left[tons \times \frac{12}{SEER} \times EFLH_{cooling} \times \left(1 - \frac{Eff_{dist,cooling,baseline}}{Eff_{dist,cooling,ee}}\right) \times \left(1 - TRF_{cooling}\right)\right] + \left[kBTU/h_{out} \times \frac{1}{HSPF} \times EFLH_{heating} \times \left(1 - \frac{Eff_{dist,heating,baseline}}{Eff_{dist,heating,ee}}\right) \times \left(1 - TRF_{heating}\right)\right]$$

For AC and HP Units with Capacity ≥65,000 BTU/h

$$\Delta kWh = \left[tons \times \frac{12}{IEER} \times EFLH_{cooling} \times \left(1 - \frac{Eff_{dist,cooling,baseline}}{Eff_{dist,cooling,ee}}\right) \times \left(1 - TRF_{cooling}\right)\right] + \left[\frac{kBTU/h_{out}}{3.412} \times \frac{1}{COP} \times EFLH_{heating} \times \left(1 - \frac{Eff_{dist,heating,baseline}}{Eff_{dist,heating,ee}}\right) \times \left(1 - TRF_{heating}\right)\right]$$

For Electric Furnaces

$$\Delta kWh = kW_{in} \times EFLH_{heating} \times \left(1 - \frac{Eff_{dist,heating,baseline}}{Eff_{dist,heating,ee}}\right) \times \left(1 - TRF_{heating}\right)$$

Summer Peak Coincident Demand Savings

For AC and HP Units

$$\Delta kW = tons \times \frac{12}{EER} \times \left(1 - \frac{Eff_{dist,cooling,baseline}}{Eff_{dist,cooling,ee}}\right) \times \left(1 - TRF_{cooling}\right) \times CF$$

Annual Fossil Fuel Energy Savings

<u>For Fossil Fuel-Fired Furnaces with Capacity < 225,000 BTU/h</u>

$$\Delta MMBtu = \frac{kBTU/h_{in}}{1{,}000} \times EFLH_{heating} \times \left(1 - \frac{Eff_{dist,heating,baseline}}{Eff_{dist,heating,ee}}\right) \times \left(1 - TRF_{heating}\right)$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
tons	= Output cooling capacity in tons (at AHRI standard rating conditions)
$kBTU/h_{out}$	= Output heating capacity in kBTU/h (at AHRI standard high-temperature rating conditions)
kW_{in}	= Input heating capacity in kW
$kBTU/h_{in}$	= Input heating capacity in kBTU/h (at AHRI standard high-temperature rating conditions)
TRF	= Thermal Regain Factor
SEER	= Seasonal energy efficiency ratio in BTU/watt-hour. Total cooling output of an air conditioner during its normal annual usage period for cooling in BTU, divided by the total electric energy input during the same period in watt-hours
IEER	= Integrated energy efficiency ratio in BTU/watt-hour. A weighted calculation of mechanical cooling efficiencies at full load and part load AHRI standard rating conditions
EER	= Energy efficiency ratio under peak conditions in BTU/watt-hour. Measurement of the cooling capacity for a unit in BTU/h divided by the connected electric power of the unit in watts (at AHRI standard rating conditions)
HSPF	= Heating seasonal performance factor, total heating output (supply heat) in BTU (including electric strip heat) during the heating season divided by the total electric energy heat pump consumed in watt-hours
COP	= Coefficient of performance, ratio of output energy/input energy (at AHRI standard high-temperature rating conditions)
$EFLH_{cooling}$	= Cooling equivalent full-load hours
$EFLH_{heating}$	= Heating equivalent full-load hours
$_{baseline}$	= Characteristic of baseline condition
$_{ee}$	= Characteristic of energy efficient condition
Eff_{dist}	= Distribution system efficiency
CF	= Coincidence factor
3.412	= Conversion factor, one watt-hour equals 3.412 BTU
12	= (kBTU/h)/ton of air conditioning capacity
1,000	= Conversion factor, one MMBtu equals 1,000 kBTU

Summary of Variables and Data Sources

Variable	Value	Notes
tons		From application.
$kBTU/h_{out}$		From application.

Variable	Value	Notes
kW_{in}		From application.
$kBTU/h_{in}$		From application.
$TRF_{cooling}$		See table in the Thermal Regain Factor section below.
$TRF_{heating}$		See table in the Thermal Regain Factor section below.
IEER		Actual equipment nameplate IEER.
EER		Actual equipment nameplate EER.
HSPF		Actual equipment nameplate HSPF.
COP		Actual equipment nameplate COP.
$EFLH_{heating}$		From application. If unknown, look up based on building type, vintage and location from Appendix G.
$EFLH_{cooling}$		From application. If unknown, look up based on building type, vintage and location from Appendix G.
$Eff_{dist,cooling,baseline}$		Look up in Appendix H for uninsulated duct system based on building type, location and duct leakage in cooling mode.
$Eff_{dist,heating,baseline}$		Look up in Appendix H for uninsulated duct system based on building type, location and duct leakage in heating mode.
$Eff_{dist,cooling,ee}$		Look up in Appendix H for R-6 insulated duct system based on building type, location and duct leakage in cooling mode.
$Eff_{dist,heating,ee}$		Look up in Appendix H for R-6 insulated duct system based on building type, location and duct leakage in heating mode.
CF	0.8	

Thermal Regain Factor[1023]

Some energy loss from poorly sealed and insulated ducts can be regained through conduction back into conditioned spaces. The table below lists default thermal regain factors depending on the location of the ductwork.

Duct Location	$TRF_{cooling}$	$TRF_{heating}$
Attic	0.10	0.10
Garage	0.10	0.10
Crawl space, unvented, uninsulated	0.60	0.60
Crawl Space, Unvented, Insulated Building Floor and Crawl Space walls	0.60	0.30
Crawl Space, Unvented, Insulated Floor Only	0.30	0.30
Crawl Space, Vented, Uninsulated	0.60	0.55
Crawl Space, Insulated Building Floor and Crawl Space Walls	0.63	0.60
Crawl Space, Vented, Insulated Floor Only	0.30	0.30
Basement, Uninsulated	0.50	0.50
Basement, Insulated Walls	0.60	0.60
Under-slab	0.20	0.20

[1023] Home Energy Saver & Score: Engineering Documentation, Thermal Distribution Efficiency

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.8. [1024]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a ducted HVAC system with insufficient sealing and insulation that has undergone duct leakage testing. Look up baseline uninsulated distribution system efficiency from Appendix H based on building type, location and duct total leakage.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a sealed and insulated duct system in a commercial building that has undergone post-implementation duct leakage testing. A duct leakage test is turned on to pressurize the duct system to 25 Pascals (the standardized pressure differential used as a baseline for a commercial duct leakage test). The results are reported as "cfm @ 25 Pascals (0.1 inches w.g.)". The post-installation case must comply with all provisions of enforced codes and standards including, but not limited to ECCCNYS and NYSMC 2020[1025]. Supply and return air ducts and plenums located in unconditioned spaces shall be insulated with a minimum of R-6 insulation. Where located outside the building, ducts and plenums shall be insulated with a minimum of R-8 insulation in Climate Zone 4 and with a minimum of R-12 in Climate Zones 5 and 6.[1026]

Look up compliance distribution system efficiency from Appendix H based on building type, location and duct total leakage from duct leakage test. Models for HVAC distribution efficiency with R-8 and R-12 insulation are currently under development; values associated with R-6 shall be used until data is available.

Operating Hours

Cooling and heating equivalent full-load hours were calculated from a DOE-2.2 simulation of prototypical commercial buildings. Operating hour assumptions for the prototypical building models are described in Appendix A. The heating EFLH for residential buildings in NY are shown in Appendix G.

Example Calculation *(Not to be used as default)*

Duct sealing rated at R-6 is installed on 15 feet of a 6" diameter duct system of a vented crawl space under an insulated floor in a full service restaurant located near Albany. A duct-blaster test conducted prior to implementation indicates total duct leakage of 25%, and follow up duct-blaster test conducted post implementation indicates a total duct leakage of 15%. The building has a 15-ton central AC system with 15 IEER and 12 EER and a 350 kBTU/h gas furnace with 82% efficiency. Annual Electric Energy Savings, Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are calculated as below. Because electric heating is not present, terms related to electric heating impacts are represented with "N/A".

[1024] *No source specified – update pending availability and review of applicable references.*
[1025] NYSMC 2020, C6 Duct Systems
[1026] ECCCNYS 2020, C403.2.9

$$\Delta kWh = \left[tons \times \frac{12}{IEER} \times EFLH_{cooling} \times \left(1 - \frac{Eff_{dist,cooling,baseline}}{Eff_{dist,cooling,ee}}\right) \times \left(1 - TRF_{cooling}\right)\right] + \left[\frac{kBTU/h_{out}}{3.412} \times \frac{1}{COP} \times EFLH_{heating} \times \left(1 - \frac{Eff_{dist,heating,baseline}}{Eff_{dist,heating,ee}}\right) \times \left(1 - TRF_{heating}\right)\right]$$

$$\Delta kW = tons \times \frac{12}{EER} \times \left(1 - \frac{Eff_{dist,cooling,baseline}}{Eff_{dist,cooling,ee}}\right) \times \left(1 - TRF_{cooling}\right) \times CF$$

$$\Delta MMBtu = \frac{kBTU/h_{in}}{1{,}000} \times EFLH_{heating} \times \left(1 - \frac{Eff_{dist,heating,baseline}}{Eff_{dist,heating,ee}}\right) \times \left(1 - TRF_{heating}\right)$$

tons = 15, from application
IEER = 15, from application
$EFLH_{cooling}$ = 437, from Appendix G based on building type, building vintage, and location from application
$Eff_{dist,cooling,baseline}$ = 0.818, from Appendix H based on duct-blaster test leakage and location
$Eff_{dist,cooling,ee}$ = 0.955, from Appendix H based on duct-blaster test leakage and location
$TRF_{cooling}$ = 0.3, from on Thermal Regain Factor based on insulation location
EER = 12, from application
CF = 0.8, from Summary of Variables and Data Sources table
$kBTU/h_{in}$ = 100, from application
$EFLH_{heating}$ = 1,502, from Appendix G based on building type, building vintage, and location from application
$Eff_{dist,heating,baseline}$ = 0.753, from Appendix H based on duct-blaster test leakage and location
$Eff_{dist,heating,ee}$ = 0.866, from Appendix H based on duct-blaster test leakage and location
$TRF_{heating}$ = 0.3, from on Thermal Regain Factor based on insulation location

$$\Delta kWh = \left[15 \times \frac{12}{15} \times 437 \times \left(1 - \frac{0.818}{0.955}\right) \times (1 - 0.3)\right] + 0 = 527\ kWh$$

$$\Delta kW = 15 \times \frac{12}{12} \times \left(1 - \frac{0.818}{0.955}\right) \times (1 - 0.3) \times 0.8 = 1.206\ kW$$

$$\Delta MMBtu = \frac{350}{1{,}000} \times 1{,}502 \times \left(1 - \frac{0.753}{0.866}\right) \times (1 - 0.3) = 48.0\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. Home Energy Saver & Score: Engineering Documentation, Thermal Distribution Efficiency Available from: http://hes-documentation.lbl.gov/calculation-methodology/calculation-of-energy-consumption/heating-and-cooling-calculation/thermal-distribution-efficiency/thermal-distribution-efficiency
2. NYSMC 2020 C6 Duct Systems
   Available from: https://up.codes/viewer/new_york/ny-mechanical-code-2020/chapter/6/duct-systems#6
3. ECCCNYS 2020 C403.2.9: Duct and Plenum Insulation and Sealing
   Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-[ce]-commercial-energy-efficiency#NYSECC2020P1_CE_Ch04_SecC403

Record of Revision

Record of Revision Number	Issue Date
1	10/15/2010
9-18-13	9/28/2018

Return to Table of Contents

ECONOMIZER - DUAL ENTHALPY AIR SIDE

Measure Description

This measure covers the installation of dual enthalpy control air-side economizers integrated into a central air handling system on packaged rooftop units. Air-side economizers reduce mechanical cooling requirements by supplying outside air to the space when the outside air meets conditions deemed suitable for cooling. Dual enthalpy control, often called differential enthalpy control, augments this functionality by measuring sensible and latent heat of both the outside air and return air, using dampers to supply the conditioning section of the air handler with the lowest enthalpy air supply. This measure applies to retrofit scenarios for small commercial applications only. This measure also only applies in cases where economizers are not required by federal, state, local or municipal codes or standards.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times tons/unit \times (\Delta kWh/ton)$$

Summer Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
tons/unit	= Tons of air conditioning per unit, based on nameplate data
(ΔkWh/ton)	= Annual electric energy savings per ton of cooling

Summary of Variables and Data Sources

Variable	Value	Notes
tons/unit		From application
(ΔkWh/ton)		Lookup based on building type and location in the Air Side Economizer table in Appendix J.

Unit energy savings were calculated from a DOE-2.2 simulation of a series of prototypical small commercial buildings. The prototype building characteristics are described in Appendix A. The unit energy savings by building type and city are shown in Appendix J.

Coincidence Factor (CF)

The prescribed value for the coincidence factor is N/A.

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a packaged rooftop unit with no economizer installed.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a packaged rooftop unit with dual enthalpy economizer installed and commissioned to ensure proper operation.

Operating Hours

HVAC system operating hours are embedded into the deemed savings shown in Appendix J and vary by building type. See Appendix A for details on prototype building simulation parameters.

Example Calculation *(Not to be used as default)*

A dual enthalpy air side economizer is installed on a 15-ton packaged RTU system in a qualifying full service restaurant located near Albany. Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings are calculated as below.

$$\Delta kWh = units \times tons/unit \times (\Delta kWh/ton)$$

units = 1, from application
tons/unit = 15, from application
(ΔkWh/ton) = 38, from Appendix J based on building type and location from application

$$\Delta kWh = 1 \times 15 \times 38 = 570\ kWh$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

N/A

Record of Revision

Record of Revision Number	Issue Date
1	10/15/2010
3-18-3	3/29/2018

Return to Table of Contents

ELECTRONICALLY COMMUTATED (EC) MOTOR - HVAC BLOWER FAN

Measure Description

This measure covers the replacement of a HVAC circulation (blower) fan motor with an electronically commutated motor (EC motor) in a commercial building. The baseline condition for this measure is assumed to be a single-speed, permanent-split capacitor (PSC) motor. EC motors provide increased efficiency over PSC motors by controlling speed and torque, providing both efficiency and reliability.

This measure addresses the specific application of EC motors rated to one horsepower (HP) or less in a replacement scenario of a direct-drive circulation fan motor in an HVAC air distribution system. This measure is not applicable to exhaust fan motors.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = \Delta kWh_{heating} + \Delta kWh_{cooling}$$

$$\Delta kWh_{cooling} = units \times \frac{(W_{baseline} \times ESF_{cooling})}{1{,}000} \times LF \times hrs \times (1 + HVAC_c)$$

$$\Delta kWh_{heating} = units \times \frac{(W_{baseline} \times ESF_{heating})}{1{,}000} \times LF \times hrs \times (1 - HVAC_c)$$

Summer Peak Coincident Demand Savings

$$\Delta kW = units \times \frac{(W_{baseline} \times ESF_{cooling})}{1{,}000} \times LF \times (1 + HVAC_d) \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = units \times \frac{(W_{baseline} \times ESF_{heating})}{1{,}000} \times LF \times hrs \times HVAC_{ff}$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
$\Delta kWh_{cooling}$	= Annual electric energy savings during the cooling season
$\Delta kWh_{heating}$	= Annual electric energy savings during the heating season
$W_{baseline}$	= Baseline PSC motor wattage
ESF	= Energy savings factor
LF	= Motor load factor
hrs	= Operating hours

$HVAC_c$ = HVAC interaction factor for annual electric energy consumption
$HVAC_d$ = HVAC interaction factor at utility summer peak hour
$HVAC_{ff}$ = HVAC interaction factor for annual fossil fuelconsumption (MMBtu/kWh)
CF = Coincidence factor
1,000 = Conversion factor, one kW equals 1,000 watts

Summary of Variables and Data Sources

Variable	Value	Notes
$W_{baseline}$		From application.
$ESF_{heating}$	0.23	US Department of Energy. [1027]
$ESF_{cooling}$	0.38	US Department of Energy. [1028]
LF	0.9	US Department of Energy. [1029]
hrs		From application, if unknown, see operating hours section below.
$HVAC_c$		HVAC interaction factor for annual electric energy consumption (dimensionless). Vintage and HVAC type weighted average by city. See Appendix D.
$HVAC_d$		HVAC interaction factor for peak demand at utility summer peak hour (dimensionless). Vintage and HVAC type weighted average by city. See Appendix D.
$HVAC_{ff}$		HVAC interaction factor for annual fossil fuel energy consumption (MMBtu/kWh). Vintage and HVAC type weighted average by city. See Appendix D.
CF	0.8	

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.8.[1030]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a standard efficiency, single-speed PSC motor in a direct-drive HVAC circulation (blower) fan application. Baseline wattage shall be derived from the nameplate rating of the existing motor.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is an EC motor as described in the Measure Description section above in a direct-drive HVAC circulation (blower) fan application.

[1027] US DOE, Evaluation of Retrofit Variable-Speed Furnace Fan Motors, January 2014, Section 4: Discussion, pg 23
[1028] Ibid
[1029] Used to reflect that motors do not typically run at 100% of rated power.
[1030] *No source specified – update pending availability and review of applicable references.*

Operating Hours

Operating hours shall be taken from application. If the operating hours are unknown and the circulation fan operates on the same schedule as the HVAC system, look up operating hours from Appendix G. If the operating hours are unknown and the circulation fan operates on the same schedule as the facility, look up hours by building type from the table below.

Facility Type	Hours (hrs/yr)	Facility Type	Hours (hrs/yr)
Auto Related[a]	2,810	Manufacturing Facility	2,857
Automotive / Transportation Service or Repair Facility (24/7)	8,760	Medical Offices	3,748
Bakery	2,854	Motion Picture Theatre	1,954
Banks	3,748	Multi-Family (Common Areas)	7,665
Church	1,955	Museum	3,748
College– Cafeteria[b]	2,713	Nursing Homes	5,840
College – Classes	2,586	Office (General Office Types)[b]	3,013
College - Dormitory	3,066	Parking Garages	4,368
Commercial Condos[c]	3,100	Parking Garages (24/7)	7,717
Convenience Stores	6,376	Parking Lots	4,100
Convention Center	1,954	Penitentiary	5,477
Court House	3,748	Performing Arts Theatre	2,586
Dining: Bar Lounge/Leisure	4,182	Police / Fire Stations (24 Hr)	7,665
Dining: Cafeteria / Fast Food	6,456	Post Office	3,748
Dining: Family	4,182	Pump Stations	1,949
Entertainment	1,952	Refrigerated Warehouse	2,602
Exercise Center	5,836	Religious Building	1,955
Fast Food Restaurants	6,376	Restaurants	4,182
Fire Station (Unmanned)	1,953	Retail	3,463
Food Stores	4,055	School / University	2,187
Gymnasium	2,586	Schools (Jr./Sr. High)	2,187
Hospitals	7,674	Schools (Preschool/Elementary)	2,187
Hospitals / Health Care	7,666	Schools (Technical/Vocational)	2,187
Industrial - 1 Shift	2,857	Small Services	3,750
Industrial - 2 Shift	4,730	Sports Arena	1,954
Industrial - 3 Shift	6,631	Town Hall	3,748
Laundromats	4,056	Transportation	6,456
Library	3,748	Warehouse (Not Refrigerated)	2,602
Light Manufacturers[b]	2,613	Waste Water Treatment Plant	6,631
Lodging (Hotels/Motels)	3,064	Workshop	3,750
Mall Concourse	4,833		

[a] New car showrooms and Big Box retail stores with evening and/or weekend hours should use the Facility Type "Retail" for lighting operating hours.
[b] Lighting operating hours data from the 2008 California DEER Update study
[c] Lighting operating hours data for offices used

Example Calculation *(Not to be used as default)*

An EC blower fan motor is installed in a full service restaurant located near Albany, replacing a 500W PSC fan motor. The building has electric air conditioning and gas fired heating. The blower fan operates approximately 4,200 hours per year. Annual Electric Energy Savings, Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta kWh = \Delta kWh_{heating} + \Delta kWh_{cooling}$$

$$\Delta kWh_{cooling} = units \times \frac{(W_{baseline} \times ESF_{cooling})}{1{,}000} \times LF \times hrs \times (1 + HVAC_c)$$

$$\Delta kWh_{heating} = units \times \frac{(W_{baseline} \times ESF_{heating})}{1{,}000} \times LF \times hrs \times (1 - HVAC_c)$$

$$\Delta kW = units \times \frac{(W_{baseline} \times ESF_{cooling})}{1{,}000} \times LF \times (1 + HVAC_d) \times CF$$

$$\Delta MMBtu = units \times \frac{(W_{baseline} \times ESF_{heating})}{1{,}000} \times LF \times hrs \times HVAC_{ff}$$

units = 1, from application
$W_{baseline}$ = 500, from application
$ESF_{cooling}$ = 0.38, from Summary of Variables and Data Sources table
LF = 0.9, from Summary of Variables and Data Sources table
hrs = 4,200, from application
$HVAC_c$ = 0.070, from Appendix D based on building type and location from application
$HVAC_d$ = 0.200, from Appendix D based on building type and location from application
CF = 0.8, from Summary of Variables and Data Sources table
$ESF_{heating}$ = 0.23, from Summary of Variables and Data Sources table
$HVAC_{ff}$ = -0.004, from Appendix D based on building type and location from application

$$\Delta kWh_{cooling} = 1 \times \frac{(500 \times 0.38)}{1{,}000} \times 0.9 \times 4{,}200 \times (1 + 0.070) = 769\ kWh$$

$$\Delta kWh_{heating} = 0$$

$$\Delta kWh = 0 + 769 = 769\ kWh$$

$$\Delta kW = 1 \times \frac{(500 \times 0.38)}{1{,}000} \times 0.9 \times (1 + 0.2) \times 0.8 = 0.164\ kW$$

$$\Delta MMBtu = 1 \times \frac{(500 \times 0.23)}{1{,}000} \times 0.9 \times 4{,}200 \times (-0.004) = -1.74\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

HVAC circulation fan EC motors generate less heat during operation, resulting in decreased cooling loads and increased heating loads. These effects are captured in the prescribed methodology detailed above. The HVAC interaction factors calculated from the prototypical building DOE-2 models as a function of the building and HVAC system type are shown in Appendix D.

Ancillary Electric Savings Impacts

HVAC circulation fan EC motors generate less heat during operation, resulting in decreased cooling loads and increased heating loads. These effects are captured in the prescribed methodology detailed above. The HVAC interaction factors calculated from the prototypical building DOE-2 models as a function of the building and HVAC system type are shown in Appendix D.

Improved fan impeller design in the efficient case may contribute to additional efficiency gains; these impacts are not considered in the prescribed methodology at this time.

References

1. US DOE, Evaluation of Retrofit Variable-Speed Furnace Fan Motors, R. Aldrich and J. Williamson, Consortium for Advanced Residential Buildings, January 2014
   Available from:
   http://digital.library.unt.edu/ark:/67531/metadc864348/m2/1/high_res_d/1122310.pdf
2. NIDEC Motor Corporation, Residential and Commercial HVACR Standard Motor Catalog, 2015
   Available from: http://acim.nidec.com/motors/usmotors/-/media/usmotors/documents/catalogs/hvacr/hvacr400.ashx?la=en

Record of Revision

Record of Revision Number	Issue Date
1-16-14	12/31/2015
6-18-13	6/26/2018

Return to Table of Contents

ELECTRONICALLY COMMUTATED (EC) MOTOR – HYDRONIC CIRCULATOR PUMPS

Measure Description

This measure covers the replacement of standard efficiency permanent split capacitor (PSC) motor circulator pumps with electronically commutated (EC) motor circulator pumps in HVAC hydronic and DHW systems. This measure is not applicable to systems used in industrial processes. A circulator pump is a specific type of pump used to circulate liquids in a closed distribution system. They are commonly found circulating water in a hydronic heating or cooling system.

Circulator pumps used in hydronic and DHW systems are typically electrically powered centrifugal pumps. For residential-rated equipment installed in commercial applications, use the residential measure entitled "Electronically Commutated (EC) Motor – Hydronic Circulator Pumps".

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times \left(\frac{hp_{baseline}}{Eff_{baseline}} - \frac{hp_{ee}}{Eff_{ee}}\right) \times 0.746 \times hrs$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \frac{\Delta kWh}{hrs} \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

where:

ΔkWh	= Annual electricity energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
baseline	= Characteristic of baseline condition
ee	= Characteristic of energy efficient condition
hp	= Circulator motor horsepower
Eff	= Efficiency
hrs	= Annual hours of operation
CF	= Coincidence factor
0.746	= Conversion factor (kW/hp), 746 watts equals one electric horsepower

Summary of Variables and Data Sources

Variable	Value	Notes
$hp_{baseline}$		From application. Defaults to hp_{ee}.
hp_{ee}		From application.
$Eff_{baseline}$	0.22	Baseline PSC pump efficiency (wire-to-water).[1031]
Eff_{ee}	0.44	Efficient ECM pump efficiency (wire-to-water),[1032] based on constant return water temperature control mode.
hrs	Continuous Heating: 3,504 Continuous Cooling: 2,208 On/Off Control Heating: From Application On/Off Control Cooling: From Application DHW: From application	From application; Continuous heating based on Assessment of New Energy Efficient Circulator Pump Technology.[1033] Continuous cooling assumes three months (92 days) of 24-hour operation. On/Off control heating and cooling from application. If unknown, lookup based on location and facility type in Operating Hours section below. DHW from application. If unknown, lookup based on facility type in Operating Hours section below.
CF	Heating: N/A Continuous Cooling: 1.0 On/Off Control Cooling: 0.8 DHW: 1.0	

Coincidence Factor (CF)

The prescribed coincidence factor for continuous or on/off control heating is N/A.
The prescribed coincidence factor for continuous cooling is 1.0 and on/off control cooling is 0.8.[1034]
The prescribed coincidence factor for DHW is 1.0. [1035]

[1031] HPAC Magazine, Siegenthaler, John, "Higher efficiency circulators are here to stay", May 2017
[1032] DOE, High-Performance Circulator Pump Demonstration, September 2018, p. 20
[1033] Assessment of New Energy Efficient Circulator Pump Technology, pg 4-3. Assumed circulator pump is utilized 40% of the year (0.40 * 8,760 = 3,504)
[1034] *No source specified – update pending availability and review of applicable references.*
[1035] *No source specified – update pending availability and review of applicable references.*

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is circulator pump operating with a standard permanent split-capacitor (PSC) motor in a commercial or industrial heating, cooling and or DHW system.

Compliance Efficiency from which Incentives are Calculated

The compliance condition for this measure is a hydronic circulator pump operating with a high efficiency EC motor in a commercial or industrial heating and/or cooling system. High efficiency circulators may include better impeller design that will increase kWh savings, but these benefits are not considered in the prescribed savings estimation methodology.

Operating Hours

Annual circulator operating hours in a continuous operation hydronic heating system are assumed to be 3,504, based on assumed 40% utilization of circulator pump.

Annual circulator operating hours in a continuous operation hydronic cooling system are assumed to be 2,208, based on assumed 25% utilization of circulator pump.

On/Off control heating or cooling system operating hours shall come from application. If unknown, lookup in the table below based on location and facility type. Default HVAC system load hours were developed from NOAA hourly normals by assuming a 65ºF balance point temperature and summing dry bulb hours above the balance point for HVAC cooling and below the balance point for HVAC heating during building operating hours.[1036] Operating hour assumptions for facility types are described in Appendix A.

Facility/System Type	Albany	Binghamton	Buffalo	Massena*	NYC	Poughkeepsie**	Syracuse
Assembly Cooling Hours	1,473	1,204	1,380	1,411	1,748	1,579	1,441
Assembly Heating Hours	3,181	3,445	3,284	3,263	2,908	3,092	3,227
Auto Repair Cooling Hours	1,405	1,170	1,309	1,341	1,639	1,475	1,369
Auto Repair Heating Hours	2,891	3,128	3,001	2,974	2,658	2,837	2,940
Big Box Retail Cooling Hours	1,317	1,105	1,218	1,252	1,520	1,360	1,274
Big Box Retail Heating Hours	2,622	2,837	2,733	2,706	2,417	2,594	2,675
Community College Cooling Hours	1,041	855	972	1,003	1,224	1,131	1,030
Community College Heating Hours	2,177	2,370	2,257	2,235	1,999	2,106	2,204
Dormitory Cooling Hours	1,761	1,309	1,722	1,587	2,863	2,327	1,672
Dormitory Heating Hours	6,784	7,292	6,801	6,978	5,735	6,257	6,872

[1036] NOAA National Centers for Environmental Information – NCEI 2010 Hourly Normals

Facility/System Type	Albany	Binghamton	Buffalo	Massena*	NYC	Poughkeepsie**	Syracuse
Elementary School Cooling Hours	959	785	895	924	1,129	1,051	947
Elementary School Heating Hours	2,008	2,182	2,077	2,057	1,838	1,929	2,027
Fast Food Restaurant Cooling Hours	1,657	1,290	1,569	1,553	2,171	1,894	1,603
Fast Food Restaurant Heating Hours	4,412	4,789	4,504	4,537	3,918	4,204	4,475
Full-Service Restaurant Cooling Hours	1,594	1,275	1,511	1,493	1,982	1,720	1,526
Full-Service Restaurant Heating Hours	3,764	4,071	3,862	3,878	3,394	3,663	3,840
Grocery Cooling Hours	1,593	1,254	1,502	1,502	2,057	1,812	1,552
Grocery Heating Hours	4,119	4,474	4,219	4,238	3,673	3,929	4,176
High School Cooling Hours	1,041	855	972	1,003	1,224	1,131	1,030
High School Heating Hours	2,177	2,370	2,257	2,235	1,999	2,106	2,204
Hospital Cooling Hours	1,761	1,309	1,722	1,587	2,863	2,327	1,672
Hospital Heating Hours	6,784	7,292	6,801	6,978	5,735	6,257	6,872
Hotel Cooling Hours	1,761	1,309	1,722	1,587	2,863	2,327	1,672
Hotel Heating Hours	6,784	7,292	6,801	6,978	5,735	6,257	6,872
Large Office Cooling Hours	938	787	870	898	1,077	997	923
Large Office Heating Hours	1,820	1,980	1,902	1,877	1,685	1,777	1,847
Large Retail Cooling Hours	1,441	1,192	1,352	1,373	1,705	1,521	1,402
Large Retail Heating Hours	3,056	3,304	3,164	3,146	2,798	2,995	3,112
Light Industrial Cooling Hours	1,034	817	967	979	1,334	1,211	1,022
Light Industrial Heating Hours	2,634	2,878	2,708	2,714	2,349	2,482	2,659
Motel Cooling Hours	1,761	1,309	1,722	1,587	2,863	2,327	1,672
Motel Heating Hours	6,784	7,292	6,801	6,978	5,735	6,257	6,872
Religious Cooling Hours	849	720	771	800	951	864	819
Religious Heating Hours	1,506	1,639	1,590	1,567	1,395	1,499	1,540
Small Office Cooling Hours	829	694	771	795	956	891	818
Small Office Heating Hours	1,622	1,765	1,692	1,670	1,498	1,574	1,642

Facility/System Type	Albany	Binghamton	Buffalo	Massena*	NYC	Poughkeepsie**	Syracuse
Small Retail Cooling Hours	1,368	1,139	1,275	1,299	1,604	1,421	1,321
Small Retail Heating Hours	2,823	3,052	2,933	2,915	2,590	2,788	2,884
University Cooling Hours	1,287	1,048	1,214	1,232	1,547	1,387	1,260
University Heating Hours	2,850	3,089	2,940	2,928	2,600	2,772	2,897
Warehouse Cooling Hours	861	681	803	817	1,045	965	849
Warehouse Heating Hours	1,947	2,141	2,015	2,002	1,769	1,861	1,966

*Massena hourly normals are approximated from Rochester airport data due to limited available data
** Poughkeepsie hourly normals are approximated from Long Island ISLIP airport data due to limited available data

DHW circulator operating hours shall come from application. If unknown, lookup in the table below based on facility type. Operating hour assumptions for the prototypical building models are described in Appendix A.

Facility Type	Hours (hrs/yr)
Auto Repair	4,368
Big Box Retail	4,004
Community College	3,276
Dormitory	8,760
Elementary School	3,016
Fast Food Restaurant	6,188
Full-Service Restaurant	5,460
Grocery	5,824
High School	3,276
Hospital	8,760
Hotel	8,760
Large Office	2,808
Large Retail	4,576
Light Industrial	3,120
Motel	8,760
Religious	2,392
Small Office	2,808
Small Retail	4,264
University	4,212
Warehouse	2,860

Example Calculation *(Not to be used as default)*

A ¾ hp PSC circulator pump PSC ¾ hp motor is replaced with a ¾ hp EC circulator in a continuous operation hydronic heating system. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

$$\Delta kWh = units \times \left(\frac{hp_{baseline}}{Eff_{baseline}} - \frac{hp_{ee}}{Eff_{ee}}\right) \times 0.746 \times hrs$$

$$\Delta kW = \frac{\Delta kWh}{hrs} \times CF$$

units = 1, from application
$hp_{baseline}$ = 0.75, from application
$Eff_{baseline}$ = 0.22, from Summary of Variables and Data Sources table
hp_{ee} = 0.75, from application
Eff_{ee} = 0.44, from Summary of Variables and Data Sources table
hrs = 2,208, from Summary of Variables and Data Sources table based on use from application
CF: 1.0, from Summary of Variables and Data Sources table

$$\Delta kWh = 1 \times \left(\frac{0.75}{0.22} - \frac{0.75}{0.44}\right) \times 0.746 \times 3{,}504 = 4{,}455\ kWh$$

$$\Delta kW = \frac{4{,}455}{3{,}504} \times 0.8 = 1.017\ kW$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Higher efficiency circulators may lead to increased fossil fuel consumption in fossil fuel heated buildings. Reduction in waste heat from increased efficiency in motors results in additional heating requirement. Reduction in waste heat from increased efficiency in motors also results in a reduced cooling requirement. These effects are not quantified in this methodology.

Ancillary Electric Savings Impacts

Higher efficiency circulators may lead to increased electric consumption in electrically heated buildings. Reduction in waste heat from increased efficiency in motors results in additional heating requirement. Reduction in waste heat from increased efficiency in motors also results in a reduced cooling requirement. These effects are not quantified in this methodology.

References

1. HPAC Magazine, Siegenthaler, John, "Higher efficiency circulators are here to stay", May 2017
   Available from: https://www.hpacmag.com/features/high-efficiency-circulators-brushless-dc-motors/#
2. DOE, High Performance Circulator Pump Demonstration, September 2018
   Available from: https://www.nrel.gov/docs/fy18osti/71705.pdf
3. Assessment of New Energy Efficient Circulator Pump Technology, Electric Power Research Institute, November 2010
   Available from:
   https://publicdownload.epri.com/PublicDownload.svc/product=000000000001020132/type=Product
4. NOAA National Centers for Environmental Information
   Available from: https://www.ncdc.noaa.gov/cdo-web/search?datasetid=NORMAL_HLY

Record of Revision

Record of Revision Number	Issue Date
12-19-13	12/23/2019

Return to Table of Contents

ENERGY AND HEAT RECOVERY VENTILATOR

Measure Description

This measure covers the installation of Energy Recovery Ventilators (ERV) and Heat Recovery Ventilators (HRV). ERVs and HRVs reduce heating and cooling loads while maintaining required ventilation rates by facilitating heat transfer between outgoing conditioned air and incoming outdoor air. ERVs and HRVs employ air-to-air heat exchangers to recover energy from exhaust air for the purpose of pre-conditioning outdoor air prior to supplying the conditioned air to the space, either directly or as part of an air-conditioning system.[1037] This measure only applies in cases where ERV/HRV functionality is not required by federal, state, local or municipal codes or standards. This measure is only applicable to retrofit of existing buildings. For the purposes of this measure, ERVs and HRVs are distinguished as follows:

Energy Recovery Ventilator (ERV)
Transfers both sensible (heat content) and latent (moisture content) heat between supply and exhaust airstreams.

Heat Recovery Ventilator (HRV)
Transfers sensible heat only between supply and exhaust airstreams.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings (for ERVs)

Annual Electric Energy Savings

$$\Delta kWh = units \times \left(\Delta kWh_{cooling} + \Delta kWh_{heating}\right)$$

$$\Delta kWh_{cooling} = \left[\left(\frac{4.5 \times CFM \times Eff_{hx,total} \times \left(H_{outdoor,cooling} - H_{indoor,cooling}\right)}{1{,}000 \times Eff_{ElecCool}}\right) - kW_{fan}\right] \times hrs_{cooling}$$

$$\Delta kWh_{heating} = \left[\left(\frac{1.08 \times CFM \times Eff_{hx,sens} \times \left(T_{indoor,heating} - T_{outdoor,heating}\right)}{1{,}000 \times Eff_{ElecHeat}} \times F_{ElecHeat}\right) - kW_{fan}\right] \times hrs_{heating}$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \left[\left(\frac{4.5 \times CFM \times Eff_{hx,total} \times \left(H_{outdoor,cooling} - H_{indoor,cooling}\right)}{1{,}000 \times Eff_{ElecCool}}\right) - kW_{fan}\right] \times CF$$

[1037] AHRI GUIDELINE V (I-P)-2011 Calculating the Efficiency of Energy Recovery Ventilation and its Effect on Efficiency and Sizing of Building HVAC Systems

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = \frac{1.08 \times CFM \times Eff_{hx,sens} \times \left(T_{indoor,heating} - T_{outdoor,heating}\right)}{1{,}000{,}000 \times Eff_{FuelHeat}} \times F_{FuelHeat} \times hrs_{heating}$$

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings (for HRVs)

Annual Electric Energy Savings

$$\Delta kWh = units \times \left(\Delta kWh_{cooling} + \Delta kWh_{heating}\right)$$

$$\Delta kWh_{cooling} = \left[\left(\frac{1.08 \times CFM \times Eff_{hx,sens} \times \left(T_{outdoor,cooling} - T_{indoor,cooling}\right)}{1{,}000 \times Eff_{ElecCool}}\right) - kW_{fan}\right] \times hrs_{cooling}$$

$$\Delta kWh_{heating} = \left[\left(\frac{1.08 \times CFM \times Eff_{hx,sens} \times \left(T_{indoor,heating} - T_{outdoor,heating}\right)}{1{,}000 \times Eff_{ElecHeat}} \times F_{ElecHeat}\right) - kW_{fan}\right] \times hrs_{heating}$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \left[\left(\frac{1.08 \times CFM \times Eff_{hx,sens} \times \left(T_{outdoor,cooling} - T_{indoor,cooling}\right)}{1{,}000 \times Eff_{ElecCool}}\right) - kW_{fan}\right] \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = \frac{1.08 \times CFM \times Eff_{hx,sens} \times \left(T_{indoor,heating} - T_{outdoor,heating}\right)}{1{,}000{,}000 \times Eff_{FuelHeat}} \times F_{FuelHeat} \times hrs_{heating}$$

where:

$$kW_{fan} = \sum\left(\frac{CFM \times \Delta P}{\frac{33{,}013}{5.202} \times Eff_{fanmech} \times Eff_{fanmotor}} \times 0.746\right)$$

where:

ΔkWh = Annual electric energy savings
ΔkW = Peak coincident demand electric savings

$\Delta MMBtu$	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
kW_{fan}	= Total electric power of ERV/HRV supply and exhaust fans (kW). Sigma operator included to indicate that this term shall include consideration of all ERV/HRV fans.
heating	= Property of heating season
cooling	= Property of cooling season
CFM	= Volume of supply air in Cubic Feet per Minute
CF	= Coincidence Factor
$Eff_{hx,total}$	= Total effectiveness of heat exchanger per rating in accordance with AHRI Standard 1060 [1038]
$Eff_{hx,sens}$	= Sensible effectiveness of heat exchanger per rating in accordance with AHRI Standard 1060 [1039]
$Eff_{ElecCool}$	= Seasonal average energy efficiency of electric cooling equipment, BTU/watt-hour, using either SEER (<65,000 BTU/h) or IEER (≥65,000 BTU/h)
$Eff_{ElecHeat}$	= Seasonal average energy efficiency of electric heating equipment. Heating Seasonal Performance Factor, BTU/watt-hour, total heating output (supply heat) in BTU (including resistance heating) during the heating season / total electric energy heat pump consumed (in watt-hour); if equipment efficiency is reported in COP, convert to HSPF using the equivalency HSPF = COP x 3.412
$Eff_{FuelHeat}$	= Efficiency of fossil fuel heating equipment (AFUE, Et, or Ec)
$Eff_{fanmech}$	= Mechanical efficiency of ERV fans
$Eff_{fanmotor}$	= Efficiency of ERV fan motors
$F_{ElecHeat}$	= Electric heating factor, used to account for the presence or absence of an electric heating system
$F_{FuelHeat}$	= Fossil fuel heating factor, used to account for the presence or absence of a fossil fuel heating system
T_{indoor}	= Indoor air temperature, in °F
$T_{outdoor}$	= Outdoor air temperature, in °F
ΔP	= Pressure drop at nominal airflow in the ERV as rated in accordance with AHRI Standard 1060, in inches of water
$H_{outdoor}$	= Enthalpy of outside air in BTU/lb
H_{indoor}	= Enthalpy of inside air at 70°F, in BTU/lb
$hrs_{heating}$	= Operating hours in the heating season
$hrs_{cooling}$	= Operating hours in the cooling season
4.5	= Density of inlet air at 70ºF x 60 min/hr, in lb-min/ft^3-hr
1.08	= Specific heat of air × density of inlet air @ 70°F × 60 min/hr[1040] in BTU/h-ºF CFM
1,000,000	= Conversion factor, one MMBtu equals 1,000,000 BTU
33,013	= Conversion factor from horsepower to ft.lb/min

[1038] Performance Rating of air-to-air exchanges for Energy Recovery Ventilation Equipment.
[1039] Ibid
[1040] The sensible heat constant at standard conditions of 1.08 is applied in accordance with standard HVAC industry practice. While the underlying assumptions are not representative characteristics of a NY heating season, the impacts to this value due to average heating season temperature and NY mean elevation offset such that the NY heating season specific value is approximately 1.08.

5.202 = Conversion factor from inches of water to pounds per square ft (lb/sq.ft.)
0.746 = Conversion factor (kW/hp), 746 watts equals one electric horsepower
1,000 = Conversion factor, one kW equals 1,000 Watts

Summary of Variables and Data Sources

Variable	Value	Notes
CFM		From application.
$Eff_{hx,total}$		From application.
$Eff_{hx,sens}$		From application.
$Eff_{ElecCool}$		From application. SEER or IEER shall be used, based on nameplate rating metric of existing equipment.
$Eff_{FuelHeat}$		From application, E_c, E_t, or AFUE shall be used, based on nameplate rating metric of existing equipment.
$Eff_{ElecHeat}$		From application. HSPF shall be used, based on nameplate rating metric of existing equipment. If equipment is rated in COP, convert to HSPF using the equivalency HSPF = COP x 3.412.
$Eff_{fanmech}$		From application, if unknown use 0.67[1041]
$Eff_{fanmotor}$		From application, if unknown use 0.70 based on 1/4hp, 4-pole polyphase motor.[1042]
$F_{ElecHeat}$		Use a value of 1.0 if the building is electrically heated. Otherwise, use 0.0.
$F_{FueHeat}$		Use a value of 1.0 if the building is fossil fuel heated. Otherwise use 0.0.
$H_{outdoor}$		Lookup from Climate Data table below based on location[1043]
H_{indoor}		If indoor set temperature is known, lookup from Indoor Enthalpy table below. Otherwise, use 25.3 based on 70°F and 50% RH indoor air conditions.
T_{indoor}		From application or use 70°F
$T_{outdoor}$		Average of temperatures from the heating and cooling season based on the city. Lookup value from table below.
ΔP		From application.
$hrs_{heating}$		Look up interval hours in the Operating Hours section table below based on location.
$hrs_{cooling}$		Look up interval hours in the Operating Hours section table below based on location.
CF	0.8	

[1041] ASHRAE 90.1 2013, Section 6.5.3.1.3
[1042] 10 CFR 431.446
[1043] NCEI 1981-2010 Annual/Seasonal Climate Normals

Indoor Enthalpy (H_{indoor})

Temperature (°F)	Relative Humidity	Enthalpy (H_{indoor})
65	50%	22.7
66	50%	23.2
67	50%	23.7
68	50%	24.2
69	50%	24.8
70	50%	25.3
71	50%	25.8
72	50%	26.4
73	50%	27.0
74	50%	27.5
75	50%	28.1
76	50%	28.7
77	50%	29.3
78	50%	29.9

Outdoor Air Temperature & Enthalpy

Look up outdoor air temperature and enthalpy based on the city in the table below. The table below summarizes the average outdoor air temperature and enthalpy during the Heating (<65°F) and Cooling (>65°F) seasons across a typical climatological year.

City	$T_{outdoor,heating}$ (°F)	$T_{outdoor,cooling}$ (°F)	$H_{outdoor,heating}$ (Btu/lb)	$H_{outdoor,cooling}$ (Btu/lb)
Albany	41.90	72.01	11.80	29.57
Binghamton	41.84	70.48	11.30	28.04
Buffalo	42.15	71.22	12.10	28.80
Massena	42.61	71.82	12.10	29.18
NYC	45.93	73.69	14.34	30.86
Poughkeepsie	45.18	72.01	13.78	30.66
Syracuse	42.11	71.94	11.94	29.33

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.8.[1044]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition for this measure is a building with an ASHRAE 62.2-compliant exhaust fan system with no heat or energy recovery.

[1044] *No source specified – update pending availability and review of applicable references.*

Compliance Efficiency from which Incentives are Calculated

The compliance condition for this measure is a building with an ASHRAE 62.2-compliant exhaust fan system equipped with AHRI certified ERV or HRV components.

Operating Hours

Lookup hours in the table below based on location and most appropriate facility operating schedule. Default HVAC system load hours were developed from NOAA hourly normals by assuming a 65ºF balance point temperature and summing dry bulb hours above the balance point for HVAC cooling and below the balance point for HVAC heating during building operating hours.[1045] Operating hour assumptions for facility types are described in Appendix A.

Typical Operating Schedule	Albany	Binghamton	Buffalo	Massena*	NYC	Poughkeepsie**	Syracuse
24/7 - 365 Cooling Hours	1,761	1,309	1,722	1,587	2,863	2,327	1,672
24/7 - 365 Heating Hours	6,784	7,292	6,801	6,978	5,735	6,257	6,872
Mon-Sun 6AM-12AM Cooling Hours	1,682	1,289	1,604	1,554	2,400	2,057	1,609
Mon-Sun 6AM-12AM Heating Hours	4,992	5,417	5,080	5,142	4,409	4,755	5,076
Mon-Sun 6AM-10PM Cooling Hours	1,593	1,254	1,502	1,502	2,057	1,812	1,552
Mon-Sun 6AM-10PM Heating Hours	4,119	4,474	4,219	4,238	3,673	3,929	4,176
Mon-Fri 7AM-7PM Sun 11AM-6PM Cooling Hours	1,291	1,046	1,215	1,230	1,547	1,386	1,257
Mon-Fri 7AM-7PM Sun 11AM-6PM Heating Hours	2,857	3,096	2,942	2,931	2,602	2,775	2,900
Mon-Fri 7AM-7PM Cooling Hours	1,038	818	967	978	1,334	1,213	1,021
Mon-Fri 7AM-7PM Heating Hours	2,639	2,879	2,707	2,714	2,347	2,483	2,659
Mon-Fri 7AM-5PM Cooling Hours	867	682	806	815	1,046	966	852
Mon-Fri 7AM-5PM Heating Hours	1,963	2,149	2,023	2,015	1,779	1,871	1,980

[1045] NOAA National Centers for Environmental Information – NCEI 2010 Hourly Normals

*Massena hourly normals are approximated from Rochester airport data due to limited available data
** Poughkeepsie hourly normals are approximated from Long Island ISLIP airport data due to limited available data

Example Calculation *(Not to be used as default)*

An ERV delivering 4,000 CFM is installed in a commercial building located near Albany. The ERV has a sensible effectiveness of 65% and total effectiveness of 62%, and runtime is set at 40%, operating 24 minutes per hour. The building is cooled by a central air conditioner with 15 SEER and heated by an 80% thermal efficient gas fired hot water boiler, where the indoor cooling temperature is set at 71ºF and the indoor heating temperature is set at 69ºF. The ERV fan has a motor efficiency of 80%, a mechanical efficiency of 65%, and a pressure drop of 0.6 inches of water. The building's closest typical operating schedule is Mon – Fri from 7AM – 7PM and Sunday 11AM – 6PM. Annual Electric Energy Savings, Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta kWh = units \times \left(\Delta kWh_{cooling} + \Delta kWh_{heating}\right)$$

$$\Delta kWh_{cooling} = \left[\left(\frac{4.5 \times CFM \times Eff_{hx,total} \times \left(H_{outdoor,cooling} - H_{indoor,cooling}\right)}{1{,}000 \times Eff_{ElecCool}}\right) - kW_{fan}\right] \times hrs_{cooling}$$

$$\Delta kWh_{heating} = \left[\left(\frac{1.08 \times CFM \times Eff_{hx,sens} \times \left(T_{indoor,heating} - T_{outdoor,heating}\right)}{1{,}000 \times Eff_{ElecHeat}} \times F_{ElecHeat}\right) - kW_{fan}\right] \times hrs_{heating}$$

$$\Delta kW = \left[\left(\frac{4.5 \times CFM \times Eff_{hx,total} \times \left(H_{outdoor,cooling} - H_{indoor,cooling}\right)}{1{,}000 \times Eff_{ElecCool}}\right) - kW_{fan}\right] \times CF$$

$$\Delta MMBtu = \frac{1.08 \times CFM \times Eff_{hx,sens} \times \left(T_{indoor,heating} - T_{outdoor,heating}\right)}{1{,}000{,}000 \times Eff_{FuelHeat}} \times F_{FuelHeat} \times hrs_{heating}$$

where:

$$kW_{fan} = \sum\left(\frac{CFM \times \Delta P}{\frac{33{,}013}{5.202} \times Eff_{fanmech} \times Eff_{fanmotor}} \times 0.746\right)$$

units = 1, from application

CFM = 4,000, from application
$Eff_{hx,total}$ = 0.62, from application
$H_{outdoor,cooling}$ = 29.57 BTU/lb, from Outdoor Air Temperature & Enthalpy table based on location from application
$H_{indoor,cooling}$ = 25.8 BTU/lb, from on Indoor Enthalpy table based on indoor temperature from application
$Eff_{ElecCool}$ = 15, from application
kW_{fan} = (4,000 x 1.0) / (33,013/5.202 x 0.65 x 0.80) x 0.746 = 0.904 kWh
ΔP = 0.6, from application
$Eff_{fanmech}$ = 0.65, from application
$Eff_{fanmotor}$ = 0.80, from application
$hrs_{cooling}$ = 1,291, from Operating Hours table based on location and operating schedule from application
min/hr = 24, from application
$Eff_{hx,sens}$ = 0.65, from application
$T_{indoor,heating}$ = 68ºF, from application
$T_{outdoor,heating}$ = 41.90ºF, from Outdoor Air Temperature & Enthalpy table based on location from application
$Eff_{ElecHeat}$ = N/A, from application
$F_{ElecHeat}$ = 0, from application
$hrs_{heating}$ = 2,857, from Operating Hours table based on location and operating schedule from application
CF = 0.8, from Summary of Variables and Data Sources table
$Eff_{FuelHeat}$ = 0.80, from application
$F_{FuelHeat}$ = 1, from application

$$kW_{fan} = \sum\left(\frac{4{,}000 \times\ 0.6}{\frac{33{,}013}{5.202} \times 0.65 \times 0.80} \times 0.746\right) = 0.543\ kW$$

$$\Delta kWh_{cooling} = \left[\left(\frac{4.5 \times 4{,}000 \times 0.62 \times (29.57 - 25.3)}{1{,}000 \times 15}\right) - 0.543\right] \times 1{,}291 \times \frac{24}{60} = 1{,}168\ kWh$$

$$\Delta kWh_{heating} = (0 -\ 0.904)\ \times 2{,}857 \times \frac{24}{60} = -620\ kWh$$

$$\Delta kWh = 1 \times (1{,}168 + (-620\ ) = 548\ kWh$$

$$\Delta kW = \left[\left(\frac{4.5 \times 4{,}000 \times 0.62 \times (29.57 - 25.3)}{1{,}000 \times 15}\right) - 0.543\right] \times 0.8 =\ \ 2.37\ kW$$

$$\Delta MMBtu = \frac{1.08 \times CFM \times 0.65 \times (69 - 41.9)}{1{,}000{,}000 \times 0.80} \times 1 \times 2{,}857 \times \frac{24}{60} = 109\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Employing ERVs in the winter may exchange latent heat decreasing the need to run a humidifier, but the impact is expected to be negligible and is not quantified in the prescribed estimation methodology for this measure at this time.

References

1. 10 CFR 431.446 Small electric motors energy conservation standards and their effective dates.
   Available from: https://gov.ecfr.io/cgi-bin/text-idx?SID=6fb7b94f1b9d3af4accb978144ba015c&mc=true&node=se10.3.431_1446&rgn=div8
2. AHRI GUIDELINE V (I-P)-2011 Calculating the Efficiency of Energy Recovery Ventilation and its Effect on Efficiency and Sizing of Building HVAC Systems
   Available from:
   http://www.ahrinet.org/App_Content/ahri/files/Guidelines/AHRI_Guideline_V_I-P_2011.pdf
3. NOAA National Center for Environmental Information – NCEI 1981 – 2010 Annual/Seasonal Climate Normals
   Available from: https://www.ncdc.noaa.gov/cdo-web/datatools/normals
4. ASHRAE Standard 90.1-2013, Energy Standard for Buildings Except Low-Rise Residential Buildings (I-P) Edition.

Record of Revision

Record of Revision Number	Issue Date
7-20-12	7/31/2020

Return to Table of Contents

HEAT PUMP – AIR SOURCE (CCASHP)

Measure Description

This measure covers the installation of cold climate Air Source Heat Pump (ccASHP) systems[1046] that provide heating and cooling for space conditioning in commercial applications including high rise multifamily buildings of four or more stories[1047] or with an occupied floor located more than 75 feet above the lowest level of fire department vehicle access.[1048] An air source heat pump is a product, other than a packaged terminal heat pump, which is powered by single phase electric current, air cooled, not contained within the same cabinet as a furnace with rated capacity above 225,000 BTU/h, and operates as a heat pump in both heating and cooling mode. This measure applies to central ducted systems, single zone split-systems with ductless indoor units that may be wall-mounted, floor-mounted, or ceiling-mounted and multi-zone split systems with one outdoor section and multiple indoor sections. These indoor sections may be a combination of ductless or compact ducted units.

This measure is based on several assumptions consistent with best practice design for a quality ASHP installation:

- NYS code and Federal Standard (ECCCNYS 2020, Code of Federal Regulations 10 CFR 430.32, 431.77, 431.87) or local legislation applicable at the time of installation should be referenced for correct baseline system and efficiency values.

- Building heating and cooling loads shall be calculated, and systems shall be sized, in accordance with applicable federal, state, local and municipal codes and standards.

- When the building peak heating load for a small commercial building in New York State exceeds the peak cooling load, it is assumed that the ASHP runs at part-load during peak cooling hours. For installation scenarios where the building load is cooling dominant a custom analysis is required.

The ASHP efficiency must meet the Northeast Energy Efficiency Partnerships (NEEP) Cold Climate Air Source Heat Pump (ccASHP) Specification (Version 3.0) effective January 1, 2019. The specification uses AHRI-certified performance ratings and manufacturer reported data to describe the efficiency and capacity of the unit under full and part load conditions. This equipment is rated under ANSI/AHRI 210/240.

[1046] NEEP Cold Climate Air Source Heat Pump (ccASHP) Specification (Version 3.0) effective January 1, 2019
[1047] NYSERDA, Mid- and High-Rise Multifamily Buildings
[1048] NYSBC 2020; Chapter 2 Definitions: High-Rise Building

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = \left(\left(BCL \times \frac{1}{1{,}000} \times \left(\frac{1}{SEER_{baseline}} - \frac{1}{EER_{season,ee}}\right) \times EFLH_{cooling} \times F_{load,cooling}\right) + \left(BHL \times \frac{1}{1{,}000} \times \left(\frac{F_{ElecHeat}}{COP_{season,baseline}} - \frac{1}{COP_{season,ee}}\right) \times \frac{1}{3.412} \times BEFLH_{heating} \times F_{load,heating,ElecHeat}\right) - \left(BHL \times \frac{1}{1{,}000} \times F_{ElecHeat,new} \times \frac{1}{3.412} \times BEFLH_{heating} \times \left(1 - F_{load,heating}\right)\right)\right)$$

Summer Peak Coincident Demand Savings

$$\Delta kW = BCL \times \frac{1}{1{,}000} \times \left(\frac{1}{EER_{baseline}} - \frac{1}{EER_{ee}}\right) \times F_{load,cooling} \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = BHL \times \frac{1}{1{,}000{,}000} \times \frac{F_{FuelHeat}}{Eff_{baseline}} \times EFLH_{heating} \times F_{load,heating,FuelHeat}$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
BCL	= Building Cooling Load at design conditions (BTU/h)
BHL	= Building Heating Load at design conditions (BTU/h)
$F_{ElecHeat}$	= Electric heating factor; used to account for the presence or absence of an electric heating system
$F_{ElecHeat,new}$	= New electric heating factor; used to account for a new heat pump's reliance on supplemental electric resistance heat to meet full heating load
$F_{FuelHeat}$	= Fossil fuel heating factor; used to account for the presence or absence of a fossil fuel heating system
baseline	= Characteristic of baseline condition
ee	= Characteristic of energy efficient condition
SEER	= Seasonal average energy efficiency ratio over the cooling season, BTU/watt-hour, used for average U.S. location/region
EER	= Full load energy efficiency ratio (BTU/watt-hour)
EER_{season}	= Seasonally adjusted average energy efficiency (BTU/watt-hour)
COP	= Coefficient of performance for heating, ratio of output energy/input energy
COP_{season}	= Seasonally adjusted average coefficient of performance
Eff	= Efficiency rating of fossil fuel heating equipment
$BEFLH_{cooling}$	= Cooling equivalent full-load hours based on building design load
$BEFLH_{heating}$	= Heating equivalent full-load hours based on building design load

$F_{load,cooling}$ = Adjustment factor to account for the portion of the seasonal[1049] cooling load met by the heat pump
$F_{load,heating}$ = Adjustment factor to account for the portion of the seasonal[1050] heating load met by the heat pump
$F_{load,heating,ElecHeat}$ = Electric heating adjustment factor to account for the portion of the seasonal heating load met by the heat pump
$F_{load,heating,FuelHeat}$ = Fossil fuel heating adjustment factor to account for the portion of the seasonal heating load met by the heat pump
CF = Coincidence Factor
3.412 = Conversion factor, one watt-hour equals 3.412 BTU
1,000 = Conversion factor, one kilowatt equals 1,000 watts
1,000,000 = Conversion factor, one MMBtu equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
BCL		Building cooling load at design conditions, from application
BHL		Building heating load at design conditions, from application
$F_{ElecHeat}$		If the baseline heating system is an electric system, set equal to 1. Otherwise, set equal to 0.
$F_{ElecHeat,new}$		If the efficient case heat pump system relies on newly installed supplemental electric resistance heat capacity to meet the peak load, set equal to 1. Otherwise, set equal to 0.
$F_{FuelHeat}$		If the baseline heating system is a fossil fuel system, set equal to 1. Otherwise, set equal to 0.
$SEER_{baseline}$		Electric cooling seasonal energy efficiency rating of baseline equipment. See Baseline Efficiencies section below for details.
$EER_{baseline}$		Electric cooling full load energy efficiency rating of baseline equipment. See Baseline Efficiencies section below for details.
EER_{ee}		Electric cooling full load energy efficiency rating of efficient equipment. See Compliance Efficiency section below for details.
$EER_{season,ee}$		Seasonally adjusted energy efficiency ratio of the efficient equipment. See Compliance Efficiency section below for details.
$COP_{season,baseline}$		Seasonally adjusted Coefficient of Performance of the baseline equipment. The assumed COP of an electric resistance/electric furnace system is 1.0. If the baseline is a conventional ASHP[1051], use the baseline calculations below.
$COP_{season,ee}$		Seasonally adjusted Coefficient of Performance of the efficient equipment. See Compliance Efficiency section below for details.

[1049] Fraction of annual (vs. design) cooling load served by the equipment as shown in the Cooling Load Factor table.
[1050] Fraction of annual (vs. design) heating load served by the equipment as shown in the Heating Load Factor table.
[1051] In this context, "conventional ASHP" is defined as a minimally code-compliant non-NEEP listed ASHP with efficiency ratings as indicated in the Baseline Efficiencies section below.

Variable	Value	Notes
$Eff_{baseline}$		Fossil fuel energy efficiency of the baseline equipment. See Baseline Efficiency section below for details.
$BEFLH_{cooling}$		Lookup based on building type, vintage and location from the appropriate table in the Operating Hours section below.
$BEFLH_{heating}$		Lookup based on building type, vintage and location from the appropriate table in the Operating Hours section below.
$F_{load,cooling}$		Lookup based on equipment sizing and control parameters from the Cooling Load Factor table below.
$F_{load,heating}$		Lookup based on equipment sizing and control parameters from the Heating Load Factor table below.
$F_{load,heating,ElecHeat}$		If the baseline heating system is an electric system that remains in place in the efficient case, or if the baseline heating system is a non-electric system, lookup based on equipment sizing and control parameters from the Heating Load Factor table below. Otherwise, set equal to 1.
$F_{load,heating,FuelHeat}$		If the baseline heating system is a fossil fuel system that remains in place in the efficient case, lookup based on equipment sizing and control parameters from the Heating Load Factor table below. Otherwise, set equal to 1.

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.80.[1052]

Baseline Efficiencies from which Energy Savings are Calculated

The baselines used in this measure are determined by the type of equipment that would have been installed without the influence of the program supporting the installation of this measure. This allows for an analysis that does not depend on a typical 'like-for-like' replacement scenario.

An ASHP system can be considered a normal replacement scenario for electric resistance heating (with or without a central electric cooling system), an ASHP system (that provides space heating and cooling), or a fossil fuel fired heating system (with or without a central electric cooling system). The tables below provide baseline efficiencies for electric cooling and heating and fossil fuel fired heating systems.

For scenarios where there is new construction or substantial renovation, the baseline is assumed to be a fossil fuel fired warm air furnace of the fuel type most likely to be installed at the project site without the influence of the program with a central air conditioning system.

The baseline efficiency for electric cooling and heating systems is defined by the Code of Federal Regulations as shown in the table below.

[1052] *No source specified – update pending availability and review of applicable references.*

Electric Cooling and Heating System Baseline Efficiencies

Product Class	Seasonal Energy Efficiency Ratio (SEER)[1053]	Energy Efficiency Ratio (EER)	Heating Seasonal Performance Factor (HSPF)[1054]
Split System – Air Conditioner (<45 kBTU/h)	13.0	11.2	N/A
Split System – Air Conditioner (≥45 and <65 kBTU/h)	13.0	11.2	N/A
Single Package – Air Conditioner	14.0	11.8	N/A
Split System – Heat Pump (<45 kBTU/h)	14.0	11.8	8.2
Split System – Heat Pump (≥45 and < 65 kBTU/h)	14.0	11.8	8.2
Single Package – Heat Pump (<65 kBTU/h)	14.0	11.8	8.0

The baseline efficiency for commercial fossil fuel fired heating systems is defined by International Energy Conservation Code [1055] and subsequently adopted by the Energy Conservation Construction Code of New York State (ECCCNYS) as shown in the table below.

Commercial Fossil Fuel Fired Heating System Baseline Efficiencies

Equipment Type	Size Range	ECCCNYS Minimum Efficiency for Climate Zones 4, 5 and 6
Warm Air Furnace, Gas Fired	< 225 kBTU/h	0.80 AFUE
	≥ 225 kBTU/h	0.80 Et
Warm Air Furnace, Oil Fired	< 225 kBTU/h	0.83 AFUE
	≥ 225 kBTU/h	0.80 Et
Warm Air Unit Heaters, Gas Fired	All Capacities	0.80 Ec
Warm Air Unit Heaters, Oil Fired	All Capacities	0.80 Ec
Boiler, Hot Water, Gas Fired	< 300 kBTU/h	0.82 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.80 Et
	> 2,500 kBTU/h	0.82 Ec

[1053] 10 CFR 430.32(c)(1)
[1054] 10 CFR 430.32(c)(1)
[1055] ECCCNYS 2020, Table C403.3.2(4) & Table C403.3.2(5)

Equipment Type	Size Range	ECCCNYS Minimum Efficiency for Climate Zones 4, 5 and 6
Boiler, Hot Water, Oil Fired	< 300 kBTU/h	0.84 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.82 Et
	> 2,500 kBTU/h	0.84 Ec
Boiler, Steam, Gas Fired, All Except Natural Draft	< 300 kBTU/h	0.80 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.79 Et
	> 2,500 kBTU/h	0.79 Et
Boiler, Steam, Gas Fired, Natural Draft	< 300 kBTU/h	0.80 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.77 Et
	> 2,500 kBTU/h	0.77 Et
Boiler, Steam, Oil Fired	< 300 kBTU/h	0.82 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.81 Et
	> 2,500 kBTU/h	0.81 Et

For scenarios where the baseline heating system is electric resistance heat or an electric furnace, the baseline efficiency is assumed to be a COP of 1.0.

For scenarios where the baseline heating system is a conventional ASHP, additional consideration is given to account for the significant difference between the rating conditions for HSPF and the typical operating conditions in New York State, as shown below:

The HSPF is the AHRI-rated heating seasonal average efficiency expressed in terms of BTU/watt-hour. A seasonally adjusted $COP_{baseline}$ of a conventional air-source heat pump is used in the above equations. This adjusted baseline COP shall be calculated as:

$$COP_{season,baseline} = \frac{HSPF \times F_{HSPF}}{3.412}$$

where:

HSPF = Heating seasonal performance factor of the baseline system
F_{HSPF} = HSPF Climate Adjustment Factor, from table below
3.412 = Conversion factor, one watt-hour equals 3.412 BTU

HSPF Climate Adjustment Factor (F_{HSPF}) for Conventional ASHP Used as a Baseline

City	HSPF < 8.5	HSPF ≥ 8.5
Albany	0.70	0.67
Binghamton	0.68	0.65
Buffalo	0.73	0.70
Massena	0.59	0.56
NYC	0.80	0.78
Poughkeepsie	0.62	0.59
Syracuse	0.69	0.66

For scenarios where the baseline cooling system is a conventional ASHP, no additional consideration is given to account for the difference between the rating conditions for SEER and the typical operating conditions in New York State, because the differences between the rating conditions and the typical operating conditions are small.

Compliance Efficiency from which Incentives are Calculated

ASHPs are rated under ANSI/AHRI 210/240. Cold climate ASHPs must meet the Northeast Energy Efficiency Partnerships (NEEP) Cold Climate Air Source Heat Pump (ccASHP) Specification (Version 3.0) effective January 1, 2019. The specification uses AHRI-certified performance ratings and manufacturer reported data to describe the efficiency and capacity of the unit under full and part load condition

The average seasonal heating efficiency for an ASHP with a two stage or variable speed compressor is calculated as:

$$COP_{season,ee} = a + b\ x\ HSPF\ \ x\ \frac{1}{3.412}$$

The average seasonal cooling efficiency for a ccASHP with a variable speed compressor is calculated as:

$$EER_{season,ee} = c + d\ x\ SEER$$

where:

a & b	= Offset and slope coefficients from Tables below for heating (select based on city and scenario)
c & d	= Offset and slope coefficients from Tables below for cooling (select based on city and scenario)
HSPF	= Rated Heating Season Performance Factor from AHRI
SEER	= Rated Seasonal Energy Efficiency Ratio from AHRI
3.412	= Conversion factor, one watt-hour equals 3.412 BTU

Note that the cooling efficiency adjustments are quite large for some ASHP units (mini-splits) but much smaller for central ducted ASHP units. For the baseline conventional ASHP we assume that no adjustment to SEER is required. Appendix F in the ASHP White Paper explains why some ASHP units require a cooling efficiency adjustment while others do not.

Summary of Variables and Data Sources

Variable	Value	Source
a & b		Coefficients to represent offset and slope from the table below to determine seasonal heating efficiency ($COP_{season,ee}$) from HSPF. Depends on city and scenario.
c & d		Coefficients to represent offset and slope from the table below to determine seasonal cooling efficiency ($EER_{season,ee}$) from SEER. Depends on city and scenario.
HSPF		Rated heating season performance factor from AHRI.
SEER		Rated seasonal energy efficiency ratio from AHRI.

The scenarios shown in the first column of the Whole Building and Displacement Scenarios table below represent various specific applications of heat pumps, with heat pump type, sizing, and control strategy shown. These scenarios may be considered "sub-measures" of this measure[1056]. Assigning applicable scenario(s) to program participants or participant groups is the responsibility of program designers and implementers. For reference, the control strategies listed in the Whole Building and Displacement Scenarios table below are defined as follows:

- **Separate:** The ASHP and backup heating system are on separate thermostats.
- **Integrated/Modulating:** The ASHP and backup heating system are on the same thermostat. The backup heater can modulate to meet the load without limiting the ASHP from delivering its maximum capacity. Also called "perfect" control.
- **Integrated/Fixed Capacity:** The ASHP and backup heating system are on the same thermostat. The backup heater has a fixed capacity to meet the load. The backup heater is larger than the ASHP, so the ASHP is not always able to deliver its maximum capacity (the backup heater supplies a larger share of the load when both are running).
- **DF/Either HP or Furnace:** The central ASHP is installed on the same ductwork as the fossil fuel-fired furnace. Once the ASHP can no longer meet the load (or when a changeover temperature is reached). The ASHP shuts off and the furnace meets the load.

Where participants fall between the numeric values in the column "HP Sizing," use the scenario with the lower of the values in the column. "Single-zone ductless" means the equipment is single-zone (1-to-1 indoor to outdoor units). There may be multiple single-zone systems to achieve the HP sizing shown. When multiple HPs are used, the capacity-weighted rated efficiencies (HSPF, SEER, and EER) for the installed units need to be determined. For cooling efficiency, use the rated cooling capacity at 95°F and the SEER and EER for each unit to find the weighted average. Similarly, for heating efficiency use the rated heating capacity at 17°F ($QH_{17,rated}$) for projects best represented by the New York City climate zone and maximum heating capacity at 5°F ($QH_{5,max}$) otherwise, as well as HSPF for each unit to find the weighted average.

[1056] Detailed descriptions of these scenarios and their parameters are found in the white paper *Savings Calculations for Residential Air Source Heat Pumps: The Basis for Modifying EFLH and Seasonal Efficiency Factors for "Whole House" and "Displacement" Applications*, Tables 2 and 3, and the associated narrative.

Whole Building and Displacement Scenarios

Scenario	Description	ASHP Type	Application	Controls	HP Sizing Ratio
1a	Central ASHP with different controls	Central, Ducted	Whole	Integrated/ Modulating	0.9
1b				Integrated/ Fixed Capacity	
1c				DF/Either HP or Furnace	
1d				Integrated/ Modulating	1.0
2a	Ductless Mini-Spilt sized at 30%, 50%, 70% and 90/100%	Single-Zone Ductless	Displace	Separate	0.3
2b					0.5
2c					0.7
2d				Integrated/ Fixed Capacity	0.3
2e					0.5
2f					0.7
2g			Whole	Integrated/ Modulating	0.9
2h					1.0
3a	Ductless Multi-Split sized to 70% and 90/100%	Multi-Zone Ductless	Displace	Separate	0.7
3b			Whole	Integrated/ Modulating	0.9
3c					1.0
4a	Compact Ducted Mini-Split sized to 50% ,70% and 90/100%	Single-Zone Compact Ducted	Displace	Separate	0.5
4b					0.7
4c			Whole	Integrated/ Modulating	0.9
4d					1.0

The HP Sizing Ratio should be determined using the rated heating capacity at 17°F ($QH_{17,rated}$) for projects best represented by the New York City climate zone and maximum heating capacity at 5°F from the NEEP Cold Climate Heat Pump List ($QH_{5,max}$) otherwise, and design heating load for the building:

$$\text{HP Sizing Ratio} = (QH_{17,rated} \text{ or } QH_{5,max}) / BHL$$

The HP Sizing Ratio corresponds to the rightmost column in the Whole Building and Displacement Scenarios table above. Choose an appropriate scenario, then use the coefficients from the tables below to determine the seasonal efficiencies and load factors.

Coefficients for Seasonal Heating Efficiency: $COP_{season,ee} = a + b \times HSPF/3.412$														
Scenario	**Albany**		**Binghamton**		**Buffalo**		**Massena**		**New York**		**Poughkeepsie**		**Syracuse**	
	a	b	a	b	a	b	a	b	a	b	a	b	a	b
1a	-0.010	0.880	0.113	0.854	0.219	0.842	-0.185	0.838	0.767	0.798	0.333	0.796	0.124	0.860
1b	-0.040	0.891	0.092	0.863	0.197	0.851	-0.168	0.830	0.742	0.814	0.301	0.813	0.093	0.871
1c	0.056	0.906	0.220	0.870	0.310	0.849	-0.057	0.922	0.802	0.805	0.579	0.802	0.183	0.875
1d	-0.117	0.902	-0.003	0.879	0.081	0.876	-0.259	0.847	0.824	0.777	0.237	0.815	-0.007	0.890
2a	2.552	0.197	2.532	0.202	2.645	0.181	2.304	0.204	2.380	0.338	2.620	0.177	2.565	0.195
2b	2.351	0.256	2.419	0.243	2.644	0.188	2.011	0.290	2.506	0.296	2.470	0.228	2.500	0.217
2c	2.441	0.228	2.480	0.224	2.619	0.198	2.358	0.203	2.768	0.210	2.459	0.239	2.550	0.206
2d	2.615	0.113	2.637	0.113	2.702	0.108	2.312	0.150	2.923	0.131	2.725	0.104	2.655	0.107
2e	2.574	0.125	2.601	0.124	2.647	0.122	2.335	0.143	2.817	0.162	2.654	0.119	2.631	0.116
2f	2.458	0.160	2.493	0.155	2.546	0.153	2.322	0.145	2.760	0.180	2.588	0.135	2.513	0.154
2g	2.351	0.172	2.382	0.169	2.440	0.161	2.125	0.178	2.637	0.210	2.424	0.162	2.415	0.163
2h	2.336	0.179	2.386	0.169	2.422	0.168	2.030	0.205	2.674	0.198	2.372	0.177	2.414	0.168
3a	-3.334	1.993	-3.307	1.991	-3.485	2.065	-2.938	1.810	-3.793	2.217	-3.093	1.929	-3.339	2.006
3b	-2.683	1.735	-2.637	1.728	-2.720	1.770	-2.004	1.446	-3.436	2.064	-2.306	1.624	-2.710	1.757
3c	-2.823	1.775	-2.783	1.769	-2.832	1.800	-1.991	1.436	-3.598	2.110	-2.395	1.645	-2.861	1.800
4a	-0.333	1.141	-0.305	1.138	-0.251	1.137	-0.852	1.263	0.260	1.068	-0.407	1.194	-0.308	1.140
4b	-0.402	1.155	-0.393	1.160	-0.300	1.147	-0.865	1.261	0.145	1.086	-0.390	1.175	-0.385	1.160
4c	-0.166	1.004	-0.019	0.963	0.018	0.961	-0.234	0.972	-0.003	1.073	0.121	0.926	-0.006	0.962
4d	-0.240	1.024	-0.102	0.983	0.027	0.950	-0.321	0.993	-0.015	1.069	0.110	0.920	-0.127	1.001

Coefficients for Seasonal Cooling Efficiency: $EER_{season,ee} = c + d \times SEER$														
Scenario	**Albany**		**Binghamton**		**Buffalo**		**Massena**		**New York**		**Poughkeepsie**		**Syracuse**	
	c	d	c	d	c	d	c	d	c	d	c	d	c	d
1a	-0.540	0.961	0.920	0.914	-1.370	1.035	-0.390	0.936	2.910	0.786	-0.510	0.965	-0.810	0.988
1b	-0.540	0.961	0.920	0.914	-1.370	1.035	-0.390	0.936	2.910	0.786	-0.510	0.965	-0.810	0.988
1c	-0.540	0.961	0.920	0.914	-1.370	1.035	-0.390	0.936	2.910	0.786	-0.510	0.965	-0.810	0.988
1d	-0.460	0.946	-0.140	0.966	-1.670	1.041	-0.210	0.916	1.520	0.859	-0.590	0.961	-0.890	0.982
2a	12.330	0.118	11.950	0.116	12.240	0.130	12.360	0.135	11.070	0.165	12.100	0.111	12.180	0.123
2b	11.440	0.208	12.210	0.146	11.010	0.229	10.330	0.273	10.080	0.277	12.130	0.167	11.330	0.210
2c	9.810	0.306	10.940	0.232	9.590	0.302	9.160	0.321	9.440	0.323	10.310	0.282	9.740	0.308
2d	12.330	0.118	11.950	0.116	12.240	0.130	12.360	0.135	11.070	0.165	12.100	0.111	12.180	0.123
2e	11.440	0.208	12.210	0.146	11.010	0.229	10.330	0.273	10.080	0.277	12.130	0.167	11.330	0.210
2f	9.810	0.306	10.940	0.232	9.590	0.302	9.160	0.321	9.440	0.323	10.310	0.282	9.740	0.308
2g	9.400	0.314	9.950	0.300	8.130	0.366	8.500	0.351	8.670	0.353	9.080	0.328	9.080	0.327
2h	8.890	0.336	9.440	0.313	7.960	0.375	8.160	0.364	8.510	0.361	9.130	0.327	9.020	0.332
3a	17.760	-0.189	6.680	0.454	10.960	0.199	18.580	-0.218	11.600	0.196	16.240	-0.105	14.460	-0.008
3b	14.530	0.035	14.100	0.009	15.660	-0.060	11.420	0.204	16.950	-0.122	18.500	-0.205	17.260	-0.147
3c	10.850	0.255	17.070	-0.164	14.630	0.017	13.740	0.066	18.850	-0.246	15.270	-0.009	14.140	0.052
4a	-12.940	1.478	-12.220	1.433	-11.550	1.396	-13.560	1.520	-9.590	1.290	-12.690	1.456	-12.770	1.473
4b	-14.160	1.556	-13.060	1.493	-3.400	0.957	-14.370	1.569	-11.850	1.424	-14.010	1.547	-4.690	1.038
4c	-14.370	1.566	-4.310	1.019	-9.600	1.300	-14.650	1.576	-14.290	1.563	-14.680	1.586	-8.450	1.246
4d	-14.440	1.566	-4.690	1.041	-10.170	1.328	-14.700	1.572	-15.140	1.609	-14.790	1.590	-16.480	1.676

Note that several scenarios are the same since control approach and UR do not apply for cooling (i.e. 1a,1b and 1c are all the same, 2a is the same as 2d, etc.)

Heating Load Factor

Factors in the table below ($F_{load,heating}$) are used to determine the fraction of the annual heating load that is met by the ASHP unit.

Fraction of Heating Load Met by the ASHP ($F_{load,heating}$)							
Scenario	**Albany**	**Binghamton**	**Buffalo**	**Massena**	**New York**	**Poughkeepsie**	**Syracuse**
1a	1.00	1.00	1.00	0.98	1.00	0.97	1.00
1b	0.99	0.99	0.99	0.96	0.99	0.95	0.99
1c	0.86	0.86	0.89	0.69	0.96	0.82	0.90
1d	1.00	1.00	1.00	0.99	1.00	0.98	1.00
2a	0.25	0.25	0.25	0.23	0.37	0.25	0.24
2b	0.39	0.38	0.39	0.37	0.55	0.39	0.38
2c	0.56	0.55	0.56	0.55	0.76	0.54	0.55
2d	0.54	0.53	0.53	0.51	0.69	0.51	0.54
2e	0.74	0.73	0.73	0.71	0.87	0.69	0.74
2f	0.86	0.85	0.85	0.82	0.95	0.81	0.86
2g	0.98	0.97	0.97	0.94	0.99	0.92	0.98
2h	0.99	0.98	0.99	0.95	1.00	0.94	0.99
3a	0.72	0.71	0.70	0.67	0.86	0.67	0.72
3b	0.96	0.94	0.94	0.92	0.98	0.90	0.95
3c	0.97	0.96	0.96	0.94	0.99	0.92	0.98
4a	0.43	0.42	0.43	0.42	0.52	0.43	0.42
4b	0.59	0.58	0.58	0.56	0.67	0.56	0.58
4c	0.97	0.96	0.97	0.94	0.98	0.92	0.98
4d	0.99	0.99	0.99	0.96	0.99	0.95	0.99

Cooling Load Factor

Factors in the table below ($F_{load,cooling}$) are used to determine the fraction of the annual cooling load that is met by the ASHP unit. The cooling sizing is determined using assumptions about the relative size of cooling loads (BCL) and heating loads (BHL) in NY based on climate.

Fraction of Cooling Load Met by the ASHP ($F_{load,cooling}$)							
Scenario	**Albany**	**Binghamton**	**Buffalo**	**Massena**	**New York**	**Poughkeepsie**	**Syracuse**
1a	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1b	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1c	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1d	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2a	0.90	0.79	0.90	0.95	0.91	0.88	0.89
2b	0.99	0.95	0.99	1.00	0.99	0.99	0.99
2c	1.00	0.99	1.00	1.00	1.00	1.00	1.00
2d	0.90	0.79	0.90	0.95	0.91	0.88	0.89
2e	0.99	0.95	0.99	1.00	0.99	0.99	0.99
2f	1.00	0.99	1.00	1.00	1.00	1.00	1.00
2g	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2h	1.00	1.00	1.00	1.00	1.00	1.00	1.00
3a	1.00	0.99	1.00	1.00	1.00	1.00	1.00
3b	1.00	1.00	1.00	1.00	1.00	1.00	1.00
3c	1.00	1.00	1.00	1.00	1.00	1.00	1.00
4a	0.99	0.96	0.99	1.00	0.98	0.99	0.99
4b	1.00	0.99	1.00	1.00	1.00	1.00	1.00
4c	1.00	1.00	1.00	1.00	1.00	1.00	1.00
4d	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Note that several scenarios are the same since control approach and UR do not apply for cooling (i.e. 1a,1b and 1c are all the same, 2a is the same as 2d, etc.)

Operating Hours

The Building Equivalent Full Load Hours for heating ($BEFLH_{heating}$) and for cooling ($BEFLH_{cooling}$) in the tables below represent equivalent full load operating hours for HVAC equipment based on EnergyPlus models for 12 commercial building types and 3 multi-family building types. These existing building models were developed by NREL, and run for three weather locations: NY JFK (zone 4A), Buffalo (zone 5A) and Massena (zone 6A).[1057]

Commercial and High-Rise Multi-Family $BEFLH_{cooling}$ by City

Building	Buffalo	Massena	NYC
High Rise Multifamily - Pre-war - uninsulated brick	752	573	1,141
High Rise Multifamily - Prior to 1979	693	494	965
High Rise Multifamily - From 1979 Through 2006	738	523	1,007
High Rise Multifamily - From 2007 Through the Present	638	697	1,192
Assembly	803	670	1,080
Auto Repair	778	641	1,186
Big Box Retail	440	363	705
Fast Food Restaurant	547	417	788
Full Service Restaurant	547	417	788
Grocery	343	263	622
Light Industrial	93	77	230
Motel	1,958	1,760	2,141
Primary School	394	323	632
Religious Worship	307	329	451
Small Office	778	641	1,186
Small Retail	440	363	705
Warehouse	93	77	230
Other	440	363	705

Commercial and High-Rise Multi-Family $BEFLH_{heating}$ by City

Building	Buffalo	Massena	NYC
High Rise Multifamily - Pre-war - uninsulated brick	1,793	1,606	1,431
High Rise Multifamily - Prior to 1979	1,625	1,375	1,242
High Rise Multifamily - From 1979 Through 2006	1,563	1,301	1,216
High Rise Multifamily - From 2007 Through the Present	1,391	1,406	1,144
Assembly	1,233	1,442	751
Auto Repair	793	790	537
Big Box Retail	983	970	779
Fast Food Restaurant	1,508	1,386	1,236
Full Service Restaurant	1,508	1,386	1,236
Grocery	1,204	1,130	1,055
Light Industrial	1,159	1,047	876
Motel	1,127	942	916
Primary School	729	709	558
Religious Worship	1,218	1,264	899
Small Office	793	790	537
Small Retail	983	970	779
Warehouse	1,159	1,047	876
Other	983	970	779

[1057] Detailed descriptions of these models are found in the white paper *Developing Building Equivalent Full Load Hour (BEFLH) Values for Commercial and Multi-Family Buildings in NYS*, Tables 1, 2 and 3, and the associated narrative.

Example Calculation *(Not to be used as default)*

A central ducted air source heat pump system is installed in a full service restaurant located near NYC. The heat pumps are rated at 20 SEER, 13.4 EER, and 11 HSPF with a total system heating capacity at 5ºF of 200 kBTU/h. The system fully replaces the existing gas fired hot water boiler and existing single package central AC system. The building cooling load is 120 kBTU/h and building heating load is 193 kBTU/h The system includes electric resisteance supplemental heat. Annual Electric Energy Savings, Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta kWh = \left(\left(BCL \times \frac{1}{1{,}000} \times \left(\frac{1}{SEER_{baseline}} - \frac{1}{EER_{season,ee}}\right) \times EFLH_{cooling} \times F_{load,cooling}\right) + \left(BHL \times \frac{1}{1{,}000} \times \left(\frac{F_{ElecHeat}}{COP_{season,baseline}} - \frac{1}{COP_{season,ee}}\right) \times \frac{1}{3.412} \times EFLH_{heating} \times F_{load,heating,ElecHeat}\right) - \left(BHL \times \frac{1}{1{,}000} \times F_{ElecHeat,new} \times \frac{1}{3.412} \times BEFLH_{heating} \times \left(1 - F_{load,heating}\right)\right)\right)$$

$$\Delta kW = BCL \times \frac{1}{1{,}000} \times \left(\frac{1}{EER_{baseline}} - \frac{1}{EER_{ee}}\right) \times F_{load,cooling} \times CF$$

$$\Delta MMBtu = BHL \times \frac{1}{1{,}000{,}000} \times \frac{F_{FuelHeat}}{Eff_{baseline}} \times BEFLH_{heating} \times F_{load,heating,FuelHeat}$$

BCL = 120,000, from application
$SEER_{baseline}$ = 14.0, from Electric Cooling and Heating System Baseline Efficiencies table based on equipment type from application
$EER_{seaons,ee}$ = c + d x SEER = 1.52 + 0.859 x 20 = 18.7
$EER_{season,ee}$ equation from Compliance Efficiency section
c and d from Coefficients for Seasonal Cooling Efficiency table based on scenario and location from application. To determine scenario, the HP Sizing Ratio is calculated: $QH_{5,max}$ / BHL= 200/193 = 1.04. Thus c and d correspond to scenario 1d based on application conditions
SEER from application
$BEFLH_{cooling}$ = 788, from Operating Hours section
$F_{load,cooling}$ = 1.00, from Cooling Load Factor table based on scenario from application
BHL = 193,000, from application
$F_{ElecHeat}$ = 0, from application
$COP_{season,baseline}$ = N/A, from application

$COP_{season,ee}$ = a + b x HSPF x 1/3.412 = 0.824 +0.777 x 11 x 1/3.412 = 2.75

$COP_{season,ee}$ equation from Compliance Efficiency section

a and b from Coefficients for Seasonal Heating Efficiency table based on scenario and location from application

HSPF from application

$BEFLH_{heating}$ = 1,236, from Operationg Hours section

$F_{load,heating,ElecHeat}$ = 1.00, from Heating Load Factor table based on scenario and existing heat system from application

$F_{ElecHeat,new}$ = 1, from application

$F_{load,heating}$ = 1.00, from Heating Load Factor table based on scenario from application

$EER_{baseline}$ = 11.8, from Electric Cooling and Heating System Baseline Efficiencies table based on equipment type from application

EER_{ee} = 13.4, from application

CF = 0.69, from Coincidence Factor section

$F_{FuelHeat}$ = 1, from application

$EFF_{baseline}$ = 0.82, from Baseline Efficiencies section based on equipment type and size from application

$F_{load,heating,FuelHeat}$ = 1, from on Summary of Variables and Data Sources table based on heating system from application

$$\Delta kWh = \left(\left(120{,}000 \times \frac{1}{1{,}000} \times \left(\frac{1}{14} - \frac{1}{18.7}\right) \times 788 \times 1.00\right) + \left(193{,}000 \times \frac{1}{1{,}000} \times \left(0 - \frac{1}{2.75}\right) \times \frac{1}{3.412} \times 1{,}236 \times 1.00\right) - \left(193{,}000 \times \frac{1}{1{,}000} \times 1 \times \frac{1}{3.412} \times 1{,}236 \times (1 - 1.00)\right)\right) = -23{,}725\ kWh$$

$$\Delta kW = 120{,}000 \times \frac{1}{1{,}000} \times \left(\frac{1}{11.8} - \frac{1}{13.4}\right) \times 1 \times 0.69 = 0.838\ kW$$

$$\Delta MMBtu = 193{,}000 \times \frac{1}{1{,}000{,}000} \times \frac{1}{0.82} \times 1{,}236 \times 1 = 292.4\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. 10 CFR 430.32 Energy and water conservation standards and their compliance dates. Available from: http://www.ecfr.gov/cgi-bin/text-idx?SID=a9921a66f2b4f66a32ec851916b7b9d9&mc=true&node=se10.3.430_132&rgn=div8
2. BG&E: Development of Residential Load Profile for Central Air Conditioners and Heat Pumps
3. Building America House Simulation Protocols, Robert Hendron and Cheryn Engebrecht, National Renewable Energy Laboratory, October 2010 Available from: https://www1.eere.energy.gov/buildings/publications/pdfs/building_america/house_simulation_revised.pdf
4. ECCCNYS 2020, Table C403.3.2(4): Warm-Air Furnaces And Combination Warm-Air Furnaces/Air-Conditioning Units, Warm-Air Duct Furnaces And Unit Heaters, Minimum Efficiency Requirements & Table C403.2.3(5): Minimum Efficiency Requirements: Gas- And Oil-Fired Boilers.
   Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-[ce]-commercial-energy-efficiency#NYSECC2020P1_CE_Ch04_SecC402
5. Fairey, P., D. Parker, B Wilcox, M Lombardi. *Climate Impacts on Heating Seasonal Performance Factor (HSPF) and Seasonal Energy Efficiency Ratio (SEER) for Air Source Heat Pumps*, ASHRAE Transactions, 110(2): 178-88.
6. Henderson, H.I., 2020. White Paper: Savings Calculations for Residential Ground Source Heat Pumps: The Basis for Equivalent Full Load Hours (EFLH) and Seasonal Efficiency Factors. Prepared for the New York State Energy Research and Development Authority (NYSERDA) and the New York State Department of Public Service. Revised in June.
7. M. M. Straub, Using Available Information for Efficient Evaluation of Demand-Side Management Programs, Electricity Journal, September 2011
   Available from: https://www.sciencedirect.com/science/article/pii/S1040619011001941
8. *Manual J Residential Load Calculation*, Arlington, VA. Air Conditioning Contractors Association
9. *Manual S Equipment Selection*, Arlington, VA. Air Conditioning Contractors Association
10. Henderson, H.I., 2021. White Paper: Developing Building Equivalent Full Load Hour (BEFLH) Values for Commercial and Multi-Family Buildings in NYS. Prepared for the New York State Energy Research and Development Authority (NYSERDA) and the New York State Department of Public Service. Revised in August.

Record of Revision

Record of Revision Number	Issue Date
1	10/15/2010
12-17-8	12/31/2017
9-18-4	9/28/2018
2-20-5	2/28/2020
7-20-23	7/31/2020

Return to Table of Contents

HEAT PUMP – WATER-TO-AIR GROUND SOURCE (GSHP)

Measure Description

This measure covers the installation of an ENERGY STAR® certified Ground Source Heat Pump (GSHP) system with a closed loop heat exchanger field or an open loop ground water system as permissible by local environmental review.[1058] The GSHP system provides heating and cooling for space conditioning by a water-to-air heat pump via a typical air-duct distribution system in a small commercial building not more than three stories above grade in height. This measure applies to individual GSHP units in small commercial applications, and where each GSHP unit has its own dedicated loop pump. It does not apply to large GSHP systems with multiple heat pump units served by centralized ground loop pumping. The GSHP analysis associated with this measure is based on several assumptions consistent with best practice design for a quality GSHP installation:

- Building heating and cooling loads shall be calculated, and systems shall be sized in accordance with applicable federal, state, local and municipal codes and standards.
- When the building peak heating load for a small commercial building in New York State exceeds the peak cooling load, it is assumed that the GSHP runs at part-load during peak cooling hours. For installation scenarios where the building load is cooling dominant a custom analysis is required.
- The ground loop heat exchanger is adequately sized and installed properly to allow the GSHP to meet the peak heating load without electric resistance auxiliary heat.
- The GSHP is equipped with either a two stage or variable-speed compressor system, a variable speed or constant speed ground loop circulator pump, and a variable-speed blower distribution fan.
- The GSHP efficiency is rated in accordance with ISO 13256-1, and AHRI-certified performance ratings are provided by the manufacturer showing the efficiency and capacity of the unit under full and part load conditions.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = \left[\frac{BCL}{1{,}000} \times \left(\frac{1}{EER_{season,baseline}} - \frac{1}{EER_{season,ee}}\right) \times BEFLH_{cooling}\right] + \left[\frac{BHL}{3{,}412} \times \left(\frac{F_{ElecHeat}}{COP_{season,baseline}} - \frac{1}{COP_{season,ee}}\right) \times BEFLH_{heating}\right]$$

[1058] This measure section does not apply to a subset of open loop systems known as standing column wells, since operating temperatures are much different in these applications.

Summer Peak Coincident Demand Savings

$$\Delta kW = \frac{BCL}{1{,}000} \times \left(\frac{1}{EER_{peak,baseline}} - \frac{1}{EER_{GSHP,full,ee}} \right) \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = \frac{BHL}{1{,}000{,}000} \times \frac{F_{FuelHeat}}{Eff_{baseline}} \times BEFLH_{heating}$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
BCL	= Building Cooling Load at design conditions (BTU/h)
BHL	= Building Heating Load at design conditions (BTU/h)
$F_{ElecHeat}$	= Electric heating factor; used to account for the presence or absence of an electric heating system
$F_{FuelHeat}$	= Fossil fuel heating factor; used to account for the presence or absence of a fossil fuel heating system
baseline	= Characteristic of baseline condition
ee	= Characteristic of energy efficient condition
EER_{season}	= Energy efficiency ratio (BTU/watt-hour) at part-load seasonally adjusted for fan and pump power
EER_{peak}	= Full load energy efficiency ratio (BTU/watt-hour)
$EER_{GSHP,full}$	= Full load energy efficiency ratio (BTU/watt-hour). Refers to Ground Loop Heat Pump (GLHP)-rated condition for closed loop GSHP systems or Ground Water Heat Pump (GWHP)-rated conditions for open loop systems.
COP_{season}	= Coefficient of performance, seasonally adjusted for fan and pump power.
Eff	= Efficiency rating of fossil fuel heating equipment
$BEFLH_{cooling}$	= Cooling equivalent full-load hours based on building design load
$BEFLH_{heating}$	= Heating equivalent full-load hours based on building design load
CF	= Coincidence Factor
3,412	= Conversion factor, one kWh equals 3,412 BTU
1,000	= Conversion factor, one kW equals 1,000 Watts
1,000,000	= Conversion factor, one MMBtu equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
BCL		Building cooling load at design conditions calculated in accordance with ASHRAE Standard 183, from application.
BHL		Building heating load at design conditions calculated in accordance with ASHRAE Standard 183, from application.
$F_{ElecHeat}$		If the baseline heating system is an electric system, set equal to 1. Otherwise, set equal to 0.

Variable	Value	Notes
$F_{FuelHeat}$		If the baseline heating system is a fossil fuel system, set equal to 1. Otherwise, set equal to 0.
$EER_{season,baseline}$		Seasonal electric cooling energy efficiency rating of baseline equipment. See Baseline Efficiency section below for details.
$EER_{peak,baseline}$		Electric cooling energy efficiency rating of baseline equipment. See Baseline Efficiency section below for details.
$EER_{season,ee}$		Energy efficiency ratio from the manufacturer's catalog data adjusted to account for applied fan and pump power. See Compliance Efficiency section below for details.
$EER_{GSHP,full,ee}$		Full load energy efficiency ratio at AHRI rated conditions. Corresponds to GLHP-rated condition with fluid temperature of 77ºF for closed loop systems, or GWHP-rated condition with fluid temperature of 59ºF for open loop systems.
$COP_{season,baseline}$		Electric heating energy efficiency rating of baseline equipment. See Baseline Efficiency section below for details.
$COP_{season,ee}$		Coefficient of performance from the manufacturer's catalog data adjusted to account for applied fan and pump power. See Compliance Efficiency section below for details.
$Eff_{baseline}$		Seasonal fossil fuel energy efficiency of the baseline equipment. See Baseline Efficiency section below for details.
$BEFLH_{cooling}$		Lookup based on building type, vintage and location from the appropriate table in the Operating Hours section below.
$BEFLH_{heating}$		Lookup based on building type, vintage and location from the appropriate table in the Operating Hours section below.

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.80.[1059]

Baseline Efficiencies from which Energy Savings are Calculated

The baselines used in this measure are determined by the type of equipment that would have been installed without the influence of the program supporting the installation of this measure. This allows for an analysis that does not depend on a typical 'like-for-like' replacement scenario.

A GSHP system can be considered a normal replacement scenario for electric resistance heating (with or without a central electric cooling system), an ASHP system (that provides space heating and cooling), or a fossil fuel fired heating system (with or without a central electric cooling system). The tables below provide baseline efficiencies for electric cooling and heating and fossil fuel fired heating systems.

For scenarios where there is new construction or substantial renovation, the baseline is assumed to be a fossil fuel fired warm air furnace of the fuel type most likely to be installed at the project site without the influence of the program with a central air conditioning system.

[1059] *No source specified – update pending availability and review of applicable references.*

The baseline efficiency for electric cooling and heating systems is defined by the Code of Federal Regulations as shown in the table below.

Electric Cooling and Heating System Baseline Efficiencies

Product Class	Seasonal Energy Efficiency Ratio (SEER)[1060]	Energy Efficiency Ratio (EER)	Heating Seasonal Performance Factor (HSPF)[1061]
Split System – Air Conditioner (<45 kBTU/h)	13.0	11.2	N/A
Split System – Air Conditioner (≥45 and <65 kBTU/h)	13.0	11.2	N/A
Single Package – Air Conditioner	14.0	11.8	N/A
Split System – Heat Pump (<45 kBTU/h)	14.0	11.8	8.2
Split System – Heat Pump (≥45 and < 65 kBTU/h)	14.0	11.8	8.2
Single Package – Heat Pump (<65 kBTU/h)	14.0	11.8	8.0

GSHP System Baseline Efficiencies

Product Application	Full-Load Rated Heating COP	Full-Load Rated Cooling EER	Adjusted Heating Efficiency ($COP_{season,base}$)	Adjusted Cooling Efficiency ($EER_{season,base}$)
Closed Loop, GLHP-rating	3.2	14.1	2.95	12.99
Open Loop, GWHP-rating	3.7	18.0	3.05	14.71

*Equipment < 135 kBTU/h cooling capacity rated by ISO/ANSI/ASHRAE 13256-1: Baseline system is assumed to be single stage.
**Adjusted values use corrections below for pumping and distribution losses assuming a pumping power of 90 Watts per ton for closed loop and 120 Watts per ton open loop.

The baseline efficiency for commercial fossil fuel fired heating systems is defined by International Energy Conservation Code [1062] and subsequently adopted by the Energy Conservation Construction Code of New York State (ECCCNYS) as shown in the table below.

[1060] 10 CFR 430.32(c)(1)
[1061] 10 CFR 430.32(c)(1)
[1062] ECCCNYS 2020, Table C403.3.2(4) & Table C403.3.2(5)

Commercial Fossil Fuel Fired Heating System Baseline Efficiencies

Equipment Type	Size Range	ECCCNYS Minimum Efficiency for Climate Zones 4, 5 and 6
Warm Air Furnace, Gas Fired	< 225 kBTU/h	0.80 AFUE
	≥ 225 kBTU/h	0.80 Et
Warm Air Furnace, Oil Fired	< 225 kBTU/h	0.83 AFUE
	≥ 225 kBTU/h	0.80 Et
Warm Air Unit Heaters, Gas Fired	All Capacities	0.80 Ec
Warm Air Unit Heaters, Oil Fired	All Capacities	0.80 Ec
Boiler, Hot Water, Gas Fired	< 300 kBTU/h	0.82 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.80 Et
	> 2,500 kBTU/h	0.82 Ec
Boiler, Hot Water, Oil Fired	< 300 kBTU/h	0.84 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.82 Et
	> 2,500 kBTU/h	0.84 Ec
Boiler, Steam, Gas Fired, All Except Natural Draft	< 300 kBTU/h	0.80 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.79 Et
	> 2,500 kBTU/h	0.79 Et
Boiler, Steam, Gas Fired, Natural Draft	< 300 kBTU/h	0.80 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.77 Et
	> 2,500 kBTU/h	0.77 Et
Boiler, Steam, Oil Fired	< 300 kBTU/h	0.82 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.81 Et
	> 2,500 kBTU/h	0.81 Et

For scenarios where the baseline heating system is electric resistance heat or an electric furnace, the baseline efficiency is assumed to be a COP of 1.0.

For scenarios where the baseline heating system is a conventional ASHP, additional consideration is given to account for the significant difference between the rating conditions for HSPF and the typical operating conditions in New York State, as shown below:

The HSPF is the AHRI-rated heating seasonal average efficiency expressed in terms of BTU/watt-hour. A seasonally adjusted $COP_{baseline}$ of a conventional air-source heat pump is used in the above equations. This adjusted baseline COP shall be calculated as:

$$COP_{season,baseline} = \frac{HSPF \times F_{HSPF}}{3.412}$$

where:

HSPF = Heating seasonal performance factor of the baseline system

F_{HSPF} = HSPF Climate Adjustment Factor, from table below

3.412 = Conversion factor, one watt-hour equals 3.412 BTU

HSPF Climate Adjustment Factor (F_{HSPF}) for Conventional ASHP Used as a Baseline

City	HSPF < 8.5	HSPF ≥ 8.5
Albany	0.70	0.67
Binghamton	0.68	0.65
Buffalo	0.73	0.70
Massena	0.59	0.56
NYC	0.80	0.78
Poughkeepsie	0.62	0.59
Syracuse	0.69	0.66

For scenarios where the baseline cooling system is a conventional ASHP, no additional consideration is given to account for the difference between the rating conditions for SEER and the typical operating conditions in New York State, because the differences between the rating conditions and the typical operating conditions are small.

For scenarios where the baseline heating and cooling system is an existing GSHP, the seasonal heating and cooling efficiencies of the baseline equipment code minimum efficiencies that have been adjusted consistent with the methodology provided for efficient equipment described in the *Compliance Efficiency from Which Incentives are Calculated* section below.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is an ENERGY STAR® certified GSHP system as defined in the Measure Description section above. If the GSHP system is closed loop, use the following formulas with the COP and EER values from the GLHP ratings. If the GSHP system is an open loop system, use the following formulas with the COP and EER values from the GWHP ratings. The formulas adjust performance for closed loop systems to an average entering water temperature of approximately 40°F for heating and 77°F for cooling. The open loop formulas adjust performance to an average entering water temperature of 50°F for both heating and cooling[1063].

The formulas determine the average seasonal cooling efficiency ($EER_{season,ee}$) and the average seasonal heating efficiency ($COP_{season,ee}$) for a GSHP system with a two-stage or variable speed compressor.

[1063] These entering temperatures were selected based on measured data from GSHP sites presented in NYSERDA Report 18-03.

Closed Loop Systems (using GLHP ratings):

$$EER_{season,ee} = \Big(\big(F_{full} \times EER_{GLHP,full} \times 1.09 \times F_{pump,full}\big) + \big(F_{part} \times EER_{GLHP,part} \times F_{pump,part}\big)\Big) \times F_{dist,c}$$

$$COP_{season,ee} = \Big(\big(F_{full} \times COP_{GLHP,full} \times 1.08 \times F_{pump,full}\big) + \big(F_{part} \times COP_{GLHP,part} \times F_{pump,part}\big)\Big) \times F_{dist,h}$$

Open Loop Systems (using GWHP ratings):

$$EER_{season,ee} = \Big(\big(F_{full} \times EER_{GWHP,full} \times F_{pump,full}\big) + \big(F_{part} \times EER_{GWHP,part} \times F_{pump,part}\big)\Big) \times 1.09 \times F_{dist,c}$$

$$COP_{season,ee} = \Big(\big(F_{full} \times COP_{GWHP,full} \times F_{pump,full}\big) + \big(F_{part} \times COP_{GWHP,part} \times F_{pump,part}\big)\Big) \times F_{dist,h}$$

where:

$COP_{GLHP,full}$	= Rated COP of the unit at GLHP full load heating conditions
$COP_{GLHP,part}$	= Rated COP of the unit at GLHP part load heating conditions
$EER_{GLHP,full}$	= Rated EER of the unit at GLHP full load cooling conditions
$EER_{GLHP,part}$	= Rated EER of the unit at GLHP part load cooling conditions
$COP_{GWHP,full}$	= Rated COP of the unit at GWHP full load heating conditions
$COP_{GWHP,part}$	= Rated COP of the unit at GWHP part load heating conditions
$EER_{GWHP,full}$	= Rated EER of the unit at GWHP full load cooling conditions
$EER_{GWHP,part}$	= Rated EER of the unit at GWHP part load cooling conditions
$F_{dist,c}$	= Factor to adjust the cooling efficiency to account for additional fan power
$F_{dist,h}$	= Factor to adjust the heating efficiency to account for additional fan power
F_{full}	= Seasonal weighting factor for full load efficiency
F_{part}	= Seasonal weighting factor for part load efficiency
$F_{pump,\ part}$	= Factor to adjust part load efficiency to account for additional pumping power
$F_{pump,full}$	= Factor to adjust full load efficiency to account for additional pumping power
1.09	= Correction for change in EER[1064]
1.08	= Correction for change in COP[1065]

[1064] Correction for 9% change in EER as the entering fluid temperature decreases from 77°F to 68°F. The 1% per °F was observed from published performance data as well as in the IGSHPA Design Manual. This factor also applies to the GWHP adjustment from 50°F to 59°F.

[1065] Correction for 8% change in COP as the entering fluid temperature increases from 32°F to 40°F. The 1% per °F was observed from published performance data as well as in the IGSHPA Design Manual.

Summary of Variables and Data Sources

Variable	Value	Source
$COP_{GLHP,full}$		The rated COP of the unit at GLHP full load (or standard) heating conditions from ASHRAE/ISO 13256-1. This value is certified by AHRI and is available in the product directory. It corresponds to an entering loop temperature of 32°F.
$COP_{GLHP,part}$		The rated COP of the unit at GLHP part load heating conditions from ASHRAE/ISO 13256-1. This value is certified by AHRI and is available in the product directory. It corresponds to an entering loop temperature of 41°F.
$EER_{GLHP,full}$		The rated EER of the unit at GLHP full load (or standard) cooling conditions from ASHRAE/ISO 13256-1. This value is certified by AHRI and is available in the product directory. It corresponds to an entering loop temperature of 77°F.
$EER_{GLHP,part}$		The rated EER of the unit at GLHP part load cooling conditions from ASHRAE/ISO 13256-1. This value is certified by AHRI and is available in the product directory. It corresponds to an entering loop temperature of 68°F.
$COP_{GWHP,full}$		The rated COP of the unit at GWHP full load (or standard) heating conditions from ASHRAE/ISO 13256-1. This value is certified by AHRI and is available in the product directory. It corresponds to an entering water temperature of 50°F.
$COP_{GWHP,part}$		The rated COP of the unit at GWHP part load heating conditions from ASHRAE/ISO 13256-1. This value is certified by AHRI and is available in the product directory. It corresponds to an entering water temperature of 50°F.
$EER_{GWHP,full}$		The rated EER of the unit at GWHP full load (or standard) cooling conditions from ASHRAE/ISO 13256-1. This value is certified by AHRI and is available in the product directory. It corresponds to an entering water temperature of 59°F.
$EER_{GWHP,part}$		The rated EER of the unit at GWHP part load cooling conditions from ASHRAE/ISO 13256-1. This value is certified by AHRI and is available in the product directory. It corresponds to an entering water temperature of 59°F.
$F_{dist,c}$		Factor to adjust the cooling efficiency to account for additional fan power that would be required, beyond the fan power corresponding to zero static in rated COP. Choose the appropriate factor from the Distribution Correction Factors table below.
$F_{dist,h}$		Factor to adjust the heating efficiency to account for additional fan power that would be required, beyond the fan power corresponding to zero static in rated COP. Choose the appropriate factor from the Distribution Correction Factors table below.

Variable	Value	Source
F_{full}	0.25	Seasonal weighting factor for full load efficiency = 0.25. Based in part on observed mix of low and high stage operation from field testing.[1066]
F_{part}	0.75	Seasonal weighting factor for part load efficiency = 0.75. Based in part on observed mix of low and high stage operation from field testing.[1067]
$F_{pump,full}$		Factor to adjust the full load efficiency to account for additional pumping power used by the system. Choose the appropriate factor from Pumping Power Adjustment Factor table below.
$F_{pump,part}$		Factor to adjust the part load efficiency to account for additional pumping power used by the system. Choose the appropriate factor from Pumping Power Adjustment Factor table below.

Loop Pumping Power Correction Factor ($F_{pump,full}$ and $F_{pump,part}$)

A correction factor for pumps ($F_{pump,full}$ and $F_{pump,part}$) is required because the rated efficiency values only include the pumping energy associated with the water-side pressure drop through the heat pump unit (typically about 5-10 Watts per nominal ton). Actual pumping power is much higher. The ASHRAE GSHP Design Guide (Kavanaugh and Rafferty 2015) developed a grading system that assigns scores based on the amount of pumping power per installed ton. For instance, it gives a grade of "A" to system that uses 45 Watts per nominal ton and a grade of "B" to a system that uses 60 Watts per nominal ton.

Analysis of observed pumping power from 45 to 120 Watts/ton was performed to determine the impact of loop pumping power on efficiency. Results are shown in the Pumping Factors table below.[1068]

Pumping Power Adjustment Factors

Different factors are required for different loop pumping power levels and loop pump control strategies. For part load performance there are multiple ways to control the pump at low stage:

- the pump can maintain constant flow regardless of compressor stage.
- the pump stages flow in proportion to the compressor capacity.
- the pump can be variable speed and modulate with the variable speed compressor.

A constant speed loop pump results in poor performance since the pump power becomes a relatively larger portion of total power at low stage. Variable speed pumping with a variable speed compressor results in the best performance. The penalty for constant speed pumping is highest for units with variable speed compressors. The last consideration is the low-to-high capacity ratio (CR), which can be calculated as follows:

[1066] New York State Energy Research and Development Authority (NYSERDA) 2017. "Analysis of Water Furnace Geothermal Heat Pump Sites in New York State with Symphony Monitoring System," NYSERDA Report Number 18-03. Prepared by CDH Energy Corp., Cazenovia, NY. nyserda.ny.gov/publications.

[1067] Ibid.

[1068] Henderson, H.I., 2020. White Paper: Savings Calculations for Residential Ground Source Heat Pumps: The Basis for Equivalent Full Load Hours (EFLH) and Seasonal Efficiency Factors. Prepared for the New York State Energy Research and Development Authority (NYSERDA) and the New York State Department of Public Service. Revised in June.

$$CR = \frac{QC_{GLHP,part}}{QC_{GLHP,full}}$$

where:

CR = Capacity ratio of part-load cooling capacity to full-load heating capacity.
$QC_{GLHP,part}$ = Part-load cooling capacity rating from AHRI certificate.
$QC_{GLHP,full}$ = Full-load heating capacity rating from AHRI certificate.

The values of QC are the rated full and part load performance values from AHRI. Units with two stage compressors typically have a value of CR of approximately 0.75. Units with variable speed compressors typically have a CR of approximately 0.40.

The table below presents the values of $F_{pump,full}$ and $F_{pump,part}$ that correspond to each loop pump arrangement (e.g. pumping control strategy, CR, and pumping power). The full load pumping factors are typically 0.86 to 0.94. Part load factors can range from 0.62 to 0.95 depending on the pumping control strategy, the capacity ratio of the heat pump, and the pumping power. The factor closest to the actual situation should be used.

Pumping Factors ($F_{pump,full}$ and $F_{pump,part}$)

Pumping Control Strategy	Capacity Ratio	Pumping Power											
		45 Watts/ton		60 Watts/ton		75 Watts/ton		90 Watts/ton		105 Watt/ton		120 Watts/ton	
		Clg	Htg	Clg	Htg	Clg	Htg	Clg	Htg	Clg	Htg	Clg	Htg
Full load ($F_{pump,full}$)		0.94	0.94	0.93	0.92	0.91	0.90	0.89	0.89	0.88	0.87	0.86	0.86
Part load – constant flow pumping ($F_{pump,part}$)	0.75	0.89	0.91	0.86	0.89	0.83	0.86	0.80	0.84	0.78	0.82	0.75	0.80
Part load – constant flow pumping ($F_{pump,part}$)	0.40	0.81	0.85	0.77	0.81	0.72	0.77	0.69	0.74	0.65	0.71	0.62	0.68
Part load – staged pumping ($F_{pump,part}$)	0.75	0.92	0.94	0.89	0.91	0.87	0.89	0.84	0.87	0.82	0.86	0.80	0.84
Part load – staged pumping ($F_{pump,part}$)	0.40	0.92	0.94	0.89	0.91	0.87	0.89	0.84	0.87	0.82	0.86	0.80	0.84
Part load – variable pumping ($F_{pump,part}$)	0.40	0.94	0.95	0.92	0.93	0.90	0.92	0.88	0.90	0.86	0.89	0.84	0.87

Distribution Power Correction

For GSHP systems with an air-duct distribution system, the fan power included in the rated efficiencies corresponds to zero external static pressure and therefore is smaller than would be expected for an actual application. The indoor fan power included in the ISO 13256-1 test

procedure is estimated to be approximately 0.15 Watts/cfm for permanent split-capacitor fan motors and 0.11 Watts/cfm for electrically commutated fan motors.[1069]

The purpose of the distribution (i.e., fan or pump) correction factor, $F_{dist,h}$ and $F_{dist,c}$ is to determine the equivalent amount of distribution power for the baseline system, such as a fossil fuel fired furnace or boiler, or a heat pump. The correction factor considers the differential distribution power between the GSHP and the baseline system. The Distribution Correction Factors to correct GSHP Seasonal Efficiency for typical baseline scenarios summarized in the table below:

Distribution Correction Factors ($F_{dist,h}$ and $F_{dist,c}$)

	If baseline system is a Furnace with conventional air conditioning	If baseline system is a Boiler with conventional air conditioning	If baseline system is a Central air source heat pump
Heating ($F_{dist,h}$)	0.96	0.96	0.97
Cooling ($F_{dist,c}$)	0.95	0.95	0.95

Note: Based on furnace and boiler ancillary power of 137 Watts

Operating Hours

The Building Equivalent Full Load Hours for heating ($BEFLH_{heating}$) and for cooling ($BEFLH_{cooling}$) in the tables below represent equivalent full load operating hours for HVAC equipment based on EnergyPlus models for 12 commercial building types and 3 multi-family building types. These existing building models were developed by NREL, and run for three weather locations: NY JFK (zone 4A), Buffalo (zone 5A) and Massena (zone 6A).[1070]

Commercial and High-Rise Multi-Family $BEFLH_{cooling}$ by City

Building	Buffalo	Massena	NYC
High Rise Multifamily - Pre-war - uninsulated brick	752	573	1,141
High Rise Multifamily - Prior to 1979	693	494	965
High Rise Multifamily - From 1979 Through 2006	738	523	1,007
High Rise Multifamily - From 2007 Through the Present	638	697	1,192
Assembly	803	670	1,080
Auto Repair	778	641	1,186
Big Box Retail	440	363	705
Fast Food Restaurant	547	417	788
Full Service Restaurant	547	417	788
Grocery	343	263	622
Light Industrial	93	77	230
Motel	1,958	1,760	2,141
Primary School	394	323	632
Religious Worship	307	329	451
Small Office	778	641	1,186
Small Retail	440	363	705
Warehouse	93	77	230
Other	440	363	705

[1069] Ibid.

[1070] Detailed descriptions of these models are found in the white paper *Developing Building Equivalent Full Load Hour (BEFLH) Values for Commercial and Multi-Family Buildings in NYS*, Tables 1, 2 and 3, and the associated narrative.

Commercial and High-Rise Multi-Family BEFLH $_{heating}$ by City

Building	Buffalo	Massena	NYC
High Rise Multifamily - Pre-war - uninsulated brick	1,793	1,606	1,431
High Rise Multifamily - Prior to 1979	1,625	1,375	1,242
High Rise Multifamily - From 1979 Through 2006	1,563	1,301	1,216
High Rise Multifamily - From 2007 Through the Present	1,391	1,406	1,144
Assembly	1,233	1,442	751
Auto Repair	793	790	537
Big Box Retail	983	970	779
Fast Food Restaurant	1,508	1,386	1,236
Full Service Restaurant	1,508	1,386	1,236
Grocery	1,204	1,130	1,055
Light Industrial	1,159	1,047	876
Motel	1,127	942	916
Primary School	729	709	558
Religious Worship	1,218	1,264	899
Small Office	793	790	537
Small Retail	983	970	779
Warehouse	1,159	1,047	876
Other	983	970	779

Example Calculation *(Not to be used as default)*

A closed loop water-to-air GSHP is installed to provide space heating and cooling for an small office building located near Buffalo. The heat pump has variable speed pumping controls and rated heating capacity of 60 kBTUh, with a full load EER of 19, part load EER of 25, full load COP of 3.5 and part load COP of 4.1. The GSHP has a 60 watts/ton system pumping power. The building has a building cooling load of 36 kBTUh and the building cooling load of 58 kBTUh, and existing HVAC equipment are a split system air conditioner and a gas fired furnace. Annual Electric Energy Savings, Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta kWh = \left[\frac{BCL}{1{,}000} \times \left(\frac{1}{EER_{season,baseline}} - \frac{1}{EER_{season,ee}}\right) \times EFLH_{cooling}\right] + \left[\frac{BHL}{3{,}412} \times \left(\frac{F_{ElecHeat}}{COP_{season,baseline}} - \frac{1}{COP_{season,ee}}\right) \times EFLH_{heating}\right]$$

$$\Delta kW = \frac{BCL}{1{,}000} \times \left(\frac{1}{EER_{peak,baseline}} - \frac{1}{EER_{GSHP,full,ee}}\right) \times CF$$

$$\Delta MMBtu = \frac{BHL}{1{,}000{,}000} \times \frac{F_{FuelHeat}}{Eff_{baseline}} \times EFLH_{heating}$$

BCL = 36,000, from application

$EER_{season,baseline}$ = 13, from Baseline Efficiencies section based on equipment type and size from application

$EER_{season,ee} = ((F_{full} \times EER_{GLHP,full} \times 1.09 \times F_{pump,full}) + (F_{part} \times EER_{GLHP,part} \times F_{pump,part})) \times F_{dist,c}$

= ((0.25 x 19 x 1.09 x 0.93) + (0.75 x 25 x 0.92)) x 0.95 = 20.96

$EER_{season,ee}$ equation from Compliance Efficiency section based on GSHP type

F_{full} from Compliance Efficiency section's Summary of Variables and Data Sources table

$EER_{GLHP,full}$ from application

$F_{pump,full}$ from Pumping Power Adjustment Factors table based on application

F_{part} from Compliance Efficiency section's Summary of Variables and Data Sources table

$EER_{GLHP,part}$ from application

$F_{pump,part}$ from Pumping Power Adjustment Factors table based on application

$F_{dist,c}$ from Distribution Correction Factors based on application

$BEFLH_{cooling}$ = 778, from Operating Hours section

BHL = 58,000, from application

$F_{ElecHeat}$ = 0, from Summary of Variables and Data Sources table based on existing HVAC from application

$COP_{seaseason,baseline}$ = N/A

$COP_{season,ee}$ = ((F_{full} x $COP_{GLHP,full}$ x 1.08 x $F_{pump,full}$) + (F_{part} x $COP_{GLHP,part}$ x $F_{pump,part}$)) x $F_{dist,h}$

= ((0.25 x 3.5 x 1.08 x 0.92) + (0.75 x 4.1 x 0.93)) x 0.96 = 3.58

$COP_{season,ee}$ equation from Compliance Efficiency section based on GSHP type

$COP_{GLHP,full}$ from application

$F_{pump,full}$ from Pumping Power Adjustment Factors table based on application

$COP_{GLHP,part}$ from application

$F_{pump,part}$ from Pumping Power Adjustment Factors table based on application

$F_{dist,h}$ from Distribution Correction Factors based on application

$BEFLH_{heating}$ = 793, from Operating Hours section

$EER_{peak,baseline}$ = 11.2, from Baseline Efficiencies section based on equipment type and size from application

$EER_{GSHP,full,ee}$ = 19, from application

CF = 0.69, from Summary of Variables and Data Sources table

$F_{FuelHeat}$ = 1, from Summary of Variables and Data Sources table based on existing HVAC from application

$EFF_{baseline}$ = 0.8, from Baseline Efficiencies section based on equipment type and size from application

$$\Delta kWh = \left[\frac{36{,}000}{1{,}000} \times \left(\frac{1}{13} - \frac{1}{20.96}\right) \times 778\right] + \left[\frac{58{,}000}{3{,}412} \times \left(0 - \frac{1}{3.58}\right) \times 793\right] = -2{,}947\ kWh$$

$$\Delta kW = \frac{36{,}000}{1{,}000} \times \left(\frac{1}{11.2} - \frac{1}{19}\right) \times 0.69 = 0.910\ kW$$

$$\Delta MMBtu = \frac{58{,}000}{1{,}000{,}000} \times \frac{1}{0.8} \times 793 = 57.5\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. 10 CFR 430.32 Energy and water conservation standards and their compliance dates. Available from: http://www.ecfr.gov/cgi-bin/text-idx?SID=a9921a66f2b4f66a32ec851916b7b9d9&mc=true&node=se10.3.430_132&rgn=div8
2. BG&E: Development of Residential Load Profile for Central Air Conditioners and Heat Pumps
3. Building America House Simulation Protocols, Robert Hendron and Cheryn Engebrecht, National Renewable Energy Laboratory, October 2010 Available from: https://www1.eere.energy.gov/buildings/publications/pdfs/building_america/house_simulation_revised.pdf
4. Carlson, S. 1997. "Geothermal Heat Pump Performance in Heating Dominated Climates." Presented at Heat Pumps in Cold Climates, 3rd International Technical Conference. August 11-12. Wolfville, Nova Scotia.
5. ECCCNYS 2020, Table C403.3.2(4): Warm-Air Furnaces And Combination Warm-Air Furnaces/Air-Conditioning Units, Warm-Air Duct Furnaces And Unit Heaters, Minimum Efficiency Requirements & Table C403.2.3(5): Minimum Efficiency Requirements: Gas- And Oil-Fired Boilers.
   Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-[ce]-commercial-energy-efficiency#NYSECC2020P1_CE_Ch04_SecC402
6. Fairey, P., D. Parker, B Wilcox, M Lombardi. *Climate Impacts on Heating Seasonal Performance Factor (HSPF) and Seasonal Energy Efficiency Ratio (SEER) for Air Source Heat Pumps*, ASHRAE Transactions, 110(2): 178-88.
7. *Guide to Geothermal Heat Pumps* (February 2011) U. S. Department of Energy, Energy Efficiency and Renewable Energy, DOE/EE-0385
8. Henderson, H.I., 2020. White Paper: Savings Calculations for Residential Ground Source Heat Pumps: The Basis for Equivalent Full Load Hours (EFLH) and Seasonal Efficiency Factors. Prepared for the New York State Energy Research and Development Authority (NYSERDA) and the New York State Department of Public Service. Revised in June.
9. International Ground Source Heat Pump Association (IGSHPA). 2011. Ground Source Heat Pump Residential and Light Commercial Design and Installation Guide. Oklahoma State University. Stillwater.

10. Kavanaugh, S and Rafferty, K (2015): *Geothermal Heating and Cooling, Design of Ground-Source Heat Pump Systems* RP-1674, Atlanta, GA. ASHRAE Inc.
11. *Manual J Residential Load Calculation*, Arlington, VA. Air Conditioning Contractors Association
12. *Manual S Equipment Selection*, Arlington, VA. Air Conditioning Contractors Association
13. M. M. Straub, Using Available Information for Efficient Evaluation of Demand-Side Management Programs, Electricity Journal, September 2011 Available from: https://www.sciencedirect.com/science/article/pii/S1040619011001941
14. Monitored data from geothermal heat pump systems installed in New York State submitted August 2015 by the New York Geothermal Energy Organization and reviewed by NYS DPS Staff.
15. New York State Energy Research and Development Authority (NYSERDA). 2017. "Analysis of Water Furnace Geothermal Heat Pump Sites in New York State with Symphony Monitoring System," NYSERDA Report Number 18-03. Prepared by CDH Energy Corp., Cazenovia, NY. nyserda.ny.gov/publications.
16. *Water Source Heat Pumps – Testing and Rating for Performance – Part 1: Water to Air and Brine to Air Heat Pumps* (2012) Arlington, VA. ANSI/ASHRAE/ISO Standard 13256-1:1998 (RA 2012), AHRI, 2012.
17. Henderson, H.I., 2021. White Paper: Developing Building Equivalent Full Load Hour (BEFLH) Values for Commercial and Multi-Family Buildings in NYS. Prepared for the New York State Energy Research and Development Authority (NYSERDA) and the New York State Department of Public Service. Revised in August.

Record of Revision

Record of Revision Number	Issue Date
1	10/15/2010
4-16-1	3/31/2016
6-17-6	6/30/2017
3-18-11	3/29/2018
2-20-6	2/28/2020
7-20-24	7/31/2020

Return to Table of Contents

HEAT PUMP – WATER-TO-AIR GROUND SOURCE (GSHPS) IN SYSTEMS WITH CENTRAL PUMPING

Measure Description

This measure covers the installation of multiple ENERGY STAR® certified Ground Source Heat Pump (GSHP) units combined into a system with a closed loop ground heat exchanger field and with central pumping. The GSHP units are water-to-air heat pumps with ducting to provide space heating and cooling to individual zones within a commercial building, including multifamily. The system can optionally include water-to-water heat pumps for domestic water heating. Methods for calculating annual DHW energy savings are presented separately below.

This measure applies to GSHPs in building applications with multiple heat pump units served by centralized ground loop pumping. The calculations only consider simple baseline conditions with separate zone-by-zone space heating and cooling equipment. They do not consider baseline conditions with centralized air handlers serving multiple zones, with terminal reheat, or with other forms of variable air volume terminals. Further, this measure only applies to single-owner facilities with closely-grouped buildings and does not consider multi-owner district, community, or shared loop systems with multiple levels of pumping and loop flow control.

The GSHP analysis associated with this measure is based on several assumptions consistent with best practice design for a quality GSHP installation:

- Building heating and cooling loads shall be calculated, and systems shall be sized in accordance with applicable federal, state, local and municipal codes and standards.

- GSHP units shall be sized in accordance with zone loads calculated with appropriate commercial load calculations, such as from the 2017 ASHRAE Fundamentals.[1071]

- The ground loop heat exchanger is adequately sized and installed properly to allow the GSHP to meet the peak heating and peak cooling loads.

- The design loop pumping power must be less than 60 Watts per nominal installed ton[1072], or 7.5 HP per 100 tons, which corresponds to a grade of "B" according to the ASHRAE GSHP Design Guide (Kavanaugh and Rafferty 2015).

- The GSHP efficiency is rated in accordance with ISO 13256-1, and AHRI-certified performance ratings are provided by the manufacturer showing the efficiency and capacity of the unit under full and part load conditions.

This measure applies for the following types of GSHP central pumping options:

- Traditional variable speed control that varies pump speed to maintain differential pressure based on a sensor installed at a remotely located GSHP unit,
- Staged (two-speed) pumping control,

[1071] 2017 ASHRAE Fundamentals Handbook, Chapter 18. Non-residential heating and cooling loads

[1072] The nominal tons are based on the rated cooling capacity at full load GLHP conditions as per ISO Standard 13256-1.

- "Sensorless" variable speed control where internal pump controls are used to approximately maintain constant pressure across the pump, or
- Hybrid options that combine central loop variable speed pumping with individual cartridge[1073] circulators on each heat pump unit.

For the first 3 options, only the central pumping energy is calculated with no pumping adjustment to the heat pump efficiency ($F_{pump,full}$ & $F_{pump,part}$ should be set to 1.0). For the hybrid option, both central pumping energy as well as an adjustment to heat pump efficiency are required ($F_{pump,full}$ & $F_{pump,part}$ come from the table below).

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Note: The algorithms below address energy impacts associated with space conditioning load only. See the *Methods for Calculating Annual Domestic Hot Water Energy Savings from a Dedicated Water-to-Water Heat Pump* section of this measure for estimating DHW savings associated with these systems.

Annual Electric Energy Savings

$$\Delta kWh = \left[\frac{BCL}{1{,}000} \times \left(\frac{F_{ElecCool}}{EER_{season,baseline}} - \frac{1}{EER_{season,ee}}\right) \times BEFLH_{cooling}\right] + \left[\frac{BHL}{3{,}412} \times \left(\frac{F_{ElecHeat}}{COP_{season,baseline}} - \frac{1}{COP_{season,ee}}\right) \times BEFLH_{heating} - \left[F_{pump,avg} \times kW_{pump,design} \times 8760\right]\right]$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \frac{BCL}{1{,}000} \times \left(\frac{F_{ElecCool}}{EER_{peak,baseline}} - \frac{1}{EER_{GSHP,full,,ee}}\right) \times CF - kW_{pump,design}$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = \frac{BHL}{1{,}000{,}000} \times \frac{F_{FuelHeat}}{AFUE_{baseline}} \times BEFLH_{heating}$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
AFUE	= Annual fuel utilization efficiency, seasonal efficiency for fuel heat equipment
baseline	= Characeristic of baseline condition
BCL	= Building Cooling "Block" Load at design conditions (BTU/h)

[1073] Cartridge circulators are inline, self-contained pumps or circulators.

$BEFLH_{cooling}$ = Cooling equivalent full-load hours based on building design load
$BEFLH_{heating}$ = Heating equivalent full-load hours based on building design load
BHL = Building Heating "Block" Load at design conditions (BTU/h)
CF = Coincidence Factor
COP = Coefficient of performance, ratio of output energy/input energy
COP_{season} = Coefficient of performance on a seasonal basis. Adjusted to account for fan and pump power.
$_{ee}$ = Characteristic of energy efficient condition
EER = Energy efficiency ratio (BTU/watt-hour)
$EER_{GSHP,full}$ = Full load energy efficiency ratio (BTU/watt-hours). Refers to GLHP-rated condition for closed loop GSHP systems.
EER_{season} = Energy efficiency ratio (BTU/watt-hour) at part-load seasonally-adjusted for fan and pump power, for baseline conditions or for energy efficient case, BTU/watt-hour
$F_{ElecCool}$ = Electric cooling factor; used to account for the presence or absence of an electric cooling system
$F_{ElecHeat}$ = Electric heating factor; used to account for the presence or absence of an electric heating system
$F_{FuelHeat}$ = Fossil fuel heating; used to account for the presence or absence of a fossil fuel heating system
$_{peak}$ = Peak rating condition
SEER = Seasonal average energy efficiency ratio over the cooling season, BTU/watt-hour,(used for average U.S. location/region)
$kW_{pump, design}$ = Pumping power at the design or full speed loop flowrate, kW
$F_{pump, avg}$ = Average pumping power percentage over the year, % or fraction
8760 = Number of hours in a year
3,412 = Conversion factor, one kWh equals 3,412 BTU
1,000 = Conversion factor, one kW equals 1,000 Watts
1,000,000 = Conversion factor, (BTU/MMBtu), one MMBtu equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
BCL		Building cooling block load at design conditions determined by appropriate commercial load estimating method. Block load is the simultaneous or coincident peak load of all thermal zones (2017 ASHRAE Fundamentals, Chapter 18).
BHL		Building heating load at design conditions determined by appropriate commercial load estimating method. Block load is the simultaneous or coincident peak load of all zones (2017 ASHRAE Fundamentals, Chapter 18).
$F_{ElecCool}$		If an electric cooling system is present, set equal to 1. Otherwise, set equal to 0.
$F_{ElecHeat}$		If an electric heating system is present, set equal to 1. Otherwise, set equal to 0.

Variable	Value	Notes
$F_{FuelHeat}$		If a fossil fuel-fired heating system is present, set equal to 1. Otherwise, set equal to 0.
$EER_{season,baseline}$		Seasonal electric cooling energy efficiency rating of baseline equipment. See Baseline Efficiency section below for details.
$EER_{peak,baseline}$		Electric cooling energy efficiency rating of baseline equipment. See Baseline Efficiency section below for details.
$EER_{season,ee}$		Energy efficiency ratio from the manufacturer's catalog data AHRI ratings adjusted to account for applied fan and pump power. See Compliance Efficiency section below for details.
$EER_{GSHP,full}$		Full load energy efficiency ratio at AHRI rated conditions. Corresponds to GLHP-rated condition with fluid temperature of 77ºF for closed loop systems.
$AFUE_{baseline}$		Annual fuel utilization efficiency, seasonal energy efficiency for fuel heating equipment. See Baseline Efficiency section below for details.
$COP_{season,baseline}$		Electric heating energy efficiency rating of baseline equipment. See Baseline Efficiency section below for details.
$COP_{season,ee}$		Coefficient of performance (ratio of heat delivered to energy input to the heat pump unit) from the manufacturer's catalog data adjusted to account for applied fan and pump power. See Compliance Efficiency section below for details.
$BEFLH_{cooling}$		Lookup based on building type, vintage and location from table below.
$BEFLH_{heating}$		Lookup based on building type, vintage and location from table below.
$kW_{pump,design}$		The power consumption of the pump motor (and variable speed drive) when the central loop pump provides the design or full speed flowrate, kW.
$F_{pump,avg}$		The average pumping power across the year, lookup based on diversity and bypass flow from table below

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.69 in multifamily applications[1074] and 0.8 in commercial and industrial applications.[1075]

[1074] Based on BG&E 'Development of Residential Load Profile for Central Air Conditioners and Heat Pumps' research, the Maryland Peak Definition coincidence factor is 0.69. This study is not publicly available, but is referenced by M. M. Straub, Using Available Information for Efficient Evaluation of Demand-Side Management Programs, Electricity Journal, September 2011 and supported by research conducted by Cadmus on behalf of the RM Management Committee.

[1075] *No source specified – update pending availability and review of applicable references.*

Baseline Efficiencies from which Energy Savings are Calculated

The baselines used in this measure are determined by the type of equipment that would have been installed without the influence of the program supporting the installation of this measure. This allows for an analysis that does not depend on a typical 'like-for-like' replacement scenario.

Tables are provided below to show the baseline efficiencies for appropriate Electric Heating and Cooling System Baseline Efficiencies, and appropriate Fossil Fuel Fired Heating System Baseline Efficiencies.

Federal energy conservation standards[1076] effective January 1, 2018 for small, large and very large package air conditioning and heating equipment are more stringent than NYS and NYC codes. These cases are denoted with footnotes in the table below.

Electric Cooling System Baseline Efficiencies

Unitary Air Conditioners				
Equipment Type	**Size Category (Cooling Capacity)**	**Heating Section Type**	**Subcategory or Rating Condition**	**Baseline Efficiency**
Air conditioners (air cooled)	< 65,000 BTU/h (single phase)	All	Split System	11.2 EER 13.0 SEER
			Single Package	11.8 EER 14.0 SEER
Through-the-wall (air cooled)	≤ 30,000 BTU/h (single phase)	All	Split System	10.6 EER 12.0 SEER
			Single Package	10.6 EER 12.0 SEER
Small-duct high-velocity (air cooled)	< 65,000 BTU/h (single phase)	All	Split System	9.9 EER 11.0 SEER

[1076] 10 CFR 431.97 (Table 3)

Unitary Air Conditioners				
Equipment Type	**Size Category (Cooling Capacity)**	**Heating Section Type**	**Subcategory or Rating Condition**	**Baseline Efficiency**
Air conditioners (air cooled)	≥ 65,000 BTU/h and < 135,000 BTU/h[1077]	Electric Resistance (or None)	Split System and Single Package	11.2 EER 12.9 IEER
		All Other	Split System and Single Package	11.0 EER 12.7 IEER
	≥ 135,000 BTU/h and < 240,000 BTU/h	Electric Resistance (or None)	Split System and Single Package	11.0 EER 12.4 IEER
		All Other	Split System and Single Package	10.8 EER 12.2 IEER
	≥ 240,000 BTU/h and < 760,000 BTU/h	Electric Resistance (or None)	Split System and Single Package	10.0 EER 11.6 IEER
		All Other	Split System and Single Package	9.8 EER 11.4 IEER
	≥ 760,000 BTU/h	Electric Resistance (or None)	Split System and Single Package	9.7 EER 11.2 IEER
		All Other	Split System and Single Package	9.5 EER 11.0 IEER

Electric Cooling and Heating System Baseline Efficiencies for Package Terminal Equipment

Equipment Type	**Size Category (Input)**	**Subcategory or Rating Condition**	**Minimum Efficiency ECCCNYS**[1078]
PTAC (Cooling Mode) Standard Size	All Capacities	95°F db Outdoor Air	EER = 14.0 - (0.300 × Cap/1,000)
PTAC (Cooling Mode) Replacements/ Nonstandard Size[1079]	All Capacities	95°F db Outdoor Air	EER = 10.9 - (0.213 × Cap/1,000)

[1077] For equipment with ≥65,000 BTU/h and <135,000 BTU/h cooling capacity, IEER values are taken from 10 CFR 431.97 (Table 3)

[1078] "Cap" = The rated cooling capacity of the project in BTU/h. If the unit's capacity is less than 7,000 BTU/h, use 7,000 BTU/h in the calculation. If the unit's capacity is greater than 15,000 BTU/h, use 15,000 BTU/h in the calculations."

[1079] Replacement/Nonstandard size units must be factory labeled as follows: "MANUFACTURED FOR REPLACEMENT APPLICATIONS ONLY; NOT TO BE INSTALLED IN NEW CONSTRUCTION PROJECTS." Replacement/Nonstandard size efficiencies apply only to units being installed in existing sleeves having an external wall opening of less than 16 in. high or less than 42 in. wide and having a cross-sectional area less than 670 in.

Equipment Type	Size Category (Input)	Subcategory or Rating Condition	Minimum Efficiency ECCCNYS[1078]
PTHP (Cooling Mode) Standard Size	All Capacities	95°F db Outdoor Air	EER = 14.0 - (0.300 × Cap/1,000)
PTHP (Cooling Mode) Replacements/ Nonstandard Size	All Capacities	95°F db Outdoor Air	EER = 10.8 - (0.213 × Cap/1,000)
PTHP (Heating Mode) Standard Size	All Capacities	—	NYS: COP = 3.2 – (0.026 × Cap/1,000) NYC: COP = 3.7 – (0.052 × Cap/1,000)
PTHP (Heating Mode) Replacements/ Nonstandard Size	All Capacities	—	COP = 2.9 - (0.026 × Cap/1,000)

Fossil Fuel Fired Heating System Baseline Efficiencies: Systems Serving Single Units [1080]

Equipment Type	Size Range	ECCCNYS and NYCECC Minimum Efficiency for Climate Zones 4, 5, and 6
Warm Air Furnace, Gas Fired	All Capacities	0.80 AFUE
Warm Air Furnace, Oil Fired	All Capacities	0.83 AFUE
Boiler, Hot Water, Gas Fired	All Capacities	0.82 AFUE
Boiler, Steam, Gas Fired	All Capacities	0.80 AFUE
Boiler, Hot Water, Oil Fired	All Capacities	0.84 AFUE
Boiler, Steam, Oil Fired	All Capacities	0.82 AFUE

Fossil Fuel Fired Heating System Baseline Efficiencies: Systems Serving Multiple Dwelling Units

Equipment Type	Size Range	ECCCNYS Minimum Efficiency for Climate Zones 4, 5 and 6
Warm Air Furnace, Gas Fired	< 225 kBTU/h	0.80 AFUE
	≥ 225 kBTU/h	0.80 Et
Warm Air Furnace, Oil Fired	< 225 kBTU/h	0.83 AFUE
	≥ 225 kBTU/h	0.80 Et
Warm Air Unit Heaters, Gas Fired	All Capacities	0.80 Ec
Warm Air Unit Heaters, Oil Fired	All Capacities	0.80 Ec

[1080] 10 CFR 430.32(e)

Equipment Type	Size Range	ECCCNYS Minimum Efficiency for Climate Zones 4, 5 and 6
Boiler, Hot Water, Gas Fired	< 300 kBTU/h	0.82 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.80 Et
	> 2,500 kBTU/h	0.82 Ec
Boiler, Hot Water, Oil Fired	< 300 kBTU/h	0.84 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.82 Et
	> 2,500 kBTU/h	0.84 Ec
Boiler, Steam, Gas Fired, All Except Natural Draft	< 300 kBTU/h	0.80 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.79 Et
	> 2,500 kBTU/h	0.79 Et
Boiler, Steam, Gas Fired, Natural Draft	< 300 kBTU/h	0.80 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.77 Et
	> 2,500 kBTU/h	0.77 Et
Boiler, Steam, Oil Fired	< 300 kBTU/h	0.82 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.81 Et
	> 2,500 kBTU/h	0.81 Et

For scenarios where the baseline heating system is electric resistance heat, the baseline seasonal efficiency is assumed to be a COP of 1.0. For scenarios with PTHPs as the baseline heating system, we assume the rated heating efficiency is derated[1081] to account for mix of electric resistance and PTHP operation:

$$COP_{season,baseline} = COP_{rated} \times F_{PTHP}$$

Where F_{PTHP} = 0.55 for NYC and 0.45 for upstate locations

For cooling, the seasonal average efficiency ($EER_{season,base}$), should be set to the values of SEER for residential equipment or IEER for commercial packaged equipment, as appropriate. For PTAC or PTHP systems use rated EER times a factor of 1.15[1082].

For scenarios where there is new construction or substantial renovation, the baseline is assumed to be a gas fired warm air furnace with a central air conditioning system when natural gas service is available at the project site.

Replacement of room air conditioners is not addressed in this analysis. To capture savings associated with removal of room air conditioners, refer to the Air Conditioner – Room (RAC) Recycling measure in the Single and Multi-Family Residential Measures section of this TRM.

[1081] As per Tables 11 and 12 from NYSERDA report "High-Performance Packaged Terminal Heat Pump Market and Development Research", Report 18-27, October 2018 completed by Taitem Engineering. Effective annual COP with resistance heat backup are 1.76 in NYC and 1.32 in Syracuse with a change-over temperature of 35°F. This equates to derating factors of 0.55 for NYC and 0.45 for Upstate NY assuming a rated COP of 3.2 in NYC and 3.0 upstate

[1082] 1.15 is the typical ratio of SEER and EER (or IEER and EER) given in the tables above.

Central Loop Pumping Energy Use for GSHP Systems

In larger GSHP systems with centralized pumping, the loop flow is modulated in response to the building load (or the number of GSHP units operating). Each GSHP unit typically has a two-way (or ON/OFF) valve that restricts loop flow through the unit when it is off[1083]. As a result, less loop flow is required at lightly-load conditions when fewer GSHP units are operating, so pumping power is significantly reduced.

The factor $F_{pump, avg}$ indicates the average fraction of the design or full power across the year. The design power is defined as the electric power required to provide the design or maximum loop flow rate ($kW_{pump, design}$). The table below provides values of $F_{pump, avg}$ based on climate cities as well as various design and operating factors. The operating factors include the type of pumping system, the amount of load diversity and the amount of bypass flow in the loop. This table was developed using a bin analysis as described in a White Paper[1084]. These design and operating factors are discussed below:

- The type of loop flow modulation can include: 1) Traditional variable speed drive (VSD) driven pump controlled to maintain the differential pressure difference at a remote location in the system, 2) a staged pumping system, or 3) a sensorless VSD pump that maintains a constant pressure difference across the pump without using a pressure sensor (see the White Paper).
- Variable speed loops may require that some bypass flow be provided so that the loop pumps can continue to operate even when all the heat pumps are off. Bypass flow can be provided by leaving off two-way valves on some heat pump units or by providing fixed bypass plumbing from the supply to the return side of the loop. The % of bypass flow affects the minimum allowable flow (and therefore the minimum pumping power). The table includes bypass flows ranging from 30 to 60%.
- The load diversity in the system also affects the pumping energy use. Since each heat pump is sized to meet the local zone loads, it is unlikely that every heat pump unit will be operating at the same time, even at design conditions. The table considers the case with modest diversity (e.g., 80 / 90% of the maximum loop flow at cooling / heating design conditions) as well as the case with more diversity (e.g., 60 / 70% of the maximum loop flow at cooling / heating design conditions). The design loop flow can often be less than the theoretical maximum flow with every heat pump operating, which effects the diversity factor. We recommend that modest diversity (80/90%) be used when the design loop flow is less than the maximum theoretical flow. Otherwise use 60/70% diversity. The White Paper provides further guidance on situations where load diversity is likely to occur.

[1083] If the GSHP unit is dual-stage or variable speed, then a modulating valve should be used to maintain a constant loop temperature difference across the unit.

[1084] Henderson, H. 2020. White Paper Savings Calculations for Large Ground Source Heat Pumps with Central Pumping, For application in Multi-Family Buildings and Other Commercial Applications. Prepared for the New York State Energy Research and Development Authority (NYSERDA) and the New York State Department of Public Service. November.

Tables for $F_{pump,avg}$ Based on Location and Other Factors

	Albany	Bing-hamton	Buffalo	Massena	New York City	Pough-keepsie	Syracuse
	Bypass Flow = 30% (10% min Power) & Diversity = 80%/90%						
Traditional VSD	18.1%	19.5%	19.5%	18.6%	19.2%	20.7%	19.1%
Two-Stage	42.6%	42.9%	43.1%	41.6%	40.9%	44.5%	43.0%
Sensorless VSD	19.0%	20.5%	20.5%	19.5%	20.1%	21.7%	20.0%
	Bypass Flow = 40% (13% min Power) & Diversity = 80%/90%						
Traditional VSD	19.7%	21.1%	21.1%	20.4%	20.7%	22.4%	20.6%
Two-Stage	42.6%	42.9%	43.1%	41.6%	40.9%	44.5%	43.0%
Sensorless VSD	20.7%	22.2%	22.1%	21.4%	21.8%	23.5%	21.7%
	Bypass Flow = 50% (22% min Power) & Diversity = 80%/90%						
Traditional VSD	25.6%	26.8%	26.7%	26.3%	26.2%	28.0%	26.2%
Two-Stage	42.6%	42.9%	43.1%	41.6%	40.9%	44.5%	43.0%
Sensorless VSD	26.8%	28.1%	28.0%	27.6%	27.5%	29.4%	27.5%
	Bypass Flow = 60% (33% min Power) & Diversity = 80%/90%						
Traditional VSD	34.3%	35.4%	35.2%	35.0%	34.7%	36.5%	34.8%
Two-Stage	42.6%	42.9%	43.1%	41.6%	40.9%	44.5%	43.0%
Sensorless VSD	36.1%	37.2%	37.0%	36.8%	36.4%	38.3%	36.5%
	Bypass Flow = 30% (10% min Power) & Diversity = 60%/70%						
Traditional VSD	13.0%	13.7%	13.7%	13.4%	13.4%	14.7%	13.4%
Two-Stage	34.0%	35.1%	35.1%	35.0%	34.2%	36.6%	33.8%
Sensorless VSD	13.7%	14.4%	14.4%	14.1%	14.1%	15.4%	14.1%
	Bypass Flow = 40% (13% min Power) & Diversity = 60%/70%						
Traditional VSD	15.2%	15.9%	15.8%	15.6%	15.5%	16.8%	15.5%
Two-Stage	34.0%	35.1%	35.1%	35.0%	34.2%	36.6%	33.8%
Sensorless VSD	16.0%	16.7%	16.6%	16.4%	16.2%	17.6%	16.3%
	Bypass Flow = 50% (22% min Power) & Diversity = 60%/70%						
Traditional VSD	22.4%	22.9%	22.8%	22.8%	22.6%	23.7%	22.6%
Two-Stage	34.0%	35.1%	35.1%	35.0%	34.2%	36.6%	33.8%
Sensorless VSD	23.5%	24.1%	23.9%	23.9%	23.7%	24.9%	23.7%
	Bypass Flow = 60% (33% min Power) & Diversity = 60%/70%						
Traditional VSD	32.6%	32.8%	32.7%	32.8%	32.7%	33.5%	32.7%
Two-Stage	34.0%	35.1%	35.1%	35.0%	34.2%	36.6%	33.8%
Sensorless VSD	34.3%	34.5%	34.3%	34.5%	34.4%	35.2%	34.3%

Compliance Efficiency from which Incentives are Calculated

The compliance condition is an ENERGY STAR® certified GSHP heat pump system as defined in the Measure Description section above. The formulas adjust performance for closed loop systems to an average entering water temperature for both heating and for cooling. For small residential systems the average entering temperatures are approximately 40°F for heating and 77°F

for cooling. For large GSHP systems, the user must specify the average entering water temperature for heating ($EWT_{avg,h}$) as well as for cooling ($EWT_{avg,c}$). Temperatures for large buildings are typically 5 to 15°F higher than the residential / small systems averages in heating and 10 to 20°F higher than the residential / small systems averages in cooling. Some loop sizing software can provide the average values. If only the design temperatures from the ground loop sizing calculations are known (EWT_{max} and EWT_{min}), then an approximate assumption would be:

$EWT_{avg,h} = EWT_{min} + 10°F$

$EWT_{avg,c} = EWT_{max} - 10°F$

The formulas determine the average seasonal cooling efficiency ($EER_{season,ee}$) and the average seasonal heating efficiency ($COP_{season,ee}$) for a GSHP system with a two-stage or variable speed compressor. For single-stage units the part load values are omitted and F_{full} =1 & F_{part}=0

$$EER_{season,ee} = \Big[\big(F_{full} \times EER_{GLHP,full} \times \big(1 + 0.01 \times (77 - EWT_{avg,c})\big) \times F_{pump,full}\big) + \big(F_{part} \times EER_{GLHP,part} \times \big(1 + 0.01 \times (68 - EWT_{avg,c})\big) \times F_{pump,part}\big)\Big] \times F_{dist,c}$$

$$COP_{season,ee} = \Big[\big(F_{full} \times COP_{GLHP,full} \times \big(1 + 0.01 \times (EWT_{avg,h} - 32)\big) \times F_{pump,full}\big) + \big(F_{part} \times COP_{GLHP,part} \times \big(1 + 0.01 \times (EWT_{avg,h} - 41)\big) \times F_{pump,part}\big)\Big] \times F_{dist,h}$$

where:

$COP_{GLHP,full}$	= Rated COP of the unit at GLHP full load heating conditions
$COP_{GLHP,part}$	= Rated COP of the unit at GLHP part load heating conditions
$EER_{GLHP,full}$	= Rated EER of the unit at GLHP full load cooling conditions
$EER_{GLHP,part}$	= Rated EER of the unit at GLHP part load cooling conditions
$EWT_{avg,h}$	= The average entering loop temperature in the heating season
$EWT_{avg,c}$	= The average entering loop temperature in the cooling season
$F_{dist,c}$	= Factor to adjust the cooling efficiency to account for additional fan power
$F_{dist,h}$	= Factor to adjust the heating efficiency to account for additional fan power
F_{full}	= Seasonal weighting factor for full load efficiency
F_{part}	= Seasonal weighting factor for part load efficiency
$F_{pump,\ part}$	= Factor to adjust part load efficiency to account for additional pumping power
$F_{pump,full}$	= Factor to adjust full load efficiency to account for additional pumping power
0.01	= Correction for fractional change in EER or COP per each 1°F in entering loop temperature[1085]

[1085] Correction for % change in EER or COP as the entering fluid temperature changes by 1°F. Observed from published performance data as well as in the IGSHPA Design Manual.

Summary of Variables and Data Sources

Variable	Value	Source
$COP_{GLHP,full}$		The rated COP of the unit at GLHP full load (or standard) heating conditions from ASHRAE/ISO 13256-1. This value is certified by AHRI and is available in the product directory. It corresponds to an entering loop temperature of 32°F.
$COP_{GLHP,part}$		The rated COP of the unit at GLHP part load heating conditions from ASHRAE/ISO 13256-1. This value is certified by AHRI and is available in the product directory. It corresponds to an entering loop temperature of 41°F.
$EER_{GLHP,full}$		The rated EER of the unit at GLHP full load (or standard) cooling conditions from ASHRAE/ISO 13256-1. This value is certified by AHRI and is available in the product directory. It corresponds to an entering loop temperature of 77°F.
$EER_{GLHP,part}$		The rated EER of the unit at GLHP part load cooling conditions from ASHRAE/ISO 13256-1. This value is certified by AHRI and is available in the product directory. It corresponds to an entering loop temperature of 68°F.
$EWT_{avg,h}$		The average entering loop temperature in the heating season, typically between 45 and 55°F for larger GSHP systems
$EWT_{avg,c}$		The average entering loop temperature in the cooling season, typically between 60 and 80°F for larger GSHP systems
EWT_{min}		The minimum expected entering loop temperature in the heating season, from the ground loop sizing calculations
EWT_{max}		The maximum expected entering loop temperature in the cooling season, from the ground loop sizing calculations
$F_{dist,c}$		Factor to adjust the cooling efficiency to account for additional fan power that would be required, beyond the fan power corresponding to zero static in rated COP. Choose the appropriate factor from the Distribution Correction Factors table below.
$F_{dist,h}$		Factor to adjust the heating efficiency to account for additional fan power that would be required, beyond the fan power corresponding to zero static in rated COP. Choose the appropriate factor from the Distribution Correction Factors table below.
F_{full}	0.25	Seasonal weighting factor for full load efficiency = 0.25, for two-stage and variable speed GSHP units. Based in part on observed mix of low and high stage operation from field testing.[1086] For single stage use 1.0.

[1086] New York State Energy Research and Development Authority (NYSERDA) 2017. "Analysis of Water Furnace Geothermal Heat Pump Sites in New York State with Symphony Monitoring System," NYSERDA Report Number 18-03. Prepared by CDH Energy Corp., Cazenovia, NY. nyserda.ny.gov/publications.

Variable	Value	Source
F_{part}	0.75	Seasonal weighting factor for part load efficiency = 0.75, for two-stage and variable speed GSHP units. Based in part on observed mix of low and high stage operation from field testing.[1087] For single stage use 0.
$F_{pump,full}$		Factor to adjust the full load efficiency to account for additional pumping power used by the system. Choose the appropriate factor from Pumping Power Adjustment Factor table below.
$F_{pump,part}$		Factor to adjust the part load efficiency to account for additional pumping power used by the system. Choose the appropriate factor from Pumping Power Adjustment Factor table below.

Loop Pumping Power Correction Factor ($F_{pump,full}$ and $F_{pump,part}$)

These correction factors are not required when centralized pumping is used with two-way valves on each heat pump. In that case set $F_{pump,full}$ and $F_{pump,part}$ to 1.0.

If the GSHP system includes central loop pumps AND also uses cartridge circulators on each GSHP unit (instead of two-way valves), then these correction factors must be applied. The discussion of pumping Watts below only applies to the cartridge circulator/pump and NOT to the central pumps.

A correction factor for cartridge pumps ($F_{pump,full}$ and $F_{pump,part}$) is required because the rated efficiency values only include the pumping energy associated with the water-side pressure drop through the heat pump unit (typically about 5-10 Watts per nominal ton). Actual pumping power is much higher. The ASHRAE GSHP Design Guide (Kavanaugh and Rafferty 2015) developed a grading system that assigns scores based on the amount of pumping power per installed ton. For instance, it gives a grade of "A" to system that uses 45 Watts per nominal ton and a grade of "B" to a system that uses 60 Watts per nominal ton.

Analysis of observed pumping power from 45 to 75 Watts/ton was performed to determine the impact of loop pumping power on efficiency. Results are shown in the Pumping Factors table below.

Pumping Power Adjustment Factors for Cartridge Pumps on each GSHP unit

Different factors are required for different loop pumping power levels and loop pump control strategies. For part load performance there are multiple ways to control the pump at low stage:

- the pump can maintain constant flow regardless of compressor stage.
- the pump stages flow in proportion to the compressor capacity.
- the pump can be variable speed and modulate with the variable speed compressor.

A constant speed loop pump with a staged or variable speed GSHP unit results in poor performance since the pump power becomes a relatively larger portion of total power at low stage. Variable speed pumping with a variable speed compressor results in the best performance. The penalty for constant speed pumping is highest for units with variable speed compressors. The last consideration is the low-to-high capacity ratio (CR), which can be calculated as follows:

[1087] Ibid.

$$CR = \frac{QC_{GLHP,part}}{QC_{GLHP,full}}$$

where:

CR = Capacity ratio of part-load cooling capacity to full-load heating capacity.
$QC_{GLHP,part}$ = Part-load cooling capacity rating from AHRI certificate.
$QC_{GLHP,full}$ = Full-load heating capacity rating from AHRI certificate.

The values of QC are the rated full and part load performance values from AHRI. Units with two stage compressors typically have a value of CR of approximately 0.75. Units with variable speed compressors typically have a CR of approximately 0.40.

The table below presents the values of $F_{pump,full}$ and $F_{pump,part}$ that correspond to each loop pump arrangement (e.g. pumping control strategy, CR, and pumping power). Single stage GSHP units only require the full load factor, while staged and variable speed GSHP units require both full and part load factors. The full load pumping factors are typically 0.86 to 0.94. Part load factors can range from 0.77 to 0.94 depending on the pumping control strategy, the capacity ratio of the heat pump, and the pumping power. The factor closest to the actual situation should be used.

Pumping Factors ($F_{pump,full}$ and $F_{pump,part}$)

Pumping Control Strategy	Capacity Ratio	45 Watts/ton		60 Watts/ton		75 Watts/ton	
		Clg	Htg	Clg	Htg	Clg	Htg
Full load ($F_{pump,full}$)		0.94	0.94	0.93	0.92	0.91	0.90
Part load – constant flow pumping ($F_{pump,part}$)	0.75	0.89	0.91	0.86	0.89	0.83	0.86
Part load – constant flow pumping ($F_{pump,part}$)	0.40	0.81	0.85	0.77	0.81	0.72	0.77
Part load – staged pumping ($F_{pump,part}$)	0.75	0.92	0.94	0.89	0.91	0.87	0.89
Part load – staged pumping ($F_{pump,part}$)	0.40	0.92	0.94	0.89	0.91	0.87	0.89
Part load – variable pumping ($F_{pump,part}$)	0.40	0.94	0.95	0.92	0.93	0.90	0.92

Distribution Power Correction

For GSHP systems with an air-duct distribution system, the fan power included in the rated efficiencies corresponds to zero external static pressure and therefore is smaller than would be expected for an actual application. The indoor fan power included in the ISO 13256-1 test procedure is estimated to be approximately 0.15 Watts/cfm for permanent split-capacitor fan motors and 0.11 Watts/cfm for electrically commutated fan motors.[1088]

[1088] Ibid.

The purpose of the distribution (i.e., fan or pump) correction factor, $F_{dist,h}$ and $F_{dist,c}$ is to determine the equivalent amount of distribution power for the baseline system, such as a fuel fired furnace or boiler. The correction factor considers the differential distribution power between the GSHP and the baseline system. The Distribution Correction Factors to correct GSHP Seasonal Efficiency for typical baseline scenarios summarized in the table below:

Distribution Correction Factors ($F_{dist,h}$ and $F_{dist,c}$)

	If baseline system is a Furnace with conventional air conditioning	If baseline system is a Boiler with conventional air conditioning	If baseline system is a Central air source heat pump
Heating ($F_{dist,h}$)	0.96	0.96	0.97
Cooling ($F_{dist,c}$)	0.95	0.95	0.95

Note: Based on furnace and boiler ancillary power of 137 Watts

Operating Hours

The Building Equivalent Full Load Hours for heating ($BEFLH_{heating}$) and for cooling ($BEFLH_{cooling}$) in the tables below represent building equivalent full load operating hours for HVAC equipment based on the design heating and cooling loads (i.e., "Block Loads"). The table includes BEFLH values for small commercial buildings as well as low and high-rise multifamily buildings. These values were developed in a White Paper based on EnergyPlus simulation runs from a NYSERDA simulation project focused on commercial and multifamily buildings (Henderson 2021b). BEFLH values are given by climate zone and by building vintage for each building type. Large commercial buildings have been excluded from the table since baseline HVAC systems in those buildings (e.g., VAV systems) are not adequately considered in this measure. For facility types not listed, central-pumped GSHP measures shall be addressed via custom analysis.

Facility Type	CZ*	BEFLH Heating			BEFLH Cooling		
		Pre-1980	Post-1980	NC	Pre-1980	Post-1980	NC
Office – Low-Rise (≤3 floors)	4A	351	537	285	1,000	1,186	984
	5A	545	793	505	634	778	786
	6A	599	790	521	495	641	672
Grocery	4A	1,029	1,055	1,269	609	622	656
	5A	1,206	1,204	1,447	358	343	506
	6A	1,130	1,130	1,344	277	263	355
Hotel – Small (≤4 floors)	4A	386	916	649	1,956	2,141	2,056
	5A	619	1,127	893	1,916	1,958	1,818
	6A	502	942	919	1,650	1,760	1,625

Facility Type	CZ*	BEFLH Heating			BEFLH Cooling		
		Pre-1980	Post-1980	NC	Pre-1980	Post-1980	NC
Restaurant	4A	1,153	1,236	778	767	788	1,141
	5A	1,481	1,508	1,183	545	547	808
	6A	1,413	1,386	1,142	381	417	663
Stand Alone Retail	4A	760	779	579	705	705	941
	5A	987	983	858	466	440	662
	6A	969	970	838	362	363	617
School	4A	550	558	178	552	632	1,160
	5A	688	729	394	362	394	885
	6A	690	709	275	327	323	818
Warehouse	4A	875	876	637	243	230	498
	5A	1,161	1,159	915	97	93	276
	6A	1,049	1,047	972	82	77	247
Multifamily (≤7 floors)	4A	1,332	1,324	1,100	900	935	987
	5A	1,713	1,668	1,320	631	666	497
	6A	1,449	1,393	1,450	453	470	542
Multifamily (>7 and ≤20 floors)	4A	1,242	1,216	1,144	965	1,007	1,192
	5A	1,625	1,563	1,391	693	738	638
	6A	1,375	1,301	1,406	494	523	697
Multifamily - Brick (>7 and ≤20 floors)	4A	1,431	1,317	1,198	1,141	1,074	1,212
	5A	1,793	1,668	1,430	752	777	639
	6A	1,606	1,382	1,478	573	572	699

* Climate Zones (CZ) shall be mapped to standard weather stations/cities as follows:

- 4A: NYC
- 5A: Albany, Buffalo, Poughkeepsie, Syracuse
- 6A: Binghamton, Massena

Example Calculation *(Not to be used as default)*

Several GSHP units are installed at a low-rise office building located near Albany (climate zone 5A) constructed in 1975. The units are combined into a system with a closed loop ground heat exchanger field with centralized pumping. The system is of hybrid design, combining traditional central loop variable speed pumping with individual cartridge circulators on each heat pump unit. Each heat pump has a full load EER of 19, part load EER of 25, full load COP of 3.5 and part load COP of 4.1. The GSHPs have 45 watts/ton system pumping power. The building has a total cooling load of 720 kBTUh and total heating load of 1,000 kBTUh. The baseline HVAC equipment comprise 20-ton packaged gas furnace/RTU AC units. The minimum expected temperature entering the loop in the heating season is 60ºF and the maximum expected temperature entering the loop in the cooling season is 60ºF. At full speed flowrate, the pump motor and variable speed drive draw 0.5 kW. The design loop flow is less than maximum theoretical flow, and when heat pumps are in off position, bypass flow is configured to 60% of design flowrate . Annual Electric Energy Savings, Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta kWh = \left[\frac{BCL}{1{,}000} \times \left(\frac{F_{ElecCool}}{EER_{season,baseline}} - \frac{1}{EER_{season,ee}}\right) \times BEFLH_{cooling}\right] + \left[\frac{BHL}{3{,}412} \times \left(\frac{F_{ElecHeat}}{COP_{season,baseline}} - \frac{1}{COP_{season,ee}}\right) \times BEFLH_{heating} - \left[F_{pump,avg} \times kW_{pump,design} \times 8760\right]\right]$$

$$\Delta kW = \frac{BCL}{1{,}000} \times \left(\frac{F_{ElecCool}}{EER_{peak,baseline}} - \frac{1}{EER_{GSHP,full,,ee}}\right) \times CF - kW_{pump,design}$$

$$\Delta MMBtu = \frac{BHL}{1{,}000{,}000} \times \frac{F_{FuelHeat}}{AFUE_{baseline}} \times BEFLH_{heating}$$

BCL = 720,000, from application

$F_{ElecCool}$ = 1, from Summary of Variables and Data Sources table based on baseline HVAC from application

$EER_{season,baseline}$ = 11.4, from Baseline Efficiencies section based on equipment type and size from application

$EER_{season,ee}$ = ((F_{full} x $EER_{GLHP,full}$ x (1 + 0.01 x (77 – $EWT_{avg,c}$)) x $F_{pump,full}$) + (F_{part} x $EER_{GLHP,part}$ (1 + 0.01 x (68 – $EWT_{avg,c}$)) x $F_{pump,part}$)) x $F_{dist,c}$
= ((0.25 x 19 x (1 + 0.01 x (77 - 50)) x 0.93) + (0.75 x 25 x (1 + 0.01 x (68- 50) x 0.92)) x 0.95 = 24.67

$EER_{season,ee}$ equation from Compliance Efficiency section based on GSHP type

F_{full} from Compliance Efficiency section's Summary of Variables and Data Sources table

$EER_{GLHP,full}$ from application

$EWT_{avg,c}$ = EWT_{min} - 10°F = 60 - 10 = 50ºF

$EWT_{avg,c}$ equation from compliance efficiency section

EWT_{min} from application

$F_{pump,full}$ from Pumping Power Adjustment Factors table based on application

F_{part} from Compliance Efficiency section's Summary of Variables and Data Sources table

$EER_{GLHP,part}$ from application

$F_{pump,part}$ from Pumping Factors table based on application

$F_{dist,c}$ from Distribution Correction Factors based on application

$BEFLH_{cooling}$ = 634, from Operating Hours section based on location, Facility Type and construction year from application

BHL = 1,000,000, from application

$F_{ElecHeat}$ = 0, from Summary of Variables and Data Sources table based on existing HVAC from application

$COP_{seaseason,baseline}$ = N/A

$COP_{season,ee}$ = ((F_{full} x $COP_{GLHP,full}$ x (1 + 0.01 x ($EWT_{avg,h}$ – 32)) x $F_{pump,full}$) + (F_{part} x $COP_{GLHP,part}$ x (1 + 0.01 x ($EWT_{avg,h}$ – 41)) x $F_{pump,part}$)) x $F_{dist,h}$

= ((0.25 x 3.5 x (1 + 0.01 x (70- 32)) x 0.92) + (0.75 x 4.1 x (1 + 0.01 x (70 - 41)) x 0.93)) x 0.96 = 4.61

$COP_{season,ee}$ equation from Compliance Efficiency section based on GSHP type

$COP_{GLHP,full}$ from application

$EWT_{avg,h} = EWT_{min} + 10°F = 60 + 10 = 70ºF$

$EWT_{avg,h}$ equation from compliance efficiency section

EWT_{min} from application

$F_{pump,full}$ from Pumping Power Adjustment Factors table based on application

$COP_{GLHP,part}$ from application

$F_{pump,part}$ from Pumping Power Adjustment Factors table based on application

$F_{dist,h}$ from Distribution Correction Factors based on application

$BEFLH_{heating}$ = 545, from Operating Hours section based on location, Facility Type and construction year from application

$F_{pump,avg}$ = 0.343, from Central Loop Pumping Energy Use for GSHP Systems section based on Bypass Flow, Diversity, type of loop flow modulation, and location from application

$kW_{pump,design}$ = 0.5, from application

$EER_{peak,baseline}$ = 9.8, from Baseline Efficiencies section based on equipment type and size from application

$EER_{GSHP,full,ee}$ = 19, from application

CF = 0.8, from Summary of Variables and Data Sources table based on application

$F_{FuelHeat}$ = 1, from Summary of Variables and Data Sources table based on existing HVAC from application

$AFUE_{baseline}$ = 0.8, from Baseline Efficiencies section based on equipment type and size from application

$$\Delta kWh = \left[\frac{720{,}000}{1{,}000} \times \left(\frac{1}{11.4} - \frac{1}{24.67}\right) \times 634\right] + \left[\frac{1{,}000{,}000}{3{,}412} \times \left(0 - \frac{1}{4.61}\right) \times 545 - [0.343 \times 0.5 \times 8760]\right] = -14{,}612\ kWh$$

$$\Delta kW = \frac{720{,}000}{1{,}000} \times \left(\frac{1}{9.8} - \frac{1}{19}\right) \times 0.8 - 0.5 = 27.96\ kW$$

$$\Delta MMBtu = \frac{1{,}000{,}000}{1{,}000{,}000} \times \frac{1}{0.8} \times 545 = 681.25\ MMBtu$$

Methods for Calculating Annual Domestic Hot Water Energy Savings from a Dedicated Water-to-Water Heat Pump

GSHP systems can meet DHW loads by installing a water-to-water heat pump (WWHP) dedicated to meeting the DHW load.

When a WWHP that is dedicated to DHW is added to the ground loop, the DHW-WWHP operates in response to the DHW loads, independently of GSHP units' operation to meet space loads. Therefore, the energy savings are more consistent across the year.

In this analysis the DHW-WWHP displaces nearly all the DHW load. Electric demand impacts are not considered at this time.

$$\Delta MMBtu_{DHW-WWHP} = \frac{Q_{DHW-WWHP}}{1{,}000{,}000} \times \frac{F_{FFDHW}}{UEF_{baseline}}$$

$$\Delta kWh_{DHW-WWHP} = \frac{Q_{DHW-WWHP}}{3{,}412} \times \left(\frac{F_{EDHW}}{UEF_{baseline}} - \frac{1}{COP_{DHW-WWHP}}\right)$$

$$Q_{DHW-WWHP} = 1.1 \times GPD \times 365 \times 8.33 \times \Delta T_{main}$$

$$COP_{DHW-WWHP} = COP_{AHRI,GLHP} \times 0.95$$

where:

$\Delta MMBtu_{DHW-WWHP}$	= Fossil fuel energy displaced by dedicated DHW-WWHP
$\Delta kWh_{DHW-WWHP}$	= Electricity savings from dedicated DHW-WWHP operation
$COP_{AHRI,GLHP}$	= Rated COP for a per ISO13256-2 at GLHP conditions (32°F source-side, 104°F load-side)
$COP_{DHW-WWHP}$	= Overall annual COP of dedicated DHW-WWHP
F_{EDHW}	= Factor indicating that baseline DHW system is electric
F_{FFDHW}	= Factor indicating that baseline DHW system is fossil fuel fired
GPD	= Gallons per day consumption, for DHW system
$Q_{DHW-WWHP}$	= Annual DHW load served by dedicated DHW-WWHP, BTU
$UEF_{baseline}$	= Uniform energy factor of baseline DHW appliance (gas or electric). For commercial systems use AFUE or Et in place of UEF, as appropriate.
ΔT_{main}	= Average temperature difference between water heater set point temperature and the supply water temperature in water main (°F)
0.95	= Correction factor from AHRI rated conditions to 50-60°F source-side, 120-130°F load-side.
1.1	= Factor to increase DHW load served by DHW-WWHP to account for 10% tank losses (that are embedded in UEF).
8.33	= Energy required (BTU) to heat one gallon of water by one-degree Fahrenheit
365	= Days in one year
3,412	= Conversion factor, one kWh equals 3,412 BTU
1,000,000	= Conversion factor (BTU/MMBtu), one therm equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
F_{EDHW}	1 for electric DHW	Factor indicating baseline DHW is electric
F_{FFDHW}	1 for gas-fired DHW	Factor indicating baseline DHW is fossil fuel-fired

Variable	Value	Notes
GPD	17.2 × # of people	Calculated based on number of people served by the system. For small commercial buildings consult the table below for proper GPD values.
T_{main}		Supply water temperature in water main (°F). Lookup in Cold Water Inlet Temperature table below based on nearest city.
T_{set}	130	Tank storage temperature (°F).
$UEF_{baseline}$		Uniform Energy Factor of the baseline condition. See Baseline Efficiencies section for details regarding derivation of this input.
ΔT_{main}	T_{set} - T_{main}	Average temperature difference between water heater set point temperature and the supply water temperature in water main (°F).

Hot Water Consumption for Commercial and Multifamily Building Applications

Building Type	GPD	Rate	Notes/Assumptions	Source
Assembly	239	7.02 GPD per 1,000 SF	Assumes 10% hot water, 34,000 SF	EIA[1089]: Public Assembly
Auto Repair	25	4.89 GPD per 1,000 SF	Assumes 10% hot water, 5,150 SF	EIA: Other
Big Box Retail	448	3.43 GPD per 1,000 SF	Assumes 10% hot water, 130,500 SF	EIA: Mercantile
Community College	1,520	1.9 GPD per person	Assumes 800 students	NREL[1090]: School with Showers
Dormitory	8,600	17.2 GPD per resident	Assumes 500 residents	Water Research Foundation[1091]
Elementary School	250	0.5 GPD per student	Assumes 500 students	NREL: School
Fast Food Restaurant	500	500 GPD per restaurant		FSTC[1092]: Quick Service
Full-Service Restaurant	2,500	2,500 GPD per restaurant		FSTC: Full Service
Grocery	172	3.43 GPD per 1,000 SF	Assumes 10% hot water, 50,000 SF	EIA: Mercantile
High School	1,520	1.9 GPD per person	Assumes 800 students	NREL: School with Showers
Hospital	16,938	54.42 GPD per 1,000 SF	Assumes 40% hot water, 250,000 SF	EIA: Health Care, Inpatient
Hotel	9,104	45.52 GPD per 1,000 SF	Assumes 40% hot water, 200,000 SF	EIA: Lodging
Large Office	550	1.1 GPD per person	Assumes 500 people	NREL: Office
Large Retail	446	3.43 GPD per 1,000 SF	Assumes 10% hot water, 130,000 SF	EIA: Mercantile
Light Industrial	489	4.89 GPD per 1,000 SF	Assumes 10% hot water, 100,000 SF	EIA: Other
Motel	1,366	45.52 GPD per 1,000 SF	Assumes 40% hot water, 30,000 SF	EIA: Lodging
Multifamily High-Rise	4,600	46 GPD per unit	Assumes 100 units	Water Research Foundation
Multifamily Low-Rise	552	46 GPD per unit	Assumes 12 units	Water Research Foundation
Refrigerated Warehouse	86	0.93 GPD per 1,000 SF	Assumes 10% hot water, 92,000 SF	EIA: Warehouse and Storage
Religious	77	7.02 GPD per 1,000 SF	Assumes 10% hot water, 11,000 SF	EIA: Public Assembly
Small Office	110	1.1 GPD per person	Assumes 100 people	NREL: Office
Small Retail	27	3.43 GPD per 1,000 SF	Assumes 10% hot water, 8,000 SF	EIA: Mercantile
University	1,000	0.5 GPD per student	Assumes 2,000 students	NREL: School
Warehouse	465	0.93 GPD per 1,000 SF	Assumes 10% hot water, 500,000 SF	EIA: Warehouse and Storage
Other	Calculate	4.89 GPD per 1,000 SF	Assumes 10% hot water	EIA: Other

[1089] U.S. Energy Information Administration, 2012 Commercial Buildings Energy Consumption Survey: Water Consumption in Large Buildings, Table WD1. Daily water consumption in large commercial buildings, 2012
[1090] National Renewable Energy Laboratory, Saving Energy in Commercial Buildings: Domestic Hot Water Assessment Guidelines, Table 1. Hot Water Use By Building Type, June 2011
[1091] Water Research Foundation: Residential End Uses of Water, Version 2, April 2016
[1092] Improving Commercial Kitchen Hot Water System Perofmrance, Design Guide – Energy Efficient Heating, Delivery and Use, Table 1. Typical hot water system cost for restaurants, March 2010

Cold Water Inlet Temperature (T_{main})

Supply water main temperatures vary according to climate and are approximately equal to the annual average outdoor temperature plus 6°F.[1093] Supply main temperatures based on the annual outdoor temperature are shown below.

City	Annual average outdoor temperature[1094] (°F)	T_{main} (°F)
Albany	48.3	54.3
Binghamton	46.3	52.3
Buffalo	48.3	54.3
Massena	43.5	49.5
NYC	55.4	61.4
Poughkeepsie	49.8	55.8
Syracuse	48.3	54.3

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a minimally code compliant water heater of type (storage-type or instantaneous) equivalent to the existing water heater and with tank volume (where applicable), input capacity and draw pattern equivalent to the efficient water heater. For new construction, the baseline condition is a minimally code compliant storage-type water heater with tank volume, input capacity and draw pattern equivalent to the efficient water heater. $UEF_{baseline}$ shall be calculated as a function of qualifying equipment tank volume (vt) for storage type water heaters. A Medium draw pattern should be assumed for storage type water heaters with rated storage capacity ≤ 50 gallons and a High draw pattern should be assumed otherwise.[1095]

Residential Water Heaters[1096]

Product Class	Rated Storage Volume and Input Rating	Draw Pattern	Uniform Energy Factor
Gas-Fired Storage Water Heater	≥ 20 gal and ≤ 55 gal	Very Small	0.3456 - (0.0020 x vt*)
		Low	0.5982 - (0.0019 x vt)
		Medium	0.6483 - (0.0017 x vt)
		High	0.6920 - (0.0013 x vt)
	> 55 gal and ≤ 100 gal	Very Small	0.6470 - (0.0006 x vt)
		Low	0.7689 - (0.0005 x vt)
		Medium	0.7897 - (0.0004 x vt)
		High	0.8072 - (0.0003 x vt)
Oil-fired Storage Water Heater	≤50 gal	Very Small	0.2509 − (0.0012 × vt)
		Low	0.5330 − (0.0016 × vt)
		Medium	0.6078 − (0.0016 × vt)
		High	0.6815 − (0.0014 × vt)

[1093] Burch, Jay and Christensen, Craig, "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory

[1094] Average annual outdoor temperatures taken from NCEI 1981-2010 climate normals.

[1095] Based on review of typical usage bins for AHRI certified residential water heating equipment. (https://www.ahridirectory.org/ahridirectory/pages/home.aspx)

[1096] 10 CFR 430.32(d)

Product Class	Rated Storage Volume and Input Rating	Draw Pattern	Uniform Energy Factor
Electric Storage Water Heater	≥ 20 gal and ≤ 55 gal	Very Small	0.8808 - (0.0008 x vt)
		Low	0.9254 - (0.0003 x vt)
		Medium	0.9307 - (0.0002 x vt)
		High	0.9349 - (0.0001 x vt)
	> 55 gal and ≤ 120 gal	Very Small	1.9236 - (0.0011 x vt)
		Low	2.0440 - (0.0011 x vt)
		Medium	2.1171 - (0.0011 x vt)
		High	2.2418 - (0.0011 x vt)

*v_t = tank volume in gallons

Commercial Water Heaters for Central Systems

Commercial Equipment Type	Efficiency Level
Tank Type: All Sizes	0.80 Et
Gas-Fired Hot Water Boiler: < 300,000 BTU/h	0.82 AFUE
Oil-Fired Hot Water Boiler: < 300,000 BTU/h	0.84 AFUE
Gas-Fired Steam Boiler, All Except Natural Draft: < 300,000 BTU/h	0.80 AFUE
Gas-Fired Steam Boiler, Natural Draft: < 300,000 BTU/h	0.80 AFUE
Oil-Fired Steam Boiler: < 300,000 BTU/h	0.82 AFUE

First Hour Rating vs. Draw Pattern (Storage Type Only)[1097]

First Hour Rating	Draw Pattern
< 18 gallons	Very Small
≥ 18 and < 51 gallons	Low
≥ 51 and < 75 gallons	Medium
≥ 75 gallons	High

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

[1097] 10 CFR 429.17

References

1. 10 CFR 430.32 Energy and water conservation standards and their compliance dates. Available from: http://www.ecfr.gov/cgi-bin/text-idx?SID=a9921a66f2b4f66a32ec851916b7b9d9&mc=true&node=se10.3.430_132&rgn=div8
2. BG&E: Development of Residential Load Profile for Central Air Conditioners and Heat Pumps, via *Mid-Atlantic Technical Reference Manual Version 6.0*, May 2016 Available from: http://www.neep.org/mid-atlantic-technical-reference-manual-v6
3. Building America House Simulation Protocols, Robert Hendron and Cheryn Engebrecht, National Renewable Energy Laboratory, October 2010 Available from: https://www1.eere.energy.gov/buildings/publications/pdfs/building_america/house_simulation_revised.pdf
4. ECCCNYS, 2016, per IECC 2015; Section R403.7 Available from: https://codes.iccsafe.org/public/document/IECC2015NY-1/chapter-4-re-residential-energy-efficiency
5. *Guide to Geothermal Heat Pumps* (February 2011) U. S. Department of Energy, Energy Efficiency and Renewable Energy, DOE/EE-0385
6. Henderson, H.I., 2020. White Paper Savings Calculations for Residential Ground Source Heat Pumps: The Basis for Equivalent Full Load Hours (EFLH) and Seasonal Efficiency Factors. Prepared for the New York State Energy Research and Development Authority (NYSERDA) and the New York State Department of Public Service. Revised in June.
7. Henderson, H.I., 2021a. Savings Calculations for Ground Source Heat Pumps with Central Pumping. For application in Multi-Family Buildings and Other Commercial Applications. Prepared for the New York State Energy Research and Development Authority (NYSERDA) and the New York State Department of Public Service. Revised March 2021.
8. Henderson, H. 2021b. White Paper: Developing Building Equivalent Full Load Hour (BEFLH) Values for Commercial and Multi-Family Buildings in NYS. Prepared for the New York State Energy Research and Development Authority (NYSERDA) and the New York State Department of Public Service. Revised in August.
9. International Ground Source Heat Pump Association (IGSHPA). 2011. Ground Source Heat Pump Residential and Light Commercial Design and Installation Guide. Oklahoma State University. Stillwater.
10. Kavanaugh, S and Rafferty, K (2015): *Geothermal Heating and Cooling, Design of Ground-Source Heat Pump Systems* RP-1674, Atlanta, GA. ASHRAE Inc.
11. *Manual J Residential Load Calculation*, Arlington, VA. Air Conditioning Contractors Association
12. *Manual S Equipment Selection*, Arlington, VA. Air Conditioning Contractors Association
13. M. M. Straub, Using Available Information for Efficient Evaluation of Demand-Side Management Programs, Electricity Journal, September 2011 Available from: https://www.sciencedirect.com/science/article/pii/S1040619011001941
14. Monitored data from geothermal heat pump systems installed in New York State submitted August 2015 by the New York Geothermal Energy Organization and reviewed by NYS DPS Staff.

15. New York State Energy Research and Development Authority (NYSERDA). 2017. "Analysis of Water Furnace Geothermal Heat Pump Sites in New York State with Symphony Monitoring System," NYSERDA Report Number 18-03. Prepared by CDH Energy Corp., Cazenovia, NY. nyserda.ny.gov/publications.
16. *Water Source Heat Pumps – Testing and Rating for Performance – Part 1: Water to Air and Brine to Air Heat Pumps* (2012) Arlington, VA. ANSI/ASHRAE/ISO Standard 13256-1:1998 (RA 2012), AHRI, 2012.
17. *Water Source Heat Pumps – Testing and Rating for Performance – Part 2: Water to Water Heat Pumps* (2012) Arlington, VA. ANSI/ASHRAE/ISO Standard 13256-2:1998 (RA 2012), AHRI, 2012.

Record of Revision

Record of Revision Number	Issue Date
7-21-14	8/30/2021

Return to Table of Contents

HIGH-VOLUME LOW SPEED (HVLS) FAN

Measure Description

This measure is applicable to the installation of high-volume low speed (HVLS) fans in C&I applications. HVLS fans are ceiling mounted fans that move large amounts of air more efficiently and with lower noise levels. For the purposes of this measure, a fan shall consist of the blade and motor assembly. Installed in exhaust, ventilation, or circulation applications, HVLS fans replace multiple smaller fans.

Variable frequency drives (VFD) may be installed along with high speed fans to increase energy savings and the associated savings are quantified by this methodology. If VFD savings are claimed via this measure, additional savings may not be claimed for VFDs utilizing a separate methodology.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = \left[\left(units_{baseline} \times \frac{lbf_{baseline}}{\left(\frac{lbf}{kW}\right)_{baseline}}\right) - \left(units_{ee} \times \frac{lbf_{ee}}{\left(\frac{lbf}{kW}\right)_{ee}} \times F_{VFD,ee}\right)\right] \times hrs$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \frac{\Delta kWh}{hrs} \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

where:

ΔkWh	= Annual electricity energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
baseline	= Characteristic of baseline condition
ee	= Characteristic of energy efficient condition
units	= Number of fans installed or removed under the program
lbf	= Thrust, in pounds-force
lbf/kW	= Thrust efficiency ratio, in pounds-force per kilowatt
F_{VFD}	= Factor to account for reduced consumption resultant from VFD control
hrs	= Annual hours of operation
CF	= Coincidence Factor

Summary of Variables and Data Sources

Variable	Value	Notes
$units_{baseline}$		From application. For new installations, assume 5 x $units_{ee}$.[1098]
$units_{ee}$		From application.
$lbf_{baseline}$		From application, look up from BESS Labs database based on manufacturer and model number. If unknown, or for new installations, use lbf_{ee} as the default value.
lbf_{ee}		From application.
$(lbf/kW)_{baseline}$		From application, look up from BESS Labs database based on manufacturer and model number. If not tested by BESS Labs, look up from Baseline Efficiencies section below based on fan diameter.
$(lbf/kW)_{ee}$		From application, look up from BESS Labs database based on manufacturer and model number or as rated by other third-party accredited laboratory
$F_{VFD,ee}$	No VFD: 1.00 VFD (Greenhouse): 0.64 VFD (Other): 0.75	Adjustment to efficient condition consumption to account for VFD control, based on presence of VFDs and fan application.[1099]
hrs		From application. If unknown, look up from table below based on location for agricultural applications. For other C&I applications, assume fan operating hours align with the operating hours prescribed in the C&I Interior and Exterior Lighting measure found in this document, based on facility type.
CF	0.8	

Coincidence Factor (CF)

The prescribed coincidence factor for this measure is 0.8.[1100]

[1098] Kammel, David & Raabe, & Kappelman, J.. (2003). Design of high volume low speed fan supplemental cooling system in dairy freestall barns. Proceedings of the Fifth International Dairy Housing Conference. 10.13031/2013.11628.

[1099] Teitel, M. & Levi, Asher & Zhao, Yun & Barak, Moti & Bar-lev, Eli & Shmuel, David. (2008). Energy saving in agricultural buildings through fan motor control by variable frequency drives. Energy and Buildings. 40. 953-960. 10.1016/j.enbuild.2007.07.010.

[1100] *No source specified – update pending availability and review of applicable references.*

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition for this measure is a standard efficiency circulating fan. Baseline fan thrust (lbf) for circulating fans and fan efficiency shall come from application. If unavailable, look up from the table below based on fan type and diameter.[1101]

Fan Diameter	Circulating Fans (lbf/kW)
24" – 35"	10.5
36" - 47"	12.9
48" - 52"	19.8
53"+	20.8

Compliance Efficiency from which Incentives are Calculated

The compliance condition for this measure is a HVLS fan, at least 16 feet in diameter.

Operating Hours

Operating hours shall come from application. If operating hours are unknown, the prescribed hours shall come from the lookup table below based on location for agricultural applications. Default hours are developed from NOAA hourly normals by summing annual hours dry bulb temperature is above 50ºF.[1102]

City	Hours
Albany	4,238
Binghamton	3,969
Buffalo	4,189
Massena*	4,156
NYC	5,162
Poughkeepsie**	4,722
Syracuse	4,179

*Massena hourly normals are approximated from Rochester airport data due to limited available data
** Poughkeepsie hourly normals are approximated from Long Island ISLIP airport data due to limited available data

For other C&I applications, assume fan operating hours align with the operating hours prescribed in the C&I Interior and Exterior Lighting measure found in this document, based on facility type.

[1101] Default baseline efficiency was determined by calculating the 10th percentile of the efficiencies of all fans in the active BESS Labs database for 48" ventilation fan. Many low efficiency fans are often not tested by BESS Labs, therefore the average tested fan is more efficient than the average market available fan. The database includes single and three phase fans at four voltages.
[1102] NOAA National Centers for Environmental information – NCEI 2010 Hourly Normals

Example Calculation *(Not to be used as default)*

Two 16 foot diameter high volume low speed fans with 50 lbf and 26.5 lbf/kW are installed on a dairy farm near Albany, replacing ten 36" diameter circulating fans with 10 lbf each. Circulating fans are estimated to operate 4,000 hours per year. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

$$\Delta kWh = \left[\left(units_{baseline} \times \frac{lbf_{baseline}}{\left(\frac{lbf}{kW}\right)_{baseline}}\right) - \left(units_{ee} \times \frac{lbf_{ee}}{\left(\frac{lbf}{kW}\right)_{ee}} \times F_{VFD,ee}\right)\right] \times hrs$$

$$\Delta kW = \frac{\Delta kWh}{hrs} \times CF$$

$units_{baseline}$ =10, from application
$units_{ee}$= 2, from application
$lbf_{baseline}$ = 10, from application
$(lbf/kW)_{baseline}$ = 12.9, lookup from Baseline Efficiency section based on existing fan dimaeter
Lbf_{ee} = 50, from application
$(lbf/kW)_{ee}$ = 26.5, from application
$F_{VFD,ee}$ = 1.00, from Summary of Variables and Data Sources Table
Hrs = 4,000 hours, from application

$$\Delta kWh = \left[\left(10 \times \frac{10}{12.9}\right) - \left(2 \times \frac{50}{26.5} \times 1.00\right)\right] \times 4{,}000 = 15{,}913\ kWh$$

$$\Delta kW = \frac{15{,}913}{4{,}000} \times 0.8 = 3.98\ kW$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

HVLS are used for air destratification. The destratification of air during heating and cooling seasons in a conditioned space can decrease heating and cooling load required to achieve occupant comfort and leads to additional energy savings. Because this measure considers HVLS fans as a replacement for multiple conventional, smaller fans, impacts to heating and cooling load are not quantified.

Ancillary Electric Savings Impacts

HVLS are used for air destratification. The destratification of air during heating and cooling seasons in a conditioned space can decrease heating and cooling load required to achieve occupant

comfort and leads to additional energy savings. Because this measure considers HVLS fans as a replacement for multiple conventional, smaller fans, impacts to heating and cooling load are not quantified.

References

1. Kammel, David & Raabe, & Kappelman, J.. (2003). Design of high volume low speed fan supplemental cooling system in dairy freestall barns. Proceedings of the Fifth International Dairy Housing Conference. 10.13031/2013.11628.
   Available from:
   https://www.researchgate.net/publication/271433461_Design_of_high_volume_low_speed_fan_supplemental_cooling_system_in_dairy_freestall_barns
2. Energy Savings Potential and Opportunities for High-Efficiency Electric Motors in Residential and Commercial Equipment, Building Technologies Office, US Department of Energy. December 2013.
   Available from:
   https://www.energy.gov/sites/prod/files/2014/02/f8/Motor%20Energy%20Savings%20Potential%20Report%202013-12-4.pdf
3. NOAA National Centers for Environmental Information
   Available from: https://www.ncdc.noaa.gov/cdo-web/search?datasetid=NORMAL_HLY
4. HVAC for Large Spaces: The Sustainable Benefits of HVLS (High Volume/Low Speed) Fans course, Continuing Education Center, Architecture + Construction
   Available from: https://continuingeducation.bnpmedia.com/courses/macroair-technologies/hvac-for-large-spaces-the-sustainable-benefits-of-hvls-high-volumelow-speed-fans/6/
5. Agricultural Ventilation Fans, Bioenvironmental and Structural Systems Laboratory, University of Illinois, Department of Agricultural and Biological Engineering, Accessed September 26, 2019
   Available from: http://www.bess.illinois.edu/current.asp

Record of Revision

Record of Revision Number	Issue Date
7-21-15	8/30/2021

Return to Table of Contents

INFRARED HEATER

Measure Description

This measure covers the installation of gas-fired, low-intensity infrared (IR) heaters, replacing existing fossil fuel-fired furnaces and warm air unit heaters in commercial and industrial facilities. Low-intensity IR heaters, also referred to as radiant tube heaters, operate through the combustion of fossil fuel to heat steel or ceramic emitter tubes that deliver infrared radiant energy to the space. IR heaters operate through radiant rather than convective heat transfer, making them ideally suited for spaces with high air exchange rates (i.e. commercial garages and loading docks). Low-intensity IR heaters have radiating surfaces that typically operate at less than 732°C (1,350°F).

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings[1103]

Annual Electric Energy Savings

$$\Delta kWh = N/A$$

Summer Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = units \times \frac{kBTU/h_{in}}{unit} \times \frac{EFLH_{heating}}{1{,}000} \times \left(1 - \frac{HDD_{55}/(55 - T_{design})}{HDD_{65}/(65 - T_{design})}\right)$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
$kBTU/h_{in}$	= Fuel input rating of the installed equipment
$EFLH_{heating}$	= Heating equivalent full-load hours
ESF	= Energy Savings Factor
HDD_{55}	= Heating Degree Days of the climate zone with a 55-degree base
HDD_{65}	= Heating Degree Days of the climate zone with a 65-degree base
T_{design}	= Equipment design temperature
1,000	= Conversion factor, one MMBtu equals 1,000 kBTU
55	= Assumed space temperature in the efficient case (°F)
65	= Assumed space temperature in the baseline case (°F)

[1103] The derivation of savings is based on the reduced input capacity requirement with the radiant heating of an IR Heater (efficient) as opposed to convective heating of a conventional heating system (baseline). The thermal efficiency is assumed to be equivalent between the baseline and efficient case.

Summary of Variables and Data Sources

Variable	Value	Notes
$(kBTU/h)_{in}$/unit		Nameplate input rating of the efficient unit, from application
$EFLH_{heating}$		From application. If unknown, lookup based on building type and location from Appendix G
HDD_{55}		From application. If unknown, lookup from Location Variables table below for 55-degree base based on location.
HDD_{65}		From application. If unknown, lookup from Location Variables table below for 65-degree base based on location.
T_{design}		Lookup from Location Variables table below based on location.

Location Variables

City	HDD_{55}[1104]	HDD_{65}[1105]	T_{design}[1106]
Albany	4,255	6,680	-0.3
Binghamton	4,624	7,193	0.0
Buffalo	4,180	6,617	3.5
Massena	5,556	8,196	-8.7
NYC	2,576	4,671	14.3
Poughkeepsie	3,833	6,210	2.7
Syracuse	4,223	6,651	-0.7

Coincidence Factor (CF)

The prescribed value for the coincidence factor is N/A.

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a minimally code-compliant fossil fuel-fired furnace or warm air unit heater, based on existing conditions. For new construction, a gas-fired warm air unit heater shall be assumed.

The baseline efficiency for commercial furnaces and unit heaters is defined by the Code of Federal Regulations (CFR) and subsequently adopted by the Energy Conservation Construction Code of New York State[1107] as shown below.

Equipment Type	Size Range	ECCCNYS Minimum Efficiency for Climate Zones 4, 5 and 6
Warm Air Furnace, Gas Fired	< 225 kBTU/h	0.80 AFUE
	≥ 225 kBTU/h	0.80 Et
Warm Air Furnace, Oil Fired	< 225 kBTU/h	0.83 AFUE
	≥ 225 kBTU/h	0.80 Et

[1104] National Oceanic and Atmospheric Administration, National Climatic Data Center, 1981-2010 Normals
[1105] Ibid
[1106] 2017 ASHRAE Handbook – Fundamentals, Appendix: Design Conditions for Selected Locations, Heating Dry Bulb 99.6%
[1107] ECCCNYS 2020, Table C403.3.2(4) and Table C403.2.3(5)

Equipment Type	Size Range	ECCCNYS Minimum Efficiency for Climate Zones 4, 5 and 6
Warm Air Unit Heaters, Gas Fired	All Capacities	0.80 Ec
Warm Air Unit Heaters, Oil Fired	All Capacities	0.80 Ec

Compliance Efficiencies from which Incentives are Calculated

The compliance condition is a low-intensity, gas-fired infrared or radiant tube heater. The methodology prescribed assumes a 10°F reduction to maintain occupant comfort in the affected space.[1108]

Operating Hours

Heating equivalent full-load hours were calculated from a DOE-2.2 simulation of prototypical commercial buildings. Operating hour assumptions for the prototypical building models are described in Appendix A. The heating EFLH for commercial buildings in NY are shown in Appendix G.

Example Calculation *(Not to be used as default)*

Four gas-fired unit heaters are replaced with four 90 kBTU/h infrared heater in a commercial facility loading dock located near Albany. The estimated heating EFLH for the space is 950 hours. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are not applicable. Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta MMBtu = units \times \frac{kBTU/h_{in}}{unit} \times \frac{EFLH_{heating}}{1{,}000} \times \left(1 - \frac{HDD_{55}/(55 - T_{design})}{HDD_{65}/(65 - T_{design})}\right)$$

unit = 4, from application
$(kBTU/h)_{in}$/unit = 90, from application
$EFLH_{heating}$ = 950, from application
HDD_{55} = 4,255, from the Location Variables table based on location from application
T_{design} = - 0.3, from the Location Variables table based on location from application
HDD_{65} = 6,680, from the Location Variables table based on location from application

$$\Delta MMBtu = 4 \times 90 \times \frac{950}{1{,}000} \times \left(1 - \frac{4{,}255/(55 - (-0.3))}{6{,}680/(65 - (-0.3))}\right) = 84.76\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

[1108] 2012 ASHRAE Handbook – HVAC Systems and Equipment, Chapter 16, Infrared Radiant Heating

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

IR heaters transmit radiant heat, eliminating fan motor load requirements associated with distribution of heated air in convective heating systems. This impact is not considered in the methodology above at this time.

References

1. 2017 ASHRAE Handbook – Fundamentals, Appendix: Design Conditions for Selected Locations
2. 2012 ASHRAE Handbook – HVAC Systems and Equipment, Chapter 16, Infrared Radiant Heating
3. National Oceanic and Atmospheric Administration, National Climatic Data Center, 1981-2010 Normals
   Available from: https://www.ncdc.noaa.gov/cdo-web/datatools/normals
4. ECCCNYS 2020 Table C403.3.2(4): Warm-Air Furnaces And Combination Warm-Air Furnaces/Air-Conditioning Units, Warm-Air Duct Furnaces And Unit Heaters, Minimum Efficiency Requirements & Table C403.2.3(5): Minimum Efficiency Requirements: Gas- And Oil-Fired Boilers.
   Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-[ce]-commercial-energy-efficiency#NYSECC2020P1_CE_Ch04_SecC402

Record of Revision

Record of Revision Number	Issue Date
12-18-11	12/28/2018

Return to Table of Contents

KITCHEN DEMAND CONTROL VENTILATION (KDCV)

Measure Description

This measure covers the installation of kitchen demand control ventilation (KDCV). KDCV uses temperature sensors within the hood or hood exhaust collar and/or optic sensors within the hood to determine ventilation rate. These sensors, along with a microprocessor-based controller, control kitchen exhaust airflow and make-up air volume via VFDs. KDCV reduces ventilation and heating loads by controlling mechanical ventilation in response to cooking activities.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times hp \times (\Delta kWh/hp)$$

Summer Peak Coincident Demand Savings

$$\Delta kW = units \times hp \times (\Delta kW/hp) \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = units \times hp \times (\Delta MMBtu/hp)$$

where:

ΔkWh = Annual electric energy savings
ΔkW = Peak coincident demand electric savings
ΔMMBtu = Annual fossil fuel energy savings
units = Number of measures installed under the program
hp = Horsepower of exhaust fan
(ΔkWh/hp) = Annual electric energy savings (in kWh) per controlled motor horsepower
(ΔkW/hp) = Electric demand savings (in kW) per controlled motor horsepower
(ΔMMBtu/hp) = Annual fossil fuel energy savings (in MMBtu) per controlled motor horsepower
CF = Coincidence factor

Summary of Variables and Data Sources

Variable	Value	Notes
hp		From application.
(ΔkWh/hp)	4,423	SCE[1109]
(ΔkW/hp)	0.612	SCE [1110]

[1109] Southern California Edison Work Paper SCE17CC008, Revision 0, pg xiii. The workpaper assumes that this value is applicable to all California climate zones. Therefore, the derivation of this value is independent of climate considerations and adjustments for New York weather data is not feasible.
[1110] Ibid.

Variable	Value	Notes
(ΔMMBtu/hp)		Look up based on location in Fossil Fuel Savings table below.[1111]
CF	0.9	

Fossil Fuel Savings

Location	ΔMMBtu/hp
Albany	26.8
Binghamton	28.8
Buffalo	26.6
Massena	32.8
NYC	18.9
Poughkeepsie	25.0
Syracuse	26.7

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.9.[1112]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a kitchen exhaust hood fan with manual or automatic on/off control and constant volume exhaust fans.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a KDCV system using smoke and heat sensors to control the exhaust hood airflow and make-up air volume via variable frequency drive based on cooking activities. The compliance condition must comply with all applicable provisions of federal, state, local and municipal mechanical/ventilation and construction code including but not limited to sections C403.2.6 and C403.2.8 of ECCCNYS and sections 402 and 403 of NYS Mechanical Code (NYSMC).

Operating Hours

Operating hours are embedded into the per horsepower savings above using assumptions based on data collected from a representative population of 72 sites of varying type across the state of California. The average hours of use across all 72 sites used to derive per horsepower savings is 17 hours per day, and the average days per year is 350.

[1111] Based on SCE Work Paper SCE17CC008 and NOAA Climate Normals. Baseline and climate dependent savings were established by assigning each California climate zone HDD values based on NOAA climate normals. The savings values from SCE Work Paper SCE17CC008 were then graphed against these HDD values. The associated trendline was then applied to New York's city specific HDD to develop location dependent savings values.
[1112] Southern California Edison Work Paper SCE17CC008, Revision 0, pg xiii

Example Calculation *(Not to be used as default)*

A kitchen demand control ventilation system is installed in a hotel kitchen located near Albany, controlling exhaust fans with total horsepower of 2 hp. Annual Electric Energy Savings, Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta kWh = units \times hp \times (\Delta kWh/hp)$$

$$\Delta kW = units \times hp \times (\Delta kW/hp) \times CF$$

$$\Delta MMBtu = units \times hp \times (\Delta MMBtu/hp)$$

units = 1, from application
hp = 2, from application
(ΔkWh/hp) = 4,423, from Summary of Variables and Data Sources table
(ΔkW/hp) = 0.612, from Summary of Variables and Data Sources table
CF = 0.9, from Summary of Variables and Data Sources table
(ΔMMBtu/hp) = 26.8, from Fossil Fuel Savings table based on location from application

$$\Delta kWh = 1 \times 2 \times 4{,}423 = 8{,}846\ kWh$$

$$\Delta kW = 1 \times 2 \times 0.612 \times 0.9 = 1.10\ kW$$

$$\Delta MMBtu = 1 \times 2 \times 26.8 = 53.6\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. Southern California Edison, Work Paper SCE17CC008 Exhaust Hoods Demand Controlled Ventilation, Revision 0, November 2017
   Available from: http://deeresources.net/workpapers

2. ECCCNYS 2020 403.2.6 Ventilation and C403.2.8 Kitchen Exhaust Systems
   Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-re-residential-energy-efficiency
3. NYSMC 2020 402 Natural Ventilation and 403 Mechanical Ventilation
   Available from: https://up.codes/viewer/new_york/ny-mechanical-code-2020/chapter/4/ventilation#4

Record of Revision

Record of Revision Number	Issue Date
12-19-14	12/23/2019

Return to Table of Contents

REFRIGERANT CHARGE CORRECTION & TUNE UP - AIR CONDITIONER AND HEAT PUMP

Measure Description

This measure estimates savings associated with refrigerant charge correction of air-cooled central air conditioners and air source heat pumps in small commercial applications. In order to be eligible for energy savings, the scope of work performed must include manufacturer recommended AC tune-up procedures including but not limited to the cleaning of condenser coils.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

For Units with Cooling Capacity < 65,000 BTU/h

$$\Delta kWh = units \times \left\{\left[tons/unit \times \left(\frac{12}{SEER_{baseline}} - \frac{12}{SEER_{ee}}\right) \times EFLH_{cooling}\right] + \left[(kBTU/h)_{out}/unit \times \left(\frac{1}{HSPF_{baseline}} - \frac{1}{HSPF_{ee}}\right) \times EFLH_{heating}\right]\right\}$$

For Units with Cooling Capacity ≥ 65,000 BTU/h

$$\Delta kWh = units \times \left\{\left[tons/unit \times \left(\frac{12}{IEER_{baseline}} - \frac{12}{IEER_{ee}}\right) \times EFLH_{cooling}\right] + \left[\frac{(kBTU/h)_{out}/unit}{3.412} \times \left(\frac{1}{COP_{baseline}} - \frac{1}{COP_{ee}}\right) \times EFLH_{heating}\right]\right\}$$

Summer Peak Coincident Demand Savings

$$\Delta kW = units \times tons/unit \times \left(\frac{12}{EER_{baseline}} - \frac{12}{EER_{ee}}\right) \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
tons/unit	= Tons of air conditioning per unit, based on AHRI certification or nameplate data of condenser or matched pair (condenser and coil)
$(kBTU/h)_{out}$/unit	= Output heating capacity in kBTU/h (at AHRI standard high-temperature rating conditions)

$_{baseline}$ = Characteristic of baseline condition
$_{ee}$ = Characteristic of energy efficient condition
SEER = Seasonal average energy efficiency ratio over the cooling season, BTU/watt-hour, (used for average U.S. location/region)
IEER = Integrated energy efficiency ratio in BTU/watt-hour. A weighted calculation of mechanical cooling efficiencies at full load and part load AHRI standard rating conditions (used only for units with cooing capacity ≥ 65,000 BTU/h)
EER = Energy efficiency ratio under peak conditions, measurement of cooling capacity for a unit (in BTU/h) / electrical energy used (watts) (at AHRI standard rating conditions)
HSPF = Heating seasonal performance factor, total heating output (supply heat) in BTU (including electric strip heat) during the heating season divided by the total electric energy heat pump consumed in watt-hours
COP = Coefficient of performance, ratio of output energy/input energy (at AHRI standard high-temperature rating conditions)
$EFLH_{cooling}$ = Cooling equivalent full-load hours
$EFLH_{heating}$ = Heating equivalent full-loadhours
CF = Coincidence factor
12 = (kBTU/h)/ton of air conditioning capacity
3,412 = Conversion factor, one watt-hour equals 3.412 BTU

Summary of Variables and Data Sources

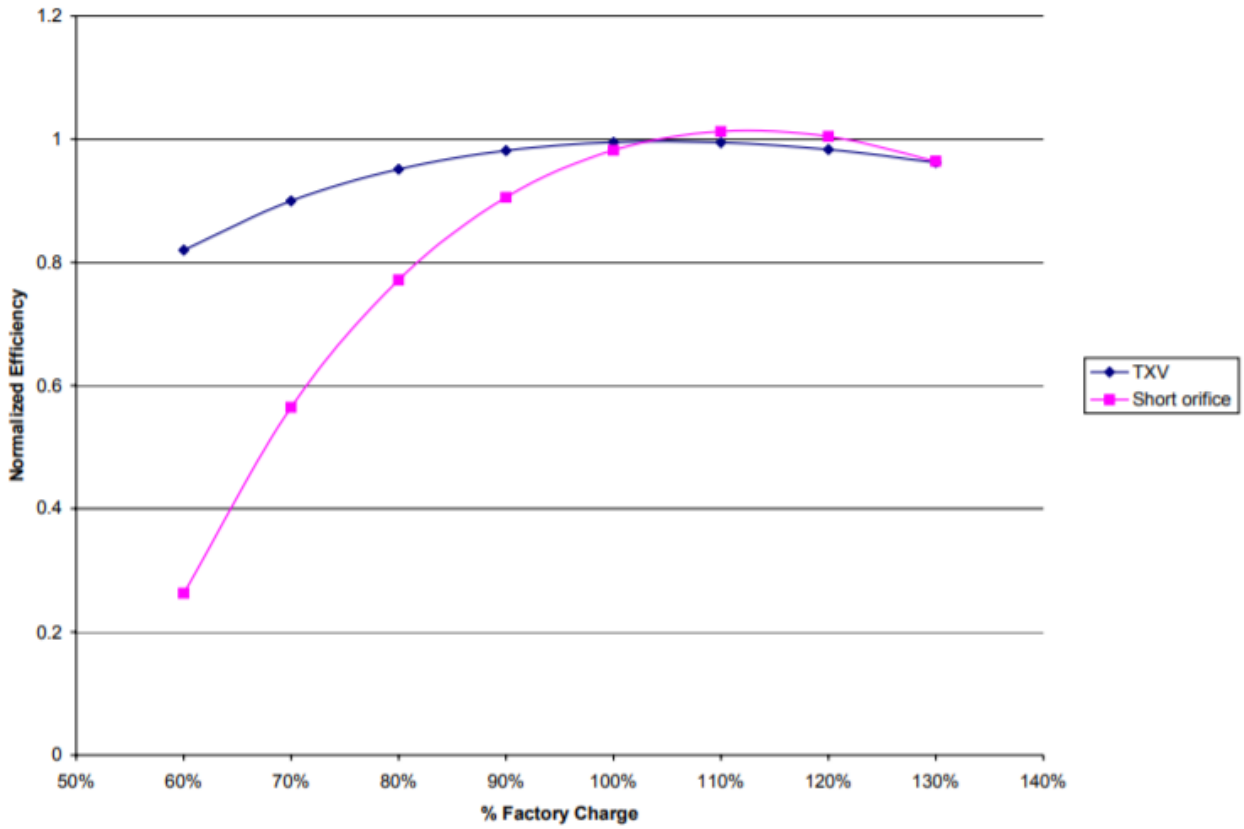
Variable	Value	Notes
tons/unit		From application
$SEER_{ee}$		Actual equipment nameplate SEER.
$SEER_{baseline}$		Actual equipment nameplate SEER, derated in accordance with the Baseline Degradation Factor section below.
$IEER_{ee}$		Actual equipment nameplate IEER.
$IEER_{baseline}$		Actual equipment nameplate IEER, derated in accordance with the Baseline Degradation Factor section below.
EER_{ee}		Actual equipment nameplate EER
$EER_{baseline}$		Actual equipment nameplate EER, derated in accordance with the Baseline Degradation Factor section below.
$HSPF_{ee}$		Actual equipment nameplate HSPF.
$HSPF_{baseline}$		Actual equipment nameplate HSPF, derated in accordance with the Baseline Degradation Factor section below.
COP_{ee}		Actual equipment nameplate COP.
$COP_{baseline}$		Actual equipment nameplate COP, derated in accordance with the Baseline Degradation Factor section below.
$EFLH_{cooling}$		From application. If unknown, look up based on building type, system type and location from Appendix G.
$EFLH_{heating}$		From application. If unknown, look up based on building type, system type and location from Appendix G.
CF	0.8	

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.8.[1113]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is equivalent to the existing condition with efficiency ratings taken from the equipment nameplate, derated to account for under or overcharging. The efficiency improvement resulting from refrigerant charge adjustment is dependent upon the discrepancy between the actual equipment charge before the adjustment was performed and the manufacturer's specification. The efficiency adjustment factor as a function of charge adjustment is taken from the figure or table below.[1114] Note the efficiency change depends on the type of expansion valve. Use the curve or column labeled "TXV" for units with thermal expansion valves; otherwise use the curve or column labeled "Short orifice".



[1113] *No source specified – update pending availability and review of applicable references.*

[1114] Efficiency as a function of charge adjustment from Small HVAC System Design Guide, New Buildings Institute, 2003, pg 40

% Factory Charge	Normalized Efficiency (Short Orifice)	Normalized Efficiency (TXV)	% Factory Charge	Normalized Efficiency (Short Orifice)	Normalized Efficiency (TXV)
60%	0.26	0.82	96%	0.96	0.99
62%	0.32	0.84	98%	0.97	0.99
64%	0.39	0.85	100%	0.98	1.00
66%	0.45	0.87	102%	0.99	1.00
68%	0.51	0.89	104%	1.00	1.00
70%	0.56	0.90	106%	1.00	1.00
72%	0.61	0.91	108%	1.00	1.00
74%	0.66	0.92	110%	1.00	1.00
76%	0.70	0.93	112%	1.00	0.99
78%	0.73	0.94	114%	1.00	0.99
80%	0.77	0.95	116%	1.00	0.99
82%	0.80	0.96	118%	1.00	0.99
84%	0.83	0.97	120%	1.00	0.99
86%	0.86	0.97	122%	1.00	0.98
88%	0.88	0.98	124%	0.99	0.98
90%	0.91	0.98	126%	0.98	0.97
92%	0.92	0.99	128%	0.97	0.97
94%	0.94	0.99	130%	0.96	0.96

If the equipment contains multiple refrigeration circuits, relevant baseline efficiency ratings shall be calculated by establishing the total degradation factor as the sum of each circuit's derating factor multiplied by its percentage of the total system capacity and multiplying this value by the system's nameplate efficiency. The equation for $EER_{baseline}$, for example, is shown below:

$$EER_{baseline} = EER_{ee} \times \sum_{n} (Cap_n \times Fderate_n)$$

where:

n = Each circuit

Cap = Fraction of total system capacity

Fderate = Baseline degradation factor, based on % over/undercharging from table above

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a commercial air conditioner or heat pump with corrected refrigerant charge. SEER, IEER, EER, HSPF, and COP are taken from application as reported by equipment manual.

Operating Hours

Equipment heating and cooling equivalent full load hours shall be taken from the application. If unknown, default EFLH by facility type, system type and location can be found in Appendix G.

Example Calculation *(Not to be used as default)*

A 7.5 ton split system heat pump with 90 kBTU/h heating capacity undergoes refrigerant charge correction and tune-up per manufacture recommended procedures at an assembly building located near Albany. The heat pump is rated at 18 IEER, 13.7 EER, and 3.2 COP and is equipped with a thermal expansion valve. It was determined that the unit was operating at 70% of factory charge prior to correction. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

$$\Delta kWh = units \times \left\{\left[tons/unit \times \left(\frac{12}{IEER_{baseline}} - \frac{12}{IEER_{ee}}\right) \times EFLH_{cooling}\right] + \left[\frac{(kBTU/h)_{out}/unit}{3.412} \times \left(\frac{1}{COP_{baseline}} - \frac{1}{COP_{ee}}\right) \times EFLH_{heating}\right]\right\}$$

$$\Delta kW = units \times tons/unit \times \left(\frac{12}{EER_{baseline}} - \frac{12}{EER_{ee}}\right) \times CF$$

units = 1, from application
tons/unit = 7.5, from application
$IEER_{baseline} = IEER_{ee} \times F_{detrate,n} = 18 \times 0.9 = 16.2$
$F_{derate,n}$ from Baseline Efficiencies table based on percentage of factory charge correction and expansion valve type from application
$IEER_{ee} = 18$, from application
$EFLH_{cooling} = 478$, from Appendix G based on building type and location from application
$(kBTU/h)_{out}/unit = 90$, from application
$COP_{baseline} = COP_{ee} \times F_{detrate,n} = 3.2 \times 0.9 = 2.88$, from Baseline Efficiencies table based on percentage of factory charge correction and expansion valve type from application
$COP_{ee} = 3.2$, from application
$EFLH_{heating} = 961$, from Appendix G based on building type and location from application
$EER_{baseline} = EER_{ee} \times F_{detrate,n} = 13.7 \times 0.9 = 12.3$, from Baseline Efficiencies table based on percentage of factory charge correction and expansion valve type from application
$EER_{ee} = 13.7$, from application
CF = 0.8, from Summary of Variables and Data Sources table

$$\Delta kWh = 1 \times \left\{\left[7.5 \times \left(\frac{12}{16.2} - \frac{12}{18}\right) \times 478\right] + \left[\frac{90}{3.412} \times \left(\frac{1}{2.88} - \frac{1}{3.2}\right) \times 961\right]\right\} = 1{,}146\ kWh$$

$$\Delta kW = 1 \times 7.5 \times \left(\frac{12}{12.3} - \frac{12}{13.7}\right) \times 0.8 = 0.585\ kW$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. Small HVAC System Design Guide, New Buildings Institute, White Salmon, WA for the California Energy Commission.
   Available from: http://www.energy.ca.gov/2003publications/CEC-500-2003-082/CEC-500-2003-082-A-12.PDF

Record of Revision

Record of Revision Number	Issue Date
1	10/15/2010
6-18-10	6/26/2018

Return to Table of Contents

TUNE-UP - BOILER

Measure Description

This measure applies to fossil fuel-fired hot water and steam boilers used for process loads or space heating not covered under 40 CFR Part 63 Subpart 6J[1115]. Tune-up will improve boiler efficiency by cleaning burners, combustion chamber and burner nozzles, adjusting air flow and reducing excessive stack temperatures, adjusting burner and gas input and checking venting, safety controls, and adequacy of combustion air intake. Combustion efficiency must be measured before and after tune-up using a flue gas analyzer.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = N/A$$

Summer Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = units \times \frac{(kBTU/h)_{in}/unit}{1{,}000 \times LF} \times \left(1 - \frac{E_{c,baseline}}{E_{c,ee}}\right) \times EFLH_{heating}$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of boilers addressed under the program
$(kBTU/h)_{in}$/unit	= Fuel input rating per boiler, based on nameplate data
$EFLH_{heating}$	= Heating equivalent full-load hours
LF	= Load Factor
$E_{c,baseline}$	= Baseline combustion efficiency as determined via flue gas analysis
$E_{c,ee}$	= Post-implementation combustion efficiency as determined via flue gas analysis
1,000	= Conversion factor, one MMBtu equals 1,000 kBTU

Summary of Variables and Data Sources

Variable	Value	Notes
$(kBTU/h)_{in}$/unit		Nominal heating input capacity is the nameplate input rating of the unit in kBTU/h, from application.
LF	1.3	Assumes 30% boiler oversizing[1116]
$E_{c,baseline}$		Efficiency as measured in pre-tune-up inspection

[1115] 40 CFR 63 Subpart JJJJJJ: https://www.ecfr.gov/cgi-bin/text-idx?node=sp40.15.63.jjjjjj
[1116] PA Consulting, KEMA, Focus on Energy Evaluation, Match 22, 2010

Variable	Value	Notes
$E_{c,ee}$		Post-tune-up efficiency as measured post-tune-up
$EFLH_{heating}$		For space heat; lookup based on building type and location, Appendix G. For process heat, use hours of operation from application.

Coincidence Factor (CF)

The prescribed value for the coincidence factor is N/A.

Baseline Efficiencies from which Energy Savings are Calculated

The baseline efficiency is the combustion efficiency of the boiler measured during pre-tune-up inspection via flue gas analysis.

Compliance Efficiency from which Incentives are Calculated

The compliance efficiency is the combustion efficiency of the boiler measured after tune-up via flue gas analysis.

Operating Hours

Heating equivalent full-load hours were calculated from a DOE-2.2 simulation of prototypical small commercial buildings. Operating hour assumptions for the prototypical building models are described in Appendix A. The heating EFLH for commercial buildings in NY are shown in Appendix G.

Example Calculation *(Not to be used as default)*

A 1,500 kBTU/h gas-fired space heating boiler undergoes a maintenance tune-up at an assembly building located near Albany. Flue gas analysis indicaed a pre-tune up combustion efficiency of 79% and post tune-up efficiency of 83%. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are not applicable. Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta MMBtu = units \times \frac{(kBTU/h)_{in}/unit}{1{,}000 \times LF} \times \left(1 - \frac{E_{c,baseline}}{E_{c,ee}}\right) \times EFLH_{heating}$$

units = 1, from application
$(kBTU/h)_{in}$/unit = 1,500, from application
LF = 1.3, from Summary of Variables and Data Sources table
$E_{c,baseline}$ = 0.79, from application
$E_{c,ee}$ = 0.83, from application
$EFLH_{heating}$ = 961, from Appendix G based on building type and location from application

$$\Delta MMBtu = 1 \times \frac{1{,}500}{1{,}000 \times 1.3} \times \left(1 - \frac{0.79}{0.83}\right) \times 961 = 53.4\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. PA Consulting, KEMA, Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0, March 22, 2010. This factor implies that boilers are 30% oversized on average.
   Available from:
   https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

Record of Revision

Record of Revision Number	Issue Date
6-17-13	6/30/2017

Return to Table of Contents

TUNE-UP - CHILLER SYSTEM

Measure Description

Chiller system tune-ups are conducted to ensure equipment is operating at optimal performance and are performed as preventative maintenance, extending the life of the equipment. The tune-ups improve the efficiency and performance of the chillers and are useful system checks to ensure maintenance is performed to keep the equipment operating. Testing and maintenance conducted as part of a typical chiller tune-up include: checking and cleaning evaporator and condenser coils/tubes, checking and replacing filters, belts, and contactors, checking cooling towers for buildup/scale, checking control operation and setpoints, checking crankcase heater operation and checking economizer function.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times \frac{tons}{unit} \times (IPLV_{baseline} \times ESF) \times EFLH_{cooling}$$

Summer Peak Coincident Demand Savings

$$\Delta kW = units \times \frac{tons}{unit} \times (FL_{baseline} \times DSF) \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of chillers addressed under the program
tons/unit	= Tons of air conditioning per chiller, based on nameplate data
$EFLH_{cooling}$	= Cooling equivalent full-load hours
CF	= Coincidence factor
$IPLV_{baseline}$	= Integrated part-load value (kW/ton)
$FL_{baseline}$	= Full load chiller efficiency under peak conditions
ESF	= Energy savings factor
DSF	= Demand savings factor

Summary of Variables and Data Sources

Variable	Value	Notes
$IPLV_{baseline}$		Based on nameplate data, if available. Otherwise, use values from Baseline Efficiency table below.

Variable	Value	Notes
$FL_{baseline}$		Based on nameplate data, if available. Otherwise, use values from Baseline Efficiency table below.
ESF	0.05	Energy Savings Factor (efficiency recovered from tune-up) [1117]
DSF	0.025	Demand Savings Factor (efficiency recovered from tune-up) [1118]
$EFLH_{cooling}$		Cooling equivalent full-load hours by building type, Appendix G.
CF	0.8	Coincidence Factor

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.8. [1119]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline full load and IPLV kW/Ton values shall be based on actual manufacturers' catalog for the existing chiller, where available. If this information is unavailable, the efficiencies listed in the table below, per the 2020 Energy Conservation Construction Code of New York State[1120] shall be used.

Equipment Type	Size Category	ECCCNYS Maximum Full Load (kW/Ton)	ECCCNYS Maximum IPLV (kW/Ton)
Air-Cooled Chillers	< 150 Tons	1.188	0.876
	≥ 150 Tons	1.188	0.857
Water-Cooled, Positive Displacement	< 75 Tons	0.750	0.600
	≥ 75 Tons and < 150 Tons	0.720	0.560
	≥ 150 Tons and < 300 Tons	0.660	0.540
	≥ 300 Tons and < 600 Tons	0.610	0.520
	≥ 600 Tons	0.560	0.500
Water Cooled, Centrifugal	< 150 Tons	0.610	0.550
	≥ 150 Tons and < 300 Tons	0.610	0.550
	≥ 300 Tons and < 400 Tons	0.560	0.520
	≥ 400 Tons and < 600 Tons	0.560	0.500
	≥ 600 Tons	0.560	0.500

Compliance Efficiency from which Incentives are Calculated

The compliance case requires the performance of all components of a typical chiller tune-up, as noted in the Measure Description above and applicable to the addressed system.

[1117] US DOE: Hospitals Benefit by Improving Inefficient Chiller Systems, August 2011
[1118] Conservative estimate based on engineering judgement, estimated at half of the established 5% energy savings factor
[1119] *No source specified – update pending availability and review of applicable references.*
[1120] ECCCNYS 2020, Table C403.2.3(7)

Operating Hours

Reference Appendix G for applicable value for specific building use type and geographic location.

Example Calculation *(Not to be used as default)*

A 125 ton air-cooled chiller undergoes tune-up in an assembly building located near Albany. The chiller has a part load efficiency of 0.870 kW/ton and a full load efficiency of 1.185 kW/ton. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

$$\Delta kWh = units \times \frac{tons}{unit} \times (IPLV_{baseline} \times ESF) \times EFLH_{cooling}$$

$$\Delta kW = units \times \frac{tons}{unit} \times \left(kW/ton_{baseline} \times DSF\right) \times CF$$

units = 1, from application
tons/unit = 125, from application
$IPLV_{baseline}$ = 0.855, from application
ESF = 0.05, from Summary of Variables and Data Sources table
$EFLH_{cooling}$ = 478, from Appendix G based on building type and location from application
$kW/ton_{baseline}$ = 1.185, from application
DSF = 0.025, from Summary of Variables and Data Sources table
CF = 0.8, from Summary of Variables and Data Sources table

$$\Delta kWh = 1 \times 125 \times (0.870 \times 0.05) \times 478 = 2{,}599\ kWh$$

$$\Delta kW = 1 \times 125 \times (1.185 \times 0.025) \times 0.8 = 2.96\ kW$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. United States Department of Energy, Building Technologies Program: Hospitals Benefit by Improving Inefficient Chiller Systems, August 2011. The paper found that dirty coils can cause a 7% reduction in cooling capacity. Therefore, coil cleaning, the primary savings mechanism associated with this tune-up measure, is conservatively assumed to save 5% of total consumption. Demand savings are conservatively assumed to be half of this, or 2.5%.
2. ECCCNYS 2020 Table C403.2.3(7): Water Chilling Packages – Efficiency Requirements Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-[ce]-commercial-energy-efficiency#NYSECC2020P1_CE_Ch04_SecC403
3. Wisconsin Public Service Commission: Equipment Useful Life Database, 2013 Excerpt available from: https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf

Record of Revision

Record of Revision Number	Issue Date
6-17-12	6/30/2017

Return to Table of Contents

TUNE-UP - FURNACE

Measure Description

This measure covers tune up of commercial furnaces to improve seasonal heating efficiency. The efficiency of commercial fossil fuel-fired furnaces degrades with age. However, with cleaning and inspection, the performance of the furnace can be improved or "tuned up". This measure describes the savings for a commercial fossil fuel furnace tune up—combustion efficiency must be measured before the tune up using a flue gas analyzer. This measure addresses tune up benefits associated with heating performance only.

The recommended tune-up requirements are listed below. It is recommended that programs require technicians performing the work are appropriately certified.

Recommended Tune-Up Practices

- Measure combustion efficiency using an electronic flue gas analyzer.
- Check and clean blower assembly and components per manufacturer's recommendations.
- Where applicable, lubricate motor and inspect and replace fan belt if required.
- Inspect for gas leaks.
- Clean burner per manufacturer's recommendations and adjust as needed.
- Check ignition system and safety systems and clean and adjust as needed.
- Check and clean heat exchanger per manufacturer's recommendations.
- Inspect exhaust/flue for proper attachment and operation.
- Inspect control box, wiring, and controls for proper connections and performance.
- Check air filter and clean or replace per manufacturer's recommendations.
- Inspect duct work connected to furnace for leaks or blockages.
- Measure temperature rise and adjust flow as needed.
- Check for correct line and load volts/amps.
- Check that thermostat operation is per manufacturer's recommendations.
- Perform Carbon Monoxide test and adjust heating system until results are within standard industry acceptable limits.
- Check and adjust gas input pressure.
- Check high limit and other safety controls.
- Where applicable, inspect condensate drain and clear, if needed.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = \Delta MMBtu \times F_{fan} \times \frac{1{,}000{,}000}{3{,}412}$$

Summer Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = \frac{kBTU/h_{in} \times EFLH_{heating} \times ESF}{1{,}000}$$

where:

$$ESF = \frac{Eff_{baseline} + \Delta Eff_{ee}}{Eff_{baseline}} - 1$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
F_{fan}	= Furnace fan energy consumption as a percentage of annual fossil fuel consumption
$kBTU/h_{in}$	= Nominal heating input capacity (kBTU/h), based on nameplate
$EFLH_{heating}$	= Heating Equivalent Full Load Hours
ESF	= Energy Savings Factor
$Eff_{baseline}$	= Actual combustion efficiency of the furnace before tune-up, based on flue gas analysis
ΔEff_{ee}	= Combustion efficiency improvement of the furnace as a result of tune-up, based on flue gas analysis
1,000,000	= Conversion factor, one MMBtu equals 1,000,000 BTU
3,412	= Conversion factor, one kWh equals 3,412 BTU
1,000	= Conversion factor, one MMBtu equals 1,000 kBTU

Summary of Variables and Data Sources

Variable	Value	Notes
F_{fan}	0.0314	AHRI[1121]
$kBTU/h_{in}$		From application
$EFLH_{heating}$		Lookup based on building type and location in Appendix G.
ESF		For small commercial settings (residential duty of 225 MBH and under), use ESF of 0.05.[1122] For large commercial settings, calculate based on the equation in the Method for Calculating Savings above and the definitions for $Eff_{baseline}$ and Eff_{ee} as outlined below.
$Eff_{baseline}$		Efficiency as measured in pre-tune-up inspection

[1121] F_{fan} is not one of the AHRI certified ratings provided for residential furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (Ef, in MMBtu/yr) and auxiliary electrical energy consumption (Eae, in kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. The sampling was conducted for development of residential furnace measures for the Ameren Missouri TRM from the AHRI database.

[1122] Energy savings on the order of 2% - 5% were realized from a boiler tune-up program in the Pacific Northwest. Building Tune-Up and Operations Program Evaluation. Washington State University Energy Program, p. 5.

Variable	Value	Notes
ΔEff_{ee}		The percentage improvement in combustion efficiency is deemed a reasonable proxy for the system improvement. If a full thermal efficiency test is performed instead, that should be used.

Coincidence Factor (CF)

While there is electric energy used in the system due to fan energy, there are no recommended demand savings due to furnaces being operated during the heating season. Therefore, the recommended coincidence factor is N/A.

Baseline Efficiencies from which Savings are Calculated

The baseline condition is the combustion efficiency of the furnace measured during pre-tune-up inspection.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is the combustion efficiency of the furnace measured after tune-up via flue gas analysis.

Operating Hours

Heating equivalent full-load hours were calculated from a DOE-2.2 simulation of prototypical commercial buildings. Operating hour assumptions for the prototypical building models are described in Appendix A. The heating EFLH for commercial buildings in NY are shown in Appendix G.

Example Calculation *(Not to be used as default)*

A 180 kBTU/h furnace in a small office building located near Albany undergoes a tune-up per the maintenance specifications. Flue gas analysis performed prior to tune-up indicates an efficiency of 80% and postim implementation analysis indicates an efficiency improvement of 4.5%.Peak Coincident Demand Savings are not applicable. Annual Electric Energy Savings and Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta kWh = \Delta MMBtu \times F_{fan} \times \frac{1{,}000{,}000}{3{,}412}$$

$$\Delta MMBtu = \frac{kBTU/h_{in} \times EFLH_{heating} \times ESF}{1{,}000}$$

F_{fan} = 0.0314, from Summary of Variables and Data Sources table
$kBTU/h_{in}$ = 180, from application
$EFLH_{heating}$ = 742, from Appendix G based on building type, location, and HVAC system from application

$ESF = (Eff_{baseline} + \Delta Eff_{ee}) / Eff_{baseline} - 1 = (0.8 + 0.045) / 0.8 - 1 = 0.0525$

ESF equation from *where* section in algorithm

$Eff_{baseline} = 0.80$, from application

$\Delta Eff_{ee} = 0.045$, from application

$$\Delta MMBtu = \frac{180 \times 961 \times 0.05625}{1{,}000} = 9.73\ MMBtu$$

$$\Delta kWh = 9.73 \times 0.0314 \times \frac{1{,}000{,}000}{3{,}412} = 90\ kWh$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. AHRI Directory of Certified Product Performance
   Available from: https://www.ahridirectory.org/ahridirectory/pages/home.aspx

Record of Revision

Record of Revision Number	Issue Date
7-20-14	7/31/2020

Return to Table of Contents

HEATING, VENTILATION AND AIR CONDITIONING (HVAC) – CONTROL

ADAPTIVE PHOTONIC CONTROL FOR HVAC FAN MOTORS

Measure Description

This measure covers the installation of adaptive photonic control systems applied to HVAC fan motors. Adaptive photonic control involves integration with an HVAC system's motors including PTACs, PTHPs, mini-splits, central air units and furnace distribution system supply fans. It enables adaptive speed control for single-speed AC fan motors using sensors by continuously adapting to end-user requirements. The controller uses photonic (opto-electronic) transducers and graphical apertures that are integrated into intelligent, signal and vector processors enabling their use as analog power controllers[1123, 1124]. It provides an adaptive airflow solution by tracking air temperature and optimizing operation based on climate conditions. Savings accrue not only from the reduction of fan speed to match thermal delivery rates, but also through better air mixing in the space and more effective heat transfer on the coils when the system is in operation. By adjusting airflow to improve heat transfer, the controller improves whole system operating efficiency and significantly reduces compressor run times.

This measure is only applicable to adaptive photonic control integrated into single-speed AC induction fan motors rated up to 5 horsepower (HP) that do not have speed variability restriction (e.g., via centrifugal speed switch).[1125, 1126] Savings estimated per this methodology may be claimed in retrofit applications as well as in new construction applications where electronically commutated (EC) motors are not otherwise required by federal, state, local or municipal codes or standards.

Method for Calculating Annual Energy and Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = \Delta kWh_{cooling} + \Delta kWh_{heating} + \Delta kWh_{fan}$$

$$\Delta kWh_{cooling} = units \times \frac{(W_{cooling} \times ESF)}{1{,}000} \times LF \times hrs_{cooling}$$

$$\Delta kWh_{heating} = units \times \frac{(W_{heating} \times ESF)}{1{,}000} \times LF \times hrs_{heating}$$

$$\Delta kWh_{fan} = units \times \frac{(W_{blowerfan} \times ESF)}{1{,}000} \times LF \times hrs_{fan}$$

Note: ΔkWh_{fan} is only applicable if fan is set to on position during occupancy

[1123] IEEE Transactions on Industrial Electronics, 'A novel switched reluctance motor drive with optical graphical programming technology', 2000.
[1124] ACHR News, Fan Coil Units Get VSD, 2005
[1125] San Diego Gas & Electric, Work Paper WPSDGENRHC1051, Revision 1, Sept 2016
[1126] Comfort-Plus Drive™, Variable Speed Drive for Fan Coil Units, 2005

Summer Peak Coincident Demand Savings

$$\Delta kW = units \times \frac{(W_{cooling} \times ESF)}{1{,}000} \times LF \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = units \times \frac{(kBtu/h_{in} \times ESF)}{1{,}000} \times LF \times hrs_{heating}$$

where:

$$W_{cooling} = W_{evaporator} + W_{compressor} + W_{condenser}$$

$$W_{heating} = W_{evaporator} + W_{ElecHeat}$$

$$W_{evaporator} = V_{evaporator} \times A_{evaporator} \times PF$$

$$W_{compressor} = V_{compressor} \times A_{compressor} \times PF$$

$$W_{condenser} = V_{condenser} \times A_{condenser} \times PF$$

$$hrs_{fan} = hrs - (hrs_{cooling} + hrs_{heating})$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
$\Delta kWh_{cooling}$	= Annual electric energy savings in cooling mode
$\Delta kWh_{heating}$	= Annual electric energy savings in heating mode
ΔkWh_{fan}	= Annual electric energy savings in fan only mode
units	= Number of measures installed under the program
$W_{cooling}$	= Retrofitted system peak wattage in cooling mode
$W_{heating}$	= Retrofitted system peak wattage in heating mode
$W_{evaporator}$	= Retrofitted system evaporator wattage, based on nameplate specifications
$W_{compressor}$	= Retrofitted system compressor wattage, based on nameplate specifications
$W_{condenser}$	= Retrofitted system condenser wattage, based on nameplate specifications
$W_{blowerfan}$	= Retrofitted system blower fan wattage, based on nameplate specifications
$W_{ElecHeat}$	= Retrofitted system electric resistance heating element wattage, based on nameplate specifications, where applicable
$V_{evaporator}$	= Retrofitted system evaporator voltage
$V_{compressor}$	= Retrofitted system compressor voltage
$V_{condenser}$	= Retrofitted system condenser voltage
$A_{evaporator}$	= Retrofitted system evaporator amps
$A_{compressor}$	= Retrofitted system compressor amps

$A_{condenser}$ = Retrofitted system condenser amps
PF = Power factor
$kBtu/h_{in}$ = Retrofitted system space heating input fuel rating (kBtu/h)
ESF = Energy savings factor
LF = Motor load factor
$hrs_{cooling}$ = Retrofitted system annual operating hours in cooling mode
$hrs_{heating}$ = Retrofitted system annual operating hours in heating mode
hrs_{fan} = Retrofitted system annual operating hours in fan only mode
hrs = Retrofitted system annual operating hours
CF = Coincidence factor
1,000 = Conversion factor, one kW equals 1,000 watts

Summary of Variables and Data Sources

Variable	Value	Notes
$W_{ElecHeat}$		From application.
$W_{blowerfan}$		From application.
$V_{evaporator}$		From application.
$V_{compressor}$		From application.
$V_{condenser}$		From application.
$A_{evaporator}$		From application.
$A_{compressor}$		From application.
$A_{condenser}$		From application.
PF	0.85	From Standard Handbook of Electrical Engineers[1127] and the Engineering Toolbox.[1128]
$kBtu/h_{in}$		From application.
ESF	0.30	Average of multiple validation tests.[1129]
LF	0.9	Assumed value to reflect that motors do not typically run at 100% of rated power.
$hrs_{cooling}$		From application. If unknown, see Operating Hours section below.
$hrs_{heating}$		From application. If unknown, see Operating Hours section below.
hrs		From application. If unknown, see Operating Hours section below.
CF	0.8	

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.8.[1130]

[1127] Standard Handbook for Electrical Engineers (McGraw-Hill Handbooks), Donald G. Fink, ISBN 10: 0070220050 / ISBN 13: 9780070220058, Published by McGraw-Hill Publishing Co., 1999
[1128] Engineering Tool Box, Power Factors for Inductive Loads, https://www.engineeringtoolbox.com/power-factor-electrical-motor-d_654.html
[1129] Aclectic, Adaptive Control Technologies, Validation Tests
[1130] *No source specified – update pending availability and review of applicable references*

Baseline Efficiencies from which Savings are Calculated

The baseline condition is a standard efficiency, single-speed AC induction motor in a direct-drive HVAC circulation (blower) fan application. Baseline wattage shall be derived from the nameplate rating of existing system components.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a single-speed AC induction motor with adaptive photonic control as described in the Measure Description section above in a direct-drive HVAC circulation (blower) fan application.

Operating Hours

Annual cooling mode, heating mode and total system operating hours shall be taken from application. If the operating hours are unknown, look up cooling and heating mode operating hours from Appendix G (i.e., cooling and heating equivalent load full hours shall be used as proxy values for annual cooling mode and annual heating mode hours, respectively). If the circulation fan is set to on during facility operation, look up total system operating hours by building type from the table below.

Facility Type	Hours (hrs/yr)	HVAC Int	Facility Type	Hours (hrs/yr)	HVAC Int
Auto Related*	2,810	AR	Manufacturing Facility	2,857	Ind
Automotive / Transportation Service or Repair Facility (24/7)	8,760	AR	Medical Offices	3,748	SOfc
Bakery	2,854	FS	Motion Picture Theatre	1,954	Asy
Banks	3,748	SOfc	Multi-Family (Common Areas)	7,665	MFL
Church	1,955	Rel	Museum	3,748	Asy
College – Cafeteria**	2,713	FS	Nursing Homes	5,840	MFL
College – Classes	2,586	CC	Office (General Office Types)**	3,013	SOfc/ LOfc
College - Dormitory	3,066	Dorm	Parking Garages	4,368	None
Commercial Condos***	3,100	SOfc	Parking Garages (24/7)	7,717	None
Convenience Stores	6,376	SRet	Parking Lots	4,100	None
Convention Center	1,954	Asy	Penitentiary	5,477	MFL
Court House	3,748	LOfc	Performing Arts Theatre	2,586	Asy
Dining: Bar Lounge/Leisure	4,182	FS	Police / Fire Stations (24 Hr)	7,665	Asy
Dining: Cafeteria / Fast Food	6,456	FF	Post Office	3,748	SRet
Dining: Family	4,182	FS	Pump Stations	1,949	Ind
Entertainment	1,952	Asy	Refrigerated Warehouse	2,602	RWH
Exercise Center	5,836	SRet	Religious Building	1,955	Rel
Fast Food Restaurants	6,376	FF	Restaurants	4,182	FS

Facility Type	Hours (hrs/yr)	HVAC Int	Facility Type	Hours (hrs/yr)	HVAC Int
Fire Station (Unmanned)	1,953	Asy	Retail	3,463	SRet/ LRet
Food Stores	4,055	Gro	School / University	2,187	Univ
Gymnasium	2,586	Asy	Schools (Jr./Sr. High)	2,187	HS
Hospitals	7,674	Hosp	Schools (Preschool/Elementary)	2,187	Sch
Hospitals / Health Care	7,666	Hosp	Schools (Technical/Vocational)	2,187	CC
Industrial - 1 Shift	2,857	Ind	Small Services	3,750	SOfc
Industrial - 2 Shift	4,730	Ind	Sports Arena	1,954	Asy
Industrial - 3 Shift	6,631	Ind	Town Hall	3,748	Asy
Laundromats	4,056	SRet	Transportation	6,456	Asy
Library	3,748	LOfc	Warehouse (Not Refrigerated)	2,602	WH
Light Manufacturers**	2,613	Ind	Waste Water Treatment Plant	6,631	Ind
Lodging (Hotels/Motels)	3,064	Hotel/ Motel	Workshop	3,750	Ind
Mall Concourse	4,833	LRet			

* New car showrooms and Big Box retail stores with evening and/or weekend hours should use the Facility Type "Retail" for lighting operating hours.
** Lighting operating hours data from the 2008 California DEER Update study
*** Lighting operating hours data for offices used

Example Calculation *(Not to be used as default)*

An adaptive photonic control system is installed on a central air conditioning and 150 kBTU/h gas heating system in a small office building. The system's compressor is rated at 230 V and 28.2 amps, the condenser is rated at 230 V and 2.4 amps and the evaporator is rated at 230 V and 12 amps. The blower fan has a rated wattage of 2.25 kW. The system runs in cooling mode for approximately 600 hours per year, in heating mode for approximately 1,600 hours per year and in fan only mode for approximately 1,500 hours per year, for a total of 3,700 hours annually. Annual Electric Energy Savings, Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta kWh = \Delta kWh_{cooling} + \Delta kWh_{heating} + \Delta kWh_{fan}$$

$$\Delta kWh_{cooling} = units \times \frac{(W_{cooling} \times ESF)}{1{,}000} \times LF \times hrs_{cooling}$$

$$\Delta kWh_{heating} = units \times \frac{(W_{heating} \times ESF)}{1{,}000} \times LF \times hrs_{heating}$$

$$\Delta kWh_{fan} = units \times \frac{(W_{blowerfan} \times ESF)}{1{,}000} \times LF \times hrs_{fan}$$

$$\Delta kW = units \times \frac{(W_{cooling} \times ESF)}{1{,}000} \times LF \times CF$$

$$\Delta MMBtu = units \times \frac{(kBtu/h_{in} \times ESF)}{1{,}000} \times LF \times hrs_{heating}$$

units = 1, from application
$W_{cooling} = W_{evaporator} + W_{compressor} + W_{condensor}$ = 2,346 + 5,513 + 469 = 8,328 W
$W_{cooling}$ equation from 'where' section
$W_{evaporator} = V_{evaporator}$ x $A_{evaporator}$ x PF = 230 x 12 x 0.85 = 2,346 W
$W_{evaporator}$ equation from 'where' section
$V_{evaporator}$ from application
$A_{evaporator}$ from application
PF from Summary of Variables and Data Sources table
$W_{compressor} = V_{compressor}$ x $A_{compressor}$ x PF = 230 x 28.2 x 0.85 = 5,513 W
$W_{compressor}$ equation from 'where' section
$V_{compressor}$ from application
$A_{compressor}$ from application
$W_{condensor} = V_{condensor}$ x $A_{condensor}$ x PF = 230 x 2.4 x 0.85 = 469 W
$W_{condensor}$ equation from 'where' section
$V_{condensor}$ from application
$A_{condensor}$ from application
ESF = 0.3 from Summary of Variables and Data Sources table
LF = 0.9 from Summary of Variables and Data Sources table
$hrs_{cooling}$ = 600, from application
$W_{heating}$ = 0, from application
$W_{blowerfan}$ = 2,250, from application
$hrs_{fan} = hrs - (hrs_{cooling} + hrs_{heating})$ = 3,700 – (600 + 1,600) = 1,500
hrs from application
$hrs_{heating}$ from application
CF = 0.69, from Summary of Variables and Data Sources table
$kBtu/h_{in}$ = 150, from application

$$\Delta kWh_{cooling} = 1 \times \frac{(8{,}328 \times 0.3)}{1{,}000} \times 0.9 \times 600 = 1{,}349\ kWh$$

$$\Delta kWh_{fan} = 1 \times \frac{(2{,}250 \times 0.3)}{1{,}000} \times 0.9 \times 1{,}500 = 911\ kWh$$

$$\Delta kWh = 1{,}349 + 0 + 911 = 2{,}260\ kWh$$

$$\Delta kW = 1 \times \frac{(8{,}328 \times 0.3)}{1{,}000} \times 0.9 \times 0.69 = 1.55\ kW$$

$$\Delta MMBtu = 1 \times \frac{(150 \times 0.3)}{1{,}000} \times 0.9 \times 1{,}600 = 64.8\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

HVAC circulation fans with adaptive photonic controlled AC motors generate less heat during operation, resulting in decreased cooling loads and increased heating loads. These effects are captured in the prescribed methodology detailed above. The HVAC interaction factors calculated from the prototypical building DOE-2 models as a function of the building and HVAC system type are shown in Appendix D.

Ancillary Electric Savings Impacts

HVAC circulation fan with adaptive photonic controlled AC motors generate less heat during operation, resulting in decreased cooling loads and increased heating loads. These effects are captured in the prescribed methodology detailed above. The HVAC interaction factors calculated from the prototypical building DOE-2 models as a function of the building and HVAC system type are shown in Appendix D.

References

1. A novel switched reluctance motor drive with optical graphical programming technology, Clarkson University, P. Pillay; Yaguang Liu; O.G. Durham, IEEE Transactions on Industrial Electronics (Volume: 47, Issue: 4, Aug 2000).
   Available from: https://ieeexplore.ieee.org/document/857972
2. Fan Coil Units Get VSD, The Air Conditioning, Heating, Refrigeration News, 2005
   Available from: https://www.achrnews.com/articles/95898-fan-coil-units-get-vsd#:~:text=They%20are%20small%20air%2Dhandling,stacked%2C%20or%20installed%20horizontally%20overhead.
3. Guest Room PTAC/PTHP Adaptive Climate Controller, San Diego Gas & Electric, Energy Efficiency Engineering, Work Paper WPSDGENRHC1051, Revision 1, Sept 2016.
   Available from: http://www.deeresources.net/workpapers
4. Comfort-Plus Drive™, Variable Speed Drive for Fan Coil Units, Carrier Corporation, 2005
   Available from: https://dms.hvacpartners.com/docs/1003/Public/08/05-02-0501-01.pdf
5. Standard Handbook for Electrical Engineers (McGraw-Hill Handbooks), Donald G. Fink, ISBN 10: 0070220050 / ISBN 13: 9780070220058, Published by McGraw-Hill Publishing Co., 1999
6. Engineering Tool Box, Power Factors for Inductive Loads
   Available from: https://www.engineeringtoolbox.com/power-factor-electrical-motor-d_654.html

7. Multiple Validation Tests of Adaptive Photonic Technology Controller at (1) ConEdison, (2) Environmental Test Laboratory, (3) EME Consulting Engineers (NYSERDA), (4) SUNY Oneonta, (5) Tim Garrison (Third Party), (6) McQuay Cooling Tests, (7) Purdue University Tests and (8) ConEdison Tests by ERS.
   Available from: https://efbb029c-a900-4301-9ab1-40fc00b9e54e.filesusr.com/ugd/9cd7aa_186d85d0a69b4da4b69f07ea0d03eeff.pdf?index=true

Record of Revision

Record of Revision Number	Issue Date
12-20-7	12/31/2020
3-21-23	4/9/2021

Return to Table of Contents

ADVANCED RTU CONTROL

Measure Description

This measure covers the installation of advanced rooftop unit (RTU) control on a constant volume, rooftop HVAC unit with a single-speed supply fan. Advanced RTU control consists of integrated demand-controlled ventilation (DCV), a multi/variable-speed fan, and dual enthalpy control air-side economizers. DCV systems determine occupancy using a CO2 sensor and reduce heating and cooling loads by modulating outdoor air intake to meet ventilation requirements. Multi/variable-speed fan motors reduce the fan speed for first stage cooling and ventilation. Air-side economizers reduce mechanical cooling requirements by supplying outside air to the space when the outside air meets conditions deemed suitable for cooling.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = \Delta kWh_{fan} + \Delta kWh_{DCV} + \Delta kWh_{Econ}$$

$$\Delta kWh_{fan} = hp \times ESF_{fan} \times hrs$$

$$\Delta kWh_{DCV} = \frac{SF}{1{,}000} \times \left(\frac{\Delta kWh}{kSF}\right)_{DCV,cool} + \frac{SF}{1{,}000} \times \left(\frac{\Delta kWh}{kSF}\right)_{DCV,heat} \times F_{ElecHeat}$$

$$\Delta kWh_{Econ} = tons \times (\Delta kWh/\text{ton})_{Econ}$$

Summer Peak Coincident Demand Savings

$$\Delta kW = hp \times ESF_{fan} \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = \frac{SF}{1{,}000} \times \left(\frac{\Delta MMBtu}{kSF}\right)_{DCV} \times F_{FuelHeat}$$

where:

ΔkWh	= Annual electricity energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
ΔkWh_{fan}	= Annual electricity energy savings resulting from supply fan control
ΔkWh_{DCV}	= Annual electricity energy savings resulting from DCV
ΔkWh_{Econ}	= Annual electricity energy savings resulting from economizer
hp	= Horsepower of RTU supply fan
ESF_{fan}	= Energy savings factor for supply fan control (kWh/hp/hour)
hrs	= Annual operating hours of RTU supply fan
SF	= Total square footage of the conditioned space impacted by the measure
$(\Delta kWh/kSF)_{DCV,cool}$	= Energy savings factor for cooling (kWh/1,000 ft^2)

$(\Delta kWh/kSF)_{DCV,heat}$ = Energy savings factor for electric heating (kWh/1,000 ft^2)
$F_{ElecHeat}$ = Electric heating factor, used to account for the presence or absence of an electric heating system
tons = Tons of air conditioning supplied by RTU, based on nameplate data
$(\Delta kWh/ton)_{Econ}$ = Annual electric energy savings per ton of cooling
$(\Delta MMBtu/kSF)_{DCV}$ = Energy savings factor for heating (MMBtu/1,000 ft^2)
$F_{FuelHeat}$ = Fuel heating factor, used to account for the presence or absence of a fossil fuel heating system
1,000 = Conversion to 1,000 ft^2

Summary of Variables and Data Sources

Variable	Value	Notes
hp		From application
ESF_{fan}	0.580	Pacific Northwest National Laboratory.[1131]
hrs		Lookup based on building type in Appendix A.
SF		From application
$(\Delta kWh/kSF)_{DCV,cool}$		Lookup from Electric Cooling Savings Associated DCV table below based on location and building type.
$(\Delta kWh/kSF)_{DCV,heat}$		Lookup from Electric Heating Savings with Heat Pump or Electric Heating Savings with Electric Resistance table below depending on electric heating type from application, based on location and building type.
$F_{ElecHeat}$		Use a value of 1.0 if the building is electrically heated. Otherwise, use 0.0.
tons		From application
$(\Delta kWh/ton)_{Econ}$		Lookup based on building type and location in the Air Side Economizer table in Appendix J.
$(\Delta MMBtu/kSF)_{DCV}$		Lookup from Fuel Savings Associated with DCV table below based on location and building type.
$F_{FuelHeat}$		Use a value of 1.0 if the building is fossil fuel heated. Otherwise, use 0.0.
CF	0.8	

Unit energy savings associated with operation of an air-side economizer were calculated from a DOE-2.2 simulation of a series of prototypical small commercial buildings. The prototype building characteristics are described in Appendix A. The unit energy savings by building type and city are shown in Appendix J.

[1131] Unweighted average of kWh/hp/hour fan savings across all test cases in Advanced Rooftop Control (ARC) Retrofit: Field-Test Results, PNNL22656, Table 10: TMY weather normalized annual savings for all units. Fan Energy Savings (kWh) is divided by RTU Fan Power (hp) and Annual RTU Running Time (hr) to determine Energy Savings Factor for supply fan controls (kWh/hp/hr)

Electric Cooling Savings Associated with DCV (ΔkWh/kSF) [1132]

(kWh/kSF)$_{DCV,cool}$							
Building Type	**Albany**	**Binghamton**	**Buffalo**	**Massena**	**NYC**	**Poughkeepsie**	**Syracuse**
Office - Low-rise (1 to 3 Stories)	205	131	187	125	398	230	196
Office - Mid-rise (4 to 11 Stories)	162	103	147	98	314	182	154
Office - High-rise (12+ Stories)	192	123	175	117	373	216	183
Religious Building	553	354	504	336	1,075	622	528
Restaurant	362	231	330	220	703	406	345
Retail - Department Store	279	178	254	169	541	313	266
Retail - Strip Mall	193	123	176	117	375	217	184
Convenience Store	253	162	231	154	492	284	242
Elementary School	260	167	237	158	506	292	248
High School	255	163	232	155	495	286	243
College/ University	302	193	275	184	587	339	288
Healthcare Clinic	251	161	229	153	488	282	240
Lodging (Hotel/Motel)	290	186	264	176	563	326	277
Manufacturing	125	80	114	76	244	141	120
Special Assembly Auditorium	412	264	375	250	800	463	393
Other	273	175	249	166	530	307	261
Enclosed Parking Garage	656	420	598	399	1,274	737	626

Electric Heating Savings with Heat Pump Associated with DCV (ΔkWh/kSF) [1133]

(kWh/kSF)$_{DCV,heat}$							
Building Type	**Albany**	**Binghamton**	**Buffalo**	**Massena**	**NYC**	**Poughkeepsie**	**Syracuse**
Office - Low-rise (1 to 3 Stories)	216	233	214	265	151	201	215
Office - Mid-rise (4 to 11 Stories)	145	157	144	178	102	135	145
Office - High-rise (12+ Stories)	195	210	193	239	136	181	194
Religious Building	1,404	1,512	1,391	1,723	982	1,306	1,398
Restaurant	1,014	1,091	1,004	1,244	709	942	1,009
Retail - Department Store	347	373	343	425	242	322	345
Retail - Strip Mall	227	244	224	278	158	211	226
Convenience Store	172	185	170	211	120	160	171
Elementary School	603	649	597	739	421	560	600
High School	588	633	582	721	411	547	585
College/ University	1,174	1,264	1,163	1,440	821	1,091	1,169
Healthcare Clinic	417	449	413	512	292	388	415
Lodging (Hotel/Motel)	194	209	192	238	136	180	193

[1132] Deemed savings calculated based on IL TRM values for Chicago, adjusted by the ratio of Cooling Degree Days for each listed NY city and Chicago, based on TMY3 data using base 65º balance point.
[1133] Ibid

$(kWh/kSF)_{DCV,heat}$							
Building Type	**Albany**	**Binghamton**	**Buffalo**	**Massena**	**NYC**	**Poughkeepsie**	**Syracuse**
Manufacturing	120	129	119	147	84	112	120
Special Assembly Auditorium	1,648	1,774	1,632	2,022	1,152	1,532	1,641
Other	564	607	558	692	394	524	561

Electric Heating Savings with Electric Resistance Associated with DCV (ΔkWh/kSF) [1134]

$(kWh/kSF)_{DCV,heat}$							
Building Type	**Albany**	**Binghamton**	**Buffalo**	**Massena**	**NYC**	**Poughkeepsie**	**Syracuse**
Office - Low-rise (1 to 3 Stories)	648	698	642	795	453	602	645
Office - Mid-rise (4 to 11 Stories)	435	469	431	534	304	405	433
Office - High-rise (12+ Stories)	584	629	578	716	408	543	581
Religious Building	4,213	4,537	4,174	5,170	2,946	3,917	4,195
Restaurant	3,041	3,274	3,012	3,731	2,126	2,827	3,028
Retail - Department Store	1,040	1,120	1,030	1,276	727	967	1,035
Retail - Strip Mall	681	733	674	835	476	633	678
Convenience Store	514	554	509	631	360	478	512
Elementary School	1,807	1,946	1,790	2,217	1,264	1,680	1,799
High School	1,763	1,898	1,746	2,163	1,233	1,639	1,755
College/ University	3,520	3,791	3,487	4,319	2,461	3,272	3,505
Healthcare Clinic	1,252	1,348	1,240	1,536	875	1,164	1,246
Lodging (Hotel/Motel)	581	625	575	712	406	540	578
Manufacturing	361	389	358	443	253	336	360
Special Assembly Auditorium	4,943	5,322	4,896	6,064	3,456	4,595	4,921
Other	1,692	1,822	1,676	2,076	1,183	1,573	1,685

Fuel Savings Associated with DCV (ΔMMBtu/kSF)[1135]

$(MMBtu/kSF)_{DCV}$							
Building Type	**Albany**	**Binghamton**	**Buffalo**	**Massena**	**NYC**	**Poughkeepsie**	**Syracuse**
Office - Low-rise (1 to 3 Stories)	2.7	2.9	2.7	3.4	1.9	2.5	2.7
Office - Mid-rise (4 to 11 Stories)	1.9	2.0	1.9	2.3	1.3	1.8	1.9
Office - High-rise (12+ Stories)	2.5	2.7	2.5	3.1	1.8	2.4	2.5
Religious Building	18.0	19.4	17.8	22.1	12.6	16.7	17.9
Restaurant	13.0	14.0	12.8	15.9	9.1	12.0	12.9
Retail - Department Store	4.4	4.8	4.4	5.4	3.1	4.1	4.4
Retail - Strip Mall	3.0	3.2	2.9	3.6	2.1	2.7	2.9
Convenience Store	2.2	2.4	2.2	2.7	1.5	2.1	2.2
Elementary School	7.7	8.3	7.6	9.4	5.4	7.2	7.7

[1134] Ibid

[1135] Deemed savings calculated based on IL TRM values for Chicago, adjusted by the ratio of Heating Degree Days for each listed NY city and Chicago, based on TMY3 data using base 65º balance point.

(MMBtu/kSF)$_{DCV}$							
Building Type	**Albany**	**Binghamton**	**Buffalo**	**Massena**	**NYC**	**Poughkeepsie**	**Syracuse**
High School	7.5	8.1	7.4	9.2	5.2	7.0	7.4
College/ University	15.1	16.2	14.9	18.5	10.5	14.0	15.0
Healthcare Clinic	5.4	5.8	5.3	6.6	3.8	5.0	5.4
Lodging (Hotel/Motel)	2.4	2.6	2.4	3.0	1.7	2.3	2.4
Manufacturing	1.6	1.7	1.6	1.9	1.1	1.5	1.6
Special Assembly Auditorium	21.1	22.7	20.9	25.9	14.7	19.6	21.0
Other	7.2	7.7	7.1	8.8	5.0	6.7	7.1

Coincidence Factor (CF)

The prescribed coincidence factor for this measure is 0.8. [1136]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline case for this measure is a single zone, packaged rooftop HVAC unit with a single speed fan, and no occupancy-based ventilation or dual enthalpy economizer controls.

Compliance Efficiency from which Incentives are Calculated

The compliance case for this measure is the installation of an advanced rooftop controller consisting of a DCV system, multi or variable speed supply fan, and a dual enthalpy control air-side economizer on a single zone, packaged rooftop HVAC unit.

The efficient condition must comply with all applicable provisions of federal, state, local and municipal mechanical/ventilation and construction code, including but not limited to section C403.2.6.1 of ECCCNYS and section 402 of NYS Mechanical Code.

Operating Hours

HVAC system operating hours are embedded into the deemed savings shown in Appendix J and vary by building type. See Appendix A for details on prototype building simulation parameters.

Example Calculation *(Not to be used as default)*

An advanced rooftop control system is installed on a 25 ton constant volume, rooftop HVAC unit with a single-speed supply fan at 10,000 square foot small office building located near Albany. The AC fan motor has a rated horsepower of 1 hp and is estimated to run approximately 3,500 hours per year. The building is gas-heated. Annual Electric Energy Savings, Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta kWh = \Delta kWh_{fan} + \Delta kWh_{DCV} + \Delta kWh_{Econ}$$

[1136] *No source specified – update pending availability and review of applicable references.*

$$\Delta kWh_{fan} = hp \times ESF_{fan} \times hrs$$

$$\Delta kWh_{DCV} = \frac{ft^2}{1{,}000} \times \left(\frac{\Delta kWh}{1000\ ft^2}\right)_{DCV,cool} + \frac{ft^2}{1{,}000} \times \left(\frac{\Delta kWh}{1000\ ft^2}\right)_{DCV,heat} \times F_{ElecHeat}$$

$$\Delta kWh_{Econ} = tons \times (\Delta kWh/\text{ton})_{Econ}$$

$$\Delta kW = hp \times ESF_{fan} \times CF$$

$$\Delta MMBtu = \frac{ft^2}{1{,}000} \times \left(\frac{\Delta MMBtu}{1000\ ft^2}\right)_{DCV} \times F_{FuelHeat}$$

hp = 1, from application
ESF_{fan} = 0.580, from Summary of Variables and Data Sources table
hrs = 3,500, from appplication
ft^2 = 10,000, from application
$(\Delta kWh/1000ft^2)_{DCV,cool}$ = 205, from Electric Cooling Savings Associated with DCV table based on location and building type from application
$F_{ElecHeat}$ = 0, from Summary of Variables and Data Sources table based on application
Tons = 25, from application
$(\Delta kWh/ton)_{Econ}$ = 202, from Appendix J based on location and building type from application
CF = 0.8, from Summary of Variables and Data Sources table
$(\Delta MMBtu/1000ft^2)_{DCV}$ = 2.7, from Fuel Savings Associated with DCV table based on location and building type from application
$F_{FuelHeat}$ = 1, from Summary of Variables and Data Sources table based on application

$$\Delta kWh_{fan} = 1 \times 0.580 \times 3{,}500 = 2{,}030\ kWh$$

$$\Delta kWh_{DCV} = \frac{10{,}000}{1{,}000} \times 205 + 0 = 2{,}050\ kWh$$

$$\Delta kWh_{Econ} = 25 \times 202 = 5{,}050\ kWh$$

$$\Delta kWh = 2{,}030 + 2{,}050 + 5{,}050 = 9{,}130\ kWh$$

$$\Delta kW = 1 \times 0.58 \times 0.8 = 0.46\ kW$$

$$\Delta MMBtu = \frac{10{,}000}{1{,}000} \times\ 2.7 \times 1 = 27\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. ECCCNYS 2020; C403.2.2 Ventilation
   Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-[ce]-commercial-energy-efficiency#NYSECC2020P1_CE_Ch04_SecC403
2. NYSMC 2020 402 Natural Ventilation
   Available from: https://codes.iccsafe.org/content/NYSMC2020P1/chapter-4-ventilation
3. Advanced Rooftop Control (ARC) Retrofit: Field-Test Results, PNNL22656. U.S. Department of Energy, July 2013.
   Available from:
   https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-22656.pdf
4. ΔkWh/kSF and ΔMMBtu/kSF factors were calculated from the IL TRM Version 9.0, September 25, 2020, values of Chicago by creating a ratio of Cooling/Heating Degree Days between the NY weather cities and Chicago CDD/HDD and multiplying by the Chicago $SF_{cooling}/SF_{heating}$ respectively
   Available from: https://ilsag.s3.amazonaws.com/IL-TRM_Effective_010121_v9.0_Vol_2_C_and_I_09252020_Final.pdf

Record of Revision

Record of Revision Number	Issue Date
7-20-13	7/31/2020
7-21-16	8/30/2021

Return to Table of Contents

DEMAND CONTROL VENTILATION (DCV)

Measure Description

Demand control ventilation systems have the capability to automatically reduce the outdoor air intake below design rates when occupancy of spaces served by the system is less than design occupancy. Typically, this is controlled by a carbon dioxide sensor, occupancy sensor or turnstile counter. Demand control ventilation systems save energy by reducing the amount of outside air which requires heating or cooling.

This measure assumes a demand control ventilation system with CO_2 sensors will be added to an existing HVAC system with fossil fuel heating that previously had no DCV system or ventilation heat recovery equipment installed. The as-built condition must comply with all applicable provisions of federal, state, local and municipal mechanical/ventilation and construction code, including but not limited to section C403.7.1 of ECCCNYS and section 402 of NYS Mechanical Code (NYSMC). Deemed savings factors associated with the heating side of heat pumps are under development and will be included in a future revision.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = \frac{SF}{1{,}000} \times ESF_{cooling}$$

Summer Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = \frac{SF}{1{,}000} \times ESF_{heating}$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
SF	= Total square footage of the conditioned space impacted by the measure
$ESF_{cooling}$	= Energy savings factor for cooling (kWh/1,000 ft^2)
$ESF_{heating}$	= Energy savings factor for heating (MMBtu/1,000 ft^2)
1,000	= Conversion to 1,000 ft^2

Summary of Variables and Data Sources

Variable	Value	Notes
SF		From application.

Variable	Value	Notes
$ESF_{cooling}$		Lookup from $ESF_{cooling}$ table below based on location and building type.
$ESF_{heating}$		Lookup from $ESF_{heating}$ table below based on location and building type.

$ESF_{cooling}$[1137]

kWh/kSF							
Building Type	**Albany**	**Binghamton**	**Buffalo**	**Massena**	**NYC**	**Poughkeepsie**	**Syracuse**
Office - Low-rise (1 to 3 Stories)	273	176	248	181	555	292	262
Office - Mid-rise (4 to 11 Stories)	258	166	235	171	525	276	248
Office - High-rise (12+ Stories)	269	174	245	178	548	288	259
Religious Building	305	196	277	202	620	326	292
Restaurant	308	199	280	204	627	330	296
Retail - Department Store	374	241	340	248	761	400	359
Retail - Strip Mall	225	145	205	149	458	241	216
Convenience Store	361	233	328	239	734	386	346
Elementary School	196	126	178	130	398	209	188
High School	189	122	172	125	385	202	182
College/ University	245	158	223	163	499	262	236
Healthcare Clinic	214	138	195	142	436	229	206
Lodging (Hotel/Motel)	346	223	315	229	704	370	332
Manufacturing	289	186	262	191	587	309	277
Special Assembly Auditorium	256	165	232	169	520	273	245
Other	274	177	249	182	558	293	263

$ESF_{heating}$[1138]

MMBtu/kSF							
Building Type	**Albany**	**Binghamton**	**Buffalo**	**Massena**	**NYC**	**Poughkeepsie**	**Syracuse**
Office - Low-rise (1 to 3 Stories)	2.9	3.1	2.9	2.2	2.0	1.9	2.9
Office - Mid-rise (4 to 11 Stories)	1.9	2.1	1.9	1.4	1.3	1.2	1.9
Office - High-rise (12+ Stories)	2.6	2.8	2.5	2.0	1.8	1.7	2.6
Religious Building	18.9	20.4	18.7	14.4	13.1	12.3	18.9
Restaurant	13.6	14.7	13.5	10.4	9.5	8.9	13.7
Retail - Department Store	4.7	5.1	4.7	3.6	3.3	3.0	4.7
Retail - Strip Mall	3.0	3.3	3.0	2.3	2.1	2.0	3.0
Convenience Store	2.3	2.5	2.3	1.8	1.6	1.5	2.4

[1137] Deemed savings calculated based on IL TRM values for Chicago, adjusted by the ratio of Cooling Degree Days for each listed NY city and Chicago.
[1138] Deemed savings calculated based on IL TRM values for Chicago, adjusted by the ratio of Heating Degree Days for each listed NY city and Chicago.

MMBtu/kSF							
Building Type	**Albany**	**Binghamton**	**Buffalo**	**Massena**	**NYC**	**Poughkeepsie**	**Syracuse**
Elementary School	8.2	8.8	8.1	6.2	5.7	5.3	8.2
High School	7.9	8.6	7.9	6.1	5.5	5.2	8.0
College/ University	15.8	17.0	15.6	12.0	10.9	10.2	15.8
Healthcare Clinic	5.6	6.0	5.5	4.3	3.9	3.6	5.6
Lodging (Hotel/Motel)	2.6	2.8	2.5	2.0	1.8	1.7	2.6
Manufacturing	2.1	2.3	2.1	1.6	1.5	1.4	2.1
Special Assembly Auditorium	22.1	23.9	21.9	16.9	15.4	14.4	22.2
Other	7.6	8.2	7.5	5.8	5.3	4.9	7.6

Coincidence Factor (CF)

The prescribed value for the coincidence factor is N/A.

Baseline Efficiencies from which Energy Savings are Calculated

The baseline system is an existing fossil fuel heated return air system with no demand control ventilation or ventilation heat recovery equipment installed.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a DCV system added to the return air system to supply air based on occupancy demands.

Operating Hours

N/A

Example Calculation *(Not to be used as default)*

Demand control ventilation is installed in a 10,000 SF auditorium located near Albany. Summer Peak Coincident Demand Savings are not applicable. Annual Electric Energy Savings and Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta kWh = \frac{SF}{1{,}000} \times ESF_{cooling}$$

$$\Delta MMBtu = \frac{SF}{1{,}000} \times ESF_{heating}$$

SF = 10,000 from application.
$ESF_{cooling}$= 256, from $ESF_{cooling}$ table based on location and building type from application
$ESF_{heating}$ = 22.1, from $ESF_{heating}$ table based on location and building type from application

$$\Delta kWh = \frac{10{,}000}{1{,}000} \times 256 = 2{,}560\ kWh$$

$$\Delta MMBtu = \frac{10{,}000}{1{,}000} \times 22.1 = 221\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. ECCCNYS 2020 C403.7 Ventilation
   Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-[ce]-commercial-energy-efficiency#NYSECC2020P1_CE_Ch04_SecC403
2. NYSMC 2020 402 Natural Ventilation
   Available from: https://codes.iccsafe.org/content/NYSMC2020P1/chapter-4-ventilation
3. $ESF_{cooling}$ and $ESF_{heating}$ factors were calculated from the IL TRM Version 6.0, February 8, 2017, values of Chicago by creating a ratio of Cooling/Heating Degree Days between the NY weather cities and Chicago CDD/HDD and multiplying by the Chicago $SF_{cooling}/SF_{heating}$ respectively
   Available from: http://www.ilsag.info/il_trm_version_6.html

Record of Revision

Record of Revision Number	Issue Date
6-17-15	6/30/2017
6-18-11	6/26/2018

Return to Table of Contents

ENERGY MANAGEMENT SYSTEM (EMS) - GUEST ROOM

Measure Description

This measure covers the installation of guest room energy management systems that control HVAC units for individual hotel and motel rooms based upon occupancy sensors, passive infrared or key cards that indicate room occupancy. Sensors controlled by a networked front desk system must also have occupancy sensors in each guest room.[1139] During unoccupied periods[1140], the default setting for controlled units must differ from the operating set point by at least five degrees Fahrenheit or shut the unit fan and heating/cooling off completely. The existing (baseline) HVAC system must be manually controlled within each guest room.

The control system may also be tied into other electric loads, such as lighting and plug loads, to shut them off when occupancy is not sensed, however energy savings of additional equipment is not considered under this measure.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times \frac{tons}{unit} \times ESF_{electric}$$

Summer Peak Coincident Demand Savings

$$\Delta kW = units \times \frac{tons}{unit} \times DSF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = units \times \frac{tons}{unit} \times ESF_{fuel}$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of guest rooms with energy management systems installed under the program
tons/unit	= Tons of air conditioning per unit, based on nameplate data
$ESF_{electric}$	= Electric energy savings factor (kWh/ton)
DSF	= Demand savings factor (kW/ton)
ESF_{fuel}	= Fossil fuel energy savings factor (MMBtu/ton)

[1139] A networked system controlled from the front desk is defined as a system capable of identifying reserved rooms according to a timed schedule and controlling HVAC in each guest room separately as defined by NYC Local Law 91, section C202 General Definitions

[1140] An unoccupied room is defined as a guest room that has been continuously unoccupied for at least 30 minutes.

Summary of Variables and Data Sources

Variable	Value	Notes
tons/unit		From application
$ESF_{electric}$		Lookup from $ESF_{cooling}$ table below based on location, building type, HVAC type, and instruction of housekeeping staff to manually setback prior to installation of EMS system.
DSF		Lookup from $DSF_{cooling}$ table below based on location, building type, HVAC type, and instruction of housekeeping staff to manually setback prior to installation of EMS system.
ESF_{fuel}		Lookup from $ESF_{heating}$ table below based on location, building type, HVAC type, and instruction of housekeeping staff to manually setback prior to installation of EMS system.

$ESF_{electric}$[1141]

kWh/ton							
Building Type, HVAC Type, Housekeeping Setback	**Albany**	**Binghamton**	**Buffalo**	**Massena**	**NYC**	**Poughkeepsie**	**Syracuse**
Motel, PTAC w/ Electric Resistance Heating, Housekeeping Setback	359	230	327	218	697	403	343
Motel, PTAC w/ Electric Resistance Heating, No Housekeeping Setback	1122	718	1022	682	2179	1261	1071
Motel, PTAC w/ Gas Heating, Housekeeping Setback	36	23	33	22	70	41	35
Motel, PTAC w/ Gas Heating, No Housekeeping Setback	116	74	105	70	225	130	110
Motel, PTHP, Housekeeping Setback	150	96	136	91	291	168	143
Motel, PTHP, No Housekeeping Setback	566	362	516	344	1099	636	540
Hotel, PTAC w/ Electric Resistance Heating, Housekeeping Setback	133	85	121	81	259	150	127
Hotel, PTAC w/ Electric Resistance Heating, No Housekeeping Setback	242	155	221	147	471	273	232
Hotel, PTAC w/ Gas Heating, Housekeeping Setback	84	54	77	51	164	95	81
Hotel, PTAC w/ Gas Heating, No Housekeeping Setback	138	88	126	84	269	155	132
Hotel, PTHP, Housekeeping Setback	103	66	94	63	200	116	98
Hotel, PTHP, No Housekeeping Setback	177	113	162	108	344	199	169
Hotel, Central Chilled Water Fan Coil w/ Electric Resistance Heating, Housekeeping Setback	114	73	104	69	222	128	109

[1141] Deemed savings calculated based on IL TRM Version 7.0 values for Chicago, adjusted by the ratio of NCEI Cooling Degree Day 1981-2010 Normals for each listed NY city and Chicago O'Hare Airport (accessed 11/26/2018). IL TRM deemed savings derived through the simulation of hotel and motel models in EnergyPlus as informed by S. Keates, ADM Associates Workpaper: "Suggested Revisions to Guest Room Energy Management (PTAC & PTHP)", 11/14/2013. This source is not publicly available but is referenced by the IL TRM Version 7.0.

kWh/ton							
Building Type, HVAC Type, Housekeeping Setback	**Albany**	**Binghamton**	**Buffalo**	**Massena**	**NYC**	**Poughkeepsie**	**Syracuse**
Hotel, Central Chilled Water Fan Coil w/ Electric Resistance Heating, No Housekeeping Setback	208	133	190	127	405	234	199
Hotel, Central Chilled Water Fan Coil w/ Gas Heating, Housekeeping Setback	65	42	59	40	127	73	62
Hotel, Central Chilled Water Fan Coil w/ Gas Heating, No Housekeeping Setback	104	67	95	63	203	117	100

DSF[1142]

kW/ton							
Building Type, HVAC Type, Housekeeping Setback	**Albany**	**Binghamton**	**Buffalo**	**Massena**	**NYC**	**Poughkeepsie**	**Syracuse**
Motel, PTAC w/ Electric Resistance Heating, Housekeeping Setback	0.04	0.03	0.04	0.03	0.08	0.05	0.04
Motel, PTAC w/ Electric Resistance Heating, No Housekeeping Setback	0.12	0.08	0.11	0.07	0.23	0.14	0.12
Motel, PTAC w/ Gas Heating, Housekeeping Setback	0.04	0.03	0.04	0.03	0.08	0.05	0.04
Motel, PTAC w/ Gas Heating, No Housekeeping Setback	0.12	0.08	0.11	0.07	0.23	0.14	0.12
Motel, PTHP, Housekeeping Setback	0.04	0.03	0.04	0.03	0.08	0.05	0.04
Motel, PTHP, No Housekeeping Setback	0.12	0.08	0.11	0.07	0.23	0.14	0.12
Hotel, PTAC w/ Electric Resistance Heating, Housekeeping Setback	0.05	0.03	0.05	0.03	0.10	0.06	0.05
Hotel, PTAC w/ Electric Resistance Heating, No Housekeeping Setback	0.08	0.05	0.07	0.05	0.15	0.09	0.07
Hotel, PTAC w/ Gas Heating, Housekeeping Setback	0.05	0.03	0.05	0.03	0.10	0.06	0.05
Hotel, PTAC w/ Gas Heating, No Housekeeping Setback	0.08	0.05	0.07	0.05	0.15	0.09	0.07
Hotel, PTHP, Housekeeping Setback	0.05	0.03	0.05	0.03	0.10	0.06	0.05
Hotel, PTHP, No Housekeeping Setback	0.08	0.05	0.07	0.05	0.15	0.09	0.07
Hotel, Central Chilled Water Fan Coil w/ Electric Resistance Heating, Housekeeping Setback	0.04	0.02	0.03	0.02	0.07	0.04	0.03
Hotel, Central Chilled Water Fan Coil w/ Electric Resistance Heating, No Housekeeping Setback	0.05	0.03	0.05	0.03	0.10	0.06	0.05

[1142] Deemed savings calculated based on IL TRM Version 7.0 values for Chicago, adjusted by the ratio of NCEI Cooling Degree Day 1981-2010 Normals for each listed NYS major city as compared to Chicago O'Hare Airport (accessed 11/27/2018). IL TRM deemed savings derived through the simulation of hotel and motel models in EnergyPlus as informed by S. Keates, ADM Associates Workpaper: "Suggested Revisions to Guest Room Energy Management (PTAC & PTHP)", 11/14/2013. This source is not publicly available but is referenced by the IL TRM Version 7.0.

kW/ton							
Building Type, HVAC Type, Housekeeping Setback	**Albany**	**Binghamton**	**Buffalo**	**Massena**	**NYC**	**Poughkeepsie**	**Syracuse**
Hotel, Central Chilled Water Fan Coil w/ Gas Heating, Housekeeping Setback	0.04	0.02	0.03	0.02	0.07	0.04	0.03
Hotel, Central Chilled Water Fan Coil w/ Gas Heating, No Housekeeping Setback	0.05	0.03	0.05	0.03	0.10	0.06	0.05

ESF_{fuel}[1143]

MMBtu/ton							
Building Type, HVAC Type, Housekeeping Setback	**Albany**	**Binghamton**	**Buffalo**	**Massena**	**NYC**	**Poughkeepsie**	**Syracuse**
Motel, PTAC w/ Gas Heating, Housekeeping Setback	2.11	2.27	2.09	2.59	1.47	1.96	2.10
Motel, PTAC w/ Gas Heating, No Housekeeping Setback	6.53	7.03	6.47	8.02	4.57	6.07	6.50
Hotel, PTAC w/ Gas Heating, Housekeeping Setback	0.32	0.34	0.31	0.39	0.22	0.29	0.31
Hotel, PTAC w/ Gas Heating, No Housekeeping Setback	0.68	0.74	0.68	0.84	0.48	0.64	0.68
Hotel, Central Chilled Water Fan Coil w/ Gas Heating, Housekeeping Setback	0.32	0.34	0.31	0.39	0.22	0.29	0.31
Hotel, Central Chilled Water Fan Coil w/ Gas Heating, No Housekeeping Setback	0.68	0.74	0.68	0.84	0.48	0.64	0.68

Reference CDD and HDD Climate Normals[1144]

Location	Cooling Degree Days (CDD)	Heating Degree Days (HDD)
Chicago (Reference)	842	6,340
Albany	597	6,680
Binghamton	382	7,193
Buffalo	544	6,617
Massena	363	8,196
New York City	1,160	4,671
Poughkeepsie	671	6,210
Syracuse	570	6,651

Coincidence Factor (CF)

The prescribed value for the coincidence factor is N/A. Peak coincidence is embedded into DSF values listed above.

[1143] Deemed savings calculated based on IL TRM Version 7.0 values for Chicago, adjusted by the ratio of NCEI Heating Degree Day 1981-2010 Normals for each listed NYS major city as compared to Chicago O'Hare Airport (accessed 11/27/2018). IL TRM deemed savings derived through the simulation of hotel and motel models in EnergyPlus as informed by S. Keates, ADM Associates Workpaper: "Suggested Revisions to Guest Room Energy Management (PTAC & PTHP)", 11/14/2013. This source is not publicly available but is referenced by the IL TRM Version 7.0.

[1144] NOAA National Centers for Environmental Information – NCEI 1981-2010 Climate Normals

Baseline Efficiencies from which Energy Savings are Calculated

The baseline is a hotel or motel guest room with manual heating/cooling temperature set point, with or without instruction to the housekeeping staff to manually setback the temperature.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a hotel or motel guest room with a guest room energy management system that automatically adjusts room temperature by at least 5 degrees of operating set point based on room occupancy. Occupancy is detected by occupancy sensors or keycard sensors that automate temperature setback. Networked front desk controlled systems must also include occupancy sensors in guest rooms.

Savings are based on the guest room energy management system's ability to automatically adjust the guest room's set temperature or reduce the cycle time of the HVAC unit for various occupancy modes.

Operating Hours

Operating hours assumptions, based on heating and cooling degree days by location, are embedded into the estimated savings listed above.

Example Calculation *(Not to be used as default)*

A guest room EMS is installed in a hotel with 50 units, located near Albany. Each room has a 1 ton PTAC equipped with water coils providing heating from a central gas-fired boiler. Prior to EMS, the housekeeping staff was instructed to setback room temperatures in unoccupied rooms. Annual Electric Energy Savings, Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta kWh = units \times \frac{tons}{unit} \times ESF_{electric}$$

$$\Delta kW = units \times \frac{tons}{unit} \times DSF$$

$$\Delta MMBtu = units \times \frac{tons}{unit} \times ESF_{fuel}$$

units = 50, from application
tons/unit = 1, from application
$ESF_{electric}$ = 84, from $ESF_{cooling}$ table based on location, building type, HVAC type, and instruction of housekeeping staff from application
DSF = 0.05,from $DSF_{cooling}$ table below based on location, building type, HVAC type, and instruction of housekeeping staff from application
ESF_{fuel} = 0.32 from $ESF_{heating}$ table based on location, building type, HVAC type, and instruction of housekeeping staff from application

$$\Delta kWh = 50 \times 1 \times 84 = 4{,}200\ kWh$$

$$\Delta kW = 50 \times 1 \times 0.05 = 2.5\ kW$$

$$\Delta MMBtu = 50 \times 1 \times 0.32 = 16\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Guest room energy management systems may be connected to lighting and plug loads in addition to HVAC systems. Shutting off power to lights and plug loads may provide additional electricity savings. These potential savings are not considered in this measure.

References

1. Local Laws of the City of New York for the year 2016, No. 91, 403.2.18 Automatic control of HVAC in hotel/motel guest rooms
   Available from: https://www1.nyc.gov/assets/buildings/local_laws/ll91of2016.pdf
2. 2019 Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 7.0. September 13, 2018 (accessed November 27, 2018)
   Available from:
   http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_7/Final/2019_IL-TRM_Version_7.0_dated_Sept-13-2018_Final_Volumes_1-4_Compiled.pdf
3. NOAA National Centers for Environmental Information – NCEI 1981-2010 Climate Normals
   Available from: https://www.ncdc.noaa.gov/cdo-web/datatools/normals

Record of Revision

Record of Revision Number	Issue Date
12-18-14	12/28/2018

Return to Table of Contents

OUTDOOR TEMPERATURE SETBACK CONTROL FOR HYDRONIC BOILER

Measure Description

This measure covers the installation of outdoor temperature setback control for commercial building fossil fuel-fired boilers. Outdoor air setback control adjusts the hot water set point temperature of the boiler in response to outdoor air temperature. This measure is only applicable to retrofit of existing boilers in space heating systems. One outdoor temperature setback measure may be applied to each boiler.

This measure is not applicable to process boilers or boilers that serve DHW through an indirect system or boiler coil. Additionally, this measure is not applicable for boilers where hot water temperature is maintained regardless of heating load.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = N/A$$

Summer Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = units \times \frac{kBTU/h_{in}}{1{,}000} \times EFLH_{heating} \times ESF$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
$kBTU/h_{in}$	= Fuel input rating (kBTU/h) of the controlled boiler
$EFLH_{heating}$	= Heating equivalent full-load hours
ESF	= Energy Savings Factor
1,000	= Conversion factor, one MMBtu equals 1,000 kBTU

Summary of Variables and Data Sources

Variable	Value	Notes
$kBTU/h_{in}$		From application.
$EFLH_{heating}$		Look up based on building type, vintage and location in Appendix G.

Variable	Value	Notes
ESF	0.05	GDS Associates, Inc. [1145]

Coincidence Factor (CF)

The prescribed value for the coincidence factor is N/A.

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is an existing commercial boiler without outdoor temperature setback control.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is an existing commercial boiler equipped with outdoor temperature setback control.

Operating Hours

Heating equivalent full-load hours were calculated from a DOE-2.2 simulation of prototypical multi-family and other commercial buildings. Operating hour assumptions for the prototypical building models are described in Appendix A. The heating EFLH for C&I buildings in NY by location, building type and vintage are tabulated in Appendix G.

Example Calculation *(Not to be used as default)*

Outdoor temperature setback control is installed on a 500 kBTUh hydronic boiler in an assembly building located near Albany. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are not applicable. Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta MMBtu = units \times \frac{kBTU/h_{in}}{1{,}000} \times EFLH_{heating} \times ESF$$

units = 1, from application
$kBTU/h_{in}$ = 500, from application
$EFLH_{heating}$ = 961, from Appendix G based on building type and location from application
ESF = 0.05, from Summary of Variables and Data Sources table

$$\Delta MMBtu = 1 \times \frac{500}{1{,}000} \times 961 \times 0.05 = 24.03\ MMBtu$$

[1145] GDS Associates, Inc. (2009). Natural Gas Energy Efficiency Potential in Massachusetts. Prepared for GasNetworks, Table 6-4: Commercial Measure Characteristics; Energy Solutions Center

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Lower boiler set point temperatures may cause hot water circulators to run longer cycles. This impact is anticipated to be minor and is not quantified in this measure.

References

1. GDS Associates, Inc. (2009). Natural Gas Energy Efficiency Potential in Massachusetts. Prepared for GasNetworks.
   Available from: http://ma-eeac.org/wordpress/wp-content/uploads/5_Natural-Gas-EE-Potenial-in-MA.pdf
2. Boiler Reset Control. Energy Solutions Center.
   Available from: http://cleanboiler.org/learn-about/boiler-efficiency-improvement/efficiency-index/boiler-reset-control/

Record of Revision

Record of Revision Number	Issue Date
12-18-15	12/28/2018

Return to Table of Contents

PNEUMATIC SYSTEM TO DIRECT DIGITAL CONTROL (DDC) SYSTEM UPGRADE

Measure Description

This measure covers the replacement of a pneumatic building HVAC control system with a new direct digital control (DDC) system. Pneumatic systems utilize compressed air as a medium of control for HVAC systems. DDC systems communicate electronically to achieve precise adjustments to the building HVAC system to maximize efficiency. The elimination of the air compressor and air dryer represent a significant improvement in load and demand reduction over the baseline condition.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = \Delta kWh_{comp} + \Delta kWh_{dryer}$$

$$\Delta kWh_{comp} = units \times \{[LF_{comp} \times (1 + Air_{loss}) \times (ACFMr/100) \times (kW/100CFM) \times Cycle \times hrs] + [LF_{idle} \times (kW_{comp,\ Fan\ Motor} + kW_{comp,\ Compressor\ Motor}) \times (1 - Cycle) \times hrs]\}$$

$$\Delta kWh_{dryer} = units \times LF_{dryer} \times [(hp_{dryer,\ Fan\ Motor} \times 0.746/Eff_{dryer,\ Fan\ Motor}) + (hp_{dryer,\ Compressor\ Motor} \times 0.746/Eff_{dryer,\ Compressor\ Motor})] \times Cycle \times hrs$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \Delta kW_{comp} + \Delta kW_{dryer}$$

$$\Delta kW_{comp} = units \times LF_{comp} \times (ACFM/100) \times (1 + Air_{loss}) \times (kW/100CFM) \times CF$$

$$\Delta kW_{dryer} = units \times LF_{dryer} \times [(hp_{dryer,\ Fan\ Motor} \times 0.746/Eff_{dryer,\ Fan\ Motor}) + (hp_{dryer,\ Compressor\ Motor} \times 0.746/Eff_{dryer,\ Compressor\ Motor})] \times Cycle \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

Note: to determine specific power from existing air compressor if cut sheet is unavailable[1146]

$$kW/100CFM = [(hp_{comp,\ Fan\ Motor} \times 0.746/Eff_{comp,\ Fan\ Motor}) + (hp_{comp,\ Compressor\ Motor} \times 0.746/Eff_{comp,\ Compressor\ Motor})]/(ACFM/100)$$

where:

ΔkWh = Annual electric energy savings

ΔkW = Peak coincident demand electric savings

[1146] How to Calculate Compressed Air Savings, Design World, January 2013

ΔMMBtu	= Annual fossil fuel energy savings
$_{comp}$	= Property of air compressor
$_{dryer}$	= Property of air dryer
$_{Compressor\ Motor}$	= Property of compressor motor
$_{Fan\ Motor}$	= Property of fan motor
$_{idle}$	= Idle time
units	= Number of units removed under the program
LF	= Load factor
Air_{loss}	= Air loss percentage in the compressed air line
ACFMr	= Actual Cubic Feet per Minute required
kW/100CFM	= Specific Power
Cycle	= Percent of time the compressor is operating
hrs	= Annual hours of operation
kW	= Rated kilowatts
hp	= Horsepower
Eff	= Motor efficiency
ACFM	= Actual Cubic feet per Minute delivered by the air compressor
CF	= Coincidence factor
0.746	= Conversion Factor (1 bhp = 0.746 kW)
100	= Conversion factor, converts CFM to 100CFM

Summary of Variables and Data Sources

Variable	Value	Notes
LF_{comp}	0.80	Default Value[1147]
LF_{dryer}	0.80	Default Value[1148]
LF_{idle}	0.254	Default Value[1149]
Air_{loss}	0.10	Default Value[1150]
ACFMr		From Application
ACFM		From Application
kW/100CFM		From Application
Cycle	0.50	Default Value
Hrs		From Application
$kW_{comp,\ Fan\ Motor}$		From Application
$kW_{dryer,\ Compressor\ Motor}$		From Application
$hp_{dryer,\ Fan\ Motor}$		From Application
$hp_{dryer,\ Compressor\ Motor}$		From Application
$hp_{comp,\ Fan\ Motor}$		From Application
$hp_{comp,\ Compressor\ Motor}$		From Application
$Eff_{dryer,\ Fan\ Motor}$		From Application
$Eff_{dryer,\ Compressor\ Motor}$		From Application

[1147] CAGI's Compressed Air and Gas Handbook, Chapter 4, Table 4.4
[1148] Ibid
[1149] How to Calculate Compressed Air Savings, Design World, January 2013. *Average % of Total Package kW Zero Flow (Idle) against Total Package kW Full Flow in Figure 3*
[1150] CAGI's Technical Briefing: Sizing Compressed Air Equipment

Variable	Value	Notes
$Eff_{comp, Fan Motor}$		From Application
$Eff_{comp, Compressor Motor}$		From Application
CF	0.8	

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.8.[1151]

Baseline Efficiencies from which Energy Savings are calculated

The baseline condition is an existing operational pneumatic building HVAC control system with an air compressor and a refrigerated air dryer. If the existing system does not include a refrigerated air dryer, the savings associated with the air dryer must be set equal to zero. The existing compressor can be a single or multi stage reciprocating, rotary screw or variable displacement compressor with load/unload controls and blow down capability.

Compliance Efficiency from which Incentives are calculated

The compliance condition is a building HVAC control system using DDC technology.

Operating Hours

The operating hours should reflect the building HVAC system operating hours and shall be defined by the application.

Example Calculation *(Not to be used as default)*

[UNDER DEVELOPMENT]

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

[1151] *No source specified – update pending availability and review of applicable references.*

References

1. How to Calculate Compressed Air Savings, by Ron Marshall for Design World Online, January 12, 2013
   Available from: https://www.designworldonline.com/how-to-calculate-compressed-air-savings/
2. CAGI's Compressed Air and Gas Handbook, Chapter 4
   Available from: https://www.cagi.org/pdfs/cagi_electhb_ch4.pdf

Record of Revisions

Record of Revision Number	Issue Date
6-19-1	6/28/2019

Return to Table of Contents

STEAM TRAP – LOW PRESSURE SPACE HEATING

Measure Description

This measure covers the repair or replacement of steam traps in low-pressure (≤15 psig) steam space heating applications on existing commercial steam systems served by fossil fuel-fired boilers. Steam systems distribute heat from boilers to satisfy space heating requirements. Steam distribution systems contain steam traps. Steam traps that fail may allow excess steam to escape, thus increasing the amount of steam that must be generated to meet end-use requirements. This measure is intended for the repair or replacement of steam traps only. This measure does not apply to municipal steam systems.

All traps are susceptible to wear and dirt contamination and require periodic inspection and maintenance to ensure correct operation. Faulty steam traps (leaking or blow-through) can be diagnosed with ultrasonic, temperature, or conductivity monitoring techniques. Regular steam trap maintenance and faulty steam trap replacement are steps that minimize steam production. There are three major types of steam traps that are applicable: 1) thermostatic (including float and thermostatic), 2) mechanical and 3) thermodynamic.

Method for Calculating Annual Energy and Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = N/A$$

Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = units \times Loss_{steam} \times \frac{\Delta H_{vap}}{Eff} \times \frac{hrs}{1{,}000{,}000} \times F_{CR}$$

$$Loss_{steam} = 60 \times \frac{\pi}{4} \times Dia^2 \times psia^{0.97} \times F_{Discharge} \times F_{Loss}$$

$$psia = psig + p_{atm}$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of steam traps repaired/replaced under the program
$Loss_{steam}$	= Hourly steam loss per failed trap (lb/hr)
ΔH_{vap}	= Heat of vaporization (latent heat), in BTU/lb, at system operating pressure (psig)
Eff	= Efficiency of boiler
hrs	= Annual hours trap pressurized

F_{CR} = Condensate Return Factor, used to account for the proportion of energy lost that is returned to the system via condensate line
Dia = Internal Diameter (I.D.) of steam trap orifice (inches)
psia = Absolute steam pressure (psi)
$F_{Discharge}$ = Discharge coefficient
F_{Loss} = Steam loss adjustment factor
psig = Steam gage pressure (psi)
p_{atm} = Atmospheric pressure (psi)
60 = An empirically derived constant in the Grashof's equation (lb_m/ $in^{0.06}$-$lb^{0.97}$-hr)[1152]
$\pi/4$ = Orifice area development factor
$^{0.97}$ = An empirically derived constant in the Grashof equation[1153]
1,000,000 = Conversion from Btu to MMBtu (1,000,000 Btu/MMBtu)

Summary of Variables and Data Sources

Variable	Value	Notes
$Loss_{steam}$		Calculated per the equation above, dependent upon system operating pressure (psig), steam trap orifice diameter (Dia) and steam loss adjustment factor (F_{Loss}).
ΔH_{vap}		Look up from table below based on system operating pressure (psig).
Eff		Boiler efficiency, from application. Either E_t or AFUE shall be used, based on nameplate rating metric of existing equipment or actual system efficiency as provided on the application and documented by the customer.
hrs		From application. If unknown, use 2,525 as a default.[1154]
$F_{Discharge}$	0.7	Based on Massachusetts Steam Trap Evaluation[1155]
F_{CR}	Condensate Return: 0.45 No Condensate Return: 1.00	Based on ERS memo to NYSEG/RG&E[1156]
Dia		From application.
psia		Calculated per the equation above, dependent upon system operating pressure (psia).
F_{Loss}	0.37	Based on Massachusetts Steam Trap Evaluation[1157]
psig		From application.
P_{atm}	14.7	Atmospheric pressure (14.7 psi).

[1152] Massachusetts Program Administrators and Energy Efficiency Advisory Council, "Steam Trap Evaluation Phase 2" March 8, 2017. pg 6
[1153] Ibid.
[1154] ERS, "Two-Tier Steam Trap Savings Study", April 26, 2018. pg 5
[1155] Ibid, pg 7
[1156] ERS Memo to NYSEG/RG&E, "Recommendations to Update Algorithms for C&I Steam Trap Repair Energy Savings in NY TRM Introduction", October 10, 2019
[1157] Massachusetts Program Administrators and Energy Efficiency Advisory Council, "Steam Trap Evaluation Phase 2" Table 4-7, March 8, 2017.

Heat of Vaporization (Btu/lb)[1158]

Pressure (psig)	Heat of Vaporization (Btu/lb)
0	970
1	968
2	966
3	964
4	962
5	961
6	959
7	957
8	956
9	954
10	953
11	951
12	950
13	948
14	947
15	946

Coincidence Factor (CF)

The recommended value for the coincidence factor is N/A.

Baseline Efficiencies from which Savings are Calculated

The baseline condition is a leaking or blow-through steam trap on a low-pressure steam space heating system.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is an intact (replaced or repaired) steam trap on a low-pressure steam space heating system. Replaced or repaired traps will no longer leak or blow-through after installation.

Operating Hours

Annual pressurized hours shall be established based on actual operation when feasible. When unknown, the default of 2,525 hours identified for low pressure steam trap operating conditions of sample sites described in MA's steam trap evaluation shall be used.[1159]

[1158] Thermodynamic Properties of Steam Including Data for the Liquid and Solid Phases (1936)
[1159] ERS, "Two-Tier Steam Trap Savings Study", April 26, 2018. pg 5

Example Calculation *(Not to be used as default)*

Four steam traps identified during a system survey as having failed open are replaced in a commercial building with an 80% gas fired steam boiler with condensate return system. Steam traps have 3/16" orifice diameter and the system has a steam gage pressure of 10 psi. The system is pressurized an estimated 2,500 hours per year. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are not applicable. Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta MMBtu = units \times Loss_{steam} \times \frac{\Delta H_{vap}}{Eff} \times \frac{hrs}{1{,}000{,}000} \times F_{CR}$$

$$Loss_{steam} = 60 \times \frac{\pi}{4} \times Dia^2 \times psia^{0.97} \times F_{Discharge} \times F_{Loss}$$

$$psia = psig + p_{atm}$$

units = 4, from application
Dia = 0.1875, from application
psia = psig + p_{atm} = 10 + 14.7 = 24.7
psig from application
p_{atm} from Summary of Variables and Data Sources table
$F_{Discharge}$ = 0.7, from Summary of Variables and Data Sources table
F_{loss} = 0.37, from Summary of Variables and Data Sources table
ΔH_{vap} = 953, from Heat of Vaporization table based on pressure from application
Eff = 0.80, from application
hrs = 2,500, from application
F_{CR} = 0.45, from Summary of Variables and Data Sources table based on conditions from application

$$Loss_{steam} = 60 \times \frac{\pi}{4} \times 0.1875^2 \times 24.7^{0.97} \times 0.7 \times 0.37 = 9.626$$

$$\Delta MMBtu = 4 \times 9.626 \times \frac{953}{0.80} \times \frac{2{,}500}{1{,}000{,}000} \times 0.45 = 51.6\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. Massachusetts Program Administrators and Energy Efficiency Advisory Council, "Steam Trap Evaluation Phase 2", March 8, 2017.
   Available from: http://www.ripuc.ri.gov/eventsactions/docket/4755-TRM-MA%20CIEC%20P59%20Steam%20Trap%20Evaluation%20Report%20FINAL%2020170308.pdf
2. ERS, "Two-Tier Steam Trap Savings Study", April 26, 2018
   Available from: https://api-plus.anbetrack.com/etrm-gateway/etrm/api/v1/etrm/documents/5ee4886f6996f22b867df794/view?authToken=bb7e8bd0f9ae7708c589a0742f8f62fdb14916a2ddcb02e3ca0cfffb741c830196cae58cbc266586c734602d97f8efed3e8f602559fd43c6cb8b8e08597356f32fefb1d3bdea07
3. ERS Memo to NYSEG/RG&E, "Recommendations to Update Algorithms for C&I Steam Trap Repair Energy Savings in NY TRM Introduction", October 10, 2019
4. Joseph Henry Keenan and Frederick G. Keyes, Thermodynamic Properties of Steam Including Data for the Liquid and Solid Phases, John Wiley and Sons, New York (1936)

Record of Revision

Record of Revision Number	Issue Date
6-17-14	6/30/2017
3-20-10	3/30/2020
3-21-24	4/9//2021

Return to Table of Contents

STEAM TRAP MONITORING SYSTEM – LOW PRESSURE SPACE HEATING

Measure Description

Many facilities that contain steam systems only perform steam trap surveys once a year. This can result in significant steam loss if a steam trap actively fails sometime between annual audits. This measure covers the installation of automatic steam trap monitoring systems, which alert maintenance personnel to failed steam traps, enabling rapid repair or replacement. Individual sensors on steam traps can feed data to a hub that displays the status of each monitored steam trap. Energy savings are based on elimination of steam trap losses occurring before the annual maintenance inspection for leaking or failed steam traps. Annual maintenance audits are expected to continue as usual post-implementation. Savings are calculated similarly to regular steam trap replacement, but due to the presence of the monitoring software, this measure has longer lifetime savings.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = N/A$$

Summer Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = units \times Loss_{steam} \times \frac{\Delta H_{vap}}{Eff} \times \frac{hrs}{1{,}000{,}000} \times F_{hrs} \times F_{Failed} \times F_{CR}$$

$$Loss_{steam} = 60 \times \frac{\pi}{4} \times Dia^2 \times psia^{0.97} \times F_{Discharge} \times F_{Loss}$$

$$psia = psig + p_{atm}$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of steam traps repaired/replaced under the program
$Loss_{steam}$	= Hourly steam loss per failed trap (lb/hr)
ΔH_{vap}	= Heat of vaporization (latent heat), in BTU/lb, at system operating pressure (psig)
Eff	= Efficiency of boiler
hrs	= Annual hours trap pressurized
F_{failed}	= The percentage of steam traps that fail annually
F_{hrs}	= Percentage of annual hours that steam traps are failed
Dia	= Internal Diameter (I.D.) of steam trap orifice (inches)
psia	= Absolute steam pressure (psi)

$F_{Discharge}$ = Discharge coefficient
F_{CR} = Condensate return factor, used to account for the proportion of energy lost that is returned to the system via condensate line
F_{Loss} = Steam loss adjustment factor
psig = Steam gage pressure (psi)
p_{atm} = Atmospheric pressure (psi)
60 = An empirically derived constant in the Grashof's equation (lb_m/ $in^{0.06}$-$lb^{0.97}$-hr)[1160]
$\pi/4$ = Orifice area development factor
$^{0.97}$ = An empirically derived constant in the Grashof equation[1161]
1,000,000 = Conversion factor (BTU/MMBtu), one MMBtu equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
$Loss_{steam}$		Calculated per the equation above, dependent upon system operating pressure (psig), steam trap orifice diameter (Dia) and steam loss adjustment factor (F_{Loss}).
ΔH_{vap}		Look up from table below based on system operating pressure (psig).
Eff		Boiler efficiency, from application. Either E_t or AFUE shall be used, based on nameplate rating metric of existing equipment or actual system efficiency as provided on the application and documented by the customer.
hrs		From application. If unknown, use 2,525 as a default.[1162]
$F_{Discharge}$	0.7	Based on Massachusetts Steam Trap Evaluation[1163]
F_{Failed}		From application, based upon historical data for facility, if unknown assume 0.15.[1164,1165,1166]
F_{hrs}	0.5	Assumes steam traps would fail for 50% of annual operating hours without monitoring system
F_{CR}	Condensate Return: 0.45 No Condensate Return: 1.00	Based on ERS memo to NYSEG/RG&E[1167]
Dia		From application.

[1160] Massachusetts Program Administrators and Energy Efficiency Advisory Council, "Steam Trap Evaluation Phase 2" March 8, 2017. pg 6
[1161] Ibid.
[1162] ERS, "Two-Tier Steam Trap Savings Study", April 26, 2018. pg 5
[1163] Ibid, pg 7
[1164] Average annual failure rate based upon EUL of 6 years
[1165] Emerson whitepaper 00840-0200-4708, "Impact of failed steam traps on process plants", Rev AA, April 2013. p 4.
[1166] U.S. DOE, Energy Tips: Steam, Inspect and Repair Steam Traps, Steam Tip Sheet #1, DOE/GO-102012-3401, January 2012
[1167] ERS Memo to NYSEG/RG&E, "Recommendations to Update Algorithms for C&I Steam Trap Repair Energy Savings in NY TRM Introduction", October 10, 2019. The CR factor is used to account for some of the steam energy being returned to the system rather than being vented into the atmosphere.

Variable	Value	Notes
psia		Calculated per the equation above, dependent upon system operating pressure (psia).
F_{Loss}	0.37	Based on Massachusetts Steam Trap Evaluation[1168]
psig		From application.
P_{atm}	14.7	Atmospheric pressure (14.7 psi).

Heat of Vaporization (Btu/lb)[1169]

Pressure (psig)	Heat of Vaporization (Btu/lb)
0	970
1	968
2	966
3	964
4	962
5	961
6	959
7	957
8	956
9	954
10	953
11	951
12	950
13	948
14	947
15	946

Coincidence Factor (CF)

The prescribed value for the coincidence factor is N/A.

Baseline Efficiencies from which Savings are Calculated

The baseline condition is a steam distribution system without a steam trap monitoring system.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a steam distribution system with a steam trap monitoring system.

[1168] Massachusetts Program Administrators and Energy Efficiency Advisory Council, "Steam Trap Evaluation Phase 2" Table 4-7, March 8, 2017.
[1169] Thermodynamic Properties of Steam Including Data for the Liquid and Solid Phases (1936)

Operating Hours

Annual pressurized hours shall be established based on actual operation when feasible. When unknown, the default of 2,525 hours identified for low pressure steam trap operating conditions of sample sites described in MA's steam trap evaluation shall be used.[1170]

Example Calculation *(Not to be used as default)*

A steam trap monitoring system is installed on a commercial gas low-pressure steam space heating system. The system comprises 30 steam traps and has nameplate efficiency of 82% with an installed condensate return system. Steam traps have 3/16" orifice diameter and the system has a steam gage pressure of 10 psi. Traps are pressurized an estimated 2,500 hours per year. Previous steam trap inspections at the site captured an annual failure rate of 20%. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are not applicable. Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta MMBtu = units \times Loss_{steam} \times \frac{\Delta H_{vap}}{Eff} \times \frac{hrs}{1{,}000{,}000} \times F_{hrs} \times F_{Failed} \times F_{CR}$$

$$Loss_{steam} = 60 \times \frac{\pi}{4} \times Dia^2 \times psia^{0.97} \times F_{Discharge} \times F_{Loss}$$

$$psia = psig + p_{atm}$$

units = 30, from application
Dia = 0.1875, from application
Psia = psig + p_{atm} = 10 + 14.7 = 24.7
psig from application
p_{atm} from Summary of Variables and Data Sources table
$F_{Discharge}$ 0.7, from Summary of Variables and Data Sources table
F_{loss} = 0.37, from Summary of Variables and Data Sources table
F_{hrs} = 0.5, from Summary of Variables and Data Sources table
F_{failed} = 0.2, from Summary of Variables and Data Sources table
ΔH_{vap} = 953, from Heat of Vaporization table based on pressure from application
Eff = 0.82, from application
hrs = 2,500, from application
F_{CR} = 0.45, from Summary of Variables and Data Sources table based on conditions from application

$$Loss_{steam} = 60 \times \frac{\pi}{4} \times 0.1875^2 \times 24.7^{0.97} \times 0.7 \times 0.37 = 9.626$$

$$\Delta MMBtu = 30 \times 9.626 \times \frac{953}{0.82} \times \frac{2{,}500}{1{,}000{,}000} \times 0.5 \times 0.2 \times 0.45 = 37.77\ MMBtu$$

[1170] ERS, "Two-Tier Steam Trap Savings Study", April 26, 2018. pg 5

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. Massachusetts Program Administrators and Energy Efficiency Advisory Council, "Steam Trap Evaluation Phase 2", March 8, 2017.
   Available from: http://www.ripuc.ri.gov/eventsactions/docket/4755-TRM-MA%20CIEC%20P59%20Steam%20Trap%20Evaluation%20Report%20FINAL%2020170308.pdf
2. ERS, "Two-Tier Steam Trap Savings Study", April 26, 2018
   Available from: https://api-plus.anbetrack.com/etrm-gateway/etrm/api/v1/etrm/documents/5ee4886f6996f22b867df794/view?authToken=bb7e8bd0f9ae7708c589a0742f8f62fdb14916a2ddcb02e3ca0cfffb741c830196cae58cbc266586c734602d97f8efed3e8f602559fd43c6cb8b8e08597356f32fefb1d3bdea07
3. ERS Memo to NYSEG/RG&E, "Recommendations to Update Algorithms for C&I Steam Trap Repair Energy Savings in NY TRM Introduction", October 10, 2019
4. Joseph Henry Keenan and Frederick G. Keyes, Thermodynamic Properties of Steam Including Data for the Liquid and Solid Phases, John Wiley and Sons, New York (1936)
5. Emmerson, White Paper 00840-0200-4708, Rev AA, "Impact of failed steam traps on process plants", April 2013
   Available from: https://www.emerson.com/documents/automation/white-paper-impact-of-failed-steam-traps-on-process-plants-rosemount-en-77018.pdf
6. US Department of Energy, Energy Tips: Steam, Inspect and Repair Steam Trap", Steam Tip Sheet #1, January 2012
   Available from: https://www.energy.gov/sites/prod/files/2014/05/f16/steam1_traps.pdf

Record of Revisions

Record of Revision Number	Issue Date
7-20-15	7/31/2020
3-21-25	4/9/2021

Return to Table of Contents

THERMOSTAT - WI-FI (COMMUNICATING)

Measure Description

This section covers Wi-Fi communicating thermostats without behavioral learning capability applied to small commercial buildings with fossil fuel-fired heat boilers or furnaces, electric heat pumps, air conditioners or electric resistance heating. These communicating thermostats allow set point adjustment via a remote application.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times \left\{ (\Delta kWh/unit)_{cooling} + \left[(\Delta MMBtu/unit) \times \frac{Eff_{FuelHeat}}{COP} \times \frac{1{,}000{,}000}{3{,}412} \times F_{ElecHeat} \right] \right\}$$

Summer Peak Coincident Demand Savings

$$\Delta kW = units \times \frac{(\Delta kWh/unit)_{cooling}}{EFLH_{cooling}} \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = units \times (\Delta MMBtu/unit) \times F_{FuelHeat}$$

where:

ΔkWh	= Annual electricity energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
$(\Delta kWh/unit)_{cooling}$	= Annual electric cooling savings per unit
(ΔMMBtu/unit)	= Annual fossil fuel savings per unit
$Eff_{FuelHeat}$	= Efficiency of fossil fuel heating equipment (AFUE, Et, or Ec)
COP	= Coefficient of performance, ratio of output energy/input energy (at AHRI standard high-temperature rating conditions)
$F_{ElecHeat}$	= Electric heating factor; used to account for the presence or absence of an electric heating system
$F_{FuelHeat}$	= Fossil fuel heating factor; used to account for the presence or absence of a fossil fuel heating system
$EFLH_{cooling}$	= Cooling equivalent full-load hours
CF	= Coincidence factor
3,412	= Conversion factor, one kWh equals 3,412 BTU
1,000,000	= Conversion factor, one MMBtu equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
$(\Delta kWh/unit)_{cooling}$	104	Annual electric cooling savings per installed thermostat, in kWh[1171]
(ΔMMBtu/unit)	6.6	Annual fossil fuel savings per installed thermostat, in MMBtu[1172]
$Eff_{FuelHeat}$		From application. If unknown, use 0.8.[1173]
COP	Heat Pump: 2.4 Electric Resistance: 1.0	Assumed efficiency of electric heating system, based on a COP of 1.0 for electric resistance heating and a minimally code compliant, 3-ton split system HP for heat pumps.[1174]
$F_{ElecHeat}$		Use a value of 1.0 if the building is electrically heated. Otherwise, use 0.0.
$F_{FuelHeat}$		Use a value of 1.0 if the building is fossil fuel heated. Otherwise, use 0.0.
$EFLH_{cooling}$		From application. If unknown, lookup based on building type and location from Appendix G.
CF	0.8	

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.8.[1175]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline efficiency is an HVAC system using fossil fuel and electricity to provide space heating and cooling controlled by a non-Wi-Fi communicating programmable thermostat.

Compliance Efficiency from which Incentives are Calculated

The compliance efficiency is an HVAC system using fossil fuel and electricity to provide space heating and cooling controlled by a Wi-Fi communicating thermostat without behavioral learning capability.

Operating Hours

HVAC system operating hours are embedded in the deemed savings values associated with Wi-Fi communicating thermostats, which are based on metering results. Equipment cooling equivalent full load hours shall be taken from the application. If unknown, default EFLH by facility type and location can be found in Appendix G.

[1171] Cadmus Group, Wi-Fi Programmable Controllable Thermostat Pilot Program Evaluation, September 2012, p. 18
[1172] Ibid. p. 12
[1173] ECCCNYS 2020, Table C403.3.2(4) and Table C403.3.2(5)
[1174] ECCCNYS 2020, Table C403.3.2(2)
[1175] *No source specified – update pending availability and review of applicable references.*

Example Calculation *(Not to be used as default)*

Three wi-fi thermostat are installed in offices in an assembly building located near Albany. The building is gas heated. Annual Electric Energy Savings, Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta kWh = units \times \left\{ (\Delta kWh/unit)_{cooling} + \left[(\Delta MMBtu/unit) \times \frac{Eff_{FuelHeat}}{COP} \times \frac{1{,}000{,}000}{3{,}412} \times F_{ElecHeat} \right] \right\}$$

$$\Delta kW = units \times \frac{(\Delta kWh/unit)_{cooling}}{EFLH_{cooling}} \times CF$$

$$\Delta MMBtu = units \times (\Delta MMBtu/unit) \times F_{FuelHeat}$$

units = 3, from application
$(\Delta kWh/unit)_{cooling}$ =104, from Summary of Variables and Data Sources table
(ΔMMBtu/unit) = 6.6, from Summary of Variables and Data Sources table
COP = N/A, based on heating source from application
$F_{ElecHeat}$ = 0, from Summary of Variables and Data Sources table based on heating source from application
$EFLH_{cooling}$ = 478, from Appendix G based on building type and location from application
$F_{FuelHeat}$ = 1, from Summary of Variables and Data Sources table based on heating source from application
CF = 0.8, from Summary of Variables and Data Sources table

$$\Delta kWh = 3 \times \{104 + [0]\} = 312\ kWh$$

$$\Delta kW = 3 \times \frac{104}{478} \times 0.8 = 0.522\ kW$$

$$\Delta MMBtu = 3 \times 6.6 \times 1 = 19.8\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this

measure algorithm in future revisions to the TRM.

References

1. Cadmus Group, Inc. (September 2012), *"Wi-Fi Programmable Controllable Thermostat Pilot Program Evaluation"*, prepared for The Electric and Gas Program Administrators of Massachusetts.
   Available from: http://ma-eeac.org/wordpress/wp-content/uploads/Wi-Fi-Programmable-Controllable-Thermostat-Pilot-Program-Evaluation_Part-of-the-Massachusetts-2011-Residential-Retrofit-Low-Income-Program-Area-Study.pdf
2. ECCCNYS 2020 Table C403.3.2(2): Minimum Efficiency Requirements: Electrically Operated Unitary and Applied Heat Pumps, Table C403.3.2(4): Warm-Air Furnaces And Combination Warm-Air Furnaces/Air-Conditioning Units, Warm-Air Duct Furnaces And Unit Heaters, Minimum Efficiency Requirements and C403.3.2(5) Minimum Efficiency Requirements: Gas- and Oil-Fired Boilers
   Available from: https://codes.iccsafe.org/public/document/IECC2015NY-1/chapter-4-cecommercial-energy-efficiency

Record of Revision

Record of Revision Number	Issue Date
1-16-5	12/31/2015
9-17-4	9/30/2017
7-20-16	7/31/2020

Return to Table of Contents

THERMOSTATIC RADIATOR VALVE (TRV)

Measure Description

This measure covers the installation of thermostatic radiator valves (TRVs) on one- and two-pipe space heating steam systems in commercial facilities. TRVs are self-regulating valves that require no ancillary power and provide local control of room air temperature by modulating the flow of steam into radiators. In one-pipe steam systems, this is accomplished by installing TRVs on radiator air vents. When in the closed position, the TRV prevents the venting of air, thereby restricting the flow of steam into the radiator. In two-pipe systems, TRVs are installed on the radiator inlets, preventing the intake of steam when closed. This measure is not applicable to district or municipal steam systems.

TRVs demonstrate the greatest potential for energy savings and financial viability when overheating is exhibited in zones throughout the system and when combined with other steam system best practices improvements. Therefore, prioritization of this measure is recommended in zones that are overheated by 3°F or greater[1176] and is only eligible for energy savings when installed as part of system inspection, balancing and commissioning including, but not limited to: burner tuning, boiler cleaning, recalibration of boiler control set points, inspection and repair/replacement of leaking inlets and air vents, installation of properly sized air vents, main line steam trap repair/replacement, recalibration of system operating pressure, insulation of bare steam lines and installation of radiator orifice plates in two-pipe systems.[1177] If the system undergoes regular maintenance, savings may be claimed upon program confirmation that the system is in proper working order.

Method for Calculating Annual Energy Savings and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = N/A$$

Summer Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = units \times \frac{\Delta MMBtu}{HDD} \times HDD_{loc}$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings

[1176] NYSERDA, Thermostatic Radiator Valve (TRV) Demonstration Project, Report No. 95-14, September 1995, pg. 5-1
[1177] US DOE, Thermostatic Radiator Valve Evaluation, January 2015, pg. 25 - 26

units = Number of measures installed under the program
ΔMMBtu/HDD = Annual fossil fuel energy savings per Heating Degree Day (HDD) per TRV
HDD_{loc} = Heating Degree Days based on location

Summary of Variables and Data Source

Variable	Value	Notes
ΔMMBtu/HDD	One-pipe: 0.0004589 Two-pipe: 0.0005983	NYSERDA[1178, 1179]
HDD_{loc}		From application. If unknown, lookup based on location from Heating Degree Days section below

Heating Degree Days

For the purposes of this measure, Heating Degree Days are defined as the number of degrees that a day's average temperature is below some baseline temperature, which represents the temperature below which buildings need to be heated. The HDD values listed in the table below are based on 30-year averages of U.S annual climate normals for the period of 1981 to 2010 using base 65° F.[1180]

City	HDD_{loc}
Albany	6,680
Binghamton	7,193
Buffalo	6,617
Massena	8,196
NYC	4,671
Poughkeepsie	6,210
Syracuse	6,651

Coincidence Factor (CF)

The prescribed value for the coincidence factor is N/A.

[1178] Results of multifamily impact evaluation used as a proxy to estimate commercial facility savings; average of three test sites implementing full installation (Phase 3) of TRVs as reported in: NYSERDA, Thermostatic Radiator Valve (TRV) Demonstration Project, Report No. 95-14, September 1995, Table 2-2: Heating Plant Characteristics, pg. 2-2, Table 2-3: TRV Installation, pg. 2-6 and Table 3-5, pg, 3-6. Annual fossil fuel energy savings figure was derived by multiplying the ratio of the number of apartments per building to the number of TRVs per building to the difference in energy consumption per apartment per degree day between Phase 1 and Phase 3.

[1179] Results of multifamily impact evaluation used as a proxy to estimate commercial facility savings; average of three test sites implementing installation of TRVs (Group C) as reported in: T. Cholewa, A. Siuta-Olcha, C.A. Balaras, Actual Energy Savings from the Use of Thermostatic Radiator Valves in Residential Buildings–Long Term Field Evaluation, Energy and Buildings, July 2017, Table 1, pg. 488 and Table 4, pg. 492, normalized to 3,825 HDD (cited value for test site location). Annual fossil fuel energy savings figure was derived by multiplying the ratio of the total heated floor surface area per building to the number of radiators per building to the difference in energy consumption per building per square meter and dividing by heating degree days.

[1180] HDD taken from NCEI 1981-2010 climate normals

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a radiator in a one- or two-pipe space heating commercial steam system with manual control valves.

Compliance Efficiency from which Savings are Calculated

The compliance condition is a radiator equipped with thermostatic radiator valve in a one- or two-pipe space heating commercial steam system that has undergone system inspection, balancing and commissioning as detailed in the Measure Description section above.

Operating Hours

Operating hours are embedded in the prescribed values for energy savings per heating degree day and are therefore not explicitly defined for this measure.

Example Calculation *(Not to be used as default)*

10 thermostatic radiator valves are installed on one-pipe steam radiators in a primary school building located near Albany. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are not applicable. Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta MMBtu = units \times \frac{\Delta MMBtu}{HDD} \times HDD_{loc}$$

units = 10, from application
ΔMMBtu/HDD = 0.0004589, from Summary of Variables and Data Sources table based on radiator type from application
HDD_{loc} = 6,680, from Heating Degree Days table based on location from application

$$\Delta MMBtu = 10 \times 0.0004318 \times 6{,}680 = 28.8\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. NYSERDA, Thermostatic Radiator Valve (TRV) Demonstration Project, Report No. 95-14, September 1995
   Available from:
   https://digital.library.unt.edu/ark:/67531/metadc620708/m2/1/high_res_d/119941.pdf
2. US DOE, Thermostatic Radiator Valve Evaluation, January 2015
   Available from: https://www.nrel.gov/docs/fy15osti/63388.pdf
3. T. Cholewa, A. Siuta-Olcha, C.A. Balaras, Actual Energy Savings from the Use of Thermostatic Radiator Valves in Residential Buildings–Long Term Field Evaluation, Energy and Buildings, July 2017
   Available from:
   https://www.sciencedirect.com/science/article/pii/S0378778817305820?viewFullText=true#bib0100
4. NOAA National Centers for Environmental Information – 1981-2010 Normals
   Available from: http://www.ncdc.noaa.gov/cdo-web/datatools/normals

Record of Revision

Record of Revision Number	Issue Date
12-18-16	12/28/2018

Return to Table of Contents

LIGHTING

INTERIOR AND EXTERIOR LIGHTING

Measure Description

This section covers energy-efficient lighting equipment, such as energy-efficient lamps, energy-efficient ballasts, compact fluorescent lamps, LED lamps, and improved lighting fixtures. Improved lighting fixtures may include reflectors and other optical improvements to lighting fixtures. These technologies, taken separately or combined into an energy-efficient lighting fixture, provide the required illumination at reduced input power.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = \left[\frac{(W \times units)_{baseline} - (W \times units)_{ee}}{1{,}000}\right] \times hrs \times (1 + HVAC_c)$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \left[\frac{(W \times units)_{baseline} - (W \times units)_{ee}}{1{,}000}\right] \times (1 + HVAC_d) \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = \left[\frac{(W \times units)_{baseline} - (W \times units)_{ee}}{1{,}000}\right] \times hrs \times HVAC_{ff}$$

New construction, space renovations or remodels may require a building permit that includes compliance with local or state energy codes. In these instances, the applicable energy code defines the baseline. The energy consumption of the efficient and baseline lighting systems are defined in terms of the lighting power density (LPD) in watts per square foot. An alternate form of the lighting equations based on LPD is as follows:

Annual Electric Energy Savings

$$\Delta kWh = SF \times \left[\frac{LPD_{baseline} - LPD_{ee}}{1{,}000}\right] \times hrs \times (1 + HVAC_c)$$

Summer Peak Coincident Demand Savings

$$\Delta kW = SF \times \left[\frac{LPD_{baseline} - LPD_{ee}}{1{,}000}\right] \times (1 + HVAC_d) \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = SF \times \left[\frac{LPD_{baseline} - LPD_{ee}}{1{,}000}\right] \times hrs \times HVAC_{ff}$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
$_{baseline}$	= Characteristic of baseline condition
$_{ee}$	= Characteristic of energy efficient condition
SF	= Extent of space or surface illuminated by lighting system (in ft^2)
LPD	= Lighting power density
W	= Rated wattage of lamp or fixture (Watts)
hrs	= Lighting operating hours
$HVAC_c$	= HVAC interaction factor for annual electric energy consumption
$HVAC_d$	= HVAC interaction factor for utility summer peak hour
$HVAC_{ff}$	= HVAC interaction factor for annual fossil fuel consumption (MMBtu/kWh)
CF	= Coincidence factor
1,000	= Conversion factor, one kW equals 1,000 watts

Summary of Variables and Data Sources

Variable	Value	Notes
$units_{baseline}$		Number of baseline measures, from application. Set equal to $Units_{ee}$ if unknown.
$units_{ee}$		Number of energy efficient measures installed under the program, from application.
$W_{baseline}$		Connected load of the baseline unit(s) displaced, from application (in Watts).
W_{ee}		Connected load of the energy-efficient unit, from application (in Watts).
hrs		Lighting operating hours. From application or default, as listed below in the Operating Hours table.
$LPD_{baseline}$		Lighting power density (in W/SF) for baseline measure, from application, based on NYS/NYC Energy Conservation code. New construction or major renovation (as defined by applicable code/permits) only.
LPD_{ee}		Lighting power density (in W/SF) for energy efficient measure, from application, based on installed system design. New construction or major renovation (as defined by applicable code/permits) only.
SF		Floor area illuminated by lighting system (in SF)

Variable	Value	Notes
$HVAC_c$	Exterior and Unconditioned Space: 0	HVAC interaction factor for annual electric energy consumption (dimensionless). Vintage and HVAC type weighted average by city. See Appendix D.
$HVAC_d$	Exterior and Unconditioned Space: 0	HVAC interaction factor for peak demand at utility summer peak hour (dimensionless). Vintage and HVAC type weighted average by city. See Appendix D.
$HVAC_{ff}$	Exterior and Unconditioned Space: 0	HVAC interaction factor for annual fossil fuel energy consumption (MMBtu/kWh). Vintage and HVAC type weighted average by city. See Appendix D.
CF	Interior: See Coincidence Factor (CF) section below Exterior: 0	"Interior" designation extends to any covered area not adequately lit during daylight hours by sunlight, thus requiring daytime operation of lighting. Lookup Interior CF based on facility type in Operating Hours section below.

HVAC system interaction factors are defined as the ratios of the cooling energy and demand reduction and heating energy increase per unit of lighting energy reduction. Much of the input energy for lighting systems is converted to heat that must be removed by the HVAC system. Reductions in lighting heat gains due to lighting power reduction decrease the need for space cooling and increase the need for space heating.

HVAC interaction factors vary by climate, HVAC system type and building type. Prescribed values for HVAC interaction factors for lighting energy and peak demand savings are shown in Appendix D. Lighting systems in unconditioned spaces or on the building exterior will have interaction factors of 0.0. The building types for the HVAC interactive effect factors by facility type are shown in the lighting Operating Hours table below.

Coincidence Factor (CF)

The prescribed coincidence factor for commercial exterior lighting is 0.0, since exterior lighting is generally off during daylight hours. Look up interior lighting CF from the table in the Operating Hours section below based on facility type.[1181]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is assumed to be the existing and operational lighting fixture in all applications other than new construction or extensive renovations that trigger the building code. See table of standard fixture wattages in Appendix C. Note, depending on local codes, new construction, space renovations or remodels may require a building permit that includes compliance with local or state energy codes. In these instances, the applicable energy code defines the baseline.

Code LPD shall be taken from chapter C405.3: Interior Lighting Power Requirements

[1181] ConEd Large C&I Program Impact and Process Evaluation Report prepared by Navigant, August 2019, slide 71

(Prescriptive) and chapter C405.4: Exterior Lighting (Mandatory) of the Energy Conservation Construction Code of New York State [1182] (ECCCNYS) that are based on IECC 2018. Alternatively, ASHRAE Standard 90.1-2013 may be referenced for compliance. In both cases, either the Building Area or Space-By-Space compliance path may be used.

Compliance Efficiency from which Incentives are Calculated

The compliance condition for individual fixture/lamp replacement scenarios shall be ENERGY STAR® and/or DLC compliant products. See table of standard fixture wattages in Appendix C. Manufacturers' cut sheets may substitute for the standard fixture watts in Appendix C if available. In new construction or major renovation projects, the new lighting system power consumption should be expressed as a lighting power density (LPD) in watts per square foot. All equipment installed under the LPD method shall comply with ENERGY STAR® and/or DLC specifications, where ENERGY STAR® and/or DLC specifications for that product exist. LPD methods shall be compliant with all applicable federal, state, local and municipal codes and standards.

Operating Hours

The average lighting operating hours are defined by building type, as shown in the table below. These are typical average values for the building types shown. Use building specific operating hours where available. For exterior lighting, the default annual operating hours are 4,380 hrs/yr (12 hours per day).

Facility Type	Lighting Hours (hrs/yr)	CF[1183]	HVAC Int	Facility Type	Lighting Hours (hrs/yr)	CF[1184]	HVAC Int
Auto Related*	2,810	0.89	AR	Manufacturing Facility	2,857	0.67	Ind
Automotive / Transportation Service or Repair Facility (24/7)	8,760	0.89	AR	Medical Offices	3,748	0.92	SOfc
Bakery	2,854	0.79	FS	Motion Picture Theatre	1,954	0.89	Asy
Banks	3,748	0.92	SOfc	Multi-Family (Common Areas)	7,665	0.98	MFL
Church	1,955	0.89	Rel	Museum	3,748	0.89	Asy
College–Cafeteria**	2,713	0.79	FS	Nursing Homes	5,840	0.92	MFL
College – Classes	2,586	0.54	CC	Office (General Office Types)**	3,013	0.92	SOfc/ LOfc
College - Dormitory	3,066	0.92	Dorm	Parking Garages	4,368	0.0	None

[1182] ECCCNYS 2020; C405.3: Interior Lighting Power Requirements (Prescriptive) & C405.4: Exterior Lighting Power (Mandatory)
[1183] ConEd Large C&I Program Impact and Process Evaluation Report prepared by Navigant, August 2019, slide 71
[1184] ConEd Large C&I Program Impact and Process Evaluation Report prepared by Navigant, August 2019, slide 71

Facility Type	Lighting Hours (hrs/yr)	CF[1183]	HVAC Int	Facility Type	Lighting Hours (hrs/yr)	CF[1184]	HVAC Int
Commercial Condos***	3,100	0.92	SOfc	Parking Garages (24/7)	7,717	0.0	None
Convenience Stores	6,376	0.97	SRet	Parking Lots	4,100	0.0	None
Convention Center	1,954	0.89	Asy	Penitentiary	5,477	0.37	MFL
Court House	3,748	0.92	LOfc	Performing Arts Theatre	2,586	0.89	Asy
Dining: Bar Lounge/Leisure	4,182	0.79	FS	Police / Fire Stations (24 Hr)	7,665	0.89	Asy
Dining: Cafeteria / Fast Food	6,456	0.79	FF	Post Office	3,748	0.97	SRet
Dining: Family	4,182	0.79	FS	Pump Stations	1,949	0.67	Ind
Entertainment	1,952	0.89	Asy	Refrigerated Warehouse	2,602	0.67	RWH
Exercise Center	5,836	0.89	SRet	Religious Building	1,955	0.89	Rel
Fast Food Restaurants	6,376	0.79	FF	Restaurants	4,182	0.79	FS
Fire Station (Unmanned)	1,953	0.89	Asy	Retail	3,463	0.85	SRet/ LRet
Food Stores	4,055	0.98	Gro	School / University	2,187	0.54	Univ
Gymnasium	2,586	0.89	Asy	Schools (Jr./Sr. High)	2,187	0.54	HS
Hospitals	7,674	0.74	Hosp	Schools (Preschool/ Elementary)	2,187	0.54	Sch
Hospitals / Health Care	7,666	0.74	Hosp	Schools (Technical/ Vocational)	2,187	0.54	CC
Industrial - 1 Shift	2,857	0.67	Ind	Small Services	3,750	0.92	SOfc
Industrial - 2 Shift	4,730	0.67	Ind	Sports Arena	1,954	0.89	Asy
Industrial - 3 Shift	6,631	0.67	Ind	Town Hall	3,748	0.89	Asy
Laundromats	4,056	0.89	SRet	Transportation	6,456	0.89	Asy
Library	3,748	0.89	LOfc	Warehouse (Not Refrigerated)	2,602	0.67	WH
Light Manufacturers**	2,613	0.67	Ind	Waste Water Treatment Plant	6,631	0.67	Ind
Lodging (Hotels/Motels)	3,064	0.92	Hotel/ Motel	Workshop	3,750	0.67	Ind
Mall Concourse	4,833	0.85	LRet				

* New car showrooms and Big Box retail stores with evening and/or weekend hours should use the Facility Type "Retail" for lighting operating hours.
** Lighting operating hours data from the 2008 California DEER Update study
*** Lighting operating hours data for offices used

Example Calculation *(Not to be used as default)*

60 3-lamp, 4-foot T8 fluorescent fixtures in an elementary school near Albany are relamped with DLC qualified LED linear tube lamps. The wattage of the existing fixtures is approximately 88 W. Following relamp, the fixture wattage is reduced to 36 W. The fixtures are on 2,200 hours per year. The school building has central air conditioning and gas heat. Annual Electric Energy Savings, Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta kWh = \left[\frac{(W \times units)_{baseline} - (W \times units)_{ee}}{1{,}000}\right] \times hrs \times (1 + HVAC_c)$$

$$\Delta kW = \left[\frac{(W \times units)_{baseline} - (W \times units)_{ee}}{1{,}000}\right] \times (1 + HVAC_d) \times CF$$

$$\Delta MMBtu = \left[\frac{(W \times units)_{baseline} - (W \times units)_{ee}}{1{,}000}\right] \times hrs \times HVAC_{ff}$$

$units_{baseline}$= 60, from application.
$units_{ee}$= 60, from application.
$W_{baseline}$ = 88, from application
W_{ee} = 36, from application
$hrs_{operating}$ = 2,200 hours/year, from application
$HVAC_c$= 0.060, from Appendix D based on building type, city and fuel type
$HVAC_d$= 0.200, from Appendix D based on building type, city and fuel type
$HVAC_{ff}$= -0.004, from Appendix D based on building type, city and fuel type
CF= 0.54, from Operating hours section based on Facility type.

$$kWh = \left[\frac{(60 \times 88)_{baseline} - (60 \times 36)_{ee}}{1{,}000}\right] \times 2{,}200 \times (1 + 0.060) = 7{,}276\ kWh$$

$$\Delta kW = \left[\frac{(60 \times 88)_{baseline} - (60 \times 36)_{ee}}{1{,}000}\right] \times (1 + 0.200) \times 0.98 = 3.67\ kW$$

$$\Delta MMBtu = \left[\frac{(60 \times 88)_{baseline} - (60 \times 36)_{ee}}{1{,}000}\right] \times 2{,}200 \times -0.004 = -13.7\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Reduction in lighting power increases space heating requirements in conditioned spaces. Interactive HVAC impacts are addressed in prescribed energy savings calculation methodology.

Ancillary Electric Savings Impacts

Reduction in lighting power decreases cooling requirements in conditioned spaces. Interactive HVAC impacts are addressed in prescribed energy savings calculation methodology.

References

1. Large Commercial & Industrial (Large C&I) Program Impact and Process Evaluation, Presented to Con Edison, Prepared by Navigant, August 2019
   Available from:
   http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7BFCA2BA08-4767-4D75-B8FD-1FDE6C09A72F%7D
2. ECCCNYS 2020 Chapter C405.3: Interior Lighting Power Requirements (Prescriptive) & C405.4: Exterior Lighting Power (Mandatory)
   Available from: https://codes.iccsafe.org/content/NYSECC2020P1
3. Lighting operating hour data taken from the CL&P and UI Program Savings Documentation for 2008 Program Year, with exceptions as noted.
   Available from:
   https://library.cee1.org/system/files/library/8821/CEE_Eval_2008ProgramSavingsDocumentPSD_1Jan2008.pdf
4. Additional lighting operating hour data taken from 2008 DEER Update – Summary of Measure Energy Analysis Revisions, August, 2008
   Available from: www.deeresources.com
5. Small Business Direct Install Program Evaluation Review, Prepared for the New York State Department of Public Service-E^2 Working Group, by the Small Commercial EM&V Review subcommittee, April 3, 2015
   Available from:
   https://www3.dps.ny.gov/W/PSCWeb.nsf/96f0fec0b45a3c6485257688006a701a/96006876d01739b785257c85005a58e3/$FILE/ATTGYZRG.pdf/SBDI%20EMV%20studies%20-%20Final%20Report%20-%202015-01-30.pdf

Record of Revision

Record of Revision Number	Issue Date
1	10/15/2010
6-15-4	6/1/2015
1-16-6	12/31/2015
9-17-5	9/30/2017
6-19-10	6/28/2019
3-20-11	3/30/2020

Return to Table of Contents

REFRIGERATED CASE LED

Measure Description

This measure pertains to installation of horizontally or vertically-mounted LED fixtures in commercial display refrigerators, coolers or freezers. Refrigerated case lighting increases the cooling load of the refrigeration system by adding heat to the unit that must be overcome through additional cooling. Replacing fluorescent lamps with low-heat generating LEDs reduces the energy consumption associated with the lighting components and reduces the amount of waste heat generated from the lamps that must be overcome by the refrigeration system.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = \left(\frac{(W \times units)_{baseline} - (W \times units)_{ee}}{1{,}000}\right) \times hrs \times (1 + (Comp_{eff} \times 0.284))$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \left(\frac{(W \times units)_{baseline} - (W \times units)_{ee}}{1{,}000}\right) \times CF \times (1 + (Comp_{eff} \times 0.284))$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

where:

ΔkWh	= Annual electricity energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
W	= Rated wattage of lamp or fixture (Watts)
$_{baseline}$	= Characteristic of baseline condition
$_{ee}$	= Characteristic of energy efficient condition
hrs	= Lighting operating hours
$Comp_{eff}$	= Efficiency of the cooler/freezer compressor (kW/Ton)
CF	= Coincidence factor
0.284	= Conversion factor from kW to tons of refrigeration (Tons/kW)
1,000	= Conversion factor, one kW equals 1,000 Watts

Summary of Variables and Data Sources

Variable	Value	Notes
$W_{baseline}$		From application, or 2 times the proposed LED wattage[1185]
W_{ee}		From application
hrs		From application
$Comp_{eff}$	Refrigerated Case: 1.00 Freezer Case: 1.92	Typical refrigeration system efficiency (kW/Ton)[1186]
CF	0.948	Taken from RLW Analytics, Inc. Coincidence Factor study, "Grocery" facility type

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.948.[1187]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline lighting wattage is the rated or deemed wattage of the existing fixture/lamp. See table of standard fixture wattages in Appendix C. If this data is not available, the baseline wattage shall be the proposed wattage multiplied by 2.

Compliance Efficiency from which Incentives are Calculated

The compliance case is a refrigerated display case with horizontally or vertically-mounted LED lighting.

Operating Hours

Operating hours for refrigerated case lighting will be site-specific and taken from the application. If unavailable, refer to the "Operating Hours" section of the Commercial and Industrial Interior and Exterior Lamps and Fixtures measure for default hours of operation.

Example Calculation *(Not to be used as default)*

Twenty 18 watt vertically mounted LED fixtures are installed in a reach-in refrigerated case in a grocery store near Albany in place of twenty 40 watt fluorescent fixtures. The refrigerated case lights are illuminated approximately 5,000 hours per year. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

[1185] *REVIEW OF UNDERLYING REFERENCE PENDING:* Based on Pacific Gas & Electric. May 2007. LED Refrigeration Case Lighting Workpaper 053007 rev1. This workpaper is not publicly available, but is referenced by Mid-Atlantic TRM Version 7.0 published May 2017. Assumes LED case lighting (7.6W per linear foot) replacing T8 fluorescent baseline (15.2W per linear foot).

[1186] Based on CDH Energy evaluation of actual refrigeration system performance for several commercially available compressors, dated 09/06/2017. Values presented reflect average efficiencies of R22 systems.

[1187] Coincidence Factor Study Residential and Commercial & Industrial Lighting Measures, RLW Analytics, Inc. Spring 2007, Table i-7 (Grocery)

$$\Delta kWh = \left(\frac{(W \times units)_{baseline} - (W \times units)_{ee}}{1{,}000}\right) \times hrs \times (1 + (Comp_{eff} \times 0.284))$$

$$\Delta kW = \left(\frac{(W \times units)_{baseline} - (W \times units)_{ee}}{1{,}000}\right) \times CF \times (1 + (Comp_{eff} \times 0.284))$$

$units_{baseline}$ = 20, from application.
$units_{ee}$ = 20, from application.
$W_{baseline}$ = 40, from application
W_{ee} = 18, from application
Hrs = 5,000 hours/year, from application
$Comp_{eff}$ = 1.00, from Summary of Variables and Data Sources table
CF = 0.948, from Summary of Variables and Data Sources table

$$\Delta kWh = \left(\frac{(40 \times 20)_{baseline} - (18 \times 20)_{ee}}{1{,}000}\right) \times 5{,}000 \times \left(1 + (1.00 \times 0.284)\right) = 2{,}825\ kWh$$

$$\Delta kW = \left(\frac{(40 \times 20)_{baseline} - (18 \times 20)_{ee}}{1{,}000}\right) \times 0.948 \times \left(1 + (1.00 \times 0.284)\right) = 0.54\ kW$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Reduction in refrigerated case lighting power reduces waste heat that must be displaced by the system. Interactive effects are addressed in the prescribed energy savings calculation methodology.

References

1. Coincidence Factor Study Residential and Commercial & Industrial Lighting Measures - For use as an Energy Efficiency Measures/Programs Reference Document for the ISO Forward Capacity Market (FCM), prepared for the New England State Program Working Group by RLW Analytics Inc., Spring 2007.
   Available from:
   https://www.puc.nh.gov/Electric/Monitoring%20and%20Evaluation%20Reports/National%20Grid/116_RLW_CF%20Res%20C&I%20ltg.pdf

Record of Revision

Record of Revision Number	Issue Date
0	10/15/2010
6-15-4	6/1/2015
9-17-6	9/30/2017

Return to Table of Contents

LIGHTING – CONTROL

BI-LEVEL LIGHTING

Measure Description

This measure addresses bi-level occupancy control of lighting in stairwells, corridors, parking garages and parking lots via the installation of controls on existing fixtures or installation of luminaires with integrated bi-level occupancy control. Bi-level occupancy control allows for the continuous lighting of spaces at code-mandated minimum illumination levels when the space is unoccupied and at higher light levels when occupied. This measure is only applicable as a retrofit or replacement in existing buildings because multi-level switching at defined lighting power densities and percentages of full connected load is mandated in many space types by federal, state, local and municipal codes and standards, including but not limited to ECCCNYS 2020[1188]and ASHRAE 90.1-2013.[1189] This measure is restricted to lighting in parking lots and in spaces that are required by fire and safety code to be illuminated continuously. The post-implementation case must comply with all provisions of applicable fire, safety and construction code including but not limited to ECCCNYS 2020[1190], NYSBC 2020[1191], NYSPMC 2020[1192], NFPA Life Safety Code[1193].

Method for Calculating Annual Energy Savings and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times \left[\frac{W_{baseline}}{1{,}000} - \left(\frac{W_{ee}}{1{,}000} \times (1 - ESF)\right)\right] \times hrs$$

Summer Peak Coincident Demand Savings

$$\Delta kW = units \times \left[\frac{W_{baseline}}{1{,}000} - \left(\frac{W_{ee}}{1{,}000} \times (1 - DSF)\right)\right] \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of fixtures equipped with bi-level occupancy control under the program

[1188] ECCCNYS 2020, Section C405
[1189] ASHRAE 90.1-2013, Section 9
[1190] ECCCNYS 2020, Chapter 4
[1191] 2020 Building Code of New York State
[1192] 2020 Property Maintenance Code of New York State
[1193] National Fire Protection Association, Life Safety Code, 2018 Edition

$W_{baseline}$ = Wattage of the existing fixture
W_{ee} = Wattage of the efficient fixture at full light output
ESF = Energy Savings Factor
DSF = Demand Savings Factor
hrs = Annual operating hours
CF = Coincidence Factor
1,000 = Conversion factor, one kW equals 1,000 watts

Summary of Variables and Data Source

Variable	Value	Notes
$W_{baseline}$		From application.
W_{ee}		From application. If bi-level occupancy controls are installed on existing fixtures, $W_{ee} = W_{baseline}$.
ESF		See Energy Savings Factor section below.
hrs	Parking Lots: 4,380 Interior: 8,760	Parking lot lighting is assumed to operate 12 hours per day. For interior spaces, this measure is restricted to those illuminated year-round.
DSF	Parking Garage: ESF Other: 0	DSF shall be set equal to the computed ESF value for parking garages. For all other space types, set DSF equal to 0.
CF	Parking Lots: 0.0 Interior: 1.0	

<u>Energy Savings Factor</u>
The energy savings factor represents the average annual percent reduction in wattage, as compared with the full light output wattage of the efficient case, resulting from bi-level occupancy control capability. The ESF is established based on the low-power mode wattage of the efficient case and assumed occupied hours of the affected space as follows:

$$ESF = F_{low} \times \left(1 - \frac{W_{low}}{W_{ee}}\right)$$

where:
F_{low} = Low-power mode factor; represents the percent of annual operating hours that the fixture operates in low-power mode.
W_{low} = Wattage of the efficient fixture in low-power mode
W_{ee} = Wattage of the efficient fixture at full light output

F_{low}, W_{low} and W_{ee} shall be taken from the application. If unknown, look up F_{low} default values from the table below, based on space type.

Space Type	F_{low}
Stairwell[1194]	0.73
Corridor[1195]	0.75
Parking Garage[1196]	0.56
Parking Lot[1197]	0.45

Coincidence Factor (CF)

The methodology and default values used in this measure assume continuous operation of lighting in affected interior spaces. Therefore, the prescribed value for the coincidence factor for interior spaces is 1.0. Since exterior lighting typically does not operate during daylight hours, the prescribed value for the coincidence factor for parking lots is 0.0.

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is lighting in interior spaces required to be illuminated year-round and lighting in parking lots automatically controlled by photocells or time clocks.

Compliance Efficiency from which Savings are Calculated

The compliance condition is lighting in interior spaces required to be illuminated year-round and parking lots with bi-level occupancy control installed and meeting all provisions of applicable federal, state, local and municipal fire, safety and construction code.

Operating Hours

This measure is restricted to lighting in interior spaces required to be illuminated year-round and parking lots, assumed to operate 12 hours per day. The annual operating hours for these spaces are 8,760 and 4,380, respectively. Typical occupancy assumptions used to derive F_{low} values are as noted in the Energy Savings Factor section above.

Example Calculation *(Not to be used as default)*

Bi-level occupancy control is installed on 40 existing 100 W LED fixtures in a parking garage near NYC. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

$$\Delta kWh = units \times \left[\frac{W_{baseline}}{1{,}000} - \left(\frac{W_{ee}}{1{,}000} \times (1 - ESF)\right)\right] \times hrs$$

[1194] California Energy Commission, Lighting Research Program, Project 5.1 Bi-level Stairwell Fixture Performance Final Report, October 2005 – Average of "Time Dimmed" across the four test sites during weekday operation (Table 2. Weekday daily average energy usage and savings, pg. 22)
[1195] CA State Partnership for Energy Efficiency Demonstrations, Interior Lighting Case Study: Adaptive Corridor Lighting, April 2014, pg. 2
[1196] California Energy Commission Public Interest Energy Research Program, Case Study: Bi-Level LED Parking Garage Luminaires – Average of unoccupied hours across the three test sites
[1197] Pacific Gas & Electric, Application Assessment of Bi-Level LED Parking Lot Lighting, February 2009, pg. 1

$$\Delta kW = units \times \left[\frac{W_{baseline}}{1{,}000} - \left(\frac{W_{ee}}{1{,}000} \times (1 - DSF)\right)\right] \times CF$$

units = 40, from application
$W_{baseline}$ = 110, from application
W_{ee} =110, from application
ESF = 0.56, from Energy Savings Factor section based on space type
Hrs = 8,760, from Summary of Variables and Data Sources table
DSF = 0.56, from Summary of Variables and Data Sources table
CF = 1.0, from Summary of Variables and Data Sources table

$$\Delta kWh = 40 \times \left[\frac{110}{1{,}000} - \left(\frac{110}{1{,}000} \times (1 - 0.56)\right)\right] \times 8{,}760 = 21{,}585\ kWh$$

$$\Delta kW = 40 \times \left[\frac{110}{1{,}000} - \left(\frac{110}{1{,}000} \times (1 - 0.56)\right)\right] \times 1.0 = 2.464\ kW$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Reduction in lighting hours reduces space cooling and increases space heating requirements in conditioned spaces. Interactive HVAC impacts are not included in this methodology.

Ancillary Electric Savings Impacts

Reduction in lighting hours reduces space cooling and increases space heating requirements in conditioned spaces. Interactive HVAC impacts are not included in this methodology.

References

1. ECCCNYS 2020 Chapter 4 Commercial Energy Efficiency
   Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-ce-commercial-energy-efficiency
2. ANSI/ASHRAE/IES Standard 90.1-2013, Energy Standard for Buildings Except Low-Rise Residential Buildings, Section 9. Lighting
3. 2020 Building Code of New York State
   Available from: https://codes.iccsafe.org/content/NYSBC2020P1
4. 2020 Property Maintenance Code of New York State
   Available from: https://codes.iccsafe.org/content/NYSPMC2020P1
5. National Fire Protection Association, Life Safety Code, 2018 Edition
   Available from: https://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards/detail?code=101

6. California Energy Commission, Lighting Research Program, Project 5.1 Bi-level Stairwell Fixture Performance Final Report, October 2005
   Available from: https://ww2.energy.ca.gov/2005publications/CEC-500-2005-141/CEC-500-2005-141-A16.PDF
7. CA State Partnership for Energy Efficiency Demonstrations, Interior Lighting Case Study: Adaptive Corridor Lighting, April 2014
   Available from: http://cltc.ucdavis.edu/sites/default/files/files/publication/CASE_STUDY_UCSF_Adaptive_Corridors_140602.pdf
8. California Energy Commission Public Interest Energy Research Program, Case Study: Bi-Level LED Parking Garage Luminaires
   Available from: http://cltc.ucdavis.edu/sites/default/files/files/publication/case-study-bi-level-led-garage-luminaires.pdf
9. Pacific Gas & Electric, Application Assessment of Bi-Level LED Parking Lot Lighting, February 2009
   Available from: https://www1.eere.energy.gov/buildings/publications/pdfs/ssl/gateway_raleys.pdf

Record of Revision

Record of Revision Number	Issue Date
1-16-11	12/31/2015
9-18-14	9/28/2018

Return to Table of Contents

INTERIOR LIGHTING CONTROL

Measure Description

This measure covers the installation of lighting control systems on lighting in interior spaces. Interior spaces are defined as any covered area not adequately lit during daylight hours by sunlight, thus requiring daytime operation of lighting. Lighting control systems covered under this measure include occupancy sensors, stepped and dimming daylighting controls and networked lighting control systems. These systems save energy and peak demand by shutting off power to lighting fixtures when the space is unoccupied or illumination is not required. They also save energy and demand by reducing power to lighting systems to correct for over-illumination due to excessive lamp output or the presence of daylight. This measure is not applicable in spaces for which occupancy or daylight-responsive controls are required by federal, state, local or municipal codes or standards. Refer to chapter C405.2 Lighting Controls (Mandatory) of the Energy Conservation Construction Code of New York State[1198] (ECCCNYS) for details. Bi-level lighting controls installed in stairwells, corridors, parking garages and parking lots shall use the Commercial Bi-Level Lighting measure detailed in this TRM document.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = \left(\frac{W_{ctrl}}{1{,}000}\right) \times hrs_{baseline} \times ESF \times (1 + HVAC_c)$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \left(\frac{W_{ctrl}}{1{,}000}\right) \times ESF \times (1 + HVAC_d) \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = \left(\frac{W_{ctrl}}{1{,}000}\right) \times hrs_{baseline} \times ESF \times HVAC_{ff}$$

where:

ΔkWh	= Annual electricity energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
W_{ctrl}	= Total wattage of controlled lighting (Watts)
hrs	= Lighting operating hours
baseline	= Characteristic of baseline condition
$HVAC_c$	= HVAC interaction factor for annual electric energy consumption
$HVAC_d$	= HVAC interaction factor at utility summer peak hour
$HVAC_{ff}$	= HVAC interaction factor for annual fossil fuel consumption (MMBtu/kWh)
ESF	= Energy savings factor

[1198] ECCCNYS 2020; C405.2: Lighting Controls (Mandatory)

CF = Coincidence factor
1,000 = Conversion factor, one kW equals 1,000 Watts

Summary of Variables and Data Sources

Variable	Value	Notes
W_{ctrl}		Connected load of controlled lighting fixtures (in Watts), from application
$hrs_{baseline}$		Lighting operating hours. From application or see Operating Hours section below.
$HVAC_c$		HVAC interaction factor for annual electric energy consumption (dimensionless). Vintage and HVAC type weighted average by city. See Appendix D. For lighting in unconditioned space, use a value of 0.
$HVAC_d$		HVAC interaction factor for peak demand at utility summer peak hour (dimensionless). Vintage and HVAC type weighted average by city. See Appendix D. For lighting in unconditioned space, use a value of 0.
$HVAC_{ff}$		HVAC interaction factor for annual fossil fuel energy consumption (MMBtu/kWh). Vintage and HVAC type weighted average by city. See Appendix D. For lighting in unconditioned space, use a value of 0.
ESF		See Energy Savings Factors table below
CF	1.0	"Interior" designation extends to any covered area not adequately lit during daylight hours by sunlight, thus requiring daytime operation of lighting.

Energy Savings Factor[1199]

The ***energy savings factor*** (ESF) is the average annual reduction in electric consumption achieved by a particular control measure type. Energy savings factors for various automated lighting control types are specified in the table below.

Control Type	ESF
Occupant Sensing Controls in large open plan offices: one sensor controlling an area no larger than 125 square feet[1200]	0.40
Occupant Sensing Controls in large open plan offices: one sensor controlling an area between 126 to 250 square feet[1201]	0.30
Occupant Sensing Controls in large open plan offices: one sensor controlling an area between 251 to 500 square feet[1202]	0.20

[1199] The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures; Chapter 3: Commercial and Industrial Lighting Controls Evaluation Protocol, National Renewable Energy Laboratory, September 2017, p. 15
[1200] 2019 Title 24, part 6, Table 140.6-A: Lighting Power Adjustment Factors (PAF)
[1201] Ibid
[1202] Ibid

Control Type	ESF
Occupant Sensing Controls: applicable to all space types other than large open plan offices with one sensor controlling an area less than 500 square feet	0.20
Institutional Tuning in non-daylit areas[1203]	0.10
Institutional Tuning in daylit areas[1204]	0.05
Demand Responsive Control in buildings 10,000 square feet or less[1205]	0.05
Daylight Dimming Control – On/Off Control: Luminaries in skylit daylit zone or primary sidelit daylit zone[1206]	0.10
Daylight Dimming Control – multiple step dimming[1207]	0.20
Daylight Dimming Control – continuous dimming[1208]	0.30
Occupant Sensing with Daylight Dimming Controls – On/Off controls[1209]	0.35
Occupant Sensing with Daylight Dimming Controls – multiple step dimming[1210]	0.35
Networked Lighting Controls[1211]	0.40
Networked Lighting Controls: High Occupancy Hours (See Operating Hours section below)[1212]	0.47

- ***Occupancy Sensor*** – Reduces lighting operating hours by switching off lighting in unoccupied spaces.
- ***Institutional Tuning*** – Allows luminaries in layouts designed with the consideration of a light loss factor to be dimmed to the recommended light level and restored to full output when lumen output has degraded. Maximum light level adjustments are available only to authorized personnel.[1213]
- ***Demand Responsive Control*** – Automatically reduces lighting in response to a demand response signal
- ***Daylight Dimming Control*** – Reduces lighting output to a set level in response to natural daylighting using continuous or stepped dimming capability.
- ***Networked Lighting Control*** – A networked lighting control system consists of an intelligent network of individually addressable luminaires and control devices, allowing for application of multiple control strategies, programmability, building- or enterprise-level control, zoning

[1203] Ibid
[1204] Ibid
[1205] Ibid
[1206] Ibid
[1207] NREL, The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures, Chapter 3: Commercial and Industrial Lighting Controls Evaluation Protocol, Table 4: Lighting Control Savings Factors by Control Type
[1208] Ibid
[1209] Ibid
[1210] Ibid

[1212] Energy Savings from Networked Lighting Control (NLC) Systems, DesignLights Consortium®, September 2017, pg 7.
[1213] 2019 Title 24, part 6, page 64

and rezoning using software, and measuring and monitoring, compliant with DesignLights Consortium V3.0 requirements.[1214]

Coincidence Factor (CF)

The prescribed coincidence factor for commercial indoor lighting measures is 1.0. [1215]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline case for this measure is a lighting system with manual or time-switch controls.

Compliance Efficiency from which Incentives are Calculated

The compliance case is a lighting system with occupancy and/or daylight-responsive controls designed and installed in accordance with manufacturers' and/or designer recommendations.

Operating Hours

The baseline lighting operating hours are the average operating hours for all fixtures subject to lighting control measures before the lighting controls are installed. This information shall be taken from the application. If unavailable, refer to the "Operating Hours" section of the Commercial and Industrial Interior and Exterior Lighting measure for default hours of operation.

Networked Lighting Controls in facilities with occupancy hours that meet or exceed the hours outlined in the table below qualify as high occupancy hour facilities and achieve greater savings.[1216]

Facility Type	Occupancy Hours
Assembly	≥ 5,000
School	≥ 5,000
Manufacturing	≥ 4,000
Retail	≥ 7,000
Restaurant	≥ 6,000
Office	≥ 4,500
Warehouse	≥ 6,000

Example Calculation *(Not to be used as default)*

Occupancy sensors are installed in 8, 150 square foot offices in a small office building near Albany. Each office contains six 24 watt fixtures for a total controlled wattage of 1,152 W. Prior to installation of controls, the fixtures were illuminated for 2,800 hours per year. The building has central air conditioning and gas heat. Annual Electric Energy Savings, Summer

[1214] Networked Lighting Controls V3.0 Requirements, DesignLights Consortium®
[1215] *No source specified – update pending availability and review of applicable references.*
[1216] Energy Savings from Networked Lighting Control (NLC) Systems, DesignLights Consortium®, September 2017, Figure 2. Only the building types listed are eligible for high occupancy designation.

Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta kWh = \left(\frac{W_{ctrl}}{1{,}000}\right) \times hrs_{baseline} \times ESF \times (1 + HVAC_c)$$

$$\Delta kW = \left(\frac{W_{ctrl}}{1{,}000}\right) \times ESF \times (1 + HVAC_d) \times CF$$

$$\Delta MMBtu = \left(\frac{W_{ctrl}}{1{,}000}\right) \times hrs_{baseline} \times ESF \times HVAC_{ff}$$

W_{ctrl} = 1,152, from application
$hrs_{baseline}$= 2,800 hours/year, from application.
$HVAC_c$= 0.100, from Appendix D based on Building Type, City and HVAC type
$HVAC_d$= 0.200, from Appendix D based on Building Type, City and HVAC type
$HVAC_{ff}$ = -0.002, from Appendix D based on Building Type, City and HVAC type
ESF= 0.30, from Energy Savings Factors table
CF =1.0, from Summary of Variables and Data Sources table

$$\Delta kWh = \left(\frac{1{,}152}{1{,}000}\right) \times 2{,}800 \times 0.30 \times (1 + 0.100) = 1{,}064\ kWh$$

$$\Delta kW = \left(\frac{1{,}152}{1{,}000}\right) \times 0.30 \times (1 + 0.200) \times 1.0 = 0.41\ kW$$

$$\Delta MMBtu = \left(\frac{1{,}152}{1{,}000}\right) \times 2{,}800 \times 0.30 \times -0.002 = -1.94\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Reduction in lighting power increases space heating requirements in conditioned spaces. Interactive HVAC impacts are addressed in the prescribed energy savings calculation methodology.

Ancillary Electric Savings Impacts

Reduction in lighting power decreases cooling requirements in conditioned spaces. Interactive HVAC impacts are addressed in the prescribed energy savings calculation methodology.

References

1. The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures; Chapter 3: Commercial and Industrial Lighting Controls Evaluation Protocol, National Renewable Energy Laboratory, September 2017
   Available from: https://www.nrel.gov/docs/fy17osti/68559.pdf
2. Title 24: part 6; 2019 Building Energy Efficiency Standards for Residential and Nonresidential Buildings, California Energy Commission,
   Available from:
   https://ww2.energy.ca.gov/publications/displayOneReport_cms.php?pubNum=CEC-400-2018-020-CMF
3. Networked Lighting Controls V3.0 Requirements, DesignLights Consortium®
   Available from: https://www.designlights.org/workplan/networked-lighting-controls-specification/
4. Energy Savings from Networked Lighting Control (NLC) Systems, DesignLights Consortium®, September 21, 2017
   Available from: https://www.designlights.org/lighting-controls/reports-tools-resources/nlc-energy-savings-report/
5. ECCCNYS 2020 Chapter C405.2: Lighting Controls (Mandatory)
   Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-[ce]-commercial-energy-efficiency#NYSECC2020P1_CE_Ch04_SecC405.2

Record of Revision

Record of Revision Number	Issue Date
1	10/15/2010
6-15-4	6/1/2015
1-16-7	12/31/2015
9-17-7	9/30/2017
3-19-10	3/29/2019
6-19-11	6/28/2019

Return to Table of Contents

MOTORS AND DRIVES

ELEVATOR MODERNIZATION

Measure Description

This measure covers the upgrade of existing elevators by replacing critical components in order for elevators to be able to handle new technology, have better performance, and to operate more efficiently. Elevator modernization typically includes motor upgrades, elevator drive system upgrades, and elevator controller replacement. This measure covers the installation of Silicon-Controlled Rectifier (SCR) drives, Pulse Width Modulation (PWM) drives, and Variable Voltage Variable Frequency (VVVF) drives only. Only the following upgrade configurations are applicable to this measure: VVVF drive systems replace PWM systems, VVVF or PWM drive systems replace SCR systems, and VVVF, PWM, or SCR drive systems replace Motor-Generator (M-G) set systems. The drives may either be regenerative or non-regenerative.

This measure is only applicable as a retrofit and only applies to office and multi-family buildings (e.g. small office, large office, low-rise multifamily, high-rise multifamily). This measure does not cover Destination Dispatch optimization technique.

Methods for calculating savings for M-G set baseline systems are presented below separate from SCR or PWM drive baseline systems in order to differentiate the baseline efficiency term as described in the Baseline Efficiency section below, but also to account for AC motor idling energy consumption present in an M-G set drive. There is no idling motor present in PWM or SCR drive systems, and thus no savings associated with idle energy is claimed in those cases.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

<u>With Motor-Generator set (M-G) as baseline system</u>

$$\Delta kWh = units \times \left[\Delta kWh_{baseline} - \Delta kWh_{ee} + \left(RegenSF \times \Delta kWh_{regen}\right)\right]$$

$$\Delta kWh_{baseline} = \left[\frac{lb_{baseline} \times (1 - OCW_{baseline}) \times (ft/min)_{baseline}}{33{,}000 \times Eff_{hoist}} \times \frac{1}{Eff_{baseline}} \times 0.746 \times LF_{avg} \times hrs\right] + \left[\frac{hp \times 0.746 \times LF_{motor,idle}}{Eff_{baseline}} \times (8{,}760 - hrs) \times F_{idle}\right]$$

$$\Delta kWh_{ee} = \frac{lb_{ee} \times (1 - OCW_{ee}) \times (ft/min)_{ee}}{33{,}000 \times Eff_{hoist}} \times \frac{1}{Eff_{ee}} \times 0.746 \times LF_{avg} \times hrs$$

$$\Delta kWh_{regen} = \frac{lb_{ee} \times (1 - OCW_{ee}) \times (ft/min)_{ee} \times Eff_{ee} \times 0.746}{33{,}000} \times Eff_{regen} \times F_{regen} \times hrs$$

<u>With SCR drive or PWM drive as baseline system</u>

$$\Delta kWh = units \times \left[\Delta kWh_{baseline} - \Delta kWh_{ee} + \left(RegenSF \times \Delta kWh_{regen}\right)\right]$$

$$\Delta kWh_{baseline} = \frac{lb_{baseline} \times (1 - OCW_{baseline}) \times (ft/min)_{baseline}}{33{,}000 \times Eff_{hoist}} \times \frac{1}{Eff_{baseline}} \times 0.746 \times LF_{avg} \times hrs$$

$$\Delta kWh_{ee} = \frac{lb_{ee} \times (1 - OCW_{ee}) \times (ft/min)_{ee}}{33{,}000 \times Eff_{hoist}} \times \frac{1}{Eff_{ee}} \times 0.746 \times LF_{avg} \times hrs$$

$$\Delta kWh_{regen} = \frac{lb_{ee} \times (1 - OCW_{ee}) \times (ft/min)_{ee} \times Eff_{ee} \times 0.746}{33{,}000} \times Eff_{regen} \times F_{regen} \times hrs$$

Summer Peak Coincident Demand Saving

<u>With Motor-Generator set (M-G) as baseline system</u>

$$\Delta kW = units \times \left\{\frac{hp \times 0.746 \times LF_{motor,run}}{Eff_{baseline}} - \frac{lb_{ee} \times (1 - OCW_{ee}) \times (ft/min)_{ee} \times 0.746 \times LF_{peak}}{33{,}000 \times Eff_{hoist} \times Eff_{ee}}\right\}$$

<u>With SCR drive or PWM drive as baseline system</u>

$$\Delta kW = units \times \left\{\left[\frac{lb_{baseline} \times (1 - OCW_{baseline}) \times (ft/min)_{baseline}}{Eff_{baseline}} - \frac{lb_{ee} \times (1 - OCW_{ee}) \times (ft/min)_{ee}}{Eff_{ee}}\right] \times \frac{LF_{peak} \times 0.746}{33{,}000 \times Eff_{hoist}}\right\}$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of units upgraded under the program
baseline	= Characteristic of baseline condition

ee	= Characteristic of energy efficient condition
regen	= Property of regenerative braking
hoist	= Property of elevator hoist system component
RegenSF	= Savings Factor for regenerative braking system
lb	= Capacity of car
OCW	= Overweight of counterbalance as a fraction of car capacity
ft/min	= Rated top velocity of car, in ft/min
Eff	= Energy efficiency
LF_{avg}	= Average load factor
hrs	= Annual hours of elevator operation
hp	= Horsepower of M-G set motor
$LF_{motor,idle}$	= M-G set motor load factor in idling mode
F_{idle}	= Idling factor; used to account for fraction of run hours M-G set system in idling mode
F_{regen}	= Regenerative breaking factor; used account for fraction of run hours regenerative braking produces energy savings
$LF_{motor,run}$	= M-G set motor load factor when loaded
LF_{peak}	= Peak load factor
0.746	= Conversion factor (kW/hp) 0.746 kW equals one electric horsepower
8,760	= Annual hours
33,000	= Conversion factor ((ft-lb/min)/hp), 33,000 foot-pounds per minute equals one electric horsepower

Summary of Variables and Data Sources

Variable	Value	Notes
RegenSF	Regenerative Breaking: 1 No Regenerative Breaking: 0	From application.
$lbs_{baseline}$		From application
lbs_{ee}		From application
$OCW_{baseline}$		From application. Use 0.50 as default. [1217]
OCW_{ee}		From application. Use 0.50 as default. [1218]
$ft/min_{baseline}$		From application
ft/min_{ee}		From application
Eff_{hoist}	0.90	International Association of Elevator Consultants[1219]
Eff_{ee}		See Compliance Efficiencies section below
$Eff_{baseline}$		See Baseline Efficiency section below
Eff_{regen}	0.5	Regenerative efficiency
LF_{avg}	0.35	International Organization for Standardization[1220]

[1217] The Vertical Transportation Handbook, 4th Edition , by George R. Strakosch and Robert S. Caporale, Page 213
[1218] Ibid, 213
[1219] Ibid, Slide 12, 13
[1220] ISO 25745-2:2015: Energy Performance of Lifts, Escalators and Moving Walks -- Part 2: Energy Calculation and Classification for Lifts (elevators)

Variable	Value	Notes
hrs		From application. If unknown, use a default of 2,750 hours.[1221]
F_{regen}	0.5	Regenerative braking eliminates excess heat and supplies electric energy to the building 50% of run time: when lightly loaded car is raised, when fully loaded car is lowered, whenever the car decelerates[1222]
hp		From application.
$LF_{motor,idle}$	0.11	
F_{idle}	Timer incorporated: 0.7 No timer: 1.0 Unknown: 0.7	A timer may be used to disable the elevator during unoccupied hours. [1223]
$LF_{motor,run}$	0.9	Assumed value to reflect that motors do not typically fun at 100% of rated power
LF_{peak}	0.75	International Organization for Standardization[1224]

Coincidence Factor (CF)

The prescribed coincidence factor for this measure is N/A. Appling average load factor at peak is a conservative approach for estimating summer peak demand savings. No further adjustment is required.

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is an existing M-G set, SCR drive, or PWM drive elevator system. The efficiency of the baseline elevator drive systems are derived as follows:

$$Eff_{baseline} = Eff_{motor,baseline} \times Eff_{gear,baseline} \times Eff_{drive,baseline}$$

Summary of Variables and Data Sources

Variable	Value	Notes
$Eff_{motor,baseline}$		NEMA premium efficiency.
$Eff_{drive,baseline}$		From application. If unknown use the following defaults[1225]: SCR6 = 0.85, SCR12 = 0.90, PWM = 0.94.

[1221] The Vertical Transportation Handbook, 4th Edition , by George R. Strakosch and Robert S. Caporale, Table 4.2, Table 4.3, Chart 4.2
[1222] Baldor Motors and Drives, Elevator Application Guide, page 3-6
[1223] No source specified. Actual idling time is based on specific site operating conditions. A value of 70% has been assumed based on a reasonable and conservative approach.
[1224] ISO 25745-2:2015: Energy Performance of Lifts, Escalators and Moving Walks -- Part 2: Energy Calculation and Classification for Lifts (elevators). Coincidence factor is embedded within the peak load factor.
[1225]International Association of Elevator Consultants, Presentation in New York City, May 2011, Slide 11

Variable	Value	Notes
$Eff_{gear,baseline}$	Geared system: 0.85 Gearless system: 1.0	International Association of Elevator Consultants[1226]

Compliance Efficiencies from which Incentives are Calculated

The compliance condition may be either Silicon-Controlled Rectifier (SCR) drive, Pulse Width Modulation (PWM) drive or Variable Voltage Variable Frequency (VVVF) based on the baseline condition, as outlined in the table below:

Acceptable Elevator Replacement Configurations

Baseline Condition	Compliance Condition
M-G Set	SCR, PWM, VVVF drives
SCR drive	PWM, VVVF drives
PWM drive	VVVF drive

The efficiency of the energy efficient elevator drive systems are derived as follows:

Efficiency for SCR, PWM, or VVVF drive energy efficient elevator systems

$$Eff_{ee} = Eff_{motor,ee} \times Eff_{gear,ee} \times Eff_{drive,ee}$$

Summary of Variables and Data Sources

Variable	Value	Notes
$Eff_{motor,ee}$		From application.
$Eff_{drive,ee}$		From application. If unknown, use the following defaults[1227]: SCR6 = 0.85, SCR12 = 0.90, PWM = 0.94, VVVF = 0.95.
$Eff_{gear,ee}$	Geared system: 0.85 Gearless system: 1.0	International Association of Elevator Consultants[1228]

Operating Hours

Elevator operation hours are set by the customer. If elevator operation hours are unknown, use a default value of 2,750 hours

Example Calculation *(Not to be used as default)*

An elevator is upgraded to a geared VVVF drive system with regenerative braking from a geared motor-generator set. The capacity of the car is 2,500 lbs and it has a velocity of 180 ft/min. The hoist motor is rated at 80 hp. The efficiency of the motor in the M-G set is 77%. The overweight of counterbalance as a fraction of car capacity is 0.5. The upgraded elevator is in a large office building and operates approximately 3,00 hours per year. Annual Fossil Fuel

[1226] Ibid, Slide 11
[1227] Ibid, Slide 11
[1228] Ibid, Slide 11

Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

<u>With Motor-Generator set (M-G) as baseline system</u>

$$\Delta kWh = units \times \left[\Delta kWh_{baseline} - \Delta kWh_{ee} + \left(RegenSF \times \Delta kWh_{regen}\right)\right]$$

$$\Delta kWh_{baseline} = \left[\frac{lb_{baseline} \times (1 - OCW_{baseline}) \times (ft/min)_{baseline}}{33{,}000 \times Eff_{hoist}} \times \frac{1}{Eff_{baseline}} \times 0.746 \times LF_{avg} \times hrs\right] + \left[\frac{hp \times 0.746 \times LF_{motor,idle}}{Eff_{baseline}} \times (8{,}760 - hrs) \times F_{idle}\right]$$

$$\Delta kWh_{ee} = \frac{lb_{ee} \times (1 - OCW_{ee}) \times (ft/min)_{ee}}{33{,}000 \times Eff_{hoist}} \times \frac{1}{Eff_{ee}} \times 0.746 \times LF_{avg} \times hrs$$

$$\Delta kWh_{regen} = \frac{lb_{ee} \times (1 - OCW_{ee}) \times (ft/min)_{ee} \times Eff_{ee} \times 0.746}{33{,}000} \times Eff_{regen} \times F_{regen} \times hrs$$

$$\Delta kW = units \times \left\{\frac{hp \times 0.746 \times LF_{motor,run}}{Eff_{baseline}} - \frac{lb_{ee} \times (1 - OCW_{ee}) \times (ft/min)_{ee} \times 0.746 \times LF_{peak}}{33{,}000 \times Eff_{hoist} \times Eff_{ee}}\right\}$$

$$Eff_{baseline} = Eff_{motor,baseline} \times Eff_{gear,baseline} \times Eff_{drive,baseline}$$

$$Eff_{ee} = Eff_{motor,ee} \times Eff_{gear,ee} \times Eff_{drive,ee}$$

units = 1, from application
RegenSF = 1, from Summary of Variables and Data Sources
$lbs_{baseline}$= 2,500, From application
lbs_{ee}= 2,500, From application
$OCW_{baseline}$ = 0.5, from application
OCW_{ee} = 0.5, from application
$ft/min_{baseline}$ = 180 ft/min, from application
ft/min_{ee} = 180 ft/min, from application
Eff_{hoist} = 0.90, from Summary of Variables and Data Sources
Eff_{regen}=0.5, from Summary of Variables and Data Sources
LF_{avg}=0.35, from Summary of Variables and Data Sources
hrs = 3,000, from application
F_{regen} = 0.5, from Summary of Variables and Data Sources

hp =80, from application.
$LF_{motor,idle}$ = 0.11, from Summary of Variables and Data Sources
F_{idle} = 0.7, from Summary of Variables and Data Sources
$LF_{motor,run}$ = 0.9, from Summary of Variables and Data Sources
LF_{peak} = 0.75, from Summary of Variables and Data Sources
$Eff_{drive,baseline}$ = 0.77, from application
$Eff_{gear,baseline}$ = 0.85, from Summary of Variables and Data Sources in Baseline Efficiency section
$Eff_{gear,ee}$ = 0.85, from Summary of Variables and Data Sources in Compliance Efficiency section
$Eff_{drive,ee}$ = 0.95, from Summary of Variables and Data Sources in Compliance Efficiency section

$$Eff_{baseline} = 0.9 \times 0.85 \times 0.77 = 0.589$$

$$Eff_{ee} = 0.9 \times 0.85 \times 0.95 = 0.727$$

$$\Delta kWh_{baseline} = \left[\frac{2{,}500 \times (1-0.5) \times 180}{33{,}000 \times 0.9} \times \frac{1}{0.589} \times 0.746 \times 0.35 \times 3{,}000\right] + \left[\frac{80 \times 0.746 \times 0.11}{0.589} \times (8{,}760 - 3{,}000) \times 0.7\right] = 55{,}014$$

$$\Delta kWh_{ee} = \frac{2{,}500 \times (1-0.5) \times 180}{33{,}000 \times 0.9} \times \frac{1}{0.727} \times 0.746 \times 0.35 \times 3{,}000 = 8{,}162$$

$$\Delta kWh_{regen} = \frac{2{,}500 \times (1-0.5) \times 180 \times 0.727 \times 0.746}{33{,}000} \times 0.5 \times 0.5 \times 3{,}000 = 2{,}773$$

$$\Delta kWh = 1 \times [55{,}014 - 8{,}162 + (1 \times 2{,}773)] = 49{,}625\ kWh$$

$$\Delta kW = 1 \times \left\{\left[\frac{2{,}500 \times (1-0.5) \times 180}{0.589} - \frac{2{,}500 \times (1-0.50) \times 180}{0.727}\right] \times \frac{0.75 \times 0.746}{33{,}000 \times 0.9}\right\} = 1.366\ kW$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

When travelling, elevators convert stored mechanical energy into electrical energy. In non-regenerative braking elevator systems, the energy is dissipated as heat. In regenerative braking elevator systems, the electrical energy is reclaimed by the building and offsets energy loads. When an elevator system is upgraded to a system with regenerative braking, energy savings are realized in the elimination of the dissipated heat and through the alleviation of building load.

References

1. The Vertical Transportation Handbook, 4th Edition , by George R. Strakosch and Robert S. Caporale
2. Elevator Application Guide, By Baldor Motors and Drives, Page 3-6;
   Available from: https://www.baldor.com/Shared/manuals/770-397.pdf
3. ISO 25745-2:2015: Energy Performance of Lifts, Escalators and Moving Walks -- Part 2: Energy Calculation and Classification for Lifts (elevators)
   ASHRAE 90.1 – 2016
4. International Association of Elevator Consultants, Presentation in New York City, May 2011;
   Available from:
   https://www.iaec.org/IAEC/IAEC_Forum_Presentations_files/Magnetek_Presentation_IAEC_NYC_May2011%5b1%5d.pdf
5. ECCCNYS 2020 Table C403.3.2(1): Minimum Efficiency Requirements: Electrically Operated Unitary Air Conditioners And Condensing Units & Table C403.3.2(5): Minimum Efficiency Requirements: Gas- And Oil-Fired Boilers.
   Available from: https://codes.iccsafe.org/content/NYSECC2020P1

Record of Revisions

Record of Revision Number	Issue Date
9-19-7	9/27/2019

Return to Table of Contents

MOTOR

Measure Description

This measure covers the installation of high efficiency, three-phase electric HVAC fan or pump motors of 200 hp or less in commercial and industrial applications.[1229] Full-load efficiency of installed equipment must exceed current code requirements as defined in the Baseline Efficiency section below to qualify. Estimated energy savings are based on increased operating efficiency.

Efficient motors generally run at slightly higher RPM than standard motors. Unless the motor drive system is modified to correct for higher RPM operation, the power delivered by the motor may increase. This increase in power delivery may negate the effects of improved efficiency. Therefore, when replacing a standard-efficiency motor, a high-efficiency motor with lower or equal full-load speed must be selected to prevent any negation of predicted energy savings resulting from a higher efficiency. To provide the correct flow, it may be necessary to adjust fan sheaves or pump-impeller diameters.[1230]

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times hp \times RLF \times 0.746\ (kW/hp) \times \left[\left(\frac{1}{Eff_{baseline}}\right) - \left(\frac{1}{Eff_{ee}}\right)\right] \times FLH$$

Summer Peak Coincident Demand Savings

$$\Delta kW = units \times hp \times RLF \times 0.746\ (kW/hp) \times \left[\left(\frac{1}{Eff_{baseline}}\right) - \left(\frac{1}{Eff_{ee}}\right)\right] \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
hp	= Horsepower
RLF	= Rated load factor
baseline	= Characteristic of baseline condition
ee	= Characteristic of energy efficient condition
Eff	= Energy efficiency (0 -100%)
FLH	= Full-load hours

[1229] Partners Listing of NEMA Premium Compliant Electric Motors (accessed 3/19/2018)
[1230] Energy Innovators Initiative, Office of Energy Efficiency, Natural Resources Canada, Premium-Efficiency Motors

CF = Coincidence factor
0.746 = Conversion factor (kW/hp), 746 watts equals one horsepower

Summary of Variables and Data Sources

Variable	Value	Notes
hp		Rated horsepower of the efficient equipment, from application.
$Eff_{baseline}$		Full-load efficiency of the baseline motor. Look up from Appendix L based on efficient motor type (open or enclosed), number of poles (2, 4 or 6) and horsepower.
Eff_{ee}		Full-load efficiency of the efficient motor, from application.
RLF		Ratio of the peak annual motor load to the maximum connected load (RLF = hp_{peak}/hp_{max}), from application. If unknown, assume 0.75.[1231]
FLH		Full-load hours in the energy efficient case, from application. If unknown, look up based on facility type and motor application in the Operating Hours section below.
CF	0.8	

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.8.[1232]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a three-phase electric HVAC fan or pump motor of equivalent type, speed and horsepower to the efficient case with minimally code compliant full-load efficiency per Appendix L, established by ECCCNYS[1233] in accordance with federal energy conservation standards.[1234]

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a three-phase electric HVAC fan or pump motor with a speed at or below that of the baseline motor and full-load efficiency exceeding the baseline NEMA premium full-load efficiency established per the Baseline Efficiencies section above.

Operating Hours

Motor full-load hours are defined as the total annual energy consumption divided by the peak hourly demand.

[1231] U.S. DOE, Determining Electric Motor Load and Efficiency, p. 1; assumes system is designed to maximize efficiency.
[1232] *No source specified – update pending availability and review of applicable references.*
[1233] ECCCNYS 2020, Table C405.7(1)
[1234] 10 CFR 431.25(h) Table 5

$$FLH = \frac{kWh}{kW_{max}}$$

For loads that do not vary with time (i.e., a motor driving a constant load), full-load hours are equal to the operating hours.

If full-load hours are unknown, use default values based on the application and building type from the table below.[1235]

Facility Type	Distribution Fan Motor	CHWP & Cooling Towers	Heating Pumps
Auto Related	4,056	1,878	5,376
Bakery	2,854	1,445	5,376
Banks, Financial Centers	3,748	1,767	5,376
Church	1,955	1,121	5,376
College - Cafeteria	6,376	2,713	5,376
College - Classes/Administrative	2,586	1,348	5,376
College - Dormitory	3,066	1,521	5,376
Commercial Condos	4,055	1,877	5,376
Convenience Stores	6,376	2,713	5,376
Convention Center	1,954	1,121	5,376
Court House	3,748	1,767	5,376
Dining: Bar Lounge/Leisure	4,182	1,923	5,376
Dining: Cafeteria / Fast Food	6,456	2,742	5,376
Dining: Family	4,182	1,923	5,376
Entertainment	1,952	1,120	5,376
Exercise Center	5,836	2,518	5,376
Fast Food Restaurants	6,376	2,713	5,376
Fire Station (Unmanned)	1,953	1,121	5,376
Food Stores	4,055	1,877	5,376
Gymnasium	2,586	1,348	5,376
Hospitals	7,674	3,180	5,376
Hospitals / Health Care	7,666	3,177	5,376
Industrial - 1 Shift	2,857	1,446	5,376
Industrial - 2 Shift	4,730	2,120	5,376
Industrial - 3 Shift	6,631	2,805	5,376
Laundromats	4,056	1,878	5,376
Library	3,748	1,767	5,376
Light Manufacturers	2,857	1,446	5,376
Lodging (Hotels/Motels)	3,064	1,521	5,376
Mall Concourse	4,833	2,157	5,376
Manufacturing Facility	2,857	1,446	5,376

[1235] Connecticut Program Savings Document, 12th Edition for 2017 Program Year, UIL Holdings Corporation and Eversource Energy, October 2016. Appendix 5, Hours of Use

Facility Type	Distribution Fan Motor	CHWP & Cooling Towers	Heating Pumps
Medical Offices	3,748	1,767	5,376
Motion Picture Theatre	1,954	1,121	5,376
Multi-Family (Common Areas)	7,665	3,177	5,376
Museum	3,748	1,767	5,376
Nursing Homes	5,840	2,520	5,376
Office (General Office Types)	3,748	1,767	5,376
Office/Retail	3,748	1,767	5,376
Parking Garages & Lots	4,368	1,990	5,376
Penitentiary	5,477	2,389	5,376
Performing Arts Theatre	2,586	1,348	5,376
Police / Fire Stations (24 Hr)	7,665	3,177	5,376
Post Office	3,748	1,767	5,376
Pump Stations	1,949	1,119	5,376
Refrigerated Warehouse	2,602	1,354	5,376
Religious Building	1,955	1,121	5,376
Residential (Except Nursing Homes)	3,066	1,521	5,376
Restaurants	4,182	1,923	5,376
Retail	4,057	1,878	5,376
School / University	2,187	1,205	5,376
Small Services	3,750	1,768	5,376
Sports Arena	1,954	1,121	5,376
Town Hall	3,748	1,767	5,376
Transportation	6,456	2,742	5,376
Warehouse (Not Refrigerated)	2,602	1,354	5,376
Waste Water Treatment Plant	6,631	2,805	5,376
Workshop	3,750	1,768	5,376

Example Calculation *(Not to be used as default)*

A 10 hp HVAC fan motor is replaced with a 97.4% efficient, three-phase, 4 pole enclosed motor with an estimated load factor of 0.74. The distribution fan motor remains in operation for 4,000 hours per year. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

$$\Delta kWh = units \times hp \times RLF \times 0.746\ (kW/hp) \times \left[\left(\frac{1}{Eff_{baseline}}\right) - \left(\frac{1}{Eff_{ee}}\right)\right] \times FLH$$

$$\Delta kW = units \times hp \times RLF \times 0.746\ (kW/hp) \times \left[\left(\frac{1}{Eff_{baseline}}\right) - \left(\frac{1}{Eff_{ee}}\right)\right] \times CF$$

hp = 10, from application

$Eff_{baseline}$ = 0.917, from Appendix L based on efficient motor type, number of poles and

horsepower
Eff_{ee}= 0.974, from application
RLF = 0.74, from application
FLH = 4,0000 hours, from application
CF=0.8

$$\Delta kWh = 1 \times 10 \times 0.74 \times 0.746 \times \left[\left(\frac{1}{0.917}\right) - \left(\frac{1}{0.974}\right)\right] \times 4{,}000 = 1{,}409\ kWh$$

$$\Delta kW = 1 \times 10 \times 0.74 \times 0.746 \times \left[\left(\frac{1}{0.917}\right) - \left(\frac{1}{0.974}\right)\right] \times 0.8 = 0.282\ kW$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

High efficiency motors reject less heat into the conditioned space increasing space heating requirements while decreasing cooling load. These impacts are not considered in the prescribed formulation of savings.

Ancillary Electric Savings Impacts

High efficiency motors reject less heat into the conditioned space increasing space heating requirements while decreasing cooling load. These impacts are not considered in the prescribed formulation of savings.

References

1. Partners Listing of NEMA Premium Compliant Electric Motors
   Available from:
   https://www.nema.org/Policy/Energy/Documents/Nema_Premium_Partners.pdf
2. Energy Innovators Initiative, Office of Energy Efficiency, Natural Resources Canada, Premium-Efficiency Motors
   Available from: https://www.prismengineering.com/sites/default/files/upload/fact-sheets/Prism-Fact-sheet-Premium-efficiency-motors.pdf
3. U.S. DOE, Determining Electric Motor Load and Efficiency
   Available from: https://energy.gov/sites/prod/files/2014/04/f15/10097517.pdf
4. ECCCNYS 2020 Table C405.7(1): Minimum Nominal Full-Load Efficiency For NEMA Design A, NEMA Design B, and IEC Design N Motors (Excluding Fire Pump) Electric Motors at 60 HZ
   Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-[ce]-commercial-energy-efficiency#NYSECC2020P1_CE_Ch04_SecC405.7

5. 10 CFR 431.25 (h) Table 5: Nominal Full-Load Efficiencies of NEMA Design A, NEMA Design B and IEC Design N Motors (Excluding Fire Pump Electric Motors) at 60Hz
   Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=5423daf354376cde95da84156e424cc8&mc=true&node=pt10.3.431&rgn=div5#sp10.3.431.b
6. Connecticut Program Savings Document, 12th Edition for 2017 Program Year, UIL Holdings Corporation and Eversource Energy, October 2016

Record of Revision

Record of Revision Number	Issue Date
1	10/15/2010
6-18-12	6/26/2018

Return to Table of Contents

NOTCHED AND SYNCHRONOUS BELT

Measure Description

This measure covers the replacement of smooth V-belts in electric HVAC fan or pump motors with notched or synchronous belts. V-belts between the motor and the supply air fan and/or return air fan are typical in larger packaged and split HVAC systems. A notched belt has grooves or notches that run perpendicular to the belt's length, which reduces the bending resistance of the belt. Notched belts can use the same pulleys as cross-section standard V-belts. They run cooler, last longer, and are about 2% more efficient than standard V-belts. Synchronous belts (also called cogged, timing, positive-drive, or high-torque drive belts) are toothed and require the installation of mating grooved sprockets. These belts operate with a consistent efficiency of 98% and maintain their efficiency over a wide load range.

Estimated savings are based upon the improved transfer of the motor shaft energy to the fan by replacing a smooth V-belt with a notched belt or synchronous belt in a belt drive system. The savings assume that the fan speed remains the same while the motor operates at a lower torque and speed. For notched belts, adjustable pulleys provide easy reductions in fan speed.[1236] For synchronous belts, belt sockets must be selected that correct for the improved transmission of motor energy or the actual operating costs can increase.[1237]

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times \frac{hp \times 0.746}{Eff_{motor}} \times RLF \times \left(\frac{1}{Eff_{baseline}} - \frac{1}{Eff_{ee}}\right) \times FLH \times (1 + HVAC_c)$$

Summer Peak Coincident Demand Savings

$$\Delta kW = units \times \frac{hp \times 0.746}{Eff_{motor}} \times RLF \times \left(\frac{1}{Eff_{baseline}} - \frac{1}{Eff_{ee}}\right) \times (1 + HVAC_d) \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = units \times \frac{hp \times 0.746}{Eff_{motor}} \times RLF \times \left(\frac{1}{Eff_{baseline}} - \frac{1}{Eff_{ee}}\right) \times FLH \times HVAC_{ff}$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of motors converted to notched or synchronous belts
hp	= Horsepower per retrofitted motor

[1236] Changing Fan Speed with an Adjustable Pulley, Rob "Doc" Falke, Contracting Business Magazine, April 18,2012

[1237] Replace V-Belts with Cogged or Synchronous Belt Drives, The News, November 3, 2008.

RLF = Rated load factor
$Eff_{baseline}$ = Efficiency of V-belts
Eff_{ee} = Efficiency of notched or synchronous belts
Eff_{motor} = Efficiency of retrofitted motor (existing motor is assumed to remain in place)
FLH = Full-load hours
$HVAC_c$ = HVAC interaction factor for annual electric energy consumption
$HVAC_d$ = HVAC interaction factor at utility summer peak hour
$HVAC_{ff}$ = HVAC interaction factor for annual fossil fuel consumption
CF = Coincidence factor
0.746 = Conversion factor (kW/hp), 746 watts equals one horsepower

Summary of Variables and Data Sources

Variable	Value	Notes
hp		Rated horsepower of the retrofitted motor, from application.
Eff_{motor}		Full-load efficiency of the baseline motor, from application. Or look up from Appendix L based on efficient motor type (open or enclosed), number of poles (2, 4 or 6) and horsepower. If unknown assume 0.93.[1238]
RLF		Percent of rated motor load at normal operation. (RLF = hp_{peak}/hp_{max}), from application. If unknown, assume 0.75.[1239]
FLH		Full-load hours in the energy efficient case, from application. If unknown, look up based on facility type and motor application in the Operating Hours section below.
$Eff_{baseline}$	0.93	US DOE[1240]
Eff_{ee}	Notched: 0.95 Synchronous: 0.98	Use default value based upon efficient belt type from application for notched[1241] and synchronous[1242] belt drives.
$HVAC_c$		HVAC interaction factor for annual electric energy consumption (dimensionless). For motors in unconditioned spaces, set to 0. Otherwise, this value shall come from Appendix D in based on vintage and HVAC type weighted average by city.
$HVAC_d$		HVAC interaction factor for peak demand at utility summer peak hour (dimensionless). For motors in unconditioned spaces, set to 0. Otherwise, this value shall come from Appendix D in based on vintage and HVAC type weighted average by city.

[1238] Premium-Efficiency Motors, Energy Innovators Initiative Technical Fact Sheet, Office of Energy Efficiency of Natural Resources Canada. Average efficiency of 75% load premium motors 5-50 hp.
[1239] U.S. DOE, Determining Electric Motor Load and Efficiency, p. 1; assumes system is designed to maximize efficiency.
[1240] U.S. DOE, Motor Tip Sheet #3, Replace V-Belts with Cogged or Synchronous Belt Drives, Motor Tip Sheet #3, DOE/GO-102000-0972, January 2000. Nominal efficiency of unmaintained belt.
[1241] Ibid. 2% better than standard V-belt
[1242] Ibid.

Variable	Value	Notes
$HVAC_{ff}$		HVAC interaction factor for annual fossil fuel energy consumption (MMBtu/kWh). For motors in unconditioned spaces, set to 0. Otherwise, this value shall come from Appendix D in based on vintage and HVAC type weighted average by city.
CF	0.8	

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.8.[1243]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is an electric HVAC fan or pump motor driven by a smooth V-belt system.

Compliance Efficiency from which Incentives are Calculated

The energy efficient condition is an electric HVAC fan or pump motor driven by a notched or synchronous belt system.

Operating Hours

Motor full-load hours are defined as the total annual energy consumption divided by the peak hourly demand.

$FLH = kWh/kW_{max}$

For loads that do not vary with time (i.e., a motor driving a constant load), full-load hours are equal to the operating hours.

If full-load hours are unknown, use default values based on the application and building type from the table below.[1244]

Annual Operating Hours

Facility Type	Distribution Fan Motor (hours)	Cooling Tower Fans (hours)
Auto Related	4,056	1,878
Bakery	2,854	1,445
Banks, Financial Centers	3,748	1,767
Church	1,955	1,121
College - Cafeteria	6,376	2,713
College - Classes/Administrative	2,586	1,348
College - Dormitory	3,066	1,521

[1243] *No source specified – update pending availability and review of applicable references.*

[1244] Connecticut Program Savings Document, 12th Edition for 2017 Program Year, UIL Holdings Corporation and Eversource Energy, October 2016. Appendix 5, Hours of Use

Facility Type	Distribution Fan Motor (hours)	Cooling Tower Fans (hours)
Commercial Condos	4,055	1,877
Convenience Stores	6,376	2,713
Convention Center	1,954	1,121
Court House	3,748	1,767
Dining: Bar Lounge/Leisure	4,182	1,923
Dining: Cafeteria / Fast Food	6,456	2,742
Dining: Family	4,182	1,923
Entertainment	1,952	1,120
Exercise Center	5,836	2,518
Fast Food Restaurants	6,376	2,713
Fire Station (Unmanned)	1,953	1,121
Food Stores	4,055	1,877
Gymnasium	2,586	1,348
Hospitals	7,674	3,180
Hospitals / Health Care	7,666	3,177
Industrial - 1 Shift	2,857	1,446
Industrial - 2 Shift	4,730	2,120
Industrial - 3 Shift	6,631	2,805
Laundromats	4,056	1,878
Library	3,748	1,767
Light Manufacturers	2,857	1,446
Lodging (Hotels/Motels)	3,064	1,521
Mall Concourse	4,833	2,157
Manufacturing Facility	2,857	1,446
Medical Offices	3,748	1,767
Motion Picture Theatre	1,954	1,121
Multi-Family (Common Areas)	7,665	3,177
Museum	3,748	1,767
Nursing Homes	5,840	2,520
Office (General Office Types)	3,748	1,767
Office/Retail	3,748	1,767
Parking Garages & Lots	4,368	1,990
Penitentiary	5,477	2,389
Performing Arts Theatre	2,586	1,348
Police / Fire Stations (24 Hr)	7,665	3,177
Post Office	3,748	1,767
Pump Stations	1,949	1,119
Refrigerated Warehouse	2,602	1,354
Religious Building	1,955	1,121
Residential (Except Nursing Homes)	3,066	1,521

Facility Type	Distribution Fan Motor (hours)	Cooling Tower Fans (hours)
Restaurants	4,182	1,923
Retail	4,057	1,878
School / University	2,187	1,205
Small Services	3,750	1,768
Sports Arena	1,954	1,121
Town Hall	3,748	1,767
Transportation	6,456	2,742
Warehouse (Not Refrigerated)	2,602	1,354
Waste Water Treatment Plant	6,631	2,805
Workshop	3,750	1,768

Example Calculation *(Not to be used as default)*

A smooth V-belt driving a 92% efficient 10 hp HVAC fan motor that operates 4,00 hours per year is replaced with a notched belt in an assembly building near Albany. The building is equipped with central air conditioning with electric heat. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

$$\Delta kWh = units \times \frac{hp \times 0.746}{Eff_{motor}} \times RLF \times \left(\frac{1}{Eff_{baseline}} - \frac{1}{Eff_{ee}}\right) \times FLH \times (1 + HVAC_c)$$

$$\Delta kW = units \times \frac{hp \times 0.746}{Eff_{motor}} \times RLF \times \left(\frac{1}{Eff_{baseline}} - \frac{1}{Eff_{ee}}\right) \times (1 + HVAC_d) \times CF$$

units = 1, from application
hp = 10, from application
Eff_{motor} = 0.92, from application
RLF = 0.75, default from Summary of Variables and Data Sources
FLH = 4,000 hours, from application
$Eff_{baseline}$ = 0.93, from Summary of Variables and Data Sources
Eff_{ee} = 0.95, from Summary of Variables and Data Sources
$HVAC_c$ = -0.536, from Appendix D in based on vintage and HVAC type weighted average by city.
$HVAC_d$= 0.200, from Appendix D in based on vintage and HVAC type weighted average by city.
CF=0.8

$$\Delta kWh = 1 \times \frac{10 \times 0.746}{0.92} \times 0.75 \times \left(\frac{1}{0.93} - \frac{1}{0.95}\right) \times 4{,}000 \times (1 + (-0.536)) = 256\ kWh$$

$$\Delta kW = 1 \times \frac{10 \times 0.746}{0.92} \times 0.75 \times \left(\frac{1}{0.93} - \frac{1}{0.95}\right) \times (1 + 0.200) \times 0.8 = 0.132\ kW$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

High efficiency belt drive systems reject less heat into the conditioned space increasing space heating requirements. The HVAC interaction factors calculated from the prototypical building DOE-2 models as a function of the building and HVAC system type are shown in Appendix D..

Ancillary Electric Savings Impacts

High efficiency belt drive systems reject less heat into the conditioned space increasing space heating requirements while decreasing cooling load. The HVAC interaction factors calculated from the prototypical building DOE-2 models as a function of the building and HVAC system type are shown in Appendix D..

References

1. Changing Fan Speed with an Adjustable Pulley, Rob "Doc" Falke, Contracting Business Magazine, April 18,2012
   Available from: https://www.contractingbusiness.com/archive/changing-fan-speed-adjustable-pulley
2. Replace V-Belts with Cogged or Synchronous Belt Drives, The News, November 3, 2008
   Available from: https://www.achrnews.com/articles/107928-replace-v-belts-with-cogged-or-synchronous-belt-drives
3. Office of Energy Efficiency of Natural Resources Canada, Energy Innovators Initiative Technical Fact Sheet, Premium-Efficiency Motors
   Available from: https://www.prismengineering.com/sites/default/files/upload/fact-sheets/Prism-Fact-sheet-Premium-efficiency-motors.pdf
4. U.S. DOE, Determining Electric Motor Load and Efficiency
   Available from: https://energy.gov/sites/prod/files/2014/04/f15/10097517.pdf
5. U.S. DOE, Motor Tip Sheet #3, Replace V-Belts with Cogged or Synchronous Belt Drives
   Available from: https://www.nrel.gov/docs/fy00osti/27833.pdf
6. Connecticut Program Savings Document, 12th Edition for 2017 Program Year, UIL Holdings Corporation and Eversource Energy, October 2016. Appendix 5, Hours of Use.
   Available from: https://www.puc.nh.gov/EESE%20Board/EERS_WG/ct_trm.pdf

Record of Revisions

Record of Revision Number	Issue Date
7-20-17	7/31/2020
12-20-10	12/31/2020

Return to Table of Contents

PEI-RATED CLEAN WATER PUMP

Measure Description

The measure covers the installation of constant and variable speed PEI-rated clean water pumps in agricultural, commercial, industrial and municipal environments. PEI-rated clean water pumps refer to clean water pumps rated using the Pump Energy Index (PEI), a metric established by the DOE to rate pump efficiency.[1245] As a rating, PEI refers to the ratio of a pump's energy rating divided by the energy rating of a minimally compliant pump with lower PEI indicating greater efficiency. As of January 27, 2020, all clean water pumps between 1 and 200 hp are required to have a PEI rating less than 1.0. Circulator pumps, pool pumps, fire pumps and magnet driven pumps fall outside of the scope of this measure. [1246]

The PEI rated clean water pumps category consists of five pump types: Radially Split Multi-Stage Vertical In-Line Diffuser Casing (RSV), Vertical Submersible Turbine (ST), End Suction Close Coupled (ESCC), In-Line (IL) and End Suction Frame Mount (ESFM).Each pump type is further broken into constant and variable speed models. Pumps are generally offered with either 1800 RPM or 3600 RPM (nominal) motors.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = hp \times 0.746 \times (1 - OF) \times (PEI_{baseline} - PEI_{ee}) \times LSAF \times hrs$$

Summer Peak Coincident Demand Savings

$$\Delta kW = hp \times 0.746 \times RLF \times (PEI_{baseline} - PEI_{ee}) \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

where:

ΔkWh	= Annual electricity energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
hp	= Pump motor horsepower
OF	= Oversize Factor
baseline	= Characteristic of baseline condition
ee	= Characteristic of energy efficient condition
PEI	= Pump Energy Index
LSAF	= Load Shape Adjustment Factor
hrs	= Annual hours of operation
RLF	= Rated load factor

[1245] 10 CFR 431.464 Appendix A
[1246] 10 CFR 431.465

CF = Coincidence factor
0.746 = Conversion factor (kW/hp), 746 watts equals one horsepower

Summary of Variables and Data Sources

Variable	Value	Notes
hp		From application.
OF		Average amount of equipment oversizing. Lookup from Oversize Factor table below based on speed control case and motor hp.
$PEI_{baseline}$		See Baseline Efficiency section below.
PEI_{ee}		From application
LSAF		Lookup from Load Shape Adjustment Factor table below based on application and speed control case.
hrs		From application. If unknown, see Operating Hours section below for default values by building sector.
RLF	0.75	Ratio of the peak motor load to the maximum connected load.[1247,1248]
CF	0.8	

Oversize Factor[1249]

Speed Control Case	Motor Size Range		Oversize Factor
	Min. HP	Max. HP	
Constant Speed	1	4.9	0.37
	5	9.9	0.31
	10	24.9	0.26
	25	49.9	0.24
	50	99.9	0.20
	100	200	0.17
Variable Speed	1	1.9	0.37
	2	2.9	0.37
	3	4.9	0.37
	5	9.9	0.31
	10	24.9	0.26
	25	49.9	0.24
	50	99.9	0.20
	100	200	0.17

[1247] U.S. DOE, Determining Electric Motor Load and Efficiency, p. 1; assumes system is designed to maximize efficiency.
[1248] RLF value assumed for PEI pumps is under review and will be revised when a substantiating reference has been identified.
[1249] Regional Technical Forum, Efficient Pumps v2.0, Parameters worksheet, row 15

Load Shape Adjustment Factor, by application and speed control case[1250]

Application	Constant Speed	Variable Speed
Agricultural	1.325	1.845
Commercial	1.250	1.000
Industrial	1.310	1.214
Municipal	0.840	0.990

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.8.[1251]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a pump with a high PEI rating. The baseline PEI rating for constant speed pumps is 1.0 per federal requirements.[1252] Baseline PEI values for variable speed pumps are based on the table below. Savings for variable speed pumps installed in new construction projects may be calculated using the constant speed pump baseline if code does not require a variable speed pump.

The PEI rated clean water pumps category consists of five pump types: Radially Split Multi-Stage Vertical In-Line Diffuser Casing (RSV), Vertical Submersible Turbine (ST), End Suction Close Coupled (ESCC), In-Line (IL) and End Suction Frame Mount (ESFM).

Variable Speed Baseline PEI[1253]

Pump Type	Motor Speed (RPM)	Pump Motor hp							
		1 to 1.9 hp	2 to 2.9 hp	3 to 4.9 hp	5 to 9.9 hp	10 to 24.9 hp	25 to 49.9 hp	50 to 99.9 hp	100 to 200 hp
RSV	1800	0.55	0.55	0.52	0.50	0.49	0.48	0.47	0.48
ST	1800	0.61	0.60	0.58	0.56	0.55	0.55	0.53	0.54
ESCC	1800	0.54	0.52	0.50	0.49	0.47	0.46	0.46	0.45
IL	1800	0.54	0.53	0.51	0.50	0.48	0.47	0.47	0.47
ESFM	1800	0.49	0.53	0.50	0.49	0.47	0.46	0.46	0.45
RSV	3600	0.56	0.55	0.53	0.52	0.50	0.49	0.48	0.48
ST	3600	0.60	0.59	0.57	0.55	0.55	0.54	0.53	0.53
ESCC	3600	0.53	0.52	0.54	0.48	0.45	0.44	0.45	0.44
IL	3600	0.54	0.54	0.54	0.50	0.46	0.46	0.47	0.46
ESFM	3600	0.53	0.52	0.50	0.49	0.47	0.47	0.47	0.47

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a constant speed pump with a PEI rating less than 0.96 or a variable speed pump with a PEI rating less than 0.49 or the corresponding baseline PEI, whichever is lower.

[1250] Regional Technical Forum, Efficient Pumps v2.0, Parameters worksheet rows 30-35
[1251] *No source specified – update pending availability and review of applicable references.*
[1252] 10 CFR 431.465
[1253] Regional Technical Forum, Efficient Pumps v2.0, PEI_CL to PEI_VL worksheet, row 83.

Operating Hours

Annual operating hours shall come from application. If actual operating hours are unknown, the values in the table below per RTF analysis and NEEA research shall be used as defaults. The default operating hours below were determined from the NEEA research from metering of existing and newly installed pumps in the field across the sectors specified.[1254]

Sector	Operating Hours
Agricultural	2,358
Commercial	3,753
Industrial	6,175
Municipal	3,360

Example Calculation *(Not to be used as default)*

A constant speed 50 hp, 1,800 RPM PEI rated RSV pump is installed at an agricultural facility near Syracuse. The pump has a 0.9 PEI rating and operates 2,400 hours per year. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

$$\Delta kWh = hp \times 0.746 \times (1 - OF) \times (PEI_{baseline} - PEI_{ee}) \times LSAF \times hrs$$

$$\Delta kW = hp \times 0.746 \times RLF \times (PEI_{baseline} - PEI_{ee}) \times CF$$

hp = 50, from application.
OF = 0.20, from Oversize Factor table based on speed control case and motor hp.
$PEI_{baseline}$ = 1.0, from Baseline Efficiency section
PEI_{ee}= 0.9, From application
LSAF = 1.325, from Load Shape Adjustment Factor table based on application and speed control case
Hrs = 2,400 hours, from application.
RLF = 0.75, default from Summary of Variables and Data Sources table
CF = 0.8, from Summary of Variables and Data Sources table

$$\Delta kWh = 50 \times 0.746 \times (1 - 0.20) \times (1 - 0.90) \times 1.325 \times 2{,}400 = 9{,}489\ kWh$$

$$\Delta kW = 50 \times 0.746 \times 0.75 \times (1 - 0.90) \times 0.8 = 2.23kW$$

Effective Useful Life (EUL)

See Appendix P.

[1254] Extended Motor Products Savings Validation Research on Clean Water Pumps and Circulators, Northwest Energy Efficiency Alliance.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. 10 CFR 431.464 - Test procedure for the measurement of energy efficiency, energy consumption, and other performance factors of pumps
   Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=fa8761ce7ff31d0c22aaf4e1c4992575&mc=true&node=pt10.3.431&rgn=div5#se10.3.431_1464
2. 10 CFR 431.465 - Pumps energy conservation standards and their compliance dates
   Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=fa8761ce7ff31d0c22aaf4e1c4992575&mc=true&node=pt10.3.431&rgn=div5#se10.3.431_1464
3. U.S. DOE, Determining Electric Motor Load and Efficiency
   Available from: https://energy.gov/sites/prod/files/2014/04/f15/10097517.pdf
4. Regional Technical Forum, Efficient Pumps v2.0
   Available from: https://nwcouncil.app.box.com/v/EfficientPumpsv2-0
5. Extended Motor Products Savings Validation Research on Clean Water Pumps and Circulators, Northwest Energy Efficiency Alliance.
   Available from: https://neea.org/resources/extended-motor-products-savings-validation-research-on-clean-water-pumps-and-circulators

Record of Revision

Record of Revision Number	Issue Date
3-21-15	4/9/2021

Return to Table of Contents

POOL PUMP

Measure Description

This measure covers the installation of ENERGY STAR® qualified multi-speed and variable frequency drive (VFD) commercial inground pool pumps. Pool pump speeds vary based on the pump's operation. Filtration, for example, only requires half the flow rate of running a pool cleaner. Conventional pool pumps, with only one speed, are set to run at the higher speeds required of the pool cleaner and waste energy during filtration operation by running faster than necessary. An ENERGY STAR® certified pool pump can run at different speeds and be programmed to match the pool operation with its appropriate pool pump speed. The energy saved is considerable; reducing pump speed by one-half allows the pump to use just one-eighth as much energy.[1255] After January 1, 2019, all pool pumps must be rated according to Weighted Energy Factor (WEF).[1256] Pool pumps that have earned this label use up to 70% less energy than non-qualified models.[1257]

This measure is applicable to multi-speed and VFD inground or self-priming pool pumps with a total horsepower rating between 1 and 3 HP. While single-speed pumps, non-self-priming pumps, and pressure cleanser booster pumps are eligible under ENERGY STAR® qualified product criteria, there was a critical lack of information regarding ENERGY STAR® calculations and assumptions pertaining to this equipment available at the time of publication of this measure. The measure scope will be expanded as more information becomes available. This measure is applicable to all pool facilities except those that fall under the NY health code Subpart 6-1: a single-family swimming pool, or other bathing facility, a spa pool or a floating tank.[1258]

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times \frac{days}{1{,}000} \times V_{pool} \times N_{turnover} \times \left[\frac{1}{EF_{baseline}} - \frac{1}{WEF_{ee}}\right]$$

Summer Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

Note- Although pump hp is not applied directly within algorithms, it must be known to establish baseline and compliance efficiency values.

[1255] ENERGY STAR® Pool Pumps
[1256] ENERGY STAR® Pool Pumps Version 2 and Version 3 Specification Cover Letter, April 2018
[1257] ENERGY STAR® Pool Pump Fact Sheet, January 2018
[1258] SubPart6-1.3, Swimming pools, NewYork Codes, Rules and Regulations

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
days	= Number of operating days per year
$_{baseline}$	= Characteristic of baseline condition
$_{ee}$	= Characteristic of energy efficient condition
WEF	= Weighted Energy factor (kgal/kWh)
EF	= Energy factor (kgal/kWh)
V_{pool}	= Volume of pool, in gallons
$N_{turnover}$	= Number of turnovers per day, where a turnover is a full cycling of pool water through the pool filter
hp	= Horsepower of qualifying pump motor
1,000	= Conversion factor, one kgal equals 1,000 gallons

Summary of Variables and Data Sources

Variable	Value	Notes
V_{pool}		From application. If unknown, assume 22,400.[1259]
$N_{turnover}$		From application. If unknown, use 4 per day. [1260]
WEF_{ee}		From application, or look up in Compliance Efficiency section below, based on nameplate hp.
hp		From application.
$EF_{baseline}$		Look up in Baseline Efficiencies section below, based on nameplate hp.
days		From application.
hrs_{annual}		From application.

Coincidence Factor (CF)

The prescribed value for the coincidence factor is N/A.

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a non-ENERGY STAR® qualified single-speed pool pump. The values for baseline EF are found in the table below, based on nameplate horsepower. Pump Performance Curve C is assumed for pool pumps. The pump curve compares the total head in feet of water to the flow rate of the water for a given pump at a given motor speed.

Pump Type and Variable	Nameplate Horsepower						
	0.5	0.75	1	1.5	2	2.5	3
$EF_{baseline}$	3.4	3.3	2.5	2.3	2.3	2.2	2.0

[1259] Savings Calculator for ENERGY STAR® Certified Inground Pool Pumps (accessed 7/14/2020)
[1260] SubPart6-1.11 Treatment, Swimming pools, NewYork Codes, Rules and Regulations

Compliance Efficiency from which Incentives are Calculated

The compliance condition is an ENERGY STAR® qualified multi or variable speed self-priming, inground pool pump. Self-priming pool pumps must have a WEF (in kgal/kWh) equal to or greater than the equation below for pumps on curve C.[1261]

$$WEF \geq -230 \times ln(hhp) + 6.59$$

where:

hhp = hydraulic horsepower, equal to or greater than 0.711

Multi-Speed and Variable Frequency Drive Pool Pumps[1262]

Typical WEF for ENERGY STAR® multi-speed and variable frequency drive pool pumps are found in the table below, based on nameplate horsepower. Pump Performance Curve C is assumed for ENERGY STAR pumps. The pump curve compares the total head in feet of water to the flow rate of the water for a given pump at a given motor speed.

Pump Type and Variable	Nameplate Horsepower at High Speed				
	1-1.4 HP (0.72 hhp)	1.65 HP (0.95 hhp)	2 HP (1.18 hhp)	2.5 HP (1.25 hhp)	3 HP (1.65 hhp)
WEF_{ee}	8.7	8.9	9.3	7.4	7.1

Operating Hours

The annual operating days shall be taken from application. While in use, the energy efficient pump cycles through pool water at a default rate of 6 hours per turnover as mandated by the NY Codes and Regulations.[1263]

Example Calculation *(Not to be used as default)*

An ENERGY STAR ® qualified 1.70 hp multi-speed inground pool pump with a 9.0 WEF rating is installed at a community college near Albany. The pump remains in operation for 90 days and 1,080 hours during the swimming season and conducts 2 turnovers per day. The volume of the swimming pool is 22,000 gallons. Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings are calculated as below.

$$\Delta kWh = units \times \frac{days}{1{,}000} \times V_{pool} \times N_{turnover} \times \left[\frac{1}{EF_{baseline}} - \frac{1}{WEF_{ee}}\right]$$

units = 1, from application

V_{pool} = 22,000, from application

[1261] ENERGY STAR® Program Requirements Product Specification for Pool Pumps, Eligibility Criteria Version 2.0, January 2019

[1262] Ibid

[1263] Subpart6-1.11 Treatment, Swimming pools, NewYork Codes, Rules and Regulations

$N_{turnover}$ = 2, from application
WEF_{ee} = 9.0, from application
hp = 1.7, from application.
$EF_{baseline}$ = 2.3, Look up in Baseline Efficiencies section below, based on nameplate hp.
Days = 90, from application.
hrs_{annual} = 1,080, from application.

$$\Delta kWh = 1 \times \frac{90}{1{,}000} \times 22{,}000 \times 2 \times \left[\frac{1}{2.3} - \frac{1}{9}\right] = 1{,}282\ kWh$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. ENERGY STAR® Program Requirements Product Specification for Pool Pumps, Eligibility Criteria Version 2.0, January 2019
   Available from:
   https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Final%20Version%202.0%20Pool%20Pumps%20Specification.pdf
2. SubPart6-1, Swimming pools, NewYork Codes, Rules and Regulations
   Available from: https://regs.health.ny.gov/content/subpart-6-1-swimming-pools
3. 10 CFR Appendix B to Subpart Y of Part 431 – Uniform Test Method for the Measurement of Energy Efficiency of Dedicated-Purpose Pool Pumps
   Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=1e172a51fbd7c0fa1753866066133e14&mc=true&node=pt10.3.431&rgn=div5#ap10.3.431_1466.b

Record of Revision

Record of Revision Number	Issue Date
12-20-11	12/31/2020

Return to Table of Contents

VARIABLE FREQUENCY DRIVE (VFD) - FAN AND PUMP

Measure Description

This measure addresses variable frequency drives applied to fans and pumps in commercial and industrial buildings. Applications covered in this section are; AHU supply and return fans, CHW pumps, cooling tower fans, condenser water pumps and heating hot water pumps.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times hp \times (\Delta kWh/hp)$$

Summer Peak Coincident Demand Savings

$$\Delta kW = units \times hp \times (\Delta kW/hp) \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
hp	= Horsepower
(ΔkWh/hp)	= Annual electric energy savings (in kWh) per controlled motor horsepower
(ΔkW/hp)	= Electric demand savings (in kW) per controlled motor horsepower
CF	= Coincidence factor

Summary of Variables and Data Sources

Variable	Value	Notes
hp		Horsepower rating of motor controlled by VFD, from application
(ΔkW/hp)		Electric demand savings from VFD per horsepower of motor controlled. Lookup in Appendix K by building type and VFD application. If no deemed savings are specified, (ΔkW/hp) = 0.
(ΔkWh/hp)		Annual energy savings from VFD per horsepower of motor controlled. Lookup in Appendix K by building type, city and VFD application.
CF	0.8	

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.8. [1264]

[1264] *No source specified – update pending availability and review of applicable references.*

Baseline Efficiencies from which Energy Savings are Calculated

The baseline system characteristics by application are as follows:

- Chilled water and hot water pumps:
  - Variable volume, constant speed secondary pumping system
    - Existing pump rides pump curve as flow varies
- Supply fans:
  - VAV system with inlet vane control
- Return fans:
  - VAV system with discharge damper control
- Cooling tower fans:
  - One speed constant volume fan
- Condenser water pumps:
  - Constant speed, constant flow condenser water pumps

Compliance Efficiency from which Incentives are Calculated

The compliance system characteristics by application are as follows:

- Chilled water and hot water pumps:
  - Variable volume, variable speed secondary pumping system
- Supply fans:
  - VAV system with VFD control
- Return fans:
  - VAV system with VFD control
- Cooling tower fans:
  - Variable speed fans controlling condenser water temperature to 85°F
- Condenser water pumps:
  - Variable speed, variable flow condenser water loop

Operating Hours

The annual energy savings from VFD per horsepower of motor controlled (ΔkWh/hp) defined in Appendix K incorporate operating hours consideration.

Example Calculation *(Not to be used as default)*

A 10 hp HVAC supply fan is equipped with a VFD in a high school building near NYC. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

$$\Delta kWh = units \times hp \times (\Delta kWh/hp)$$

$$\Delta kW = units \times hp \times (\Delta kW/hp) \times CF$$

units = 1, from application
hp = 10, from application
(ΔkWh/hp) = 707, from Appendix K based on building type and VFD application

(ΔkW/hp) = 0.070, from Appendix K based on building type and VFD application
CF = 0.8, from Summary of Variables and Data Sources

$$\Delta kWh = 1 \times 10 \times 707 = 7{,}070\ kWh$$

$$\Delta kW = 1 \times 10 \times 0.070 \times 0.8 = 0.56\ kW$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

N/A

Record of Revision

Record of Revision Number	Issue Date
1	10/15/2010
7-13-12	7/31/2013
9-17-8	9/30/2017

Return to Table of Contents

OTHER

POOL HEATER

Measure Description

This measure covers the installation of high efficiency fossil fuel-fired pool heaters.[1265] Fossil fuel-fired pool heaters are designed for heating non-potable water and employ fossil fuel-fired burners. High-efficiency fossil fuel heaters can have thermal efficiency ratings as high as 95%.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = N/A$$

Summer Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = units \times (MMBtu/(kBTU/h)_{baseline} - MMBtu/(kBTU/h)_{ee}) \times kBTU/h$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
baseline	= Characteristic of baseline condition
ee	= Characteristic of energy efficient condition
MMBtu/(kBTU/h)	= Annual fossil fuel consumption per pool heater heating capacity
kBTU/h	= Pool heater input heating capacity, in kBTU/h

Summary of Variables and Data Sources

Variable	Value	Notes
$MMBtu/(kBTU/h)_{baseline}$	0.146	From the annual energy consumption table below, based on a thermal efficiency rating of 82%.
$MMBtu/(kBTU/h)_{ee}$		Look up from energy consumption table below based on thermal efficiency rating of fossil fuel efficient pool heater. Interpolation may be performed for pool heater efficiencies not listed.

[1265] Similar to other measures in the NY TRM, this measure will continue to be reviewed for accuracy and for potential updates, based on up-take in programs, changes in codes and standards, and the availability of other measure-specific information.

Variable	Value	Notes
kBTU/h		Pool heater input capacity as indicated on equipment nameplate or manufacturer specifications, from application.

Annual Energy Consumption[1266]

Thermal Efficiency (%)	Annual Fossil Fuel Consumption (MMBtu/(kBTU/h)$_{ee}$)
82 (baseline)	0.146
84	0.138
86	0.134
90	0.128
95	0.122

Coincidence Factor (CF)

The prescribed value for the coincidence factor is N/A.

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a fossil fuel-fired pool heater with a thermal efficiency of 82% as mandated by federal standards. [1267]

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a fossil fuel-fired pool heater that has a thermal efficiency of 84% or greater. [1268]

Operating Hours

Pool heater run hours are embedded in the values found in the Annual Energy Consumption table provided above. The derivation assumes a 250-kBTU/h input pool heater, 26.5% of heaters equipped with a pilot light with an input rate of 1-kBTU/h, an average pilot light operating hours of 4,464 hours per year, and a distribution range of pool operational hours from 235 to 8,760 per year.

Example Calculation *(Not to be used as default)*

A gas-fired pool heater with 86% thermal efficiency and 250 kBTU/h is installed at a community college near Albany, replacing a gas-fired pool heater with 82% thermal efficiency. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are not applicable.

[1266] US DOE, Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters, Chapter 7, Table 7.4.2: Annual Energy Consumption for Gas-Fired Pool Heaters. The derivation assumes a 250-kBTU/h pool heater and 26.5% of heaters equipped with a pilot light with an input rate of 1-kBTU/h.
[1267] 10 CFR 430.32.(k)(2)
[1268] Compliance requirement based on SoCal Gas minimum thermal efficiency to qualify for incentive (accessed 11/27/2018)

Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta MMBtu = units \times (MMBtu/(kBTU/h)_{baseline} - MMBtu/(kBTU/h)_{ee}) \times kBTU/h$$

units =1, from application
$MMBtu/(kBTU/h)_{baseline}$= 0.146, from Summary of Variables and Data Sources table
$MMBtu/(kBTU/h)_{ee}$= 0.134, from Annual Energy Consumption table based on thermal efficiency rating of fossil fuel efficient pool heater
kBTU/h = 250 kBTU/h, from application.

$$\Delta MMBtu = 1 \times (0.146 - 0.134) \times 250 = 3.0\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Analysis of baseline and high-efficiency fossil fuel-fired pool heaters conducted using the DOE test procedure suggests that auxiliary and stand-by electric loads are slightly higher for more efficient equipment.[1269] The magnitude of these effects is considered negligible relative to anticipated fossil fuel savings and electric impacts have thus been excluded from the prescribed methodology.

References

1. 10 CFR 430.32 Energy and water conservation standards and their compliance dates. Available from: https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=e2b12730e1b0fd7608318eb139d57b10&mc=true&n=pt10.3.430&r=PART&ty=HTML#se10.3.430_132
2. Department of Energy; Notice of Proposed Rulemaking Technical Support Document Energy Conservation Program for Consumer Products: Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters, Chapter 7: Energy Use Characterization, November 23, 2009 Available from: https://www.regulations.gov/contentStreamer?documentId=EERE-2006-STD-0129-0170&attachmentNumber=8&contentType=pdf
3. SoCal Gas, Pool Heater List (accessed November 27, 2018) Available from: https://www.socalgas.com/pool-heater-list

[1269] US DOE, Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters, Chapter 7, Table 7.4.2: Annual Energy Consumption for Gas-Fired Pool Heaters

Record of Revision

Record of Revision Number	Issue Date
3-19-13	3/29/2019

Return to Table of Contents

HEAT PUMP POOL HEATER

Measure Description

This measure is applicable to electric heat pump pool heaters in commercial and multifamily community pool applications. Heat pumps capture heat and move it from one place to another. The saving equations presented herein comprise three aspects of pool heating: convective heat loss via pool surface area due to water and air temperature differential, initial heat of full pool volume for seasonal pool use and reheat of pool refill on year round pools, and the heating of added pool water to offset water loss through evaporation. [1270] If baseline equipment is a fossil fuel-fired pool heater, electric energy impacts result in a penalty.

This measure is restricted to inground pools and is not applicable to spas.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = \frac{\left(BTU_{Surface} + BTU_{Reheat} + BTU_{Evap}\right)}{3{,}412} \times \left(\frac{F_{elec,baseline}}{COP_{baseline}} - \frac{1}{COP_{ee}}\right)$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \frac{\Delta kWh}{hrs} \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = \frac{\left(BTU_{Surface} + BTU_{Reheat} + BTU_{Evap}\right)}{1{,}000{,}000} \times \frac{F_{fuel,baseline}}{E_{t,baseline}}$$

where:

$$BTU_{Surface} = \left(T_{pool} - T_{amb}\right) \times A_{pool} \times U \times \left[hrs - \left(hrs_{cover} \times ESF_{cover,surface}\right)\right]$$

$$BTU_{Reheat} = V_{pool} \times 8.33 \times \left(T_{pool} - T_{main}\right) \times F_{Reheat}$$

$$BTU_{Evap} = 0.1 \times AF \times A_{pool} \times \left(P_{\omega} - P_{dp}\right) \times \left(T_{pool} - T_{main}\right) \times \left[hrs - \left(hrs_{cover} \times ESF_{cover,evap}\right)\right]$$

where:

ΔkWh = Annual electricity energy savings

[1270] ASHRAE Handbook: HVAC Applications, 2019, pg 51.25. ASHRAE states that except in aboveground pools and rare cases where cold groundwater flows past the pool walls, conductive losses through pool walls are small and can be ignored. ASRHAE additionally indicates that radiation losses that occur due to sky temperature differentials at night may be offset by solar heat gains of an unshaded pool during the day.

ΔkW	= Peak coincident demand electric savings
$\Delta MMBtu$	= Annual fossil fuel energy savings
$BTU_{Surface}$[1271]	= Annual heating energy load contributed by convection and radiation heat losses via pool surface, (BTU)
BTU_{Reheat}[1272]	= Annual heating energy load contributed by heating the full volume of pool water, (BTU)
BTU_{Evap}[1273]	= Annual heating energy load contributed by evaporation, (BTU)
$F_{elec,baseline}$	= Baseline electric pool heater factor; used to account for the presence or absence of an electric pool heater
$F_{fuel,baseline}$	= Baseline fossil fuel pool heater factor; used to account for the presence or absence of a fossil fuel pool heater
$COP_{baseline}$	= Coefficient of performance, ratio of output energy/input energy of baseline electric resistance pool heater, if present
COP_{ee}	= Coefficient of performance, ratio of output energy/input energy of heat pump pool heater
$E_{t,baseline}$	= Thermal efficiency of baseline fossil fuel-fired pool heater, if present
T_{pool}	= Pool temperature set point, (ºF)
T_{amb}	= Average temperature of surrounding ambient air, (ºF)
T_{main}	= Supply water temperature in water main, (ºF)
A_{pool}	= Surface area of pool, (ft^2)
V_{pool}	= Volume of pool water, (gallons)
F_{Reheat}	= Factor capturing annual number of times full pool volume is heated to the desired temperature, whether as the result of refill or heating of pool water from ground water temperature at start of season
U	= Surface heat loss coefficient, (BTU/hr-ft^2-ºF)
AF	= Activity Factor, consideration of activity within pool
P_{ω}	= Saturation vapor pressure taken at surface water temperature, (in. Hg)
P_{dp}	= Saturation pressure at dew point, (in. Hg)
hrs	= Total annual swimming season hours
hrs_{cover}	= Total annual hours pool covered during the swimming season
$ESF_{cover,surface}$	= Energy Savings Factor of pool cover to insulate from convective and radiation heat losses
$ESF_{cover,evap}$	= Energy Savings Factor of pool cover to insulate from evaporative heat loss
CF	= Coincidence factor
0.1	= Simplified empirically derived evaporation factor considering latent heat and air flow[1274]; assumes 1,000 BTU/lb of latent heat required to change water to vapor at surface water temperature and air velocity over water surface ranging from 10 to 30 fpm, (lb/hr-ft^2-in. hg)
8.33	= Energy required (BTU) to heat one gallon of water by one degree Fahrenheit
3,412	= Conversion factor, one kWh equals 3,412 BTU

[1271] ASHRAE Handbook: HVAC Applications, 2019, Ch 51 Service Water Heating, Swimming Pools/Health Clubs, eqn. 15
[1272] Ibid, eqn. 14
[1273] ASHRAE Handbook: HVAC Applications, 2019, Ch 6 Indoor Swimming Pools, eqn. 3, multiplied by required heating temperature difference
[1274] Simplified constant presented in ASHRAE Handbook: HVAC Application 2019 Ch 6 based on empirically derived eqn (2) constants and ASHRAE's variable assumptions

1,000,000 = Conversion factor, one MMBtu equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
$F_{elec,baseline}$		If baseline system is an electric resistance pool heater, set equal to 1. Otherwise, set equal to 0.
$F_{fuel,baseline}$		If baseline system is a fossil fuel-fired pool heater, set equal to 1. Otherwise, set equal to 0.
$COP_{baseline}$		If baseline pool heater is electric, assume 1.0.
COP_{ee}		From application.
$E_{t,baseline}$		From application. If unknown, use 0.82 as default.[1275]
T_{pool}		From application.
T_{amb}		Indoor pool ambient temperature shall come from application. For outdoor pool ambient temperature, lookup in Outdoor Pool table in the Air Temperature and Pressure section below based on nearest city.
T_{main}		Supply water temperature in water main (ºF). Lookup in Cold Water Inlet Temperature table below based on nearest city.
A_{pool}		Pool surface area, from application.[1276] Assistance in determining the area of common pool shapes as follows: Elliptical: 3.14 x short radius x long radius Kidney Shaped: 0.45 x length x (width at one end x width at other end) Oval: 3.14 x radius^2 + (length of straight sides x width) Rectangular: length x width
V_{pool}		Volume of water, from application.
F_{Reheat}		From application. If pool is filled by delivery service providing preheated water, set F_{Reheat} equal to 0. Otherwise F_{Reheat} shall default to 1.[1277]

[1275] 10 CFR 430.32 (k)(2)
[1276] Guidance for determining surface area of common pool shapes can be found at ASHRAE Handbook: HVAC Applications, 2019, pg 51.25
[1277] The water temperature of an undrained pool between swim seasons is assumed to have reached the water main temperature by the beginning of the next swim season. If the pool remains open throughout the year, it is assumed the pool undergoes one effective full pool volume reheat from water main temperature for cleaning and other maintenance (CDC, Healthy Swimming, Operating Public Swimming Pools).

Variable	Value	Notes
U	Indoor pool: 3.9 Outdoor pool, sheltered: 5.3 Outdoor pool, unsheltered: 6.6	Surface heat loss coefficient (BTU/hr-ft^2-ºF).[1278]
AF		Lookup from table in Activity Factor section below based on pool function.
P_ω		Lookup from Saturation Vapor Pressure section below based on pool water temperature. Linear interpolation and extrapolation of the data in the table is acceptable for pool templates not provided.
P_{dp}		Lookup from indoor or outdoor pool tables in Air Temperature and Pressure section below based on ambient temperature and relative humidity (RH) or city, respectively. Linear interpolation and extrapolation of the data in the table is acceptable for pool templates not provided.
hrs		From application. Hours shall reflect the total annual hours through the swimming season (number of days between season opening and season closing x 24).
hrs_{cover}		From application. Hours shall reflect the total hours pool covered during the swimming season. Set equal to 0 if pool is left uncovered throughout swimming season. If installing a heat pump pool heater in conjunction with a newly added pool cover, calculate savings from this measure without pool cover consideration and calculate savings from pool cover with efficiency of heat pump pool heater.
$ESF_{cover,surface}$	0.8	Based on cost savings from DOE for gas and heat pump pool heater savings[1279]
$ESF_{cover,evap}$	0.95	Effectiveness of Pool Covers to Reduce Evaporation from Swimming Pools. [1280]
CF	Outdoor pool: 0 Indoor pool: 0.8	

Cold Water Inlet Temperature (T_{main})

Supply water main temperatures vary according to climate, and are approximately equal to the annual average outdoor temperature plus 6°F.[1281] Supply main temperatures based on the annual

[1278] ASHRAE Handbook: HVAC Applications, 2019, Ch 51, eqn. 15. Surface heat loss coefficient adjusted from ASHRAE Handbook rolled up surface heat transfer conservations by discounting contribution of evaporation (50-60%) and applying the following assumption for wind velocity: Indoor pools experience wind speeds less than 3.5 mph (10.5x0.5x0.75), outdoor sheltered pools experience wind speeds between 3.5 and 5 mph (10.5x0.5), and outdoor unsheltered pools experience wind speeds above 5 mph (10.5x0.5x1.25).

[1279] U.S. D.O.E., Swimming Pool Covers

[1280] National Plasterers Council, Effectiveness of Pool Covers to Reduce Evaporation from Swimming Pools, prepared by California Polytechnic State University, January 2016

[1281] Burch, Jay and Christensen, Craig, "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory

outdoor temperature are shown below.

City	Annual average outdoor temperature[1282] (°F)	T_{main} (°F)
Albany	48.3	54.3
Binghamton	46.3	52.3
Buffalo	48.3	54.3
Massena	43.5	49.5
NYC	55.4	61.4
Poughkeepsie	49.8	55.8
Syracuse	48.3	54.3

Saturation Vapor Pressure (P_ω)
Lookup saturation vapor pressure taken at surface water temperature from the table below, based on pool temperature.[1283]

Pool Temperature, T_{pool} (°F)	P_ω (in Hg)
72	0.79
74	0.85
76	0.91
78	0.97
80	1.03
82	1.10
84	1.18

Ambient Air Temperature and Pressure (T_{amb} and P_{dp})
Indoor pools shall apply ambient air temperature from application based on facility set point temperature. Lookup saturation vapor pressure based on facility set point temperature and relative humidity (RH) from the table below, based on psychrometric analysis. Interpolation may be performed for indoor pool ambient temperatures not listed.

Indoor Pool T_{amb} (°F)	Indoor Pool, P_{dp} (in. Hg)		
	RH 50%	RH 55%	RH 60%
72	0.40	0.44	0.47
74	0.42	0.47	0.51
76	0.45	0.50	0.54
78	0.48	0.53	0.58
80	0.52	0.56	0.62
82	0.55	0.61	0.66
84	0.59	0.65	0.71
86	0.63	0.69	0.75

[1282] Average annual outdoor temperatures taken from NCDC 1981-2010 climate normals
[1283] ASHRAE Handbook: Fundamentals 2017, Ch 1 Psychrometrics, Table 3 Thermodynamic Properties of Water at Saturation

For outdoor pools, lookup T_{amb} and P_{dp} from the table below based on location. Ambient temperature averages for outdoor pools apply a 4-month swimming season[1284].

City	Outdoor Pool T_{amb}[1285] (°F)	Outdoor Pool P_{dp} (in. Hg)
Albany	67.8	0.48
Binghamton	65.0	0.44
Buffalo	67.3	0.47
Massena	64.6	0.47
NYC	73.4	0.53
Poughkeepsie	68.6	0.54
Syracuse	67.5	0.48

Activity Factor

Activity Factor considers activity level of the pool, allowing for splashing and a limited area of wetted deck.[1286] Look up Activity Factor from the table below based on pool application.

Type of Pool	Activity Factor (AF)
Condominium	0.65
Therapy	0.65
Hotel	0.80
Public, School	1.00
Whirlpool	1.00
Wavepool, Water Slide	1.50

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0 for outdoor pools and is 0.8 for indoor pools.[1287]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition for this measure is an electric resistance or fossil fuel-fired pool heater.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is an AHRI-certified heat pump pool heater.

[1284] It is assumed that 50% of pools are unheated and operate for 3 months per year and the other 50% of pools are heated and operate for 5 months per year, giving an average of 4 months of usage per year; June 1 through Sept 30

[1285] Average ambient temperatures taken from NCDC 1981-2010 climate normals, averaged from June 1 through Sept 30

[1286] ASHRAE Handbook, Applications, 2019, Ch 6, Table 1

[1287] *No source specified – update pending availability and review of applicable references.*

Operating Hours

The annual operating hours shall be taken from application based on the number of total hours of facility's swimming season and total hours pool is covered during the swimming season.

Example Calculation *(Not to be used as default)*

A gas pool heater is replaced with a heat pump pool heater at an indoor pool at a public school located near Albany. The pool is open year round (8,760 hours). The pool is covered every night, for 12 hours/day (4,380 hours/year). The pool is 75 ft by 35 ft and has 80,000 gallons of water. The pool temperature is maintained at 78ºF and the ambient air temperature is maintained at 76ºF and a relative humidity of 55%. The pool is drained once annually on average for cleaning and maintenance. The replaced gas pool heater has an efficiency of 86% and the heat pump pool heater has an efficiency of 5.0 COP. Annual Electric Energy Savings, Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta kWh = \frac{\left(BTU_{Surface} + BTU_{Reheat} + BTU_{Evap}\right)}{3{,}412} \times \left(\frac{F_{elec,baseline}}{COP_{baseline}} - \frac{1}{COP_{ee}}\right)$$

$$\Delta kW = \frac{\Delta kWh}{hrs} \times CF$$

$$\Delta MMBtu = \frac{\left(BTU_{Surface} + BTU_{Reheat} + BTU_{Evap}\right)}{1{,}000{,}000} \times \frac{F_{fuel,baseline}}{E_{t,baseline}}$$

where:

$$BTU_{Surface} = \left(T_{pool} - T_{amb}\right) \times A_{pool} \times U \times \left[hrs - \left(hrs_{cover} \times ESF_{cover,surface}\right)\right]$$

$$BTU_{Reheat} = V_{pool} \times 8.33 \times \left(T_{pool} - T_{main}\right) \times F_{Reheat}$$

$$BTU_{Evap} = 0.1 \times AF \times A_{pool} \times \left(P_{\omega} - P_{dp}\right) \times \left(T_{pool} - T_{main}\right) \times \left[hrs - \left(hrs_{cover} \times ESF_{cover,evap}\right)\right]$$

T_{pool} = 78, from application
T_{amb} = 76, from application
A_{pool} = width x length = 75' x 35' = 2,625'
Width and length from application
U = 3.9, from Summary of Variables and Data Sources table based on conditions from application
hrs = 8,760, from application
hrs_{cover} = 4,380, from application
$ESF_{cover,surface}$ = 0.8, from Summary of Variables and Data Sources table

V_{pool} = 80,000, from application
T_{main} = 54.3, from Cold Water Inlet Temperature table based on location from application
F_{Reheat} = 1, from Summary of Variables and Data Sources table
AF = 1.0, from Activity Factor section based on type of pool from application
P_{ω} = 0.97, from Saturation Vapor Pressure section based on pool temperature from application
P_{dp} = 0.48, from Ambient Air Temperature and Pressure section based on location from application
$ESF_{cover,evap}$ = 0.95, from Summary of Variables and Data Sources table
$F_{elec,baseline}$ = 0, from Summary of Variables and Data Sources table based on application
COP_{ee} = 5.0, from application
CF = 0.8, from Summary of Variables and Data Sources table based on application
$F_{fuel,baseline}$ = 1, from Summary of Variables and Data Sources table based on application
$E_{t,baseline}$ = 0.86, from application

$$BTU_{Surface} = (78 - 76) \times 2{,}625 \times 3.9 \times [8{,}760 - (4{,}380 \times 0.8)] = 107{,}616{,}600\ Btu$$

$$BTU_{Reheat} = 80{,}000 \times 8.33 \times (78 - 54.3) \times 1 = 15{,}793{,}680\ Btu$$

$$BTU_{Evap} = 0.1 \times 1.0 \times 2{,}625 \times (0.97 - 0.5) \times (78 - 54.3) \times [8{,}760 - (4{,}380 \times 0.97)] = 13{,}191{,}277\ Btu$$

$$\Delta kWh = \frac{(107{,}616{,}600 + 15{,}793{,}680 + 13{,}191{,}277)}{3{,}412} \times \left(0 - \frac{1}{5.0}\right) = -8{,}007\ kWh$$

$$\Delta kW = \frac{-8{,}007}{8{,}760} \times 0.8 = -0.731\ kW$$

$$\Delta MMBtu = \frac{(107{,}616{,}600 + 15{,}793{,}680 + 13{,}191{,}277)}{1{,}000{,}000} \times \frac{1}{0.86} = 158.84\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Higher efficiency heat pump pool heaters may require fewer pool water circulations through the pool pump, alleviating some of the pool pump energy load. This energy impact is not considered in the methodology for this measure.

References

1. 2019 ASHRAE Handbook – HVAC Applications, Chapter 6: Indoor Swimming Pools
2. 2019 ASHRAE Handbook – HVAC Applications, Chapter 51: Service Water Heating
3. 2017 ASHRAE Handbook – Fundamentals, Chapter 1, Psychrometrics
4. 10 CFR 430.32 Energy and water conservation standards and their compliance dates
   Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=840d2f09fea283237b0f345001c03a28&mc=true&node=pt10.3.430&rgn=div5#se10.3.430_132
5. U.S. D.O.E., Swimming Pool Covers.
   Available from: https://www.energy.gov/energysaver/swimming-pool-covers
6. Burch, Jay and Craig Christensen; "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory
   Available from:
   http://citeseerx.ist.psu.edu/viewdoc/download;jsessionid=05D73BA6EF5ECCF71969D083FB317991?doi=10.1.1.515.6885&rep=rep1&type=pdf
7. NOAA National Center for Environmental Information – NCEI 1981 – 2010 Annual/Seasonal Climate Normals
   Available from: https://www.ncdc.noaa.gov/cdo-web/datatools/normals
8. National Plasterers Council, Effectiveness of Pool Covers to Reduce Evaporation from Swimming Pools, prepared by California Polytechnic State University, January 2016
   Available from:
   https://cdn.ymaws.com/www.npconline.org/resource/resmgr/Docs/Evaporation_Study_Report.pdf
9. Center for Disease Control and Prevention, Healthy Swimming, Operating Public Swimming Pools, accessed 6/18/2021
   Available from: https://www.cdc.gov/healthywater/swimming/aquatics-professionals/operating-public-swimming-pools.html

Record of Revision

Record of Revision Number	Issue Date
7-21-18	8/30/2021

Return to Table of Contents

HIGH EFFICIENCY TRANSFORMER

Measure Description

This measure covers the installation of new electric transformers (i.e. not refurbished equipment) exceeding codes and standards required efficiency in commercial and industrial applications. These transformers are used to step down power from distribution voltage to serve HVAC, process and plug loads in commercial and industrial facilities.

This measure is only applicable to low-voltage dry-type distribution transformers, liquid-immersed distribution transformers, and medium-voltage dry-type distribution transformers installed behind the meter, for which minimum federal efficiency standards are defined.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = kVA \times \left(\frac{1}{Eff_{baseline}} - \frac{1}{Eff_{ee}}\right) \times LF \times PF \times hrs$$

Summer Peak Coincident Demand Savings

$$\Delta kW = kVA \times \left(\frac{1}{Eff_{baseline}} - \frac{1}{Eff_{ee}}\right) \times LF \times PF \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

where:

ΔkWh	= Annual electricity energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
kVA	= Power rating of the transformer, in kVA
baseline	= Characteristic of baseline condition
ee	= Characteristic of energy efficient condition
Eff	= Efficiency rating of transformer (must be entered as a decimal value)
PF	= Power Factor, ratio of real power to apparent power supplied to the transformer
LF	= Load Factor, ratio of average annual transformer load to peak load rating
hrs	= Annual operating hours
CF	= Coincidence factor

Summary of Variables and Data Sources

Variable	Value	Notes
kVA		From application.
$Eff_{baseline}$		Lookup based on transformer type, phase and kVA rating in Baseline Efficiency section below.

Variable	Value	Notes
Eff_{ee}		From application.
LF		From application. Can be approximated as total annual facility kWh consumption divided by the product of transformer kVA rating and 8,760.
PF		From application. If unavailable, use 1.0 as default.[1288]
hrs		From application. If unknown, use 8,760.
CF	1.0	

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 1.0.[1289]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a minimally code compliant commercial transformer of type and kVA rating equivalent to the efficient equipment.

Low-Voltage Dry-Type Distribution Transformers.[1290,1291]

The baseline efficiency for low-voltage dry-type distribution transformers shall be established based on phase and kVA rating from the table below. Low-voltage dry-type distribution transformers with kVA ratings not appearing in the table shall have their minimum efficiency level determined by linear interpolation of the kVA and efficiency values immediately above and below that kVA rating.

Single-phase		Three-phase	
kVA	**Efficiency (%)**	**kVA**	**Efficiency (%)**
15	97.70	15	97.89
25	98.00	30	98.23
37.5	98.20	45	98.40
50	98.30	75	98.60
75	98.50	112.5	98.74
100	98.60	150	98.83
167	98.70	225	98.94
250	98.80	300	99.02
333	98.90	500	99.14
		750	99.23
		1,000	99.28

Liquid-Immersed Distribution Transformers[1292]

The baseline efficiency for liquid-immersed distribution transformers shall be established based on phase and kVA rating from the table below. Liquid-immersed distribution transformers with

[1288] Default unity power factor as used in the test procedures provided by US DOE. Energy Conservation Program: Test Procedures for Distribution Transformers; Final Rule. Effective May 30, 2006.
[1289] Coincidence factor for distribution transformers is 1.0 by definition.
[1290] 10 CFR 431.196(a)(2)
[1291] ECCCNYS 2020, Table C405.6
[1292] 10 CFR 431.196(b)(2)

kVA ratings not appearing in the table shall have their minimum efficiency level determined by linear interpolation of the kVA and efficiency -values immediately above and below that kVA rating.

Single-phase		Three-phase	
kVA	**Efficiency (%)**	**kVA**	**Efficiency (%)**
10	98.70	15	98.65
15	98.82	30	98.83
25	98.95	45	98.92
37.5	99.05	75	99.03
50	99.11	112.5	99.11
75	99.19	150	99.16
100	99.25	225	99.23
167	99.33	300	99.27
250	99.39	500	99.35
333	99.43	750	99.40
500	99.49	1000	99.43
667	99.52	1500	99.48
833	99.55	2000	99.51
		2500	99.53

Medium-Voltage Dry-Type Distribution Transformers[1293]

The baseline efficiency for a medium-voltage dry-type distribution transformer shall be established based on phase, BIL and kVA rating from the table below. Medium-voltage dry-type distribution transformers with kVA ratings not appearing in the table shall have their minimum efficiency level determined by linear interpolation of the kVA and efficiency values immediately above and below that kVA rating.

[1293] 10 CFR 431.196(c)(2)

Single-phase				Three-phase			
kVA	BIL*			kVA	BIL		
	20-45 kV	46-95 kV	≥96 kV		20-45 kV	46-95 kV	≥96 kV
	Efficiency (%)	Efficiency (%)	Efficiency (%)		Efficiency (%)	Efficiency (%)	Efficiency (%)
15	98.10	97.86		15	97.50	97.18	
25	98.33	98.12		30	97.90	97.63	
37.5	98.49	98.30		45	98.10	97.86	
50	98.60	98.42		75	98.33	98.13	
75	98.73	98.57	98.53	112.5	98.52	98.36	
100	98.82	98.67	98.63	150	98.65	98.51	
167	98.96	98.83	98.80	225	98.82	98.69	98.57
250	99.07	98.95	98.91	300	98.93	98.81	98.69
333	99.14	99.03	98.99	500	99.09	98.99	98.89
500	99.22	99.12	99.09	750	99.21	99.12	99.02
667	99.27	99.18	99.15	1,000	99.28	99.20	99.11
833	99.31	99.23	99.20	1,500	99.37	99.30	99.21
				2,000	99.43	99.36	99.28
				2,500	99.47	99.41	99.33

*BIL = Basic impulse insulation level

Note: All efficiency values are at 50 percent of nameplate rated load, determined according to the DOE Test Method for Measuring the Energy Consumption of Distribution Transformers under Appendix A to Subpart K of 10 CFR part 431.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a new electric transformer exceeding codes and standards required efficiency . The efficiency of the compliant equipment must exceed the efficiency of the baseline equipment.

Operating Hours

Operating hours shall come from application. If transformer operating hours are unknown, use 8,760 as default.

Example Calculation *(Not to be used as default)*

A low-voltage three phase dry-type distribution transformer with a power rating of 75 kVA and 99.20% efficiency and an estimated load factor of 22% is installed at a commercial facility, replacing an existing transformer with an efficiency of 98.60%. The facility operates 8,600 hours annually. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

$$\Delta kWh = kVA \times \left(\frac{1}{Eff_{baseline}} - \frac{1}{Eff_{ee}}\right) \times LF \times PF \times hrs$$

$$\Delta kW = kVA \times \left(\frac{1}{Eff_{baseline}} - \frac{1}{Eff_{ee}}\right) \times LF \times PF \times CF$$

kVA = 75, from application.
$Eff_{baseline}$ = 0.9860, from Baseline Efficiency section based on transformer type, phase and kVA rating
Eff_{ee} = 0.9920, from application.
LF = 0.22, from application
PF = 1.0, from application
Hrs = 8,600, from application
CF=1.0, from Summary of Variables and Data Sources table

$$\Delta kWh = 75 \times \left(\frac{1}{0.9860} - \frac{1}{0.9920}\right) \times 0.22 \times 1.0 \times 8{,}600 = 870\ kWh$$

$$\Delta kW = 75 \times \left(\frac{1}{0.9860} - \frac{1}{0.9920}\right) \times 0.22 \times 1.0 \times 1.0 = 0.101\ kW$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Installation of high efficiency transformers reduces waste heat, which impacts heating loads when this equipment is installed in conditioned spaces. These effects are not quantified in the prescribed savings estimation methodology for this measure at this time.

Ancillary Electric Savings Impacts

Installation of high efficiency transformers reduces waste heat, which impacts heating loads when this equipment is installed in conditioned spaces. These effects are not quantified in the prescribed savings estimation methodology for this measure at this time.

References

1. 10 CFR Part 431 Docket No. EE -TP-98-550, Energy Conservation Program: Test Procedures for Distribution Transformers
   Available from: https://www.govinfo.gov/content/pkg/FR-2006-04-27/pdf/06-3165.pdf
2. 10 CFR 431.196: Appendix A to Subpart K for Measuring the Energy Consumption of Distribution Transformer
   Available here: https://www.ecfr.gov/cgi-bin/text-idx?SID=cfc3276c3d076eb67bbf51af135e2a9c&mc=true&node=sp10.3.431.k&rgn=div6#se10.3.431_1196

3. ECCCNYS 2020, Table C405.6 Minimum Nominal Efficiency Levels for 10 CFR 431 Low-Voltage Dry-Type Distribution Transformers.
   Available here: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-ce-commercial-energy-efficiency

Record of Revision

Record of Revision Number	Issue Date
3-21-16	4/9/2021

Return to Table of Contents

HIGH FREQUENCY BATTERY CHARGER

Measure Description

This measure covers the installation of high frequency battery chargers replacing existing ferroresonant, SCR (silicon-controlled rectifier) or hybrid charging technology. Industrial high-frequency battery chargers are used for portable industrial equipment like forklifts and airport transport equipment in factories, warehouses and similar facilities. They convert standard AC power to DC power stored in batteries. System inefficiencies occur during charging, charge maintenance and standby.

This measure is only applicable to high frequency battery chargers with a rated input power of more than 2 kW and may be single phase or three phase. This measure does not apply to vehicle chargers or smaller chargers like those used for golf carts.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = \left\{ Cap \times DOD \times Charge_{year} \times \left(\frac{CRF_{baseline}}{PCE_{baseline}} - \frac{CRF_{ee}}{PCE_{ee}} \right) + \left[\frac{(W_{MM,baseline} \times hrs_{MM}) + (W_{NBM,baseline} \times hrs_{NBM})}{1{,}000} - \frac{(W_{MM,ee} \times hrs_{MM}) + (W_{NBM,ee} \times hrs_{NBM})}{1{,}000} \right] \right\} \times (1 + HVAC_c)$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \left(\frac{PF_{baseline}}{PCE_{baseline}} - \frac{PF_{ee}}{PCE_{ee}} \right) \times V \times \frac{A}{1{,}000} \times CF \times (1 + HVAC_d)$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = \left\{ Cap \times DOD \times Charge_{year} \times \left(\frac{CRF_{baseline}}{PCE_{baseline}} - \frac{CRF_{ee}}{PCE_{ee}} \right) + \left[\frac{(W_{MM,baseline} \times hrs_{MM}) + (W_{NBM,baseline} \times hrs_{NBM})}{1{,}000} - \frac{(W_{MM,ee} \times hrs_{MM}) + (W_{NBM,ee} \times hrs_{NBM})}{1{,}000} \right] \right\} \times HVAC_{ff}$$

where:

ΔkWh	= Annual electricity energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
Cap	= Nameplate capacity of battery (in kWh)
DOD	= Depth of discharge

$Charge_{year}$ = Number of charging cycles per year
$_{baseline}$ = Characteristic of baseline condition
$_{ee}$ = Characteristic of energy efficient condition
CRF = Charge return factor, the ratio of energy out of the battery versus the energy into the battery.
PCE = Power conversion efficiency, the ratio of energy out of charger to the energy into charger
W_{MM} = Power in maintenance mode, when connected battery is fully charged (watts)
W_{NBM} = Power used by charger when no battery is connected (watts)
hrs_{MM} = Hours per year in maintenance mode
hrs_{NBM} = Hours per year in no battery mode
PF = Power factor of charger
V = Charger nameplate volts
A = Charger nameplate amps
$HVAC_c$ = HVAC interaction factor for annual electric energy consumption
$HVAC_d$ = HVAC interaction factor at utility summer peak hour
$HVAC_{ff}$ = HVAC interaction factor for annual fossil fuel consumption (MMBtu/kWh)
3.412 = Conversion factor, one watt-hour equals 3.412 BTU
1,000 = Conversion factor, one kW equals 1,000 watts
CF = Coincidence Factor

Summary of Variables and Data Sources

Variable	Value	Notes
Cap		From application. If unknown, use 35 kWh.[1294]
DOD		From application. If unknown, use 0.80.[1295]
$Charge_{year}$		From application. If unknown, lookup in Number of Charges Per Year table below based on facility operation.
$CRF_{baseline}$		Lookup based on existing equipment type in Baseline Efficiencies section below.
$PCE_{baseline}$		Lookup based on existing equipment type in Baseline Efficiencies section below.
CRF_{ee}		From application. If unknown, lookup in Compliance Efficiency section below.
PCE_{ee}		From application. If unknown, lookup in Compliance Efficiency section below.
$W_{MMbaseline}$		Lookup based on existing equipment type in Baseline Efficiencies section below.
$W_{NBM,baseline}$		Lookup based on existing equipment type in Baseline Efficiencies section below.
$W_{MM,ee}$		From application. If unknown, lookup in Compliance Efficiency section below.

[1294] Jacob V. Renquist, Brian Dickman, and Thomas H. Bradley: "Economic Comparison of fuel cell powered forklifts to battery powered forklifts", International Journal of Hydrogen Energy Volume 37, Issue 17, (2012)
[1295] Emerging Technologies Program Application Assessment Report #0808, Industrial Battery Charger Energy Savings Opportunities, Pacific Gas & Electric. May 29, 2009

Variable	Value	Notes
$W_{NBM,ee}$		From application. If unknown, lookup in Compliance Efficiency section below.
$PF_{baseline}$		Lookup based on existing equipment type in Baseline Efficiency section below.
PF_{ee}		Lookup in Compliance Efficiency section below.
V		From application. If unknown, use 48 volts.[1296]
A		From application. If unknown, use 81 amps.[1297]
hrs_{NBM}		From application.
hrs_{MM}		From application.
$HVAC_c$	Exterior and Unconditioned Spaces: 0	HVAC interaction factor for annual electric energy consumption (dimensionless). Vintage and HVAC type weighted average by city. See Appendix D.
$HVAC_d$	Exterior and Unconditioned Spaces: 0	HVAC interaction factor for annual electric energy consumption (dimensionless). Vintage and HVAC type weighted average by city. See Appendix D.
$HVAC_{ff}$	Exterior and Unconditioned Spaces: 0	HVAC interaction factor for annual fossil fuel energy consumption (MMBtu/kWh), from Appendix D based on facility type, location and HVAC type.
CF	0 for single and 2- shift, 1.0 for 3-shift and 4-shift.	

Number of Charges Per Year

Facility Operating Schedule (hours per day / days per week)	Number of Charges Per Year[1298]
Single Shift 7AM – 3 PM, weekdays	260
Two Shifts 7AM – 11 PM, weekdays	520
Three Shifts 24 hours per day, weekdays	780
Four Shifts or Continual Operation 24 hours per day, 7 days a week	1,092

[1296] Ibid. Voltage rating based on the assumption of 35 kWh battery with a normalized average amp-hour capacity of 760 Ah charged over a 7.5 hour charge cycle.
[1297] Ibid. Ampere rating based on the assumption of 35 kWh battery with a normalized average amp-hour capacity of 760 Ah charged over a 7.5 hour charge cycle
[1298] Values are based on an estimated one charge per 8-hour shift.

Coincidence Factor (CF)

The recommended value for the coincidence factor is 0.0 for single shift and two shift and 1.0 for three and forth shift.[1299]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a ferroresonant, SCR or hybrid battery charger with a minimum of single shift operation as shown in the table below.[1300]

Equipment Type	$CRF_{baseline}$	$PCE_{baseline}$	$W_{MM, baseline}$	$W_{NBM, baseline}$	$PF_{baseline}$
Ferroresonant	1.15	0.85	81.7	18.2	0.92
SCR	1.18	0.85	137.1	125.3	0.76
Hybrid	1.12	0.86	62.3	14.1	0.91
Unknown	1.16	0.85	99.9	55.4	0.86

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a high frequency battery charger with a minimum 8-hour shift operation five days per week, with CRF, PCE and PF meeting or exceeding and W_{MM} and W_{NBM} at or below the values shown in the table below. [1301]

Equipment Type	CRF_{ee}	PCE_{ee}	$W_{MM,ee}$	$W_{NBM,ee}$	PF_{ee}
High Frequency	1.15	0.92	48.4	48.4	0.96

Operating Hours

Annual operating hours are embedded in number of charges per year term and shall come from application or shall be based on facility operating schedule. Annual maintenance mode and no battery mode hours shall come from application.

Example Calculation *(Not to be used as default)*

A high frequency battery charger is installed, replacing an SCR charger for a forklift in a single shift warehouse near Albany. The charger has 33kWh capacity, 82% depth of discharge, charge return factor of 0.93, nameplate voltage of 50 V, nameplate amps of 80 A and draws 48.4 W in maintenance mode and 40.4W when no battery is connected. Time spent in maintenance mode is estimated at 1,150 hours per year and time spent in no battery mode is 625 hours per year. The warehouse is equipped with central air conditioning and gas heat. Annual Electric Energy Savings, Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are calculated as below.

[1299] Emerging Technologies Program Application Assessment Report #0808, Industrial Battery Charger Energy Savings Opportunities, Pacific Gas & Electric. May 29, 2009
[1300] Field Study of Industrial High Frequency Battery Chargers, MN Department of Commerce, pg 11. The 'unknown' baseline equipment type is derived as a weighted average of ferroresonant, SCR and hybrid batteries. The population fraction was derived from Table 1 of the MN study.
[1301] Ibid.

$$kWh = \left\{ Cap \times DOD \times Charge_{year} \times \left(\frac{CRF_{baseline}}{PCE_{baseline}} - \frac{CRF_{ee}}{PCE_{ee}} \right) + \left[\frac{(W_{MM,baseline} \times hrs_{MM}) + (W_{NBM,baseline} \times hrs_{NBM})}{1{,}000} - \frac{(W_{MM,ee} \times hrs_{MM}) + (W_{NBM,ee} \times hrs_{NBM})}{1{,}000} \right] \right\} \times (1 + HVAC_c)$$

$$\Delta kW = \left(\frac{PF_{baseline}}{PCE_{baseline}} - \frac{PF_{ee}}{PCE_{ee}} \right) \times V \times \frac{A}{1{,}000} \times CF \times (1 + HVAC_d)$$

$$\Delta MMBtu = \left\{ Cap \times DOD \times Charge_{year} \times \left(\frac{CRF_{baseline}}{PCE_{baseline}} - \frac{CRF_{ee}}{PCE_{ee}} \right) + \left[\frac{(W_{MM,baseline} \times hrs_{MM}) + (W_{NBM,baseline} \times hrs_{NBM})}{1{,}000} - \frac{(W_{MM,ee} \times hrs_{MM}) + (W_{NBM,ee} \times hrs_{NBM})}{1{,}000} \right] \right\} \times HVAC_{ff}$$

Cap = 33, from application
DOD = 0.82, from application
$Charge_{year}$ = 260, from Number of Charges Per Year table below based on facility operation.
$CRF_{baseline}$ = 1.18, from existing equipment type in Baseline Efficiencies section
$PCE_{baseline}$ = 0.85, from existing equipment type in Baseline Efficiencies section
CRF_{ee} = 1.15, from application
PCE_{ee}= 0.93, from application
$W_{MMbaseline}$ = 137.1, from existing equipment type in Baseline Efficiencies section
$W_{NBM,baseline}$ = 125.3, from existing equipment type in Baseline Efficiencies section
$W_{MM,ee}$ = 48.4, from application
$W_{NBM,ee}$ = 40.4, from application
$PF_{baseline}$ = 0.76, from existing equipment type in Baseline Efficiencies section
PF_{ee} = 0.96, in Compliance Efficiency section below.
V = 50 V, from application
A = 80 amps, from application
hrs_{NBM} = 625 hrs/year, from application.
hrs_{MM} = 1,150 hrs/year, from application.
$HVAC_c$ = 0.063, from Appendix D based on building type, city and vintage
$HVAC_d$ = 0.200, from Appendix D based on building type, city and vintage
$HVAC_{ff}$ = -0.001, from Appendix D based on building type, city and vintage
CF = 0, from Summary of Variables and Data Sources table

$$kWh = \left\{33 \times 0.82 \times 260 \times \left(\frac{1.18}{0.85} - \frac{1.15}{0.93}\right) + \left[\frac{(137.1 \times 1{,}150) + (125.3 \times 625)}{1{,}000} - \frac{(48.4 \times 1{,}150) + (40.4 \times 625)}{1{,}000}\right]\right\} \times (1 + 0.063) = 1{,}299\ kWh$$

$$\Delta kW = \left(\frac{0.76}{0.85} - \frac{0.96}{0.93}\right) \times 50 \times \frac{80}{1{,}000} \times 0 \times (1 + 0.200) = 0$$

$$\Delta MMBtu = \left\{33 \times 0.82 \times 260 \times \left(\frac{1.18}{0.85} - \frac{1.15}{0.93}\right) + \left[\frac{(137.1 \times 1{,}150) + (125.3 \times 625)}{1{,}000} - \frac{(48.4 \times 1{,}150) + (40.4 \times 625)}{1{,}000}\right]\right\} \times -0.001 = -1.22\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary effects are captured in the prescribed methodology detailed above. The HVAC interaction factors calculated from the prototypical building DOE-2 models as a function of the building and HVAC system type are shown in Appendix D.

Ancillary Electric Savings Impacts

Ancillary effects are captured in the prescribed methodology detailed above. The HVAC interaction factors calculated from the prototypical building DOE-2 models as a function of the building and HVAC system type are shown in Appendix D.

References

1. Emerging Technologies Program Application Assessment Report #0808, Industrial Battery Charger Energy Savings Opportunities, Pacific Gas & Electric. May 29, 2009 Available from: https://www.etcc-ca.com/reports/forklift-battery-charger?dl=1607628531
2. Jacob V. Renquist, Brian Dickman, and Thomas H. Bradley: "Economic Comparison of fuel cell powered forklifts to battery powered forklifts", International Journal of Hydrogen Energy Volume 37, Issue 17, (2012)
3. Field Study of Industrial High Frequency Battery Chargers, September 8, 2017. Minnesota Department of Commerce, Division of Energy Resources. Available from: https://www.cards.commerce.state.mn.us/CARDS/security/search.do?documentId=%7b7849AB55-DFC6-4F87-AC80-BD0356BB32D9%7d

Record of Revision

Record of Revision Number	Issue Date
3-21-17	4/9/2021

Return to Table of Contents

SOLAR POOL COVER

Measure Description

This measure is applicable to solar pool covers, which are partially transparent plastic covers that allow solar heat to transfer to the pool water without allowing heat out of the pool. Solar pool covers are typically made of several sheets of plastic with an inner layer of air bubbles. This design ensures the cover can float on the pool surface. Solar pool covers are assumed to be removed when the pool is open and in place when the pool is closed.

The solar pool cover measure is intended to reflect the installation of new solar pool covers on heated pools. Solar pool covers are meant to be used during the pool's off-hours to insulate and heat the pool water, while also preventing evaporation of the pool water.

Pools must have an existing or newly installed pool heater to be eligible for savings. Seasonal pool covers are not eligible. This measure is restricted to outdoor pools only.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = F_{elec} \times \left(\frac{\Delta kBTU_{cover}}{Eff_{poolheater}}\right) \times \frac{1}{3.412}$$

Summer Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = F_{ff} \times \left(\frac{\Delta kBTU_{cover}}{Eff_{poolheater}}\right) \times \frac{1}{1{,}000}$$

where:

$$\Delta kBTU_{cover} = \frac{\left[\left(BTU_{surface} \times ESF_{cover,surface}\right) + \left(BTU_{evap} \times ESF_{cover,evap}\right)\right]}{1{,}000} \times \frac{hrs_{cover}}{hrs}$$

$$BTU_{surface} = \left(T_{pool} - T_{amb}\right) \times A_{pool} \times U \times hrs$$

$$BTU_{evap} = 0.1 \times AF \times A_{pool} \times \left(\mathrm{P}_{\omega} - P_{dp}\right) \times \left(T_{pool} - T_{main}\right) \times hrs$$

where:

ΔkWh	= Annual electricity energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings

F_{elec} = Electric pool heating factor; use to account for the presence or absence of an electric pool heater
F_{ff} = Fossil fuel pool heating factor; use to account for the presence or absence of a fossil fuel pool heater
$\Delta kBTU_{cover}$ = Annual reduction of heat loss due to installation of cover
$Eff_{poolheater}$ = Efficiency of pool heater
$BTU_{surface}$ = Convective loss from the surface of the pool to the surrounding air
BTU_{evap} = Water evaporated from the surface of the pool to the surrounding area
hrs_{cover} = Total annual hours pool covered during the swimming season
$ESF_{cover,surface}$ = Energy Savings Factor of pool cover to insulate from convective and radiation heat losses
$ESF_{cover,evap}$ = Energy Savings Factor of pool cover to insulate from evaporative heat loss
T_{pool} = Pool temperature set point, (ºF)
T_{amb} = Average temperature of surrounding ambient air, (ºF)
T_{main} = Supply water temperature in water main, (ºF)
A_{pool} = Surface area of pool, (ft^2)
U = Surface heat loss coefficient, (BTU/hr-ft^2-ºF)
AF = Activity Factor, consideration of activity within pool
P_{ω} = Saturation vapor pressure taken at surface water temperature, (in. Hg)
P_{dp} = Saturation pressure at dew point, (in. Hg)
hrs = Total annual swimming season hours
0.1 = Simplified empirically derived evaporation factor considering latent heat and air flow[1302]; assumes 1,000 BTU/lb of latent heat required to change water to vapor at surface water temperature and air velocity over water surface ranging from 10 to 30 fpm, (lb/hr-ft^2-in. hg)
3.412 = Conversion factor, one watt-hour equals 3.412 BTU
1,000 = Conversion factor, one MMBtu equals 1,000 kBTU

Summary of Variables and Data Sources

Variable	Value	Notes
F_{elec}		If pool heater is electric, set equal to 1. Otherwise, set equal to 0.
F_{ff}		If pool heater is fossil-fuel fired, set equal to 1. Otherwise, set equal to 0.
$Eff_{poolheater}$		From application. If unknown, see table below.
$ESF_{cover,surface}$	0.80	Based on cost savings from DOE for gas and heat pump pool heater savings[1303]
$ESF_{cover,evap}$	0.95	Effectiveness of Pool Covers to Reduce Evaporation from Swimming Pools. [1304]

[1302] Simplified constant presented in ASHRAE Handbook: HVAC Application 2019 Ch 6 based on empirically derived eqn (2) constants and ASHRAE's variable assumptions
[1303] U.S. D.O.E., Swimming Pool Covers
[1304] National Plasterers Council, Effectiveness of Pool Covers to Reduce Evaporation from Swimming Pools, prepared by California Polytechnic State University, January 2016

Variable	Value	Notes
hrs_{cover}		From application. If unknown, assume 12 hours multiplied by the total number of days that of the pool season .
T_{pool}		From application. If pool temperature is not known, liner interpolation and extrapolation is acceptable to establish values.
T_{amb}		For outdoor pool ambient temperature, lookup in Outdoor Pool table in the Air Temperature and Pressure section below based on nearest city.
T_{main}		Supply water temperature in water main (ºF). Lookup in Cold Water Inlet Temperature table below based on nearest city.
A_{pool}		Pool surface area, from application.[1305] Assistance in determining the area of common pool shapes as follows: Elliptical: 3.14 x short radius x long radius Kidney Shaped: 0.45 x length x (width at one end x width at other end) Oval: 3.14 x radius^2 + (length of straight sides x width) Rectangular: length x width
U	Outdoor pool, sheltered: 5.3 Outdoor pool, unsheltered: 6.6	Surface heat loss coefficient (BTU/hr-ft^2-ºF).[1306]
AF		Lookup from table in Activity Factor section below based on pool function.
P_{ω}		Lookup from Saturation Vapor Pressure section below based on pool water temperature.
P_{dp}		Lookup from indoor or outdoor pool tables in Air Temperature and Pressure section below based on ambient temperature and relative humidity (RH) or city, respectively.

[1305] Guidance for determining surface area of common pool shapes can be found at ASHRAE Handbook: HVAC Applications, 2019, pg 51.25

[1306] ASHRAE Handbook: HVAC Applications, 2019, Ch 51, eqn. 15. Surface heat loss coefficient adjusted from ASHRAE Handbook rolled up surface heat transfer conservations by discounting contribution of evaporation (50-60%) and applying the following assumption for wind velocity: Indoor pools experience wind speeds less than 3.5 mph (10.5x0.5x0.75), outdoor sheltered pools experience wind speeds between 3.5 and 5 mph (10.5x0.5), and outdoor unsheltered pools experience wind speeds above 5 mph (10.5x0.5x1.25).

Variable	Value	Notes
hrs		From application. Hours shall reflect the total annual hours through the swimming season (number of days between season opening and season closing x 24).

Efficiency of Pool Heater by Heater Type

Pool Heater Type	$Eff_{poolheater}$	Source
Electric Heat Pump Pool Heater	5.0 COP	Heat pump pool heater COP's range from 3.0 to 7.0.
Electric Resistance Pool Heater	1.0 COP	Standard for electric resistance heating
Gas Pool Heater	0.82	10 CFR 430.32 (k)(2)

Cold Water Inlet Temperature (T_{main})

Supply water main temperatures vary according to climate, and are approximately equal to the annual average outdoor temperature plus 6°F.[1307] Supply main temperatures based on the annual outdoor temperature are shown below.

City	T_{amb}[1308] (°F)	T_{main} (°F)
Albany	48.3	54.3
Binghamton	46.3	52.3
Buffalo	48.3	54.3
Massena	43.5	49.5
NYC	55.4	61.4
Poughkeepsie	49.8	55.8
Syracuse	48.3	54.3

Saturation Vapor Pressure (P_ω)

Lookup saturation vapor pressure taken at surface water temperature from the table below, based on pool temperature.[1309]

Pool Temperature, T_{pool} (°F)	P_ω (in Hg)
72	0.79
74	0.85
76	0.91
78	0.97
80	1.03
82	1.10
84	1.18

[1307] Burch, Jay and Christensen, Craig, "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory

[1308] Average annual outdoor temperatures taken from NCDC 1981-2010 climate normals

[1309] ASHRAE Handbook: Fundamentals 2017, Ch 1 Psychrometrics, Table 3 Thermodynamic Properties of Water at Saturation

Ambient Air Temperature and Pressure (T_{amb} and P_{dp})

For outdoor pools, lookup T_{amb} and P_{dp} from the table below based on location. Ambient temperature averages for outdoor pools apply a 4-month swimming season[1310].

City	Outdoor Pool T_{amb}[1311] (°F)	Outdoor Pool P_{dp} (in. Hg)
Albany	67.8	0.48
Binghamton	65.0	0.44
Buffalo	67.3	0.47
Massena	64.6	0.47
NYC	73.4	0.53
Poughkeepsie	68.6	0.54
Syracuse	67.5	0.48

Activity Factor

Activity Factor considers activity level of the pool, allowing for splashing and a limited area of wetted deck.[1312] Look up Activity Factor from the table below based on pool application.

Type of Pool	Activity Factor (AF)
Condominium	0.65
Therapy	0.65
Hotel	0.80
Public, School	1.00
Whirlpool	1.00
Wavepool, Water Slide	1.50

Coincidence Factor (CF)

The recommended value for the coincidence factor is N/A.

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition assumes no existing solar or nighttime cover. Existing seasonal covers used during the off season are not considered baseline.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is an outdoor pool with a solar pool cover.

[1310] It is assumed that 50% of pools are unheated and operate for 3 months per year and the other 50% of pools are heated and operate for 5 months per year, giving an average of 4 months of usage per year; June 1 through Sept 30

[1311] Average ambient temperatures taken from NCDC 1981-2010 climate normals, averaged from June 1 through Sept 30

[1312] ASHRAE Handbook, Applications, 2019, Ch 6, Table 1

Operating Hours

Operating hours shall reflect the total annual hours of the swimming season. Covered hours are reflective of the times the pool cover is in use and should not reflect the times the pool is in use. Covered hours will correlate to the hours the pool is unoccupied during the seasons that the pool is filled for use.

Example Calculation *(Not to be used as default)*

A solar pool cover is installed on a heated, unsheltered outdoor pool at a public school near Albany. The swimming season spans 90 days or 2,160 hours per year. The cover is in place for 12 hours per day or 1,080 hours per year during the swimming season. The surface area of the rectangular pool is 1,200 square feet. The efficiency of the pool heater is 82% and the temperature of the pool is set to 72 °F. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are not applicable. Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta MMBtu = F_{ff} \times \left(\frac{\Delta kBTU_{cover}}{Eff_{poolheater}}\right) \times \frac{1}{1{,}000}$$

where:

$$\Delta kBTU_{cover} = \frac{\left[\left(BTU_{surface} \times ESF_{cover,surface}\right) + \left(BTU_{evap} \times ESF_{cover,evap}\right)\right]}{1{,}000} \times \frac{hrs_{cover}}{hrs}$$

$$BTU_{surface} = \left(T_{pool} - T_{amb}\right) \times A_{pool} \times U \times hrs$$

$$BTU_{evap} = 0.1 \times AF \times A_{pool} \times \left(\mathrm{P}_{\omega} - P_{dp}\right) \times \left(T_{pool} - T_{main}\right) \times hrs$$

T_{pool} = 72 °F, from application
T_{amb} = 67.8 °F, from Cold Water Inlet Temperature Table
T_{main}= 54.3 °F, from Cold Water Inlet Temperature Table
U = 6.6, from Summary of Variables and Data Sources
hrs = 2,160 hours, from application.
AF = 1, from Activity Factor table based on type of pool
A_{pool} = 1,200 SF, from application
$ESF_{cover,surface}$ = 0.80, from Summary of Variables and Data Sources
$ESF_{cover,evap}$ = 0.95, , from Summary of Variables and Data Sources
P_{ω} = 0.79, from Saturation Vapor Pressure table based on pool temperature
P_{dp} = 0.48, from Ambient Air Temperature and Pressure table based on city
$Eff_{poolheater}$ = 0.82, from application
hrs_{cover} = 1,080 hours, from application
F_{ff} = 1, from Summary of Variables and Data Sources

$$BTU_{surface} = (72 - 67.8) \times 1{,}200 \times 6.6 \times 2{,}160 = 71{,}850{,}240$$

$$BTU_{evap} = 0.1 \times 1 \times 1{,}200 \times (0.79 - 0.48) \times (72 - 67.8) \times 2{,}160 = 337{,}478$$

$$\Delta kBTU_{cover} = \frac{[(71{,}850{,}240 \times 0.8) + (337{,}478 \times 0.95)]}{1{,}000} \times \frac{1{,}080}{2{,}160} = 28{,}900\ kBTU$$

$$\Delta MMBtu = 1 \times \left(\frac{28{,}900}{0.82}\right) \times \frac{1}{1{,}000} = 35.24\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

While indoor pools may achieve some additional savings from the reduced ventilation required to remove the evaporated pool water, no relevant studies have been performed to date that would allow quantification of these impacts. Until additional information is available, these impacts are excluded from the prescribed formulation of savings.

References

1. 2019 ASHRAE Handbook – HVAC Applications, Chapter 6: Indoor Swimming Pools
2. 2019 ASHRAE Handbook – HVAC Applications, Chapter 51: Service Water Heating
3. 2017 ASHRAE Handbook – Fundamentals, Chapter 1, Psychrometrics
4. 10 CFR 430.32 Energy and water conservation standards and their compliance dates
   Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=840d2f09fea283237b0f345001c03a28&mc=true&node=pt10.3.430&rgn=div5#se10.3.430_132
5. U.S. D.O.E., Swimming Pool Covers.
   Available from: https://www.energy.gov/energysaver/swimming-pool-covers
6. Burch, Jay and Craig Christensen; "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory
   Available from:
   http://citeseerx.ist.psu.edu/viewdoc/download;jsessionid=05D73BA6EF5ECCF71969D083FB317991?doi=10.1.1.515.6885&rep=rep1&type=pdf
7. NOAA National Center for Environmental Information – NCEI 1981 – 2010 Annual/Seasonal Climate Normals
   Available from: https://www.ncdc.noaa.gov/cdo-web/datatools/normals

8. National Plasterers Council, Effectiveness of Pool Covers to Reduce Evaporation from Swimming Pools, prepared by California Polytechnic State University, January 2016 Available from: https://cdn.ymaws.com/www.npconline.org/resource/resmgr/Docs/Evaporation_Study_Report.pdf

Record of Revision

Record of Revision Number	Issue Date
7-21-19	8/30/2021

Return to Table of Contents

PROCESS EQUIPMENT

OZONE GENERATOR FOR ON-PREMISES LAUNDRY

Measure Description

This measure covers the addition of an ozone (O_3) generator to on-site commercial-grade laundry equipment, such as those found in hotels, nursing homes, health fitness centers and correctional facilities. Ozone helps break down soils into smaller molecules allowing simple agitation to release them from fabrics. As a result, ozone is a good alternative to conventional detergents and bleach, and allows washing machines to clean effectively using significantly less hot water. Using ozone in the wash cycle reduces the need for hot water and, in many situations, eliminates the need for hot water entirely. In addition, demonstration projects have found reductions in chemical and detergent use, as well as a reduction in overall water use.

This measure is only applicable to facilities with fossil fuel-fired water heating.

Method for Calculating Annual Energy and Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = N/A$$

Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings[1313]

$$\Delta MMBtu = \frac{(H_{set} - H_{main}) \times 8.33}{Eff_{boiler} \times 1{,}000{,}000} \times WUF \times HWUF \times HWRF \times Load$$

where:

ΔkWh	= Annual electricity energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
H_{set}	= Enthalpy of water at the hot water setpoint temperature (BTU/lb)
H_{main}	= Enthalpy of water at the main water supply temperature (BTU/lb)
Eff_{boiler}	= Thermal efficiency of the hot water boiler
WUF	= Washer Utilization Factor, a measure of the runtime of a typical laundry facility (lbs laundry/lbs capacity)
HWUF	= Hot Water Usage Factor, a measure of efficiency of baseline system (gal/lb)
HWRF	= Hot Water Reduction Factor
Load	= Washer capacity in pounds of laundry

[1313] Pacific Gas & Electric Company, Work Paper PGECOAPP123, Ozone Laundry Nonresidential, Revision 6, August 22, 2017.

8.33 = Density of water (lb/gal)
1,000,000 = Conversion factor, one MMBtu equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
H_{set}		From application. Enthalpies for certain water setpoint temperatures are listed in the Water Setpoint Enthalpy table below (°F).[1314] Linear interpolation is permitted for water setpoint temperatures falling between provided temperatures.
H_{main}		Supply water enthalpy in water main. Lookup in Cold Water Inlet Enthalpy table below based on nearest city.
Eff_{boiler}	0.80	Thermal Efficiency of fossil fuel-fired boiler.[1315]
WUF	4,380	Washer Utilization Factor, a measure of washer user rate, median value from the California ozone laundry demonstration projects.[1316]
HWUF	1.34	Hot Water Usage Factor, average hot water usage by baselines system per pound of laundry from the California demonstration projects.[1317]
HWRF	0.86	Hot Water Reduction Factor, average reduction of hot water reduction due to the use of ozone from the California demonstration projects.[1318]
Load		From application.

Water Setpoint Enthalpy (H_{set}) [1319]

Water Setpoint Temperature (°F)	H_{set} (BTU/lb)	Water Setpoint Temperature (°F)	H_{set} (BTU/lb)
140	107.98	180	148.01
150	117.97	190	158.05
160	127.98	200	168.10
170	137.99		

Cold Water Inlet Enthalpy (H_{main})

Supply water main temperatures vary according to climate, and are approximately equal to the annual average outdoor temperature plus 6°F.[1320] Supply main enthalpies and temperatures based on the annual outdoor temperature are shown below.

[1314] Enthalpy obtained from ASHRAE Fundamentals.
[1315] 10 CFR 431.110 (a)
[1316] PG&E Work Paper PGECOAPP123, Revision 4. Table 6.
[1317] Ibid. Table 7
[1318] Ibid. Table 8
[1319] Enthalpy obtained from ASHRAE Fundamentals.
[1320] Burch, Jay and Christensen, Craig, "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory

City	Annual average outdoor temperature[1321] (°F)	Temperature Main (°F)	H_{main}[1322] (BTU/lb)
Albany	48.3	54.3	22.37
Binghamton	46.3	52.3	20.37
Buffalo	48.3	54.3	22.37
Massena	43.5	49.5	17.57
NYC	55.4	61.4	29.48
Poughkeepsie	49.8	55.8	23.88
Syracuse	48.3	54.3	22.37

Coincidence Factor (CF)

The prescribed value for the coincidence factor is N/A.

Baseline Efficiencies from which Savings are Calculated

The baseline condition is an existing on-premises laundry facility using commercial grade laundry machines without an existing ozone generator, and either a fossil fuel-fired boiler or fossil fuel-fired water heater supplying hot water to the laundry equipment. The baseline efficiency of the water heating system is assumed to be 80% for these deemed measure savings.[1323]

Compliance Efficiency from which Incentives are Calculated

The energy efficient condition is the addition of a new ozone generator to the on-premises laundry facility. The following specific requirements apply:

- The washing capacity of each washing machine supplied by the ozone generator must be rated at 200 pounds or less,
- Laundry systems equipped with tunnel washers are not eligible,
- The ozone laundry system must be a new purchased product and installed with either a new or existing commercial washing machine,
- The ozone laundry system must transfer ozone into the water with either a venturi injection or bubble diffusion process, and;
- The replacement an existing ozone generator, either operating or failed, does not qualify for this measure.

Operating Hours

The operating hours is captured in the utilization factor. The Washer Utilization Factor, a measure of the runtime of a typical laundry facility, as determined in California demonstration projects as the median value of the annual pounds of laundry washed divided by the washer's laundry capacity in pounds which equals 4,380.

[1321] Average annual outdoor temperatures taken from NCEI 1981-2010 climate normals
[1322] ASHRAE Fundamentals Handbook, saturated water based on temperature mains
[1323] 10 CFR 431.110 (a)

Example Calculation *(Not to be used as default)*

An ozone generator is added to on-site laundry equipment in a hotel near Albany. The water heater setpoint is 140°F and the washer capacity per load is 160 lbs. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are not applicable. Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta MMBtu = \frac{(H_{set} - H_{main}) \times 8.33}{Eff_{boiler} \times 1{,}000{,}000} \times WUF \times HWUF \times HWRF \times Load$$

H_{set} = 107.98, from Water Setpoint Enthalpy table based on setpoint temperature
H_{main} = 22.37, from Cold Water Inlet Enthalpy table based on city.
Eff_{boiler} = 0.80, from Summary of Variables and Data Sources table
WUF = 4,380, from Summary of Variables and Data Sources table
HWUF = 1.34, from Summary of Variables and Data Sources table
HWRF = 0.86, from Summary of Variables and Data Sources table
Load = 160 lbs, from application.

$$\Delta MMBtu = \frac{(107.98 - 22.37) \times 8.33}{0.80 \times 1{,}000{,}000} \times 4{,}380 \times 1.34 \times 0.86 \times 160 = 719.91\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Additional electric energy is required to generate ozone in the efficient case. This is offset by pumping load savings resulting from a reduction in water consumption. As such, this methodology does not quantify these impacts.

References

1. Work Paper PGECOAPP123, Ozone Laundry Nonresidential, Revision 4, August 22, 2017. Pacific Gas & Electric Company, Customer Energy Solutions. Available from: http://deeresources.net/workpapers
2. OSHA Legionnaire's Disease eTool: Section II: C-1. Domestic Hot-Water Systems Available from: https://www.osha.gov/SLTC/legionnairesdisease/control_prevention.html

3. Burch, Jay and Craig Christensen; "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory.
   Available from:
   http://citeseerx.ist.psu.edu/viewdoc/download;jsessionid=05D73BA6EF5ECCF71969D083FB317991?doi=10.1.1.515.6885&rep=rep1&type=pdf
4. U.S. Energy Information Administration, Updated Buildings Sector Appliance and Equipment Costs and Efficiencies, June 2018
   Available from: https://www.eia.gov/analysis/studies/buildings/equipcosts/pdf/full.pdf
5. 10 CFR 430 Subpart B Appendix E Uniform Test Method for Measuring the Energy Consumption of Water Heaters
   Available from: https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=6dc64a198ad50a16b0ff6af63189872b&mc=true&n=pt10.3.430&r=PART&ty=HTML#ap10.3.430_127.e

Record of Revisions

Record of Revision Number	Issue Date
3-20-13	3/30/2020

Return to Table of Contents

PROCESS EXHAUST FILTRATION AND RECIRCULATION

Measure Description

Process exhaust air filtration systems save energy by reducing the heat load on a make-up air system by recirculating filtered process air instead of bringing in colder outdoor make-up air during the heating season. Energy savings result from the reduced temperature difference through the heat exchanger of the supply air system. The temperature difference between the filtered indoor air and the indoor supply air temperature is much lower than the difference between outdoor air and indoor supply air temperature. This reduction in heat load results in fossil fuel savings. Exhaust filtration systems typically use cartridge filters and are frequently found in welding fume exhaust and paint booth exhaust applications. Process exhaust systems must run a minimum of 2,000 hours during the heating season to be eligible for savings claims.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = \Delta kWh_{fan} = -\frac{CFM \times \Delta P \times hrs}{\frac{33{,}013}{5{,}202} \times Eff_{fanmech} \times Eff_{fanmotor}} \times 0.746$$

Summer Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = \frac{CFM \times 1.08 \times \Delta T \times hrs}{Eff_{fuelheat} \times 1{,}000{,}000}$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
ΔkWh_{fan}	= Increased fan energy consumption due to pressure drop associated with installation of filters.
CFM	= Volumetric flow rate of eliminated make-up air unit
ΔP	= Pressure drop at nominal airflow across cartridge filter, in inches of water
hrs	= Operating hours of process system coincident with heating season
$Eff_{fanmech}$	= Mechanical efficiency of process exhaust fan
$Eff_{fanmotor}$	= Efficiency of process exhaust fan motor
ΔT	= Average difference between process exhaust air temperature and outdoor heating season temperature
$Eff_{FuelHeat}$	= Efficiency of fossil fuel heating equipment (AFUE, Et, or Ec)
0.746	= Conversion factor (kW/hp), 746 watts equals one electric horsepower

1.08 = Specific heat of air × density of inlet air @ 70˚F × 60 min/hr.[1324]
5.202 = Conversion factor from inches of water to pounds per square ft (lb/sq.ft.)
33,013 = Conversion factor from horsepower to ft.lb/min
1,000,000 = Conversion factor, one MMBtu equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
CFM		From application.
ΔP		From application.
$Eff_{fanmech}$		From application, if unknown use 0.67.[1325]
$Eff_{fanmotor}$		From application.
ΔT		From application. If unknown refer to New York weather data table below.
hrs		From application, hours that process equipment is operating coincident with the heating season (October 1st through May 31st).
$Eff_{FuelHeat}$		From application. If unknown use 0.8.[1326]

New York Weather Data Table[1327]

City	Outdoor Winter Air Temp (°F)	Process Exhaust Air Temp (°F)	Temp Difference, ΔT (°F)
Albany	30.1	70	39.9
Binghamton	28.5	70	41.5
Buffalo	30.4	70	39.6
Massena	30.7	70	39.3
NYC	38.7	70	31.3
Poughkeepsie	37.2	70	32.8
Syracuse	30.1	70	39.9

Coincidence Factor (CF)

The prescribed value for the coincidence factor is N/A.

[1324] The sensible heat constant at standard conditions of 1.08 is applied in accordance with standard HVAC industry practice. While the underlying assumptions are not representative characteristics of a NY heating season, the impacts to this value due to average heating season temperature and NY mean elevation offset such that the NY heating season specific value is approximately 1.08.
[1325] ASHRAE 90.1 2013, Section 6.5.3.1.3
[1326] Assumed standard combustion efficiency of heating equipment, Franklin Energy Services Analysis of AHRI listed devices available 1/1/2016
[1327] NOAA National Centers for Environmental Information – NCEI 1981-2010 Climate Normals. Temperatures are based on facilities operating 2 shifts (16 hours, 7am – 11pm) during weekdays (5 days per week) during winter months (December through March)

Baseline Efficiencies from which Savings are Calculated

The baseline condition is an industrial process in which all process waste heat is expelled from the building without heat recovery for the building's outdoor make-up air ventilation system.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is an industrial process with a waste heat recovery exhaust filtration system that can reclaim waste heat from the process exhaust through filtration and recirculation, reducing the heating requirements of the building's outdoor make-up air ventilation.

Operating Hours

Operating hours shall reflect hours that process equipment is operating coincident with the heating season (October 1st through May 31st).

Example Calculation *(Not to be used as default)*

A process exhaust air filtration system is installed in an industrial facility in Albany to filter and recirculate indoor process air. The flow rate of the eliminated make up air unit is rated at 200 CFM. The exhaust fan motor efficiency is 91% and the mechanical efficiency of the fan is 72%. The pressure drop across the filter is 5 psi. The average temperature differential between outdoor air and the indoor set point temperature during the heating season is 40°F and the process coincides with the heating season for 2,880 hours per year. The building is equipped with central AC and gas heat. Summer Peak Coincident Demand Savings are not applicable. Annual Electric Energy Savings and Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta kWh = \Delta kWh_{fan} = -\frac{CFM \times \Delta P \times hrs}{\frac{33{,}013}{5.202} \times Eff_{fanmech} \times Eff_{fanmotor}} \times 0.746$$

$$\Delta MMBtu = \frac{CFM \times 1.08 \times \Delta T \times hrs}{Eff_{HVAC} \times 1{,}000{,}000}$$

CFM = 200 CFM, from application.
ΔP = 5, from application.
$Eff_{fanmech}$ = 0.72, from application
$Eff_{fanmotor}$ = 0.91, from application.
ΔT= 40°F, from application
Hrs = 2,880 hours, from application
$Eff_{FuelHeat}$ = 0.8, from application

$$\Delta kWh = \Delta kWh_{fan} = -\frac{200 \times 5 \times 2{,}880}{\frac{33{,}013}{5.202} \times 0.72 \times 0.91} \times 0.746 = -517\ kWh$$

$$\Delta MMBtu = \frac{200 \times 1.08 \ \times 40 \times 2{,}880}{0.8 \times 1{,}000{,}000} = 31.10\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. NOAA National Centers for Environmental Information – NCEI 1981-2010 Climate Normals
   Available from: https://www.ncdc.noaa.gov/cdo-web/datatools/normals
2. Assumed standard combustion efficiency of heating equipment, Franklin Energy Services Analysis of AHRI listed devices available 1/1/2016
3. ASHRAE Standard 90.1-2013, Energy Standard for Buildings Except Low-Rise Residential Buildings (I-P) Edition
4. 10 CFR 431.446 Small electric motors energy conservation standards and their effective dates.
   Available from: https://gov.ecfr.io/cgi-bin/text-idx?SID=6fb7b94f1b9d3af4accb978144ba015c&mc=true&node=se10.3.431_1446&rgn=div8

Record of Revisions

Record of Revision Number	Issue Date
7-20-18	7/31/2020

Return to Table of Contents

STEAM TRAP - OTHER APPLICATION

Measure Description

Steam systems distribute heat from boilers to satisfy space heating, process, and commercial end-use requirements. Steam distribution systems contain steam traps, which are automatic valves that remove condensate, air, and other non-condensable gases, while preventing or minimizing steam loss. Steam traps that fail may allow excess steam to escape, thus increasing the amount of steam that must be generated to meet end-use requirements. This measure and calculations are applicable to steam traps served by fossil fuel-fired boilers, for low, medium, and high pressure (0-3,000 psig) non-space heating steam applications, where flash steam on the condensate side of steam traps is not utilized for other heating processes. These steam applications include but are not limited to: steam humidifiers, high pressure PRV stations, medium pressure PRV stations, and steam to hot water heat exchangers. This measure does not apply to municipal steam systems.

All traps are susceptible to wear and dirt contamination and require periodic inspection and maintenance to ensure correct operation. Faulty steam traps (leaking or blow-through) can be diagnosed with ultrasonic, temperature, or conductivity monitoring techniques. Regular steam trap maintenance and faulty steam trap replacement are steps that minimize steam production. There are three major types of steam traps that are applicable: 1) thermostatic (including float and thermostatic) 2) mechanical and 3) thermodynamic traps. A system-wide assessment of steam trap operation and functionality is required for this measure and estimated energy savings is restricted to the repair or replacement of faulty traps only.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = N/A$$

Summer Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = units \times Loss_{steam} \times \frac{\Delta H_{vap}}{Eff} \times \frac{hrs}{1{,}000{,}000} \times F_{CR}$$

$$Loss_{steam} = 60 \times \frac{\pi}{4} \times Dia^2 \times psia^{0.97} \times F_{Discharge} \times F_{Loss}$$

$$psia = psig + p_{atm}$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings

units = Number of steam traps repaired/replaced under the program
$Loss_{steam}$ = Hourly steam loss per failed trap (lb/hr)
ΔH_{vap} = Heat of vaporization (latent heat), in BTU/lb, at system operating pressure (psig)
Eff = Efficiency of boiler
hrs = Annual hours of steam trap operation
$F_{Discharge}$ = Discharge coefficient
F_{CR} = Condensate Return Factor, used to account for the proportion of energy lost that is returned to the system via condensate line
Dia = Internal Diameter (I.D.) of steam trap orifice (inches)
psia = Absolute steam pressure (psia)
F_{Loss} = Steam loss adjustment factor
psig = Steam gauge pressure (psi)
p_{atm} = Atmospheric pressure (psi) where system is vented and not a pressurized or vacuum condensate return system; otherwise, psia should be established such that P_a reflects the pressure differential between the inlet and outlet of the steam trap
60 = An empirically derived constant in the Grashof's equation (lb_m/ $in^{0.06}$-$lb^{0.97}$-hr).[1328]
$\pi/4$ = Orifice area development factor
$^{0.97}$ = An empirically derived constant in the Grashof equation
1,000,000 = Conversion factor, one MMBtu equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
$Loss_{steam}$		Calculated per the equation above, dependent upon system operating pressure (psig), steam trap orifice diameter (Dia) and steam loss adjustment factor (F_{Loss}).
ΔH_{vap}		Look up from table below based on system operating pressure (psig).
Eff		Boiler efficiency, from application. Either E_t or AFUE shall be used, based on nameplate rating metric of existing equipment or actual system efficiency as provided on the application and documented by the customer.
hrs		From application. If unknown, use a default of 8,424 for industrial applications[1329] and 2,425 for dry cleaners.[1330]
$F_{Discharge}$	0.7	Based on Massachusetts Steam Trap Evaluation[1331]

[1328] Massachusetts Program Administrators and Energy Efficiency Advisory Council, "Steam Trap Evaluation Phase 2" March 8, 2017. pg 6
[1329] Assumes constant operation except for 2 weeks out of the year when boilers are often shutoff for maintenance
[1330] CLEAResult "Work Paper Steam Traps Revision #2" Revision 3 dated March 2, 2012. The CLEAResults Work Paper is not publicly available, but is referenced by the Illinois TRM Version 6, pg 214
[1331] Ibid, pg 7

Variable	Value	Notes
F_{CR}	Condensate Return: 0.45 No Condensate Return: 1.00	Based on ERS memo to NYSEG/RG&E[1332]
Dia		From application. If unknown, defaults are provided for certain system pressure ranges in the Orifice Diameter table below.
psia		Calculated per the equation above, dependent upon system operating pressure (psia).
F_{Loss}	0.37	Based on Massachusetts Steam Trap Evaluation[1333]
psig		From application.
P_{atm}		Atmospheric pressure (14.7 psi) where system is vented and not a pressurized or vacuum condensate return system; otherwise, P_{atm} should be established such that psia reflects the pressure differential across the steam trap.

Heat of Vaporization (BTU/lb)[1334]

Pressure (psig)	Heat of Vaporization (BTU/lb)	Pressure (psig)	Heat of Vaporization (BTU/lb)	Pressure (psig)	Heat of Vaporization (BTU/lb)
0	970	**70**	898	**500**	752
1	968	**75**	895	**550**	740
2	966	**80**	892	**600**	729
3	964	**85**	889	**700**	707
4	962	**90**	886	**800**	686
5	961	**95**	884	**900**	667
6	959	**100**	881	**1,000**	647
7	957	**110**	876	**1,100**	628
8	956	**120**	871	**1,200**	612
9	954	**130**	866	**1,300**	591
10	953	**140**	862	**1,400**	573
15	946	**150**	857	**1,500**	555
20	940	**160**	853	**1,600**	536
25	934	**170**	849	**1,700**	518
30	929	**180**	845	**1,800**	500
35	924	**190**	842	**1,900**	481
40	920	**200**	838	**2,000**	462
45	916	**250**	821	**2,250**	412

[1332] ERS Memo to NYSEG/RG&E, "Recommendations to Update Algorithms for C&I Steam Trap Repair Energy Savings in NY TRM Introduction", October 10, 2019

[1333] Massachusetts Program Administrators and Energy Efficiency Advisory Council, "Steam Trap Evaluation Phase 2" Table 4-7, March 8, 2017.

[1334] Calculated from NIST Standard Reference Database 10, "NIST/ASME Steam Properties," Ver. 2.11, National Institute of Standards and Technology, U.S. Department of Commerce, Gaithersburg, MD, 1997

Pressure (psig)	Heat of Vaporization (BTU/lb)	Pressure (psig)	Heat of Vaporization (BTU/lb)	Pressure (psig)	Heat of Vaporization (BTU/lb)
50	912	**300**	805	**2,500**	357
55	908	**350**	791	**2,750**	293
60	905	**400**	777	**3,000**	209
65	901	**450**	764		

Orifice Diameter[1335]

System Pressure	Diameter of Orifice (in)
< 15 psig	No Default
≥ 15 psig and < 30 psig	0.1875
≥ 30 psig and < 300 psig	0.2500
≥ 300 psig	No Default

Coincidence Factor (CF)

The prescribed value for the coincidence factor is N/A.

Baseline Efficiencies from which Energy Savings are Calculated

The baseline is assumed to be a leaking or blow-through steam trap failed open on a non-space heating steam system.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is an intact (replaced or repaired) steam trap on a non-space heating steam system. Replaced or repaired steam traps will no longer leak or blow-through after installation.

Operating Hours

Operating hours of steam trap system are assumed to be 8,424[1336] for industrial and process applications and 2,425[1337] for steam traps used in dry cleaners.

Example Calculation *(Not to be used as default)*

Four steam traps identified during a system survey as having failed open are replaced in an industrial process facility with an 80% gas fired steam boiler with condensate return system. Steam traps have 1/4" orifice diameter and the system has a steam gage pressure of 200 psi. The system is pressurized an estimated 8,250 hours per year. Annual Electric Energy Savings

[1335] Illinois TRM via ConEd Large C&I Program Impact and Process Evaluation, prepared by Navigant, August 2019, slide 74

[1336] Assumes constant operation except for 2 weeks out of the year when boilers are often shutoff for maintenance

[1337] CLEAResult "Work Paper Steam Traps Revision #2" Revision 3 dated March 2, 2012, Work Paper not publicly available, but reported in Illinois TRM Version 6, pg 214

and Summer Peak Coincident Demand Savings are not applicable. Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta MMBtu = units \times Loss_{steam} \times \frac{\Delta H_{vap}}{Eff} \times \frac{hrs}{1{,}000{,}000} \times F_{CR}$$

$$Loss_{steam} = 60 \times \frac{\pi}{4} \times Dia^2 \times psia^{0.97} \times F_{Discharge} \times F_{Loss}$$

$$psia = psig + p_{atm}$$

units = 4, from application
Dia = 0.25, from application
psia = psig + p_{atm} = 200 + 14.7 = 214.7
psig from application
p_{atm} from Summary of Variables and Data Sources table
$F_{Discharge}$ = 0.7, from Summary of Variables and Data Sources table
F_{loss} = 0.37, from Summary of Variables and Data Sources table
ΔH_{vap} = 838, from Heat of Vaporization table based on pressure from application
Eff = 0.80, from application
hrs = 8,250, from application
F_{CR} = 0.45, from Summary of Variables and Data Sources table based on conditions from application

$$Loss_{steam} = 60 \times \frac{\pi}{4} \times 0.25^2 \times 214.7^{0.97} \times 0.7 \times 0.37 = 139.411$$

$$\Delta MMBtu = 4 \times 139.411 \times \frac{838}{0.80} \times \frac{8{,}250}{1{,}000{,}000} \times 0.45 = 2{,}168.59\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. Massachusetts Program Administrators and Energy Efficiency Advisory Council, "Steam Trap Evaluation Phase 2", March 8, 2017.
   Available from: http://ma-eeac.org/wordpress/wp-content/uploads/Steam-Trap-Evaluation-Phase-II.pdf
2. Illinois Technical Reference Manual, Version 8, October 17, 2019
   Available from: https://www.ilsag.info/technical-reference-manual/il_trm_version_8/
3. ERS Memo to NYSEG/RG&E, "Recommendations to Update Algorithms for C&I Steam Trap Repair Energy Savings in NY TRM Introduction", October 10, 2019
4. "NIST/ASME Steam Properties," Ver. 2.11, National Institute of Standards and Technology, U.S. Department of Commerce, Gaithersburg, MD, 1997
5. Large Commercial & Industrial (Large C&I) Program Impact and Process Evaluation, Presented to Con Edison, Prepared by Navigant, August 2019
   Available from:
   http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7B614F67CD-8511-4E76-A963-38B3079505B5%7D

Record of Revision

Record of Revision Number	Issue Date
9-18-17	9/28/2018
3-19-11	3/29/2019
3-20-12	3/30/2020

Return to Table of Contents

STEAM TRAP MONITORING SYSTEM – OTHER APPLICATIONS

Measure Description

Many facilities that contain steam systems only perform steam trap surveys once a year. This can result in significant steam loss if a steam trap actively fails sometime between annual audits.
This measure covers the installation of automatic steam trap monitoring systems, which alert maintenance personnel to failed steam traps, enabling rapid repair or replacement. Individual sensors on steam traps can feed data to a hub that displays the status of each monitored steam trap. Energy savings are based on elimination of steam trap losses occurring before the annual maintenance inspection for leaking or failed steam traps. Savings are calculated similarly to regular steam trap replacement, but due to the presence of the monitoring software, this measure has longer lifetime savings.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = N/A$$

Summer Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = units \times Loss_{steam} \times \frac{\Delta H_{vap}}{Eff} \times \frac{hrs}{1{,}000{,}000} \times F_{Failed} \times F_{hrs} \times F_{CR}$$

$$Loss_{steam} = 60 \times \frac{\pi}{4} \times Dia^2 \times psia^{0.97} \times F_{Discharge} \times F_{Loss}$$

$$psia = psig + p_{atm}$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of steam traps repaired/replaced under the program
$Loss_{steam}$	= Hourly steam loss per failed trap (lb/hr)
ΔH_{vap}	= Heat of vaporization (latent heat), in BTU/lb, at system operating pressure (psig)
Eff	= Efficiency of boiler
hrs	= Annual hours of steam trap operation
F_{Failed}	= The percentage of steam traps that fail annually
F_{hrs}	= Percentage of annual hours that steam traps are failed
Dia	= Internal Diameter (I.D.) of steam trap orifice (inches)
F_{CR}	= Condensate Return Factor, used to account for the proportion of energy lost that is returned to the system via condensate line

psia = Absolute steam pressure (psi)
$F_{Discharge}$ = Discharge coefficient
F_{Loss} = Steam loss adjustment factor
psig = Steam gage pressure (psi)
p_{atm} = Atmospheric pressure (psi)
60 = An empirically derived constant in the Grashof's equation (lb_m/ $in^{0.06}$-$lb^{0.97}$-hr)[1338]
$\pi/4$ = Orifice area development factor
$^{0.97}$ = An empirically derived constant in the Grashof equation[1339]
1,000,000 = Conversion factor, one MMBtu equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
$Loss_{steam}$		Calculated per the equation above, dependent upon system operating pressure (psig), steam trap orifice diameter (Dia) and steam loss adjustment factor (F_{Loss}).
ΔH_{vap}		Look up from table below based on system operating pressure (psig).
Eff		Boiler efficiency, from application. Either E_t or AFUE shall be used, based on nameplate rating metric of existing equipment or actual system efficiency as provided on the application and documented by the customer.
hrs		Look up in Operating Hours Section below.
$F_{Discharge}$	0.7	Based on Massachusetts Steam Trap Evaluation[1340]
F_{Failed}		From application, based upon historical data for facility, if unknown assume 0.15.[1341]
F_{CR}	Condensate Return: 0.45 No Condensate Return: 1.00	Based on ERS memo to NYSEG/RG&E[1342]
Dia		From application.
psia		Calculated per the equation above, dependent upon system operating pressure (psia).
F_{Loss}	0.37	Based on Massachusetts Steam Trap Evaluation[1343]
F_{hrs}	0.5	Assumes steam traps would fail for 50% of annual operating hours without monitoring system

[1338] Massachusetts Program Administrators and Energy Efficiency Advisory Council, "Steam Trap Evaluation Phase 2" March 8, 2017. pg 6
[1339] Ibid.
[1340] Ibid, pg 7
[1341] Average annual failure rate based upon EUL of 6 years
[1342] ERS Memo to NYSEG/RG&E, "Recommendations to Update Algorithms for C&I Steam Trap Repair Energy Savings in NY TRM Introduction", October 10, 2019. The CR factor is used to account for some of the steam energy being returned to the system rather than being vented into the atmosphere.
[1343] Massachusetts Program Administrators and Energy Efficiency Advisory Council, "Steam Trap Evaluation Phase 2" Table 4-7, March 8, 2017.

Variable	Value	Notes
psig		From application.
P_{atm}	14.7	Atmospheric pressure (14.7 psi) where system is vented and not a pressurized or vacuum condensate return system; otherwise, psia should be established such that P_a reflects the pressure differential across the steam trap.

Heat of Vaporization (BTU/lb)[1344]

Pressure (psig)	Heat of Vaporization (BTU/lb)	Pressure (psig)	Heat of Vaporization (BTU/lb)	Pressure (psig)	Heat of Vaporization (BTU/lb)
0	970	**70**	898	**500**	752
1	968	**75**	895	**550**	740
2	966	**80**	892	**600**	729
3	964	**85**	889	**700**	707
4	962	**90**	886	**800**	686
5	961	**95**	884	**900**	667
6	959	**100**	881	**1,000**	647
7	957	**110**	876	**1,100**	584
8	956	**120**	871	**1,200**	354
9	954	**130**	866	**1,300**	591
10	953	**140**	862	**1,400**	573
15	946	**150**	857	**1,500**	555
20	940	**160**	853	**1,600**	536
25	934	**170**	849	**1,700**	518
30	929	**180**	845	**1,800**	500
35	924	**190**	842	**1,900**	481
40	920	**200**	838	**2,000**	462
45	916	**250**	821	**2,250**	412
50	912	**300**	805	**2,500**	357
55	908	**350**	791	**2,750**	293
60	905	**400**	777	**3,000**	209
65	901	**450**	764		

Coincidence Factor (CF)

The prescribed value for the coincidence factor is N/A.

Baseline Efficiencies from which Savings are Calculated

The baseline condition is a steam distribution system without a steam trap monitoring system.

[1344] Values in this table were calculated from NIST Standard Reference Database 10, "NIST/ASME Steam Properties," Ver. 2.11, National Institute of Standards and Technology, U.S. Department of Commerce, Gaithersburg, MD, 1997

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a steam distribution system with a steam trap monitoring system.

Operating Hours

Operating hours of steam trap system are assumed to be 8,424 for industrial and process applications and 2,425 for steam traps used in dry cleaners.

Example Calculation *(Not to be used as default)*

A steam trap monitoring system is installed on an industrial process steam system. The system comprises 30 steam traps and has nameplate efficiency of 82% with an installed condensate return system. Steam traps have 1/4" orifice diameter and the system has a steam gage pressure of 200 psi. Traps are pressurized an estimated 8,250 hours per year. Previous steam trap inspections at the site captured an annual failure rate of 20%. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are not applicable. Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta MMBtu = units \times Loss_{steam} \times \frac{\Delta H_{vap}}{Eff} \times \frac{hrs}{1{,}000{,}000} \times F_{hrs} \times F_{Failed} \times F_{CR}$$

$$Loss_{steam} = 60 \times \frac{\pi}{4} \times Dia^2 \times psia^{0.97} \times F_{Discharge} \times F_{Loss}$$

$$psia = psig + p_{atm}$$

units = 30, from application
Dia = 0.25, from application
Psia = psig + p_{atm} = 200 + 14.7 = 214.7
psig from application
p_{atm} from Summary of Variables and Data Sources table
$F_{Discharge}$ 0.7, from Summary of Variables and Data Sources table
F_{loss} = 0.37, from Summary of Variables and Data Sources table
F_{hrs} = 0.5, from Summary of Variables and Data Sources table
F_{failed} = 0.2, from Summary of Variables and Data Sources table
ΔH_{vap} = 838, from Heat of Vaporization table based on pressure from application
Eff = 0.82, from application
hrs = 8,250, from application
F_{CR} = 0.45, from Summary of Variables and Data Sources table based on conditions from application

$$Loss_{steam} = 60 \times \frac{\pi}{4} \times 0.25^2 \times 214.7^{0.97} \times 0.7 \times 0.37 = 139.411$$

$$\Delta MMBtu = 30 \times 139.411 \times \frac{838}{0.82} \times \frac{8{,}250}{1{,}000{,}000} \times 0.5 \times 0.2 \times 0.45 = 1{,}586.77\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. Massachusetts Program Administrators and Energy Efficiency Advisory Council, "Steam Trap Evaluation Phase 2", March 8, 2017.
   Available from: http://ma-eeac.org/wordpress/wp-content/uploads/Steam-Trap-Evaluation-Phase-II.pdf
2. ERS Memo to NYSEG/RG&E, "Recommendations to Update Algorithms for C&I Steam Trap Repair Energy Savings in NY TRM Introduction", October 10, 2019
3. "NIST/ASME Steam Properties," Ver. 2.11, National Institute of Standards and Technology, U.S. Department of Commerce, Gaithersburg, MD, 1997

Record of Revisions

Record of Revision Number	Issue Date
7-20-19	7/31/2020

Return to Table of Contents

REFRIGERATION

AIR-COOLED REFRIGERATION CONDENSER

Measure Description

This measure covers the installation of efficient, close approach remote air-cooled refrigeration system condensers typically found in supermarkets. An approach temperature of 8°F or less for low temperature systems and 13°F for medium temperature systems is required. Additionally, condenser efficiency must be greater than or equal to 85 BTU/h of heat rejection capacity per watt of fan power. Savings are derived from the reduction in condensing temperatures and improved efficiency of the condenser fan system.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times tons/unit \times (\Delta kWh/ton)$$

Summer Peak Coincident Demand Savings

$$\Delta kW = units \times tons/unit \times (\Delta kW/ton) \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
tons/unit	= Tons of refrigeration per unit, based on compressor nameplate
(ΔkWh/ton)	= Annual electric energy savings per ton of compressor capacity
(ΔkW/ton)	= Electric demand savings per ton of compressor capacity
CF	= Coincidence factor

Summary of Variables and Data Sources

Variable	Value	Notes
tons/unit		From application.
(ΔkWh/ton)		Look up based on city from Energy and Demand Savings table below.
(ΔkW/ton)		Look up based on city from Energy and Demand Savings table below.
CF	1.0	

Energy and Demand Savings

Unit energy and demand savings were calculated from a DOE-2.2 simulation of a prototypical grocery store. The prototype building characteristics are described in Appendix A. The unit energy and demand savings for seven different cities in NY are shown below.

City	(ΔkWh/ton)	(ΔkW/ton)
Albany	1,296	0.136
Binghamton	1,290	0.143
Buffalo	1,297	0.103
Massena	1,301	0.123
NYC	1,220	0.152
Poughkeepsie	1,258	0.144
Syracuse	1,283	0.149

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 1.0.[1345]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is assumed to be a standard efficiency air-cooled refrigeration system condenser, with a 15ºF approach temperature on low temperature applications and a 20ºF approach temperature on medium temperature applications. The baseline condition assumes a standard efficiency of 45 BTU/h of heat rejection capacity per watt of fan power.[1346]

Compliance Efficiency from which Incentives are Calculated

The compliance condition is an efficient air-cooled refrigeration system condenser, with an approach temperature of 8ºF or less on low temperature applications and an approach temperature of 13ºF or less on medium temperature applications. Condenser efficiency must be greater than or equal to 85 BTU/h of heat rejection capacity per watt of fan power. [1347]

Operating Hours

Refrigeration equipment is assumed to be available for operation 8,760 hours per year.

Example Calculation *(Not to be used as default)*

A 2-ton, close approach air-cooled refrigeration system condenser is installed in a supermarket located near Albany. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

$$\Delta kWh = units \times tons/unit \times (\Delta kWh/ton)$$

[1345] *No source specified – update pending availability and review of applicable references.*
[1346] DEER Update Study, Final Report, December 2005. p. 7-69
[1347] DEER Update Study, Final Report, December 2005. p. 7-69

$$\Delta kW = units \times tons/unit \times (\Delta kW/ton) \times CF$$

units = 1, from application
tons/unit = 2, from application.
(ΔkWh/ton) = 1,296, from Energy and Demand Savings table based on location from application
(ΔkW/ton) = 0.136, from Energy and Demand Savings table based on location from application
CF=1.0, from Summary of Variables and Data Sources table

$$\Delta kWh = 1 \times 2 \times 1{,}296 = 2{,}592\ kWh$$

$$\Delta kW = 1 \times 2 \times 0.136 \times 1 = 0.272\ kW$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. California DEER, 2004-2005 Database for Energy Efficiency Resources (DEER) Update Study, Final Report, Itron, Inc. Vancouver, WA. December, 2005
   Available from: www.calmac.org/publications/2004-05_DEER_Update_Final_Report-Wo.pdf

Record of Revision

Record of Revision Number	Issue Date
1	10/15/2010
3-18-15	3/29/2018

Return to Table of Contents

AUTOMATIC DOOR CLOSER FOR WALK-IN COOLER/FREEZER

Measure Description

This measure covers the installation of an auto-closer to the main insulated opaque door(s) of an existing walk-in cooler or freezer. Auto-closers on walk-in coolers and freezers can reduce the amount of time that doors are open, thereby reducing infiltration and refrigeration loads. The auto-closer must firmly close the door when it is within 1-inch of full closure. The walk-in door perimeter must be ≥ 16 ft.[1348]

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times (\Delta kWh/unit)$$

Summer Peak Coincident Demand Savings

$$\Delta kW = units \times (\Delta kW/unit)$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

where:

ΔkWh = Annual electric energy savings
ΔkW = Peak coincident demand electric savings
ΔMMBtu = Annual fossil fuel energy savings
units = Number of doors equipped with automatic door closers installed under the program
(ΔkWh/unit) = Annual electric energy savings per door equipped with an automatic door closer
(ΔkW/unit) = Peak coincident demand electric savings per door equipped with an automatic door closer

Summary of Variables and Data Sources

Variable	Value	Notes
(ΔkWh/unit)		Lookup based on location in table below.[1349]
(ΔkW/unit)		Lookup based on location in table below.[1350]

[1348] Lower limit of eligible door size based on Cadmus Group, Inc., *"Energy Smart Grocer Impact Evaluation"*, October 21, 2013.
[1349] Based on PG&E Work Paper PGECOREF110 and NOAA Climate Normals. Baseline and climate dependent savings were established by comparing savings values from PG&E Work Paper PGECOREF110 against respective California climate zone NOAA climate normal CDD_{65} values. The established trendline was then applied to New York's city specific CDD values to develop New York savings.
[1350] Ibid

Per Unit Savings Lookup Table

Location	Cooler Savings (ΔkWh/unit)	Cooler Savings (ΔkW/unit)	Freezer Savings (ΔkWh/unit)	Freezer Savings (ΔkW/unit)
Albany	1,860	0.570	3,469	0.778
Binghamton	1,822	0.550	3,398	0.735
Buffalo	1,851	0.565	3,451	0.768
Massena	1,819	0.549	3,392	0.731
New York City	1,959	0.621	3,653	0.891
Poughkeepsie	1,873	0.576	3,493	0.793
Syracuse	1,855	0.567	3,460	0.773

Coincidence Factor (CF)

The prescribed value for the coincidence factor is N/A. Peak coincidence is embedded into kW per unit savings above.

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is an existing walk in cooler or freezer without an existing auto-closer or strip curtains.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a walk-in cooler or freezer with an automatic, spring-loaded or hydraulic-type door closer installed. The walk-in door perimeter must be ≥ 16 ft.

Operating Hours

Operating hours are embedded into the PG&E energy models used to estimate the energy savings listed above.

Example Calculation *(Not to be used as default)*

An automatic door closer is installed on a walk-in cooler in a commercial facility located near Albany. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

$$\Delta kWh = units \times (\Delta kWh/unit)$$

$$\Delta kW = units \times (\Delta kW/unit)$$

units = 1, from application
(ΔkWh/unit) = 1,860, from Per Unit Savings Lookup Table based on location and refrigeration type from application
(ΔkW/unit) = 0.57, from Per Unit Savings Lookup Table based on location and refrigeration type from application

$$\Delta kWh = 1 \times 1{,}860 = 1{,}860\ kWh$$

$$\Delta kW = 1 \times 0.57 = 0.57\ kW$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Reduction in heat transfer between the refrigerated case and ambient air during periods when the main door is open will result in a negligible reduction in space heating requirements and a small increase in cooling requirements. Consideration of these effects is not included in this methodology.

Ancillary Electric Savings Impacts

Reduction in heat transfer between the refrigerated case and ambient air during periods when the main door is open will result in a negligible reduction in space heating requirements and a small increase in cooling requirements. Consideration of these effects is not included in this methodology.

References

1. Pacific Gas & Electric Company. Work Paper PGECOREF110 Refrigerated Storage Auto Closer Revision 7, June 14, 2018
   Available from: www.deeresources.net/workpapers
2. Cadmus Group, Inc., *"Energy Smart Grocer Impact Evaluation"*, October 21, 2013. Prepared for Bonneville Power Administration.
   Available from:
   https://www.bpa.gov/EE/Utility/Evaluation/Evaluation/Cadmus_ESG_Impact_Evaluation_Report_Final.pdf
3. NOAA National Centers for Environmental Information – NCEI 1981-2010 Climate Normals
   Available from: https://www.ncdc.noaa.gov/cdo-web/datatools/normals

Record of Revision

Record of Revision Number	Issue Date
6-19-2	6/28/2019

Return to Table of Contents

COOLER AND FREEZER DOOR GASKET

Measure Description

This measure covers the replacement of reach-in and walk-in refrigerated display case door gaskets that have become damaged due to normal use and/or the failure of anti-condensate heater elements. When damaged and/or missing, the warmer, more humid air present in the store will infiltrate the case increasing the refrigeration system load while often reducing the efficiency of the evaporator unit as a result of frost accumulation. This measure applies to gaskets on both reach-in doors and the main door of walk-in units typical of supermarkets, convenience stores, and restaurants.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = ft_{door} \times (\Delta kWh/ft)$$

Peak Coincident Electric Demand Savings

$$\Delta kW = \frac{ft_{door} \times (\Delta kWh/ft)}{8{,}760} \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
ft_{door}	= Linear feet of damaged and/or missing door gasket
(ΔkWh/ft)	= Annual electric energy savings per linear foot of damaged and/or missing door gasket
CF	= Coincidence factor
8,760	= Hours per year

Summary of Variables and Data Sources

Variable	Value	Notes
ft_{door}		From application.
(ΔkWh/ft)	Cooler (>32 °F): 15 Freezer (<32 °F): 114	Annual kWh per linear foot of replaced door gasket.[1351]
CF	1.0	

[1351] ADM Associates, Inc., Commercial Facilities Contract Group 2006-2008 Direct Impact Evaluation, February 2010, Table 5-3, Assumes baseline gaskets are 50% effective.

Coincidence Factor (CF)

The prescribed coincidence factor for this measure is 1.0.[1352]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is premised on a door with damaged and/or missing gaskets, assumed to be 50% effective.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is the installation of intact door gaskets so as to achieve a minimum 1.5% infiltration rate or lower.

Operating Hours

Refrigeration equipment is assumed to be available for operation 8,760 hours per year.

Example Calculation *(Not to be used as default)*

A ten foot linear section of damaged freezer door gasket is replaced in a commercial facility. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

$$\Delta kWh = ft_{door} \times (\Delta kWh/ft)$$

$$\Delta kW = \frac{ft_{door} \times (\Delta kWh/ft)}{8{,}760} \times CF$$

ft_{door} = 10, from application
(ΔkWh/ft) = 114, from Summary of Variables and Data Sources table based on refrigeration type from application
CF = 1.0, from Summary of Variables and Data Sources table

$$\Delta kWh = 10 \times 114 = 1{,}140\ kWh$$

$$\Delta kW = \frac{10 \times 114}{8{,}760} \times 1 = 0.130\ kW$$

Effective Useful Life (EUL)

See Appendix P.

[1352] *No source specified – update pending availability and review of applicable references.*

Ancillary Fossil Fuel Savings Impacts

Reduction of ambient air infiltration into the refrigerated case due to improved gaskets reduces the space heating requirements in the heating season while increasing the cooling load in the cooling season. These impacts are not quantified in this methodology.

Ancillary Electric Savings Impacts

Reduction of ambient air infiltration into the refrigerated case due to improved gaskets, reduces the space heating requirements in the heating season while increasing the cooling load in the cooling season. These impacts are not quantified in this methodology.

References

1. ADM Associates, Inc. "Commercial Facilities Contract Group 2006-2008 Direct Impact Evaluation" February 18, 2010, California Public Utilities Commission Energy Division Available from: http://www.calmac.org/publications/ComFac_Evaluation_V1_Final_Report_02-18-2010.pdf

Record of Revision

Record of Revision Number	Issue Date
1-16-17	12/31/2015
6-18-14	6/26/2018

Return to Table of Contents

COOLER AND FREEZER DOOR STRIP

Measure Description

This measure covers the repair or replacement of existing damaged or missing strip curtains on walk-in freezers and coolers with a chilled storage area of less than 3,000SF.[1353] Strip curtains on both walk-in freezers (≤ 32°F) and walk-in coolers (> 32°F and ≤ 55°F) serve to prevent air infiltration during periods when the main door is open for routine stocking activity. When damaged or missing, the warmer, more humid air present in the store will infiltrate the unit, increasing the load of the refrigeration system and often reducing the efficiency of the evaporator unit as frost accumulates, impairing its effectiveness. This measure applies to strip curtains on the main door of walk-in units typical of supermarkets, convenience stores and restaurants.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = SF_{door} \times (\Delta kWh/SF)_{door}$$

Summer Peak Coincident Demand Savings

$$\Delta kW = SF_{door} \times \frac{(\Delta kWh/SF)_{door}}{hrs} \times \mathrm{CF}$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

where:

ΔkWh = Annual electric energy savings
ΔkW = Peak coincident demand electric savings
ΔMMBtu = Annual fossil fuel energy savings
SF_{door} = Area of cooler or freezer door opening, in square feet
$(\Delta kWh/SF)_{door}$ = Annual electric energy savings per square foot of door opening
hrs = Annual cooler or freezer operating hours per year
CF = Coincidence Factor

Summary of Variables and Data Sources

Variable	Value	Notes
SF_{door}		From application.
$(\Delta kWh/SF)_{door}$		Look up in Deemed Savings table below based on case type and application.
hrs		Lookup from table in Operating Hours section below based on case type and application.
CF	1.0	

[1353] 10 CFR 431.302

Deemed Savings $(\Delta kWh/SF)_{door}$[1354]

Case Type	Application	ΔkWh/SF
Cooler (> 32°F)	Supermarket	159
	Restaurant	18
	Convenience Store	14
Freezer (≤ 32 °F)	Supermarket	409
	Restaurant	77
	Convenience Store	16

Coincidence Factor (CF)

The prescribed coincidence factor for this measure is 1.0[1355]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition efficiency is a walk-in cooler or freezer door with damaged or missing strip curtains in excess of 15% of the door area.[1356]

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a walk-in cooler or freezer with repaired or replaced strip curtains covering the entire open door area.

Operating Hours

Annual hours during which the door is open and strip curtains are therefore preventing heat exchange between the refrigerated case and ambient air is used to determine an estimate of associated demand savings. Prescribed annual hours for formulation of demand savings are provided in the table below.[1357]

Case Type	Application	hrs
Cooler (> 32°F)	Supermarket	803
	Restaurant	274
	Convenience Store	231
Freezer (≤ 32 °F)	Supermarket	621
	Restaurant	231
	Convenience Store	55

[1354] ADM Associates, Inc. Commercial Facilities Contract Group 2006-2008 Direct Impact Evaluation, Table 6-3, p. 6-6.
[1355] *No source specified – update pending availability and review of applicable references.*
[1356] ADM Associates, Inc. Commercial Facilities Contract Group 2006-2008 Direct Impact Evaluation, p. 6-10
[1357] ADM Associates, Inc. Commercial Facilities Contract Group 2006-2008 Direct Impact Evaluation, Table 6-5, p. 6-10

Example Calculation *(Not to be used as default)*

A restaurant replaces 16 square feet of damaged strip curtains on a walk-in freezer. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

$$\Delta kWh = SF_{door} \times (\Delta kWh/SF)_{door}$$

$$\Delta kW = SF_{door} \times \frac{(\Delta kWh/SF)_{door}}{hrs} \times \mathrm{CF}$$

SF_{door} = 16, from application
$(\Delta kWh/SF)_{door}$ = 77, from Deemed Savings table based on case type and facility based on application
hrs = 231, from Operating Hours section based on case type and facility based on application
CF = 1.0

$$\Delta kWh = 16 \times 77 = 1{,}232 \text{ kWh}$$

$$\Delta kW = 16 \times \frac{77}{231} \times 1 = 0.333 \text{ kW}$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Reduction in heat transfer between the refrigerated case and ambient air during periods when the main door is open will result in a small reduction in space heating requirements and a small increase in cooling requirements. This impact is negligible and is not considered in this methodology.

Ancillary Electric Savings Impacts

Reduction in heat transfer between the refrigerated case and ambient air during periods when the main door is open will result in a small reduction in space heating requirements and a small increase in cooling requirements. This impact is negligible and is not considered in this methodology.

References

1. 10 CFR 431.302 Definitions concerning walk-in coolers and walk-in freezers. Available from: https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=863517ec5f69fb78dad68864aa84c128&mc=true&n=pt10.3.431&r=PART&ty=HTML#se10.3.431_1302

2. ADM Associates, Inc. "Commercial Facilities Contract Group 2006-2008 Direct Impact Evaluation," California Public Utilities Commission Energy Division, February 18, 2010. Available from: http://www.calmac.org/publications/ComFac_Evaluation_V1_Final_Report_02-18-2010.pdf

Record of Revision

Record of Revision Number	Issue Date
1-16-16	12/31/2015
3-18-16	3/29/2018
6-19-12	6/28/2019

Return to Table of Contents

ELECTRONICALLY COMMUTATED (EC) MOTOR - REFRIGERATED CASE OR WALK-IN COOLER/FREEZER EVAPORATOR FAN

Measure Description

This measure covers replacement of single-phase shaded pole (SP) or permanent split capacitor (PSC) evaporator fan motors with electronically commutated (EC) motors in walk-in and reach-in refrigerated cases. These high-efficiency motors achieve savings by reducing evaporator fan power and through interactive effects with the system's compressor. EC motors introduce less waste heat into the refrigerated case, reducing the total refrigeration load. This measure is only applicable in a 1:1 replacement of existing, single-phase SP or PSC motor output. This measure applies to equipment manufactured before January 1, 2009 only, as the Code of Federal Regulations requires the use of EC or three-phase motors in evaporator fans in equipment manufactured on or after that date.[1358]

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings for Walk-In Coolers/Freezers

Annual Electric Energy Savings

$$\Delta kWh = \Delta kWh_{EFan} + \Delta kWh_{RH}$$

$$\Delta kWh_{EFan} = units \times \left(\frac{W_{EFan}}{1{,}000}\right) \times F_{PA} \times F_{EFan} \times hrs_{EFan}$$

$$\Delta kWh_{RH} = \Delta kWh_{EFan} \times COP_{ref} \times 0.284$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \Delta kW_{EFan} + \Delta kW_{RH}$$

$$\Delta kW_{EFan} = units \times \left(\frac{W_{EFan}}{1{,}000}\right) \times F_{PA} \times F_{EFan} \times CF$$

$$\Delta kW_{RH} = \Delta kW_{EFan} \times COP_{ref} \times 0.284$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
ΔkWh_{EFan}	= Annual electric savings due to evaporator fan motor replacement

[1358] 10 CFR 431.306

ΔkWh_{RH} = Annual electric savings due to reduced heat from evaporator fan motor replacement
ΔkW_{EFan} = Summer Peak Coincident Demand Savings due to evaporator fan motor replacement
ΔkW_{RH} = Summer Peak Coincident Demand Savings due to reduced heat from evaporator fan motor replacement
W_{EFan} = Nameplate wattage of existing evaporator fan motor
F_{PA} = Power adjustment factor
F_{EFan} = Reduction of load by replacing evaporator fan motor
hrs_{EFan} = Evaporator fan motor annual operating hours
COP_{ref} = Coefficient of performance of refrigeration equipment
CF = Coincidence factor
0.284 = Conversion factor from kW to Tons of refrigeration (Tons/kW)
1,000 = Conversion factor, one kW equals 1,000 W

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings for Refrigerated Cases

Annual Electric Energy Savings

$$\Delta kWh = \Delta kWh_{CM} + \Delta kWh_{RH}$$

$$\Delta kWh_{CM} = units \times \left(\frac{W_{EFan}}{1{,}000}\right) \times F_{PA} \times F_{CM} \times hrs_{CM}$$

$$\Delta kWh_{RH} = \Delta kWh_{CM} \times COP_{ref} \times 0.284$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \Delta kW_{CM} + \Delta kW_{RH}$$

$$\Delta kW_{CM} = units \times \left(\frac{W_{EFan}}{1{,}000}\right) \times F_{PA} \times F_{CM} \times CF$$

$$\Delta kW_{RH} = \Delta kW_{CM} \times COP_{ref} \times 0.284$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

where:
ΔkWh = Annual electric energy savings
ΔkW = Peak coincident demand electric savings
$\Delta MMBtu$ = Annual fossil fuel energy savings
ΔkWh_{CM} = Annual electric savings due to case motor replacement
ΔkWh_{RH} = Annual electric savings due to reduced heat from case motor replacement
ΔkW_{CM} = Summer Peak Coincident Demand Savings due to case motor replacement

ΔkW_{RH} = Summer Peak Coincident Demand Savings due to reduced heat from case motor replacement
units = Number of measures installed under the program
W_{EFan} = Nameplate wattage of existing evaporator fan
F_{PA} = Power adjustment factor
F_{CM} = Reduction of load by replacing case motor
hrs_{CM} = Case motor annual operating hours
COP_{ref} = Coefficient of performance of refrigeration equipment
1,000 = Conversion factor, one kW equals 1,000 W
0.284 = Conversion factor from kW to Tons of refrigeration (Tons/kW)
CF = Coincidence factor

Summary of Variables and Data Sources

Variable	Value	Notes
W_{EFan}	$= Volts \times Amps \times \sqrt{Phase}$	Based on nameplate Volts, Amps, and Phase of existing evaporator fan.
F_{PA}	0.601	Oak Ridge National Laboratory. [1359]
hrs_{EFan}	On/Off Control: 5,571 Multistep Control: 6,062 No Cooler Control: 8,567	Based on refrigeration control type.[1360]
hrs_{CM}	8,573	PG&E.[1361]
F_{EFan}	0.65	Based on numerous pre and post meter readings conducted by NRM and supported by RLW Analytics evaluation.[1362]
F_{CM}	Shaded Pole: 0.44 PSC: 0.3	US DOE.[1363]
COP_{ref}		From application. If this information is unavailable, use default of 1.00 for Cooler and 1.92 for Freezer.[1364] This default shall be used only in circumstances where manufacturer/nameplate data is missing, and facility staff is not able to provide it.
CF	1.0	

[1359] Oak Ridge National Laboratory, Q-Sync Motors in Commercial Refrigeration: Preliminary Test Results and Projected Benefits, September 2015, page 5.
[1360] Cadmus, Commercial Refrigeration Loadshape Project, October 2015, Table 4. Average Parameters – EF Motors pg. 6. The study analyzes reach-in and walk-in coolers and freezers.
[1361] PG&E Work Paper PGE3PREF124 Revision 2. Average of operating hours of medium temperature applications and low temperature applications.
[1362] Small Business Services, Custom Measure Impact Evaluation, RLW Analytics, Inc., March 2007.
[1363] US DOE, Commercial Refrigeration Equipment (CRE) Technical Support Document, table 5.6.4. Ratio of actual power (watts) of EC motors vs actual power (watts) of shaded-pole motor and PSC motor.
[1364] Based on CDH Energy evaluation of actual refrigeration system performance for several commercially available compressors, dated 09/06/2017. Values presented reflect average efficiencies of systems using R-22, which was the most common refrigerant in active refrigeration systems in 2008 (per Analysis of Equipment and Practices in the Reclamation Industry, October 2010). Because this methodology applies to existing equipment manufactured prior to January 1, 2009, 2008 data is considered most pertinent for the purposes of this measure.

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 1.0.[1365]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline case is a walk-in cooler/freezer or refrigerated display case with shaded pole or permanent split capacitor (PSC) evaporator fan motors.

Compliance Efficiency from which Incentives are Calculated

The compliance case is a walk-in cooler/freezer or refrigerated display case with electronically commutated (EC) evaporator fan motors with full load efficiency exceeding that prescribed by federal energy conservation standards for electric motors in 10 CFR 431.446 and/or 10 CFR 431.25 as applicable.

Operating Hours

The annual operating hours of a walk-in cooler or freezer evaporator fan motor without controls is derived as 97.8% x 8,760 = 8,567 hours. The effective full load annual run time of evaporator fans with on/off control are assumed to be 63.6% x 8,760 = 5,571 hours, while the effective full load annual run time of evaporator fans with multispeed control are assumed to be 69.2% x 8,760 = 6,062 hours.[1366]

Example Calculation *(Not to be used as default)*

A walk-in freezer's PSC evaporator fan motor is replaced with an EC motor. The existing single-phase PSC motor is 115 V and 1.1 amps. The walk-in freezer has multistep control and a COP of 3.2. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

$$\Delta kWh = \Delta kWh_{EFan} + \Delta kWh_{RH}$$

$$\Delta kW = \Delta kW_{EFan} + \Delta kW_{RH}$$

where:

$$\Delta kWh_{EFan} = units \times \left(\frac{W_{EFan}}{1{,}000}\right) \times F_{PA} \times F_{EFan} \times hrs_{EFan}$$

$$\Delta kWh_{RH} = \Delta kWh_{EFan} \times COP_{ref} \times 0.284$$

$$\Delta kW_{EFan} = units \times \left(\frac{W_{EFan}}{1{,}000}\right) \times F_{PA} \times F_{EFan} \times CF$$

[1365] *No source specified – update pending availability and review of applicable references.*
[1366] Cadmus, Commercial Refrigeration, Loadshape Project, October 2015

$$\Delta kW_{RH} = \Delta kW_{EFan} \times COP_{ref} \times 0.284$$

units = 1, from application
W_{EFan} = Volts x Amps x (Phase)$^{(1/2)}$ = 115 x 1.1 x 1 = 126.5 watts
W_{EFan} equation from Summary of Variables and Data Sources table
Volts from application
Amps from application
Phase from application
F_{PA} = 0.601, from Summary of Variables and Data Sources table
hrs_{EFan} = 6,062, from Summary of Variables and Data Sources table based on refrigeration control type from application
hrs_{CM} = 8,57, from Summary of Variables and Data Sources table
F_{EFan} = 0.65, from Summary of Variables and Data Sources table
COP_{ref} = 3.2, from application
CF=1.0, from Summary of Variables and Data Sources table

$$\Delta kWh_{EFan} = 1 \times \left(\frac{126.5}{1{,}000}\right) \times 0.601 \times 0.65 \times 6.062 = 299.6\ kWh$$

$$\Delta kWh_{RH} = 299.6\ \times 3.2\ \times 0.284 = \ \ 272.2\ kWh$$

$$\Delta kW_{EFan} = 1 \times \left(\frac{126.5}{1{,}000}\right) \times 0.601 \times 0.65 \times 1.0 = 0.0494\ kW$$

$$\Delta kW_{RH} = 0.0494 \times 3.2\ \times 0.284 = 0.0449\ kW$$

$$\Delta kWh = 299.6 + 272.2 = 571.8\ kWh$$

$$\Delta kW = 0.0494 + 0.0449 = 0.0943\ kW$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Reduction in evaporator fan power reduces waste heat that must be displaced by the compressor. Interactive effects are addressed in the prescribed energy savings calculation methodology.

References

1. *Cooler Control Measure Impact Spreadsheet Users' Manual*, Select Energy Services, Inc. for NSTAR, March 9, 2004
2. Cadmus, Commercial Refrigeration Loadshape Project, October 2015
   Available from: https://neep.org/commercial-refrigeration-loadshape-report-10-2015-0
3. Small Business Services, Custom Measure Impact Evaluation, RLW Analytics, Inc. for National Grid, March 23, 2007
   Available from:
   https://library.cee1.org/system/files/library/8713/CEE_Eval_2007CustomMeasureImpactEvaluation_23Mar2007.pdf
4. 10 CFR 431.306 Energy conservations standards and their effective dates
   Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=bf918c7935d524eeb5d031252bb66fba&mc=true&node=pt10.3.431&rgn=div5#se10.3.431_1306
5. Analysis of Equipment and Practices in the Reclamation Industry
   Available from: https://www.epa.gov/sites/production/files/2015-08/documents/analysis_of_equipment_and_practices_in_the_reclamation_industry.pdf
6. 10 CFR 431.446 Small electric motors energy conservation standards and their effective dates
   Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=f7f8d64bb400ae3dc2d13f131cf116bb&mc=true&node=pt10.3.431&rgn=div5#se10.3.431_1446
7. 10 CFR 431.25 Energy conservation standards and effective dates
   Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=070fc8cd95943842a1e7a6f793d73496&mc=true&node=pt10.3.431&rgn=div5#se10.3.431_125
8. US Department of Energy, Commercial Refrigeration Equipment (CRE) Technical Support Document
   Available from:
   https://www1.eere.energy.gov/buildings/appliance_standards/pdfs/cre2_nopr_tsd_2013_08_28.pdf
9. Oak Ridge National Laboratory, Q-Sync Motors in Commercial Refrigeration: Preliminary Test Results and Projected Benefits, September 2015
   Available from: https://info.ornl.gov/sites/publications/files/Pub58600.pdf
10. Pacific Gas & Electric Company, Work Paper PGE3PREF124 Display Case ECM Motor Retrofit, Revision #2, April 2014
    Available from: http://www.deeresources.net/workpapers

Record of Revision

Record of Revision Number	Issue Date
1	10/15/2010
7-13-17	7/31/2013
9-17-9	9/30/2017
9-18-15	9/28/2018
12-19-15	12/23/2019
7-21-20	8/30/2021

Return to Table of Contents

EVAPORATOR FAN MOTOR – WITH PERMANENT MAGNET SYNCHRONOUS MOTOR (PMSM), FOR REFRIGERATED CASE OR WALK-IN COOLER/FREEZER

Measure Description

This measure covers the replacement of shaded pole (SP), permanent split capacitor (PSC), or electrically commutated (EC) evaporator fan motors with permanent magnet synchronous motors (PMSM) in commercial refrigeration equipment. PMSMs provide increased efficiency over other motors requiring less energy to operate and introducing less heat into the refrigerated case, which reduces the total refrigeration load.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times \frac{W_{ee}}{1{,}000} \times \left(\frac{1}{Eff_{baseline}} - \frac{1}{Eff_{ee}}\right) \times \left(1 + \frac{1}{COP_{ref}}\right) \times hrs$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \frac{\Delta kWh}{hrs} \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
$_{baseline}$	= Characteristic of baseline condition
$_{ee}$	= Characteristic of energy efficient condition
W	= Rated motor wattage
Eff	= Motor efficiency
COP_{ref}	= Coefficient of performance of refrigerator compressor
hrs	= Annual operating hours
CF	= Coincidence Factor
1,000	= Conversion factor, one kW equals 1,000 W

Summary of Variables and Data Sources

Variable	Value	Notes
W_{ee}		From application.

Variable	Value	Notes
$Eff_{baseline}$	Shaded Pole: 0.20 PSC: 0.29 EC: 0.66	For replacement of motors in reach-in cases, look up based on existing motor type.[1367] For new construction, unknown existing conditions and walk-in coolers and freezers, use value associated with EC motors.
Eff_{ee}	0.73	Oak Ridge National Laboratory[1368]
COP_{ref}		From application; COP = 3.517/(kW/ton), where kW/ton is the rated efficiency of the compressor in input kW per ton of refrigeration capacity.
hrs	On/Off Control: 5,571 Multistep Control: 6,062 No Control: 8,567	Based on refrigeration control type.[1369]
CF	1.0	

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 1.0.[1370]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition for walk-in coolers or freezers manufactured on or after January 1, 2009 is an EC motor[1371] with full load efficiency as prescribed by federal energy conservation standards for electric motors in 10 CFR 431.446 and 10 CFR 431.25, as applicable. The baseline condition for walk-in coolers or freezers manufactured before January 1, 2009 and reach-in refrigerated display cases is equivalent to the equipment being replaced (shaded pole or PSC motor). Baseline equipment shall be assumed to be of equivalent speed and horsepower to the efficient case.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a PMSM installed in a commercial refrigerated reach-in display case or walk-in cooler/freezer with full-load efficiency exceeding that prescribed by federal energy conservation standards for electric motors in 10 CFR 431.446 or 10 CFR 431.25, as applicable.

Operating Hours

The annual operating hours of a walk-in cooler or freezer evaporator fan motor without controls is derived as 97.8% x 8,760 = 8,567 hours. The effective full load annual run time of evaporator

[1367] U.S. DOE, Technical Support Document Commercial Refrigeration Equipment, Chapter 5, Table 5.6.4: Details for Evaporator Fan Motor Design Option
[1368] ORNL, Q-Sync Motors in Commercial Refrigeration: Preliminary Test Results and Projected Benefits, p 5
[1369] Cadmus, Commercial Refrigeration Loadshape Project, October 2015, Table 4. Average Parameters – EF Motors pg. 6. The study analyzes reach-in and walk-in coolers and freezers.
[1370] *No source specified – update pending availability and review of applicable references.*
[1371] 10 CFR 431.306

fans with on/off control are assumed to be 63.6% x 8,760 = 5,571 hours, while the effective full load annual run time of evaporator fans with multispeed control are assumed to be 69.2% x 8,760 = 6,062 hours.[1372]

Example Calculation *(Not to be used as default)*

A PSC evaporator fan motor is replaced with a 12-watt PMSM in a commercial refrigerated case. The compressor is connected to an on/off control and has a 3.2 COP. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

$$\Delta kWh = units \times \frac{W_{ee}}{1{,}000} \times \left(\frac{1}{Eff_{baseline}} - \frac{1}{Eff_{ee}}\right) \times \left(1 + \frac{1}{COP_{ref}}\right) \times hrs$$

$$\Delta kW = \frac{\Delta kWh}{hrs} \times CF$$

W_{ee} = 12, from application
$Eff_{baseline}$ = 0.29, from Summary of Variables and Data Sources table based on baseline motor type from application
Eff_{ee} = 0.73, from Summary of Variables and Data Sources table
COP_{ref} = 3.2, from application
hrs = 6,062, from Summary of Variables and Data Sources table based on control type from application
CF = 1.0, from Summary of Variables and Data Sources table

$$\Delta kWh = 1 \times \frac{12}{1{,}000} \times \left(\frac{1}{0.29} - \frac{1}{0.73}\right) \times \left(1 + \frac{1}{3.2}\right) \times 6{,}062 = 198\ kWh$$

$$\Delta kW = \frac{198}{6{,}062} \times 1.0 = 0.0327\ kW$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

[1372] Cadmus, Commercial Refrigeration, Loadshape Project, October 2015

Ancillary Electric Savings Impacts

Reduction in evaporator fan power reduces waste heat that must be displaced by the compressor. The refrigeration savings are addressed in the prescribed energy savings calculation methodology.

References

1. 10 CFR 431.306 Energy conservations standards and their effective dates
   Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=bf918c7935d524eeb5d031252bb66fba&mc=true&node=pt10.3.431&rgn=div5#se10.3.431_1306
2. Department of Energy; Technical Support Document Commercial Refrigeration Equipment, Chapter 5: Engineering Analysis, August 2013
   Available from: https://www1.eere.energy.gov/buildings/appliance_standards/pdfs/cre2_nopr_tsd_2013_08_28.pdf
3. Cadmus, Commercial Refrigeration Loadshape Project, October 2015
   Available from: https://neep.org/commercial-refrigeration-loadshape-report-10-2015-0
4. Oak Ridge National Laboratory, Q-Sync Motors in Commercial Refrigeration: Preliminary Test Results and Projected Benefits
   Available from: https://info.ornl.gov/sites/publications/files/Pub58600.pdf
5. Analysis of Equipment and Practices in the Reclamation Industry
   Available from: https://www.epa.gov/sites/production/files/2015-08/documents/analysis_of_equipment_and_practices_in_the_reclamation_industry.pdf
6. 10 CFR 431.446 Small electric motors energy conservation standards and their effective dates
   Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=5f939105042a95e8488cfb789366eb50&mc=true&node=pt10.3.431&rgn=div5#se10.3.431_1446
7. 10 CFR 431.25 Energy conservation standards and effective dates
   Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=5f939105042a95e8488cfb789366eb50&mc=true&node=pt10.3.431&rgn=div5#se10.3.431_125

Record of Revision

Record of Revision Number	Issue Date
6-19-3	6/28/2019
12-19-16	12/23/2019

Return to Table of Contents

REFRIGERATED CASE DOOR

Measure Description

This measure covers the installation of doors on existing open vertical refrigerated cases. Case doors are installed over open refrigerated cases to prevent air infiltration between the refrigerated case and the facility space. This barrier alleviates cooling loads on the refrigeration system and heating loads on the conditioned space.

This measure is applicable to refrigerated case doors with and without anti-condensation heaters. Standard refrigerated case doors include anti-condensation heaters in the frames, doors, or within the glass to prevent condensation from forming and obstructing view of refrigerated products. High efficiency doors with no anti-condensation heaters use a combination of multiple layers of glass, low-conductivity filler gas, and low-emissivity glass coatings to prevent condensation.

Method for Calculating Annual Energy and Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = l_{door} \times (\Delta kWh/ft) \times \left(1 - \frac{hrs_{cooling}}{8{,}760} \times \frac{COP_{ref}}{COP_{HVAC}}\right)$$

Peak Coincident Demand Savings

$$\Delta kW = l_{door} \times \frac{(\Delta kWh/ft)}{8{,}760} \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = l_{door} \times \frac{(\Delta kWh/ft) \times 3{,}412}{1{,}000{,}000} \times \frac{hrs_{heating}}{8{,}760} \times \frac{1}{Eff}$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
l_{door}	= Length of cooler or freezer door opening, in feet
ΔkWh/ft	= Annual electric energy savings per foot of door opening
$hrs_{cooling}$	= Cooling HVAC load hours
$hrs_{heating}$	= Heating HVAC load hours
COP_{ref}	= Coefficient of performance of refrigeration equipment
COP_{HVAC}	= Coefficient of performance of heating, ventilation, and cooling equipment
Eff	= Fossil fuel-fired heating system efficiency
CF	= Coincidence factor
3,412	= Conversion factor, one kWh equals 3,412 BTU
8,760	= Hours in one year
1,000,000	= Conversion factor, one MMBtu equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
ft_{door}		From application.
ΔkWh/ft	High-Efficiency Doors on Cooler: 477 High-Efficiency Doors on Freezer: 747 Standard Doors on Cooler: 183 Standard Doors on Freezer: 392	Use defaults, based on the door type.[1373] Electric energy savings of Standard Doors do not consider anti-condensation heater controls. See Anti-Condensation Heater Control measure to claim additional savings.
$hrs_{heating}$		From application. If unknown, look up based on location and facility type in Operating Hours section below.
$hrs_{cooling}$		From application. If unknown, look up based on location and facility type in Operating Hours section below.
COP_{ref}		From application; COP = 3.517/(kW/ton), where kW/ton is the rated efficiency of the compressor in input kW per ton of refrigeration capacity.
COP_{HVAC}	Grocery Store: 2.93 Other: 3.57	From application; COP = EER/3.412. If unknown, use default values provided based on facility type.[1374]
Eff	0.80	From application. E_c, E_t or AFUE shall be used, based on nameplate rating metric of existing equipment. If unknown, use default value provided.[1375]
CF	1.0	

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 1.0.[1376]

Baseline Efficiencies from which Savings are Calculated

The baseline condition is an existing open vertical refrigerated display case.

[1373] Fricke, Brian and Becker, Bryan, "Energy Use of Doored and Open Vertical Refrigerated Display Cases". Energy savings of high efficiency doors are calculated by eliminating anti-condensation heater energy draw and proportionally reducing associated work required from the refrigeration equipment while assuming an HVAC system COP of 3.28, refrigeration COP of 3.03 for coolers and 1.66 for freezers. Measured energy savings on medium temperature units was adjusted with $COP_{cooler}/COP_{freezer}$ ratios to develop savings for standard doors installed on freezer units.

[1374] ASHRAE 90.1 2010 Standard for Unitary HVAC: Grocery Store default assumes a 25-ton packaged RTU (cooling only); Other default assumes a 10-ton packaged RTU (cooling only)

[1375] ASHRAE 90.1 2010 Standard for natural gas hot water boilers, 300-2,500 MBH

[1376] *No source specified – update pending availability and review of applicable references.*

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a vertical refrigerated display case fitted with glass doors. Doors may be standard doors operating with anti-condensation heaters or high efficiency doors with advanced technology operating without anti-condensation heaters.

Operating Hours

Doored refrigerated display cases are assumed to be operating 8,760 hours per year.

Heating and cooling HVAC system load hours shall be taken from application. If unknown, look up default values in table below based on location and facility type. Default HVAC system load hours were developed from NOAA hourly normals by assuming a 65ºF balance point temperature and summing dry bulb hours above the balance point for HVAC cooling and below the balance point for HVAC heating during building operating hours.[1377] Grocery stores are assumed to operate between 7AM-10PM and other building are assumed to operate between 7AM-7PM.

City	Grocery Cooling Hours	Other Cooling Hours	Grocery Heating Hours	Other Heating Hours
Albany	1,593	1,324	3,769	2,968
Binghamton	1,254	1,051	4,109	3,251
Buffalo	1,502	1,234	3,876	3,066
Massena*	1,502	1,254	3,873	3,049
NYC	1,965	1,597	3,408	2,698
Poughkeepsie**	1,749	1,464	3,636	2,847
Syracuse	1,552	1,305	3,826	3,001

*Massena hourly normals are approximated from Rochester airport data due to limited available data
** Poughkeepsie hourly normals are approximated from Long Island ISLIP airport data due to limited available data

Example Calculation *(Not to be used as default)*

High-efficiency doors are installed on a total of 10 linear feet of open cooler case in a grocery store located near Albany. The cooler's compressor has a COP of 3.2 and the facility is cooled 1,600 hours annually and heated 3,500 hours annually by a 78% efficient hot water boiler. Annual Electric Energy Savings, Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta kWh = l_{door} \times (\Delta kWh/ft) \times \left(1 - \frac{hrs_{cooling}}{8{,}760} \times \frac{COP_{ref}}{COP_{HVAC}}\right)$$

$$\Delta kW = l_{door} \times \frac{(\Delta kWh/ft)}{8{,}760} \times CF$$

$$\Delta MMBtu = l_{door} \times \frac{(\Delta kWh/ft) \times 3{,}412}{1{,}000{,}000} \times \frac{hrs_{heating}}{8{,}760} \times \frac{1}{Eff}$$

[1377] NOAA National Centers for Environmental Information – NCEI 2010 Hourly Normals

l_{door} = 10, from application
ΔkWh/ft = 477, from Summary of Variables and Data Sources table based on refrigeration and door type from application
$hrs_{cooling}$ = 1,600, from application
COP_{ref} = 3.2, from application
COP_{HVAC} = 2.93, from Summary of Variables and Data Sources table based on facility type from application
$hrs_{heating}$ = 3,500, from application
Eff = 0.78, from application
CF = 1.0, from Summary of Variables and Data Sources table

$$\Delta kWh = 10 \times 477 \times \left(1 - \frac{1{,}600}{8{,}760} \times \frac{3.2}{2.93}\right) = 3{,}818\ kWh$$

$$\Delta kW = 10 \times \frac{477}{8{,}760} \times 1.0 = 0.545\ kW$$

$$\Delta MMBtu = 10 \times \frac{477 \times 3{,}412}{1{,}000{,}000} \times \frac{3{,}500}{8{,}760} \times \frac{1}{0.78} = 8.34\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Reduction in heat transfer between the refrigerated case and the ambient air will result in reduction in space heating requirements. This impact is included in this methodology.

Ancillary Electric Savings Impacts

Retrofitting open display cases with doors may lead to the requirement of additional lighting to maintain visibility of products. The load of additional lighting was considered in this analysis.

Reduction in heat transfer between the refrigerated case and the ambient air will result in an increase in cooling requirements. This impact is included in this methodology.

References

1. Fricke, Brian and Becker, Bryan, "Energy Use of Doored and Open Vertical Refrigerated Display Cases" (2010). International Refrigeration and Air Conditioning Conference. Paper 1154.
   Available from:
   https://docs.lib.purdue.edu/cgi/viewcontent.cgi?article=2153&context=iracc
2. American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)

Standard 90.1-2016
Available from: https://www.ashrae.org/technical-resources/standards-and-guidelines/read-only-versions-of-ashrae-standards

3. NOAA National Centers for Environmental Information
Available from: https://www.ncdc.noaa.gov/cdo-web/search?datasetid=NORMAL_HLY

Record of Revision

Record of Revision Number	Issue Date
3-19-14	3/29/2019
9-19-8	9/27/2019

Return to Table of Contents

REFRIGERATED CASE NIGHT COVER

Measure Description

This measure covers the installation of retractable curtains on open horizontal or multi-deck refrigerated display cases in grocery stores. These covers serve as a barrier between the contents of the refrigerated case and the ambient air during off-business hours. They conserve energy by reducing the infiltration of ambient air into the refrigerated space, thereby reducing the load on the refrigeration system. Grocery stores operating 24 hours per day are not eligible for energy savings.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times TDEC \times ESF \times 365$$

Summer Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of display cases addressed by the program
TDEC	= Total Daily Energy Consumption (kWh/day)
ESF	= Energy savings factor
365	= Days in one year

Summary of Variables and Data Sources

Variable	Value	Notes
TDEC		Total Daily Energy Consumption (kWh/day), calculate based on Total Display Area (TDA) from table below
ESF	0.09	Energy savings factor associated with installation of refrigerated case night covers[1378]

Coincidence Factor (CF)

Energy savings associated with installation of refrigerated case night covers occur during off-peak hours, so no coincident peak demand savings are deemed for this measure.

[1378] Southern California Edison, Effects of the Low Emissivity Shields on Performance and Power Use of a Refrigerated Display Case, August 1997

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a vertical or horizontal open refrigerated display case left uncovered during off-business hours and meeting the minimum federal energy standards presented in the tables below.[1379] Equipment with an operating temperature above 32°F is classified as Medium with a rating temperature of 38°F, while equipment with an operating temperature of 32°F or below is classified as Low with a rating temperature of 0°F. Ice Cream freezers have a rating temperature of -15°F and operate at temperatures below -5°F.

Total Daily Energy Consumption (TDEC) shall be calculated per the table below for the appropriate display case type, configuration and rating temperature. For refrigeration equipment with two or more compartments (i.e. hybrid refrigerators, freezers, refrigerator-freezers and non-hybrid refrigerator freezers), the TDEC shall be established as the sum of the TDEC values associated with each component compartment. Total Display Area (TDA), if unspecified by the manufacturer, should be calculated as:

$$TDA = l \times Ht$$

where:

TDA = Total display area of the open case (SF)
l = Length of the display case opening (ft)
Ht = Height (vertical) or Depth (horizontal) of the display case opening (ft)

Baseline Efficiencies for Refrigerators, Freezers, or Refrigerator-freezers manufactured on or after March 27, 2017

Equipment Family	Condensing Unit Configuration	Rating Temperature	TDEC (kWh/day)
Vertical Open	Remote Condensing	Medium (38°F)	0.64 x TDA + 4.07
Vertical Open	Remote Condensing	Low (0°F)	2.20 x TDA + 6.85
Vertical Open	Remote Condensing	Ice Cream (-15°F)	2.79 x TDA + 8.70
Vertical Open	Self-Contained	Medium (38°F)	1.69 x TDA + 4.71
Vertical Open	Self-Contained	Low (0°F)	4.25 x TDA + 11.82
Vertical Open	Self-Contained	Ice Cream (-15°F)	5.40 x TDA + 15.02
Horizontal Open	Remote Condensing	Medium (38°F)	0.35 x TDA + 2.88
Horizontal Open	Remote Condensing	Low (0°F)	0.55 x TDA + 6.88
Horizontal Open	Remote Condensing	Ice Cream (-15°F)	0.70 x TDA + 8.74
Horizontal Open	Self-Contained	Medium (38°F)	0.72 x TDA + 5.55
Horizontal Open	Self-Contained	Low (0°F)	1.90 x TDA + 7.08
Horizontal Open	Self-Contained	Ice Cream (-15°F)	2.42 x TDA + 9.00

[1379] 10 CFR 431.66(e)(1)

Baseline Efficiencies for Refrigerators, Freezers, and Refrigerator-freezers manufactured before March 27, 2017

Equipment Family	Condensing Unit Configuration	Rating Temperature	TDEC (kWh/day)
Vertical Open	Remote Condensing	Medium (38°F)	0.82 × TDA + 4.07
Vertical Open	Remote Condensing	Low (0°F)	2.27 × TDA + 6.85
Vertical Open	Remote Condensing	Ice Cream (-15°F)	2.89 × TDA + 8.70
Vertical Open	Self-Contained	Medium (38°F)	1.74 × TDA + 4.71
Vertical Open	Self-Contained	Low (0°F)	4.37 × TDA + 11.82
Vertical Open	Self-Contained	Ice Cream (-15°F)	5.55 × TDA + 15.02
Horizontal Open	Remote Condensing	Medium (38°F)	0.35 × TDA + 2.88
Horizontal Open	Remote Condensing	Low (0°F)	0.57 × TDA + 6.88
Horizontal Open	Remote Condensing	Ice Cream (-15°F)	2.44 × TDA + 9.00
Horizontal Open	Self-Contained	Medium (38°F)	0.77 × TDA + 5.55
Horizontal Open	Self-Contained	Low (0°F)	1.92 × TDA + 7.08
Horizontal Open	Self-Contained	Ice Cream (-15°F)	2.44 × TDA + 9.00

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a vertical or horizontal open refrigerated display case with retractable night covers installed.

Operating Hours

Energy savings are based on installation of refrigerated case night covers in an 18-hour[1380] supermarket assumed to operate 365 days per year. Therefore, the annual hours that night covers are assumed to be in use are (24 – 18) x 365 = 2,190 hours.

Example Calculation *(Not to be used as default)*

A night case cover is installed on a 10 ft by 5 ft refrigerated display case. The medium temperature (operating above 32ºF) vertical display case has a self-contained condensing unit. Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings are calculated as below.

$$\Delta kWh = units \times TDEC \times ESF \times 365$$

units = 1, from application

TDEC = 1.69 x TDA + 4.71 = 1.69 x 50 + 4.71 = 89.21

TDEC equation from Baseline Efficiencies section based on equipment family, condensing unit configuration, and equipment rating temperature from application

TDA = l x Ht = 10 x 5 = 50

Length (l) from application

Height (Ht) from application

[1380] Southern California Edison, Effects of the Low Emissivity Shields on Performance and Power Use of a Refrigerated Display Case, August 1997

ESF = 0.09, from Summary of Variables and Data Sources table

$$\Delta kWh = 1 \times 89.21 \times 0.09 \times 365 = 2{,}931\ kWh$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Reduction in heat transfer between the refrigerated case and the ambient air will result in a small reduction in space heating requirements. This impact is negligible and occurs only during unoccupied hours, so is not considered in this methodology.

Ancillary Electric Savings Impacts

Reduction in heat transfer between the refrigerated case and the ambient air will result in a small reduction in space heating requirements and a small increase in cooling requirements. This impact is negligible and occurs only during unoccupied hours, so is not considered in this methodology.

References

1. Southern California Edison, Effects of the Low Emissivity Shields on Performance and Power Use of a Refrigerated Display Case, August 1997
   Available from: http://www.econofrost.com/acrobat/sce_report_long.pdf
2. 10 CFR 431.66 Energy conservation standards and their effective dates.
   Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=991ee62d32fb598ccb945f43a316ff32&mc=true&node=pt10.3.431&rgn=div5#se10.3.431_166

Record of Revision

Record of Revision Number	Issue Date
1	10/15/2010
3-18-4	3/29/2018

Return to Table of Contents

REFRIGERATION - CONTROL

ANTI-CONDENSATION HEATER CONTROL

Measure Description

This measure covers the installation of anti-condensation heater controls on glass door reach-in refrigerated cases. These controls save energy by reducing door heater run times based on feedback from door moisture sensors or dew point calculated via indoor air temperature and humidity sensors. Additional savings are achieved through interactive effects with the system's compressor. By running less often, door heaters emit less heat that must be overcome by the compressor. There are two primary categories of anti-condensation heater controls – (1) on/off controls and (2) pulse modulating controls. On/off controls cycle door heaters for several minutes at a time whereas pulse modulating controls pulse the door heaters at varying frequencies to satisfy calls for heating.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = (kW_{DH} \times hrs_{baseline}) - (kW_{DH} \times F_{PA} \times hrs_{ee})$$

Summer Peak Coincident Demand Savings

$$\Delta kW = kW_{DH} \times F_{hrs} \times DF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
kW_{DH}	= Total power of door heaters (in kW)
hrs	= Operating hours
baseline	= Characteristic of baseline condition
ee	= Characteristic of energy efficient condition
F_{PA}	= Power adjustment factor
F_{hrs}	= Operating hours reduction factor
DF	= Demand diversity factor

Summary of Variables and Data Sources

Variable	Value	Notes
kW_{DH}		From application, calculated based on door heater nameplate voltage and amperage.

Variable	Value	Notes
$hrs_{baseline}$	8,760	Pre-installation operating hours; assumes 24/7, year-round operation of door heaters
hrs_{ee}	Coolers: 3,760 Freezers: 8,760	Post-installation operating hours. Freezer hours assume 24/7, year round operation of door heaters and varying power factors. Cooler hours estimated by National Resource Management (NRM) based on monitoring data collected of cooler door heater controls.[1381]
F_{PA}	Coolers: 0.60 Freezers: 0.54	Average operating percentage of total door heater power after installation. Estimated by NRM based on monitoring data collected of cooler and freezer door heater controls. F_{PA} for freezers is calculated based on 4,000 hours of operation at 40% power and 4,760 hours at 65%.[1382]
F_{hrs}	Coolers: 0.74 Freezers: 0.46	Annual operating hour reduction factor. Estimated by National Resource Management (NRM) based on monitoring data collected of cooler and freezer door heater controls.[1383]
DF	0.75	Estimated adjustment to account for diversity and peak coincidence.[1384]

Coincidence Factor (CF)

The prescribed value for the coincidence factor is N/A. Adjustments to account for peak coincidence are embedded in the demand diversity factor defined above.

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a glass door reach-in refrigerated case anti-condensation heaters without temperature/humidity sensing controls.

Compliance Efficiency from which Incentives are Calculated

The compliance case is a glass door reach-in refrigerated case with on/off or pulse modulating anti-condensation heater controls installed.

Operating Hours

Anti-condensation door heaters without automated controls operate 24/7 year-round (8,760 hours annually). Operating hours for the compliance case are as specified above.

[1381] *REVIEW OF UNDERLYING REFERENCE PENDING:* Cooler Control Measure Impact Spreadsheet User's Manual, Select Energy Services, Inc., March 2004
[1382] Ibid.
[1383] Ibid.
[1384] Ibid.

Example Calculation *(Not to be used as default)*

Anti-condensation heater controls are installed on door heaters totaling 190 watts on reach-in freezer cases in a commercial facility. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

$$\Delta kWh = (kW_{DH} \times hrs_{baseline}) - (kW_{DH} \times F_{PA} \times hrs_{ee})$$

$$\Delta kW = kW_{DH} \times F_{hrs} \times DF$$

kW_{DH} = 0.190, from application
$hrs_{baseline}$ = 8,760, from Summary of Variables and Data Sources table
hrs_{ee} = 8,760, from Summary of Variables and Data Sources table based on refrigeration application
F_{PA} = 0.54, from Summary of Variables and Data Sources table based on refrigeration application
F_{hrs} = 0.46, from Summary of Variables and Data Sources table based on refrigeration application
DF = 0.75, from Summary of Variables and Data Sources table

$$\Delta kWh = (0.190 \times 8{,}760) - (0.190 \times 0.54 \times 8{,}760) = 765.6\ kWh$$

$$\Delta kW = 0.190 \times 0.46 \times 0.75 = 0.0656\ kW$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Reduction of door heater operation will slightly increase space heating load. However, these impacts are negligible and not considered at this time.

Ancillary Electric Savings Impacts

Reduction in door heater operation reduces heat that must be displaced by the compressor. Interactive effects are addressed in the prescribed energy savings calculation methodology.

References

1. National Resource Management monitoring data pending review.
2. *Cooler Control Measure Impact Spreadsheet Users' Manual*, Select Energy Services, Inc. for NSTAR, March 9, 2004

Record of Revision

Record of Revision Number	Issue Date
1	10/15/2010
9-17-10	9/30/2017

Return to Table of Contents

EVAPORATOR FAN CONTROL

Measure Description

This measure covers the installation of on/off or multispeed controls on electronically commutated or shaded pole evaporator fan motors in walk-in refrigerated cases. Evaporator fans in walk-in coolers and freezers that are not equipped with controls operate at constant speed continuously, even when there is no call for refrigeration and the compressor is idle. Installation of controls allows for modulation of evaporator fans, reducing fan speed or turning them off when the compressor is not running. Reduction in energy consumption results from reduced run time of the evaporator fans as well as reduction in waste heat due to fan operation that must be rejected by the system.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times hp \times (\Delta kWh/hp)$$

Summer Peak Coincident Demand Savings

$$\Delta kW = units \times hp \times (\Delta kW/hp)$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of evaporator fans controlled
hp	= Horsepower per evaporator fan
(ΔkWh/hp)	= Annual electric savings per evaporator fan horsepower
(ΔkW/hp)	= Peak coincident demand electric savings per evaporator fan horsepower

Summary of Variables and Data Sources

Variable	Value	Notes
hp		From application. If unknown, assume 1/15 hp.[1385]
(ΔkWh/hp)		Lookup from Deemed Savings table below based on case type, evaporator fan motor type and control type.
(ΔkW/hp)		Lookup from Deemed Savings table below based on case type, evaporator fan motor type and control type.

[1385] Cadmus, Commercial Refrigeration Loadshape Project, October 2015, pg. 6

Deemed Savings (ΔkWh/hp and ΔkW/hp)[1386]

Case Type	Motor Type	Control Type	ΔkWh/hp	ΔkW/hp
Cooler	Shaded Pole	On/Off	8,650	0.776
		Multispeed	7,224	0.741
	ECM	On/Off	3,142	0.282
		Multispeed	2,624	0.269
Freezer	Shaded Pole	On/Off	10,991	0.990
		Multispeed	9,178	0.945
	ECM	On/Off	3,992	0.360
		Multispeed	3,334	0.343

Coincident Factor (CF)

Demand savings provided in the table above represent peak coincident summer demand savings. Coincidence factor is embedded in deemed savings values; therefore, no coincidence factor is independently prescribed.

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a walk-in cooler or freezer with shaded pole or electronically commutated evaporator fan motors that operate continuously at constant speed (i.e. with no controls installed).

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a walk-in cooler or freezer with shaded pole or electronically commutated evaporator fan motors equipped with on/off or multispeed evaporator fan controls.

Operating Hours

Annual evaporator fan operating hours for the baseline and proposed case are embedded in the deemed savings values provided above. It is assumed that evaporator fans without controls have an effective full load annual run time of 97.8% x 8,760 = 8,567 hours. The effective full load annual run time of evaporator fans with on/off control are assumed to be 63.6% x 8,760 = 5,571 hours, while the effective full load annual run time of evaporator fans with multispeed control are assumed to be 69.2% x 8,760 = 6,062 hours.

Example Calculation *(Not to be used as default)*

On/Off controls are installed on a 1/12 hp evaporator fan motor in a walk-in cooler in a commercial facility. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

$$\Delta kWh = units \times hp \times (\Delta kWh/hp)$$

[1386] ΔkW/hp savings are calculated by dividing Summer Peak Savings (W/hp) by 1,000W/kW to convert it to the appropriate units. Cadmus, Commercial Refrigeration Loadshape Project, October 2015, pg. 10.

$$\Delta kW = units \times hp \times (\Delta kW/hp)$$

units = 1, from application
hp = 0.0833, from application
(ΔkWh/hp) = 8,650, from Deemed Savings table based on case and control type from application
(ΔkW/hp) = 0.776 , from Deemed Savings table based on case and control type from application

$$\Delta kWh = 1 \times 0.0833 \times 8{,}650 = 721\ kWh$$

$$\Delta kW = 1 \times 0.0833 \times 0.776 = 0.065\ kW$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. Cadmus, Commercial Refrigeration Loadshape Project, October 2015
   Available from: https://neep.org/commercial-refrigeration-loadshape-report-10-2015-0

Record of Revision

Record of Revision Number	Issue Date
1	10/15/2010
7-13-16	7/31/2013
1-16-8	12/31/2015
3-18-5	3/29/2018

Return to Table of Contents

FLOATING HEAD PRESSURE CONTROL

Measure Description

This measure covers the installation of refrigeration control to lower the condensing pressure on commercial refrigeration systems during times of ambient temperatures below 75°F. Systems are typically designed to have a constant saturated condensing temperature equivalent to approximately 95°F. By allowing the condensing pressure to drop during lower ambient conditions, the work on the refrigeration system is reduced, saving refrigeration system energy and prolonging the life of the equipment.

Method for Calculating Annual Energy and Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = (\Delta kWh/hp) \times hp$$

Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

where:

ΔkWh = Annual electric energy savings
ΔkW = Peak coincident demand electric savings
ΔMMBtu = Annual fossil fuel energy savings
(ΔkWh/hp) = kWh savings per refrigeration compressor horsepower
hp = Total refrigeration compressor horsepower

Summary of Variables and Data Sources

Variable	Value	Notes
(ΔkWh/hp)		Lookup based on location, condenser type, temperature, and horsepower in Savings for Floating Head Pressure Controls table below.
hp		From application

Savings for Floating Head Pressure Controls (ΔkWh/hp)

System Type/Size	Albany	Binghamton	Buffalo	Massena	NYC	Poughkeepsie	Syracuse
Unitary Condenser, Low Temp, 0-3 hp	252.03	252.03	252.03	252.03	252.03	252.03	252.03
Unitary Condenser, Low Temp, >3-6 hp	241.86	241.86	241.86	241.86	241.86	241.86	241.86
Unitary Condenser, Low Temp, >6-10 hp	248.68	248.68	248.68	248.68	248.68	248.68	248.68
Unitary Condenser, Low Temp, >10 hp	282.24	282.24	282.24	282.24	282.24	282.24	282.24

System Type/Size	Albany	Binghamton	Buffalo	Massena	NYC	Poughkeepsie	Syracuse
Unitary Condenser, Medium Temp, 0-3 hp	131.45	131.45	131.45	131.45	131.45	131.45	131.45
Unitary Condenser, Medium Temp, >3-6 hp	127.32	127.32	127.32	127.32	127.32	127.32	127.32
Unitary Condenser, Medium Temp, >6-10 hp	128.1	128.1	128.1	128.1	128.1	128.1	128.1
Unitary Condenser, Medium Temp, >10 hp	132.58	132.58	132.58	132.58	132.58	132.58	132.58
Remote Condenser, Low Temp, 0-3 hp	669.58	716.77	668.31	672.30	505.37	563.20	672.70
Remote Condenser, Low Temp, >3-6 hp	637.37	682.29	636.16	639.96	481.06	536.11	640.34
Remote Condenser, Low Temp, >6-10 hp	642.54	687.83	641.32	645.15	484.96	540.45	645.54
Remote Condenser, Low Temp, >10 hp	666.86	713.86	665.60	669.57	503.32	560.91	669.97
Remote Condenser, Medium Temp, 0-3 hp	521.20	557.93	520.21	523.32	393.38	438.39	523.63
Remote Condenser, Medium Temp, >3-6 hp	513.45	549.63	512.47	515.53	387.53	431.87	515.84
Remote Condenser, Medium Temp, >6-10 hp	525.85	562.91	524.85	527.98	396.89	442.30	528.30
Remote Condenser, Medium Temp, >10 hp	536.15	573.93	535.13	538.32	404.66	450.96	538.65

Background on Derivation of Per Unit Savings

Annual energy savings for remote condenser units were derived by adjusting the savings values from the Regional Technical Forum, "Commercial: Grocery - Floating Head Pressure Controls for Single Compressor Systems" to accommodate New York weather. NOAA data for Portland, OR and the seven cities/weather zones in NY; Albany, Binghamton, Buffalo, Massena, New York City, Poughkeepsie and Syracuse, was used to correlate the energy savings potential from Portland, OR to NY locations.

Based on the Regional Technical Forum, "Commercial: Grocery - Floating Head Pressure Controls for Single Compressor Systems", savings were based on the refrigeration compressor type along with the saturated suction temperature ranges and horsepower ranges for the evaporators.

The Regional Technical Forum, "Commercial: Grocery - Floating Head Pressure Controls for Single Compressor Systems" classifies refrigeration compressors based on evaporator temperature ranges:

- Low Temperature (Freezer)
- Medium Temperature (Refrigerator)

The Regional Technical Forum, "Commercial: Grocery - Floating Head Pressure Controls for Single Compressor Systems" classifies refrigeration compressors based on horsepower ranges:

- 0-3 hp
- > 3-6 hp
- > 6-10 hp
- > 10 hp

Portland, OR Annual Energy Savings for Remote Condenser Units based on Evaporator Temperature Range and Horsepower Range

System Type/Size	kWh/hp
Remote Condenser, Low Temp, 0-3 hp	534.90
Remote Condenser, Low Temp, >3-6 hp	509.17
Remote Condenser, Low Temp, >6-10 hp	513.30
Remote Condenser, Low Temp, >10 hp	532.73
Remote Condenser, Medium Temp, 0-3 hp	416.37
Remote Condenser, Medium Temp, >3-6 hp	410.17
Remote Condenser, Medium Temp, >6-10 hp	420.08
Remote Condenser, Medium Temp, >10 hp	428.31

A linear interpolation on energy savings from Portland, OR as a function of temperature was used to determine the energy savings in New York based on temperature bins. The two points used for interpolation were the point at/above which minimal savings occur, 75°F, and the average temperature below 75°F where the average kWh/hp savings is expected to occur, which varies by location.

Savings for unitary condensers are not adjusted for climate. This is because heat rejected by the system in these cases is rejected into the conditioned space, and therefore, refrigeration end use savings do not vary significantly by climate.

Coincidence Factor (CF)

The recommended value for the coincidence factor is N/A. It is assumed that NY temperatures below 75°F occur during non-summer peak hours.

Baseline Efficiencies from which Savings are Calculated

The baseline condition is a refrigeration system without floating head pressure controls; fixed head pressure typically set for approximately 95°F saturated condensing temperature, which correlates to approximately 82°F ambient temperature.

Compliance Efficiency from which Incentives are Calculated

The energy efficient condition is a refrigeration system that is controlled to allow the head pressure to float down during cooler ambient conditions.

Operating Hours

Operating hours are based on NOAA bin data for the seven cities/weather zones in NY; Albany, Binghamton, Buffalo, Massena, New York City, Poughkeepsie and Syracuse.

Example Calculation *(Not to be used as default)*

Floating head pressure controls are installed on a commercial low-temperature, unitary condenser refrigeration system with a total refrigeration compressor horsepower of 1.5 in a facility located near Albany. Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings are calculated as below.

$$\Delta kWh = (\Delta kWh/hp) \times hp$$

(ΔkWh/hp) = From application
hp = From application

$$\Delta kWh = 252.03 \times 1.5 = 378\ kWh$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. Regional Technical Forum, "Commercial: Grocery - Floating Head Pressure Controls for Single Compressor Systems", workbook ComGroceryFHPCSingleCompressor_v2_1.xlsm, September 20, 2019. Available from: https://rtf.nwcouncil.org/measure/floating-head-pressure-controls-single-compressor-systems
2. NOAA National Centers for Environmental Information – NCEI 1981-2010 Climate Normals Available from: https://www.ncdc.noaa.gov/cdo-web/datatools/normals

Record of Revisions

Record of Revision Number	Issue Date
3-20-14	3/30/2020

Return to Table of Contents

CUSTOM MEASURES

This section is designed to provide New York's program administrators (PAs) with additional clarification of the DPS review and oversight procedures for custom measures and applications. The overriding DPS goal is to conduct its oversight responsibilities in a manner that protects ratepayer dollars without unduly limiting the ability of PAs to meet their energy savings goals and administer their programs effectively.

The PAs have the responsibility to develop accurate and unbiased estimates of energy savings of custom projects including addressing quality control, project application review, and energy savings calculations. The processes used by PAs to meet these responsibilities will be reviewed by DPS to ensure accountability and transparency. To minimize the impact on the delivery of services through currently operating programs, PAs may continue to operate their programs while the DPS review process is ongoing.

DEFINITIONS

Quality Control (QC) – Policies and procedures established by the PA to ensure the quality of the energy efficiency measures and services delivered to customers. Quality control activities may include factors such as the minimum requirements for energy calculations, model calibration to billing data, application review criteria, reporting requirements, pre and/or post inspections, measurement and verification (M&V) of energy savings, and qualifications of service providers.

Quality Assurance (QA) – Third party verification activities that ensure QC policies and procedures established by the PAs are working as intended, and provide recommendations for modification of QC policies and procedures as necessary.

Prescriptive Measure – Measure which is offered within specific efficiency programs with a prescribed incentive amount or level for all customers participating in the applicable programs. Not all prescriptive measures are necessarily prequalified (i.e., approved by the DPS for offering within a program).

Prequalified Measure – Measure reviewed for cost-effectiveness by the DPS and approved for offering within a program. All prequalified measures are prescriptive measures, but it is the responsibility of the PAs to ensure that all prequalified measures are cost effective within their programs.

Custom Measure – The traditional definition of a custom measure involves unique, and often complex, technologies and processes installed in large facilities. A detailed engineering analysis is usually required and incentives are offered based on the site-specific expected energy savings and costs. Energy savings are estimated using a site-specific engineering analysis. The engineering analysis technique is chosen based on the measure and facility type with the calculations driven by site and measure-specific data. For our purposes, this category also covers infrequently implemented measures or applications that are not listed in an existing prescriptive program.

CUSTOM MEASURES

For energy efficiency programs, custom measures include the following five categories:

Measures that are not included in the TRM and are unique to a specific non-standard process or application, as application conditions can substantially change from project to project. For example, this category might include custom industrial processes, snowmaking, and computer chip fabrication facilities.

Measures that are not in category 1, including prescriptive measures that are promoted by the programs, but are not included in the TRM. Examples in this category include EC motors on HVAC system fans and indirect water heaters.

Measures that are in the TRM, but that are installed in a different environment or have a different use conditions than those assumed in the TRM. Examples in this category include certain comprehensive chiller and cooling tower upgrades.

Measures that are in the TRM, but that require simulation modeling or other advanced approaches in order to estimate interactive effects within a facility (if different from category 3). Examples in this category include whole-building performance programs addressing single and multi-family projects and commercial new construction.

Measures that are in the TRM, but that are installed as a standard measure package for residential retrofit where savings are predetermined by a predefined standardized simulation approach rather than requiring whole building simulation modeling or advanced approaches to determine savings for a single building as under category 4. Examples in this category include air sealing and insulation whole-building retrofit programs for single family and 2-4 unit homes.

CATEGORY 1 – UNIQUE MEASURES/PROJECTS

This section outlines the DPS's policy for reviewing quality control and quality assurance policies and procedures for programs offering measures unique to a specific non-standard process or application.

Critical review of the project energy savings projections and costs is essential to ensure projects are cost-effective and deliver the expected savings. This is especially important for one-of-a-kind projects, where the savings are large, and the expertise needed to understand and verify energy savings projections is specialized. DPS expects that the PAs will utilize an internal process for reviewing and approving large custom projects including screening for cost-effectiveness. DPS will review this process for completeness and transparency. PAs offering large custom incentive programs must also submit their QC and QA processes to the DPS for review. Any issues resulting from these reviews will be reported to the PAs, along with a list of requirements and a schedule for resolving these issues. The QC and QA functions may be staffed internally or provided by outside contractors. Contractors must possess appropriate certification and demonstrated expertise in the technology or processes proposed for the project. As a component of the QC and QA process review, the qualifications of contractors will be reviewed by the DPS.

If the PA has an existing impact evaluation study capable of informing the energy savings of a custom measure(s), this study may serve as the basis for reporting energy savings, provided the study is reviewed by DPS and meets current EEPS evaluation guidelines and standards.

In order to keep the DPS informed of projects and to assist in its review, the PAs will submit monthly reports showing the progress of all "unique" custom projects in the review and approval pipeline. The report must include a description of customer type and the proposed project, the stage of development, energy and demand savings estimates including baseline assumptions, and the expected approval and construction schedule. The DPS, at its discretion, will review selected projects. The DPS will inform the PAs of its intent to review selected projects and provide the PAs with a review schedule.

As part of the PAs evaluation plan, PAs must conduct impact evaluation on a sample of these custom projects to verify the estimated energy savings. Staff may require a project specific impact evaluation for very large projects. Realization rates will be reviewed and possibly revised as evaluation studies provide more data.

CATEGORY 2 – MEASURES INCLUDING PRESCRIPTIVE MEASURES NOT IN THE TRM

The DPS understands that PAs are offering, or will be offering, incentives for measures not included in the TRM. It is the responsibility of the PAs to ensure that all measures are cost effective. The DPS will review the calculation procedures used by the PAs to estimate energy savings, set incentive levels, and show cost-effectiveness. The calculation reviews will be used to verify energy savings and cost-effectiveness, reconcile differences between PAs offering similar measures, and along with results from impact evaluations, inform updates of the TRMs.

PAs must submit calculations for review in a timely manner. The DPS will establish a priority for reviewing these calculations based on the expected number of program applications and the expected uncertainty in the energy savings estimates. PAs can report energy savings using their internal estimates prior to the completion of the calculation reviews. Once the reviews are completed and the energy savings adjustments are identified, the DPS will establish a schedule for incorporating the revised energy savings estimates into the reporting process.

CATEGORY 3 – MEASURES IN TRM BUT USED IN A DIFFERENT APPLICATION/ENVIRONMENT

The DPS will review the PAs processes for reviewing and approving these custom installations, along with the associated QC and QA policies and procedures. Project review and approval must include a cost-effectiveness screening for each custom project. The QC and QA functions may be staffed internally or provided by outside contractors. Contractors must possess appropriate certification and demonstrated expertise in the technology or processes proposed for the project. As a component of the QC and QA process review, the qualifications of contractors will be reviewed by the DPS.

If the PA has an existing impact evaluation study capable of informing the energy savings of a custom measure(s), this study may serve as the basis for reporting energy saving

provided that the study is reviewed by the DPS and the meets current EEPS evaluation guidelines and standards.

The DPS will review procedures used to verify energy savings and approve projects for incentives. Processes used to establish project baselines and energy savings, including engineering analysis tools and simulation software, will be reviewed by the DPS. The DPS may review a sample of project energy savings and cost-effectiveness calculations to check compliance with the approved internal QC processes. Any issues resulting from DPS reviews will be reported to the PAs, along with a list of requirements and a schedule for resolving these issues.

As part of the evaluation plan, PAs must conduct impact evaluations on at least a sample of custom measures to verify the estimated energy savings. Staff may require a project specific impact evaluation for very large projects. Realization rates will be reviewed by the DPS and possibly revised as evaluation studies provide more data.

CATEGORY 4 – WHOLE-BUILDING ANALYSIS

The whole-building approach is commonly applied to new construction projects (both residential and commercial) and specialized retrofit programs such as the Home Performance with ENERGY STAR®. These programs use a building energy simulation model to calculate energy savings for a combination or "package" of measures. The building energy simulation models are informed by detailed building audits and may include building diagnostic testing to identify energy savings opportunities.

Many of the PAs have developed internal processes for reviewing and verifying savings estimates developed under the whole-building analysis approach. PAs offering programs utilizing the whole-building approach must submit their QC and QA processes to the DPS for review. Any issues resulting from DPS reviews will be reported to the PAs along with a list of requirements and a schedule for resolving these issues. The QC and QA functions may be staffed internally or provided by outside contractors. Contractors must possess appropriate certification and demonstrated expertise in whole-building performance analysis. As a component of the QC and QA process review, the qualifications of contractors will be reviewed by the DPS.

The DPS will review the processes used to establish project baselines and energy savings estimates, including requirements for calibrating models to measured data or benchmarking results to established energy metrics. This effort will include a review of analysis tools and simulation software including the administrator's expertise in their application. Evidence of certifications by a third party organization such as the Building Performance Institute or RESNET would be helpful and should be provided by the PA, if available. At the discretion of the DPS, a sample of project energy savings and cost-effectiveness calculations will be reviewed to check compliance with the approved internal QC processes.

Since the measures contained within the package can influence and interact with each other, the whole building analysis gives a good representation of the savings of the overall package of measures, but does not necessarily provide the information needed to

understand the contributions of individual measures to the total savings estimate. It is also difficult to isolate the costs of each energy savings measure from the total project cost (especially in new construction projects). As a result, individual measure cost-effectiveness screening is difficult to conduct within a whole-building analysis framework. Although the overall project may be cost effective, there may be "cross subsidies", where highly cost effective measures are compensating for the lack of cost-effectiveness of other measures. Each measure should be cost effective on its own.

As part of the PAs evaluation plan, PAs must conduct impact evaluation on at least a sample of custom projects to verify the estimated energy savings. Staff may require a project specific impact evaluation for very large projects. Realization rates will be reviewed and possibly revised as evaluation studies provide more data.

Recommended Application Review and QC Procedures for Custom Programs
As stated above, the DPS will conduct reviews of the application review and QC procedures in place for custom programs. The following tables provide a list of issues the application review QC procedures for custom programs should address.

Energy Savings Calculations

Issue	Criteria
Baseline definition	List the criteria used to define the project baseline. The DPS will issue further clarification on baseline requirements in a separate document.
Energy savings calculation methods	List acceptable calculation methods, including approved building energy simulation models and other software
Calibration	Define when calculations must be calibrated with measured data. The acceptable sources of measured data should be defined. The calibration statistics in terms of allowable deviation between calculations and measured data should be defined along with allowable adjustment ranges on important input parameters.
Calculations outside of approved tools	When approved tools are required, list restrictions on calculations that can be performed outside of the tools.
Simulation guidelines	Provide general guidance on acceptable modeling practices for building energy simulation models.
Field measurement requirements	List requirements for field measurements that must be taken and included in the measure savings calculation process.

Application Review Process

Issue	Criteria
Program applicability	Check that the application meets each of the program applicability requirements.

Issue	Criteria
Measure cost requirements	Provide guidance on acceptable sources and processes for estimating measure costs. Clarify the need for full measure costs and incremental costs, and breakdowns by labor and materials as required.
Cost-effectiveness calculation method	Provide guidance on how cost-effectiveness calculations should be done, including the required formulas and data sources. Spreadsheets and other software tools conforming to approved cost-effectiveness calculation procedures may be used to meet this requirement.
Consideration of non-energy benefits (NEBs)	Describe requirements for identifying and quantifying expected non-energy benefits as applicable.
Application approval procedures	Describe the application review procedures, including the affiliations and qualifications of reviewers.

Project QC Procedures

Issue	Criteria
Sampling requirements	Describe sampling procedures used to review projects, including numbers of projects reviewed and the distribution of the sample across contractors and consultants. Describe sampling procedures for measures within a particular project as required.
Pre Inspections	Describe requirements for pre-installation inspections, including data collection requirements and the role of pre-installation inspections in the energy savings calculations.
Post inspections	Describe requirements for post-installation inspections, including data collection requirements and the role of post-installation inspections in the energy savings calculations, measure verification and incentive payment release.
Performance testing	Describe requirements for performance testing of measures as a component of post-installation measure installation verification and incentive payment release.
Commissioning	Describe requirements for project or building commissioning as applicable, including review and approval of commissioning plans and qualifications of commissioning agents and/or service providers.
M&V	Describe post-installation M&V requirements and the role of M&V in project verification and incentive payment release.
Contractor certification	Describe certification requirements for contractors providing project construction and quality control services.
Minimum experience	In addition to certifications, any minimum experience requirements for contractors should be listed.

Issue	Criteria
Training	List requirements for ongoing training.
PA notification requirements	Protocols for informing a PA representative of issues with project quality should be described.

Consultant QC Procedures

Issue	Criteria
Reporting requirements	Minimum requirements for consultant reports should be described.
Report review and approval	The report review procedures and affiliations and qualifications of report reviewers should be described.
Evaluation criteria	Evaluation criteria for consultant QC reviews should be listed.
Sampling requirements	Sampling procedures for consultant QC reviews should be described.
Consultant certifications	Certification requirements for consultants should be listed.
Consultant skills and experience	Beyond basic certification requirements, a description of the skill and experience requirements for consultants should be listed.
PA notification requirements	Protocols for informing a PA representative of issues with consultant services quality should be described.

CATEGORY 5 – RESIDENTIAL RETROFIT STANDARDIZED SIMULATION FOR MEASURE PACKAGES

The standardized simulation savings approach outlined here can be used to determine savings for residential retrofit measure packages proposed for inclusion in residential retrofit programs to reduce heating and cooling loads to prepare homes for electrification. Savings are calculated using a standardized simulation that is an open source, physics-based calculation method with simplified inputs, optimized to reduce input error and contractor data collection effort. The method offers a streamlined alternative to deemed and partially deemed savings calculations or whole house energy simulations. The simulation physics are transparent and the underlying assumptions are explicitly defined thereby providing consistency in the simulated savings for complex measure packages while eliminating the need for whole house modeling often required of contractors participating in residential home performance programs.

The standardized simulation uses an OpenStudio/EnergyPlus framework[1387] and is capable of supporting calculations for a wide range of energy conservation measures (ECMs) and standardized packages for the residential sector, and could be readily expanded for application to commercial and multifamily buildings. The OpenStudio

[1387] The OpenStudio/EnergyPlus framework and the validation testing conducted by US Department of Energy and others is described in supplemental documentation for the *Custom Measure Category 5: Residential Retrofit Standard Simulations for Measure Packages, Chapter A: Third Party Validation for the Open Source Tools (EnergyPlus and OpenStudio*). <Link to DMM pending publication>

building performance simulation software runs on top of the EnergyPlus engine, where OpenStudio "Measures" are defined scripts that leverage the OpenStudio framework to automate performance simulation processes. The ECMs incorporated into standard measure packages can include complex measures such as heat pumps, controls, energy storage and other improvements.

These standardized simulation methods support a set of flexible and extensible residential retrofit measure packages that can be used by PAs to readily incorporate envelope improvements into weatherization programs suitable for the residential sector. Packages are flexible in that the PA may select one or more energy efficiency improvements and extensible in that energy efficiency and clean energy improvements can be added to the retrofit measure package. Realization rate studies have shown that calibrated energy models can improve savings prediction accuracy.[1388] Field studies of asset ratings, using similar standardized simulation methods and standard occupancy related inputs, also have shown strong correlations between predicted and actual usage.[1389]

Standardized Simulation Benefits

Standardized simulations have a number of advantages over the typical partially deemed calculations and whole house modeling, and leverage the underlying physics models to address complex measures such as:

- Packages: Groups, or packages of measures interact with each other within the physics of the simulation. For example, envelope measures combine to change the reference temperature in the building.
- Floors: Floors above unconditioned spaces are not exposed to the outdoor temperature. Calculating the temperature of this unconditioned space is complicated. Uninsulated floors also reduce cooling load.
- Windows: Improvements to window U-Value also reduces the transmission of solar gain into the building. This solar gain varies with the direction of the window.
- Complex Technologies: Technologies where performance varies with temperature (e.g., heat pumps) or with changes in schedule can be represented accurately.
- Fuel conversions: Load reductions resulting from implementation of residential retrofit measure packages may include fuel conversion retrofits that are readily accounted for by standardized simulation methods.

The standardized simulation allows for a wider range of inputs, relative to the limitations of tables of variables, thereby increasing accuracy. Notable impacts:

[1388] Jerone Gagliano et al., *NYSERDA Home Performance with Energy Star Realization Rate Attribution Study* (Ithaca, NY: 2015); Dana Nilsson et al., *HPwES On Bill Recovery Impact Evaluation* (Albany, NY: 2019).
[1389] David Roberts et al., *Assessment of the U.S. Department of Energy's Home Energy Scoring Tool*, (Golden, Colorado: July 2012); Brett Dillion et. al., *Standard for the Calculation and Labeling of the Energy Performance of Low-Rise Residential Buildings using an Energy Rating Index* (January 2016)

- Expansion in the number of weather files available, from 7 to 49, offering improvements in accuracy of up to 10% for building locations outside of the seven urban areas currently in the TRM.
- Operation hours for heating and cooling equipment are not fixed Equivalent Full Load Hours. Equipment run times are flexible and determined by the load in the simulation.
- Thermostat settings can be adjusted to more closely reflect occupant operation of equipment. This can help reduce overestimation of savings.

The standard simulation provides improved metrics, including:

- Time and location dependent peak impacts, for both electricity and gas, using program defined flexible definitions of peak periods.
- Building design load reduction due to the weatherization measure packages using an Equivalent Block Design Load method

Description of the Residential Retrofit Measure Packages

This section describes the flexible and extensible residential retrofit measure packages developed using the standardized simulation.

Three packages are presented by order of priority based on the estimated load reduction and savings impact realized from the package installation in the climate zone as identified by building zip code and mapped to the appropriate NREL TMY3 weather file.[1390] By standardizing the package offered to the consumer, the contractor may reduce customer acquisition costs while driving consumer choice of greatest impact. The package improvements are intended to be implemented in a tiered approach to achieve the highest reduction in the home's heating and cooling loads thereby making the home ready for clean heating solutions aligned with electrification goals in New York.
The simulation methods are both flexible and extensible enabling custom packages to satisfy policy goals specific to given regions.

The three standard packages and the minimum requirements for each measure included in a specific package are presented in Table Residential Retrofit Measure Packages, shown below.

- **Package 1**: attic air sealing and insulation, basement rim joist seal and insulate
- **Package 2**: wall insulation, floor insulation, and all measures included in Package 1
- **Package 3**: ENERGYSTAR windows (or equivalent) and all measures included in Package 2

[1390] The standardized simulation method may be updated to reflect the most current weather long-term average weather data used by the NY TRM.

Measure Category	Measure	Package 1	Package 2	Package 3	Compliance Efficiency
Air Leakage Sealing	**Air leakage improvement**	X	X	X	Ensure air leakage paths between the attic and living space are sealed, leakage paths between basement rim joist and outside are sealed and the final air leakage rate (ACH50) is measured with a blower door.
	Attic hatch sealing and insulation and pull-down stairs	X	X	X	R-20/R-13
Blown in cellulose attic insulation	**Attic insulation**	X	X	X	R-49
Insulation, Opaque shell	**Duct insulation (external to envelope)**	X	X	X	R-12
	Rim joist, spray foam	X	X	X	R-14
	Knee walls (Cape Cods)	X	X	X	R-15
	Wall cavity insulation		X	X	R-14
Window	**Window replacement**			X	U-Factor: 0.28 SHGC: 0.32

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.69.[1391]

[1391] Based on BG&E 'Development of Residential Load Profile for Central Air Conditioners and Heat Pumps'
research, the Maryland Peak Definition coincidence factor is 0.69. This study is not publicly available, but is
referenced by M. M. Straub, Using Available Information for Efficient Evaluation of Demand-Side Management

Baseline efficiencies

The baseline condition is a building's existing condition, inclusive of housing type, vintage, housing characteristics, and estimated air leakage (or actual blower door test value).

Compliance efficiencies

The compliance condition is a residential opaque building shell with increased insulation meeting or exceeding the Package 1, Package 2, and Package 3 described in the table above.

Opaque shell insulation improvements performed under this measure shall be installed such that all altered envelope components comply with all federal, state, local and municipal codes and standards applicable to alterations to existing buildings, including but not limited to SectionR503.1 of ECCCNYS 2020[1392] requiring all existing ceiling, wall, and floor cavities exposed during construction to be filled with insulation. Thermal envelope components not altered as part of this measure (e.g., continuous insulation in wood-framed buildings) are not required to meet code for compliance.

Residential Retrofit Measure Package Inputs

The standardized simulations include simplification and optimization of inputs. Analysis of the influence of various inputs on savings is used to focus the standardized simulation data collection on the inputs that influence savings the most, defaulting or abstracting other inputs.

These input simplifications, along with conservative assumptions on preconditions in the buildings, are key to managing the variability in results. Packages, described in the table above, combined with the sensitivity analysis,[1393] drive the definition of the standardized program data model (aka, Heat Pump Ready eXtensible Markup Language HPRXML).

Method for Calculation: Transforming Program Data (HPRXML) into HPXML

The standardized simulation data collection and inputs have been simplified significantly over that generally required for energy modeling tools and leverages the BPI-2100-S-2013 Standard for Home Performance-Related Data Transfer (Home Performance XML). The HPRXML is transformed to HPXML and is aligned with the US Department of Energy Home Energy Score data set to provide a future option to generate a post retrofit Home Energy Score, albeit with current credentialing requirements. The US DOE has conducted a considerable amount of field validation on this data model as a front end for

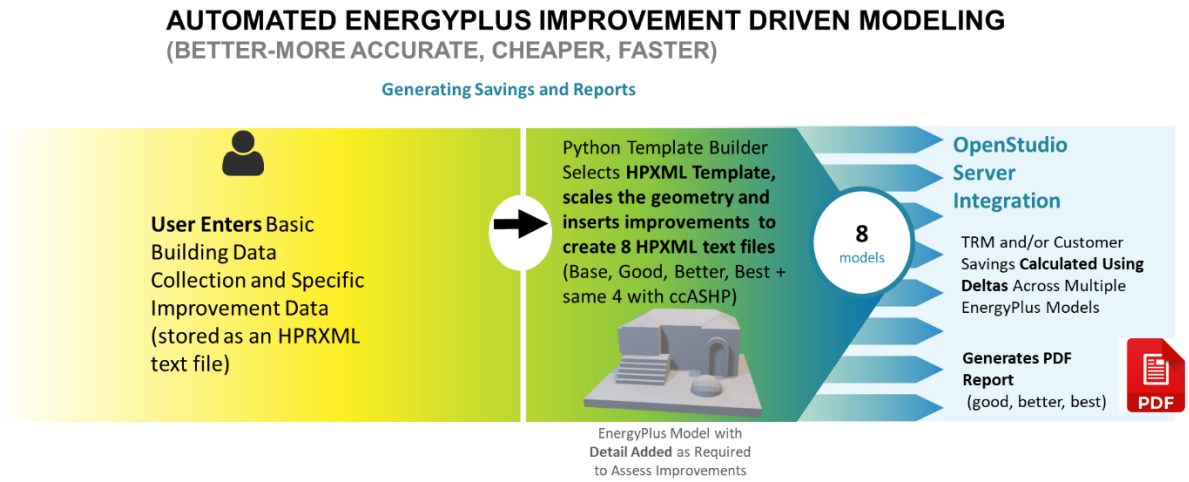
Programs, Electricity Journal, September 2011 and supported by research conducted by Cadmus on behalf of the
RM Management Committee.

[1392] ECCCNYS 2020, Section R503 Building Thermal Envelope

[1393] The sensitivity analysis is described in supplemental documentation for *the Custom Measure Category 5: Residential Retrofit Standard Simulations for Measure Packages, Chapter C: Validation of Savings Results.* <Link to DMM pending publication>

a simulation.[1394] Additionally, the HPRXML data taxonomy was aligned with Home Energy Score where possible.

The transformation of the HPRXML data model into HPXML uses an approach called "Improvement Driven Modeling" (see figure below). This approach leverages the fact that the energy savings is primarily driven by the change in the model. Detailed data collection efforts are focused on defining the specifications of the changes to the building. The building itself is generalized as a box, defined by primary characteristics.



The HPXML files generated by the method are fed into the open source OpenStudio-HPXML Measure[1395] developed by the National Renewable Energy Lab (NREL). OpenStudio is "middleware" software, also developed by NREL, built to simplify the process of working with the EnergyPlus simulation engine. OpenStudio Measures are scripts, or interpreted programs, that leverage the OpenStudio Application Programming Interface to manage the simulation processes. The OpenStudio-HPXML Measure is called to run the EnergyPlus simulations using the building descriptions in corresponding HPXML files.[1396]

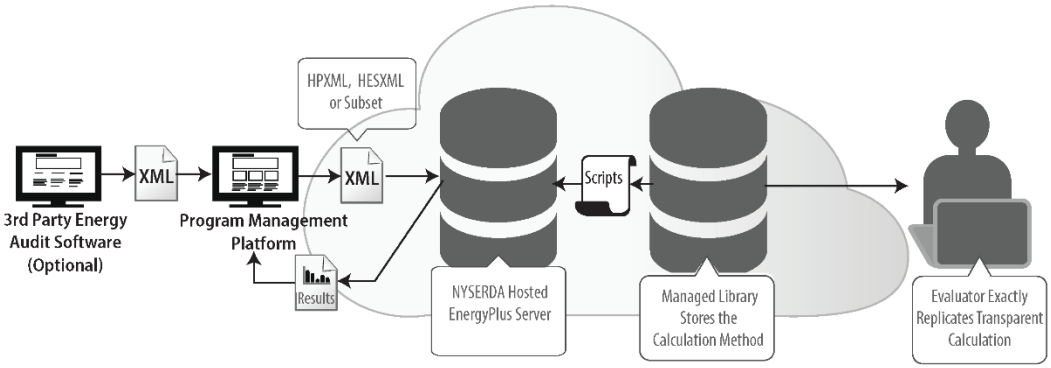
Total electricity end use, total natural gas or other fuel end use, peak electric and gas demand, zone sensible heating load, and zone sensible cooling load are pulled from the results for each simulation. The process returns a CSV file with the result for each run in a row of the CSV file.
To calculate savings, the values for performance metrics across improvement packages are subtracted by the program management software from those for the base (pre-improvement) building energy model.

[1394] The OpenStudio/EnergyPlus framework and the validation testing conducted by US Department of Energy and others is described in supplemental documentation for *the Custom Measure Category 5: Residential Retrofit Standard Simulations for Measure Packages, Chapter A: Third Party Validation for the Open Source Tools (EnergyPlus and OpenStudio).* <Link to DMM pending publication>
[1395] https://github.com/NREL/OpenStudio-HPXML
[1396] More information about this Measure can be found here: https://openstudio-hpxml.readthedocs.io/en/latest/

The formulas, assumptions, and tables supporting the transformation from HPRXML into HPXML are provided in supplemental documentation for the *Custom Measure 5: Residential Retrofit Standard Simulations for Measure Packages, Chapter B: Detailed Description for Transforming Standardized Program Data (HPRXML) into HPXML*.

Managing Workflows

The standardized simulation is maintained by transparently transforming the program data into the HPXML data standard before processing by the OpenStudio/EnergyPlus simulation framework. An open source OpenStudio "measure" or script processes the HPXML file producing an EnergyPlus simulation run for each HPXML file it processes. This approach allows the calculations of the standardized simulation to be replicated on a local computer as shown in the figure below.[1397]



The standardized simulation is deployed on a central cloud server. Access to the server is through an online Application Programming Interface (API). Data files in a standard format (HPRXML) are sent by a program administration platform to the cloud server and processed into different HPXML files representing the existing building, including any required baseline values and the Package 1, Package 2, and Package 3 files.

Detailed Extract Transform Load Workflow Description

The Residential Retrofit Standardized Simulation for Measure Packages uses a transparent *extract-transform-load (ETL) workflow* to support standardized EnergyPlus simulation savings estimation for Package 1, Package 2, and Package 3 improvements in single-family detached residences. This is a data industry standard approach to managing the transformation of data with algorithms. The following describes the processes associated with each stage of this workflow.

[1397] Support for replicating the generation of an EnergyPlus simulation using the OpenStudio "measure" is provided in supplemental documentation for the *Custom Measure Category 5: Residential Retrofit Standard Simulations for Measure Packages, Chapter G: Methods for Third Party Review of the Residential Retrofit Standard Simulations for Measure Packages Savings Method*.

Extract

Data extraction is the first stage of an ETL workflow. Data is collected using a program management platform that validates contractor entries according to a set of tests described in supplemental documentation for the *Custom Measure 5: Residential Retrofit Standard Simulations for Measure Packages, Chapter D: Quality Assurance Methods for Standardized Simulations*. Data is extracted from the Program Management platform in XML format. The building level XML data file that is passed into the next stage of this workflow is called a Heat Pump Ready XML (HPRXML).[1398] The calculation related inputs to the HPRXML file are described in the Summary of Data Source and Variables section below. HPRXML contains a combination of building description and improvement description. When the HPRXML is processed into HPXML the detailed descriptions of the improvements are embedded in the package HPXML files. Improvements are added in stages to create packages with increasing savings depth.

Transform

The extracted HPRXML is read for transformation. The goal of this step is to convert a HPRXML into Home Performance XML files (HPXML). These HPXMLs represent the:

- Base Building: The building as it currently exists.
- Package 1, Package 2, and Package 3 Packages: Improvements from corresponding packages within the extracted HPRXML are used to create the improved buildings.

Documentation for the full transform is described in supplemental documentation for the *Custom Measure Category 5: Residential Retrofit Standard Simulations for Measure Packages, Chapter B: Detailed Description for Transforming Standardized Program Data (HPRXML) into HPXML*. HPXML files generated can be downloaded and inspected, and the changes in the HPXML data compared to transforms described in the documentation. The files can then be run in the OpenStudio/EnergyPlus framework, generating the same results as the cloud-based simulation. This provides full transparency on the calculation method.

To support multiple envelope designs and HVAC types, there are individual XML templates for each primary building component. See tables below for examples. Combining the templates that match the envelope design and HVAC type for an inspected home creates a base building HPXML. Three building styles, five foundation types, and eight HVAC systems are supported (see Table Supported Envelope Designs and HVAC Types). All buildings are modeled with vented attics. Contractors can select the closest type for buildings outside of the three primary types supported.

[1398] Further details are described in supplemental documentation for the *Custom Measure Category 5: Residential Retrofit Standard Simulations for Measure Packages, Chapter B: Detailed Description for Transforming Standardized Program Data (HPRXML) into HPXML*.

Table: Supported Envelope Designs and HVAC Types

Building Component	Enumeration
Style	Ranch, Colonial, Cape Cod
Foundation Type	Slab, Conditioned Basement, Unconditioned Basement, Vented Crawl Space, Unvented Crawl Space
Heating Systems	Condensing and Non-Condensing Furnaces, Wall Furnaces, Condensing and Non-Condensing Boilers, Electric Baseboards
Cooling Systems	Room Air Conditioners, Central Air Conditioners
Heat Pumps	Air Source Heat Pumps, Ductless Mini-Splits, Ground Source Heat Pumps

Table Data Transform Abstractions

HPRXML Inputs	Abstracted HPXML Specifications
Construction Era	Attic Floor R-Value
Building Style, Number of Stories, Conditioned Floor Area	Roof Pitch, Roof Area, Attic Gable Area, Cape Cod Knee Wall Area, Cape Cod Knee Roof Area, Above Grade Wall Area, Window Area, Rim Joist Area, Attic Floor/ Slab / Floor above Foundation Area, Foundation Wall Area, Hot Water Piping Length, Supply and Return Duct Areas
Foundation Type	Conditioned Building Volume, Foundation Wall Area

Load

During this stage, the HPXML files are fed into the OpenStudio-HPXML Measure. The OpenStudio-HPXML Measure will run the residential EnergyPlus simulations using the building descriptions in corresponding HPXML files.[1399]

Total electricity end use, total natural gas or additional fuel end use, peak electric demand, ,peak gas demand, zone sensible heating load, and zone sensible cooling load are pulled from the results for each simulation. Before calculating savings, the HPXML file results are grouped into categories. To calculate savings in each group, the values for performance metrics across improvement packages are subtracted from those for the corresponding base building.

Operating Hours

Operating hours are the occupancy assumptions of the standardized simulation, including thermostat schedule.

[1399] More information about this Measure can be found here: https://openstudio-hpxml.readthedocs.io/en/latest/

Operation hours for heating and cooling equipment are not fixed Equivalent Full Load Hours. Equipment run times are flexible and determined by the load in the in the simulation. Changes in load, such as in the measures being submitted, affect the equipment run times

Effective Useful Life

Standardized simulation results are at the whole building per fuel level. The standardized Package 1, Package 2, and Package 3 for different buildings will contain different mixes of measures based on the requirements of each building. Table Estimated Average Measure Impacts, below, contains the estimated average improvements per measure for each package and an estimate of the expected savings contribution from that measure on an average home.

Residential Retrofit Measure	**Estimated Area**	**Estimated Average Existing Condition**	**Estimated Average Improved Condition**	**Units**
Air Leakage	NA	3200	2400	CFM50
Attic Insulation	800	11	49	R Value
Rim Joist Insulation	130	5	19	R Value
Duct Insulation	50	2	23	R Value
Wall Insulation	1200	5	14	R Value
Floor Insulation	500	7	24	R Value
Window Replacement	200	0.556	0.270	U Value

Table Estimated Average Measure Impacts

These percentages are used to create a Composite Weighted Package Life, presented in Table Calculation of Composite Weighed Package Life, below.

Package	**Measure**	**Measure Life from TRM in Years** (See NY TRM Appendix P)	**Estimated Average % Contribution per Measure to Package 1**	**Estimated Average % Contribution per Measure to Package 2**	**Estimated Average % Contribution per Measure to Package 3**	**Estimated Composite Weighted Package Life (Years)**
Package 1	Air Sealing	15	37%	16%	14%	20.3
Package 1	Attic Insulation	25	36%	16%	13%	
Package 1	Rim Joist Insulation	25	12%	5%	5%	
Package 1	Duct Insulation	18	15%	6%	5%	

Package	Measure	Measure Life from TRM in Years (See NY TRM Appendix P)	Estimated Average % Contribution per Measure to Package 1	Estimated Average % Contribution per Measure to Package 2	Estimated Average % Contribution per Measure to Package 3	Estimated Composite Weighted Package Life (Years)
Package 2	Wall Insulation	25		43%	37%	22.9
Package 2	Floor Insulation	25		14%	12%	
Package 3	Replacement Windows	20			14%	22.5

Table Calculation of Composite Weighed Package Life

Ancillary Fossil Fuel Savings Impact

Ancillary savings impacts are implicitly captured in the simulation.

Ancillary Electric Savings Impact

Ancillary savings impacts are implicitly captured in the simulation.

Additional Outputs from the Residential Retrofit Measure Packages

The OpenStudio/EnergyPlus based method provides additional metrics beyond annual savings and demand impacts that may be of high value to programs.

- **Manual J "Equivalent" Heating and Cooling Loads** The EnergyPlus / OpenStudio workflow also outputs "Whole House" Peak Heating and Cooling loads calculated using an approach which mimics Manual J8 AE. When modeled HVAC equipment is indicated as 'auto-sized', these capacities are used to set the auto-sized capacity values. The "Manual J8 AE Equivalent" method estimates the peak heating and cooling load contributions of windows, doors, walls, roofs, floors and infiltration/ventilation components and occupant related internal gains that are described within an HPXML file.
- **Time and Location Dependent Peak Demand** The EnergyPlus / OpenStudio workflow generates several data outputs that supports the estimation of location specific values of Peak Demand. A machine learning algorithm (also used by the DOE Asset Score Tool) has been used to map one of 49 different TMY3 Weather files to each of the 1,753 New York Zip Codes. For each HPXML file and associated simulation run, a maximum value of the whole building electricity meter is reported, along with the paired 10-minute time stamp of occurrence. In addition, the simulation provides the peak value (and time of peak) of all electricity end-uses, such as electric heating or electric cooling. Finally, the workflow also produces time series outputs for whole building electricity, which

can be post processed to estimate values associated with a coincident system peak.

- **Gas Peak Heating Load** The EnergyPlus / OpenStudio workflow can use the same techniques available for estimating Peak Electrical Demand impacts that are described above, for Natural Gas. For each HPXML file and associated simulation, both the time of peak and magnitude of peak Natural Gas, for both whole building usage and the heating end-use, can be generated.
- **Customer Facing Interacted Fuel Conversion Calculations** The standardized simulation supports the calculation of interacted savings, such as the conversion from existing equipment to heat pumps, without any envelope improvements, and in combination with each of the measure packages.

Change Management for Standardized Simulations

The centralized cloud-based calculations support cost effective and timely change management. A change to the method can be implemented in a central location, affecting all subsequent calculations. These can be done on an annual or semiannual basis. The Residential Retrofit Standard Simulations for Measure Packages utilizes an automated validation framework that supports analysis and reporting on the changes in the savings for both packages and individual measures within packages. Updates to these reports are a part of the approval process for any subsequent improvements to the calculations. The results of the validation are described in supplemental documentation for the *Custom Measure 5: Residential Retrofit Standard Simulations for Measure Packages, Chapter C: Validation of Savings Results.*

The credentialed savings method of the standardized simulation is subject to change management similar to other custom measures. Changes to the calculation methods will be evaluated and submitted for approval to DPS before being deployed to the centralized server. The cloud-based, centralized server implementation of the standardized simulation reduces the cost of deploying changes to the calculation method when compared to calculations distributed across many different users.

Changes could include upgrades to the EnergyPlus and OpenStudio software, adding new ECMs to the packages, changes to the HPRXML to HPXML transform based on program experience and evaluation results.

Summary of Variables and Data Sources

The variables used in the calculation are described in supplemental documentation for the *Custom Measure Category 5: Residential Retrofit Standard Simulations for Measure Packages, Chapter B: Detailed Description for Transforming Standardized Program Data (HPRXML) into HPXML.* Chapter B contains the details for transforming the program data input file (HPRXML) into the HPXML data standard that is read by the NREL OpenStudio to EnergyPlus measure. *Supplemental documentation for the Custom Measure Category 5: Residential Retrofit Standard Simulations for Measure Packages,*

Chapter A: Third Party Validation for the Open Source Tools (EnergyPlus and OpenStudio), contains documentation on the testing that these tools undergo.

Data collection is from contractors and can include remote data collection. The contractor entered fields are described in the table below.

Input Type	Variable Name	Description	Values	Notes
Assessment	YearBuilt	Estimated Construction Era	2010 2000 1990 1980 1970 1960 1950 1940 1930 1920 1900	Select the decade range the main part of the house was constructed.
Assessment	FloorArea	Conditioned Floor Area	Integer	Enter the total conditioned floor area of the house
Assessment	BuildingType	Building Type	Cape Cod Colonial Ranch	Select the type of the home
Assessment	NumberStories	Number of Stories	Integer	Enter a value between 1 and 3
Assessment	StoryHeight	Average Story height (ft)	Integer	Enter a value between 6 and 12
Assessment	Bedrooms	Number of Bedrooms	Integer	Enter value between 1 and 10
Assessment	FoundationType	Foundation Type	Conditioned Basement Slab on Grade Unconditioned Basement Unvented Crawlspace Vented Crawlspace	Enter the predominant foundation type in the house
Assessment	WallInsulation_Depth	Depth of wall cavity	2x4 2x6	Select the wall cavity depth based on framing members of the wall

Input Type	Variable Name	Description	Values	Notes
Assessment	RimJoistInsulation	Rim/Band Insulation level	None Partial Full	Select the level of existing insulation for the rim joist/band
Assessment	BlowerDoorIn	Blower Door CFM50	Integer	Enter the Existing air leakage in CFM50
Assessment	EstimatedAirLeakage	Estimated Air Leakage	Measured Very Leaky Leaky Average Fairly Tight Tight	Enter estimated air leakage if friable asbestos is present in the home or measured leakage if available
Assessment	WindowGlazing	Window Glazing Type	Single-pane, clear Single-pane, tinted Double-pane, clear Double-pane, tinted Double-pane, insulating low-E Double-pane, insulating low-E, argon gas fill Double-pane, solar-control low-E Double-pane, solar-control low-E, argon gas fill Triple-pane, insulating low-E, argon gas fill	Select the predominant glazing type for existing windows
Assessment	PrimaryHeatingFuel	Primary Heating Fuel	Electric Natural Gas LPG (Propane) Fuel Oil	Select the fuel for the primary heating system

Input Type	Variable Name	Description	Values	Notes
Assessment	PrimaryHeatingSystem	Primary Heating Type	Heat Pump Boiler Condensing boiler Baseboard Condensing furnace Central furnace Ground Coupled Heat Pump Ductless mini split heat pump Wall furnace	Select the type of the primary heating system
Assessment	PrimaryHeatingSystemAge	Primary Heating System Age	2010 2000 1990 1980 1970	Select the decade in which the primary heating system was installed
Assessment	CoolingEquipmentType	Primary Cooling Type	Heat Pump Central furnace Ground Coupled Heat Pump Ductless mini split heat pump Room None	Select the type of the primary cooling system
Assessment	CoolingSystemYear	Primary Cooling System Age	2010 2000 1990 1980 1970	Select the decade in which the primary cooling system was installed
Assessment	HotWaterFuel	Hot Water Fuel	Electricity Natural Gas LPG (Propane) Fuel Oil Wood Wood Pellets	Select the fuel used to provide hot water

Input Type	Variable Name	Description	Values	Notes
Assessment	ThemostatSchedule	Thermostat Schedule	None Nightly and Weekday Nightly Only	Are most of the thermostats set up on a schedule?
Assessment	ElectricityUse	Annual Electricity Cost ($)	Decimal	Enter the annual electricity use in USD ($)
Assessment	OtherFuel1	Other Fuel 1	None Natural Gas LPG (Propane) Fuel Oil Wood Wood Pellets	If there is another fuel in the house for other purpose, select from the list
Assessment	OtherFuelUse1	Annual Other Fuel 1 Cost ($)	Decimal	Enter the annual use in USD ($) for the other fuel
Assessment	OtherFuel2	Other Fuel 2	None Natural Gas LPG (Propane) Fuel Oil Wood Wood Pellets	If there is another fuel in the house for other purpose, select from the list
Assessment	OtherFuelUse2	Annual Other Fuel 2 Cost ($)	Decimal	Enter the annual use in USD ($) for the 2nd other fuel
Improvement Package 1	BlowerDoorOut	Improved Blower Door CFM50	Integer	Enter the improved air leakage in CFM50
Improvement Package 1	PrimaryAttic_ImprovedArea	Primary Attic Improved Area	Integer	Enter the area in sq. ft. of the improved attic floor, else enter the area in sq.ft of the roof. Enter 0 if no improvement is needed
Improvement Package 1	PrimaryAttic_ImprovedRValue	Primary Attic Improved R-Value	Integer	Enter the improved attic R-Value of either floor or roof, depending on what is insulated

Input Type	Variable Name	Description	Values	Notes
Improvement Package 1	SecondaryAttic_ImprovedArea	Secondary Attic Improved Area	String	If insulating attic floor, Enter the area in sq. ft. of the improved attic floor, else enter the area in sq.ft of the roof. Enter 0 if no improvement is needed.
Improvement Package 1	SecondaryAttic_ImprovedRValue	Secondary Attic Improved R-Value	Integer	Enter the improved attic R-Value of either floor or roof, depending on what is insulated
Improvement Package 2	BlowerDoorOut	Improved Blower Door CFM50	Integer	Enter the improved air leakage in CFM50
Improvement Package 2	ExposedFloor_Area	Improved Floor Area	Integer	Enter the area in sq.ft. of the improved floor insulation. Enter 0 if no improvement is needed.
Improvement Package 2	WallInsulation_Area	Improved Wall Area	Integer	Enter the area in sq. ft. of the improved wall insulation. Enter 0 if no improvement is needed.
Improvement Package 3	BlowerDoorOut	Improved Blower Door CFM50	Integer	Enter the improved air leakage in CFM50
Improvement Package 3	WindowArea_North	Window Improved Area - North (Sq Ft)	Integer	Enter the area in sq.ft. of improved windows on the North side of the house. Enter 0 if no improvement is needed.
Improvement Package 3	WindowArea_East	Window Improved Area - East (Sq Ft)	Integer	Enter the area in sq.ft. of improved windows on the East side of the house. Enter 0 if no improvement is needed.

Input Type	Variable Name	Description	Values	Notes
Improvement Package 3	WindowArea _South	Window Improved Area - South (Sq Ft)	Integer	Enter the area in sq.ft. of improved windows on the South side of the house. Enter 0 if no improvement is needed.
Improvement Package 3	WindowArea _West	Window Improved Area - West (Sq Ft)	Integer	Enter the area in sq.ft. of improved windows on the West side of the house. Enter 0 if no improvement is needed.
Improvement Package 3	Window_Imp rovedUValue	Window New U-Value (Predominant)	Integer	Enter the predominant improved U-Value
Improvement Package 3	Window_Imp rovedSHGC	Window New SHGC (Predominant)	Integer	Enter the predominant improved Solar Heat Gain Coefficient

Quality Assurance and Quality Control Procedures

Quality Assurance measures are designed to increase the speed and reduce the cost of review compared to typical custom measures. Supplemental documentation for the *Custom Measure Category 5: Residential Retrofit Standard Simulations for Measure Packages, Chapter D: Quality Assurance Methods for Standardized Simulations* contains a list of automated data checks measures that will administered by a program management tool before sending a program XML file to the EnergyPlus calculation server. Results of the automated data checks can include triggering a manual review. The set of data checks can be expanded and statistics for identifying outliers can be established.

References

1. New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs – Residential, Multi-Family, and Commercial/Industrial Measures Supplemental Documentation Custom Measure Category 5: Residential Retrofit Standard Simulations for Measure
   Available from: *Pending publication on DMM*
2. Dillion et. al., *Standard for the Calculation and Labeling of the Energy Performance of Low-Rise Residential Buildings using an Energy Rating Index* (January 2016)
3. ECCCNYS 2020, Section R503 Building Thermal Envelope
4. Gagliano et al., *NYSERDA Home Performance with Energy Star Realization Rate Attribution Study* (Ithaca, NY: 2015)

5. Roberts et al., *Assessment of the U.S. Department of Energy's Home Energy Scoring Tool*, (Golden, Colorado: July 2012).
6. https://github.com/NREL/OpenStudio-HPXML
7. https://openstudio-hpxml.readthedocs.io/en/latest/

Record of Revision

Record of Revision Number	Issue Date
0	10/15/2010
7-21-24	8/30/2021

Return to Table of Contents

APPENDIX A

BUILDING TYPES

The sections that follow provides savings data by building type. A description and additional details of each building type is shown in the table below and the sections that follow.

Note: the building type classifications are defined primarily by activity, HVAC system type, and number of floors since the deemed parameters in the TRM are generally normalized to equipment or measure size.

Building Type	*Description*
Assembly	Public buildings that include community centers, libraries, performance and movie theaters, auditoria, police and fire stations, gymnasia, sports arenas, and transportation terminals
Auto	Repair shops and auto dealerships, including parking lots and parking structures.
Big Box	Single story, high-bay retail stores with ceiling heights of 25 feet or more. Majority of floor space is dedicated to non-food items, but could include refrigerated and non-refrigerated food sales areas.
Community College	Community college campus and post-secondary technical and vocational education buildings, including classroom, computer labs, dining and office. Conditioned by packaged HVAC systems
Dormitory	College or University dormitories
Fast Food	Self-service restaurants with primarily disposable plates, utensils etc.
Full Service Restaurant	Full service restaurants with full dishwashing facilities
Grocery	Refrigerated and non-refrigerated food sales, including convenience stores and specialty food sales
Heavy Industrial	Single or multistory buildings containing industrial processes including pump stations, water and wastewater treatment plants; may be conditioned or unconditioned.
Hospital	Inpatient and outpatient care facility conditioned by built-up HVAC systems. Excludes medical offices
Hotel	Multifunction lodging facility with guest rooms, meeting space, foodservice conditioned by built-up HVAC system
Industrial Refrigeration	Refrigerated warehouses and food processing facilities maintained at space temperatures of 55 ^{o}F or less.
Large Office	Office space in buildings greater than 3 stories conditioned by built-up HVAC system.
Light Industrial	Single story work space with heating and air-conditioning; conditioned by packaged HVAC systems
Multi-family high-rise	Multi-family building with more than 3 stories conditioned by built up HVAC system
Multi-family low-rise	Multi-family building with 3 stories or less conditioned by packaged HVAC system
Motel	Lodging facilities with primarily guest room space served by packaged HVAC systems
Multi Story Retail	Retail building with 2 or more stories served by built-up HVAC system
Primary School	K-8 school
Religious	Religious worship

Building Type	*Description*
Secondary School	9-12 school
Single-family residential	Single-family detached residences
Small Office	Office occupancy in buildings 3 stories or less served by packaged HVAC systems; includes Medical offices
Small Retail	Single story retail with ceiling height of less than 25 feet; primarily non-food retail and storage areas served by packaged HVAC systems. Includes service businesses, post offices, Laundromats, and exercise facilities.
University	University campus buildings, including classroom, computer labs, biological and/or chemical labs, workshop space, dining and office. Conditioned by built-up HVAC systems
Warehouse	Primarily non-refrigerated storage space could include attached offices served by packaged HVAC system.

Note: for commercial buildings that cannot be reasonably associated with one the building types above, savings values for the "other" category should be used.

PROTOTYPICAL BUILDING DESCRIPTIONS

RESIDENTIAL BUILDING PROTOTYPES

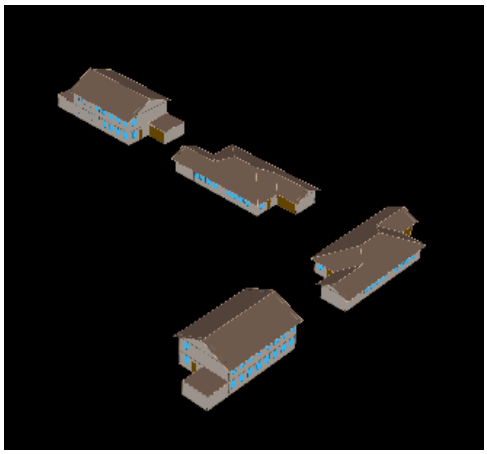
Analysis used to develop parameters for the energy and demand savings calculations are based on DOE-2.2 simulations of a set of prototypical residential buildings. The prototypical simulation models were derived from the residential building prototypes used in the California Database for Energy Efficiency Resources (DEER)[1400] study, with adjustments made for local building practices and climate. Three separate models were created to represent general vintages of buildings:

- Old, poorly insulated buildings constructed before 1979, before the NY State Energy Code went into effect. This vintage is referred to as the "old" vintage.
- Existing, average insulated buildings conforming to 1980s era building codes. This vintage is referred to as the "average" vintage, covering buildings constructed from 1979 to 2006.
- New construction conforming to the 2007 Energy Conservation Construction Code of New York State (ECCCNYS) for residential buildings. This vintage is referred to as the "new" vintage, and covers buildings constructed from 2007 to present.

SINGLE-FAMILY RESIDENTIAL PROTOTYPE

The single-family "model" in fact contains four separate residential buildings: 2 one-story and 2 two-story buildings. Each version of the 1 story and 2 story buildings are identical except for the orientation, which is shifted by 90 degrees. The selection of these four buildings is designed to give a reasonable average response of buildings of different design and orientation to the impact of energy efficiency measures. A sketch of the single-family residential prototype buildings is shown below.

[1400] 2004-2005 Database for Energy Efficiency Resources (DEER) Update Study, Final Report, Itron, Inc. Vancouver, WA. December 2005. Available at www.calmac.org/publications/2004-05_DEER_Update_Final_Report-Wo.pdf



The general characteristics of the single-family residential building prototype model are summarized below.

SINGLE-FAMILY RESIDENTIAL BUILDING PROTOTYPE DESCRIPTION

Characteristic	Value
Vintage	Three vintages simulated – old poorly insulated buildings, existing average insulated buildings and new buildings
Conditioned floor area	1 story house: 1465 SF (not including basement) 2 story house: 2930 SF (not including basement)
Wall construction and R-value	Wood frame with siding, R-value varies by vintage
Roof construction and R-value	Wood frame with asphalt shingles, R-value varies by vintage
Glazing type	Single and double pane; properties vary by vintage
Lighting and appliance power density	0.51 W/SF average
HVAC system type	Packaged single zone AC or heat pump
HVAC system size	Based on peak load with 20% over-sizing.
HVAC system efficiency	Baseline SEER = 13
Thermostat set points	Heating: 70°F with setback to 67°F Cooling: 75°F with setup to 78°F
Duct location	Buildings without basement: attic Buildings with basement: basement
Duct surface area	Single story house: 390 SF supply, 72 SF return Two story house: 505 SF supply, 290 SF return
Duct insulation	Uninsulated
Duct leakage	20% of fan flow total leakage evenly split between supply and return.
Natural ventilation	Allowed during cooling season when cooling set point exceeded and outdoor temperature < 65°F. 3 air changes per hour

Wall, Floor and Ceiling Insulation Levels

The assumed values for wall and ceiling by vintage are shown below.

WALL INSULATION R-VALUE ASSUMPTIONS BY VINTAGE

Vintage	Assumed R-value of insulated wall	Notes
Older, poorly insulated	4.8	No insulation in 2 by 4 wall; 3.5 in. air gap resistance only
Existing, average insulation	11	Fiberglass insulation in 2 by 4 wall per MEC 1980
New construction	19	Code

CEILING INSULATION R-VALUE ASSUMPTIONS BY VINTAGE

Vintage	Assumed R-value of insulated ceiling	Notes
Older, poorly insulated	11	Minimal ceiling insulation
Existing, average insulation	19	Fiberglass insulation per MEC 1980
New construction	30 (NYC), 38 (all others)	Code

Windows

The glazing U-value and solar heat gain coefficient (SHGC) assumptions for the three vintages are shown below.

WINDOW PROPERTY ASSUMPTIONS BY VINTAGE

Vintage	U-value (BTU/hr-F-SF)	SHGC	Notes
Older, poorly insulated	0.93	0.87	Single pane clear
Existing, average insulation	0.87	0.77	Double pane clear
New construction	0.28	0.49	Double low e

Infiltration

Infiltration rate assumptions were set by vintage as shown below.

INFILTRATION RATE ASSUMPTIONS BY VINTAGE

Vintage	Assumed infiltration rate	Notes
Older, poorly insulated	1 ACH	
Existing, average insulation	0.5 ACH	
New construction	0.35 ACH	Minimum without forced ventilation per ASHRAE Standard 66.

MULTI-FAMILY LOW-RISE

The low-rise prototype "model" in fact contains 2 separate buildings. Each version of the buildings is identical except for the orientation, which is shifted by 90 degrees. The selection of these 2 buildings is designed to give a reasonable average response of buildings of different design and orientation to the impact of energy efficiency measures.

Four separate models were created to represent general vintages of buildings:

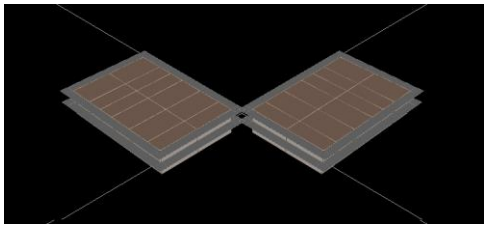
- Built prior to 1940, uninsulated masonry buildings. This vintage is referred to as "Pre-war uninsulated brick."

- Built prior to 1979 when the NYS Energy Code (known as the Energy Conservation Construction Code of New York State – ECCCNYS) went into effect, poorly insulated wood-frame buildings This vintage is referred to as "Prior to 1979"

- Built from 1979 through 2006, with insulation conforming to 1980s era building codes (1979 ECCCNYS.) This vintage is referred to as "From 1979 through 2006."

- Built from 2007 through the present, new construction with insulation conforming to the 2007 ECCCNYS for residential buildings and the New York City Energy Conservative Construction Code (if applicable.) This vintage is referred to as "From 2007 through the present."

Each building vintage was run with 7 different HVAC system types to capture the range of HVAC systems common in low-rise multi-family buildings. A sketch of the low-rise prototype buildings is shown below.



The general characteristics of the residential building prototype model are summarized below.

MULTI-FAMILY LOW-RISE RESIDENTIAL BUILDING PROTOTYPE DESCRIPTION

Characteristic	Value
Vintage	Four vintages simulated: Pre-war uninsulated brick; Prior to 1979 (wood frame); From 1979-2006; and From 2007 to present
Conditioned floor area	949 SF per unit; 6 units per floor, 2 floors per building, 11,388 SF total.
Wall construction and R-value	R-value and construction vary by vintage.
Roof construction and R-value	Wood frame with asphalt shingles. R-value varies by vintage.
Glazing type	Single or double pane. Properties vary by vintage.
Lighting and appliance power density	0.87 W/SF average in bedrooms, 0.58 W/SF in living space.

Characteristic	Value
HVAC system types	1. Split system AC with central gas heat 2. Split system AC with electric heat 3. Split system heat pump 4. PTAC with electric heat 5. PTHP 6. Electric heat only (no AC) 7. Central gas heat only (no AC) 8. Central steam (within the building) heat only (no AC)
HVAC system size	Based on peak load with 20% over-sizing.
HVAC system efficiency	AC and heat pump: SEER = 13 PTAC and PTHP: EER = 7.7 Furnace / boiler: AFUE = 78% Steam boiler: AFUE = 75%
Thermostat set points	1. Heating: 70^{0}F with setback to 67^{0}F(outside of NYC); 73^{0}F with setback to 70^{0}F (NYC only) 2. Cooling: 75°F with setup to 78°F
Duct location (for systems with ducts)	In attic and plenum space between first and second floors. PTACs and PTHPs have no ductwork.
Duct surface area (for systems with ducts)	256 SF supply, 47 SF return per system
Duct insulation (for systems with ducts)	Uninsulated
Duct leakage (for systems with ducts)	20% of fan flow total leakage, evenly split between supply and return.
Natural ventilation	Allowed during cooling season when cooling set point exceeded and outdoor temperature < 65°F. 3 air changes per hour

Wall and Ceiling Insulation Levels

The assumed values for wall and ceiling by vintage are below.

WALL INSULATION R-VALUE ASSUMPTIONS BY VINTAGE

Vintage	Assumed R-value of insulated wall	Notes
Pre-war uninsulated brick	4	Three 4” brick layers. No insulation. 2” air gap resistance only.
Prior to 1979	7	Wood frame with siding. No insulation in 2 by 4 wall; 3.5” air gap resistance only
From 1979 through 2006	11	Wood frame with siding. Fiberglass insulation in 2 by 4 wall per MEC 1980.
From 2007 through the present	19	Code

CEILING INSULATION R-VALUE ASSUMPTIONS BY VINTAGE

Vintage	Assumed R-value of insulated ceiling	Notes
Pre-war uninsulated brick	2	No ceiling insulation
Prior to 1979	11	Minimal ceiling insulation
From 1979 through 2006	19	Fiberglass insulation per MEC 1980
From 2007 through the present	38	NYS Code for climate zones 4 & 5
	49	NYS Code for climate zone 6

THERMOSTATIC HEATING SET POINT ASSUMPTIONS BY VINTAGE

Vintage	Set point and setback (°F)	Notes
Pre-war uninsulated brick	73, 70	NYC
	70, 67	All others
Prior to 1979	70, 67	
From 1979 through 2006	70, 67	
From 2007 through the present	70, 67	

Windows

The glazing U-value and solar heat gain coefficient (SHGC) assumptions for the four vintages are shown below.

WINDOW PROPERTY ASSUMPTIONS BY VINTAGE

Vintage	U-value (BTU/hr-°F-SF)	SHGC	Notes
Pre-war uninsulated brick	0.93	0.87	Single pane clear
Prior to 1979	0.93	0.87	Single pane clear
From 1979 through 2006	0.68	0.77	Double pane clear
From 2007 through the present	0.28	0.49	Double low e per code

Infiltration

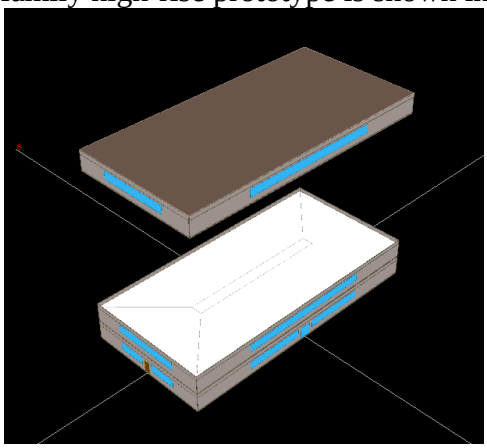
Infiltration rate assumptions were set by vintage as shown below.

INFILTRATION RATE ASSUMPTIONS BY VINTAGE

Vintage	Assumed infiltration rate	Notes
Pre-war uninsulated brick	1 ACH	
Prior to 1979	1 ACH	
From 1979 through 2006	0.5 ACH	
From 2007 through the present	0.35 ACH	Minimum without forced ventilation per ASHRAE Standard 66.

MULTI-FAMILY HIGH-RISE

The multi-family high-rise model was developed using the conceptual design "wizard" in eQUEST program, rather than a DEER prototype. A computer-generated sketch of the multi-family high-rise prototype is shown in the figure below.



Note: The middle floors, since they thermally equivalent, are simulated as a single floor, and the results are multiplied by 8 to represent the energy consumption of the 8 middle floors. The general characteristics of the multi-family high-rise building prototype model are summarized below.

MULTI-FAMILY HIGH-RISE RESIDENTIAL BUILDING PROTOTYPE DESCRIPTION

Characteristic	Value
Vintage	Four vintages simulated: Pre-war uninsulated brick; Prior to 1979 (wood frame); From 1979-2006; and From 2007 to present
Conditioned floor area	810 SF per unit; 10 units per floor, 10 floors per building; 81,000 SF total living space. Corridors and common space: 18,255 SF; Laundry rooms: 6,845 SF Storage: 7,985 SF Total: 114,085 SF
Wall construction and R-value	Masonry wall with brick exterior, R-value varies by vintage
Roof construction and R-value	Wood frame with built-up roofing, R-value varies by vintage
Glazing type	Single or double pane; properties vary by vintage
Lighting and appliance power density	0.7 W/SF average
HVAC system type	1. Four pipe fan coil with air cooled electric chiller and gas hot water boiler 2. Central building steam
HVAC system size	Based on peak load with 20% over-sizing.
HVAC system efficiency	Chiller: COP = 3.9 Hot water boiler: Thermal efficiency = 78% Steam boiler: thermal efficiency = 75%
Thermostat set points	1. Heating: 70^0F with setback to 67^0F(outside of NYC); 73^0F with setback to 700F (NYC only) 2. Cooling: 75°F with setup to 78°F

Wall, Floor Insulation Levels

The assumed values for wall and ceiling by vintage are shown below.

WALL INSULATION R-VALUE ASSUMPTIONS BY VINTAGE

Vintage	Assumed R-value of insulated wall	Notes
Pre-war uninsulated brick	4	Same as low-rise
Prior to 1979	7	No insulation; air gap resistance only
From 1979 through 2006	11	Same as low-rise
From 2007 through the present	19	Code

ROOF INSULATION R-VALUE ASSUMPTIONS BY VINTAGE

Vintage	Assumed R-value of insulated ceiling	Notes
Pre-war uninsulated brick	2	Same as low-rise
Prior to 1979	11	Same as low-rise
From 1979 through 2006	19	Same as low-rise
From 2007 through the present	38	Code for climate zone 4 & 5
	49	Code for climate zone 6

THERMOSTATIC HEATING SET POINT ASSUMPTIONS BY VINTAGE

Vintage	Assumed R-value of insulated ceiling	Notes
Pre-war uninsulated brick	2	Same as low-rise
Prior to 1979	11	Same as low-rise
From 1979 through 2006	19	Same as low-rise
From 2007 through the present	38	Code for climate zone 4 & 5
	49	Code for climate zone 6

Windows

The glazing U-value and solar heat gain coefficient (SHGC) assumptions for the four vintages are shown below.

WINDOW PROPERTY ASSUMPTIONS BY VINTAGE

Vintage	U-value (BTU/hr-F-SF)	SHGC	Notes
Pre-war uninsulated brick	0.93	0.87	Single pane clear
Prior to 1979	0.93	0.87	Single pane clear
From 1979 through 2006	0.68	0.77	Double pane clear
From 2007 through the present	0.28	0.49	Double low E per code

Infiltration

Infiltration rate assumptions were set by vintage as shown below.

INFILTRATION RATE ASSUMPTIONS BY VINTAGE

Vintage	Assumed infiltration rate	Notes
Pre-war uninsulated brick	1 ACH	
Prior to 1979	1 ACH	Same as low-rise
From 1979 through 2006	0.5 ACH	Same as low-rise
From 2007 through the present	0.35 ACH	Minimum without forced ventilation per ASHRAE Standard 66.

COMMERCIAL BUILDING PROTOTYPES

Analysis used to develop parameters for the energy and demand savings calculations is based on DOE-2.2 simulations of a set of prototypical small and large buildings. The prototypical simulation models were derived from the commercial building prototypes used in the California Database for Energy Efficiency Resources (DEER)[1401] study, with adjustments made for local building practices and climate.

The primary distinction between small and large buildings is the HVAC system type rather than a specific conditioned floor area criterion. Small buildings in this study utilize packaged rooftop HVAC systems or packaged terminal air conditioners (PTAC). Large buildings use built-up HVAC systems with chillers and boilers.

Note: for purposes of applying the building type specific results to buildings not included in the prototype list, use the "other" category within each applicable measure savings section.

[1401] 2004-2005 Database for Energy Efficiency Resources (DEER) Update Study, Final Report, Itron, Inc. Vancouver, WA. December 2005. Available at www.calmac.org/publications/2004-05_DEER_Update_Final_Report-Wo.pdf

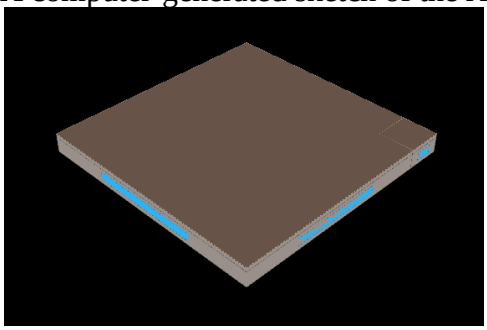
Assembly

A prototypical building energy simulation model for an assembly building was developed using the DOE-2.2 building energy simulation program. The simulations were driven using TMY3 long-term average weather data. The characteristics of the prototype are summarized below.

ASSEMBLY PROTOTYPE BUILDING DESCRIPTION

Characteristic	Value
Vintage	Existing (1970s) vintage
Size	34,000 square feet Auditorium: 33,240 SF Office: 760 SF
Number of floors	1
Wall construction and R-value	Concrete block, R-5
Roof construction and R-value	Wood frame with built-up roof, R-12
Glazing type	Single pane clear
Lighting power density	Auditorium: 3.4 W/SF Office: 2.2 W/SF
Plug load density	Auditorium: 1.2 W/SF Office: 1.7 W/SF
Operating hours	Mon-Sun: 8am – 9pm
HVAC system type	Packaged single zone, no economizer
HVAC system size	100 - 110 SF/ton depending on climate
Thermostat set points	Occupied hours: 76 cooling, 72 heating Unoccupied hours: 79 cooling, 69 heating

A computer-generated sketch of the Assembly Building prototype is shown below.



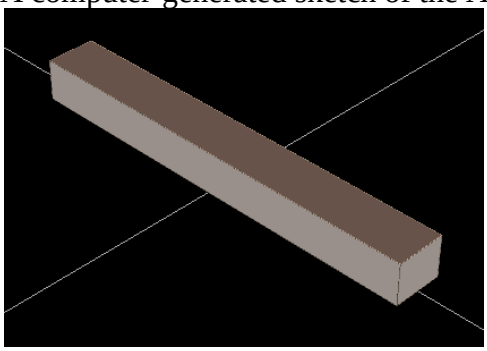
Auto Repair

A prototypical building energy simulation model for an auto repair building was developed using the DOE-2.2 building energy simulation program. The simulations were driven using TMY3 long-term average weather data. The characteristics of the prototype are summarized below.

AUTO REPAIR PROTOTYPE BUILDING DESCRIPTION

Characteristic	Value
Vintage	Existing (1970s) vintage
Size	5150 square feet
Number of floors	1
Wall construction and R-value	Concrete block, R-7.5
Roof construction and R-value	Wood frame with built-up roof, R-13,5
Glazing type	Double pane clear; SHGC = ,74 U-value = 0,72
Lighting power density	2.2 W/SF
Plug load density	1.2 W/SF
Operating hours	Mon-Sun: 9am – 9pm
HVAC system type	Packaged single zone, no economizer
HVAC system size	280 SF/ton
Thermostat set points	Occupied hours: 76 cooling, 72 heating Unoccupied hours: 81 cooling, 67 heating

A computer-generated sketch of the Auto Repair Building prototype is shown below.



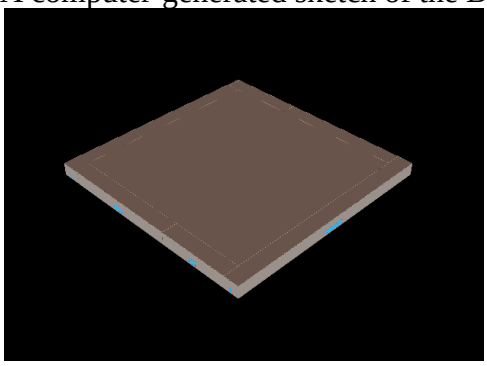
Big Box Retail

A prototypical building energy simulation model for a big box retail building was developed using the DOE-2.2 building energy simulation program. The simulations were driven using TMY3 long-term average weather data. The characteristics of the prototype are summarized below.

BIG BOX RETAIL PROTOTYPE BUILDING DESCRIPTION

Characteristic	Value
Vintage	Existing (1970s) vintage
Size	130,500 square feet Sales: 107,339 SF Storage: 11,870 SF Office: 4,683 SF Auto repair: 5,151 SF Kitchen: 1,459 SF
Number of floors	1
Wall construction and R-value	Concrete block with insulation, R-5
Roof construction and R-value	Metal frame with built-up roof, R-12
Glazing type	Single pane clear
Lighting power density	Sales: 3.36 W/SF Storage: 0.88 W/SF Office: 2.2 W/SF Auto repair: 2.15 W/SF Kitchen: 4.3 W/SF
Plug load density	Sales: 1.15 W/SF Storage: 0.23 W/SF Office: 1.73 W/SF Auto repair: 1.15 W/SF Kitchen: 3.23 W/SF
Operating hours	Mon-Sun: 10am – 9pm
HVAC system type	Packaged single zone, no economizer
HVAC system size	230 - 260 SF/ton depending on climate
Thermostat set points	Occupied hours: 76 cooling, 72 heating Unoccupied hours: 79 cooling, 69 heating

A computer-generated sketch of the Big Box Building prototype is shown below.



Community College

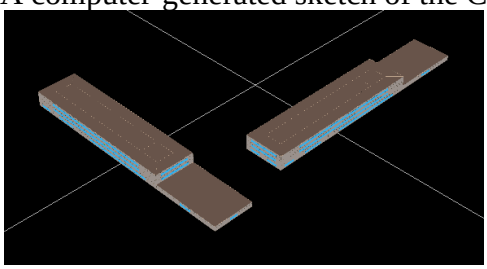
A prototypical building energy simulation model for a community college was developed using the DOE-2.2 building energy simulation program. The simulations were driven using TMY3 long-term average weather data. The model is really two identical buildings oriented 90 degrees apart. The characteristics of the prototype are summarized below.

Community College Prototype Building Description

Characteristic	Value
Vintage	Existing (1970s) vintage
Size	2 buildings, 150,000 square feet each; oriented 90° from each other Classroom: 150,825 SF Computer room: 9,625 SF Dining area: 26,250 SF Kitchen: 5,625 SF Office: 70,175 SF Total: 300,000 SF
Number of floors	3
Wall construction and R-value	CMU with brick veneer, plus R-7.5
Roof construction and R-value	Wood frame with built-up roof, R-13.5
Glazing type	Double pane clear, SHGC = 0.73; U-value = 0,72
Lighting power density	Classroom: 3.6 W/SF Computer room: 3.6 W/SF Dining area: 1.5 W/SF Gymnasium: 1.8 W/SF Kitchen: 3.6 W/SF
Plug load density	Classroom: 1.1 W/SF Computer room: 5.5 W/SF Dining area: 0.6 W/SF Gymnasium: 0.6 W/SF Kitchen: 3.3 W/SF
Operating hours	Mon-Fri: 8am – 7pm Sat: 8am – 4pm Sun: closed
HVAC system type	Combination PSZ and built-up with screw chiller and hot water boiler.
HVAC system size	250 SF/ton
Thermostat set points	Occupied hours: 76 cooling, 72 heating Unoccupied hours: 81 cooling, 67 heating
Chiller type	Water cooled and air cooled
Chilled water system type	Variable volume with 2 way control valves,
Chilled water system control	Constant CHW Temp, 45 °F set point
Boiler type	Hot water, 80% efficiency
Hot water system type	Variable volume with 2 way control valves,
Hot water system control	Constant HW Temp, 180 °F set point

Each set of measures was run using each of three different HVAC system configurations: a constant volume reheat system without economizer, a constant volume reheat system with economizer, and a VAV system with economizer. The constant volume reheat system without economizer represents a system with the most heating and cooling operating hours, while the VAV system with economizer represents a system with the least heating and cooling hours. This presents a range of system loads and energy savings for each measure analyzed.

A computer-generated sketch of the Community College Building prototype is shown below.



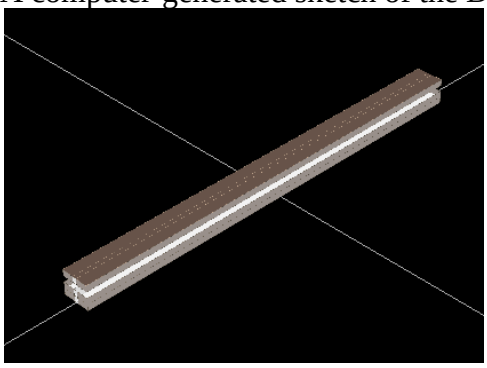
Dormitory

A prototypical building energy simulation model for a university dormitory was developed using the DOE-2.2 building energy simulation program. The dormitory building was extracted from the DEER university prototype and modeled separately. The model consists of two identical buildings oriented 90 degrees apart. The simulations were driven using TMY3 long-term average weather data. The characteristics of the prototype are summarized below.

DORMITORY PROTOTYPE BUILDING DESCRIPTION

Characteristic	Value
Vintage	Existing (1970s) vintage
Size	170,000 square feet
Number of floors	4
Wall construction and R-value	CMU with R-7.5
Roof construction and R-value	Wood frame with built-up roof, R-13.5
Glazing type	Double pane clear; SHGC = 0.73 U-value = 0.72
Lighting power density	Rooms: 0.5 W/SF Corridors and common space: 0.8
Plug load density	Rooms: 0.6 W/SF Corridors and common space: 0.2
Operating hours	24/7 - 365
HVAC system type	Fan coils with centrifugal chiller and hot water boiler
HVAC system size	800 SF/ton
Thermostat set points	Daytime hours: 76 cooling, 72 heating Night setback hours: 81 cooling, 67 heating

A computer-generated sketch of the Dormitory Building prototype is shown below.



Note: The middle floors, since they thermally equivalent, are simulated as a single floor, and the results are multiplied by 2 to represent the energy consumption of the 2 middle floors.

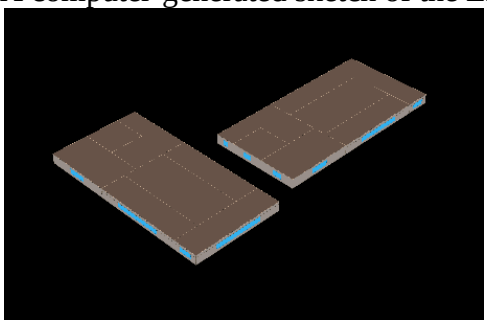
Elementary School

A prototypical building energy simulation model for an elementary school was developed using the DOE-2.2 building energy simulation program. The simulations were driven using TMY3 long-term average weather data. The model is really of two identical buildings oriented in two different directions. The characteristics of the prototype are summarized below.

ELEMENTARY SCHOOL PROTOTYPE BUILDING DESCRIPTION

Characteristic	Value
Vintage	Existing (1970s) vintage
Size	2 buildings, 25,000 square feet each; oriented 90° from each other Classroom: 15,750 SF Cafeteria: 3,750 SF Gymnasium: 3,750 SF Kitchen: 1,750 SF
Number of floors	1
Wall construction and R-value	Wood frame with brick veneer, R-5
Roof construction and R-value	Wood frame with built-up roof, R-12
Glazing type	Single pane clear
Lighting power density	Classroom: 4.4 W/SF Cafeteria: 1.7 W/SF Gymnasium: 2.1 W/SF Kitchen: 4.3 W/SF
Plug load density	Classroom: 1.2 W/SF Cafeteria: 0.6 W/SF Gymnasium: 0.6 W/SF Kitchen: 4.2 W/SF
Operating hours	Mon-Fri: 8am – 6pm Sun: 8am – 4pm
HVAC system type	Packaged single zone, no economizer
HVAC system size	160 - 180 SF/ton depending on climate
Thermostat set points	Occupied hours: 76 cooling, 72 heating Unoccupied hours: 79 cooling, 69 heating

A computer-generated sketch of the Elementary School Building prototype is shown below.



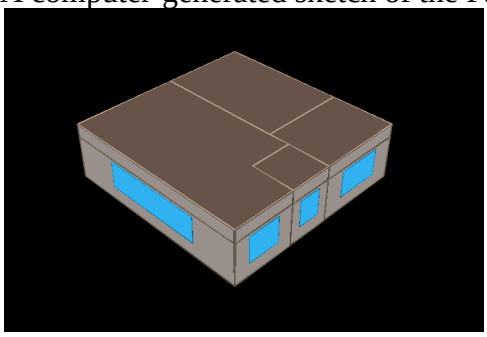
Fast Food Restaurant

A prototypical building energy simulation model for a fast food restaurant was developed using the DOE-2.2 building energy simulation program. The simulations were driven using TMY3 long-term average weather data. The characteristics of the prototype are summarized below.

FAST FOOD RESTAURANT PROTOTYPE BUILDING DESCRIPTION

Characteristic	Value
Vintage	Existing (1970s) vintage
Size	2000 square feet 1,000 SF dining 600 SF entry/lobby 300 SF kitchen 100 SF restroom
Number of floors	1
Wall construction and R-value	Concrete block with brick veneer, R-5
Roof construction and R-value	Concrete deck with built-up roof, R-12
Glazing type	Single pane clear
Lighting power density	1.7 W/SF dining 2.5 W/SF entry/lobby 4.3 W/SF kitchen 1.0 W/SF restroom
Plug load density	0.6 W/SF dining 0.6 W/SF entry/lobby 4.3 W/SF kitchen 0.2 W/SF restroom
Operating hours	Mon-Sun: 6am – 11pm
HVAC system type	Packaged single zone, no economizer
HVAC system size	100 – 120 SF/ton depending on climate
Thermostat set points	Occupied hours: 77 cooling, 72 heating Unoccupied hours: 80 cooling, 69 heating

A computer-generated sketch of the Fast Food Building prototype is shown below.



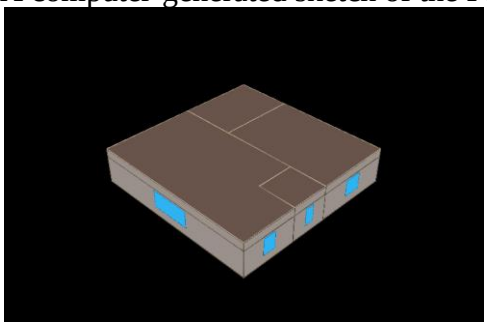
Full-Service Restaurant

A prototypical building energy simulation model for a full-service restaurant was developed using the DOE-2.2 building energy simulation program. The simulations were driven using TMY3 long-term average weather data. The characteristics of the full service restaurant prototype are summarized below.

FULL SERVICE RESTAURANT PROTOTYPE DESCRIPTION

Characteristic	Value
Vintage	Existing (1970s) vintage
Size	2000 square foot dining area 600 square foot entry/reception area 1200 square foot kitchen 200 square foot restrooms
Number of floors	1
Wall construction and R-value	Concrete block with brick veneer, R-5
Roof construction and R-value	Wood frame with built-up roof, R-12
Glazing type	Single pane clear
Lighting power density	Dining area: 1.7 W/SF Entry area: 2.5 W/SF Kitchen: 4.3 W/SF Restrooms: 1.0 W/SF
Plug load density	Dining area: 0.6 W/SF Entry area: 0.6 W/SF Kitchen: 3.1 W/SF Restrooms: 0.2 W/SF
Operating hours	9am – 12am
HVAC system type	Packaged single zone, no economizer
HVAC system size	140 – 160 SF/ton depending on climate
Thermostat set points	Occupied hours: 77 cooling, 72 heating Unoccupied hours: 80 cooling, 69 heating

A computer-generated sketch of the Full-Service Restaurant Building prototype is shown below.



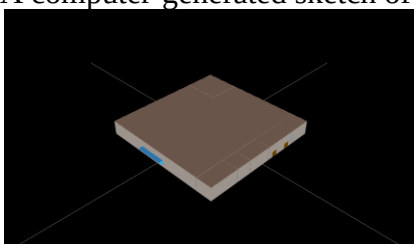
Grocery

A prototypical building energy simulation model for a grocery building was developed using the DOE-2.2R[1402] building energy simulation program. The simulations were driven using TMY3 long-term average weather data. The characteristics of the prototype are summarized below.

GROCERY PROTOTYPE BUILDING DESCRIPTION

Characteristic	Value
Vintage	Existing (1970s) vintage
Size	50,000 square feet Sales: 40,000 SF Office and employee lounge: 3,500 SF Dry storage: 2,860 SF 50 °F prep area: 1,268 SF 35 °F walk-in cooler: 1,560 SF - 5 °F walk-in freezer: 812 SF
Number of floors	1
Wall construction and R-value	Concrete block with insulation, R-5
Roof construction and R-value	Metal frame with built-up roof, R-12
Glazing type	Single pane clear
Lighting power density	Sales: 3.36 W/SF Office: 2.2 W/SF Storage: 1.82 W/SF 50°F prep area: 4.3 W/SF 35°F walk-in cooler: 0.9 W/SF - 5°F walk-in freezer: 0.9 W/SF
Equipment power density	Sales: 1.15 W/SF Office: 1.73 W/SF Storage: 0.23 W/SF 50°F prep area: 0.23 W/SF + 36 kBTU/h process load 35°F walk-in cooler: 0.23 W/SF + 17 kBTU/h process load - 5°F walk-in freezer: 0.23 W/SF+ 29 kBTU/h process load
Operating hours	Mon-Sun: 6am – 10pm
HVAC system type	Packaged single zone, no economizer
Refrigeration system type	Air cooled multiplex
Refrigeration system size	Low temperature (-20°F suction temp): 23 compressor ton Medium temperature (18°F suction temp): 45 compressor ton
Refrigeration condenser size	Low temperature: 535 kBTU/h THR Medium temperature: 756 kBTU/h THR
Thermostat set points	Occupied hours: 74°F cooling, 70°F heating Unoccupied hours: 79°F cooling, 65°F heating

A computer-generated sketch of the Grocery Building prototype is shown below.



[1402] DOE-2.2R is a specialized version of the DOE-2.2 program, designed specifically to model refrigeration systems.

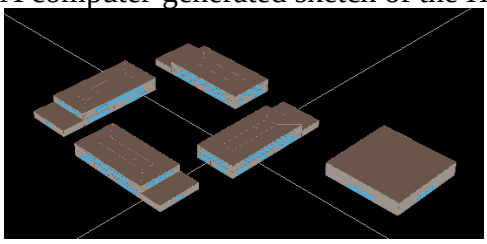
High School

A prototypical building energy simulation model for a high school was developed using the DOE-2.2 building energy simulation program. The simulations were driven using TMY3 long-term average weather data. The model is really of four identical buildings oriented in four different directions, with a common gymnasium. The characteristics of the prototype are summarized below.

HIGH SCHOOL PROTOTYPE BUILDING DESCRIPTION

Characteristic	Value
Vintage	Existing (1970s) vintage
Size	4 buildings, 25,000 square feet each; oriented 90° from each other Classroom: 88,200 SF Computer room: 3082 SF Dining area: 22,500 SF Gymnasium: 22.500 SF Kitchen: 10,500 SF Office: 3218 SF Total: 150,000 SF
Number of floors	2
Wall construction and R-value	CMU with brick veneer, plus R-7.5
Roof construction and R-value	Wood frame with built-up roof, R-13.5
Glazing type	Double pane clear, SHGC = 0.73; U-value = 0,72
Lighting power density	Classroom: 3.6 W/SF Computer room: 3.6 W/SF Dining area: 1.5 W/SF Gymnasium: 1.8 W/SF Kitchen: 3.6 W/SF
Plug load density	Classroom: 1.1 W/SF Computer room: 5.5 W/SF Dining area: 0.6 W/SF Gymnasium: 0.6 W/SF Kitchen: 3.3 W/SF
Operating hours	Mon-Fri: 8am – 7pm Sat: 8am – 4pm Sun: closed
HVAC system type	Combination PSZ and built-up with screw chiller and hot water boiler.
HVAC system size	250 SF/ton
Thermostat set points	Occupied hours: 76 cooling, 72 heating Unoccupied hours: 81 cooling, 67 heating

A computer-generated sketch of the High School Building prototype is shown below.



Hospital

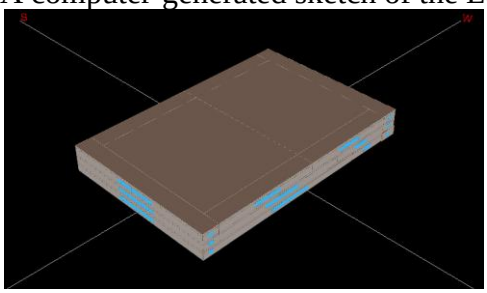
A prototypical building energy simulation model for a large hospital building was developed using the DOE-2.2 building energy simulation program. The simulations were driven using TMY3 long-term average weather data. The characteristics of the prototype are summarized below.

LARGE HOSPITAL PROTOTYPE BUILDING DESCRIPTION

Characteristic	Value
Vintage	Existing (1970s) vintage
Size	250,000 square feet
Number of floors	3
Wall construction and R-value	Brick and CMU, R=7.5
Roof construction and R-value	Built-up roof, R-13.5
Glazing type	Multi-pane; Shading-coefficient = 0.84 U-value = 0.72
Lighting power density	Patient rooms: 2.3 W/SF Office: 2.2 W/SF Lab: 4.4 Dining: 1.7 Kitchen and food prep: 4.3
Plug load density	Patient rooms: 1.7 W/SF Office: 1.7 W/SF Lab: 1.7 Dining: 0.6 Kitchen and food prep: 4.6
Operating hours	24/7, 365
HVAC system types	Patient Rooms: 4 pipe fan coil Kitchen: Rooftop DX Remaining space; 1. Central constant volume system with hydronic reheat, without economizer; 2. Central constant volume system with hydronic reheat, with economizer; 3. Central VAV system with hydronic reheat, with economizer
HVAC system size	Based on ASHRAE design day conditions, 10% over-sizing assumed.
Chiller type	Water cooled and air cooled
Chilled water system type	Constant volume with 3 way control valves,
Chilled water system control	Constant CHW Temp, 45 ^{o}F set point
Boiler type	Hot water, 80% efficiency
Hot water system type	Constant volume with 3 way control valves,
Hot water system control	Constant HW Temp, 180 ^{o}F set point
Thermostat set points	Occupied hours: 76 cooling, 72 heating Unoccupied hours: 79 cooling, 69 heating

Each set of measures was run using each of three different HVAC system configurations: a constant volume reheat system without economizer, a constant volume reheat system with economizer, and a VAV system with economizer. The constant volume reheat system without economizer represents a system with the most heating and cooling operating hours, while the VAV system with economizer represents a system with the least heating and cooling hours. This presents a range of system loads and energy savings for each measure analyzed.

A computer-generated sketch of the Large Hospital Building prototype is shown below.



Hotel

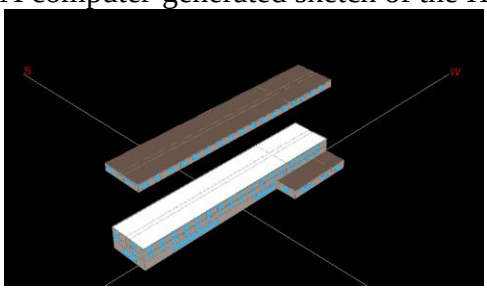
A prototypical building energy simulation model for a hotel building was developed using the DOE-2.2 building energy simulation program. The characteristics of the prototype are summarized below.

HOTEL PROTOTYPE BUILDING DESCRIPTION

Characteristic	Value
Vintage	Existing (1970s) vintage
Size	200,000 square feet total Bar, cocktail lounge – 800 SF Corridor – 20,100 SF Dining Area – 1,250 SF Guest rooms – 160,680 SF Kitchen – 750 SF Laundry – 4,100 SF Lobby – 8,220 Office – 4,100 SF
Number of floors	11
Wall construction and R-value	Block construction, R-7.5
Roof construction and R-value	Wood deck with built-up roof, R-13.5
Glazing type	Multi-pane; Shading-coefficient = 0.84 U-value = 0.72
Lighting power density	Bar, cocktail lounge – 1.7 W/SF Corridor – 1.0 W/SF Dining Area – 1.7 W/SF Guest rooms – 0.6 W/SF Kitchen – 4.3 W/SF Laundry – 1.8 W/SF Lobby – 3.1 W/SF Office – 2.2 W/SF
Plug load density	Bar, cocktail lounge – 1.2 W/SF Corridor – 0.2 W/SF Dining Area – 0.6 W/SF Guest rooms – 0.6 W/SF Kitchen – 3.0 W/SF Laundry – 3.5 W/SF Lobby – 0.6 W/SF Office – 1.7 W/SF
Operating hours	Rooms: 60% occupied 40% unoccupied All others: 24 hr / day
HVAC system type	Central built-up system: All except corridors and rooms 1. Central constant volume system with perimeter hydronic reheat, without economizer; 2. Central constant volume system with perimeter hydronic reheat, with economizer; 3. Central VAV system with perimeter hydronic reheat, with economizer PTAC (Packaged Terminal Air Conditioner): Guest rooms PSZ: Corridors

Characteristic	Value
HVAC system size	Based on ASHRAE design day conditions, 10% over-sizing assumed.
Minimum outdoor air fraction	Built up system 0.3; PSZ: 0.14; PTAC: 0.11 is typical.
Chiller type	Water cooled and air cooled
Chilled water system type	Constant volume with 3 way control valves,
Chilled water system control	Constant CHW Temp, 45 ^{o}F set point
Boiler type	Hot water, 80% efficiency
Hot water system type	Constant volume with 3 way control valves,
Hot water system control	Constant HW Temp, 180 ^{o}F set point
Thermostat set points	Occupied hours: 76 cooling, 72 heating Unoccupied hours: 81 cooling, 67 heating

A computer-generated sketch of the Hotel Building prototype is shown below.



Large Office

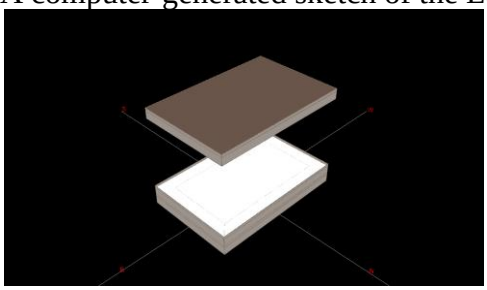
A prototypical building energy simulation model for a large office building was developed using the DOE-2.2 building energy simulation program. The simulations were driven using TMY3 long-term average weather data. The characteristics of the prototype are summarized below.

LARGE OFFICE PROTOTYPE BUILDING DESCRIPTION

Characteristic	Value
Vintage	Existing (1970s) vintage
Size	350,000 square feet
Number of floors	10
Wall construction and R-value	Glass curtain wall, R-7.5
Roof construction and R-value	Built-up roof, R-13.5
Glazing type	Multi-pane; Shading-coefficient = 0.84 U-value = 0.72
Lighting power density	Perimeter offices: 1.55 W/SF Core offices: 1.45 W/SF
Plug load density	Perimeter offices: 1.6 W/SF Core offices: 0.7 W/SF
Operating hours	Mon-Sat: 9am – 6pm Sun: Unoccupied
HVAC system types	1. Central constant volume system with hydronic reheat, without economizer; 2. Central constant volume system with hydronic reheat, with economizer; 3. Central VAV system with hydronic reheat, with economizer
HVAC system size	Based on ASHRAE design day conditions, 10% over-sizing assumed.
Chiller type	Water cooled and air cooled
Chilled water system type	Constant volume with 3 way control valves,
Chilled water system control	Constant CHW Temp, 45 ^{o}F set point
Boiler type	Hot water, 80% efficiency
Hot water system type	Constant volume with 3 way control valves,
Hot water system control	Constant HW Temp, 180 ^{o}F set point
Thermostat set points	Occupied hours: 75 cooling, 70 heating Unoccupied hours: 78 cooling, 67 heating

Each set of measures was run using each of three different HVAC system configurations: a constant volume reheat system without economizer, a constant volume reheat system with economizer, and a VAV system with economizer. The constant volume reheat system without economizer represents a system with the most heating and cooling operating hours, while the VAV system with economizer represents a system with the least heating and cooling hours. This presents a range of system loads and energy savings for each measure analyzed.

A computer-generated sketch of the Large Office Building prototype is shown below.



Note: The middle floors, since they thermally equivalent, are simulated as a single floor, and the results are multiplied by 8 to represent the energy consumption of the eight middle floors.

Large Retail

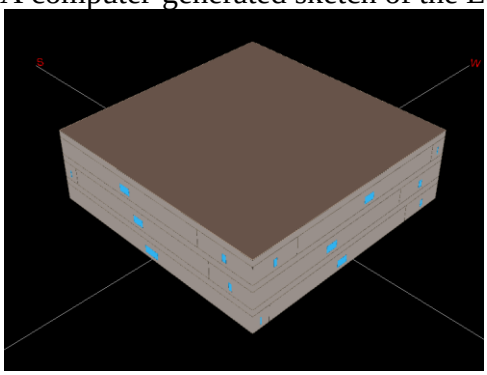
A prototypical building energy simulation model for a large retail building was developed using the DOE-2.2 building energy simulation program. The simulations were driven using TMY3 long-term average weather data. The characteristics of the prototype are summarized below.

LARGE RETAIL PROTOTYPE BUILDING DESCRIPTION

Characteristic	Value
Vintage	**Existing (1970s) vintage**
Size	130,000 square feet Sales area: 96,000 SF Storage: 18,000 SF Office: 6,000 SF
Number of floors	3
Wall construction and R-value	Brick and CMU with R-7.5
Roof construction and R-value	Built-up roof, R-13.5
Glazing type	Multi-pane; SHGC= 0.73 U-value = 0.72
Lighting power density	Sales area: 2.8 W/SF Storage: 0.8 W/SF Office: 1.8 W/SF
Plug load density	Sales area: 1.1 W/SF Storage: 0.2 W/SF Office: 1.7 W/SF
Operating hours	Mon-Sat: 9am – 10pm Sun: 9am – 7pm
HVAC system types	1. Central constant volume system with hydronic reheat, without economizer; 2. Central constant volume system with hydronic reheat, with economizer; 3. Central VAV system with hydronic reheat, with economizer
HVAC system size	340 SF/ton
Chiller type	Water cooled and air cooled
Chilled water system type	Variable volume with 2 way control valves,
Chilled water system control	Constant CHW Temp, 45 ^{o}F set point
Boiler type	Hot water, 80% efficiency
Hot water system type	Variable volume with 2 way control valves,
Hot water system control	Constant HW Temp, 180 ^{o}F set point
Thermostat set points	Occupied hours: 76 cooling, 72 heating Unoccupied hours: 81 cooling, 67 heating

Each set of measures was run using each of three different HVAC system configurations: a constant volume reheat system without economizer, a constant volume reheat system with economizer, and a VAV system with economizer. The constant volume reheat system without economizer represents a system with the most heating and cooling operating hours, while the VAV system with economizer represents a system with the least heating and cooling hours. This presents a range of system loads and energy savings for each measure analyzed.

A computer-generated sketch of the Large Retail Building prototype is shown below.



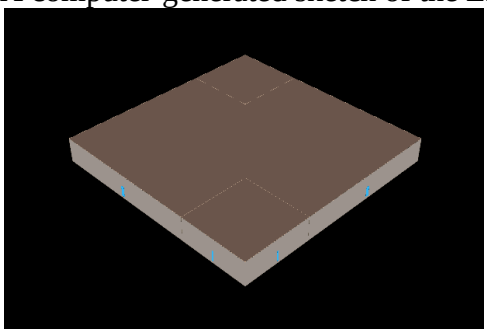
Light Industrial

A prototypical building energy simulation model for a light industrial building was developed using the DOE-2.2 building energy simulation program. The simulations were driven using TMY3 long-term average weather data. The characteristics of the prototype are summarized below.

LIGHT INDUSTRIAL PROTOTYPE BUILDING DESCRIPTION

Characteristic	Value
Vintage	Existing (1970s) vintage
Size	100,000 square feet total 80,000 SF factory 20,000 SF warehouse
Number of floors	1
Wall construction and R-value	Concrete block with insulation, R-5
Roof construction and R-value	Concrete deck with built-up roof, R-12
Glazing type	Single pane clear
Lighting power density	Factory – 2.1 W/SF Warehouse – 0.9 W/SF
Plug load density	Factory – 1.2 W/SF Warehouse – 0.2 W/SF
Operating hours	Mon-Fri: 6am – 6pm Sat Sun: Unoccupied
HVAC system type	Packaged single zone, no economizer
HVAC system size	500 - 560 SF/ton depending on climate
Thermostat set points	Occupied hours: 78 cooling, 70 heating Unoccupied hours: 81 cooling, 67 heating

A computer-generated sketch of the Light Industrial Building prototype is shown below.



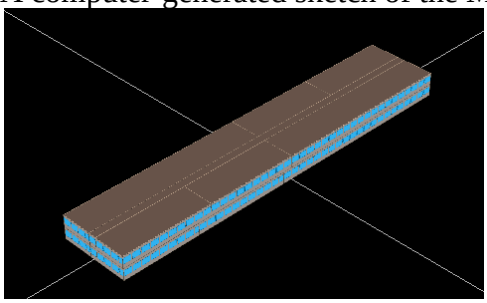
Motel

A prototypical building energy simulation model for a motel was developed using the DOE-2.2 building energy simulation program. The simulations were driven using TMY3 long-term average weather data. The characteristics of the prototype are summarized below.

MOTEL PROTOTYPE BUILDING DESCRIPTION

Characteristic	Value
Vintage	Existing (1970s) vintage
Size	30,000 square feet
Number of floors	2
Wall construction and R-value	Frame with R-5
Roof construction and R-value	Wood frame with built-up roof, R-12
Glazing type	Single pane clear; SHGC = .87 U-value = 1.2
Lighting power density	0.6 W/SF
Plug load density	0.6 W/SF
Operating hours	24/7 - 365
HVAC system type	PTAC with electric heat
HVAC system size	540 SF/ton
Thermostat set points	Daytime hours: 76 cooling, 72 heating Night setback hours: 81 cooling, 67 heating

A computer-generated sketch of the Motel Building prototype is shown below.



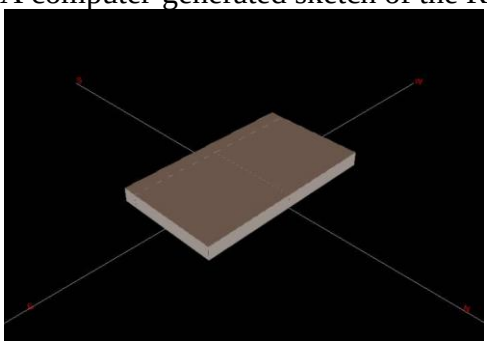
Refrigerated Warehouse

A prototypical building energy simulation model for a refrigerated warehouse building was developed using the DOE-2.2R[1403] building energy simulation program. The simulations were driven using TMY3 long-term average weather data. The characteristics of the prototype are summarized below.

PROTOTYPICAL REFRIGERATED WAREHOUSE MODEL DESCRIPTION

Characteristic	Value
Vintage	New construction
Shape	Rectangular (400 ft by 230 ft)
Floor area	Freezer: 40,000 SF Cooler: 40,000 SF Shipping Dock: 12,000 SF Total: 92,000 SF
Number of floors	1
Floor to ceiling height	30 ft
Exterior wall construction	Insulated metal panel
Ext wall R-Value	Cooler and loading dock – R-20; Freezer – R-26

A computer-generated sketch of the Refrigerated Warehouse Building prototype is shown below.



[1403] DOE-2.2R is a specialized version of the DOE-2.2 program, designed specifically to model refrigeration systems.

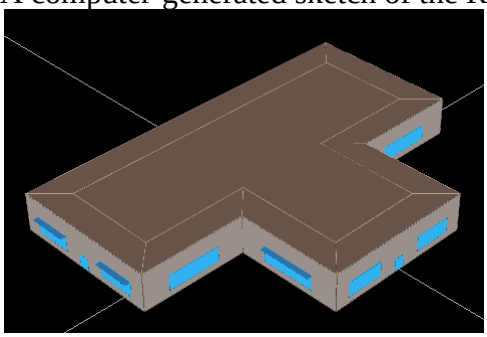
Religious

A prototypical building energy simulation model for a religious worship building was developed using the DOE-2.2 building energy simulation program. The simulations were driven using TMY3 long-term average weather data. The characteristics of the prototype are summarized below.

RELIGIOUS WORSHIP PROTOTYPE BUILDING DESCRIPTION

Characteristic	Value
Vintage	Existing (1970s) vintage
Size	11,000 square feet
Number of floors	1
Wall construction and R-value	Brick with R-5
Roof construction and R-value	Wood frame with built-up roof, R-12
Glazing type	Single pane clear; SHGC = .87 U-value = 1.2
Lighting power density	1.7 W/SF
Plug load density	1.2 W/SF
Operating hours	Mon-Sat: 12pm-6pm Sun: 9am – 7pm
HVAC system type	Packaged single zone, no economizer
HVAC system size	250 SF/ton
Thermostat set points	Occupied hours: 76 cooling, 70 heating Unoccupied hours: 82 cooling, 64 heating

A computer-generated sketch of the Religious Building prototype is shown below.



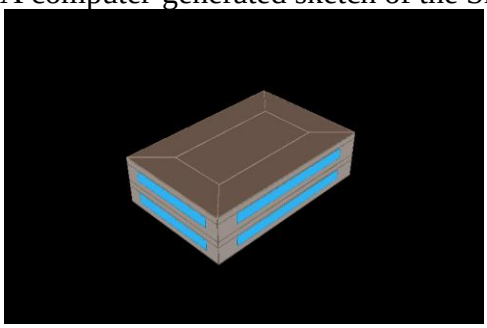
Small Office

A prototypical building energy simulation model for a small office was developed using the DOE-2.2 building energy simulation program. The simulations were driven using TMY3 long-term average weather data. The characteristics of the small office prototype are summarized below.

SMALL OFFICE PROTOTYPE BUILDING DESCRIPTION

Characteristic	Value
Vintage	**Existing (1970s) vintage**
Size	10,000 square feet
Number of floors	2
Wall construction and R-value	Wood frame with brick veneer, R-5
Roof construction and R-value	Wood frame with built-up roof, R-12
Glazing type	Single pane clear
Lighting power density	Perimeter offices: 2.2 W/SF Core offices: 1.5 W/SF
Plug load density	Perimeter offices: 1.6 W/SF Core offices: 0.7 W/SF
Operating hours	Mon-Sat: 9am – 6pm Sun: Unoccupied
HVAC system type	Packaged single zone, no economizer
HVAC system size	230 - 245 SF/ton depending on climate
Thermostat set points	Occupied hours: 76 cooling, 72 heating Unoccupied hours: 79 cooling, 69 heating

A computer-generated sketch of the Small Office Building prototype is shown below.



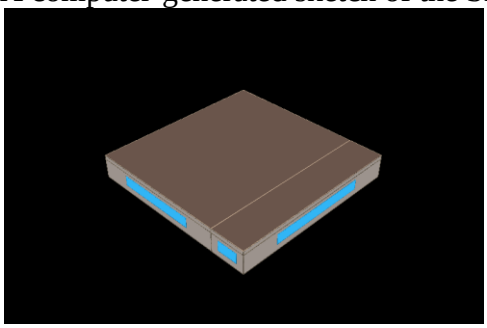
Small Retail

A prototypical building energy simulation model for a small retail building was developed using the DOE-2.2 building energy simulation program. The simulations were driven using TMY3 long-term average weather data. The characteristics of the small retail building prototype are summarized below.

SMALL RETAIL PROTOTYPE DESCRIPTION

Characteristic	Value
Vintage	Existing (1970s) vintage
Size	6400 square foot sales area 1600 square foot storage area 8000 square feet total
Number of floors	1
Wall construction and R-value	Concrete block with brick veneer, R-5
Roof construction and R-value	Wood frame with built-up roof, R-12
Glazing type	Single pane clear
Lighting power density	Sales area: 3.4 W/SF Storage area: 0.9 W/SF
Plug load density	Sales area: 1.2 W/SF Storage area: 0.2 W/SF
Operating hours	10 – 10 Monday-Saturday 10 – 8 Sunday
HVAC system type	Packaged single zone, no economizer
HVAC system size	230 – 250 SF/ton depending on climate
Thermostat set points	Occupied hours: 76 cooling, 72 heating Unoccupied hours: 79 cooling, 69 heating

A computer-generated sketch of the Small Retail Building prototype is shown below.



University

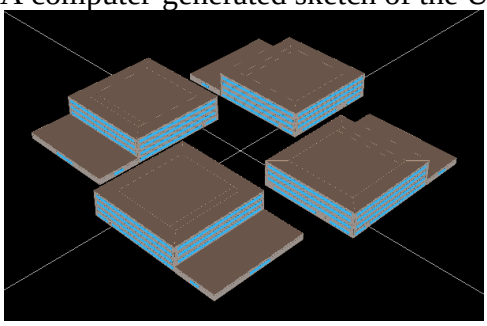
A prototypical building energy simulation model for a university building was developed using the DOE-2.2 building energy simulation program. The simulations were driven using TMY3 long-term average weather data. The model is really four identical buildings oriented 90 degrees apart. The characteristics of the prototype are summarized below.

UNIVERSITY PROTOTYPE BUILDING DESCRIPTION

Characteristic	Value
Vintage	Existing (1970s) vintage
Size	4 buildings, 200,000 square feet each; oriented 90° from each other Classroom: 431,160 SF Computer room: 27,540 SF Dining area: 24,000 SF Kitchen: 10,500 SF Office: 226,800 SF Total: 800,000 SF
Number of floors	4
Wall construction and R-value	Insulated frame wall with R-7.5
Roof construction and R-value	Wood frame with built-up roof, R-13.5
Glazing type	Double pane clear, SHGC = 0.73; U-value = 0,72
Lighting power density	Classroom: 3.6 W/SF Computer room: 3.6 W/SF Dining area: 1.5 W/SF Office: 2.0 W/SF Kitchen: 3.6 W/SF
Plug load density	Classroom: 1.1 W/SF Computer room: 5.5 W/SF Dining area: 0.6 W/SF Office: 1.6 W/SF Kitchen: 3.3 W/SF
Operating hours	Mon-Fri: 8am – 10pm Sat: 8am – 7pm Sun: closed
HVAC system type	Combination PSZ and built-up with centrifugal chiller and hot water boiler.
HVAC system size	400 SF/ton
Thermostat set points	Occupied hours: 76 cooling, 72 heating Unoccupied hours: 81 cooling, 67 heating
Chiller type	Water cooled and air cooled
Chilled water system type	Variable volume with 2 way control valves,
Chilled water system control	Constant CHW Temp, 45 ^{o}F set point
Boiler type	Hot water, 80% efficiency
Hot water system type	Variable volume with 2 way control valves,
Hot water system control	Constant HW Temp, 180 ^{o}F set point

Each set of measures was run using each of three different HVAC system configurations: a constant volume reheat system without economizer, a constant volume reheat system with economizer, and a VAV system with economizer. The constant volume reheat system without economizer represents a system with the most heating and cooling operating hours, while the VAV system with economizer represents a system with the least heating and cooling hours. This presents a range of system loads and energy savings for each measure analyzed.

A computer-generated sketch of the University Building prototype is shown below.



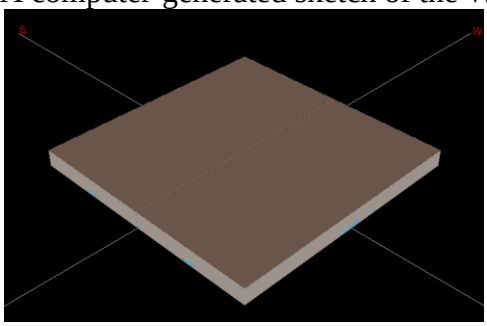
Warehouse

A prototypical building energy simulation model for a warehouse building was developed using the DOE-2.2 building energy simulation program. The characteristics of the prototype are summarized below.

WAREHOUSE PROTOTYPE BUILDING DESCRIPTION

Characteristic	Value
Vintage	Existing (1970s) vintage
Size	500,000
Number of floors	1
Wall construction and insulation R-value	Concrete block, R-5
Roof construction and insulation R-value	Wood deck with built-up roof, R-12
Glazing type	Multi-pane; Shading-coefficient = 0.84 U-value = 0.72
Lighting power density	0.9 W/SF
Plug load density	0.2 W/SF
Operating hours	Mon-Fri: 7am – 6pm Sat Sun: Unoccupied
HVAC system type	Packaged single zone, no economizer
HVAC system size	Based on ASHRAE design day conditions, 10% over-sizing assumed.
Thermostat set points	Occupied hours: 80 cooling, 68 heating Unoccupied hours: 85 cooling, 63 heating

A computer-generated sketch of the Warehouse Building prototype is shown below.



Record of Revision

Record of Revision Number	Issue Date
0	10/15/2010
7-13-1	7/31/2013
7-13-18	7/31/2013
7-13-19	7/31/2013
7-13-21	7/31/2013
3-14-1	3/17/2014

APPENDIX B

HVAC WEIGHTING FACTORS

As described in the data sources and default value tables, it is permissible to use weighted average values across HVAC system types and building vintages when measure specific data are not available. Program administrators shall submit weighting factors used in their calculations for review and approval by the DPS. The weighting factors presented in this section may be used in lieu of program-specific weighting factors until such data are available.

Weighting factors developed for this section were taken from survey data compiled by the US Energy Information Agency (EIA), as part of the 2005 Residential Energy Consumption Survey (RECS) and the 2003 Commercial Building Energy Consumption Survey (CBECS). RECS survey data were collected specifically for New York state; CBECS data were collected for census division 2 (Middle Atlantic), which includes New York, New Jersey, and Pennsylvania.

SINGLE-FAMILY RESIDENTIAL BUILDING CALCULATIONS

The fractions of total building floor space for the Old and Average vintages are shown below. These data are compiled for building total (conditioned and unconditioned), heated and cooled floor space.

Vintage Weights for Single-family Detached Residential Buildings

	Total	Heated	Cooled
Old	0.441	0.420	0.358
Average	0.559	0.580	0.642

For example, approximately 64% of the cooled floor space is in buildings within the Average vintage, while 36% of the cooled floor space is in the Old vintage. Note, the RECS data did not provide information for new construction. Weighting calculations involving cooling savings should use the cooled floor space weights, while weighting calculations involving heating savings should use the heated floor space weights. Within each building vintage category, the weights by HVAC system type are shown below.

System Type Weights by Vintage for Single-family Detached Residential Buildings

System Type	Old	Average
AC with fuel heat	0.474	0.616
Heat Pump	0.000	0.049
AC with electric heat	0.002	0.013
Electric heat only	0.004	0.017
Fuel heat only	0.519	0.306
Room AC	0.629	0.371

MULTI-FAMILY RESIDENTIAL BUILDING CALCULATIONS

The fractions of total multi-family low-rise building floor space for the Old and Average vintage are shown below. These data are compiled for building total (conditioned and unconditioned), heated and cooled floor space. Low-rise buildings were identified as buildings with 2-4 units; or 1 or 2 story buildings with 5 or more units.

Vintage Weights for Low-rise Multi-family Residential Buildings

	Total	Heated	Cooled
Old	0.097	0.089	0.134
Average	0.903	0.911	0.866

The fractions of total multi-family high-rise building floor space for the Old and Average vintage are shown below. These data are compiled for building total (conditioned and unconditioned), heated and cooled floor space. High-rise buildings were identified as buildings with 3 or more stories.

Vintage Weights for High-rise Multi-family Residential Buildings

	Total	Heated	Cooled
Old	0.827	0.828	0.712
Average	0.173	0.172	0.288

Note, the RECS data did not provide information for new construction. Weighting calculations involving cooling savings should use the cooled floor space weights, while weighting calculations involving heating savings should use the heated floor space weights. For low-rise building calculations, weights by HVAC system type have been compiled. Within each building vintage category, the weights by HVAC system type are shown below.

HVAC System Type	Old	Average
AC with fuel heat	0.542	0.350
Heat Pump	0.000	0.000
AC with electric heat	0.000	0.000
Electric heat only	0.006	0.012
Fuel heat only	0.450	0.627
PTAC	0.003	0.012
PTHP	0.000	0.000

Note: The TRM assumes a single HVAC system type for high-rise buildings, thus weighting across HVAC system types is not required.

COMMERCIAL BUILDING CALCULATIONS

Weighting Factors for Commercial Building Calculations

The TRM currently lists energy savings estimates for small commercial buildings for a single vintage and HVAC system type, with the exception of HVAC interactive effects multipliers. Use the weights in the table below for HVAC interactive effects:

System Type Weights for Built-Up HVAC Systems from CBECS

Building Type	AC with fuel heat	Heat Pump	AC with electric heat	Electric heat only	Fuel heat only
Assembly	0.63	0.08	0.12	0.03	0.14
Auto Repair	0.54	0.08	0.10	0.04	0.24
Big Box	0.66	0.07	0.18	0.02	0.07
Elementary School	0.68	0.11	0.11	0.01	0.08
Fast Food	0.67	0.09	0.18	0.01	0.06
Full Service	0.67	0.09	0.18	0.01	0.06
Grocery	0.66	0.07	0.18	0.02	0.07
Light Industrial	0.46	0.06	0.00	0.10	0.37
Motel	0.46	0.23	0.26	0.02	0.03
Religious	0.57	0.11	0.13	0.03	0.15
Small Office	0.69	0.10	0.19	0.00	0.02
Small Retail	0.66	0.07	0.18	0.02	0.07
Warehouse	0.46	0.06	0.00	0.10	0.37
Other	0.60	0.10	0.14	0.03	0.13

(Note: Some types do not add up to exactly 1.00 due to rounding.)

Savings estimates for large commercial buildings are developed for several HVAC system and chiller type combinations. The CBECS data were analyzed to develop system type weights for these building types. The weighting factors for each of the two HVAC system types constant volume reheat (CV) and variable air volume (VAV) are shown below.

System Type Weights for Built-Up HVAC Systems from CBECS

System Type	Building					
	Hospital	Office	Education	Lodging	Retail	Other
CV	0.16	0.14	0.31	1.00	0.16	0.35
VAV	0.84	0.86	0.69	0.00	0.84	0.65

Record of Revision

Record of Revision Number	Issue Date
0	10/15/2010
7-13-22	7/31/2013
9-13-3	9/27/2013

APPENDIX C

As a cross reference, the Effective Useful life (in hours) used for some lighting products, including LEDs, may be found in Appendix P which relies upon estimates established by the Design Lights Consortium and ENERGY STAR®.[1404]

Standard Fixture Watts [1405]

Fixture Code	Lamp Code	Description	Ballast	Lamp/Fixture	Watt / Lamp	Watt / Fixture
COMPACT FLUORESCENT FIXTURES						
(Hard-wired or Pin-based only)						
CF10/2D	CFD10W	Compact Fluorescent, 2D, (1) 10W lamp	Mag-STD	1	10	16
CF10/2D-L	CFD10W	Compact Fluorescent, 2D, (1) 10W lamp	Electronic	1	10	12
CF11/1	CF11W	Compact Fluorescent, (1) 11W lamp	Mag-STD	1	11	13
CF11/2	CF11W	Compact Fluorescent, (2) 11W lamp	Mag-STD	2	11	26
CF16/2D	CFD16W	Compact Fluorescent, 2D, (1) 16W lamp	Mag-STD	1	16	26
CF16/2D-L	CFD16W	Compact Fluorescent, 2D, (1) 16W lamp	Electronic	1	16	18
CF18/3-L	CF18W	Compact Fluorescent, (3) 18W lamp	Electronic	3	18	60
CF21/2D	CFD21W	Compact Fluorescent, 2D, (1) 21W lamp	Mag-STD	1	21	26
CF21/2D-L	CFD21W	Compact Fluorescent, 2D, (1) 21W lamp	Electronic	1	21	22
CF23/1	CF23W	Compact Fluorescent, (1) 23W lamp	Mag-STD	1	23	29
CF23/1-L	CF23W	Compact Fluorescent, (1) 23W lamp	Electronic	1	23	25
CF26/3-L	CF26W	Compact Fluorescent, (3) 26W lamp	Electronic	3	26	82
CF26/4-L	CF26W	Compact Fluorescent, (4) 26W lamp	Electronic	4	26	108
CF26/6-L	CF26W	Compact Fluorescent, (6) 26W lamp	Electronic	6	26	162
CF26/8-L	CF26W	Compact Fluorescent, (8) 26W lamp	Electronic	8	26	216
CF28/2D	CFD28W	Compact Fluorescent, 2D, (1) 28W lamp	Mag-STD	1	28	35
CF28/2D-L	CFD28W	Compact Fluorescent, 2D, (1) 28W lamp	Electronic	1	28	28
CF32/3-L	CF32W	Compact Fluorescent, (3) 32W lamp	Electronic	3	32	114
CF32/4-L	CF32W	Compact Fluorescent, (4) 32W lamp	Electronic	4	32	152
CF32/6-L	CF32W	Compact Fluorescent, (6) 32W lamp	Electronic	6	32	228
CF32/8-L	CF32W	Compact Fluorescent, (8) 32W lamp	Electronic	8	32	304

[1404] Some of the EULs of LED lighting products are based on the listing found in the Qualified Products List by the Design Light Consortium (DLC) at 35,000 or 50,000 hours, according to the appropriate Application Category as specified in the DLC"s *Product Qualification Criteria, Technical Requirement Table* version 2.0 or higher. The EUL of other LED products are based on the listing found in *the ENERGY STAR® Qualified Fixture List*, according to the appropriate luminaire classification as specified in the *ENERGY STAR®Program requirements for Luminaires*, version 1.2. The total hours are divided by estimated annual use, but capped at 15 years regardless (consistent with C&I redecoration and business type change patterns.)

[1405] (Reference: NYSERDA Existing Buildings Lighting Table with Circline Additions from CA SPC Table)

Fixture Code	Lamp Code	Description	Ballast	Lamp/Fixture	Watt / Lamp	Watt / Fixture
CF38/2D	CFD38W	Compact Fluorescent, 2D, (1) 38W lamp	Mag-STD	1	38	46
CF38/2D-L	CFD38W	Compact Fluorescent, 2D, (1) 38W lamp	Electronic	1	38	36
CF42/1-L	CF42W	Compact Fluorescent, (1) 42W lamp	Electronic	1	42	48
CF42/2-L	CF42W	Compact Fluorescent, (2) 42W lamp	Electronic	2	42	100
CF42/3-L	CF42W	Compact Fluorescent, (3) 42W lamp	Electronic	3	42	141
CF42/4-L	CF42W	Compact Fluorescent, (4) 42W lamp	Electronic	4	42	188
CF42/6-L	CF42W	Compact Fluorescent, (6) 42W lamp	Electronic	6	42	282
CF42/8-L	CF42W	Compact Fluorescent, (8) 42W lamp	Electronic	8	42	376
CFQ10/1	CFQ10W	Compact Fluorescent, quad, (1) 10W lamp	Mag-STD	1	10	15
CFQ13/1	CFQ13W	Compact Fluorescent, quad, (1) 13W lamp	Mag-STD	1	13	17
CFQ13/1-L	CFQ13W	Compact Fluorescent, quad, (1) 13W lamp, BF=1.05	Electronic	1	13	15
CFQ13/2	CFQ13W	Compact Fluorescent, quad, (2) 13W lamp	Mag-STD	2	13	31
CFQ13/2-L	CFQ13W	Compact Fluorescent, quad, (2) 13W lamp, BF=1.0	Electronic	2	13	28
CFQ13/3	CFQ13W	Compact Fluorescent, quad, (3) 13W lamp	Mag-STD	3	13	48
CFQ15/1	CFQ15W	Compact Fluorescent, quad, (1) 15W lamp	Mag-STD	1	15	20
CFQ17/1	CFQ17W	Compact Fluorescent, quad, (1) 17W lamp	Mag-STD	1	17	24
CFQ17/2	CFQ17W	Compact Fluorescent, quad, (2) 17W lamp	Mag-STD	2	17	48
CFQ18/1	CFQ18W	Compact Fluorescent, quad, (1) 18W lamp	Mag-STD	1	18	26
CFQ18/1-L	CFQ18W	Compact Fluorescent, quad, (1) 18W lamp, BF=1.0	Electronic	1	18	20
CFQ18/2	CFQ18W	Compact Fluorescent, quad, (2) 18W lamp	Mag-STD	2	18	45
CFQ18/2-L	CFQ18W	Compact Fluorescent, quad, (2) 18W lamp, BF=1.0	Electronic	2	18	38
CFQ18/4	CFQ18W	Compact Fluorescent, quad, (4) 18W lamp	Mag-STD	2	18	90
CFQ20/1	CFQ20W	Compact Fluorescent, quad, (1) 20W lamp	Mag-STD	1	20	23
CFQ20/2	CFQ20W	Compact Fluorescent, quad, (2) 20W lamp	Mag-STD	2	20	46
CFQ22/1	CFQ22W	Compact Fluorescent, quad, (1) 22W lamp	Mag-STD	1	22	24
CFQ22/2	CFQ22W	Compact Fluorescent, quad, (2) 22W lamp	Mag-STD	2	22	48
CFQ22/3	CFQ22W	Compact Fluorescent, quad, (3) 22W lamp	Mag-STD	3	22	72
CFQ25/1	CFQ25W	Compact Fluorescent, quad, (1) 25W lamp	Mag-STD	1	25	33
CFQ25/2	CFQ25W	Compact Fluorescent, quad, (2) 25W lamp	Mag-STD	2	25	66
CFQ26/1	CFQ26W	Compact Fluorescent, quad, (1) 26W lamp	Mag-STD	1	26	33
CFQ26/1-L	CFQ26W	Compact Fluorescent, quad, (1) 26W lamp, BF=0.95	Electronic	1	26	27
CFQ26/2	CFQ26W	Compact Fluorescent, quad, (2) 26W lamp	Mag-STD	2	26	66

Fixture Code	Lamp Code	Description	Ballast	Lamp/Fixture	Watt / Lamp	Watt / Fixture
CFQ26/2-L	CFQ26W	Compact Fluorescent, quad, (2) 26W lamp, BF=0.95	Electronic	2	26	50
CFQ26/3	CFQ26W	Compact Fluorescent, quad, (3) 26W lamp	Mag-STD	3	26	99
CFQ26/6-L	CFQ26W	Compact Fluorescent, quad, (6) 26W lamp, BF=0.95	Electronic	6	26	150
CFQ28/1	CFQ28W	Compact Fluorescent, quad, (1) 28W lamp	Mag-STD	1	28	33
CFQ9/1	CFQ9W	Compact Fluorescent, quad, (1) 9W lamp	Mag-STD	1	9	14
CFQ9/2	CFQ9W	Compact Fluorescent, quad, (2) 9W lamp	Mag-STD	2	9	23
CFS7/1	CFS7W	Compact Fluorescent, spiral, (1) 7W lamp	Electronic	1	7	7
CFS9/1	CFS9W	Compact Fluorescent, spiral, (1) 9W lamp	Electronic	1	9	9
CFS11/1	CFS11W	Compact Fluorescent, spiral, (1) 11W lamp	Electronic	1	11	11
CFS15/1	CFS15W	Compact Fluorescent, spiral, (1) 15W lamp	Electronic	1	15	15
CFS20/1	CFS20W	Compact Fluorescent, spiral, (1) 20W lamp	Electronic	1	20	20
CFS23/1	CFS23W	Compact Fluorescent, spiral, (1) 23W lamp	Electronic	1	23	23
CFS27/1	CFS27W	Compact Fluorescent, spiral, (1) 27W lamp	Electronic	1	27	27
CFT13/1	CFT13W	Compact Fluorescent, twin, (1) 13W lamp	Mag-STD	1	13	17
CFT13/2	CFT13W	Compact Fluorescent, twin, (2) 13W lamp	Mag-STD	2	13	31
CFT13/3	CFT13W	Compact Fluorescent, twin, (3) 13 W lamp	Mag-STD	3	13	48
CFT18/1	CFT18W	Compact Fluorescent, long twin., (1) 18W lamp	Mag-STD	1	18	24
CFT22/1	CFT22W	Compact Fluorescent, twin, (1) 22W lamp	Mag-STD	1	22	27
CFT22/2	CFT22W	Compact Fluorescent, twin, (2) 22W lamp	Mag-STD	2	22	54
CFT22/4	CFT22W	Compact Fluorescent, twin, (4) 22W lamp	Mag-STD	4	22	108
CFT24/1	CFT24W	Compact Fluorescent, long twin, (1) 24W lamp	Mag-STD	1	24	32
CFT28/1	CFT28W	Compact Fluorescent, twin, (1) 28W lamp	Mag-STD	1	28	33
CFT28/2	CFT28W	Compact Fluorescent, twin, (2) 28W lamp	Mag-STD	2	28	66
CFT32/1-L	CFM32W	Compact Fluorescent, twin or multi, (1) 32W lamp	Electronic	1	32	34
CFT32/2-L	CFM32W	Compact Fluorescent, twin or multi, (2) 32W lamp	Electronic	2	32	62
CFT32/6-L	CFM32W	Compact Fluorescent, twin or multi, (2) 32W lamp	Electronic	6	32	186
CFT36/1	CFT36W	Compact Fluorescent, long twin, (1) 36W lamp	Mag-STD	1	36	51
CFT36/4-BX	CFT36W	Compact Fluorescent, Biax, (4) 36W lamp	Electronic	4	36	148
CFT36/6-BX	CFT36W	Compact Fluorescent, Biax, (6) 36W lamp	Electronic	6	36	212
CFT36/6-L	CFT36W	Compact Fluorescent, long Twin, (6) 36W lamp	Electronic	6	36	198

Fixture Code	Lamp Code	Description	Ballast	Lamp/Fixture	Watt / Lamp	Watt / Fixture
CFT36/6-L	CFT36W	Compact Fluorescent, long Twin, (6) 36W lamp/ High Ballast Factor	Electronic	6	36	210
CFT36/8-BX	CFT36W	Compact Fluorescent, Biax, (8) 36W lamp	Electronic	8	36	296
CFT36/8-L	CFT36W	Compact Fluorescent, long Twin, (8) 36W lamp	Electronic	8	36	270
CFT36/8-L	CFT36W	Compact Fluorescent, long Twin, (8) 36W lamp/ High Ballast Factor	Electronic	8	36	286
CFT36/9-BX	CFT36W	Compact Fluorescent, Biax, (9) 36W lamp	Electronic	9	36	318
CFT40/1	CFT40W	Compact Fluorescent, twin, (1) 40W lamp	Mag-STD	1	40	46
CFT40/12-BX	CFT40W	Compact Fluorescent, Biax, (12) 40W lamp	Electronic	12	40	408
CFT40/1-BX	CFT40W	Compact Fluorescent, Biax, (1) 40W lamp	Electronic	1	40	46
CFT40/1-L	CFT40W	Compact Fluorescent, long twin, (1) 40W lamp	Electronic	1	40	43
CFT40/2	CFT40W	Compact Fluorescent, twin, (2) 40W lamp	Mag-STD	2	40	85
CFT40/2-BX	CFT40W	Compact Fluorescent, Biax, (2) 40W lamp	Electronic	2	40	72
CFT40/2-L	CFT40W	Compact Fluorescent, long twin, (2) 40W lamp	Electronic	2	40	72
CFT40/3	CFT40W	Compact Fluorescent, twin, (3) 40 W lamp	Mag-STD	3	40	133
CFT40/3-BX	CFT40W	Compact Fluorescent, Biax, (3) 40W lamp	Electronic	3	40	102
CFT40/3-L	CFT40W	Compact Fluorescent, long twin, (3) 40W lamp	Electronic	3	40	105
CFT40/4-BX	CFT40W	Compact Fluorescent, Biax, (4) 40W lamp	Electronic	4	40	144
CFT40/5-BX	CFT40W	Compact Fluorescent, Biax, (5) 40W lamp	Electronic	5	40	190
CFT40/6-BX	CFT40W	Compact Fluorescent, Biax, (6) 40W lamp	Electronic	6	40	204
CFT40/6-L	CFT40W	Compact Fluorescent, long Twin, (6) 40W lamp	Electronic	6	40	220
CFT40/6-L	CFT40W	Compact Fluorescent, long Twin, (6) 40W lamp/ High Ballast Factor	Electronic	6	40	233
CFT40/8-BX	CFT40W	Compact Fluorescent, Biax, (8) 40W lamp	Electronic	8	40	288
CFT40/8-L	CFT40W	Compact Fluorescent, long Twin, (8) 40W lamp	Electronic	8	40	300
CFT40/8-L	CFT40W	Compact Fluorescent, long Twin, (8) 40W lamp/ High Ballast Factor	Electronic	8	40	340
CFT40/9-BX	CFT40W	Compact Fluorescent, Biax, (9) 40W lamp	Electronic	9	40	306
CFT5/1	CFT5W	Compact Fluorescent, twin, (1) 5W lamp	Mag-STD	1	5	9
CFT5/2	CFT5W	Compact Fluorescent, twin, (2) 5W lamp	Mag-STD	2	5	18
CFT50/12-BX	CFT50W	Compact Fluorescent, Biax, (12) 50W lamp	Electronic	12	50	648
CFT50/1-BX	CFT50W	Compact Fluorescent, Biax, (1) 50W lamp	Electronic	1	50	54
CFT50/2-BX	CFT50W	Compact Fluorescent, Biax, (2) 50W lamp	Electronic	2	50	108
CFT50/3-BX	CFT50W	Compact Fluorescent, Biax, (3) 50W lamp	Electronic	3	50	162

Fixture Code	Lamp Code	Description	Ballast	Lamp/Fixture	Watt / Lamp	Watt / Fixture
CFT50/4-BX	CFT50W	Compact Fluorescent, Biax, (4) 50W lamp	Electronic	4	50	216
CFT50/5-BX	CFT50W	Compact Fluorescent, Biax, (5) 50W lamp	Electronic	5	50	270
CFT50/6-BX	CFT50W	Compact Fluorescent, Biax, (6) 50W lamp	Electronic	6	50	324
CFT50/8-BX	CFT50W	Compact Fluorescent, Biax, (8) 50W lamp	Electronic	8	50	432
CFT50/9-BX	CFT50W	Compact Fluorescent, Biax, (9) 50W lamp	Electronic	9	50	486
CFT55/12-BX	CFT55W	Compact Fluorescent, Biax, (12) 55W lamp	Electronic	12	55	672
CFT55/1-BX	CFT55W	Compact Fluorescent, Biax, (1) 55W lamp	Electronic	1	55	56
CFT55/2-BX	CFT55W	Compact Fluorescent, Biax, (2) 55W lamp	Electronic	2	55	112
CFT55/3-BX	CFT55W	Compact Fluorescent, Biax, (3) 55W lamp	Electronic	3	55	168
CFT55/4-BX	CFT55W	Compact Fluorescent, Biax, (4) 55W lamp	Electronic	4	55	224
CFT55/5-BX	CFT55W	Compact Fluorescent, Biax, (5) 55W lamp	Electronic	5	55	280
CFT55/6-BX	CFT55W	Compact Fluorescent, Biax, (6) 55W lamp	Electronic	6	55	336
CFT55/6-L	CFT55W	Compact Fluorescent, long Twin, (6) 55W lamp	Electronic	6	55	352
CFT55/6-L	CFT55W	Compact Fluorescent, long Twin, (6) 55W lamp/ High Ballast Factor	Electronic	6	55	373
CFT55/8-BX	CFT55W	Compact Fluorescent, Biax, (8) 55W lamp	Electronic	8	55	448
CFT55/8-L	CFT55W	Compact Fluorescent, long Twin, (8) 55W lamp	Electronic	8	55	468
CFT55/8-L	CFT55W	Compact Fluorescent, long Twin, (8) 55W lamp/ High Ballast Factor	Electronic	8	55	496
CFT55/9-BX	CFT55W	Compact Fluorescent, Biax, (9) 55W lamp	Electronic	9	55	504
CFT7/1	CFT7W	Compact Fluorescent, twin, (1) 7W lamp	Mag-STD	1	7	10
CFT7/2	CFT7W	Compact Fluorescent, twin, (2) 7W lamp	Mag-STD	2	7	21
CFT9/1	CFT9W	Compact Fluorescent, twin, (1) 9W lamp	Mag-STD	1	9	11
CFT9/2	CFT9W	Compact Fluorescent, twin, (2) 9W lamp	Mag-STD	2	9	23
CFT9/3	CFT9W	Compact Fluorescent, twin, (3) 9W lamp	Mag-STD	3	9	34
EXIT SIGN FIXTURES						
ECF5/1	CFT5W	EXIT Compact Fluorescent, (1) 5W lamp	Mag-STD	1	5	9
ECF5/2	CFT5W	EXIT Compact Fluorescent, (2) 5W lamp	Mag-STD	2	5	20
ECF7/1	CFT7W	EXIT Compact Fluorescent, (1) 7W lamp	Mag-STD	1	7	10
ECF7/2	CFT7W	EXIT Compact Fluorescent, (2) 7W lamp	Mag-STD	2	7	21
ECF8/1	F8T5	EXIT T5 Fluorescent, (1) 8W lamp	Mag-STD	1	8	12
ECF8/2	F8T5	EXIT T5 Fluorescent, (2) 8W lamp	Mag-STD	2	8	24
ECF9/1	CFT9W	EXIT Compact Fluorescent, (1) 9W lamp	Mag-STD	1	9	12
ECF9/2	CFT9W	EXIT Compact Fluorescent, (2) 9W lamp	Mag-STD	2	9	20

Fixture Code	Lamp Code	Description	Ballast	Lamp/Fixture	Watt / Lamp	Watt / Fixture
EI10/2	I10	EXIT Incandescent, (2) 10W lamp		2	10	20
EI15/1	I15	EXIT Incandescent, (1) 15W lamp		1	15	15
EI15/2	I15	EXIT Incandescent, (2) 15W lamp		2	15	30
EI20/1	I20	EXIT Incandescent, (1) 20W lamp		1	20	20
EI20/2	I20	EXIT Incandescent, (2) 20W lamp		2	20	40
EI25/1	I25	EXIT Incandescent, (1) 25W lamp		1	25	25
EI25/2	I25	EXIT Incandescent, (2) 25W lamp		2	25	50
EI34/1	I34	EXIT Incandescent, (1) 34W lamp		1	34	34
EI34/2	I34	EXIT Incandescent, (2) 34W lamp		2	34	68
EI40/1	I40	EXIT Incandescent, (1) 40W lamp		1	40	40
EI40/2	I40	EXIT Incandescent, (2) 40W lamp		2	40	80
EI5/1	I5	EXIT Incandescent, (1) 5W lamp		1	5	5
EI5/2	I5	EXIT Incandescent, (2) 5W lamp		2	5	10
EI50/2	I50	EXIT Incandescent, (2) 50W lamp		2	50	100
EI7.5/1	I7.5	EXIT Tungsten, (1) 7.5 W lamp		1	7.5	8
EI7.5/2	I7.5	EXIT Tungsten, (2) 7.5 W lamp		2	7.5	15
ELED0.5/1	LED0.5W	EXIT Light Emitting Diode, (1) 0.5W lamp, Single Sided		1	0.5	0.5
ELED0.5/2	LED0.5W	EXIT Light Emitting Diode, (2) 0.5W lamp, Dual Sided		2	0.5	1
ELED1.5/1	LED1.5W	EXIT Light Emitting Diode, (1) 1.5W lamp, Single Sided		1	1.5	1.5
ELED1.5/2	LED1.5W	EXIT Light Emitting Diode, (2) 1.5W lamp, Dual Sided		2	1.5	3
ELED10.5/1	LED10.5W	EXIT Light Emitting Diode, (1) 10.5W lamp, Single Sided		1	10.5	10.5
ELED10.5/2	LED10.5W	EXIT Light Emitting Diode, (2) 10.5W lamp, Dual Sided		2	10.5	21
ELED2/1	LED2W	EXIT Light Emitting Diode, (1) 2W lamp, Single Sided		1	2	2
ELED2/2	LED2W	EXIT Light Emitting Diode, (2) 2W lamp, Dual Sided		2	2	4
ELED3/1	LED3W	EXIT Light Emitting Diode, (1) 3W lamp, Single Sided		1	3	3
ELED3/2	LED3W	EXIT Light Emitting Diode, (2) 3W lamp, Dual Sided		2	3	6

Fixture Code	Lamp Code	Description	Ballast	Lamp/Fixture	Watt / Lamp	Watt / Fixture
ELED5/1	LED5W	EXIT Light Emitting Diode, (1) 5W lamp, Single Sided		1	5	5
ELED5/2	LED5W	EXIT Light Emitting Diode, (2) 5W lamp, Dual Sided		2	5	10
ELED8/1	LED8W	EXIT Light Emitting Diode, (1) 8W lamp, Single Sided		1	8	8
ELED8/2	LED8W	EXIT Light Emitting Diode, (2) 8W lamp, Dual Sided		2	8	16
LINEAR FLUORESCENT FIXTURES						
F1.51LS	F15T8	Fluorescent, (1) 18" T8 lamp	Mag-STD	1	15	19
F1.51SS	F15T12	Fluorescent, (1) 18" T12 lamp	Mag-STD	1	15	19
F1.52LS	F15T8	Fluorescent, (2) 18" T8 lamp	Mag-STD	2	15	36
F1.52SS	F15T12	Fluorescent, (2) 18", T12 lamp	Mag-STD	2	15	36
F21HS	F24T12/HO	Fluorescent, (1) 24", HO lamp	Mag-STD	1	35	62
F21ILL	F17T8	Fluorescent, (1) 24", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	1	17	20
F21ILL/T2	F17T8	Fluorescent, (1) 24", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95), Tandem 2 Lamp Ballast	Electronic	1	17	17
F21ILL/T2-R	F17T8	Fluorescent, (1) 24", T-8 lamp, Instant Start Ballast, RLO (BF<.85), Tandem 2 Lamp Ballast	Electronic	1	17	15
F21ILL/T3	F17T8	Fluorescent, (1) 24", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95), Tandem 3 Lamp Ballast	Electronic	1	17	16
F21ILL/T3-R	F17T8	Fluorescent, (1) 24", T-8 lamp, Instant Start Ballast, RLO (BF<.85), Tandem 3 Lamp Ballast	Electronic	1	17	14
F21ILL/T4	F17T8	Fluorescent, (1) 24", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95), Tandem 4 Lamp Ballast	Electronic	1	17	15
F21ILL/T4-R	F17T8	Fluorescent, (1) 24", T-8 lamp, Instant Start Ballast, RLO (BF<.85), Tandem 4 Lamp Ballast	Electronic	1	17	14
F21ILX-R	F17T8	Fluorescent, (1) 24", T-8 lamp, HE Instant/Program Start Ballast, RLO (BF<0.85)	Electronic	1	17	15

Fixture Code	Lamp Code	Description	Ballast	Lamp/Fixture	Watt / Lamp	Watt / Fixture
F21ILX	F17T8	Fluorescent, (1) 24", T-8 lamp, HE Instant/Program Start Ballast, NLO (BF: .85-.95)	Electronic	1	17	16
F21LL	F17T8	Fluorescent, (1) 24", T-8 lamp, Rapid Start Ballast, NLO (BF: .85-.95)	Electronic	1	17	16
F21LL/T2	F17T8	Fluorescent, (1) 24", T-8 lamp, Rapid Start Ballast, NLO (BF: .85-.95), Tandem 2 Lamp Ballast	Electronic	1	17	16
F21LL/T3	F17T8	Fluorescent, (1) 24", T-8 lamp, Rapid Start Ballast, NLO (BF: .85-.95), Tandem 3 Lamp Ballast	Electronic	1	17	17
F21LL/T4	F17T8	Fluorescent, (1) 24", T-8 lamp, Rapid Start Ballast, NLO (BF: .85-.95), Tandem 4 Lamp Ballast	Electronic	1	17	17
F21LL-R	F17T8	Fluorescent, (1) 24", T-8 lamp, Rapid Start Ballast, RLO (BF<0.85)	Electronic	1	17	15
F21LS	F17T8	Fluorescent, (1) 24", T8 lamp, Standard Ballast	Mag-STD	1	17	24
F21GL	F24T5	Fluorescent, (1) 24", STD T5 lamp	Electronic	1	14	18
F21SE	F20T12	Fluorescent, (1) 24", STD lamp	Mag-ES	1	20	26
F21SS	F20T12	Fluorescent, (1) 24", STD lamp	Mag-STD	1	20	28
F21GHL	F24T5/HO	Fluorescent, (1) 24", STD HO T5 lamp	Electronic	1	24	29
F22SHS	F24T12/HO	Fluorescent, (2) 24", HO lamp	Mag-STD	2	35	90
F22GHL	F24T5/HO	Fluorescent, (2) 24", STD HO T5 lamp	Electronic	2	24	55
F22ILE	F17T8	Fluorescent, (2) 24", T-8 Instant Start lamp, Energy Saving Magnetic Ballast	Mag-ES	2	17	45
F22ILL	F17T8	Fluorescent, (2) 24", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	2	17	33
F22ILL/T4	F17T8	Fluorescent, (2) 24", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95), Tandem 4 Lamp Ballast	Electronic	2	17	31
F22ILL/T4-R	F17T8	Fluorescent, (2) 24", T-8 lamp, Instant Start Ballast, RLO (BF<.85), Tandem 4 Lamp Ballast	Electronic	2	17	28
F22ILL-R	F17T8	Fluorescent, (2) 24", T-8 lamp, Instant Start Ballast, RLO (BF<0.85)	Electronic	2	17	29

Fixture Code	Lamp Code	Description	Ballast	Lamp/Fixture	Watt / Lamp	Watt / Fixture
F22ILX-R	F17T8	Fluorescent, (2) 24", T-8 lamp, HE Instant/Program Start Ballast, RLO (BF<0.85)	Electronic	2	17	27
F22ILX	F17T8	Fluorescent, (2) 24", T-8 lamp, HE Instant/Program Start Ballast, NLO (BF: .85-.95)	Electronic	2	17	31
F22LL	F17T8	Fluorescent, (2) 24", T-8 lamp, Rapid Start Ballast, NLO (BF: .85-.95)	Electronic	2	17	31
F22LL/T4	F17T8	Fluorescent, (2) 24", T-8 lamp, Rapid Start Ballast, NLO (BF: .85-.95), Tandem 4 Lamp Ballast	Electronic	2	17	34
F22LL-R	F17T8	Fluorescent, (2) 24", T-8 lamp, Rapid Start Ballast, RLO (BF<0.85)	Electronic	2	17	28
F22GL	F24T5	Fluorescent, (2) 24", STD T5 lamp	Electronic	2	14	35
F22SE	F20T12	Fluorescent, (2) 24", STD lamp	Mag-ES	2	20	51
F22SS	F20T12	Fluorescent, (2) 24", STD lamp	Mag-STD	2	20	56
F23ILL	F17T8	Fluorescent, (3) 24", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	3	17	47
F23ILL-H	F17T8	Fluorescent, (3) 24", T-8 lamp, Instant Start Ballast, HLO (BF:.96-1.1)	Electronic	3	17	49
F23ILL-R	F17T8	Fluorescent, (3) 24", T-8 lamp, Instant Start Ballast, RLO (BF<0.85)	Electronic	3	17	43
F23ILX	F17T8	Fluorescent, (3) 24", T-8 lamp, HE Instant/Program Start Ballast, NLO (BF: .85-.95)	Electronic	3	17	45
F23ILX-R	F17T8	Fluorescent, (3) 24", T-8 lamp, HE Instant/Program Start Ballast, RLO (BF<0.85)	Electronic	3	17	40
F23LL	F17T8	Fluorescent, (3) 24", T-8 lamp, Rapid Start Ballast, NLO (BF: .85-.95)	Electronic	3	17	52
F23LL-R	F17T8	Fluorescent, (3) 24", T-8 lamp, Rapid Start Ballast, RLO (BF<0.85)	Electronic	3	17	41
F23SE	F20T12	Fluorescent, (3) 24", STD lamp	Mag-ES	3	20	77
F23SS	F20T12	Fluorescent, (3) 24", STD lamp	Mag-STD	3	20	84
F24ILL	F17T8	Fluorescent, (4) 24", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	4	17	61
F24ILL-R	F17T8	Fluorescent, (4) 24", T-8 lamp, Instant Start Ballast, RLO (BF<0.85)	Electronic	4	17	55

Fixture Code	Lamp Code	Description	Ballast	Lamp/Fixture	Watt / Lamp	Watt / Fixture
F24ILX-R	F17T8	Fluorescent, (4) 24", T-8 lamp, HE Instant/Program Start Ballast, RLO (BF<0.85)	Electronic	4	17	53
F24LL	F17T8	Fluorescent, (4) 24", T-8 lamp, Rapid Start Ballast, NLO (BF: .85-.95)	Electronic	4	17	68
F24LL-R	F17T8	Fluorescent, (4) 24", T-8 lamp, Rapid Start Ballast, RLO (BF<0.85)	Electronic	4	17	57
F24SE	F20T12	Fluorescent, (4) 24", STD lamp	Mag-ES	4	20	102
F24SS	F20T12	Fluorescent, (4) 24", STD lamp	Mag-STD	4	20	112
F26SE	F20T12	Fluorescent, (6) 24", STD lamp	Mag-ES	6	20	153
F26SS	F20T12	Fluorescent, (6) 24", STD lamp	Mag-STD	6	20	168
F31EE	F30T12/ES	Fluorescent, (1) 36", ES lamp	Mag-ES	1	25	38
F31EE/T2	F30T12/ES	Fluorescent, (1) 36", ES lamp, Tandem wired	Mag-ES	1	25	33
F31EL	F30T12/ES	Fluorescent, (1) 36", ES lamp	Electronic	1	25	26
F31ES	F30T12/ES	Fluorescent, (1) 36", ES lamp	Mag-STD	1	25	42
F31ES/T2	F30T12/ES	Fluorescent, (1) 36", ES lamp, Tandem wired	Mag-STD	1	25	37
F31ILL	F25T8	Fluorescent, (1) 36", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	1	25	26
F31ILL/T2	F25T8	Fluorescent, (1) 36", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95), Tandem 2 Lamp Ballast	Electronic	1	25	23
F31ILL/T2-H	F25T8	Fluorescent, (1) 36", T-8 lamp, Instant Start Ballast, HLO (BF: .96-1.1), Tandem 2 Lamp Ballast	Electronic	1	25	24
F31ILL/T2-R	F25T8	Fluorescent, (1) 36", T-8 lamp, Instant Start Ballast, RLO (BF: .85-.95), Tandem 2 Lamp Ballast	Electronic	1	25	23
F31ILL/T3	F25T8	Fluorescent, (1) 36", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95), Tandem 3 Lamp Ballast	Electronic	1	25	22
F31ILL/T3-R	F25T8	Fluorescent, (1) 36", T-8 lamp, Instant Start Ballast, RLO (BF<.85), Tandem 3 Lamp Ballast	Electronic	1	25	22
F31ILL/T4	F25T8	Fluorescent, (1) 36", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95), Tandem 4 Lamp Ballast	Electronic	1	25	22

Fixture Code	Lamp Code	Description	Ballast	Lamp/Fixture	Watt / Lamp	Watt / Fixture
F31ILL/T4-R	F25T8	Fluorescent, (1) 36", T-8 lamp, Instant Start Ballast, RLO (BF<.85), Tandem 4 Lamp Ballast	Electronic	1	25	22
F31ILL-H	F25T8	Fluorescent, (1) 36", T-8 lamp, Instant Start Ballast, HLO (BF:.96-1.1)	Electronic	1	25	28
F31ILL-R	F25T8	Fluorescent, (1) 36", T-8 lamp, Instant Start Ballast, RLO (BF<0.85)	Electronic	1	25	27
F31LL	F25T8	Fluorescent, (1) 36", T-8 lamp, Rapid Start Ballast, NLO (BF: .85-.95)	Electronic	1	25	24
F31LL/T2	F25T8	Fluorescent, (1) 36", T-8 lamp, Rapid Start Ballast, NLO (BF: .85-.95), Tandem 2 Lamp Ballast	Electronic	1	25	23
F31LL/T3	F25T8	Fluorescent, (1) 36", T-8 lamp, Rapid Start Ballast, NLO (BF: .85-.95), Tandem 3 Lamp Ballast	Electronic	1	25	24
F31LL/T4	F25T8	Fluorescent, (1) 36", T-8 lamp, Rapid Start Ballast, NLO (BF: .85-.95), Tandem 4 Lamp Ballast	Electronic	1	25	22
F31LL-H	F25T8	Fluorescent, (1) 36", T-8 lamp, Rapid Start Ballast, HLO (BF:.96-1.1)	Electronic	1	25	26
F31LL-R	F25T8	Fluorescent, (1) 36", T-8 lamp, Rapid Start Ballast, RLO (BF<0.85)	Electronic	1	25	23
F31ILX-R	F25T8	Fluorescent, (1) 36", T-8 lamp, HE Instant/Program Start Ballast, RLO (BF<0.85)	Electronic	1	25	21
F31SE/T2	F30T12	Fluorescent, (1) 36", STD lamp, Tandem wired	Mag-ES	1	30	37
F31GHL	F36T5/HO	Fluorescent, (1) 36", STD HO T5 lamp	Electronic	1	39	43
F31SHS	F36T12/HO	Fluorescent, (1) 36", HO lamp	Mag-STD	1	50	70
F31SL	F30T12	Fluorescent, (1) 36", STD lamp	Electronic	1	30	31
F31GL	F36T5	Fluorescent, (1) 36", STD T5 lamp	Electronic	1	21	27
F31SS	F30T12	Fluorescent, (1) 36", STD lamp	Mag-STD	1	30	46
F31SS/T2	F30T12	Fluorescent, (1) 36", STD lamp, Tandem wired	Mag-STD	1	30	41
F32EE	F30T12/ES	Fluorescent, (2) 36", ES lamp	Mag-ES	2	25	66
F32EL	F30T12/ES	Fluorescent, (2) 36", ES lamp	Electronic	2	25	50
F32ES	F30T12/ES	Fluorescent, (2) 36", ES lamp	Mag-STD	2	25	73
F32ILL	F25T8	Fluorescent, (2) 36", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	2	25	46

Fixture Code	Lamp Code	Description	Ballast	Lamp/Fixture	Watt / Lamp	Watt / Fixture
F32ILL/T4	F25T8	Fluorescent, (2) 36", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95), Tandem 4 Lamp Ballast	Electronic	2	25	44
F32ILL/T4-R	F25T8	Fluorescent, (2) 36", T-8 lamp, Instant Start Ballast, RLO (BF<.85), Tandem 4 Lamp Ballast	Electronic	2	25	43
F32ILL-H	F25T8	Fluorescent, (2) 36", T-8 lamp, Instant Start Ballast, HLO (BF:.96-1.1)	Electronic	2	25	48
F32ILL-R	F25T8	Fluorescent, (2) 36", T-8 lamp, Instant Start Ballast, RLO (BF<0.85)	Electronic	2	25	46
F32ILX-R	F25T8	Fluorescent, (2) 36", T-8 lamp, HE Instant/Program Start Ballast, RLO (BF<0.85)	Electronic	2	25	39
F32LE	F25T8	Fluorescent, (2) 36", T-8 lamp	Mag-ES	2	25	65
F32LL	F25T8	Fluorescent, (2) 36", T-8 lamp, Rapid Start Ballast, NLO (BF: .85-.95)	Electronic	2	25	46
F32LL/T4	F25T8	Fluorescent, (2) 36", T-8 lamp, Rapid Start Ballast, NLO (BF: .85-.95), Tandem 4 Lamp Ballast	Electronic	2	25	45
F32LL-H	F25T8	Fluorescent, (2) 36", T-8 lamp, Rapid Start Ballast, HLO (BF:.96-1.1)	Electronic	2	25	50
F32LL-R	F25T8	Fluorescent, (2) 36", T-8 lamp, Rapid Start Ballast, RLO (BF<0.85)	Electronic	2	25	42
F32LL-V	F25T8	Fluorescent, (2) 36", T-8 lamp, Rapid Start Ballast, VHLO (BF>1.1)	Electronic	2	25	70
F32SE	F30T12	Fluorescent, (2) 36", STD lamp	Mag-ES	2	30	74
F32GHL	F36T5/HO	Fluorescent, (1) 36", STD HO T5 lamp	Electronic	2	39	85
F32SHS	F36T12/HO	Fluorescent, (2) 36", HO, lamp	Mag-STD	2	50	114
F32SL	F30T12	Fluorescent, (2) 36", STD lamp	Electronic	2	30	58
F32GL	F36T5	Fluorescent, (1) 36", STD T5 lamp	Electronic	2	21	52
F32SS	F30T12	Fluorescent, (2) 36", STD lamp	Mag-STD	2	30	81
F33ES	F30T12/ES	Fluorescent, (3) 36", ES lamp	Mag-STD	3	25	115
F33ILL	F25T8	Fluorescent, (3) 36", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	3	25	67
F33ILL-R	F25T8	Fluorescent, (3) 36", T-8 lamp, Instant Start Ballast, RLO (BF<0.85)	Electronic	3	25	66
F33LL	F25T8	Fluorescent, (3) 36", T-8 lamp, Rapid Start Ballast, NLO (BF: .85-.95)	Electronic	3	25	72

Fixture Code	Lamp Code	Description	Ballast	Lamp/Fixture	Watt / Lamp	Watt / Fixture
F33LL-R	F25T8	Fluorescent, (3) 36", T-8 lamp, Rapid Start Ballast, RLO (BF<0.85)	Electronic	3	25	62
F33SE	F30T12	Fluorescent, (3) 36", STD lamp, (1) STD ballast and (1) ES ballast	Mag-ES	3	30	120
F33SS	F30T12	Fluorescent, (3) 36", STD lamp	Mag-STD	3	30	127
F34ILL	F25T8	Fluorescent, (4) 36", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	4	25	87
F34ILL-R	F25T8	Fluorescent, (4) 36", T-8 lamp, Instant Start Ballast, RLO (BF<0.85)	Electronic	4	25	86
F34LL	F25T8	Fluorescent, (4) 36", T-8 lamp, Rapid Start Ballast, NLO (BF: .85-.95)	Electronic	4	25	89
F34LL-R	F25T8	Fluorescent, (4) 36", T-8 lamp, Rapid Start Ballast, RLO (BF<0.85)	Electronic	4	25	84
F34SE	F30T12	Fluorescent, (4) 36", STD lamp	Mag-ES	4	30	148
F34SL	F30T12	Fluorescent, (4) 36", STD lamp	Electronic	4	30	116
F34SS	F30T12	Fluorescent, (4) 36", STD lamp	Mag-STD	4	30	162
F36EE	F30T12/ES	Fluorescent, (6) 36", ES lamp	Mag-ES	6	25	198
F36ILL-R	F25T8	Fluorescent, (6) 36", T-8 lamp, Instant Start Ballast, RLO (BF<.85)	Electronic	6	25	134
F36SE	F30T12	Fluorescent, (6) 36", STD lamp	Mag-ES	6	30	238
F40EE/D1	None	Fluorescent, (0) 48" lamp, Completely delamped fixture with (1) hot ballast	Mag-ES	0	0	4
F40EE/D2	None	Fluorescent, (0) 48" lamp, Completely delamped fixture with (2) hot ballast	Mag-ES	0	0	8
F41EE	F40T12/ES	Fluorescent, (1) 48", ES lamp	Mag-ES	1	34	43
F41EE/D2	F40T12/ES	Fluorescent, (1) 48", ES lamp, 2 ballast	Mag-ES	1	34	43
F41EE/T2	F40T12/ES	Fluorescent, (1) 48", ES lamp, tandem wired, 2-lamp ballast	Mag-ES	1	34	36
F41EHS	F48T12/HO/ES	Fluorescent, (1) 48", ES HO lamp	Mag-STD	1	55	80
F41EIS	F48T12/ES	Fluorescent, (1) 48" ES Instant Start lamp. Magnetic ballast	Mag-STD	1	30	51
F41EL	F40T12/ES	Fluorescent, (1) 48", T12 ES lamp, Electronic Ballast	Electronic	1	34	32
F41EL/T2	F40T12/ES	Fluorescent, (1) 48", T-12 ES lamp, Rapid Start Ballast, NLO (BF: .85-.95), Tandem 2 Lamp Ballast	Electronic	1	34	32
F41ES	F40T12/ES	Fluorescent, (1) 48", ES lamp	Mag-STD	1	34	50

Fixture Code	Lamp Code	Description	Ballast	Lamp/Fixture	Watt / Lamp	Watt / Fixture
F41EVS	F48T12/VHO/ES	Fluorescent, (1) 48", VHO ES lamp	Mag-STD	1		123
F41IAL	F25T12	Fluorescent, (1) 48", F25T12 lamp, Instant Start Ballast	Electronic	1	25	25
F41IAL/T2-R	F25T12	Fluorescent, (1) 48", F25T12 lamp, Instant Start, Tandem 2-Lamp Ballast, RLO (BF<0.85)	Electronic	1	25	19
F41IAL/T3-R	F25T12	Fluorescent, (1) 48", F25T12 lamp, Instant Start, Tandem 3-Lamp Ballast, RLO (BF<0.85)	Electronic	1	25	20
F41ILL	F32T8	Fluorescent, (1) 48", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	1	32	31
F41SILL	F30T8	Fluorescent, (1) 48", Super T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	1	30	28
F41SILL/T2	F30T8	Fluorescent, (1) 48", Super T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95), Tandem 2 Lamp Ballast	Electronic	1	30	27
F41SILL/T3	F30T8	Fluorescent, (1) 48", Super T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95), Tandem 3 Lamp Ballast	Electronic	1	30	27
F41SILL/T4	F30T8	Fluorescent, (1) 48", Super T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95), Tandem 4 Lamp Ballast	Electronic	1	30	26
F41SILL-R	F30T8	Fluorescent, (1) 48", Super T-8 lamp, Instant Start Ballast, RLO (BF<0.85)	Electronic	1	30	25
F41SILL/T2-R	F30T8	Fluorescent, (1) 48", Super T-8 lamp, IS Ballast, RLO (BF<0.85), Tandem 2 Lamp Ballast	Electronic	1	30	24
F41SILL/T3-R	F30T8	Fluorescent, (1) 48", Super T-8 lamp, IS Ballast, RLO (BF<0.85), Tandem 3 Lamp Ballast	Electronic	1	30	24
F41SILL/T4-R	F30T8	Fluorescent, (1) 48", Super T-8 lamp, IS Ballast, RLO (BF<0.85), Tandem 4 Lamp Ballast	Electronic	1	30	23
F41SILL-H	F30T8	Fluorescent, (1) 48", Super T-8 lamp, Instant Start Ballast, HLO (BF:.96-1.1)	Electronic	1	30	37
F41SILL/T2-H	F30T8	Fluorescent, (1) 48", Super T-8 lamp, Instant Start Ballast, HLO (BF:.96-1.1), Tandem 2 Lamp Ballast	Electronic	1	30	36

Fixture Code	Lamp Code	Description	Ballast	Lamp/Fixture	Watt / Lamp	Watt / Fixture
F41SILL/T3-H	F30T8	Fluorescent, (1) 48", Super T-8 lamp, Instant Start Ballast, HLO (BF:.96-1.1), Tandem 3 Lamp Ballast	Electronic	1	30	36
F41SSILL	F28T8	Fluorescent, (1) 48", Super T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	1	28	26
F41SSILL/T2	F28T8	Fluorescent, (1) 48", Super T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95), Tandem 2 Lamp Ballast	Electronic	1	28	25
F41SSILL/T3	F28T8	Fluorescent, (1) 48", Super T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95), Tandem 3 Lamp Ballast	Electronic	1	28	25
F41SSILL/T4	F28T8	Fluorescent, (1) 48", Super T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95), Tandem 4 Lamp Ballast	Electronic	1	28	24
F41SSILL-R	F28T8	Fluorescent, (1) 48", Super T-8 lamp, Instant Start Ballast, RLO (BF<0.85)	Electronic	1	28	23
F41SSILL/T2-R	F28T8	Fluorescent, (1) 48", Super T-8 lamp, IS Ballast, RLO (BF<0.85), Tandem 2 Lamp Ballast	Electronic	1	28	22
F41SSILL/T3-R	F28T8	Fluorescent, (1) 48", Super T-8 lamp, IS Ballast, RLO (BF<0.85), Tandem 3 Lamp Ballast	Electronic	1	28	22
F41SSILL/T4-R	F28T8	Fluorescent, (1) 48", Super T-8 lamp, IS Ballast, RLO (BF<0.85), Tandem 4 Lamp Ballast	Electronic	1	28	21
F41SSILL-H	F28T8	Fluorescent, (1) 48", Super T-8 lamp, Instant Start Ballast, HLO (BF:.96-1.1)	Electronic	1	28	33
F41SSILL/T2-H	F28T8	Fluorescent, (1) 48", Super T-8 lamp, Instant Start Ballast, HLO (BF:.96-1.1), Tandem 2 Lamp Ballast	Electronic	1	28	32
F41SSILL/T3-H	F28T8	Fluorescent, (1) 48", Super T-8 lamp, Instant Start Ballast, HLO (BF:.96-1.1), Tandem 3 Lamp Ballast	Electronic	1	28	32
F41ILL/T2	F32T8	Fluorescent, (1) 48", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95), Tandem 2 Lamp Ballast	Electronic	1	32	30

Fixture Code	Lamp Code	Description	Ballast	Lamp/Fixture	Watt / Lamp	Watt / Fixture
F41ILL/T2-H	F32T8	Fluorescent, (1) 48", T-8 lamp, Instant Start Ballast, HLO (BF:.96-1.1), Tandem 2 Lamp Ballast	Electronic	1	32	33
F41ILL/T2-R	F32T8	Fluorescent, (1) 48", T-8 lamp, IS Ballast, RLO (BF<0.85), Tandem 2 Lamp Ballast	Electronic	1	32	26
F41ILL/T3	F32T8	Fluorescent, (1) 48", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95), Tandem 3 Lamp Ballast	Electronic	1	32	30
F41ILL/T3-H	F32T8	Fluorescent, (1) 48", T-8 lamp, Instant Start Ballast, HLO (BF:.96-1.1), Tandem 3 Lamp Ballast	Electronic	1	32	31
F41ILL/T3-R	F32T8	Fluorescent, (1) 48", T-8 lamp, IS Ballast, RLO (BF<0.85), Tandem 3 Lamp Ballast	Electronic	1	32	26
F41ILL/T4	F32T8	Fluorescent, (1) 48", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95), Tandem 4 Lamp Ballast	Electronic	1	32	28
F41ILL/T4-R	F32T8	Fluorescent, (1) 48", T-8 lamp, IS Ballast, RLO (BF<0.85), Tandem 4 Lamp Ballast	Electronic	1	32	26
F41ILL-H	F32T8	Fluorescent, (1) 48", T-8 lamp, Instant Start Ballast, HLO (BF:.96-1.1)	Electronic	1	32	36
F41ILX-H	F32T8	Fluorescent, (1) 48", T-8 lamp, HE Instant/Program Start Ballast, HLO (BF:.96-1.1)	Electronic	1	32	35
F41ILX-R	F32T8	Fluorescent, (1) 48", T-8 lamp, HE Instant/Program Start Ballast, RLO (BF<0.85)	Electronic	1	32	25
F41LE	F32T8	Fluorescent, (1) 48", T-8 lamp	Mag-ES	1	32	35
F41LL	F32T8	Fluorescent, (1) 48", T-8 lamp, Rapid Start Ballast, NLO (BF: .85-.95)	Electronic	1	32	32
F41LL/T2	F32T8	Fluorescent, (1) 48", T-8 lamp, Rapid Start Ballast, NLO (BF: .85-.95), Tandem 2 Lamp Ballast	Electronic	1	32	30
F41LL/T2-H	F32T8	Fluorescent, (1) 48", T-8 lamp, Rapid Start Ballast, HLO (BF:.96-1.1), Tandem 2 Lamp Ballast	Electronic	1	32	39
F41LL/T2-R	F32T8	Fluorescent, (1) 48", T-8 lamp, Rapid Start Ballast, RLO (BF<0.85), Tandem 2 Lamp Ballast	Electronic	1	32	27

Fixture Code	Lamp Code	Description	Ballast	Lamp/Fixture	Watt / Lamp	Watt / Fixture
F41LL/T3	F32T8	Fluorescent, (1) 48", T-8 lamp, Rapid Start Ballast, NLO (BF: .85-.95), Tandem 3 Lamp Ballast	Electronic	1	32	31
F41LL/T3-H	F32T8	Fluorescent, (1) 48", T-8 lamp, Rapid Start Ballast, HLO (BF:.96-1.1), Tandem 3 Lamp Ballast	Electronic	1	32	33
F41LL/T3-R	F32T8	Fluorescent, (1) 48", T-8 lamp, Rapid Start Ballast, RLO (BF<0.85), Tandem 3 Lamp Ballast	Electronic	1	32	25
F41LL/T4	F32T8	Fluorescent, (1) 48", T-8 lamp, Rapid Start Ballast, NLO (BF: .85-.95), Tandem 4 Lamp Ballast	Electronic	1	32	30
F41LL/T4-R	F32T8	Fluorescent, (1) 48", T-8 lamp, Rapid Start Ballast, RLO (BF<0.85), Tandem 4 Lamp Ballast	Electronic	1	32	26
F41LL-H	F32T8	Fluorescent, (1) 48", T-8 lamp, Rapid Start Ballast, HLO (BF:.96-1.1)	Electronic	1	32	39
F41LL-R	F32T8	Fluorescent, (1) 48", T-8 lamp, Rapid Start Ballast, RLO (BF<0.85)	Electronic	1	32	27
F41SE	F40T12	Fluorescent, (1) 48", STD lamp	Mag-ES	1	40	50
F41GHL	F48T5/HO	Fluorescent, (1) 48", STD HO T5 lamp	Electronic	1	54	59
F41SHS	F48T12/HO	Fluorescent, (1) 48", STD HO lamp	Mag-STD	1	60	85
F41SIL	F48T12	Fluorescent, (1) 48", STD IS lamp, Electronic ballast	Electronic	1	39	46
F41SIL/T2	F48T12	Fluorescent, (1) 48", STD IS lamp, Electronic ballast, tandem wired	Electronic	1	39	37
F41SIS	F48T12	Fluorescent, (1) 48", STD IS lamp	Mag-STD	1	39	60
F41SIS/T2	F48T12	Fluorescent, (1) 48", STD IS lamp, tandem to 2-lamp ballast	Mag-STD	1	39	52
F41GL	F48T5	Fluorescent, (1) 48", STD T5 lamp	Electronic	1	28	32
F41SL/T2	F40T12	Fluorescent, (1) 48", T-12 STD lamp, Rapid Start Ballast, NLO (BF: .85-.95), Tandem 2 Lamp Ballast	Electronic	1	40	36
F41SS	F40T12	Fluorescent, (1) 48", STD lamp	Mag-STD	1	40	57
F41SVS	F48T12/VHO	Fluorescent, (1) 48", STD VHO lamp	Mag-STD	1	110	135
F41TS	F40T10	Fluorescent, (1) 48", T-10 lamp	Mag-STD	1	40	51
F42EE	F40T12/ES	Fluorescent, (2) 48", ES lamp	Mag-ES	2	34	72

Fixture Code	Lamp Code	Description	Ballast	Lamp/Fixture	Watt / Lamp	Watt / Fixture
F42EE/D2	F40T12/ES	Fluorescent, (2) 48", ES lamp, 2 Ballasts (delamped)	Mag-ES	2	34	76
F42EHS	F48T12/HO/ES	Fluorescent, (2) 42", HO lamp (3.5' lamp)	Mag-STD	2	55	135
F42EIS	F48T12/ES	Fluorescent, (2) 48" ES Instant Start lamp. Magnetic ballast	Mag-STD	2	30	82
F42EL	F40T12/ES	Fluorescent, (2) 48", T12 ES lamps, Electronic Ballast	Electronic	2	34	60
F42ES	F40T12/ES	Fluorescent, (2) 48", ES lamp	Mag-STD	2	34	80
F42EVS	F48T12/VHO/ES	Fluorescent, (2) 48", VHO ES lamp	Mag-STD	2		210
F42IAL/T4-R	F25T12	Fluorescent, (2) 48", F25T12 lamp, Instant Start, Tandem 4-Lamp Ballast, RLO (BF<0.85)	Electronic	2	25	40
F42IAL-R	F25T12	Fluorescent, (2) 48", F25T12 lamp, Instant Start Ballast, RLO (BF<0.85)	Electronic	2	25	39
F42ILL	F32T8	Fluorescent, (2) 48", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	2	32	59
F42SILL	F30T8	Fluorescent, (2) 48", Super T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	2	30	53
F41SILL/T4	F30T8	Fluorescent, (2) 48", Super T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95), Tandem 4 Lamp Ballast	Electronic	2	30	52
F42SILL-R	F30T8	Fluorescent, (2) 48", Super T-8 lamp, Instant Start Ballast, RLO (BF<0.85)	Electronic	2	30	47
F41SILL/T4-R	F30T8	Fluorescent, (2) 48", Super T-8 lamp, IS Ballast, RLO (BF<0.85), Tandem 4 Lamp Ballast	Electronic	2	30	46
F42SILL-H	F30T8	Fluorescent, (2) 48", Super T-8 lamp, Instant Start Ballast, HLO (BF:.96-2.2)	Electronic	2	30	72
F42SSILL	F28T8	Fluorescent, (2) 48", Super T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	2	28	48
F41SSILL/T4	F28T8	Fluorescent, (2) 48", Super T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95), Tandem 4 Lamp Ballast	Electronic	2	28	47
F42SSILL-R	F28T8	Fluorescent, (2) 48", Super T-8 lamp, Instant Start Ballast, RLO (BF<0.85)	Electronic	2	28	45
F41SSILL/T4-R	F28T8	Fluorescent, (2) 48", Super T-8 lamp, IS Ballast, RLO (BF<0.85), Tandem 4 Lamp Ballast	Electronic	2	28	44

Fixture Code	Lamp Code	Description	Ballast	Lamp/Fixture	Watt / Lamp	Watt / Fixture
F42SSILL-H	F28T8	Fluorescent, (2) 48", Super T-8 lamp, Instant Start Ballast, HLO (BF:.96-2.2)	Electronic	2	28	67
F42ILL/T4	F32T8	Fluorescent, (2) 48", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95), Tandem 4 Lamp Ballast	Electronic	2	32	56
F42ILL/T4-R	F32T8	Fluorescent, (2) 48", T-8 lamp, Instant Start Ballast, RLO (BF<0.85), Tandem 4 Lamp Ballast	Electronic	2	32	51
F42ILL-H	F32T8	Fluorescent, (2) 48", T-8 lamp, Instant Start Ballast, HLO (BF:.96-1.1)	Electronic	2	32	65
F42ILL-R	F32T8	Fluorescent, (2) 48", T-8 lamp, Instant Start Ballast, RLO (BF<0.85)	Electronic	2	32	52
F42ILL-V	F32T8	Fluorescent, (2) 48", T-8 lamp, Instant Start Ballast, VHLO (BF>1.1)	Electronic	2	32	79
F42ILX-H	F32T8	Fluorescent, (2) 48", T-8 lamp, HE Instant/Program Start Ballast, HLO (BF:.96-1.1)	Electronic	2	32	63
F42ILX-R	F32T8	Fluorescent, (2) 48", T-8 lamp, HE Instant/Program Start Ballast, RLO (BF<0.85)	Electronic	2	32	48
F42ILX-V	F32T8	Fluorescent, (2) 48", T-8 lamp, HE Instant/Program Start Ballast, VHLO (BF>1.1)	Electronic	2	32	74
F42LE	F32T8	Fluorescent, (2) 48", T-8 lamp	Mag-ES	2	32	71
F42LL	F32T8	Fluorescent, (2) 48", T-8 lamp, Rapid Start Ballast, NLO (BF: .85-.95)	Electronic	2	32	60
F42LL/T4	F32T8	Fluorescent, (2) 48", T-8 lamp, Rapid Start Ballast, NLO (BF: .85-.95), Tandem 4 Lamp Ballast	Electronic	2	32	59
F42LL/T4-R	F32T8	Fluorescent, (2) 48", T-8 lamp, Rapid Start Ballast, RLO (BF<0.85), Tandem 4 Lamp Ballast	Electronic	2	32	53
F42LL-H	F32T8	Fluorescent, (2) 48", T-8 lamp, Rapid Start Ballast, HLO (BF:.96-1.1)	Electronic	2	32	70
F42LL-R	F32T8	Fluorescent, (2) 48", T-8 lamp, Rapid Start Ballast, RLO (BF<0.85)	Electronic	2	32	54
F42LL-V	F32T8	Fluorescent, (2) 48", T-8 lamp, Rapid Start Ballast, VHLO (BF>1.1)	Electronic	2	32	85
F42SE	F40T12	Fluorescent, (2) 48", STD lamp	Mag-ES	2	40	86

Fixture Code	Lamp Code	Description	Ballast	Lamp/Fixture	Watt / Lamp	Watt / Fixture
F42GHL	F48T5/HO	Fluorescent, (2) 48", STD HO T5 lamp	Electronic	2	54	117
F42SHS	F48T12/HO	Fluorescent, (2) 48", STD HO lamp	Mag-STD	2	60	145
F42SIL	F48T12	Fluorescent, (2) 48", STD IS lamp, Electronic ballast	Electronic	2	39	74
F42SIS	F48T12	Fluorescent, (2) 48", STD IS lamp	Mag-STD	2	39	103
F42GL	F48T5	Fluorescent, (2) 48", STD T5 lamp	Electronic	2	28	63
F42SS	F40T12	Fluorescent, (2) 48", STD lamp	Mag-STD	2	40	94
F42SVS	F48T12/VHO	Fluorescent, (2) 48", STD VHO lamp	Mag-STD	2	110	242
F43EE	F40T12/ES	Fluorescent, (3) 48", ES lamp	Mag-ES	3	34	115
F43EHS	F48T12/HO/ES	Fluorescent, (3) 48", ES HO lamp (3.5' lamp)	Mag-STD	3	55	215
F43EIS	F48T12/ES	Fluorescent, (3) 48" ES Instant Start lamp. Magnetic ballast	Mag-STD	3	30	133
F43EL	F40T12/ES	Fluorescent, (3) 48", T12 ES lamps, Electronic Ballast	Electronic	3	34	92
F43ES	F40T12/ES	Fluorescent, (3) 48", ES lamp	Mag-STD	3	34	130
F43EVS	F48T12/VHO/ES	Fluorescent, (3) 48", VHO ES lamp	Mag-STD	3		333
F43IAL-R	F25T12	Fluorescent, (3) 48", F25T12 lamp, Instant Start Ballast, RLO (BF<0.85)	Electronic	3	25	60
F43ILL	F32T8	Fluorescent, (3) 48", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	3	32	89
F43SILL	F30T8	Fluorescent, (3) 48", Super T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	3	30	78
F43SILL-R	F30T8	Fluorescent, (3) 48", Super T-8 lamp, Instant Start Ballast, RLO (BF<0.85)	Electronic	3	30	70
F43SILL-H	F30T8	Fluorescent, (3) 48", Super T-8 lamp, Instant Start Ballast, HLO (BF:.96-3.3)	Electronic	3	30	105
F43SSILL	F28T8	Fluorescent, (3) 48", Super T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	3	28	72
F43SSILL-R	F28T8	Fluorescent, (3) 48", Super T-8 lamp, Instant Start Ballast, RLO (BF<0.85)	Electronic	3	28	66
F43SSILL-H	F28T8	Fluorescent, (3) 48", Super T-8 lamp, Instant Start Ballast, HLO (BF:.96-3.3)	Electronic	3	28	98
F43ILL/2	F32T8	Fluorescent, (3) 48", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95), (2) ballast	Electronic	3	32	90
F43ILL-H	F32T8	Fluorescent, (3) 48", T-8 lamp, Instant Start Ballast, HLO (BF:.96-1.1)	Electronic	3	32	93

Fixture Code	Lamp Code	Description	Ballast	Lamp/Fixture	Watt / Lamp	Watt / Fixture
F43ILL-R	F32T8	Fluorescent, (3) 48", T-8 lamp, Instant Start Ballast, RLO (BF<0.85)	Electronic	3	32	78
F43ILL-V	F32T8	Fluorescent, (3) 48", T-8 lamp, Instant Start Ballast, VHLO (BF>1.1)	Electronic	3	32	112
F43ILX-H	F32T8	Fluorescent, (3) 48", T-8 lamp, HE Instant/Program Start Ballast, HLO (BF:.96-1.1)	Electronic	3	32	90
F43ILX-R	F32T8	Fluorescent, (3) 48", T-8 lamp, HE Instant/Program Start Ballast, RLO (BF<0.85)	Electronic	3	32	73
F43ILX-R/2	F32T8	Fluorescent, (3) 48", T-8 lamp, HE Instant/Program Start Ballast, RLO (BF<0.85), (2) ballast	Electronic	3	32	73
F43LE	F32T8	Fluorescent, (3) 48", T-8 lamp	Mag-ES	3	32	110
F43LL	F32T8	Fluorescent, (3) 48", T-8 lamp, Rapid Start Ballast, NLO (BF: .85-.95)	Electronic	3	32	93
F43LL/2	F32T8	Fluorescent, (3) 48", T-8 lamp, Rapid Start Ballast, NLO (BF: .85-.95), (2) ballast	Electronic	3	32	92
F43LL-H	F32T8	Fluorescent, (3) 48", T-8 lamp, Rapid Start Ballast, HLO (BF:.96-1.1)	Electronic	3	32	98
F43LL-R	F32T8	Fluorescent, (3) 48", T-8 lamp, Rapid Start Ballast, RLO (BF<0.85)	Electronic	3	32	76
F43SE	F40T12	Fluorescent, (3) 48", STD lamp	Mag-ES	3	40	136
F43GHL	F48T5/HO	Fluorescent, (3) 48", STD HO T5 lamp	Electronic	3	54	177
F43SHS	F48T12/HO	Fluorescent, (3) 48", STD HO lamp	Mag-STD	3	60	230
F43SIL	F40T12	Fluorescent, (3) 48", STD IS lamp, Electronic ballast	Electronic	3	39	120
F43SIS	F48T12	Fluorescent, (3) 48", STD IS lamp	Mag-STD	3	39	162
F43SS	F40T12	Fluorescent, (3) 48", STD lamp	Mag-STD	3	40	151
F43SVS	F48T12/VHO	Fluorescent, (3) 48", STD VHO lamp	Mag-STD	3	110	377
F44EE	F40T12/ES	Fluorescent, (4) 48", ES lamp	Mag-ES	4	34	144
F44EE/D4	F40T12/ES	Fluorescent, (4) 48", ES lamp, 4 Ballasts (delamped)	Mag-ES	4	34	152
F44EHS	F48T12/HO/ES	Fluorescent, (4) 48", ES HO lamp	Mag-STD	4	55	270
F44EIS	F48T12/ES	Fluorescent, (4) 48" ES Instant Start lamp, Magnetic ballast	Mag-STD	4	30	164
F44EL	F40T12/ES	Fluorescent, (4) 48", T12 ES lamp, Electronic Ballast	Electronic	4	34	120

Fixture Code	Lamp Code	Description	Ballast	Lamp/Fixture	Watt / Lamp	Watt / Fixture
F44ES	F40T12/ES	Fluorescent, (4) 48", ES lamp	Mag-STD	4	34	160
F44EVS	F48T12/VHO/ES	Fluorescent, (4) 48", VHO ES lamp	Mag-STD	4		420
F44IAL-R	F25T12	Fluorescent, (4) 48", F25T12 lamp, Instant Start Ballast, RLO (BF<0.85)	Electronic	4	25	80
F44ILL	F32T8	Fluorescent, (4) 48", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	4	32	112
F44SILL	F30T8	Fluorescent, (4) 48", Super T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	4	30	105
F44SILL-R	F30T8	Fluorescent, (4) 48", Super T-8 lamp, Instant Start Ballast, RLO (BF<0.85)	Electronic	4	30	91
F44SILL-H	F30T8	Fluorescent, (4) 48", Super T-8 lamp, Instant Start Ballast, HLO (BF:.96-4.4)	Electronic	4	30	140
F44SSILL	F28T8	Fluorescent, (4) 48", Super T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	4	28	96
F44SSILL-R	F28T8	Fluorescent, (4) 48", Super T-8 lamp, Instant Start Ballast, RLO (BF<0.85)	Electronic	4	28	86
F44SSILL-H	F28T8	Fluorescent, (4) 48", Super T-8 lamp, Instant Start Ballast, HLO (BF:.96-4.4)	Electronic	4	28	131
F44ILL/2	F32T8	Fluorescent, (4) 48", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95), (2) ballast	Electronic	4	32	118
F44ILL-R	F32T8	Fluorescent, (4) 48", T-8 lamp, Instant Start Ballast, RLO (BF<0.85)	Electronic	4	32	102
F44ILX-R	F32T8	Fluorescent, (4) 48", T-8 lamp, HE Instant/Program Start Ballast, RLO (BF<0.85)	Electronic	4	32	96
F44ILX-R/2	F32T8	Fluorescent, (4) 48", T-8 lamp, HE Instant/Program Start Ballast, RLO (BF<0.85), (2) ballast	Electronic	4	32	96
F44LE	F32T8	Fluorescent, (4) 48", T-8 lamp	Mag-ES	4	32	142
F44LL	F32T8	Fluorescent, (4) 48", T-8 lamp, Rapid Start Ballast, NLO (BF: .85-.95)	Electronic	4	32	118
F44LL/2	F32T8	Fluorescent, (4) 48", T-8 lamp, Rapid Start Ballast, NLO (BF: .85-.95), (2) ballast	Electronic	4	32	120
F44LL-R	F32T8	Fluorescent, (4) 48", T-8 lamp, Rapid Start Ballast, RLO (BF<0.85)	Electronic	4	32	105
F44SE	F40T12	Fluorescent, (4) 48", STD lamp	Mag-ES	4	40	172
F44GHL	F48T5/HO	Fluorescent, (4) 48", STD HO T5 lamp	Electronic	4	54	234
F44SHS	F48T12/HO	Fluorescent, (4) 48", STD HO lamp	Mag-STD	4	60	290

Fixture Code	Lamp Code	Description	Ballast	Lamp/Fixture	Watt / Lamp	Watt / Fixture
F44SIL	F48T12	Fluorescent, (4) 48", STD IS lamp, Electronic ballast	Electronic	4	39	148
F44SIS	F48T12	Fluorescent, (4) 48", STD IS lamp	Mag-STD	4	39	204
F44SS	F40T12	Fluorescent, (4) 48", STD lamp	Mag-STD	4	40	188
F44SVS	F48T12/VHO	Fluorescent, (4) 48", STD VHO lamp	Mag-STD	4	110	484
F45ILL	F32T8	Fluorescent, (5) 48", T-8 lamp, (1) 3-lamp IS ballast and (1) 2-lamp IS ballast, NLO (BF: .85-.95)	Electronic	5	32	148
F45GHL	F48T5/HO	Fluorescent, (5) 48", STD HO T5 lamp	Electronic	5	54	294
F46EE	F40T12/ES	Fluorescent, (6) 48", ES lamp	Mag-ES	6	34	216
F46EL	F40T12/ES	Fluorescent, (6) 48", ES lamp	Electronic	6	34	186
F46ES	F40T12/ES	Fluorescent, (6) 48", ES lamp	Mag-STD	6	34	236
F46ILL	F32T8	Fluorescent, (6) 48", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	6	32	175
F46ILL-R	F32T8	Fluorescent, (6) 48", T-8 lamp, Instant Start Ballast, RLO (BF< .85)	Electronic	6	32	156
F46ILX-R	F32T8	Fluorescent, (6) 48", T-8 lamp, HE Instant/Program Start Ballast, RLO (BF< .85)	Electronic	6	32	146
F46LL	F32T8	Fluorescent, (6) 48", T-8 lamp, NLO (BF: .85-.95)	Electronic	6	32	182
F46GHL	F48T5/HO	Fluorescent, (6) 48", STD HO T5 lamp	Electronic	6	54	351
F46SE	F40T12	Fluorescent, (6) 48", STD lamp	Mag-ES	6	40	258
F46SS	F40T12	Fluorescent, (6) 48", STD lamp	Mag-STD	6	40	282
F48EE	F40T12/ES	Fluorescent, (8) 48", ES lamp	Mag-ES	8	34	288
F48ILL	F32T8	Fluorescent, (8) 48", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	8	32	224
F48ILL-R	F32T8	Fluorescent, (8) 48", T-8 lamp, Instant Start Ballast, RLO (BF<0.85)	Electronic	8	32	204
F48ILX-R	F32T8	Fluorescent, (8) 48", T-8 lamp, HE Instant/Program Start Ballast, RLO (BF<0.85)	Electronic	8	32	192
F48GHL	F48T5/HO	Fluorescent, (8) 48", STD HO T5 lamp	Electronic	8	54	468
F51ILHL	F60T12/HO	Fluorescent, (1) 60", T-8 HO lamp, Instant Start Ballast	Electronic	1	55	59
F51ILL	F40T8	Fluorescent, (1) 60", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	1	40	36

Fixture Code	Lamp Code	Description	Ballast	Lamp/Fixture	Watt / Lamp	Watt / Fixture
F51ILL/T2	F40T8	Fluorescent, (1) 60", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95), Tandem 2 Lamp Ballast	Electronic	1	40	36
F51ILL/T3	F40T8	Fluorescent, (1) 60", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95), Tandem 3 Lamp Ballast	Electronic	1	40	35
F51ILL/T4	F40T8	Fluorescent, (1) 60", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95), Tandem 4 Lamp Ballast	Electronic	1	40	34
F51ILL-R	F40T8	Fluorescent, (1) 60", T-8 lamp, Instant Start Ballast, RLO (BF<0.85)	Electronic	1	40	43
F51SHE	F60T12/HO	Fluorescent, (1) 60", STD HO lamp	Mag-ES	1	75	88
F51SHL	F60T12/HO	Fluorescent, (1) 60", STD HO lamp	Electronic	1	75	69
F51GHL	F60T5/HO	Fluorescent, (1) 60", STD HO T5 lamp	Electronic	1	80	89
F51SHS	F60T12/HO	Fluorescent, (1) 60", STD HO lamp	Mag-STD	1	75	92
F51SL	F60T12	Fluorescent, (1) 60", STD lamp	Electronic	1	50	44
F51GL	F60T5	Fluorescent, (1) 60", STD T5 lamp	Electronic	1	35	39
F51SS	F60T12	Fluorescent, (1) 60", STD lamp	Mag-STD	1	50	63
F51SVS	F60T12/VHO	Fluorescent, (1) 60", VHO ES lamp	Mag-STD	1	135	165
F52ILHL	F60T12/HO	Fluorescent, (2) 60", T-8 HO lamp, Instant Start Ballast	Electronic	2	55	123
F52ILL	F40T8	Fluorescent, (2) 60", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	2	40	72
F52ILL/T4	F40T8	Fluorescent, (2) 60", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95), Tandem 2 Lamp Ballast	Electronic	2	40	67
F52ILL-H	F40T8	Fluorescent, (2) 60", T-8 lamp, Instant Start Ballast, HLO (BF:.96-1.1)	Electronic	2	40	80
F52ILL-R	F40T8	Fluorescent, (2) 60", T-8 lamp, Instant Start Ballast, RLO (BF<0.85)	Electronic	2	40	73
F52SHE	F60T12/HO	Fluorescent, (2) 60", STD HO lamp	Mag-ES	2	75	176
F52SHL	F60T12/HO	Fluorescent, (2) 60", STD HO lamp	Electronic	2	75	138
F52GHL	F60T5/HO	Fluorescent, (2) 60", STD HO T5 lamp	Electronic	2	49	106
F52SHS	F60T12/HO	Fluorescent, (2) 60", STD HO lamp	Mag-STD	2	75	168
F52SL	F60T12	Fluorescent, (2) 60", STD lamp	Electronic	2	50	88
F52GL	F60T5	Fluorescent, (2) 60", STD T5 lamp	Electronic	2	35	76
F52SS	F60T12	Fluorescent, (2) 60", STD lamp	Mag-STD	2	50	128

Fixture Code	Lamp Code	Description	Ballast	Lamp/Fixture	Watt / Lamp	Watt / Fixture
F52SVS	F60T12/VHO	Fluorescent, (2) 60", VHO ES lamp	Mag-STD	2	135	310
F53ILL	F40T8	Fluorescent, (3) 60", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	3	40	106
F53ILL-H	F40T8	Fluorescent, (3) 60", T-8 lamp, Instant Start Ballast, HLO (BF:.96-1.1)	Electronic	3	40	108
F54ILL	F40T8	Fluorescent, (4) 60", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	4	40	134
F54ILL-H	F40T8	Fluorescent, (4) 60", T-8 lamp, Instant Start Ballast, HLO (BF:.96-1.1)	Electronic	4	40	126
F61ISL	F72T12	Fluorescent, (1) 72", STD lamp, IS electronic ballast	Electronic	1	55	68
F61SE	F72T12	Fluorescent, (1) 72", STD lamp	Mag-ES	1	55	76
F61SHS	F72T12/HO	Fluorescent, (1) 72", STD HO lamp	Mag-STD	1	85	120
F61SS	F72T12	Fluorescent, (1) 72", STD lamp	Mag-STD	1	55	90
F61SVS	F72T12/VHO	Fluorescent, (1) 72", VHO lamp	Mag-STD	1	160	180
F62ILHL	F72T8	Fluorescent, (2) 72", T-8 HO lamp, Instant Start Ballast	Electronic	2	65	147
F62ISL	F72T12	Fluorescent, (2) 72", STD lamp, IS electronic ballast	Electronic	2	55	108
F62SE	F72T12	Fluorescent, (2) 72", STD lamp	Mag-ES	2	55	122
F62SHE	F72T12/HO	Fluorescent, (2) 72", STD HO lamp	Mag-ES	2	85	194
F62SHS	F72T12/HO	Fluorescent, (2) 72", STD HO lamp	Mag-STD	2	85	220
F62SL	F72T12	Fluorescent, (2) 72", STD lamp	Electronic	2	55	108
F62SS	F72T12	Fluorescent, (2) 72", STD lamp	Mag-STD	2	55	145
F62SVS	F72T12/VHO	Fluorescent, (2) 72", VHO lamp	Mag-STD	2	160	330
F63ISL	F72T12	Fluorescent, (3) 72", STD lamp, IS electronic ballast	Electronic	3	55	176
F63SS	F72T12	Fluorescent, (3) 72", STD lamp	Mag-STD	3	55	202
F64ISL	F72T12	Fluorescent, (4) 72", STD lamp, IS electronic ballast	Electronic	4	55	216
F64SE	F72T12	Fluorescent, (4) 72", STD lamp	Mag-ES	4	55	230
F64SHE	F72T12/HO	Fluorescent, (4) 72", STD HO lamp	Mag-ES	4	85	388
F64SS	F72T12	Fluorescent, (4) 72", STD lamp	Mag-STD	4	55	244
F81EE/T2	F96T12/ES	Fluorescent, (1) 96", ES lamp, tandem to 2-lamp ballast	Mag-ES	1	60	62
F81EHL	F96T12/HO/ES	Fluorescent, (1) 96", ES HO lamp	Electronic	1	95	80

Fixture Code	Lamp Code	Description	Ballast	Lamp/Fixture	Watt / Lamp	Watt / Fixture
F81EHL/T2	F96T12/HO/ES	Fluorescent, (1) 96", ES HO lamp, Rapid Start Ballast, NLO (BF: .85-.95), Tandem 2 Lamp Ballast	Electronic	1	95	85
F81EHS	F96T12/HO/ES	Fluorescent, (1) 96", ES HO lamp	Mag-STD	1	95	125
F81EL	F96T12/ES	Fluorescent, (1) 96", ES lamp	Electronic	1	60	60
F81EL/T2	F96T12/ES	Fluorescent, (1) 96", ES lamp, Rapid Start Ballast, NLO (BF: .85-.95), Tandem 2 Lamp Ballast	Electronic	1	60	55
F81ES	F96T12/ES	Fluorescent, (1) 96", ES lamp	Mag-STD	1	60	83
F81ES/T2	F96T12/ES	Fluorescent, (1) 96", ES lamp, tandem to 2-lamp ballast	Mag-STD	1	60	64
F81EVS	F96T12/VHO/ES	Fluorescent, (1) 96", ES VHO lamp	Mag-STD	1	185	200
F81ILL	F96T8	Fluorescent, (1) 96", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	1	59	58
F81ILL/T2	F96T8	Fluorescent, (1) 96", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95), Tandem 2 Lamp Ballast	Electronic	1	59	55
F81ILL/T2-R	F96T8	Fluorescent, (1) 96", T-8 lamp, Instant Start Ballast, RLO (BF<.85), Tandem 2 Lamp Ballast	Electronic	1	59	49
F81ILL-H	F96T8	Fluorescent, (1) 96", T-8 lamp, Instant Start Ballast, HLO (BF:.96-1.1)	Electronic	1	59	68
F81ILL-R	F96T8	Fluorescent, (1) 96", T-8 lamp, Instant Start Ballast, RLO (BF<0.85)	Electronic	1	59	57
F81ILL-V	F96T8	Fluorescent, (1) 96", T-8 lamp, Instant Start Ballast, VHLO (BF>1.1)	Electronic	1	59	71
F81LHL	F96T8/HO	Fluorescent, (1) 96", T8 HO lamp	Electronic	1	86	85
F81LHL/T2	F96T8/HO	Fluorescent, (1) 96", T8 HO lamp, tandem wired to 2-lamp ballast	Electronic	1	86	80
F81SE	F96T12	Fluorescent, (1) 96", STD lamp	Mag-ES	1	75	91
F81EHS	F96T12/HO	Fluorescent, (1) 96", ES HO lamp	Mag-STD	1	95	125
F81SHE	F96T12/HO	Fluorescent, (1) 96", STD HO lamp	Mag-ES	1	110	132
F81SHL/T2	F96T12/HO	Fluorescent, (1) 96", STD HO lamp, Rapid Start Ballast, NLO (BF: .85-.95), Tandem 2 Lamp Ballast	Electronic	1	110	98
F81SHS	F96T12/HO	Fluorescent, (1) 96", STD HO lamp	Mag-STD	1	110	145

Fixture Code	Lamp Code	Description	Ballast	Lamp/Fixture	Watt / Lamp	Watt / Fixture
F81SL	F96T12	Fluorescent, (1) 96", STD lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	1	75	70
F81SL/T2	F96T12	Fluorescent, (1) 96", STD lamp, Rapid Start Ballast, NLO (BF: .85-.95), Tandem 2 Lamp Ballast	Electronic	1	75	67
F81SS	F96T12	Fluorescent, (1) 96", STD lamp	Mag-STD	1	75	100
F81SVS	F96T12/VHO	Fluorescent, (1) 96", STD VHO lamp	Mag-STD	1	215	230
F82EE	F96T12/ES	Fluorescent, (2) 96", ES lamp	Mag-ES	2	60	123
F82EHE	F96T12/HO/ES	Fluorescent, (2) 96", ES HO lamp	Mag-ES	2	95	207
F82EHL	F96T12/HO/ES	Fluorescent, (2) 96", ES HO lamp	Electronic	2	95	170
F82EHS	F96T12/HO/ES	Fluorescent, (2) 96", ES HO lamp	Mag-STD	2	95	227
F82EL	F96T12/ES	Fluorescent, (2) 96", ES lamp	Electronic	2	60	110
F82ES	F96T12/ES	Fluorescent, (2) 96", ES lamp	Mag-STD	2	60	138
F82EVS	F96T12/VHO/ES	Fluorescent, (2) 96", ES VHO lamp	Mag-STD	2	185	390
F82ILL	F96T8	Fluorescent, (2) 96", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	2	59	109
F82ILL-R	F96T8	Fluorescent, (2) 96", T-8 lamp, Instant Start Ballast, RLO (BF<0.85)	Electronic	2	59	98
F82LHL	F96T8/HO	Fluorescent, (2) 96", T8 HO lamp	Electronic	2	86	160
F82SE	F96T12	Fluorescent, (2) 96", STD lamp	Mag-ES	2	75	158
F82SHE	F96T12/HO	Fluorescent, (2) 96", STD HO lamp	Mag-ES	2	110	237
F82SHL	F96T12/HO	Fluorescent, (2) 96", STD HO lamp	Electronic	2	110	195
F82SHS	F96T12/HO	Fluorescent, (2) 96", STD HO lamp	Mag-STD	2	110	257
F82SL	F96T12	Fluorescent, (2) 96", STD lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	2	75	134
F82SS	F96T12	Fluorescent, (2) 96", STD lamp	Mag-STD	2	75	173
F82SVS	F96T12/VHO	Fluorescent, (2) 96", STD VHO lamp	Mag-STD	2	215	450
F83EE	F96T12/ES	Fluorescent, (3) 96", ES lamp	Mag-ES	3	60	210
F83EHE	F96T12/HO/ES	Fluorescent, (3) 96", ES HO lamp, (1) 2-lamp ES Ballast, (1) 1-lamp STD Ballast	Mag-ES/STD	3	95	319
F83EHS	F96T12/HO/ES	Fluorescent, (3) 96", ES HO lamp	Mag-STD	3	95	352
F83EL	F96T12/ES	Fluorescent, (3) 96", ES lamp	Electronic	3	60	179
F83ES	F96T12/ES	Fluorescent, (3) 96", ES lamp	Mag-STD	3	60	221
F83EVS	F96T12/VHO/ES	Fluorescent, (3) 96", ES VHO lamp	Mag-STD	3	185	590
F83ILL	F96T8	Fluorescent, (3) 96", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	3	59	167
F83SHS	F96T12/HO	Fluorescent, (3) 96", STD HO lamp	Mag-STD	3	110	392

Fixture Code	Lamp Code	Description	Ballast	Lamp/Fixture	Watt / Lamp	Watt / Fixture
F83SS	F96T12	Fluorescent, (3) 96", STD lamp	Mag-STD	3	75	273
F83SVS	F96T12/VHO	Fluorescent, (3) 96", STD VHO lamp	Mag-STD	3	215	680
F84EE	F96T12/ES	Fluorescent, (4) 96", ES lamp	Mag-ES	4	60	246
F84EHE	F96T12/HO/ES	Fluorescent, (4) 96", ES HO lamp	Mag-ES	4	95	414
F84EHL	F96T12/HO/ES	Fluorescent, (4) 96", ES HO lamp	Electronic	4	95	340
F84EHS	F96T12/HO/ES	Fluorescent, (4) 96", ES HO lamp	Mag-STD	4	95	454
F84EL	F96T12/ES	Fluorescent, (4) 96", ES lamp	Electronic	4	60	220
F84ES	F96T12/ES	Fluorescent, (4) 96", ES lamp	Mag-STD	4	60	276
F84EVS	F96T12/VHO/ES	Fluorescent, (4) 96", ES VHO lamp	Mag-STD	4	185	780
F84ILL	F96T8	Fluorescent, (4) 96", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	4	59	219
F84LHL	F96T8/HO	Fluorescent, (4) 96", T8 HO lamp	Electronic	4	86	320
F84SE	F96T12	Fluorescent, (4) 96", STD lamp	Mag-ES	4	75	316
F84SHE	F96T12/HO	Fluorescent, (4) 96", STD HO lamp	Mag-ES	4	110	474
F84SHL	F96T12/HO	Fluorescent, (3) 96", STD HO lamp	Electronic	4	110	390
F84SHS	F96T12/HO	Fluorescent, (4) 96", STD HO lamp	Mag-STD	4	110	514
F84SL	F96T12	Fluorescent, (4) 96", STD lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	4	75	268
F84SS	F96T12	Fluorescent, (4) 96", STD lamp	Mag-STD	4	75	346
F84SVS	F96T12/VHO	Fluorescent, (4) 96", STD VHO lamp	Mag-STD	4	215	900
F86EHS	F96T12/HO/ES	Fluorescent, (6) 96", ES HO lamp	Mag-STD	6	95	721
F86ILL	F96T8	Fluorescent, (6) 96", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	6	59	328
CIRCLINE FLUORESCENT FIXTURES						
FC12/1	FC12T9	Fluorescent, (1) 12" circular lamp, RS ballast	Mag-STD	1	32	31
FC12/2	FC12T9	Fluorescent, (2) 12" circular lamp, RS ballast	Mag-STD	2	32	62
FC16/1	FC16T9	Fluorescent, (1) 16" circular lamp	Mag-STD	1	40	35
FC20	FC6T9	Fluorescent, Circline, (1) 20W lamp, Preheat ballast	Mag-STD	1	20	20
FC22/1	FC8T9	Fluorescent, Circline, (1) 22W lamp, preheat ballast	Mag-STD	1	22	20
FC22/32/1	FC22/32T9	Fluorescent, Circline, (1) 22W/32W lamp, preheat ballast	Mag-STD	1	22/32	58
FC32/1	FC12T9	Fluorescent, Circline, (1) 32W lamp, preheat ballast	Mag-STD	1	32	40

Fixture Code	Lamp Code	Description	Ballast	Lamp/Fixture	Watt / Lamp	Watt / Fixture
FC32/40/1	FC32/40T9	Fluorescent, Circline, (1) 32W/40W lamp, preheat ballast	Mag-STD	1	32/40	80
FC40/1	FC16T9	Fluorescent, Circline, (1) 32W lamp, preheat ballast	Mag-STD	1	32	42
FC44/1	FC44T9	Fluorescent, Circline, (1) 44W lamp, preheat ballast	Mag-STD	1	44	46
FC6/1	FC6T9	Fluorescent, (1) 6" circular lamp, RS ballast	Mag-STD	1	20	25
FC8/1	FC8T9	Fluorescent, (1) 8" circular lamp, RS ballast	Mag-STD	1	22	26
FC8/2	FC8T9	Fluorescent, (2) 8" circular lamp, RS ballast	Mag-STD	2	22	52
U-TUBE FLUORESCENT FIXTURES						
FU1EE	FU40T12/ES	Fluorescent, (1) U-Tube, ES lamp	Mag-ES	1	34	43
FU1ILL	FU31T8/6	Fluorescent, (1) U-Tube, T-8 lamp, Instant Start ballast	Electronic	1	32	31
FU1LL	FU31T8/6	Fluorescent, (1) U-Tube, T-8 lamp	Electronic	1	32	32
FU1LL-R	FU31T8/6	Fluorescent, (1) U-Tube, T-8 lamp, RLO (BF<0.85)	Electronic	1	31	27
FU1ILX-R	FU31T8/6	Fluorescent, (1) U-Tube, T-8 lamp, HE Instant/Program Start Ballast RLO (BF<0.85)	Electronic	1	31	25
FU2SS	FU40T12	Fluorescent, (2) U-Tube, STD lamp	Mag-STD	2	40	96
FU2SE	FU40T12	Fluorescent, (2) U-Tube, STD lamp	Mag-ES	2	40	85
FU2EE	FU40T12/ES	Fluorescent, (2) U-Tube, ES lamp	Mag-ES	2	34	72
FU2ES	FU40T12/ES	Fluorescent, (2) U-Tube, ES lamp	Mag-STD	2	34	82
FU2ILL	FU31T8/6	Fluorescent, (2) U-Tube, T-8 lamp, Instant Start Ballast	Electronic	2	32	59
FU2ILL/T4	FU31T8/6	Fluorescent, (2) U-Tube, T-8 lamp, Instant Start Ballast, tandem wired	Electronic	2	32	56
FU2ILL/T4-R	FU31T8/6	Fluorescent, (2) U-Tube, T-8 lamp, Instant Start Ballast, RLO, tandem wired	Electronic	2	32	51
FU2ILL-H	FU31T8/6	Fluorescent, (2) U-Tube, T-8 lamp, Instant Start HLO Ballast	Electronic	2	32	65
FU2ILL-R	FU31T8/6	Fluorescent, (2) U-Tube, T-8 lamp, Instant Start RLO Ballast	Electronic	2	32	52
FU2ILX-R	FU31T8/6	Fluorescent, (2) U-Tube, T-8 lamp, HE Instant/Program Start Ballast RLO (BF<0.85)	Electronic	2	31	48
FU2LL	FU31T8/6	Fluorescent, (2) U-Tube, T-8 lamp	Electronic	2	32	60

Fixture Code	Lamp Code	Description	Ballast	Lamp/Fixture	Watt / Lamp	Watt / Fixture
FU2LL/T2	FU31T8/6	Fluorescent, (2) U-Tube, T-8 lamp, Tandem 4 lamp ballast	Electronic	2	32	59
FU2LL-R	FU31T8/6	Fluorescent, (2) U-Tube, T-8 lamp, RLO (BF<0.85)	Electronic	54	31	54
FU3EE	FU40T12/ES	Fluorescent, (3) U-Tube, ES lamp	Mag-ES	3	35	115
FU3ILL	FU31T8/6	Fluorescent, (3) U-Tube, T-8 lamp, Instant Start Ballast	Electronic	3	32	89
FU3ILL-R	FU31T8/6	Fluorescent, (3) U-Tube, T-8 lamp, Instant Start RLO Ballast	Electronic	3	32	78
STANDARD INCANDESCENT FIXTURES						
I100/1	I100	Incandescent, (1) 100W lamp	N/A	1	100	100
I100/2	I100	Incandescent, (2) 100W lamp	N/A	2	100	200
I100/3	I100	Incandescent, (3) 100W lamp	N/A	3	100	300
I100/4	I100	Incandescent, (4) 100W lamp	N/A	4	100	400
I100/5	I100	Incandescent, (5) 100W lamp	N/A	5	100	500
I1000/1	I1000	Incandescent, (1) 1000W lamp	N/A	1	1000	1000
I100E/1	I100/ES	Incandescent, (1) 100W ES lamp	N/A	1	90	90
I100EL/1	I100/ES/LL	Incandescent, (1) 100W ES/LL lamp	N/A	1	90	90
I120/1	I120	Incandescent, (1) 120W lamp	N/A	1	120	120
I120/2	I120	Incandescent, (2) 120W lamp	N/A	2	120	240
I125/1	I125	Incandescent, (1) 125W lamp	N/A	1	125	125
I135/1	I135	Incandescent, (1) 135W lamp	N/A	1	135	135
I135/2	I135	Incandescent, (2) 135W lamp	N/A	2	135	270
I15/1	I15	Incandescent, (1) 15W lamp	N/A	1	15	15
I15/2	I15	Incandescent, (2) 15W lamp	N/A	2	15	30
I150/1	I150	Incandescent, (1) 150W lamp	N/A	1	150	150
I150/2	I150	Incandescent, (2) 150W lamp	N/A	2	150	300
I1500/1	I1500	Incandescent, (1) 1500W lamp	N/A	1	1500	1500
I150E/1	I150/ES	Incandescent, (1) 150W ES lamp	N/A	1	135	135
I150EL/1	I150/ES/LL	Incandescent, (1) 150W ES/LL lamp	N/A	1	135	135
I170/1	I170	Incandescent, (1) 170W lamp	N/A	1	170	170
I20/1	I20	Incandescent, (1) 20W lamp	N/A	1	20	20
I20/2	I20	Incandescent, (2) 20W lamp	N/A	2	20	40
I200/1	I200	Incandescent, (1) 200W lamp	N/A	1	200	200
I200/2	I200	Incandescent, (2) 200W lamp	N/A	2	200	400
I2000/1	I2000	Incandescent, (1) 2000W lamp	N/A	1	2000	2000

Fixture Code	Lamp Code	Description	Ballast	Lamp/Fixture	Watt / Lamp	Watt / Fixture
I200L/1	I200/LL	Incandescent, (1) 200W LL lamp	N/A	1	200	200
I25/1	I25	Incandescent, (1) 25W lamp	N/A	1	25	25
I25/2	I25	Incandescent, (2) 25W lamp	N/A	2	25	50
I25/4	I25	Incandescent, (4) 25W lamp	N/A	4	25	100
I250/1	I250	Incandescent, (1) 250W lamp	N/A	1	250	250
I300/1	I300	Incandescent, (1) 300W lamp	N/A	1	300	300
I34/1	I34	Incandescent, (1) 34W lamp	N/A	1	34	34
I34/2	I34	Incandescent, (2) 34W lamp	N/A	2	34	68
I36/1	I36	Incandescent, (1) 36W lamp	N/A	1	36	36
I40/1	I40	Incandescent, (1) 40W lamp	N/A	1	40	40
I40/2	I40	Incandescent, (2) 40W lamp	N/A	2	40	80
I400/1	I400	Incandescent, (1) 400W lamp	N/A	1	400	400
I40E/1	I40/ES	Incandescent, (1) 40W ES lamp	N/A	1	34	34
I40EL/1	I40/ES/LL	Incandescent, (1) 40W ES/LL lamp	N/A	1	34	34
I42/1	I42	Incandescent, (1) 42W lamp	N/A	1	42	42
I448/1	I448	Incandescent, (1) 448W lamp	N/A	1	448	448
I45/1	I45	Incandescent, (1) 45W lamp	N/A	1	45	45
I50/1	I50	Incandescent, (1) 50W lamp	N/A	1	50	50
I50/2	I50	Incandescent, (2) 50W lamp	N/A	2	50	100
I500/1	I500	Incandescent, (1) 500W lamp	N/A	1	500	500
I52/1	I52	Incandescent, (1) 52W lamp	N/A	1	52	52
I52/2	I52	Incandescent, (2) 52W lamp	N/A	2	52	104
I54/1	I54	Incandescent, (1) 54W lamp	N/A	1	54	54
I54/2	I54	Incandescent, (2) 54W lamp	N/A	2	54	108
I55/1	I55	Incandescent, (1) 55W lamp	N/A	1	55	55
I55/2	I55	Incandescent, (2) 55W lamp	N/A	2	55	110
I60/1	I60	Incandescent, (1) 60W lamp	N/A	1	60	60
I60/2	I60	Incandescent, (2) 60W lamp	N/A	2	60	120
I60/3	I60	Incandescent, (3) 60W lamp	N/A	3	60	180
I60/4	I60	Incandescent, (4) 60W lamp	N/A	4	60	240
I60/5	I60	Incandescent, (5) 60W lamp	N/A	5	60	300
I60E/1	I60/ES	Incandescent, (1) 60W ES lamp	N/A	1	52	52
I60EL/1	I60/ES/LL	Incandescent, (1) 60W ES/LL lamp	N/A	1	52	52
I65/1	I65	Incandescent, (1) 65W lamp	N/A	1	65	65
I65/2	I65	Incandescent, (2) 65W lamp	N/A	2	65	130
I67/1	I67	Incandescent, (1) 67W lamp	N/A	1	67	67
I67/2	I67	Incandescent, (2) 67W lamp	N/A	2	67	134

Fixture Code	Lamp Code	Description	Ballast	Lamp/Fixture	Watt / Lamp	Watt / Fixture
I67/3	I67	Incandescent, (3) 67W lamp	N/A	3	67	201
I69/1	I69	Incandescent, (1) 69W lamp	N/A	1	69	69
I7.5/1	I7.5	Tungsten exit light, (1) 7.5 W lamp, used in night light application	N/A	1	7.5	8
I7.5/2	I7.5	Tungsten exit light, (2) 7.5 W lamp, used in night light application	N/A	2	7.5	15
I72/1	I72	Incandescent, (1) 72W lamp	N/A	1	72	72
I75/1	I75	Incandescent, (1) 75W lamp	N/A	1	75	75
I75/2	I75	Incandescent, (2) 75W lamp	N/A	2	75	150
I75/3	I75	Incandescent, (3) 75W lamp	N/A	3	75	225
I75/4	I75	Incandescent, (4) 75W lamp	N/A	4	75	300
I750/1	I750	Incandescent, (1) 750W lamp	N/A	1	750	750
I75E/1	I75/ES	Incandescent, (1) 75W ES lamp	N/A	1	67	67
I75EL/1	I75/ES/LL	Incandescent, (1) 75W ES/LL lamp	N/A	1	67	67
I80/1	I80	Incandescent, (1) 80W lamp	N/A	1	80	80
I85/1	I85	Incandescent, (1) 85W lamp	N/A	1	85	85
I90/1	I90	Incandescent, (1) 90W lamp	N/A	1	90	90
I90/2	I90	Incandescent, (2) 90W lamp	N/A	2	90	180
I90/3	I90	Incandescent, (3) 90W lamp	N/A	3	90	270
I93/1	I93	Incandescent, (1) 93W lamp	N/A	1	93	93
I95/1	I95	Incandescent, (1) 95W lamp	N/A	1	95	95
I95/2	I95	Incandescent, (2) 95W lamp	N/A	2	95	190
HALOGEN INCANDESCENT FIXTURES						
H100/1	H100	Halogen Incandescent, (1) 100W lamp	N/A	1	100	100
H1000/1	H1000	Halogen Incandescent, (1) 1000W lamp	N/A	1	1000	1000
H1200/1	H1200	Halogen Incandescent, (1) 1200W lamp	N/A	1	1200	1200
H150/1	H150	Halogen Incandescent, (1) 150W lamp	N/A	1	150	150
H150/2	H150	Halogen Incandescent, (2) 150W lamp	N/A	2	150	300
H1500/1	H1500	Halogen Incandescent, (1) 1500W lamp	N/A	1	1500	1500
H200/1	H200	Halogen Incandescent, (1) 200W lamp	N/A	1	200	200
H250/1	H250	Halogen Incandescent, (1) 250W lamp	N/A	1	250	250
H300/1	H300	Halogen Incandescent, (1) 300W lamp	N/A	1	300	300
H35/1	H35	Halogen Incandescent, (1) 35W lamp	N/A	1	35	35
H350/1	H350	Halogen Incandescent, (1) 350W lamp	N/A	1	350	350
H40/1	H40	Halogen Incandescent, (1) 40W lamp	N/A	1	40	40
H400/1	H400	Halogen Incandescent, (1) 400W lamp	N/A	1	400	400

Fixture Code	Lamp Code	Description	Ballast	Lamp/Fixture	Watt / Lamp	Watt / Fixture
H42/1	H42	Halogen Incandescent, (1) 42W lamp	N/A	1	42	42
H425/1	H425	Halogen Incandescent, (1) 425W lamp	N/A	1	425	425
H45/1	H45	Halogen Incandescent, (1) 45W lamp	N/A	1	45	45
H45/2	H45	Halogen Incandescent, (2) 45W lamp	N/A	2	45	90
H50/1	H50	Halogen Incandescent, (1) 50W lamp	N/A	1	50	50
H50/2	H50	Halogen Incandescent, (2) 50W lamp	N/A	2	50	100
H500/1	H500	Halogen Incandescent, (1) 500W lamp	N/A	1	500	500
H52/1	H52	Halogen Incandescent, (1) 52W lamp	N/A	1	52	52
H55/1	H55	Halogen Incandescent, (1) 55W lamp	N/A	1	55	55
H55/2	H55	Halogen Incandescent, (2) 55W lamp	N/A	2	55	110
H60/1	H60	Halogen Incandescent, (1) 60W lamp	N/A	1	60	60
H72/1	H72	Halogen Incandescent, (1) 72W lamp	N/A	1	72	72
H75/1	H75	Halogen Incandescent, (1) 75W lamp	N/A	1	75	75
H75/2	H75	Halogen Incandescent, (2) 75W lamp	N/A	2	75	150
H750/1	H750	Halogen Incandescent, (1) 750W lamp	N/A	1	750	750
H90/1	H90	Halogen Incandescent, (1) 90W lamp	N/A	1	90	90
H90/2	H90	Halogen Incandescent, (2) 90W lamp	N/A	2	90	180
H900/1	H900	Halogen Incandescent, (1) 900W lamp	N/A	1	900	900
HLV20/1	H20/LV	Halogen Low Voltage Incandescent, (1) 20W lamp	N/A	1	20	30
HLV25/1	H25/LV	Halogen Low Voltage Incandescent, (1) 25W lamp	N/A	1	25	35
HLV35/1	H35/LV	Halogen Low Voltage Incandescent, (1) 35W lamp	N/A	1	35	45
HLV42/1	H42/LV	Halogen Low Voltage Incandescent, (1) 42W lamp	N/A	1	42	52
HLV50/1	H50/LV	Halogen Low Voltage Incandescent, (1) 50W lamp	N/A	1	50	60
HLV65/1	H65/LV	Halogen Low Voltage Incandescent, (1) 65W lamp	N/A	1	65	75
HLV75/1	H75/LV	Halogen Low Voltage Incandescent, (1) 75W lamp	N/A	1	75	85
QL INDUCTION FIXTURES						
QL55/1	QL55	QL Induction, (1) 55W lamp	Generator	1	55	55
QL85/1	QL85	QL Induction, (1) 85W lamp	Generator	1	85	85
QL165/1	QL165	QL Induction, (1) 165W lamp	Generator	1	165	165

Fixture Code	Lamp Code	Description	Ballast	Lamp/Fixture	Watt / Lamp	Watt / Fixture
HIGH PRESSURE SODIUM FIXTURES						
HPS100/1	HPS100	High Pressure Sodium, (1) 100W lamp	CWA	1	100	138
HPS1000/1	HPS1000	High Pressure Sodium, (1) 1000W lamp	CWA	1	1000	1100
HPS150/1	HPS150	High Pressure Sodium, (1) 150W lamp	CWA	1	150	188
HPS200/1	HPS200	High Pressure Sodium, (1) 200W lamp	CWA	1	200	250
HPS225/1	HPS225	High Pressure Sodium, (1) 225W lamp	CWA	1	225	275
HPS250/1	HPS250	High Pressure Sodium, (1) 250W lamp	CWA	1	250	295
HPS310/1	HPS310	High Pressure Sodium, (1) 310W lamp	CWA	1	310	365
HPS35/1	HPS35	High Pressure Sodium, (1) 35W lamp	CWA	1	35	46
HPS360/1	HPS360	High Pressure Sodium, (1) 360W lamp	CWA	1	360	414
HPS400/1	HPS400	High Pressure Sodium, (1) 400W lamp	CWA	1	400	465
HPS50/1	HPS50	High Pressure Sodium, (1) 50W lamp	CWA	1	50	66
HPS600/1	HPS600	High Pressure Sodium, (1) 600W lamp	CWA	1	600	675
HPS70/1	HPS70	High Pressure Sodium, (1) 70W lamp	CWA	1	70	95
HPS750/1	HPS750	High Pressure Sodium, (1) 750W lamp	CWA	1	750	835
METAL HALIDE FIXTURES						
MH100/1	MH100	Metal Halide, (1) 100W lamp	CWA	1	100	128
MH1000/1	MH1000	Metal Halide, (1) 1000W lamp	CWA	1	1000	1080
MH150/1	MH150	Metal Halide, (1) 150W lamp	CWA	1	150	190
MH1500/1	MH1500	Metal Halide, (1) 1500W lamp	CWA	1	1500	1610
MH175/1	MH175	Metal Halide, (1) 175W lamp	CWA	1	175	215
MH1800/1	MH1800	Metal Halide, (1) 1800W lamp	CWA	1	1800	1875
MH200/1	MH200	Metal Halide, (1) 200W lamp	CWA	1	200	232
MH250/1	MH250	Metal Halide, (1) 250W lamp	CWA	1	250	295
MH32/1	MH32	Metal Halide, (1) 32W lamp	CWA	1	32	43
MH300/1	MH300	Metal Halide, (1) 300W lamp	CWA	1	300	342
MH320/1	MH320	Metal Halide, (1) 320W lamp	CWA	1	320	365
MH350/1	MH350	Metal Halide, (1) 350W lamp	CWA	1	350	400
MH360/1	MH360	Metal Halide, (1) 360W lamp	CWA	1	360	430
MH400/1	MH400	Metal Halide, (1) 400W lamp	CWA	1	400	458
MH400/2	MH400	Metal Halide, (2) 400W lamp	CWA	2	400	916
MH450/1	MH450	Metal Halide, (1) 450W lamp	CWA	1	450	508
MH35/1	MH35	Metal Halide, (1) 35W lamp	CWA	1	35	44
MH50/1	MH50	Metal Halide, (1) 50W lamp	CWA	1	50	72
MH70/1	MH70	Metal Halide, (1) 70W lamp	CWA	1	70	95

Fixture Code	Lamp Code	Description	Ballast	Lamp/Fixture	Watt / Lamp	Watt / Fixture
MH750/1	MH750	Metal Halide, (1) 750W lamp	CWA	1	750	850
MHPS/LR/100/1	MHPS100	Metal Halide Pulse Start, (1) 100W lamp w/ Linear Reactor Ballast	LR	1	100	118
MHPS/LR/150/1	MHPS150	Metal Halide Pulse Start, (1) 150W lamp w/ Linear Reactor Ballast	LR	1	150	170
MHPS/LR/175/1	MHPS175	Metal Halide Pulse Start, (1) 175W lamp w/ Linear Reactor Ballast	LR	1	175	194
MHPS/LR/200/1	MHPS200	Metal Halide Pulse Start, (1) 200W lamp w/ Linear Reactor Ballast	LR	1	200	219
MHPS/LR/250/1	MHPS250	Metal Halide Pulse Start, (1) 250W lamp w/ Linear Reactor Ballast	LR	1	250	275
MHPS/LR/300/1	MHPS300	Metal Halide Pulse Start, (1) 300W lamp w/ Linear Reactor Ballast	LR	1	300	324
MHPS/LR/320/1	MHPS320	Metal Halide Pulse Start, (1) 320W lamp w/ Linear Reactor Ballast	LR	1	320	349
MHPS/LR/350/1	MHPS350	Metal Halide Pulse Start, (1) 350W lamp w/ Linear Reactor Ballast	LR	1	350	380
MHPS/LR/400/1	MHPS400	Metal Halide Pulse Start, (1) 400W lamp w/ Linear Reactor Ballast	LR	1	400	435
MHPS/LR/450/1	MHPS450	Metal Halide Pulse Start, (1) 450W lamp w/ Linear Reactor Ballast	LR	1	450	485
MHPS/LR/750/1	MHPS750	Metal Halide Pulse Start, (1) 750W lamp w/ Linear Reactor Ballast	LR	1	750	805
MHPS/SCWA/100/1	MHPS100	Metal Halide Pulse Start, (1) 100W lamp w/ Super Constant Wattage Autotransformer Ballast	SCWA	1	100	128
MHPS/SCWA/1000/1	MHPS1000	Metal Halide Pulse Start, (1) 1000W lamp w/ Super Constant Wattage Autotransformer Ballast	SCWA	1	1000	1080
MHPS/SCWA/150/1	MHPS150	Metal Halide Pulse Start, (1) 150W lamp w/ Super Constant Wattage Autotransformer Ballast	SCWA	1	150	190
MHPS/SCWA/175/1	MHPS175	Metal Halide Pulse Start, (1) 175W lamp w/ Super Constant Wattage Autotransformer Ballast	SCWA	1	175	208

Fixture Code	Lamp Code	Description	Ballast	Lamp/Fixture	Watt / Lamp	Watt / Fixture
MHPS/SCWA/200/1	MHPS200	Metal Halide Pulse Start, (1) 200W lamp w/ Super Constant Wattage Autotransformer Ballast	SCWA	1	200	232
MHPS/SCWA/250/1	MHPS250	Metal Halide Pulse Start, (1) 250W lamp w/ Super Constant Wattage Autotransformer Ballast	SCWA	1	250	288
MHPS/SCWA/300/1	MHPS300	Metal Halide Pulse Start, (1) 300W lamp w/ Super Constant Wattage Autotransformer Ballast	SCWA	1	300	342
MHPS/SCWA/320/1	MHPS320	Metal Halide Pulse Start, (1) 320W lamp w/ Super Constant Wattage Autotransformer Ballast	SCWA	1	320	368
MHPS/SCWA/350/1	MHPS350	Metal Halide Pulse Start, (1) 350W lamp w/ Super Constant Wattage Autotransformer Ballast	SCWA	1	350	400
MHPS/SCWA/400/1	MHPS400	Metal Halide Pulse Start, (1) 400W lamp w/ Super Constant Wattage Autotransformer Ballast	SCWA	1	400	450
MHPS/SCWA/450/1	MHPS450	Metal Halide Pulse Start, (1) 450W lamp w/ Super Constant Wattage Autotransformer Ballast	SCWA	1	450	506
MHPS/SCWA/750/1	MHPS750	Metal Halide Pulse Start, (1) 750W lamp w/ Super Constant Wattage Autotransformer Ballast	SCWA	1	750	815
MERCURY VAPOR FIXTURES						
MV100/1	MV100	Mercury Vapor, (1) 100W lamp	CWA	1	100	125
MV1000/1	MV1000	Mercury Vapor, (1) 1000W lamp	CWA	1	1000	1075
MV175/1	MV175	Mercury Vapor, (1) 175W lamp	CWA	1	175	205
MV250/1	MV250	Mercury Vapor, (1) 250W lamp	CWA	1	250	290
MV40/1	MV40	Mercury Vapor, (1) 40W lamp	CWA	1	40	50
MV400/1	MV400	Mercury Vapor, (1) 400W lamp	CWA	1	400	455
MV400/2	MV400	Mercury Vapor, (2) 400W lamp	CWA	2	400	910
MV50/1	MV50	Mercury Vapor, (1) 50W lamp	CWA	1	50	74
MV700/1	MV700	Mercury Vapor, (1) 700W lamp	CWA	1	700	780
MV75/1	MV75	Mercury Vapor, (1) 75W lamp	CWA	1	75	93

Record of Revision

Record of Revision Number	Issue Date
0	10/15/2010
7-13-23	7/31/2013

Return to Table of Contents

APPENDIX D

HVAC INTERACTIVE EFFECTS MULTIPLIERS

Multipliers by facility type and HVAC type are presented in the tables found throughout this appendix. The Default Values table below presents HVAC Interactive Effects Multiplier that are weighted averages of the Small & Large Commercial Building Types outlined in this appendix with typical HVAC system assumed for each region. These may be used in the estimation of interactive impacts when building type and/or HVAC system type cannot be sourced from application because program design/delivery does not allow for the collection of this detail.

DEFAULT VALUES

City	HVACc	HVACd	HVACff
Albany	0.054	0.174	-0.002
Binghamton	0.046	0.173	-0.002
Buffalo	0.049	0.174	-0.002
Massena	0.042	0.174	-0.002
Poughkeepsie	0.066	0.175	-0.002
Syracuse	0.057	0.174	-0.002
NYC	0.080	0.175	-0.002

SINGLE-FAMILY RESIDENTIAL

City	AC with fuel heat			Heat Pump			AC with electric heat			Electric heat only			Fuel heat only		
	HVACc	HVACd	HVACff	HVACc	HVACd	HVACff	HVACc	HVACd	HVACff	HVACc	HVACd	HVACff	HVACc	HVACd	HVACff
Albany	0.043	0.073	-0.003	-0.214	0.119	0.000	-0.575	0.073	0.000	-0.521	0.000	0.000	0.000	0.000	-0.003
Binghamton	0.034	0.182	-0.001	-0.148	0.169	0.000	-0.603	0.182	0.000	-0.313	0.000	0.000	0.000	0.000	-0.001
Buffalo	0.040	0.171	-0.003	-0.230	0.190	0.000	-0.655	0.171	0.000	-0.551	0.000	0.000	0.000	0.000	-0.003
Massena	0.034	0.112	-0.003	-0.298	0.131	0.000	-0.489	0.112	0.000	-0.607	0.000	0.000	0.000	0.000	-0.003
NYC	0.077	0.085	-0.002	-0.105	0.111	0.000	-0.579	0.085	0.000	-0.403	0.000	0.000	0.000	0.000	-0.002
Poughkeepsie	0.060	0.079	-0.003	-0.160	0.115	0.000	-0.577	0.079	0.000	-0.462	0.000	0.000	0.000	0.000	-0.002
Syracuse	0.045	0.095	-0.002	-0.157	0.119	0.000	-0.615	0.095	0.000	-0.382	0.000	0.000	0.000	0.000	-0.002

MULTI-FAMILY LOW-RISE

City	AC with fuel heat			Heat Pump			AC with electric heat			Electric heat only			Fuel heat only		
	HVACc	HVACd	HVACff	HVACc	HVACd	HVACff	HVACc	HVACd	HVACff	HVACc	HVACd	HVACff	HVACc	HVACd	HVACff
Albany	0.020	0.128	-0.002	-0.140	0.150	0.000	-0.329	0.128	0.000	-0.363	0.000	0.000	-0.014	0.000	-0.002
Binghamton	0.003	0.137	-0.002	-0.178	0.151	0.000	-0.384	0.137	0.000	-0.407	0.000	0.000	-0.020	0.000	-0.002
Buffalo	0.014	0.142	-0.002	-0.143	0.157	0.000	-0.332	0.142	0.000	-0.359	0.000	0.000	-0.014	0.000	-0.002
Massena	0.015	0.158	-0.002	-0.161	0.181	0.000	-0.349	0.158	0.000	-0.377	0.000	0.000	-0.013	0.000	-0.002
NYC	0.055	0.136	-0.002	-0.064	0.163	0.000	-0.260	0.136	0.000	-0.320	0.000	0.000	-0.005	0.000	-0.002
Poughkeepsie	0.038	0.132	-0.002	-0.102	0.157	0.000	-0.295	0.132	0.000	-0.342	0.000	0.000	-0.010	0.000	-0.002
Syracuse	0.017	0.140	-0.002	-0.160	0.150	0.000	-0.361	0.140	0.000	-0.391	0.000	0.000	-0.013	0.000	-0.002

MULTI-FAMILY HIGH-RISE

City	Fan coil with chiller and hot water boiler			Steam heat only		
	HVACc	HVACd	HVACff	HVACc	HVACd	HVACff
Albany	0.080	0.113	-0.003	0.000	0.000	-0.003
Binghamton	0.068	0.073	-0.003	0.000	0.000	-0.003
Buffalo	0.072	0.113	-0.003	0.000	0.000	-0.003
Massena	0.073	0.094	-0.003	0.000	0.000	-0.003
NYC	0.101	0.194	-0.002	0.000	0.000	-0.002
Poughkeepsie	0.092	0.168	-0.002	0.000	0.000	-0.003
Syracuse	0.080	0.113	-0.002	0.000	0.000	-0.003

SMALL COMMERCIAL BUILDINGS

Building	City	AC with fuel heat			Heat Pump			AC with electric heat			Electric heat only			Fuel heat only		
		HVACc	HVACd	HVACff	HVACc	HVACd	HVACff	HVACc	HVACd	HVACff	HVACc	HVACd	HVACff	HVACc	HVACd	HVACff
Assembly (Asy)	Albany	0.100	0.200	-0.003	-0.388	0.200	0.000	-0.536	0.200	0.000	-0.644	0.000	0.000	0.000	0.000	-0.003
	Binghamton	0.090	0.200	-0.004	-0.444	0.200	0.000	-0.676	0.200	0.000	-0.778	0.000	0.000	0.000	0.000	-0.004
	Buffalo	0.100	0.200	-0.003	-0.405	0.200	0.000	-0.645	0.200	0.000	-0.757	0.000	0.000	0.000	0.000	-0.004
	Massena	0.090	0.200	-0.004	-0.491	0.200	0.000	-0.653	0.200	0.000	-0.764	0.000	0.000	0.000	0.000	-0.004
	NYC	0.160	0.200	-0.002	-0.052	0.200	0.000	-0.243	0.200	0.000	-0.400	0.000	0.000	0.000	0.000	-0.002
	Poughkeepsie	0.130	0.200	-0.003	-0.361	0.200	0.000	-0.578	0.200	0.000	-0.700	0.000	0.000	0.000	0.000	-0.003
	Syracuse	0.110	0.200	-0.003	-0.364	0.200	0.000	-0.481	0.200	0.000	-0.610	0.000	0.000	0.000	0.000	-0.003
Auto repair (AR)	Albany	0.044	0.200	-0.003	-0.377	0.200	0.000	-0.630	0.200	0.000	-0.699	0.000	0.000	0.000	0.000	-0.003
	Binghamton	0.038	0.200	-0.003	-0.345	0.200	0.000	-0.564	0.200	0.000	-0.614	0.000	0.000	0.000	0.000	-0.003
	Buffalo	0.043	0.200	-0.003	-0.316	0.200	0.000	-0.661	0.200	0.000	-0.724	0.000	0.000	0.000	0.000	-0.003
	Massena	0.039	0.200	-0.003	-0.443	0.200	0.000	-0.653	0.200	0.000	-0.715	0.000	0.000	0.000	0.000	-0.003
	NYC	0.076	0.200	-0.004	-0.308	0.200	0.000	-0.795	0.200	0.000	-0.891	0.000	0.000	0.000	0.000	-0.004
	Poughkeepsie	0.057	0.200	-0.004	-0.408	0.200	0.000	-0.726	0.200	0.000	-0.811	0.000	0.000	0.000	0.000	-0.004
	Syracuse	0.046	0.200	-0.004	-0.394	0.200	0.000	-0.727	0.200	0.000	-0.809	0.000	0.000	0.000	0.000	-0.004
Big Box (BB)	Albany	0.120	0.200	-0.002	-0.166	0.200	0.000	-0.330	0.200	0.000	-0.458	0.000	0.000	0.000	0.000	-0.002
	Binghamton	0.110	0.200	-0.002	-0.172	0.200	0.000	-0.330	0.200	0.000	-0.462	0.000	0.000	0.000	0.000	-0.002
	Buffalo	0.110	0.200	-0.002	-0.163	0.200	0.000	-0.299	0.200	0.000	-0.424	0.000	0.000	0.000	0.000	-0.002
	Massena	0.100	0.200	-0.003	-0.298	0.200	0.000	-0.463	0.200	0.000	-0.572	0.000	0.000	0.000	0.000	-0.003
	NYC	0.170	0.200	-0.001	0.055	0.200	0.000	-0.065	0.200	0.000	-0.226	0.000	0.000	0.000	0.000	-0.001
	Poughkeepsie	0.145	0.200	-0.002	-0.085	0.200	0.000	-0.200	0.200	0.000	-0.350	0.000	0.000	0.000	0.000	-0.002
	Syracuse	0.120	0.200	-0.002	-0.144	0.200	0.000	-0.301	0.200	0.000	-0.425	0.000	0.000	0.000	0.000	-0.002
Elementary School (Elem)	Albany	0.060	0.200	-0.004	-0.399	0.200	0.000	-0.809	0.200	0.000	-0.916	0.000	0.000	0.000	0.000	-0.004
	Binghamton	0.040	0.200	-0.004	-0.406	0.200	0.000	-0.818	0.200	0.000	-0.950	0.000	0.000	0.000	0.000	-0.004
	Buffalo	0.040	0.200	-0.004	-0.382	0.200	0.000	-0.773	0.200	0.000	-0.908	0.000	0.000	0.000	0.000	-0.004
	Massena	0.040	0.200	-0.004	-0.509	0.200	0.000	-0.850	0.200	0.000	-0.963	0.000	0.000	0.000	0.000	-0.004
	NYC	0.110	0.200	-0.003	-0.150	0.200	0.000	-0.481	0.200	0.000	-0.646	0.000	0.000	0.000	0.000	-0.003
	Poughkeepsie	0.085	0.200	-0.003	-0.327	0.200	0.000	-0.743	0.200	0.000	-0.907	0.000	0.000	0.000	0.000	-0.004
	Syracuse	0.060	0.200	-0.004	-0.385	0.200	0.000	-0.778	0.200	0.000	-0.902	0.000	0.000	0.000	0.000	-0.004
Fast Food (FF)	Albany	0.070	0.200	-0.004	-0.702	0.200	0.000	-0.702	0.200	0.000	-0.818	0.000	0.000	0.000	0.000	-0.004
	Binghamton	0.060	0.200	-0.004	-0.732	0.200	0.000	-0.732	0.200	0.000	-0.808	0.000	0.000	0.000	0.000	-0.004
	Buffalo	0.070	0.200	-0.004	-0.677	0.200	0.000	-0.677	0.200	0.000	-0.815	0.000	0.000	0.000	0.000	-0.004
	Massena	0.070	0.200	-0.004	-0.717	0.200	0.000	-0.717	0.200	0.000	-0.814	0.000	0.000	0.000	0.000	-0.004
	NYC	0.110	0.200	-0.003	-0.471	0.200	0.000	-0.471	0.200	0.000	-0.827	0.000	0.000	0.000	0.000	-0.004
	Poughkeepsie	0.090	0.200	-0.003	-0.660	0.200	0.000	-0.660	0.200	0.000	-0.816	0.000	0.000	0.000	0.000	-0.004
	Syracuse	0.070	0.200	-0.004	-0.682	0.200	0.000	-0.682	0.200	0.000	-0.817	0.000	0.000	0.000	0.000	-0.004
Full Service Restaurant (FS)	Albany	0.070	0.200	-0.004	-0.656	0.200	0.000	-0.656	0.200	0.000	-0.792	0.000	0.000	0.000	0.000	-0.004
	Binghamton	0.060	0.200	-0.004	-0.738	0.200	0.000	-0.738	0.200	0.000	-0.856	0.000	0.000	0.000	0.000	-0.004
	Buffalo	0.070	0.200	-0.004	-0.645	0.200	0.000	-0.645	0.200	0.000	-0.777	0.000	0.000	0.000	0.000	-0.004
	Massena	0.060	0.200	-0.004	-0.720	0.200	0.000	-0.720	0.200	0.000	-0.821	0.000	0.000	0.000	0.000	-0.004
	NYC	0.110	0.200	-0.003	-0.486	0.200	0.000	-0.486	0.200	0.000	-0.637	0.000	0.000	0.000	0.000	-0.003
	Poughkeepsie	0.090	0.200	-0.004	-0.573	0.200	0.000	-0.573	0.200	0.000	-0.756	0.000	0.000	0.000	0.000	-0.004
	Syracuse	0.080	0.200	-0.004	-0.631	0.200	0.000	-0.631	0.200	0.000	-0.762	0.000	0.000	0.000	0.000	-0.004

Building	City	AC with fuel heat			Heat Pump			AC with electric heat			Electric heat only			Fuel heat only		
		HVACc	HVACd	HVACff	HVACc	HVACd	HVACff	HVACc	HVACd	HVACff	HVACc	HVACd	HVACff	HVACc	HVACd	HVACff
Grocery	Albany	0.120	0.200	-0.002	-0.166	0.200	0.000	-0.330	0.200	0.000	-0.458	0.000	0.000	0.000	0.000	-0.002
	Binghamton	0.110	0.200	-0.002	-0.172	0.200	0.000	-0.330	0.200	0.000	-0.462	0.000	0.000	0.000	0.000	-0.002
	Buffalo	0.110	0.200	-0.002	-0.163	0.200	0.000	-0.299	0.200	0.000	-0.424	0.000	0.000	0.000	0.000	-0.002
	Massena	0.100	0.200	-0.003	-0.298	0.200	0.000	-0.463	0.200	0.000	-0.572	0.000	0.000	0.000	0.000	-0.003
	NYC	0.170	0.200	-0.001	0.055	0.200	0.000	-0.065	0.200	0.000	-0.226	0.000	0.000	0.000	0.000	-0.001
	Poughkeepsie	0.145	0.200	-0.002	-0.085	0.200	0.000	-0.200	0.200	0.000	-0.350	0.000	0.000	0.000	0.000	-0.002
	Syracuse	0.120	0.200	-0.002	-0.144	0.200	0.000	-0.301	0.200	0.000	-0.425	0.000	0.000	0.000	0.000	-0.002
Light Industrial (Ind)	Albany	0.070	0.200	-0.003	-0.213	0.200	0.000	-0.456	0.200	0.000	-0.539	0.000	0.000	0.000	0.000	-0.003
	Binghamton	0.060	0.200	-0.003	-0.277	0.200	0.000	-0.507	0.200	0.000	-0.582	0.000	0.000	0.000	0.000	-0.003
	Buffalo	0.060	0.200	-0.003	-0.236	0.200	0.000	-0.474	0.200	0.000	-0.550	0.000	0.000	0.000	0.000	-0.003
	Massena	0.060	0.200	-0.003	-0.286	0.200	0.000	-0.490	0.200	0.000	-0.568	0.000	0.000	0.000	0.000	-0.003
	NYC	0.100	0.200	-0.002	-0.083	0.200	0.000	-0.313	0.200	0.000	-0.415	0.000	0.000	0.000	0.000	-0.002
	Poughkeepsie	0.085	0.200	-0.002	-0.165	0.200	0.000	-0.399	0.200	0.000	-0.491	0.000	0.000	0.000	0.000	-0.002
	Syracuse	0.070	0.200	-0.003	-0.218	0.200	0.000	-0.459	0.200	0.000	-0.542	0.000	0.000	0.000	0.000	-0.003
Motel (Motel)	Albany	0.080	0.200	-0.003	-0.318	0.200	0.000	-0.485	0.200	0.000	-0.586	0.000	0.000	0.000	0.000	-0.003
	Binghamton	0.069	0.200	-0.003	-0.342	0.200	0.000	-0.519	0.200	0.000	-0.613	0.000	0.000	0.000	0.000	-0.003
	Buffalo	0.073	0.200	-0.003	-0.314	0.200	0.000	-0.495	0.200	0.000	-0.597	0.000	0.000	0.000	0.000	-0.003
	Massena	0.068	0.200	-0.003	-0.383	0.200	0.000	-0.537	0.200	0.000	-0.627	0.000	0.000	0.000	0.000	-0.003
	NYC	0.114	0.200	-0.002	-0.155	0.200	0.000	-0.340	0.200	0.000	-0.482	0.000	0.000	0.000	0.000	-0.002
	Poughkeepsie	0.097	0.200	-0.003	-0.271	0.200	0.000	-0.453	0.200	0.000	-0.577	0.000	0.000	0.000	0.000	-0.003
	Syracuse	0.081	0.200	-0.003	-0.313	0.200	0.000	-0.485	0.200	0.000	-0.591	0.000	0.000	0.000	0.000	-0.003
Religious (Rel)	Albany	0.078	0.200	-0.001	-0.119	0.200	0.000	-0.193	0.200	0.000	-0.274	0.000	0.000	0.000	0.000	-0.001
	Binghamton	0.071	0.200	-0.001	-0.122	0.200	0.000	-0.229	0.200	0.000	-0.309	0.000	0.000	0.000	0.000	-0.001
	Buffalo	0.075	0.200	-0.001	-0.117	0.200	0.000	-0.194	0.200	0.000	-0.272	0.000	0.000	0.000	0.000	-0.001
	Massena	0.069	0.200	-0.001	-0.151	0.200	0.000	-0.219	0.200	0.000	-0.289	0.000	0.000	0.000	0.000	-0.001
	NYC	0.092	0.200	-0.001	-0.060	0.200	0.000	-0.199	0.200	0.000	-0.291	0.000	0.000	0.000	0.000	-0.001
	Poughkeepsie	0.089	0.200	-0.001	-0.078	0.200	0.000	-0.220	0.200	0.000	-0.310	0.000	0.000	0.000	0.000	-0.001
	Syracuse	0.081	0.200	-0.001	-0.118	0.200	0.000	-0.204	0.200	0.000	-0.285	0.000	0.000	0.000	0.000	-0.001
Small Office (SOfc)	Albany	0.100	0.200	-0.002	-0.112	0.200	0.000	-0.283	0.200	0.000	-0.376	0.000	0.000	0.000	0.000	-0.002
	Binghamton	0.090	0.200	-0.002	-0.145	0.200	0.000	-0.321	0.200	0.000	-0.413	0.000	0.000	0.000	0.000	-0.002
	Buffalo	0.090	0.200	-0.002	-0.129	0.200	0.000	-0.307	0.200	0.000	-0.405	0.000	0.000	0.000	0.000	-0.002
	Massena	0.090	0.200	-0.002	-0.177	0.200	0.000	-0.333	0.200	0.000	-0.426	0.000	0.000	0.000	0.000	-0.002
	NYC	0.120	0.200	-0.002	-0.003	0.200	0.000	-0.157	0.200	0.000	-0.239	0.000	0.000	0.000	0.000	-0.001
	Poughkeepsie	0.110	0.200	-0.002	-0.061	0.200	0.000	-0.219	0.200	0.000	-0.335	0.000	0.000	0.000	0.000	-0.002
	Syracuse	0.100	0.200	-0.002	-0.119	0.200	0.000	-0.286	0.200	0.000	-0.383	0.000	0.000	0.000	0.000	-0.002
Small Retail (SRet)	Albany	0.100	0.200	-0.003	-0.191	0.200	0.000	-0.428	0.200	0.000	-0.555	0.000	0.000	0.000	0.000	-0.003
	Binghamton	0.090	0.200	-0.003	-0.190	0.200	0.000	-0.448	0.200	0.000	-0.568	0.000	0.000	0.000	0.000	-0.003
	Buffalo	0.090	0.200	-0.003	-0.205	0.200	0.000	-0.447	0.200	0.000	-0.555	0.000	0.000	0.000	0.000	-0.003
	Massena	0.080	0.200	-0.003	-0.264	0.200	0.000	-0.535	0.200	0.000	-0.632	0.000	0.000	0.000	0.000	-0.003
	NYC	0.130	0.200	-0.002	-0.044	0.200	0.000	-0.258	0.200	0.000	-0.375	0.000	0.000	0.000	0.000	-0.002
	Poughkeepsie	0.115	0.200	-0.003	-0.137	0.200	0.000	-0.350	0.200	0.000	-0.481	0.000	0.000	0.000	0.000	-0.002
	Syracuse	0.090	0.200	-0.003	-0.180	0.200	0.000	-0.451	0.200	0.000	-0.563	0.000	0.000	0.000	0.000	-0.003

Building	City	AC with fuel heat			Heat Pump			AC with electric heat			Electric heat only			Fuel heat only		
		HVACc	HVACd	HVACff	HVACc	HVACd	HVACff	HVACc	HVACd	HVACff	HVACc	HVACd	HVACff	HVACc	HVACd	HVACff
Warehouse (WH)	Albany	0.063	0.200	-0.002	-0.170	0.200	0.000	-0.311	0.200	0.000	-0.373	0.000	0.000	0.000	0.000	-0.002
	Binghamton	0.054	0.200	-0.002	-0.187	0.200	0.000	-0.341	0.200	0.000	-0.397	0.000	0.000	0.000	0.000	-0.002
	Buffalo	0.054	0.200	-0.002	-0.178	0.200	0.000	-0.325	0.200	0.000	-0.380	0.000	0.000	0.000	0.000	-0.002
	Massena	0.055	0.200	-0.001	-0.156	0.200	0.000	-0.280	0.200	0.000	-0.335	0.000	0.000	0.000	0.000	-0.001
	NYC	0.078	0.200	-0.002	-0.109	0.200	0.000	-0.273	0.200	0.000	-0.352	0.000	0.000	0.000	0.000	-0.002
	Poughkeepsie	0.073	0.200	-0.002	-0.127	0.200	0.000	-0.312	0.200	0.000	-0.388	0.000	0.000	0.000	0.000	-0.002
	Syracuse	0.066	0.200	-0.002	-0.205	0.200	0.000	-0.334	0.200	0.000	-0.401	0.000	0.000	0.000	0.000	-0.002
Other	Albany	0.080	0.200	-0.003	-0.318	0.200	0.000	-0.485	0.200	0.000	-0.586	0.000	0.000	0.000	0.000	-0.003
	Binghamton	0.069	0.200	-0.003	-0.342	0.200	0.000	-0.519	0.200	0.000	-0.613	0.000	0.000	0.000	0.000	-0.003
	Buffalo	0.073	0.200	-0.003	-0.314	0.200	0.000	-0.495	0.200	0.000	-0.597	0.000	0.000	0.000	0.000	-0.003
	Massena	0.068	0.200	-0.003	-0.383	0.200	0.000	-0.537	0.200	0.000	-0.627	0.000	0.000	0.000	0.000	-0.003
	NYC	0.114	0.200	-0.002	-0.155	0.200	0.000	-0.340	0.200	0.000	-0.482	0.000	0.000	0.000	0.000	-0.002
	Poughkeepsie	0.097	0.200	-0.003	-0.271	0.200	0.000	-0.453	0.200	0.000	-0.577	0.000	0.000	0.000	0.000	-0.003
	Syracuse	0.081	0.200	-0.003	-0.313	0.200	0.000	-0.485	0.200	0.000	-0.591	0.000	0.000	0.000	0.000	-0.003

LARGE COMMERCIAL BUILDINGS

Building	City	CV No econ			CV Econ			VAV Econ		
		HVACc	HVACd	HVACff	HVACc	HVACd	HVACff	HVACc	HVACd	HVACff
Community College (CC)	Albany	0.045	0.200	-0.001	0.016	0.200	-0.002	0.080	0.200	-0.001
	Binghamton	0.042	0.200	-0.001	0.014	0.200	-0.001	0.064	0.200	-0.001
	Buffalo	0.042	0.200	-0.001	0.014	0.200	-0.001	0.065	0.200	-0.001
	Massena	0.040	0.200	-0.002	0.013	0.200	-0.002	0.043	0.200	-0.001
	NYC	0.044	0.200	-0.003	0.019	0.200	-0.002	0.124	0.200	0.000
	Poughkeepsie	0.040	0.200	-0.002	0.014	0.200	-0.002	0.083	0.200	-0.001
	Syracuse	0.045	0.200	-0.002	0.016	0.200	-0.002	0.087	0.200	-0.001
High School (HS)	Albany	0.033	0.200	-0.003	0.014	0.200	-0.003	0.037	0.200	-0.002
	Binghamton	0.028	0.200	-0.003	0.009	0.200	-0.003	0.030	0.200	-0.002
	Buffalo	0.031	0.200	-0.003	0.010	0.200	-0.003	0.035	0.200	-0.002
	Massena	0.030	0.200	-0.003	0.012	0.200	-0.003	0.026	0.200	-0.002
	NYC	0.042	0.200	-0.003	0.022	0.200	-0.003	0.049	0.200	-0.002
	Poughkeepsie	0.037	0.200	-0.003	0.016	0.200	-0.003	0.034	0.200	-0.002
	Syracuse	0.033	0.200	-0.003	0.015	0.200	-0.003	0.037	0.200	-0.002
Hospital (Hosp)	Albany	0.029	0.200	-0.002	0.014	0.200	-0.002	0.045	0.200	-0.002
	Binghamton	0.027	0.200	-0.002	0.011	0.200	-0.002	0.039	0.200	-0.002
	Buffalo	0.027	0.200	-0.002	0.012	0.200	-0.002	0.044	0.200	-0.002
	Massena	0.026	0.200	-0.002	0.012	0.200	-0.002	0.033	0.200	-0.002
	NYC	0.033	0.200	-0.002	0.019	0.200	-0.002	0.065	0.200	-0.001
	Poughkeepsie	0.029	0.200	-0.002	0.014	0.200	-0.002	0.053	0.200	-0.002
	Syracuse	0.029	0.200	-0.002	0.014	0.200	-0.002	0.054	0.200	-0.002

Building	City	CV No econ			CV Econ			VAV Econ		
		HVACc	HVACd	HVACff	HVACc	HVACd	HVACff	HVACc	HVACd	HVACff
Hotel (Hotel)	Albany	0.029	0.200	-0.002	0.014	0.200	-0.002	0.045	0.200	-0.002
	Binghamton	0.027	0.200	-0.002	0.011	0.200	-0.002	0.039	0.200	-0.002
	Buffalo	0.027	0.200	-0.002	0.012	0.200	-0.002	0.044	0.200	-0.002
	Massena	0.026	0.200	-0.002	0.012	0.200	-0.002	0.033	0.200	-0.002
	NYC	0.033	0.200	-0.002	0.019	0.200	-0.002	0.065	0.200	-0.001
	Poughkeepsie	0.029	0.200	-0.002	0.014	0.200	-0.002	0.053	0.200	-0.002
	Syracuse	0.029	0.200	-0.002	0.014	0.200	-0.002	0.054	0.200	-0.002
Large Office (LOfc)	Albany	0.029	0.200	-0.002	0.014	0.200	-0.002	0.045	0.200	-0.002
	Binghamton	0.027	0.200	-0.002	0.011	0.200	-0.002	0.039	0.200	-0.002
	Buffalo	0.027	0.200	-0.002	0.012	0.200	-0.002	0.044	0.200	-0.002
	Massena	0.026	0.200	-0.002	0.012	0.200	-0.002	0.033	0.200	-0.002
	NYC	0.033	0.200	-0.002	0.019	0.200	-0.002	0.065	0.200	-0.001
	Poughkeepsie	0.029	0.200	-0.002	0.014	0.200	-0.002	0.053	0.200	-0.002
	Syracuse	0.029	0.200	-0.002	0.014	0.200	-0.002	0.054	0.200	-0.002
Large Retail (LRet)	Albany	0.031	0.200	-0.003	0.018	0.200	-0.003	0.043	0.200	-0.002
	Binghamton	0.032	0.200	-0.003	0.015	0.200	-0.003	0.044	0.200	-0.002
	Buffalo	0.030	0.200	-0.003	0.017	0.200	-0.003	0.045	0.200	-0.002
	Massena	0.029	0.200	-0.003	0.016	0.200	-0.003	0.036	0.200	-0.003
	NYC	0.037	0.200	-0.002	0.023	0.200	-0.002	0.057	0.200	-0.002
	Poughkeepsie	0.033	0.200	-0.003	0.018	0.200	-0.003	0.056	0.200	-0.002
	Syracuse	0.032	0.200	-0.003	0.017	0.200	-0.003	0.044	0.200	-0.002
University (Univ)	Albany	0.051	0.200	-0.002	0.018	0.200	-0.003	0.111	0.200	-0.001
	Binghamton	0.049	0.200	-0.002	0.014	0.200	-0.002	0.098	0.200	-0.001
	Buffalo	0.052	0.200	-0.002	0.018	0.200	-0.002	0.104	0.200	-0.001
	Massena	0.042	0.200	-0.003	0.012	0.200	-0.003	0.086	0.200	-0.001
	NYC	0.048	0.200	-0.003	0.020	0.200	-0.003	0.142	0.200	-0.001
	Poughkeepsie	0.044	0.200	-0.003	0.014	0.200	-0.003	0.120	0.200	-0.001
	Syracuse	0.047	0.200	-0.002	0.016	0.200	-0.003	0.110	0.200	-0.001

COLLEGE DORMITORY

City	Fan coil with chiller and hot water boiler			Steam heat only		
	HVACc	HVACd	HVACff	HVACc	HVACd	HVACff
Albany	0.029	0.200	-0.001	0.000	0.000	-0.002
Binghamton	0.029	0.200	-0.001	0.000	0.000	-0.002
Buffalo	0.027	0.200	-0.001	0.000	0.000	-0.002
Massena	0.025	0.200	-0.002	0.000	0.000	-0.002
NYC	0.025	0.200	-0.001	0.000	0.000	-0.001
Poughkeepsie	0.035	0.200	-0.001	0.000	0.000	-0.002
Syracuse	0.028	0.200	-0.001	0.000	0.000	-0.002

REFRIGERATED WAREHOUSE

City	Water Cooled Ammonia Screw Compressors	
	HVACc	HVACd
Albany	0.370	.200
Binghamton	0.400	.200
Buffalo	0.400	.200
Massena	0.390	.200
NYC	0.390	.200
Poughkeepsie	0.410	.200
Syracuse	0.390	.200

Record of Revision

Record of Revision Number	Issue Date
0	10/15/2010

Return to Table of Contents

APPENDIX E

OPAQUE SHELL MEASURE SAVINGS

SINGLE-FAMILY RESIDENTIAL INSULATION UPGRADES

Building: Single-Family Low-rise **City: Albany** **HVAC: AC with Fuel Heat** **Measure: Wall Insulation**

Base	0			11			13			17			19		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	51.2	0.065	51.9												
13	58.7	0.076	60.3	7.6	0.011	8.3									
17	70.2	0.098	72.1	19.1	0.033	20.2	11.5	0.022	11.8						
19	74.1	0.098	76.4	23.0	0.033	24.5	15.4	0.022	16.2	3.9	0.000	4.3			
21	77.9	0.108	80.0	26.8	0.043	28.1	19.2	0.033	19.7	7.7	0.011	7.9	3.8	0.011	3.6
25	83.0	0.108	85.6	31.9	0.043	33.7	24.3	0.033	25.4	12.8	0.011	13.5	8.9	0.011	9.2
27	85.3	0.119	87.9	34.1	0.054	36.0	26.6	0.043	15.8	15.1	0.022	15.8	11.2	0.022	11.5

Building: Single-Family **City: Albany** **HVAC: Heat Pump** **Measure: Wall Insulation**

Base	0		11		13		17		19	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	772.8	0.043								
13	896.3	0.054	123.5	0.011						
17	1,065.6	0.065	292.8	0.022	169.3	0.011				
19	1,126.6	0.076	353.8	0.033	230.3	0.022	61.0	0.011		
21	1,178.0	0.076	405.2	0.033	281.7	0.022	112.4	0.011	51.4	0.000
25	1,257.9	0.076	485.0	0.033	361.6	0.022	192.3	0.011	131.3	0.000
27	1,290.5	0.087	517.7	0.043	224.9	0.033	224.9	0.022	163.9	0.011

Building: Single-Family **City: Albany** **HVAC: AC with Electric Heat** **Measure: Wall Insulation**

Base	0		11		13		17		19	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	1,192.1	0.065								
13	1,382.2	0.076	190.1	0.011						
17	1,650.6	0.098	458.5	0.033	268.4	0.022				
19	1,748.1	0.098	556.0	0.033	365.9	0.022	97.6	0.000		
21	1,830.2	0.108	638.1	0.043	448.0	0.033	179.6	0.011	82.1	0.011
25	1,958.5	0.108	766.4	0.043	576.3	0.033	307.9	0.011	210.4	0.011
27	2,010.2	0.119	818.1	0.054	628.0	0.043	359.6	0.022	262.1	0.022

Building: Single-Family **City: Albany** **HVAC: Electric Heat, no AC** **Measure: Wall Insulation**

Base	0		11		13		17		19	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	1,166.2	00.0								
13	1,352.7	00.0	186.5	00.0						
17	1,615.2	00.0	449.1	00.0	262.5	00.0				
19	1,710.9	00.0	544.8	00.0	358.2	00.0	95.7	00.0		
21	1,790.9	00.0	624.8	00.0	438.2	00.0	175.7	00.0	80.0	00.0
25	1,916.9	00.0	750.7	00.0	564.2	00.0	301.6	00.0	205.9	00.0
27	1,967.4	00.0	801.2	00.0	614.7	00.0	352.2	00.0	256.4	00.0

Building: Single-Family **City: Albany** **HVAC: Fuel Heat, no AC** **Measure: Wall Insulation**

Base	0			11			13			17			19		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	25.1	00.0	51.9												
13	29.2	00.0	60.3	4.0	00.0	8.3									
17	34.9	00.0	72.1	9.8	00.0	20.2	5.7	00.0	11.8						
19	37.0	00.0	76.4	11.8	00.0	24.5	7.8	00.0	16.2	2.1	00.0	4.3			
21	38.7	00.0	80.0	13.5	00.0	28.1	9.5	00.0	19.7	3.8	00.0	7.9	1.7	00.0	3.6
25	41.4	00.0	85.6	16.3	00.0	33.7	12.2	00.0	25.4	6.5	00.0	13.5	4.4	00.0	9.2
27	42.5	00.0	87.9	17.3	00.0	36.0	13.3	00.0	27.6	7.6	00.0	15.8	5.5	00.0	11.5

Building: Single-Family **City: Albany** **HVAC: AC with Fuel Heat** **Measure: Ceiling Insulation**

Base	0			11			19			30			38		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	336.9	0.119	322.4												
19	380.5	0.188	362.3	43.7	0.068	39.9									
30	403.4	0.222	385.8	66.6	0.102	63.5	22.9	0.034	23.5						
38	414.8	0.239	395.1	78.0	0.119	72.7	34.3	0.051	32.8	11.4	0.017	9.2			
49	421.2	0.239	403.1	84.3	0.119	80.7	40.6	0.051	40.8	17.7	0.017	17.2	6.3	0.000	8.0
60	425.4	0.256	408.4	88.6	0.137	86.0	44.9	0.068	46.1	22.0	0.034	22.5	10.6	0.017	13.3

Building: Single-Family **City: Albany** **HVAC: Heat Pump** **Measure: Ceiling Insulation**

Base	0		11		19		30		38	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	5,582.8	0.188								
19	6,213.0	0.239	630.2	0.051						
30	6,570.8	0.273	988.1	0.085	357.8	0.034				
38	6,710.4	0.273	1,127.6	0.085	497.4	0.034	139.6	0.000		
49	6,828.0	0.290	1,245.2	0.102	615.0	0.051	257.2	0.017	117.6	0.017
60	6,904.8	0.290	1,322.0	0.102	691.8	0.051	334.0	0.017	194.4	0.017

Building: Single-Family **City: Albany** **HVAC: AC with Electric Heat** **Measure: Ceiling Insulation**

Base	0		11		19		30		38	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	7,631.9	0.119								
19	8,563.5	0.188	931.6	0.068						
30	9,106.8	0.222	1,474.9	0.102	543.3	0.034				
38	9,320.3	0.239	1,688.4	0.119	756.8	0.051	213.5	0.017		
49	9,502.6	0.239	1,870.6	0.119	939.1	0.051	395.7	0.017	182.3	0.000
60	9,621.8	0.256	1,989.9	0.137	1,058.4	0.068	515.0	0.034	301.5	0.017

Building: Single-Family **City: Albany** **HVAC: Electric Heat, no AC** **Measure: Ceiling Insulation**

Base	0		11		19		30		38	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	7,449.5	00.0								
19	8,356.1	00.0	906.7	00.0						
30	8,887.5	00.0	1,438.1	00.0	531.4	00.0				
38	9,093.9	00.0	1,644.4	00.0	737.7	00.0	206.3	00.0		
49	9,273.5	00.0	1,824.1	00.0	917.4	00.0	386.0	00.0	179.7	00.0
60	9,391.0	00.0	1,941.5	00.0	1,034.8	00.0	503.4	00.0	297.1	00.0

Building: Single-Family **City: Albany** **HVAC: Fuel Heat No AC** **Measure: Ceiling Insulation**

Base	0			11			19			30			38		
Measure	kWh/ kSF	kW/ kSF	therm / kSF	kWh / kSF	kW/ kSF	therm / kSF	kWh / kSF	kW/ kSF	therm / kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh / kSF	kW/ kSF	therm / kSF
11	154.6	00.0	322.5												
19	173.4	00.0	362.5	18.8	00.0	39.9									
30	184.3	00.0	386.0	29.7	00.0	63.5	10.9	00.0	23.5						
38	188.6	00.0	395.2	34.0	00.0	72.7	15.2	00.0	32.8	4.3	00.0	9.2			
49	192.3	00.0	403.2	37.7	00.0	80.7	18.9	00.0	40.8	8.0	00.0	17.2	3.8	00.0	8.0
60	194.7	00.0	408.5	40.1	00.0	86.0	21.3	00.0	46.1	10.4	00.0	22.5	6.1	00.0	13.3

Building: Single-Family **City: Buffalo** **HVAC: AC with Fuel Heat** **Measure: Wall Insulation**

Base	0			11			13			17			19		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	46.4	0.043	54.2												
13	53.7	0.043	62.8	7.3	0.000	8.6									
17	64.9	0.054	74.9	18.5	0.011	20.7	11.3	0.011	12.1						
19	68.6	0.054	79.3	22.2	0.011	25.1	15.0	0.011	16.6	3.7	0.000	4.4			
21	71.3	0.054	83.0	24.9	0.011	28.8	17.7	0.011	20.3	6.4	0.000	8.1	2.7	0.000	3.7
25	76.0	0.054	88.9	29.6	0.011	34.7	22.3	0.011	26.1	11.1	0.000	14.0	7.4	0.000	9.5
27	77.0	0.065	91.2	30.6	0.022	37.0	23.3	0.022	16.3	12.0	0.011	16.3	8.3	0.011	11.8

Building: Single-Family **City: Buffalo** **HVAC: Heat Pump** **Measure: Wall Insulation**

Base	0		11		13		17		19	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	841.3	0.043								
13	972.3	0.043	130.9	0.000						
17	1,154.8	0.054	313.5	0.011	182.5	0.011				
19	1,221.2	0.054	379.9	0.011	249.0	0.011	66.4	0.000		
21	1,275.0	0.054	433.7	0.011	302.7	0.011	120.2	0.000	53.8	0.000
25	1,360.1	0.065	518.8	0.022	387.8	0.022	205.3	0.011	138.8	0.011
27	1,394.0	0.065	552.7	0.022	239.2	0.022	239.2	0.011	172.8	0.011

Building: Single-Family **City: Buffalo** **HVAC: AC with Electric Heat** **Measure: Wall Insulation**

Base	0		11		13		17		19	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	1,246.8	0.043								
13	1,444.4	0.043	197.6	0.000						
17	1,722.6	0.054	475.8	0.011	278.2	0.011				
19	1,823.7	0.054	576.8	0.011	379.3	0.011	101.0	0.000		
21	1,907.4	0.054	660.6	0.011	463.0	0.011	184.8	0.000	83.8	0.000
25	2,039.8	0.054	793.0	0.011	595.4	0.011	317.1	0.000	216.1	0.000
27	2,091.9	0.065	845.1	0.022	647.5	0.022	369.3	0.011	268.3	0.011

Building: **Single-Family** **City: Buffalo** **HVAC: Electric Heat, no AC** **Measure: Wall Insulation**

Base	0		11		13		17		19	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	1,227.4	00.0								
13	1,422.0	00.0	194.6	00.0						
17	1,694.9	00.0	467.5	00.0	272.9	00.0				
19	1,794.4	00.0	567.0	00.0	372.4	00.0	99.5	00.0		
21	1,877.4	00.0	650.0	00.0	455.5	00.0	182.5	00.0	83.0	00.0
25	2,007.9	00.0	780.5	00.0	586.0	00.0	313.0	00.0	213.5	00.0
27	2,060.2	00.0	832.8	00.0	638.2	00.0	365.3	00.0	265.8	00.0

Building: **Single-Family** **City: Buffalo** **HVAC: Fuel Heat, no AC** **Measure: Wall Insulation**

Base	0			11			13			17			19		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	26.9	00.0	54.2												
13	31.2	00.0	62.8	4.3	00.0	8.6									
17	37.2	00.0	74.9	10.3	00.0	20.7	6.0	00.0	12.1						
19	39.3	00.0	79.3	12.5	00.0	25.1	8.1	00.0	16.6	2.2	00.0	4.4			
21	41.2	00.0	83.0	14.3	00.0	28.8	10.0	00.0	20.3	4.0	00.0	8.1	1.8	00.0	3.7
25	44.0	00.0	88.9	17.1	00.0	34.7	12.8	00.0	26.1	6.8	00.0	14.0	4.7	00.0	9.5
27	45.2	00.0	91.3	18.3	00.0	37.1	14.0	00.0	28.5	8.0	00.0	16.4	5.9	00.0	11.9

Building: **Single-Family** **City: Buffalo** **HVAC: AC with Fuel Heat** **Measure: Ceiling Insulation**

Base	0			11			19			30			38		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	292.5	0.256	320.6												
19	327.0	0.290	360.6	34.5	0.034	39.9									
30	350.3	0.307	384.0	57.8	0.051	63.3	23.4	0.017	23.4						
38	357.0	0.324	393.2	64.5	0.068	72.5	30.0	0.034	32.6	6.7	0.017	9.2			
49	366.7	0.324	401.2	74.2	0.068	80.5	39.8	0.034	40.6	16.4	0.017	17.2	9.7	0.000	8.0
60	370.5	0.324	406.5	78.0	0.068	85.8	43.5	0.034	45.9	20.1	0.017	22.5	13.5	0.000	13.3

Building: Single-Family **City:** Buffalo **HVAC:** Heat Pump **Measure:** Ceiling Insulation

Base	0		11		19		30		38	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	5,565.7	0.239								
19	6,216.2	0.273	650.5	0.034						
30	6,586.5	0.307	1,020.8	0.068	370.3	0.034				
38	6,729.7	0.307	1,164.0	0.068	513.5	0.034	143.2	0.000		
49	6,857.7	0.307	1,292.0	0.068	641.5	0.034	271.2	0.000	128.0	0.000
60	6,938.4	0.307	1,372.7	0.068	722.2	0.034	351.9	0.000	208.7	0.000

Building: Single-Family **City:** Buffalo **HVAC:** AC with Electric Heat **Measure:** Ceiling Insulation

Base	0		11		19		30		38	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	7,602.2	0.256								
19	8,528.5	0.290	926.3	0.034						
30	9,073.4	0.307	1,471.2	0.051	544.9	0.017				
38	9,284.0	0.324	1,681.7	0.068	755.5	0.034	210.6	0.017		
49	9,472.2	0.324	1,870.0	0.068	943.7	0.034	398.8	0.017	188.2	0.000
60	9,592.3	0.324	1,990.1	0.068	1,063.8	0.034	518.9	0.017	308.4	0.000

Building: Single-Family **City:** Buffalo **HVAC:** Electric Heat, no AC **Measure:** Ceiling Insulation

Base	0		11		19		30		38	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	7,464.7	00.0								
19	8,375.4	00.0	910.8	00.0						
30	8,907.8	00.0	1,443.2	00.0	532.4	00.0				
38	9,116.2	00.0	1,651.5	00.0	740.8	00.0	208.4	00.0		
49	9,298.5	00.0	1,833.8	00.0	923.0	00.0	390.6	00.0	182.3	00.0
60	9,417.2	00.0	1,952.6	00.0	1,041.8	00.0	509.4	00.0	301.0	00.0

Building: Single-Family **City:** Buffalo **HVAC:** Fuel Heat No AC **Measure:** Ceiling Insulation

Base	0			11			19			30			38		
Measure	kWh/ kSF	kW/ kSF	therm / kSF	kWh / kSF	kW/ kSF	therm / kSF	kWh / kSF	kW/ kSF	therm / kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh / kSF	kW/ kSF	therm / kSF
11	154.9	00.0	320.6												
19	173.9	00.0	360.6	18.9	00.0	39.9									
30	184.8	00.0	384.0	29.9	00.0	63.3	10.9	00.0	23.4						
38	189.2	00.0	393.2	34.3	00.0	72.5	15.4	00.0	32.6	4.4	00.0	9.2			
49	193.0	00.0	401.2	38.1	00.0	80.5	19.1	00.0	40.6	8.2	00.0	17.2	3.8	00.0	8.0
60	195.4	00.0	406.5	40.4	00.0	85.8	21.5	00.0	45.9	10.6	00.0	22.5	6.1	00.0	13.3

Building: Single-family **City: Massena** **HVAC: AC with Fuel Heat** **Measure: Wall Insulation**

Base	0			11			13			17			19		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	53.2	0.065	61.7												
13	61.1	0.076	71.5	7.9	0.011	9.9									
17	72.9	0.087	85.5	19.7	0.022	23.8	11.8	0.011	14.0						
19	77.5	0.098	90.7	24.3	0.033	29.0	16.4	0.022	19.2	4.6	0.011	5.2			
21	80.2	0.098	94.9	27.0	0.033	33.3	19.1	0.022	23.4	7.3	0.011	9.4	2.7	0.000	4.2
25	87.4	0.108	101.7	34.1	0.043	40.0	26.2	0.033	30.1	14.4	0.022	16.2	9.9	0.011	10.9
27	89.4	0.108	104.4	36.2	0.043	42.7	28.3	0.033	18.9	16.5	0.022	18.9	11.9	0.011	13.7

Building: **Single-family** **City: Massena** **HVAC: Heat Pump** **Measure: Wall Insulation**

Base	0		11		13		17		19	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	1,039.7	0.043								
13	1,201.9	0.054	162.3	0.011						
17	1,430.7	0.076	391.1	0.033	228.8	0.022				
19	1,514.0	0.076	474.3	0.033	312.1	0.022	83.2	0.000		
21	1,582.1	0.087	542.4	0.043	380.1	0.033	151.3	0.011	68.1	0.011
25	1,688.9	0.098	649.3	0.054	487.0	0.043	258.2	0.022	174.9	0.022
27	1,734.9	0.098	695.2	0.054	304.1	0.043	304.1	0.022	220.9	0.022

Building: **Single-family** **City: Massena** **HVAC: AC with Electric Heat** **Measure: Wall Insulation**

Base	0		11		13		17		19	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	1,423.9	0.065								
13	1,651.2	0.076	227.3	0.011						
17	1,971.8	0.087	547.9	0.022	320.6	0.011				
19	2,089.2	0.098	665.3	0.033	438.0	0.022	117.4	0.011		
21	2,186.2	0.098	762.3	0.033	535.0	0.022	214.4	0.011	97.0	0.000
25	2,341.6	0.108	917.7	0.043	690.4	0.033	369.8	0.022	252.4	0.011
27	2,403.2	0.108	979.3	0.043	752.0	0.033	431.4	0.022	314.0	0.011

Building: **Single-family** **City: Massena** **HVAC: Electric Heat, no AC** **Measure: Wall Insulation**

Base	0		11		13		17		19	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	1,400.7	00.0								
13	1,624.9	00.0	224.1	00.0						
17	1,940.3	00.0	539.6	00.0	315.4	00.0				
19	2,055.9	00.0	655.2	00.0	431.1	00.0	115.7	00.0		
21	2,152.1	00.0	751.4	00.0	527.2	00.0	211.8	00.0	96.1	00.0
25	2,303.6	00.0	902.9	00.0	678.7	00.0	363.3	00.0	247.7	00.0
27	2,364.8	00.0	964.1	00.0	740.0	00.0	424.6	00.0	308.9	00.0

Building: Single-family **City: Massena** **HVAC: Fuel Heat, no AC** **Measure: Wall Insulation**

Base	0			11			13			17			19		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	30.0	00.0	61.7												
13	34.9	00.0	71.5	4.9	00.0	9.9									
17	41.6	00.0	85.5	11.6	00.0	23.8	6.7	00.0	14.0						
19	44.1	00.0	90.7	14.1	00.0	29.0	9.2	00.0	19.2	2.5	00.0	5.2			
21	46.2	00.0	94.9	16.2	00.0	33.3	11.3	00.0	23.4	4.6	00.0	9.4	2.1	00.0	4.2
25	49.4	00.0	101.8	19.4	00.0	40.1	14.5	00.0	30.2	7.8	00.0	16.3	5.3	00.0	11.1
27	50.7	00.0	104.5	20.7	00.0	42.8	15.8	00.0	33.0	9.1	00.0	19.0	6.6	00.0	13.8

Building: Single-family **City: Massena** **HVAC: AC with Fuel Heat** **Measure: Ceiling Insulation**

Base	0			11			19			30			38		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	338.4	0.290	381.2												
19	377.0	0.341	429.0	38.6	0.051	47.8									
30	400.2	0.375	457.2	61.8	0.085	75.9	23.2	0.034	28.2						
38	412.5	0.392	468.3	74.1	0.102	87.0	35.5	0.051	39.2	12.3	0.017	11.1			
49	420.6	0.392	477.8	82.3	0.102	96.6	43.7	0.051	48.8	20.5	0.017	20.6	8.2	0.000	9.6
60	426.3	0.410	484.1	87.9	0.119	102.9	49.3	0.068	55.1	26.1	0.034	27.0	13.8	0.017	15.9

Building: **Single-family** **City: Massena** **HVAC: Heat Pump** **Measure: Ceiling Insulation**

Base	0		11		19		30		38	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	7,099.8	0.222								
19	7,936.3	0.273	836.5	0.051						
30	8,425.4	0.290	1,325.6	0.068	489.1	0.017				
38	8,614.0	0.307	1,514.2	0.085	677.6	0.034	188.6	0.017		
49	8,776.5	0.307	1,676.6	0.085	840.1	0.034	351.0	0.017	162.5	0.000
60	8,883.6	0.324	1,783.8	0.102	947.3	0.051	458.2	0.034	269.6	0.017

Building: **Single-family** **City: Massena** **HVAC: AC with Electric Heat** **Measure: Ceiling Insulation**

Base	0		11		19		30		38	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	9,089.2	0.290								
19	10,202.2	0.341	1,113.0	0.051						
30	10,854.3	0.375	1,765.0	0.085	652.0	0.034				
38	11,112.8	0.392	2,023.5	0.102	910.6	0.051	258.5	0.017		
49	11,336.0	0.392	2,246.8	0.102	1,133.8	0.051	481.7	0.017	223.2	0.000
60	11,481.7	0.410	2,392.5	0.119	1,279.5	0.068	627.5	0.034	368.9	0.017

Building: **Single-family** **City: Massena** **HVAC: Electric Heat, no AC** **Measure: Ceiling Insulation**

Base	0		11		19		30		38	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	8,931.1	00.0								
19	10,027.6	00.0	1,096.6	00.0						
30	10,670.0	00.0	1,738.9	00.0	642.3	00.0				
38	10,921.5	00.0	1,990.4	00.0	893.9	00.0	251.5	00.0		
49	11,140.6	00.0	2,209.6	00.0	1,113.0	00.0	470.6	00.0	219.1	00.0
60	11,284.0	00.0	2,352.9	00.0	1,256.3	00.0	614.0	00.0	362.5	00.0

Building: Single-family **City: Massena** **HVAC: Fuel Heat, no AC** **Measure: Ceiling Insulation**

Base	0			11			19			30			38		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	180.4	00.0	381.4												
19	202.9	00.0	429.2	22.5	00.0	47.8									
30	216.0	00.0	457.3	35.7	00.0	75.9	13.1	00.0	28.2						
38	221.3	00.0	468.4	41.0	00.0	87.0	18.4	00.0	39.2	5.3	00.0	11.1			
49	225.8	00.0	478.0	45.4	00.0	96.6	22.9	00.0	48.8	9.7	00.0	20.6	4.4	00.0	9.6
60	228.7	00.0	484.3	48.3	00.0	102.9	25.8	00.0	55.1	12.6	00.0	27.0	7.3	00.0	15.9

Building: Single-family **City: NYC** **HVAC: AC with Fuel Heat** **Measure: Wall Insulation**

Base	0			11			13			17			19		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	60.0	0.054	36.6												
13	66.7	0.065	42.3	6.6	0.011	5.6									
17	80.6	0.076	50.6	20.6	0.022	14.0	14.0	0.011	8.3						
19	85.8	0.076	53.7	25.8	0.022	17.0	19.2	0.011	11.4	5.2	0.000	3.0			
21	90.1	0.076	56.1	30.0	0.022	19.5	23.4	0.011	13.9	9.4	0.000	5.5	4.2	0.000	2.5
25	95.5	0.087	60.2	35.4	0.033	23.5	28.8	0.022	17.9	14.8	0.011	9.5	9.6	0.011	6.5
27	97.8	0.087	61.7	37.7	0.033	25.0	31.1	0.022	11.1	17.1	0.011	11.1	11.9	0.011	8.0

Building: **Single-family** **City: NYC** **HVAC: Heat Pump** **Measure: Wall Insulation**

Base	0		11		13		17		19	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	430.4	0.076								
13	493.8	0.087	63.4	0.011						
17	590.6	0.098	160.2	0.022	96.8	0.011				
19	626.1	0.108	195.6	0.033	132.2	0.022	35.4	0.011		
21	654.8	0.108	224.4	0.033	161.0	0.022	64.2	0.011	28.7	0.000
25	698.8	0.108	268.4	0.033	205.0	0.022	108.2	0.011	72.7	0.000
27	717.2	0.119	286.8	0.043	126.6	0.033	126.6	0.022	91.2	0.011

Building: **Single-family** **City: NYC** **HVAC: AC with Electric Heat** **Measure: Wall Insulation**

Base	0		11		13		17		19	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	840.8	0.054								
13	968.0	0.065	127.2	0.011						
17	1,158.0	0.076	317.3	0.022	190.0	0.011				
19	1,227.4	0.076	386.6	0.022	259.4	0.011	69.4	0.000		
21	1,284.8	0.076	444.1	0.022	316.8	0.011	126.8	0.000	57.4	0.000
25	1,374.3	0.087	533.5	0.033	406.2	0.022	216.2	0.011	146.9	0.011
27	1,410.1	0.087	569.4	0.033	442.1	0.022	252.1	0.011	182.7	0.011

Building: **Single-family** **City: NYC** **HVAC: Electric Heat, no AC** **Measure: Wall Insulation**

Base	0		11		13		17		19	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	798.1	00.0								
13	921.6	00.0	123.6	00.0						
17	1,101.2	00.0	303.2	00.0	179.6	00.0				
19	1,166.7	00.0	368.6	00.0	245.1	00.0	65.5	00.0		
21	1,221.5	00.0	423.5	00.0	299.9	00.0	120.3	00.0	54.8	00.0
25	1,307.6	00.0	509.5	00.0	386.0	00.0	206.4	00.0	140.9	00.0
27	1,341.6	00.0	543.6	00.0	420.0	00.0	240.4	00.0	174.9	00.0

Building: Single-family **City: NYC** **HVAC: Fuel Heat, no AC** **Measure: Wall Insulation**

Base	0			11			13			17			19		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	17.2	00.0	36.7												
13	19.8	00.0	42.4	2.6	00.0	5.6									
17	23.7	00.0	50.6	6.5	00.0	13.9	3.9	00.0	8.2						
19	25.1	00.0	53.8	7.9	00.0	17.0	5.3	00.0	11.4	1.4	00.0	3.1			
21	26.3	00.0	56.3	9.1	00.0	19.5	6.5	00.0	13.9	2.6	00.0	5.6	1.2	00.0	2.5
25	28.3	00.0	60.3	11.1	00.0	23.5	8.5	00.0	17.9	4.6	00.0	9.6	3.1	00.0	6.5
27	29.0	00.0	61.8	11.8	00.0	25.0	9.2	00.0	19.4	5.3	00.0	11.2	3.9	00.0	8.0

Building: Single-family **City: NYC** **HVAC: AC with Fuel Heat** **Measure: Ceiling Insulation**

Base	0			11			19			30			38		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	415.2	0.307	224.4												
19	468.9	0.375	252.4	53.8	0.068	28.0									
30	497.8	0.392	268.6	82.6	0.085	44.2	28.8	0.017	16.2						
38	508.4	0.410	275.1	93.2	0.102	50.7	39.4	0.034	22.7	10.6	0.017	6.5			
49	515.2	0.410	280.5	100.0	0.102	56.1	46.2	0.034	28.2	17.4	0.017	11.9	6.8	0.000	5.5
60	521.8	0.427	284.1	106.7	0.119	59.7	52.9	0.051	31.7	24.1	0.034	15.5	13.5	0.017	9.0

Building: **Single-family** **City: NYC** **HVAC: Heat Pump** **Measure: Ceiling Insulation**

Base	0		11		19		30		38	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	2,988.4	0.341								
19	3,333.1	0.410	344.7	0.068						
30	3 528.3	0.461	539.9	0.119	195.2	0.051				
38	3 604.4	0.478	616.0	0.137	271.3	0.068	76.1	0.017		
49	3,665.9	0.478	677.5	0.137	332.8	0.068	137.5	0.017	61.4	0.000
60	3,708.9	0.495	720.5	0.154	375.8	0.085	180.5	0.034	104.4	0.017

Building: **Single-family** **City: NYC** **HVAC: AC with Electric Heat** **Measure: Ceiling Insulation**

Base	0		11		19		30		38	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	5,338.7	0.307								
19	5,996.6	0.375	657.8	0.068						
30	6,373.9	0.392	1,035.2	0.085	377.3	0.017				
38	6,520.6	0.410	1,181.9	0.102	524.1	0.034	146.8	0.017		
49	6,646.8	0.410	1,308.0	0.102	650.2	0.034	272.9	0.017	126.1	0.000
60	6,731.1	0.427	1,392.3	0.119	734.5	0.051	357.2	0.034	210.4	0.017

Building: **Single-family** **City: NYC** **HVAC: Electric Heat, no AC** **Measure: Ceiling Insulation**

Base	0		11		19		30		38	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	5,028.7	00.0								
19	5,645.6	00.0	616.9	00.0						
30	6,001.4	00.0	972.7	00.0	355.8	00.0				
38	6,140.8	00.0	1,112.1	00.0	495.2	00.0	139.4	00.0		
49	6,262.6	00.0	1,234.0	00.0	617.1	00.0	261.3	00.0	121.8	00.0
60	6,342.2	00.0	1,313.5	00.0	696.6	00.0	340.8	00.0	201.4	00.0

Building: Single-family **City: NYC** **HVAC: AC with Fuel Heat** **Measure: Ceiling Insulation**

Base	0			11			19			30			38		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	105.6	00.0	224.4												
19	118.4	00.0	252.6	12.8	00.0	28.2									
30	125.9	00.0	268.8	20.3	00.0	44.4	7.5	00.0	16.2						
38	128.8	00.0	275.1	23.2	00.0	50.7	10.4	00.0	22.5	2.9	00.0	6.3			
49	131.4	00.0	280.7	25.8	00.0	56.3	13.0	00.0	28.2	5.5	00.0	11.9	2.6	00.0	5.6
60	133.1	00.0	284.3	27.5	00.0	59.9	14.7	00.0	31.7	7.2	00.0	15.5	4.3	00.0	9.2

Building: Single-family **City: Syracuse** **HVAC: AC with Fuel Heat** **Measure: Wall Insulation**

Base	0			11			13			17			19		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	49.2	0.033	51.4												
13	57.2	0.033	59.6	8.0	0.000	8.2									
17	72.6	0.043	71.2	23.4	0.011	19.8	15.4	0.011	11.6						
19	74.9	0.043	75.4	25.7	0.011	24.1	17.7	0.011	15.8	2.3	0.000	4.2			
21	79.4	0.043	79.0	30.2	0.011	27.6	22.2	0.011	19.4	6.8	0.000	7.8	4.6	0.000	3.6
25	84.5	0.054	84.5	35.3	0.022	33.2	27.3	0.022	24.9	11.9	0.011	13.3	9.6	0.011	9.1
27	88.0	0.054	86.8	38.8	0.022	35.4	30.8	0.022	15.6	15.4	0.011	15.6	13.1	0.011	11.4

Building: Single-family **City: Syracuse** **HVAC: Heat Pump** **Measure: Wall Insulation**

Base	0		11		13		17		19	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	760.8	0.033								
13	878.8	0.033	118.0	0.000						
17	1,046.2	0.043	285.4	0.011	167.4	0.011				
19	1,105.9	0.043	345.1	0.011	227.1	0.011	59.7	0.000		
21	1,154.8	0.043	394.0	0.011	276.0	0.011	108.6	0.000	48.9	0.000
25	1,233.0	0.054	472.3	0.022	354.2	0.022	186.9	0.011	127.1	0.011
27	1,265.8	0.054	505.0	0.022	219.6	0.022	219.6	0.011	159.9	0.011

Building: Single-family **City: Syracuse** **HVAC: AC with Electric Heat** **Measure: Wall Insulation**

Base	0		11		13		17		19	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	1,175.9	0.033								
13	1,363.4	0.033	187.5	0.000						
17	1,631.7	0.043	455.8	0.011	268.3	0.011				
19	1,726.3	0.043	550.4	0.011	362.9	0.011	94.6	0.000		
21	1,807.7	0.043	631.8	0.011	444.3	0.011	176.0	0.000	81.4	0.000
25	1,933.8	0.054	757.9	0.022	570.3	0.022	302.1	0.011	207.5	0.011
27	1,985.6	0.054	809.7	0.022	622.2	0.022	353.9	0.011	259.3	0.011

Building: **Single-family** **City: Syracuse** **HVAC: Electric Heat, no AC** **Measure: Wall Insulation**

Base	0		11		13		17		19	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	1,151.6	00.0								
13	1,335.1	00.0	183.5	00.0						
17	1,593.5	00.0	441.9	00.0	258.4	00.0				
19	1,688.1	00.0	536.4	00.0	352.9	00.0	94.5	00.0		
21	1,766.6	00.0	615.0	00.0	431.5	00.0	173.1	00.0	78.6	00.0
25	1,890.3	00.0	738.7	00.0	555.2	00.0	296.8	00.0	202.3	00.0
27	1,939.7	00.0	788.1	00.0	604.6	00.0	346.2	00.0	251.7	00.0

,

Building: Single-family **City: Syracuse** **HVAC: Fuel Heat, no AC** **Measure: Wall Insulation**

Base	0			11			13			17			19		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	25.0	00.0	51.5												
13	29.0	00.0	59.6	4.0	00.0	8.1									
17	34.7	00.0	71.3	9.6	00.0	19.8	5.6	00.0	11.7						
19	36.7	00.0	75.5	11.7	00.0	24.1	7.7	00.0	15.9	2.1	00.0	4.2			
21	38.4	00.0	79.1	13.3	00.0	27.6	9.3	00.0	19.5	3.7	00.0	7.8	1.6	00.0	3.6
25	41.1	00.0	84.7	16.0	00.0	33.2	12.0	00.0	25.0	6.4	00.0	13.3	4.3	00.0	9.1
27	42.2	00.0	86.8	17.1	00.0	35.3	13.1	00.0	27.2	7.5	00.0	15.5	5.4	00.0	11.3

Building: Single-family **City: Syracuse** **HVAC: AC with Fuel Heat** **Measure: Ceiling Insulation**

Base	0			11			19			30			38		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	344.0	0.188	318.9												
19	384.3	0.205	357.8	40.3	0.017	38.9									
30	406.0	0.222	380.7	61.9	0.034	61.8	21.7	0.017	22.9						
38	416.4	0.239	389.8	72.4	0.051	70.8	32.1	0.034	31.9	10.4	0.017	9.0			
49	420.6	0.239	397.6	76.6	0.051	78.7	36.3	0.034	39.8	14.7	0.017	16.9	4.3	0.000	7.8
60	426.3	0.239	402.7	82.3	0.051	83.8	42.0	0.034	44.9	20.3	0.017	22.0	9.9	0.000	13.0

Building: **Single-family** **City: Syracuse** **HVAC: Heat Pump** **Measure: Ceiling Insulation**

Base	0		11		19		30		38	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	5,539.8	0.188								
19	6,144.0	0.205	604.3	0.017						
30	6,488.6	0.222	948.8	0.034	344.5	0.017				
38	6,621.2	0.239	1,081.4	0.051	477.1	0.034	132.6	0.017		
49	6,737.4	0.239	1,197.6	0.051	593.3	0.034	248.8	0.017	116.2	0.000
60	6,813.0	0.256	1,273.2	0.068	668.9	0.051	324.4	0.034	191.8	0.017

Building: **Single-family** **City: Syracuse** **HVAC: AC with Electric Heat** **Measure: Ceiling Insulation**

Base	0		11		19		30		38	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	7,544.0	0.188								
19	8,444.2	0.205	900.2	0.017						
30	8,970.3	0.222	1,426.3	0.034	526.1	0.017				
38	9,178.5	0.239	1,634.5	0.051	734.3	0.034	208.2	0.017		
49	9,355.3	0.239	1,811.3	0.051	911.1	0.034	385.0	0.017	176.8	0.000
60	9,473.7	0.239	1,929.7	0.051	1,029.5	0.034	503.4	0.017	295.2	0.000

Building: **Single-family** **City: Syracuse** **HVAC: Electric Heat, no AC** **Measure: Ceiling Insulation**

Base	0		11		19		30		38	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	7,354.6	00.0								
19	8,232.6	00.0	878.0	00.0						
30	8,747.6	00.0	1,393.0	00.0	515.0	00.0				
38	8,949.5	00.0	1,594.9	00.0	716.9	00.0	201.9	00.0		
49	9,125.8	00.0	1,771.2	00.0	893.2	00.0	378.2	00.0	176.3	00.0
60	9,241.0	00.0	1,886.3	00.0	1,008.4	00.0	493.3	00.0	291.5	00.0

Building: Single-family **City: Syracuse** **HVAC: Fuel Heat No AC** **Measure: Ceiling Insulation**

Base	0			11			19			30			38		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	154.4	00.0	318.9												
19	172.7	00.0	357.8	18.3	00.0	38.9									
30	183.3	00.0	380.7	28.8	00.0	61.8	10.6	00.0	22.9						
38	187.4	00.0	389.8	32.9	00.0	70.8	14.7	00.0	31.9	4.1	00.0	9.0			
49	191.1	00.0	397.6	36.7	00.0	78.7	18.4	00.0	39.8	7.8	00.0	16.9	3.8	00.0	7.8
60	193.5	00.0	402.7	39.1	00.0	83.8	20.8	00.0	44.9	10.2	00.0	22.0	6.1	00.0	13.0

Building: Single-family **City: Binghamton** **HVAC: AC with Fuel Heat** **Measure: Wall Insulation**

0			11			13			17			19		
kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
46.2	0.043	54.0												
54.3	0.054	62.6	8.1	0.011	8.7									
64.3	0.065	74.8	18.1	0.022	20.8	10.0	0.011	12.1						
67.4	0.065	79.2	21.2	0.022	25.3	13.1	0.011	16.6	3.1	0.000	4.4			
71.0	0.076	82.9	24.8	0.033	28.9	16.7	0.022	20.3	6.7	0.011	8.1	3.6	0.011	3.7
75.4	0.076	88.7	29.3	0.033	34.7	21.1	0.022	26.0	11.2	0.011	13.9	8.0	0.011	9.4
77.5	0.076	90.9	31.3	0.033	37.0	23.2	0.022	16.2	13.2	0.011	16.2	10.1	0.011	11.7

Single-family **City: Binghamton** **HVAC: Heat Pump** **Measure: Wall Insulation**

0		11		13		17		19	
kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
846.0	0.054								
978.9	0.054	132.9	0.000						
1,165.7	0.065	319.7	0.011	186.9	0.011				
1,232.2	0.076	386.2	0.022	253.3	0.022	66.4	0.011		
1,288.1	0.076	442.1	0.022	309.2	0.022	122.4	0.011	55.9	0.000
1,374.2	0.087	528.2	0.033	395.3	0.033	208.4	0.022	142.0	0.011
1,407.8	0.087	561.8	0.033	242.0	0.033	242.0	0.022	175.6	0.011

Single-family **City: Binghamton** **HVAC: AC with Electric Heat** **Measure: Wall Insulation**

0		11		13		17		19	
kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
1,241.4	0.043								
1,440.0	0.054	198.6	0.011						
1,717.9	0.065	476.5	0.022	277.9	0.011				
1,818.7	0.065	577.3	0.022	378.7	0.011	100.8	0.000		
1,903.9	0.076	662.5	0.033	463.9	0.022	186.0	0.011	85.2	0.011
2,035.0	0.076	793.6	0.033	595.1	0.022	317.1	0.011	216.3	0.011
2,087.1	0.076	845.8	0.033	647.2	0.022	369.3	0.011	268.5	0.011

Single-family **City: Binghamton** **HVAC: Electric Heat, no AC** **Measure: Wall Insulation**

0		11		13		17		19	
kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
1,222.6	00.0								
1,417.4	00.0	194.8	00.0						
1,691.4	00.0	468.8	00.0	274.0	00.0				
1,791.5	00.0	568.8	00.0	374.1	00.0	100.0	00.0		
1,874.9	00.0	652.3	00.0	457.5	00.0	183.5	00.0	83.5	00.0
2,004.4	00.0	781.8	00.0	587.0	00.0	313.0	00.0	213.0	00.0
2,055.6	00.0	833.0	00.0	638.2	00.0	364.2	00.0	264.1	00.0

City: Binghamton **HVAC: Fuel Heat, no AC** **Measure: Wall Insulation**

0			11			13			17			19		
kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
27.3	00.0	54.0												
31.8	00.0	62.6	4.4	00.0	8.7									
37.8	00.0	74.8	10.5	00.0	20.8	6.1	00.0	12.1						
40.1	00.0	79.2	12.8	00.0	25.3	8.3	00.0	16.6	2.3	00.0	4.4			
41.9	00.0	82.9	14.6	00.0	28.9	10.2	00.0	20.3	4.1	00.0	8.1	1.8	00.0	3.7
44.9	00.0	88.7	17.6	00.0	34.7	13.1	00.0	26.0	7.0	00.0	13.9	4.8	00.0	9.4
46.0	00.0	90.9	18.6	00.0	37.0	14.2	00.0	28.3	8.1	00.0	16.2	5.9	00.0	11.7

City: Binghamton **HVAC: AC with Fuel Heat** **Measure: Ceiling Insulation**

0			11			19			30			38		
kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
311.4	0.290	332.9												
350.9	0.341	374.4	39.4	0.051	41.5									
369.8	0.358	398.8	58.4	0.068	65.9	18.9	0.017	24.4						
377.1	0.375	408.2	65.7	0.085	75.3	26.3	0.034	33.8	7.3	0.017	9.4			
385.2	0.392	416.6	73.7	0.102	83.6	34.3	0.051	42.2	15.4	0.034	17.7	8.0	0.017	8.4
389.4	0.392	422.0	78.0	0.102	89.1	38.6	0.051	47.6	19.6	0.034	23.2	12.3	0.017	13.8

Single-family **City: Binghamton** **HVAC: Heat Pump** **Measure: Ceiling Insulation**

0		11		19		30		38	
kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
5,853.1	0.273								
6,534.8	0.324	681.7	0.051						
6,923.9	0.358	1,070.8	0.085	389.1	0.034				
7,075.4	0.358	1,222.4	0.085	540.6	0.034	151.5	0.000		
7,208.7	0.375	1,355.6	0.102	673.9	0.051	284.8	0.017	133.3	0.017
7,294.7	0.375	1,441.6	0.102	759.9	0.051	370.8	0.017	219.3	0.017

Single-family **City: Binghamton** **HVAC: AC with Electric Heat** **Measure: Ceiling Insulation**

0		11		19		30		38	
kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
7,921.3	0.290								
8,887.9	0.341	966.6	0.051						
9,449.0	0.358	1,527.6	0.068	561.1	0.017				
9,668.3	0.375	1,746.9	0.085	780.4	0.034	219.3	0.017		
9,861.9	0.392	1,940.6	0.102	974.1	0.051	413.0	0.034	193.7	0.017
9,987.0	0.392	2,065.7	0.102	1,099.1	0.051	538.1	0.034	318.8	0.017

Single-family **City: Binghamton** **HVAC: Electric Heat, no AC** **Measure: Ceiling Insulation**

0		11		19		30		38	
kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
7,775.8	00.0								
8,723.0	00.0	947.3	00.0						
9,277.1	00.0	1,501.4	00.0	554.1	00.0				
9,493.9	00.0	1,718.1	00.0	770.8	00.0	216.7	00.0		
9,683.4	00.0	1,907.7	00.0	960.4	00.0	406.3	00.0	189.6	00.0
9,807.0	00.0	2,031.2	00.0	1,084.0	00.0	529.9	00.0	313.1	00.0

City: Binghamton **HVAC: Fuel Heat No AC** **Measure: Ceiling Insulation**

0			11			19			30			38		
kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
166.0	00.0	333.1												
186.3	00.0	374.6	20.3	00.0	41.5									
198.1	00.0	398.8	32.1	00.0	65.7	11.8	00.0	24.2						
202.7	00.0	408.4	36.7	00.0	75.3	16.4	00.0	33.8	4.6	00.0	9.6			
206.8	00.0	416.7	40.8	00.0	83.6	20.5	00.0	42.2	8.7	00.0	17.9	4.1	00.0	8.4
209.4	00.0	422.2	43.3	00.0	89.1	23.0	00.0	47.6	11.3	00.0	23.4	6.7	00.0	13.8

Building: Single-family **City: Poughkeepsie** **HVAC: AC with Fuel Heat** **Measure: Wall Insulation**

Base	0			11			13			17			19		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	48.3	0.043	46.2												
13	53.4	0.054	53.8	5.1	0.011	7.6									
17	67.3	0.065	64.4	19.0	0.022	18.2	13.9	0.011	10.6						
19	71.0	0.065	68.3	22.7	0.022	22.1	17.6	0.011	14.5	3.7	0.000	3.9			
21	73.7	0.076	71.8	25.4	0.033	25.6	20.3	0.022	18.0	6.4	0.011	7.4	2.7	0.011	3.5
25	79.0	0.076	76.8	30.7	0.033	30.7	25.6	0.022	23.1	11.7	0.011	12.5	8.0	0.011	8.6
27	81.7	0.076	78.9	33.4	0.033	32.7	28.3	0.022	14.5	14.4	0.011	14.5	10.7	0.011	10.6

Building: **Single-family** **City: Poughkeepsie** **HVAC: Heat Pump** **Measure: Wall Insulation**

Base	0		11		13		17		19	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	591.6	0.054								
13	686.4	0.065	94.8	0.011						
17	823.1	0.076	231.5	0.022	136.7	0.011				
19	871.1	0.087	279.5	0.033	184.7	0.022	48.0	0.011		
21	914.8	0.087	323.2	0.033	228.4	0.022	91.7	0.011	43.7	0.000
25	978.4	0.098	386.8	0.043	292.0	0.033	155.3	0.022	107.3	0.011
27	1,004.0	0.098	412.4	0.043	180.9	0.033	180.9	0.022	132.9	0.011

Building: **Single-family** **City: Poughkeepsie** **HVAC: AC with Electric Heat** **Measure: Wall Insulation**

Base	0		11		13		17		19	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	1,031.3	0.043								
13	1,197.2	0.054	165.8	0.011						
17	1,435.7	0.065	404.4	0.022	238.6	0.011				
19	1,521.5	0.065	490.1	0.022	324.3	0.011	85.7	0.000		
21	1,597.1	0.076	565.8	0.033	400.0	0.022	161.4	0.011	75.7	0.011
25	1,710.1	0.076	678.7	0.033	512.9	0.022	274.3	0.011	188.6	0.011
27	1,755.9	0.076	724.6	0.033	558.7	0.022	320.2	0.011	234.4	0.011

Building: Single-family **City: Poughkeepsie** **HVAC: Electric Heat, no AC** **Measure: Wall Insulation**

Base	0		11		13		17		19	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	1,005.0	00.0								
13	1,169.5	00.0	164.5	00.0						
17	1,399.1	00.0	394.1	00.0	229.6	00.0				
19	1,483.0	00.0	478.0	00.0	313.5	00.0	83.9	00.0		
21	1,558.0	00.0	553.0	00.0	388.5	00.0	158.9	00.0	75.0	00.0
25	1,667.5	00.0	662.5	00.0	497.9	00.0	268.4	00.0	184.5	00.0
27	1,711.5	00.0	706.5	00.0	541.9	00.0	312.4	00.0	228.5	00.0

Building: Single-family **City: Poughkeepsie** **HVAC: Fuel Heat, no AC** **Measure: Wall Insulation**

Base	0			11			13			17			19		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	21.8	00.0	46.3												
13	25.4	00.0	53.8	3.6	00.0	7.5									
17	30.2	00.0	64.5	8.5	00.0	18.2	4.9	00.0	10.7						
19	32.1	00.0	68.4	10.3	00.0	22.1	6.7	00.0	14.6	1.8	00.0	3.9			
21	33.7	00.0	71.9	11.9	00.0	25.6	8.3	00.0	18.1	3.5	00.0	7.4	1.6	00.0	3.5
25	36.1	00.0	77.0	14.3	00.0	30.7	10.7	00.0	23.2	5.9	00.0	12.5	4.0	00.0	8.6
27	37.0	00.0	79.0	15.2	00.0	32.7	11.6	00.0	25.3	6.7	00.0	14.5	4.9	00.0	10.6

Building: Single-family **City: Poughkeepsie** **HVAC: AC with Fuel Heat** **Measure: Ceiling Insulation**

Base	0			11			19			30			38		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	333.4	0.410	297.6												
19	374.6	0.461	335.5	41.1	0.051	37.9									
30	393.0	0.478	357.8	59.6	0.068	60.2	18.4	0.017	22.4						
38	402.7	0.495	366.7	69.3	0.085	69.1	28.2	0.034	31.2	9.7	0.017	8.9			
49	411.8	0.495	374.6	78.3	0.085	77.0	37.2	0.034	39.1	18.8	0.017	16.7	9.0	0.000	7.8
60	416.7	0.512	379.5	83.3	0.102	81.9	42.2	0.051	44.0	23.7	0.034	21.7	14.0	0.017	12.8

Building: **Single-family** **City: Poughkeepsie** **HVAC: Heat Pump** **Measure: Ceiling Insulation**

Base	0		11		19		30		38	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	4,368.1	0.444								
19	4,865.2	0.512	497.1	0.068						
30	5,151.0	0.529	782.9	0.085	285.8	0.017				
38	5,265.7	0.546	897.6	0.102	400.5	0.034	114.7	0.017		
49	5,364.7	0.563	996.6	0.119	499.5	0.051	213.7	0.034	99.0	0.017
60	5,427.1	0.563	1,059.0	0.119	561.9	0.051	276.1	0.034	161.4	0.017

Building: **Single-family** **City: Poughkeepsie** **HVAC: AC with Electric Heat** **Measure: Ceiling Insulation**

Base	0		11		19		30		38	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	6,888.1	0.410								
19	7,742.8	0.461	854.8	0.051						
30	8,240.6	0.478	1,352.6	0.068	497.8	0.017				
38	8,439.1	0.495	1,551.0	0.085	696.2	0.034	198.5	0.017		
49	8,613.3	0.495	1,725.3	0.085	870.5	0.034	372.7	0.017	174.2	0.000
60	8,725.8	0.512	1,837.7	0.102	982.9	0.051	485.2	0.034	286.7	0.017

Building: **Single-family** **City: Poughkeepsie** **HVAC: Electric Heat, no AC** **Measure: Ceiling Insulation**

Base	0		11		19		30		38	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	6,694.7	00.0								
19	7,526.8	00.0	832.1	00.0						
30	8,017.2	00.0	1,322.5	00.0	490.4	00.0				
38	8,209.6	00.0	1,514.8	00.0	682.8	00.0	192.3	00.0		
49	8,376.8	00.0	1,682.1	00.0	850.0	00.0	359.6	00.0	167.2	00.0
60	8,486.9	00.0	1,792.2	00.0	960.1	00.0	469.6	00.0	277.3	00.0

Building: Single-family **City: Poughkeepsie** **HVAC: Fuel Heat No AC** **Measure: Ceiling Insulation**

Base	0			11			19			30			38		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm / kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm / kSF
11	140.8	00.0	297.6												
19	158.4	00.0	335.5	17.6	00.0	37.9									
30	168.6	00.0	358.0	27.8	00.0	60.4	10.2	00.0	22.5						
38	172.5	00.0	366.7	31.7	00.0	69.1	14.2	00.0	31.2	3.9	00.0	8.7			
49	176.1	00.0	374.4	35.3	00.0	76.8	17.7	00.0	38.9	7.5	00.0	16.4	3.6	00.0	7.7
60	178.3	00.0	379.5	37.5	00.0	81.9	20.0	00.0	44.0	9.7	00.0	21.5	5.8	00.0	12.8

MULTI-FAMILY LOW-RISE INSULATION UPGRADES

Building: Multi-Family Low-rise **City: Albany** **HVAC: AC with Fuel Heat** **Measure: Wall Insulation**

Base	0			11			13			17			19		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	44.5	0.046	61.0												
13	57.4	0.057	80.7	13.0	0.011	19.7									
17	77.2	0.069	108.7	32.7	0.023	47.7	19.7	0.011	28.0						
19	84.5	0.080	119.0	40.0	0.034	58.0	27.1	0.023	38.3	7.3	0.011	10.3			
21	87.9	0.080	128.0	43.5	0.034	67.0	30.5	0.023	47.2	10.8	0.011	19.3	3.4	0.000	8.9
25	99.0	0.092	141.7	54.5	0.046	80.7	41.5	0.034	61.0	21.8	0.023	33.0	14.4	0.011	22.7
27	100.9	0.092	147.2	56.4	0.046	86.2	43.5	0.034	66.5	23.7	0.023	38.5	16.4	0.011	28.2

Building: **Multi-Family Low-rise** **City: Albany** **HVAC: Heat Pump** **Measure: Wall Insulation**

Base	0		11		13		17		19	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	764.5	0.000								
13	1,010.1	0.011	245.6	0.000						
17	1,348.0	0.034	583.5	0.023	337.9	0.000				
19	1,472.4	0.034	707.9	0.023	462.3	0.000	124.4	0.000		
21	1,577.3	0.034	812.9	0.023	567.3	0.000	229.3	0.000	104.9	0.000
25	1,743.4	0.046	978.9	0.034	733.3	0.011	395.4	0.011	271.0	0.000
27	1,809.9	0.046	1,045.4	0.034	799.8	0.011	461.9	0.011	337.5	0.000

Building: **Multi-Family Low-rise** **City: Albany** **HVAC: AC with Electric Heat** **Measure: Wall Insulation**

Base	0		11		13		17		19	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	989.8	0.000								
13	1,301.1	0.011	311.3	0.000						
17	1,740.6	0.023	750.8	0.011	439.5	0.000				
19	1,901.3	0.034	911.5	0.023	600.2	0.011	160.6	0.000		
21	2,032.9	0.034	1,043.1	0.023	731.8	0.011	292.3	0.000	131.6	0.000
25	2,245.8	0.046	1,256.0	0.034	944.7	0.023	505.2	0.011	344.6	0.000
27	2,328.6	0.046	1,338.8	0.034	1,027.5	0.023	588.0	0.011	427.4	0.000

Building: **Multi-Family Low-rise** **City: Albany** **HVAC: Electric Heat, no AC** **Measure: Wall Insulation**

Base	0		11		13		17		19	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	980.4	0.0								
13	1,289.9	0.0	309.5	0.0						
17	1,724.5	0.0	744.1	0.0	434.6	0.0				
19	1,883.4	0.0	903.0	0.0	593.5	0.0	158.9	0.0		
21	2,015.5	0.0	1,035.1	0.0	725.6	0.0	291.0	0.0	132.1	0.0
25	2,226.0	0.0	1,245.6	0.0	936.1	0.0	501.5	0.0	342.6	0.0
27	2,309.6	0.0	1,329.2	0.0	1,019.7	0.0	585.1	0.0	426.2	0.0

Building: Multi-Family Low-rise **City: Albany** **HVAC: Fuel Heat, no AC** **Measure: Wall Insulation**

Base	0			11			13			17			19		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	35.1	0.0	61.0												
13	46.2	0.0	80.7	11.1	0.0	19.7									
17	60.9	0.0	108.7	25.8	0.0	47.7	14.7	0.0	28.0						
19	66.5	0.0	119.0	31.4	0.0	58.0	20.3	0.0	38.3	5.6	0.0	10.3			
21	70.4	0.0	128.0	35.3	0.0	67.0	24.2	0.0	47.2	9.5	0.0	19.3	3.9	0.0	8.9
25	79.3	0.0	141.7	44.3	0.0	80.7	33.1	0.0	61.0	18.5	0.0	33.0	12.8	0.0	22.7
27	82.1	0.0	147.2	47.0	0.0	86.2	35.9	0.0	66.5	21.2	0.0	38.5	15.6	0.0	28.2

Building: Multi-Family Low-rise **City: Albany** **HVAC: AC with Fuel Heat** **Measure: Ceiling Insulation**

Base	0			11			19			30			38		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	344.6	0.351	253.9												
19	406.0	0.413	301.5	61.3	0.061	47.6									
30	443.0	0.448	332.1	98.4	0.097	78.2	37.1	0.035	30.6						
38	459.5	0.466	344.5	114.8	0.114	90.6	53.5	0.053	43.0	16.4	0.018	12.4			
49	473.2	0.483	355.8	128.5	0.132	101.9	67.2	0.070	54.3	30.1	0.035	23.7	13.7	0.018	11.3
60	481.1	0.492	363.2	136.4	0.141	109.3	75.1	0.079	61.7	38.0	0.044	31.1	21.6	0.026	18.7

Building: **Multi-Family Low-rise** **City: Albany** **HVAC: Heat Pump** **Measure: Ceiling Insulation**

Base	0		11		19		30		38	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	4,386.5	0.343								
19	5,086.8	0.404	700.3	0.061						
30	5,517.8	0.439	1,131.3	0.097	431.0	0.035				
38	5,694.0	0.448	1,307.6	0.105	607.2	0.044	176.2	0.009		
49	5,849.7	0.466	1,463.2	0.123	762.9	0.061	331.9	0.026	155.7	0.018
60	5,952.4	0.474	1,565.9	0.132	865.6	0.070	434.6	0.035	258.4	0.026

Building: **Multi-Family Low-rise** **City: Albany** **HVAC: AC with Electric Heat** **Measure: Ceiling Insulation**

Base	0		11		19		30		38	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	5,034.2	0.351								
19	5,883.8	0.413	849.6	0.061						
30	6,408.2	0.448	1,374.0	0.097	524.4	0.035				
38	6,620.8	0.466	1,586.6	0.114	737.0	0.053	212.6	0.018		
49	6,809.0	0.483	1,774.8	0.132	925.2	0.070	400.9	0.035	188.3	0.018
60	6,933.1	0.492	1,899.0	0.141	1,049.4	0.079	525.0	0.044	312.4	0.026

Building: **Multi-Family Low-rise** **City: Albany** **HVAC: Electric Heat, no AC** **Measure: Ceiling Insulation**

Base	0		11		19		30		38	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	4,849.7	0.0								
19	5,667.1	0.0	817.4	0.0						
30	6,173.5	0.0	1,323.8	0.0	506.4	0.0				
38	6,375.7	0.0	1,526.0	0.0	708.6	0.0	202.2	0.000		
49	6,558.3	0.0	1,708.6	0.0	891.2	0.0	384.8	0.000	182.6	0.0
60	6,678.5	0.0	1,828.8	0.0	1,011.3	0.0	505.0	0.000	302.7	0.0

Building: Multi-Family Low-rise **City: Albany** **HVAC: Fuel Heat No AC** **Measure: Ceiling Insulation**

Base	0			11			19			30			38		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	160.2	0.0	253.9												
19	189.3	0.0	301.5	29.2	0.0	47.6									
30	208.4	0.0	332.1	48.2	0.0	78.2	19.1	0.0	30.6						
38	214.5	0.0	344.5	54.4	0.0	90.6	25.2	0.0	43.0	6.1	0.0	12.4			
49	222.4	0.0	355.8	62.3	0.0	101.9	33.1	0.0	54.3	14.1	0.0	23.7	7.9	0.0	11.3
60	226.5	0.0	363.2	66.3	0.0	109.3	37.2	0.0	61.7	18.1	0.0	31.1	11.9	0.0	18.7

Building: Multi-Family Low-rise **City: Buffalo** **HVAC: AC with Fuel Heat** **Measure: Wall Insulation**

Base	0			11			13			17			19		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	35.3	0.023	61.7												
13	48.8	0.023	81.0	13.5	0.000	19.3									
17	62.5	0.034	107.7	27.2	0.011	46.0	13.6	0.011	26.7						
19	67.7	0.034	117.5	32.3	0.011	55.8	18.8	0.011	36.6	5.2	0.000	9.9			
21	72.6	0.046	125.8	37.3	0.023	64.1	23.7	0.023	44.8	10.1	0.011	18.1	4.9	0.011	8.3
25	80.5	0.046	139.1	45.2	0.023	77.4	31.6	0.023	58.1	18.0	0.011	31.4	12.8	0.011	21.6
27	83.7	0.046	144.5	48.4	0.023	82.8	34.9	0.023	63.5	21.2	0.011	36.8	16.1	0.011	26.9

Building: **Multi-Family Low-rise** **City: Buffalo** **HVAC: Heat Pump** **Measure: Wall Insulation**

Base	0		11		13		17		19	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	760.8	0.000								
13	1,005.4	0.000	244.6	0.000						
17	1,336.9	0.011	576.1	0.011	331.5	0.000				
19	1,457.6	0.011	696.8	0.011	452.2	0.000	120.7	0.000		
21	1,557.4	0.011	796.6	0.011	552.0	0.000	220.5	0.000	99.8	0.000
25	1,716.5	0.023	955.7	0.023	711.2	0.011	379.7	0.011	258.9	0.000
27	1,781.2	0.023	1,020.4	0.023	775.8	0.011	444.3	0.011	323.6	0.000

Building: **Multi-Family Low-rise** **City: Buffalo** **HVAC: AC with Electric Heat** **Measure: Wall Insulation**

Base	0		11		13		17		19	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	964.0	0.000								
13	1,275.2	0.000	311.2	0.000						
17	1,698.2	0.011	734.2	0.011	423.0	0.000				
19	1,852.5	0.011	888.5	0.011	577.3	0.000	154.3	0.000		
21	1,982.3	0.023	1,018.3	0.023	707.1	0.011	284.1	0.011	129.8	00.000
25	2,187.0	0.023	1,223.0	0.023	911.8	0.011	488.8	0.011	334.5	00.000
27	2,268.8	0.023	1,304.8	0.023	993.6	0.011	570.6	0.011	416.2	00.000

Building: Multi-Family Low-rise **City: Buffalo** **HVAC: Electric Heat, no AC** **Measure: Wall Insulation**

Base	0		11		13		17		19	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	960.2	0.000								
13	1,267.2	0.000	307.0	0.000						
17	1,690.7	-0.023	730.5	-0.023	423.6	0.000				
19	1,843.7	0.000	883.5	0.000	576.5	0.023	153.0	0.000		
21	1,975.5	0.000	1015.3	0.000	708.3	0.023	284.7	0.000	131.8	00.000
25	2,177.4	-0.023	1217.2	-0.023	910.2	0.000	486.6	-0.023	333.7	00.000
27	2,260.1	0.000	1299.9	0.000	992.9	0.023	569.3	0.000	416.4	00.000

Building: Multi-Family Low-rise **City: Buffalo** **HVAC: Fuel Heat, no AC** **Measure: Wall Insulation**

Base	0			11			13			17			19		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	31.5	0.000	61.7												
13	40.8	0.000	81.0	9.3	0.000	19.3									
17	55.2	-0.023	107.7	23.6	-0.023	46.0	14.3	0.000	26.7						
19	58.7	0.000	117.5	27.2	0.000	55.8	17.9	0.023	36.6	3.6	0.000	9.9			
21	65.8	0.000	125.8	34.3	0.000	64.1	25.0	0.023	44.8	10.7	0.000	18.1	7.1	0.000	8.3
25	70.9	-0.023	139.1	39.3	-0.023	77.4	30.0	0.000	58.1	15.7	-0.023	31.4	12.2	0.000	21.6
27	74.9	0.000	144.5	43.3	0.000	82.8	34.1	0.023	63.5	19.7	0.000	36.8	16.2	0.000	26.9

Building: Multi-Family Low-rise **City: Buffalo** **HVAC: AC with Fuel Heat** **Measure: Ceiling Insulation**

Base	0			11			19			30			38		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	283.9	0.193	255.7												
19	332.8	0.237	302.5	48.8	0.044	46.7									
30	364.2	0.246	332.2	80.3	0.053	76.4	31.5	0.009	29.7						
38	377.1	0.255	344.2	93.1	0.061	88.5	44.3	0.018	41.7	12.8	0.009	12.0			
49	387.5	0.272	354.8	103.6	0.079	99.1	54.7	0.035	52.4	23.3	0.026	22.7	10.5	0.018	10.6
60	394.8	0.272	361.9	110.9	0.079	106.2	62.0	0.035	59.5	30.6	0.026	29.8	17.7	0.018	17.7

Building: **Multi-Family Low-rise** **City: Buffalo** **HVAC: Heat Pump** **Measure: Ceiling Insulation**

Base	0		11		19		30		38	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	4,262.2	0.193								
19	4,950.5	0.228	688.3	0.035						
30	5,361.6	0.246	1,099.4	0.053	411.1	0.018				
38	5,525.9	0.246	1,263.6	0.053	575.3	0.018	164.3	0.000		
49	5,670.6	0.255	1,408.4	0.061	720.1	0.026	309.1	0.009	144.8	0.009
60	5,769.6	0.264	1,507.3	0.070	819.0	0.035	408.0	0.018	243.7	0.018

Building: **Multi-Family Low-rise** **City: Buffalo** **HVAC: AC with Electric Heat** **Measure: Ceiling Insulation**

Base	0		11		19		30		38	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	5,017.6	0.193								
19	5,846.5	0.237	829.0	0.044						
30	6,357.2	0.246	1,339.6	0.053	510.7	0.009				
38	6,562.5	0.255	1,544.9	0.061	716.0	0.018	205.3	0.009		
49	6,743.3	0.272	1,725.7	0.079	896.8	0.035	386.1	0.026	180.8	0.018
60	6,862.8	0.272	1,845.2	0.079	1,016.3	0.035	505.6	0.026	300.3	0.018

Building: **Multi-Family Low-rise** **City: Buffalo** **HVAC: Electric Heat, no AC** **Measure: Ceiling Insulation**

Base	0		11		19		30		38	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	4,884.2	0.000								
19	5,690.2	-0.044	806.0	0.000						
30	6,186.5	-0.018	1,302.3	0.026	496.3	0.000				
38	6,385.3	-0.018	1,501.1	0.026	695.1	0.000	198.8	0.000		
49	6,561.2	-0.018	1,677.0	0.026	870.9	0.000	374.7	0.000	175.9	0.000
60	6,677.4	-0.018	1,793.2	0.026	987.2	0.000	490.9	0.000	292.1	0.000

Building: Multi-Family Low-rise **City: Buffalo** **HVAC: Fuel Heat No AC** **Measure: Ceiling Insulation**

Base	0			11			19			30			38		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	150.6	0.000	255.7												
19	176.6	-0.044	302.5	26.0	0.000	46.7									
30	193.6	-0.018	332.2	43.0	0.026	76.4	17.0	0	29.7						
38	199.9	-0.018	344.2	49.3	0.026	88.5	23.3	0	41.7	6.2	0	12.0			
49	205.4	-0.018	354.8	54.8	0.026	99.1	28.8	0	52.4	11.8	0	22.7	5.5	0.000	10.6
60	209.4	-0.018	361.9	58.9	0.026	106.2	32.9	0	59.5	15.8	0	29.8	9.6	0.000	17.7

Building: Multi-Family Low-rise **City: Massena** **HVAC: AC with Fuel Heat** **Measure: Wall Insulation**

Base	0			11			13			17			19		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	43.1	0.034	68.1												
13	56.8	0.046	90.7	13.6	0.011	22.6									
17	77.3	0.057	122.9	34.2	0.023	54.8	20.5	0.011	32.2						
19	83.0	0.069	134.6	39.9	0.034	66.5	26.3	0.023	43.9	5.7	0.011	11.7			
21	87.9	0.069	144.1	44.8	0.034	76.0	31.2	0.023	53.4	10.7	0.011	21.2	4.9	0.000	9.5
25	96.4	0.080	159.7	53.3	0.046	91.6	39.7	0.034	69.0	19.1	0.023	36.8	13.4	0.011	25.1
27	100.4	0.080	166.0	57.3	0.046	97.9	43.7	0.034	75.3	23.2	0.023	43.1	17.4	0.011	31.4

Building: **Multi-Family Low-rise** **City: Massena** **HVAC: Heat Pump** **Measure: Wall Insulation**

Base	0		11		13		17		19	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	933.6	0.000								
13	1,229.6	0.011	296.0	0.000						
17	1,645.5	0.023	711.8	0.011	415.9	0.000				
19	1,795.1	0.034	861.5	0.023	565.5	0.011	149.6	0.000		
21	1,921.3	0.034	987.7	0.023	691.8	0.011	275.9	0.000	126.2	00.000
25	2,118.2	0.046	1,184.6	0.034	888.7	0.023	472.8	0.011	323.1	00.000
27	2,195.4	0.046	1,261.8	0.034	965.8	0.023	549.9	0.011	400.3	0.000

Building: **Multi-Family Low-rise** **City: Massena** **HVAC: AC with Electric Heat** **Measure: Wall Insulation**

Base	0		11		13		17		19	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	1,142.6	0.000								
13	1,504.5	0.011	361.9	0.000						
17	2,034.9	0.023	892.2	0.011	530.3	0.000				
19	2,219.4	0.034	1,076.7	0.023	714.8	0.011	184.5	0.000		
21	2,373.1	0.034	1,230.5	0.023	868.6	0.011	338.3	0.000	153.8	00.000
25	2,616.9	0.046	1,474.3	0.034	1,112.4	0.023	582.0	0.011	397.5	0.000
27	2,715.5	0.046	1,572.9	0.034	1,211.0	0.023	680.7	0.011	496.2	0.000

Building: Multi-Family Low-rise City: Massena HVAC: Electric Heat, no AC Measure: Wall Insulation

Base	0		11		13		17		19	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	1,136.1	0.0								
13	1,496.4	0.0	360.3	0.0						
17	2,022.1	0.0	886.0	0.0	525.7	0.0				
19	2,206.7	0.0	1,070.6	0.0	710.4	00.0	184.6	00.0		
21	2,362.3	0.0	1,226.2	0.0	866.0	00.0	340.2	00.0	155.6	00.0
25	2,604.1	0.0	1,468.0	0.0	1,107.7	00.0	581.9	00.0	397.3	00.0
27	2,703.2	0.0	1,567.1	0.0	1,206.9	00.0	681.1	00.0	496.5	00.0

Building: Multi-Family Low-rise City: Massena HVAC: Fuel Heat, no AC Measure: Wall Insulation

Base	0			11			13			17			19		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	36.2	0	68.1												
13	48.2	0	90.7	11.9	0	22.6									
17	64.4	0	122.8	28.2	0	54.7	16.3	0	32.1						
19	70.6	0	134.5	34.4	0	66.4	22.5	0	43.8	6.2	0	11.7			
21	76.9	0	144.0	40.7	0	75.9	28.8	0	53.3	12.5	0	21.2	6.3	0.000	9.5
25	83.5	0	159.6	47.2	0	91.5	35.3	0	68.9	19.0	00	36.8	12.8	0.000	25.1
27	88.1	0	166.0	51.8	0	97.9	39.9	0	75.3	23.6	00	43.2	17.4	00.000	31.5

Building: Multi-Family Low-rise City: Massena HVAC: AC with Fuel Heat Measure: Ceiling Insulation

Base	0			11			19			30			38		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	350.3	0.404	301.6												
19	414.3	0.466	357.2	64.0	0.061	55.6									
30	450.0	0.510	392.4	99.7	0.105	90.8	35.7	0.044	35.2						
38	466.7	0.527	406.7	116.4	0.123	105.2	52.4	0.061	49.5	16.7	0.018	14.3			
49	480.0	0.536	419.7	129.8	0.132	118.2	65.7	0.070	62.5	30.0	0.026	27.3	13.4	0.009	13.0
60	487.8	0.545	428.1	137.6	0.141	126.5	73.5	0.079	70.9	37.9	0.035	35.7	21.2	0.018	21.3

Building: Multi-Family Low-rise **City: Massena** **HVAC: Heat Pump** **Measure: Ceiling Insulation**

Base	0		11		19		30		38	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	5,933.3	0.387								
19	6,907.4	0.457	974.1	0.070						
30	7,488.7	0.492	1,555.4	0.105	581.3	0.035				
38	7,715.0	0.501	1,781.7	0.114	807.6	0.044	226.3	0.009		
49	7,921.5	0.518	1,988.1	0.132	1,014.1	0.061	432.8	0.026	206.4	0.018
60	8,056.0	0.527	2,122.7	0.141	1,148.6	0.070	567.3	0.035	341.0	0.026

Building: Multi-Family Low-rise **City: Massena** **HVAC: AC with Electric Heat** **Measure: Ceiling Insulation**

Base	0		11		19		30		38	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	6,004.7	0.404								
19	7,014.4	0.466	1,009.8	0.061						
30	7,635.5	0.510	1,630.9	0.105	621.1	0.044				
38	7,887.7	0.527	1,883.1	0.123	873.3	0.061	252.2	0.018		
49	8,110.2	0.536	2,105.5	0.132	1,095.8	0.070	474.7	0.026	222.4	0.009
60	8,255.6	0.545	2,251.0	0.141	1,241.2	0.079	620.1	0.035	367.9	0.018

Building: Multi-Family Low-rise **City: Massena** **HVAC: Electric Heat, no AC** **Measure: Ceiling Insulation**

Base	0		11		19		30		38	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	5,829.0	0.000								
19	6,806.8	-0.026	977.8	0.000						
30	7,412.7	-0.044	1,583.7	-0.018	605.9	00.000				
38	7,655.7	-0.044	1,826.7	-0.018	848.9	00.000	243.0	0.000		
49	7,871.7	-0.044	2,042.6	-0.018	1,064.8	00.000	458.9	0.000	215.9	0.000
60	8,014.6	-0.044	2,185.5	-0.018	1,207.8	0.000	601.9	0.000	358.9	0.000

Building: Multi-Family Low-rise **City: Massena** **HVAC: Fuel Heat No AC** **Measure: Ceiling Insulation**

Base	0			11			19			30			38		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	174.8	0.000	301.6												
19	206.7	-0.026	357.2	31.9	0.000	55.6									
30	227.2	-0.044	392.4	52.4	-0.018	90.8	20.5	0.000	35.2						
38	234.7	-0.044	406.7	59.9	-0.018	105.2	28.0	0.000	49.5	7.6	0.000	14.3			
49	241.8	-0.044	419.7	66.9	-0.018	118.1	35.1	0.000	62.5	14.6	0.000	27.2	7.0	0.000	12.9
60	247.0	-0.044	428.1	72.2	-0.018	126.5	40.3	0.000	70.9	19.9	0.000	35.7	12.3	0.000	21.3

Building: Multi-Family Low-rise **City: NYC** **HVAC: AC with Fuel Heat** **Measure: Wall Insulation**

Base	0			11			13			17			19		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	37.8	0.034	44.1												
13	51.6	0.046	59.1	13.8	0.011	14.9									
17	70.1	0.069	78.9	32.2	0.034	34.7	18.5	0.023	19.8						
19	75.2	0.069	86.0	37.4	0.034	41.9	23.6	0.023	26.9	5.2	0.000	7.1			
21	79.3	0.080	92.1	41.5	0.046	47.9	27.7	0.034	33.0	9.3	0.011	13.2	4.1	0.011	6.1
25	88.5	0.080	101.6	50.7	0.046	57.4	36.9	0.034	42.5	18.5	0.011	22.7	13.3	0.011	15.6
27	90.8	0.080	105.1	53.0	0.046	61.0	39.2	0.034	46.1	20.8	0.011	26.3	15.6	0.011	19.1

Building: **Multi-Family Low-rise** **City: NYC** **HVAC: Heat Pump** **Measure: Wall Insulation**

Base	0		11		13		17		19	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	469.7	0.000								
13	618.2	0.011	148.5	0.000						
17	832.5	0.023	362.8	0.011	214.3	0.000				
19	908.6	0.023	438.9	0.011	290.4	0.000	76.1	0.000		
21	971.4	0.034	501.8	0.023	353.3	0.011	139.0	0.011	62.8	0.000
25	1,070.9	0.034	601.2	0.023	452.7	0.011	238.4	0.011	162.3	0.000
27	1,104.2	0.046	634.6	0.034	486.1	0.023	271.8	0.023	195.6	0.000

Building: **Multi-Family Low-rise** **City: NYC** **HVAC: AC with Electric Heat** **Measure: Wall Insulation**

Base	0		11		13		17		19	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	687.5	0.000								
13	905.2	0.011	217.6	0.000						
17	1,210.0	0.034	522.4	0.023	304.8	0.000				
19	1,319.6	0.034	632.0	0.023	414.4	0.000	109.6	0.000		
21	1,411.0	0.046	723.4	0.034	505.8	0.011	201.0	0.011	91.4	0.000
25	1,557.0	0.046	869.5	0.034	651.9	0.011	347.1	0.011	237.5	0.000
27	1,603.8	0.046	916.3	0.034	698.7	0.011	393.9	0.011	284.3	0.000

Building: Multi-Family Low-rise **City: NYC** **HVAC: Electric Heat, no AC** **Measure: Wall Insulation**

Base	0		11		13		17		19	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	673.1	0.0								
13	883.3	0.0	210.2	0.0						
17	1,178.3	0.0	505.2	0.0	295.0	0.0				
19	1,287.4	0.0	614.3	0.0	404.1	0.0	109.0	0.0		
21	1,375.9	0.0	702.8	0.0	492.6	0.0	197.6	0.0	88.5	0.0
25	1,518.4	0.0	845.3	0.0	635.1	0.0	340.1	0.0	231.1	0.0
27	1,564.3	0.0	891.2	0.0	681.0	0.0	386.0	0.0	276.9	0.0

Building: Multi-Family Low-rise **City: NYC** **HVAC: Fuel Heat, no AC** **Measure: Wall Insulation**

Base	0			11			13			17			19		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	23.4	0.0	44.1												
13	29.6	0.0	59.1	6.2	0.0	14.9									
17	38.3	0.0	78.9	14.9	0.0	34.7	8.7	0.0	19.8						
19	42.8	0.0	86.0	19.4	0.0	41.9	13.2	0.0	26.9	4.5	0.0	7.1			
21	44.3	0.0	92.1	20.9	00.0	47.9	14.7	0.0	33.0	6.0	0.0	13.2	1.5	0.0	6.1
25	49.9	0.0	101.7	26.5	00.0	57.6	20.3	0.0	42.7	11.6	0.0	22.8	7.1	0.0	15.7
27	51.1	0.0	105.1	27.7	0.0	61.0	21.6	0.0	46.1	12.8	0.0	26.3	8.4	0.0	19.1

Building: Multi-Family Low-rise **City: NYC** **HVAC: AC with Fuel Heat** **Measure: Ceiling Insulation**

Base	0			11			19			30			38		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	372.7	0.369	181.6												
19	436.9	0.430	214.3	64.2	0.061	32.7									
30	475.4	0.466	235.4	102.7	0.097	53.9	38.5	0.035	21.2						
38	491.4	0.483	243.9	118.8	0.114	62.3	54.6	0.053	29.6	16.1	0.018	8.4			
49	505.1	0.492	251.0	132.4	0.123	69.4	68.2	0.061	36.7	29.7	0.026	15.5	13.6	0.009	7.1
60	514.9	0.501	256.1	142.2	0.132	74.5	78.0	0.070	41.8	39.5	0.035	20.6	23.5	0.018	12.2

Building: Multi-Family Low-rise **City: NYC** **HVAC: Heat Pump** **Measure: Ceiling Insulation**

Base	0		11		19		30		38	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	2,594.7	0.351								
19	3,016.6	0.413	421.9	0.061						
30	3,275.1	0.448	680.5	0.097	258.5	0.035				
38	3,379.9	0.466	785.2	0.114	363.3	0.053	104.7	0.018		
49	3,472.5	0.474	877.8	0.123	455.9	0.061	197.3	0.026	92.6	0.009
60	3,531.2	0.483	936.6	0.132	514.6	0.070	256.1	0.035	151.4	0.018

Building: Multi-Family Low-rise **City: NYC** **HVAC: AC with Electric Heat** **Measure: Ceiling Insulation**

Base	0		11		19		30		38	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	3,591.8	0.369								
19	4,183.7	0.430	591.8	0.061						
30	4,546.3	0.466	954.5	0.097	362.6	0.035				
38	4,692.6	0.483	1,100.8	0.114	508.9	0.053	146.3	0.018		
49	4,822.2	0.492	1,230.3	0.123	638.5	0.061	275.8	0.026	129.6	0.009
60	4,908.4	0.501	1,316.5	0.132	724.7	0.070	362.0	0.035	215.8	0.018

Building: Multi-Family Low-rise **City: NYC** **HVAC: Electric Heat, no AC** **Measure: Ceiling Insulation**

Base	0		11		19		30		38	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	3,350.2	0.0								
19	3,900.6	0.0	550.5	0.0						
30	4,238.8	0.0	888.6	0.0	338.1	0.0				
38	4,375.1	0.0	1,024.9	0.0	474.5	0.0	136.3	0.0		
49	4,495.1	0.0	1,145.0	0.0	594.5	0.0	256.3	0.0	120.0	0.0
60	4,574.6	0.0	1,224.5	0.0	674.0	0.0	335.9	0.0	199.5	0.0

Building: Multi-Family Low-rise **City: NYC** **HVAC: Fuel Heat No AC** **Measure: Ceiling Insulation**

Base	0			11			19			30			38		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
1,	131.1	0.0	181.6												
19	153.9	0.0	214.3	22.8	00.0	32.7									
30	167.7	0.0	235.4	36.6	00.0	53.9	13.8	00.0	21.2						
38	173.9	0.0	243.9	42.9	00.0	62.3	20.0	00.0	29.6	6.2	00.0	8.4			
49	178.1	0.0	251.0	47.0	00.0	69.4	24.2	00.0	36.7	10.4	00.0	15.5	4.1	00.0	7.1
60	181.3	0.0	256.1	50.3	00.0	74.5	27.4	00.0	41.8	13.6	00.0	20.6	7.4	00.0	12.2

Building: Multi-Family Low-rise **City: Syracuse** **HVAC: AC with Fuel Heat** **Measure: Wall Insulation**

Base	0			11			13			17			19		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	44.8	0.034	61.3												
13	60.0	0.057	80.8	15.1	0.023	19.5									
17	79.1	0.069	108.5	34.3	0.034	47.1	19.1	0.011	27.6						
19	87.6	0.080	118.7	42.8	0.046	57.3	27.6	0.023	37.8	8.5	0.011	10.2			
21	93.7	0.092	127.5	48.8	0.057	66.2	33.7	0.034	46.7	14.6	0.023	19.0	6.1	0.011	8.8
25	103.4	0.092	140.9	58.6	0.057	79.6	43.5	0.034	60.1	24.3	0.023	32.5	15.8	0.011	22.2
27	106.9	0.103	146.5	62.0	0.069	85.2	46.9	0.046	65.7	27.7	0.034	38.1	19.3	0.023	27.9

Building: **Multi-Family Low-rise** **City: Syracuse** **HVAC: Heat Pump** **Measure: Wall Insulation**

Base	0		11		13		17		19	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	785.3	0.000								
13	1,030.8	0.011	245.5	0.000						
17	1380.9	0.034	595.6	0.023	350.1	0.000				
19	1,506.7	0.046	721.4	0.034	475.9	0.011	125.8	0.000		
21	1,613.9	0.046	828.6	0.034	583.1	0.011	233.0	0.000	107.2	00.000
25	1,780.3	0.057	995.0	0.046	749.5	0.023	399.4	0.011	273.6	00.000
27	1,847.5	0.057	1,062.1	0.046	816.6	0.023	466.6	0.011	340.8	00.000

Building: Multi-Family Low-rise **City: Syracuse** **HVAC: AC with Electric Heat** **Measure: Wall Insulation**

Base	0		11		13		17		19	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	1,009.1	0.000								
13	1,328.2	0.023	319.1	0.000						
17	1,775.4	0.034	766.3	0.011	447.2	0.000				
19	1,940.4	0.046	931.3	0.023	612.2	0.011	165.0	0.000		
21	2,078.0	0.057	1,068.9	0.034	749.8	0.023	302.6	0.011	137.6	00.000
25	2,294.2	0.057	1,285.2	0.034	966.1	0.023	518.9	0.011	353.9	00.000
27	2,380.3	0.069	1,371.3	0.046	1,052.2	0.034	605.0	0.023	440.0	00.000

Building: Multi-Family Low-rise City: Syracuse HVAC: Electric Heat, no AC Measure: Wall Insulation

Base	0		11		13		17		19	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	1,002.1	0.000								
13	1,316.7	0.000	314.6	0.000						
17	1,762.6	0.000	760.6	0.000	445.9	0.000				
19	1,924.7	0.000	922.6	0.000	608.0	0.000	162.0	0.000		
21	2,062.4	-0.023	1,060.3	-0.023	745.7	-0.023	299.7	-0.023	137.7	00.000
25	2,277.6	0.000	1,275.5	0.000	960.9	0.000	515.0	0.000	352.9	00.000
27	2,363.4	0.000	1,361.3	0.000	1,046.7	0.000	600.7	0.000	438.7	00.000

Building: Multi-Family Low-rise City: Syracuse HVAC: Fuel Heat, no AC Measure: Wall Insulation

Base	0			11			13			17			19		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	38.0	0.000	61.3												
13	48.4	0.000	80.8	10.4	0.000	19.5									
17	66.3	0.000	108.5	28.3	0.000	47.1	17.9	0.000	27.6						
19	71.9	0.000	118.7	33.9	0.000	57.3	23.5	0.000	37.8	5.6	0.000	10.2			
21	78.0	-0.023	127.5	40.0	-0.023	66.2	29.6	-0.023	46.7	11.7	-0.023	19.0	6.1	00.000	8.8
25	86.7	0.000	140.9	48.7	0.000	79.6	38.3	0.000	60.1	20.4	0.000	32.5	14.8	00.000	22.2
27	89.9	0.000	146.5	51.9	0.000	85.2	41.5	0.000	65.7	23.6	0.000	38.1	18.0	00.000	27.9

Building: Multi-Family Low-rise City: Syracuse HVAC: AC with Fuel Heat Measure: Ceiling Insulation

Base	0			11			19			30			38		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	351.8	0.290	248.3												
19	414.0	0.351	294.7	62.1	0.061	46.5									
30	454.5	0.395	324.4	102.7	0.105	76.2	40.6	0.044	29.7						
38	470.3	0.413	337.3	118.4	0.123	89.0	56.3	0.061	42.5	15.7	0.018	12.8			
49	485.1	0.430	348.6	133.3	0.141	100.3	71.2	0.079	53.9	30.6	0.035	24.2	14.8	0.018	11.3
60	494.8	0.439	356.7	142.9	0.149	108.4	80.8	0.088	61.9	40.2	0.044	32.2	24.5	0.026	19.4

Building: Multi-Family Low-rise City: Syracuse HVAC: Heat Pump Measure: Ceiling Insulation

Base	0		11		19		30		38	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	4,182.6	0.290								
19	4,851.0	0.351	668.4	0.061						
30	5,270.0	0.387	1,087.3	0.097	419.0	0.035				
38	5,441.1	0.404	1,258.5	0.114	590.1	0.053	171.1	0.018		
49	5,593.8	0.422	1,411.1	0.132	742.8	0.070	323.8	0.035	152.7	0.018
60	5,693.9	0.430	1,511.3	0.141	842.9	0.079	424.0	0.044	252.8	0.026

Building: Multi-Family Low-rise City: Syracuse HVAC: AC with Electric Heat Measure: Ceiling Insulation

Base	0		11		19		30		38	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	4,874.3	0.290								
19	5,701.5	0.351	827.2	0.061						
30	6,220.2	0.395	1,345.9	0.105	518.7	0.044				
38	6,431.1	0.413	1,556.8	0.123	729.6	0.061	210.9	0.018		
49	6,620.7	0.430	1,746.4	0.141	919.2	0.079	400.5	0.035	189.6	0.018
60	6,745.7	0.439	1,871.4	0.149	1,044.2	0.088	525.5	0.044	314.6	0.026

Building: Multi-Family Low-rise City: Syracuse HVAC: Electric Heat, no AC Measure: Ceiling Insulation

Base	0		11		19		30		38	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	4,685.6	0.000								
19	5,480.2	-0.044	794.6	0.000						
30	5,977.4	-0.044	1,291.8	0.000	497.2	0.000				
38	6,181.4	-0.061	1,495.8	-0.018	701.2	-0.018	204.0	0.000		
49	6,362.0	-0.061	1,676.4	-0.018	881.8	-0.018	384.6	0.000	180.6	0.000
60	6,481.5	-0.061	1,795.9	-0.018	1,001.3	-0.018	504.1	0.000	300.1	0.000

Building: Multi-Family Low-rise City: Syracuse HVAC: Fuel Heat No AC Measure: Ceiling Insulation

Base	0			11			19			30			38		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	163.3	0.000	248.3												
19	192.7	-0.044	294.7	29.4	0.000	46.5									
30	211.9	-0.044	324.4	48.6	0.000	76.2	19.2	0.000	29.7						
38	220.7	-0.061	337.3	57.4	-0.018	89.0	27.9	-0.018	42.5	8.8	0.000	12.8			
49	226.7	-0.061	348.6	63.3	-0.018	100.3	33.9	-0.018	53.9	14.8	0.000	24.2	6.0	0.000	11.3
60	230.7	-0.061	356.7	67.4	-0.018	108.4	38.0	-0.018	61.9	18.8	0.000	32.2	10.0	0.000	19.4

Building: Multi-Family Low-rise **City: Binghamton** **HVAC: AC with Fuel Heat** **Measure: Wall Insulation**

Base	0			11			13			17			19		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	41.6	0.023	62.8												
13	55.7	0.034	82.8	14.1	0.011	20.0									
17	73.2	0.046	112.0	31.5	0.023	49.2	17.4	0.011	29.2						
19	80.7	0.046	122.7	39.1	0.023	59.9	25.0	0.011	39.9	7.6	0.000	10.7			
21	87.5	0.046	132.1	45.9	0.023	69.3	31.8	0.011	49.3	14.3	0.000	20.1	6.8	0.000	9.4
25	96.2	0.057	146.5	54.6	0.034	83.7	40.5	0.023	63.8	23.0	0.011	34.5	15.5	0.011	23.9
27	99.8	0.057	152.2	58.1	0.034	89.3	44.0	0.023	69.4	26.6	0.011	40.1	19.0	0.011	29.5

Building: **Multi-Family Low-rise** **City: Binghamton** **HVAC: Heat Pump** **Measure: Wall Insulation**

Base	0		11		13		17		19	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	791.9	0.000								
13	1,040.8	0.011	248.9	0.000						
17	1,395.4	0.023	603.5	0.011	354.5	0.000				
19	1,524.5	0.023	732.6	0.011	483.7	0.000	129.1	0.000		
21	1,633.2	0.023	841.3	0.011	592.4	0.000	237.8	0.000	108.7	0.000
25	1,802.5	0.034	1,010.7	0.023	761.7	0.011	407.2	0.011	278.1	0.000
27	1,869.7	0.034	1,077.9	0.023	828.9	0.011	474.4	0.011	345.3	0.000

Building: **Multi-Family Low-rise** **City: Binghamton** **HVAC: AC with Electric Heat** **Measure: Wall Insulation**

Base	0		11		13		17		19	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	1,019.7	0.000								
13	1,341.6	0.011	321.9	0.000						
17	1,793.1	0.023	773.4	0.011	451.6	0.000				
19	1,960.3	0.023	940.6	0.011	618.7	0.000	167.2	0.000		
21	2,101.1	0.023	1,081.4	0.011	759.5	0.000	308.0	0.000	140.8	0.000
25	2,319.2	0.034	1,299.5	0.023	977.6	0.011	526.1	0.011	358.9	0.000
27	2,406.7	0.034	1,387.0	0.023	1,065.1	0.011	613.6	0.011	446.4	0.000

Building: Multi-Family Low-rise City: Binghamton HVAC: Electric Heat, no AC Measure: Wall Insulation

Base	0		11		13		17		19	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	1,014.6	0.000								
13	1,333.0	0.000	318.4	0.000						
17	1,785.0	0.011	770.4	0.011	452.0	0.000				
19	1,950.6	0.011	936.0	0.011	617.6	0.000	165.6	0.000		
21	2,089.0	0.011	1,074.4	0.011	756.0	0.000	304.0	0.000	138.4	0.000
25	2,307.5	0.023	1,293.0	0.023	974.5	0.011	522.5	0.011	357.0	0.000
27	2,394.3	0.023	1,379.8	0.023	1,061.3	0.011	609.3	0.011	443.8	0.000

Building: Multi-Family Low-rise City: Binghamton HVAC: Fuel Heat, no AC Measure: Wall Insulation

Base	0			11			13			17			19		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	36.6	0.000	62.8												
13	47.1	0.000	82.8	10.5	0.000	20.0									
17	64.9	0.011	112.0	28.3	0.011	49.2	17.8	0.000	29.2						
19	71.2	0.011	122.7	34.6	0.011	59.9	24.1	0.000	39.9	6.3	0.000	10.7			
21	75.2	0.011	132.1	38.6	0.011	69.3	28.1	0.000	49.3	10.3	0.000	20.1	4.0	0.000	9.4
25	84.5	0.023	146.4	47.9	0.023	83.6	37.4	0.011	63.6	19.6	0.011	34.4	13.3	0.000	23.7
27	87.3	0.023	152.2	50.7	0.023	89.3	40.1	0.011	69.4	22.4	0.011	40.1	16.1	0.000	29.5

Building: Multi-Family Low-rise City: Binghamton HVAC: AC with Fuel Heat Measure: Ceiling Insulation

Base	0			11			19			30			38		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	301.9	0.264	257.9												
19	356.6	0.307	306.3	54.7	0.044	48.4									
30	392.1	0.343	337.3	90.2	0.079	79.3	35.5	0.035	30.9						
38	404.6	0.351	350.3	102.7	0.088	92.4	48.0	0.044	44.0	12.5	0.009	13.1			
49	417.3	0.360	360.9	115.4	0.097	103.0	60.7	0.053	54.6	25.2	0.018	23.6	12.7	0.009	10.5
60	424.9	0.369	368.4	123.1	0.105	110.4	68.3	0.061	62.0	32.9	0.026	31.1	20.4	0.018	18.0

Building: Multi-Family Low-rise City: Binghamton HVAC: Heat Pump Measure: Ceiling Insulation

Base	0		11		19		30		38	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	4,382.6	0.255								
19	5,099.3	0.299	716.7	0.044						
30	5,544.9	0.334	1,162.3	0.079	445.7	0.035				
38	5,723.0	0.343	1,340.4	0.088	623.7	0.044	178.1	0.009		
49	5,881.2	0.351	1,498.6	0.097	782.0	0.053	336.3	0.018	158.2	0.009

60	5,987.4	0.360	1,604.8	0.105	888.2	0.061	442.5	0.026	264.4	0.018

Building: Multi-Family Low-rise **City: Binghamton** **HVAC: AC with Electric Heat** **Measure: Ceiling Insulation**

Base	**0**		**11**		**19**		**30**		**38**	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	5,076.3	0.264								
19	5,946.5	0.307	870.2	0.044						
30	6,484.6	0.343	1,408.2	0.079	538.1	0.035				
38	6,698.7	0.351	1,622.3	0.088	752.2	0.044	214.1	0.009		
49	6,890.3	0.360	1,813.9	0.097	943.8	0.053	405.7	0.018	191.6	0.009
60	7,015.9	0.369	1,939.6	0.105	1,069.4	0.061	531.3	0.026	317.2	0.018

Building: **Multi-Family Low-rise** **City: Binghamton** **HVAC: Electric Heat, no AC** **Measure: Ceiling Insulation**

Base	**0**		**11**		**19**		**30**		**38**	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	4,935.8	0.000								
19	5,778.6	0.018	842.8	0.000						
30	6,301.2	0.026	1,365.5	0.009	522.6	0.000				
38	6,510.2	0.026	1,574.5	0.009	731.6	0.000	209.0	0.000		
49	6,696.9	0.026	1,761.1	0.009	918.3	0.000	395.7	0.000	186.7	0.000
60	6,818.9	0.026	1,883.1	0.009	1,040.2	0.000	517.6	0.000	308.6	0.000

Building: Multi-Family Low-rise **City: Binghamton** **HVAC: Fuel Heat No AC** **Measure: Ceiling Insulation**

Base	**0**			**11**			**19**			**30**			**38**		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	161.2	0.000	257.9												
19	188.5	0.018	306.3	27.3	0.000	48.4									
30	208.6	0.026	337.3	47.4	0.009	79.3	20.1	0.000	30.9						
38	215.9	0.026	350.3	54.7	0.009	92.4	27.4	0.000	44.0	7.3	0.000	13.1			
49	223.8	0.026	360.9	62.5	0.009	103.0	35.2	0.000	54.6	15.1	0.000	23.6	7.8	0.000	10.5
60	227.8	0.026	368.4	66.6	0.009	110.4	39.3	0.000	62.0	19.2	0.000	31.1	11.9	0.000	18.0

Building: Multi-Family Low-rise **City: Poughkeepsie** **HVAC: AC with Fuel Heat** **Measure: Wall Insulation**

Base	0			11			13			17			19		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	39.4	0.023	61.6												
13	53.3	0.023	81.6	13.9	0.000	20.1									
17	69.3	0.046	110.9	29.8	0.023	49.3	15.9	0.023	29.2						
19	77.4	0.046	121.8	38.0	0.023	60.2	24.1	0.023	40.1	8.1	0.000	10.9			
21	82.7	0.046	130.7	43.2	0.023	69.1	29.4	0.023	49.1	13.4	0.000	19.8	5.3	0.000	8.9
25	91.5	0.057	145.3	52.1	0.034	83.7	38.2	0.034	63.6	22.2	0.011	34.4	14.1	0.011	23.5
27	94.8	0.057	151.1	55.4	0.034	89.6	41.5	0.034	69.5	25.6	0.011	40.2	17.4	0.011	29.4

Building: **Multi-Family Low-rise** **City: Poughkeepsie** **HVAC: Heat Pump** **Measure: Wall Insulation**

Base	0		11		13		17		19	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	663.6	0.000								
13	873.5	0.011	210.0	0.000						
17	1,171.2	0.023	507.6	0.011	297.7	0.000				
19	1,284.4	0.023	620.8	0.011	410.8	0.000	113.2	0.000		
21	1,374.0	0.023	710.5	0.011	500.5	0.000	202.8	0.000	89.7	0.000
25	1,519.1	0.034	855.5	0.023	645.6	0.011	347.9	0.011	234.7	0.000
27	1,577.0	0.034	913.4	0.023	703.5	0.011	405.8	0.011	292.6	0.000

Building: **Multi-Family Low-rise** **City: Poughkeepsie** **HVAC: AC with Electric Heat** **Measure: Wall Insulation**

Base	0		11		13		17		19	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	867.7	0.000								
13	1,144.5	0.000	276.8	0.000						
17	1,532.2	0.023	664.5	0.023	387.7	0.000				
19	1,676.5	0.023	808.9	0.023	532.0	0.000	144.4	0.000		
21	1,795.8	0.023	928.1	0.023	651.3	0.000	263.6	0.000	119.3	0.000
25	1,984.6	0.034	1,117.0	0.034	840.2	0.011	452.5	0.011	308.1	0.000
27	2,060.1	0.034	1,192.4	0.034	915.6	0.011	527.9	0.011	383.6	0.000

Building: Multi-Family Low-rise City: Poughkeepsie HVAC: Electric Heat, no AC Measure: Wall Insulation

Base	0		11		13		17		19	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	863.4	0.000								
13	1,137.9	0.000	274.5	0.000						
17	1,524.7	0.000	661.3	0.000	386.8	0.000				
19	1,666.8	0.023	803.3	0.023	528.8	0.023	142.1	0.000		
21	1,786.3	0.023	922.8	0.023	648.3	0.023	261.6	0.000	119.5	0.000
25	1,974.8	0.000	1,111.3	0.000	836.8	0.000	450.1	-0.023	308.0	0.000
27	2,050.5	0.000	1,187.0	0.000	912.5	0.000	525.7	-0.023	383.7	0.000

Building: Multi-Family Low-rise City: Poughkeepsie HVAC: Fuel Heat, no AC Measure: Wall Insulation

Base	0			11			13			17			19		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	35.4	0.000	61.6												
13	47.0	0.000	81.8	11.6	0.000	20.2									
17	62.1	0.000	110.9	26.7	0.000	49.3	15.1	0.000	29.1						
19	67.9	0.023	121.8	32.5	0.023	60.2	20.9	0.023	40.0	5.7	0.000	10.9			
21	73.4	0.023	130.6	38.0	0.023	69.0	26.4	0.023	48.8	11.2	0.000	19.7	5.5	0.000	8.8
25	81.8	0.000	145.3	46.3	0.000	83.7	34.7	0.000	63.5	19.6	-0.023	34.4	13.9	0.000	23.5
27	85.2	0.000	151.2	49.8	0.000	89.7	38.2	0.000	69.5	23.0	-0.023	40.4	17.3	0.000	29.5

Building: Multi-Family Low-rise City: Poughkeepsie HVAC: AC with Fuel Heat Measure: Ceiling Insulation

Base	0			11			19			30			38		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	357.2	0.343	246.5												
19	423.3	0.395	298.1	66.1	0.053	51.6									
30	464.6	0.430	332.0	107.4	0.088	85.5	41.3	0.035	33.9						
38	481.2	0.448	346.5	124.0	0.105	100.0	57.9	0.053	48.4	16.6	0.018	14.5			
49	495.7	0.457	359.4	138.5	0.114	112.9	72.5	0.061	61.3	31.2	0.026	27.4	14.6	0.009	12.9
60	504.6	0.466	368.1	147.4	0.123	121.6	81.3	0.070	70.0	40.1	0.035	36.1	23.5	0.018	21.6

Building: Multi-Family Low-rise City: Poughkeepsie HVAC: Heat Pump Measure: Ceiling Insulation

Base	0		11		19		30		38	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	3,838.4	0.334								
19	4,496.7	0.387	658.4	0.053						
30	4,908.8	0.422	1,070.5	0.088	412.1	0.035				
38	5,074.2	0.439	1,235.9	0.105	577.5	0.053	165.4	0.018		
49	5,221.4	0.448	1,383.0	0.114	724.7	0.061	312.6	0.026	147.1	0.009
60	5,317.8	0.448	1,479.4	0.114	821.0	0.061	408.9	0.026	243.5	0.009

Building: Multi-Family Low-rise City: Poughkeepsie HVAC: AC with Electric Heat Measure: Ceiling Insulation

Base	0		11		19		30		38	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	4,482.9	0.343								
19	5,283.0	0.395	800.1	0.053						
30	5,783.2	0.430	1,300.3	0.088	500.2	0.035				
38	5,985.8	0.448	1,502.9	0.105	702.8	0.053	202.6	0.018		
49	6,165.8	0.457	1,682.9	0.114	882.8	0.061	382.6	0.026	180.0	0.009
60	6,284.3	0.466	1,801.4	0.123	1001.3	0.070	501.1	0.035	298.5	0.018

Building: Multi-Family Low-rise City: Poughkeepsie HVAC: Electric Heat, no AC Measure: Ceiling Insulation

Base	0		11		19		30		38	
Measure	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF	kWh/ kSF	kW/ kSF
11	4,298.9	0.000								
19	5,064.3	-0.018	765.4	0.000						
30	5,544.0	-0.018	1,245.1	0.000	479.7	0.000				
38	5,738.0	-0.018	1,439.2	0.000	673.7	0.000	194.1	0.000		
49	5,911.7	-0.018	1,612.8	0.000	847.4	0.000	367.7	0.000	173.7	0.000
60	6,026.6	-0.018	1,727.8	0.000	962.3	0.000	482.6	0.000	288.6	0.000

Building: Multi-Family Low-rise City: Poughkeepsie HVAC: Fuel Heat No AC Measure: Ceiling Insulation

Base	0			11			19			30			38		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	173.1	0.000	246.5												
19	204.6	-0.018	298.1	31.5	0.000	51.6									
30	225.4	-0.018	332.0	52.4	0.000	85.5	20.8	0.000	33.9						
38	233.5	-0.018	346.5	60.4	0.000	100.0	28.9	0.000	48.4	8.1	0.000	14.5			
49	241.5	-0.018	359.5	68.4	0.000	113.0	36.9	0.000	61.4	16.1	0.000	27.5	8.0	0.000	13.0
60	246.8	-0.018	368.2	73.7	0.000	121.7	42.2	0.000	70.1	21.3	0.000	36.2	13.3	0.000	21.7

MULTI-FAMILY HIGH-RISE INSULATION UPGRADES

Building: Multi-Family High-rise **City:** Albany **HVAC:** Chiller and Boiler with FPFC **Measure:** Wall Insulation

Base	0			11			13			17			19		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	14.6	0.008	51.3												
13	18.9	0.014	67.0	4.3	0.005	15.7									
17	24.7	0.016	88.9	10.1	0.008	37.5	5.8	0.003	21.8						
19	26.8	0.019	96.9	12.2	0.011	45.6	7.9	0.005	29.9	2.1	0.003	8.1			
21	28.5	0.022	103.6	13.9	0.014	52.2	9.6	0.008	36.5	3.8	0.005	14.7	1.7	0.003	6.6
25	31.0	0.022	113.5	16.3	0.014	62.2	12.0	0.008	46.5	6.2	0.005	24.7	4.2	0.003	16.6
27	32.0	0.024	117.6	17.4	0.016	66.3	13.1	0.011	50.6	7.3	0.008	28.7	5.2	0.005	20.7

Building: Multi-Family High-rise **City:** Albany **HVAC:** Chiller and Boiler with FPFC **Measure:** Ceiling Insulation

Base	0			11			19			30			38		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	138.1	0.254	411.4												
19	150.5	0.263	476.4	12.4	0.009	65.0									
30	156.8	0.281	515.6	18.8	0.026	104.2	6.3	0.018	39.2						
38	159.1	0.281	531.1	21.0	0.026	119.7	8.6	0.018	54.7	2.3	0.000	15.5			
49	160.9	0.298	545.2	22.9	0.044	133.9	10.4	0.035	68.8	4.1	0.018	29.6	1.8	0.018	14.1
60	162.1	0.307	554.7	24.0	0.053	143.3	11.6	0.044	78.3	5.3	0.026	39.1	3.0	0.026	23.6

Building: Multi-Family High-rise **City:** Albany **HVAC:** Steam Boiler Only **Measure:** Wall Insulation

Base	0			11			13			17			19		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	0.0	0.0	57.2												
13	0.0	0.0	74.7	0.0	0.0	17.5									
17	0.0	0.0	99.0	0.0	0.0	41.8	0.0	0.0	24.3						
19	0.0	0.0	108.0	0.0	0.0	50.8	0.0	0.0	33.3	0.0	0.0	9.0			
21	0.0	0.0	115.4	0.0	0.0	58.2	0.0	0.0	40.7	0.0	0.0	16.4	0.0	0.0	7.4
25	0.0	0.0	126.5	0.0	0.0	69.3	0.0	0.0	51.8	0.0	0.0	27.5	0.0	0.0	18.5
27	0.0	0.0	131.1	0.0	0.0	73.9	0.0	0.0	56.4	0.0	0.0	32.0	0.0	0.0	23.1

Building: **Multi-Family High-rise** **City:** **Albany** **HVAC:** **Steam Boiler Only** **Measure:** **Ceiling Insulation**

Base	0			11			19			30			38		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	0.0	0.0	458.4												
19	0.0	0.0	530.9	0.0	0.0	72.5									
30	0.0	0.0	574.5	0.0	0.0	116.1	0.0	0.0	43.7						
38	0.0	0.0	591.8	0.0	0.0	133.4	0.0	0.0	60.9	0.0	0.0	17.3			
49	0.0	0.0	607.5	0.0	0.0	149.2	0.0	0.0	76.7	0.0	0.0	33.0	0.0	0.0	15.7
60	0.0	0.0	618.1	0.0	0.0	159.7	0.0	0.0	87.2	0.0	0.0	43.6	0.0	0.0	26.3

Building: **Multi-Family High-rise** **City:** **Buffalo** **HVAC:** **Chiller and Boiler with FPFC** **Measure:** **Wall Insulation**

Base	0			11			13			17			19		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	10.2	0.005	52.3												
13	13.2	0.008	68.8	3.0	0.003	16.5									
17	17.3	0.011	91.8	7.1	0.005	39.5	4.1	0.003	23.0						
19	18.7	0.011	100.0	8.5	0.005	47.7	5.5	0.003	31.2	1.4	0.000	8.2			
21	19.9	0.014	106.8	9.7	0.008	54.5	6.7	0.005	38.0	2.6	0.003	15.0	1.2	0.003	6.8
25	21.7	0.014	117.4	11.4	0.008	65.1	8.4	0.005	48.6	4.4	0.003	25.6	3.0	0.003	17.4
27	22.4	0.014	121.7	12.2	0.008	69.4	9.1	0.005	52.9	5.1	0.003	29.9	3.7	0.003	21.7

Building: **Multi-Family High-rise** **City:** **Buffalo** **HVAC:** **Chiller and Boiler with FPFC** **Measure:** **Ceiling Insulation**

Base	0			11			19			30			38		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	110.0	0.079	406.5												
19	117.0	0.105	468.2	7.0	0.026	61.7									
30	120.1	0.123	506.7	10.1	0.044	100.3	3.1	0.018	38.6						
38	121.0	0.131	521.7	11.0	0.053	115.2	3.9	0.026	53.5	0.9	0.009	14.9			
49	121.7	0.131	535.6	11.7	0.053	129.1	4.6	0.026	67.4	1.6	0.009	28.8	0.7	0.000	13.9
60	122.1	0.140	544.5	12.1	0.061	138.1	5.1	0.035	76.3	2.0	0.018	37.8	1.1	0.009	22.9

Building: **Multi-Family High-rise** **City:** **Buffalo** **HVAC:** **Steam Boiler Only** **Measure:** **Wall Insulation**

Base	0			11			13			17			19		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	0.0	0.0	58.3												
13	0.0	0.0	76.7	0.0	0.0	18.4									
17	0.0	0.0	102.3	0.0	0.0	44.0	0.0	0.0	25.6						
19	0.0	0.0	111.4	0.0	0.0	53.1	0.0	0.0	34.8	0.0	0.0	9.1			
21	0.0	0.0	119.0	0.0	0.0	60.7	0.0	0.0	42.4	0.0	0.0	16.7	0.0	0.0	7.6
25	0.0	0.0	130.8	0.0	0.0	72.5	0.0	0.0	54.1	0.0	0.0	28.5	0.0	0.0	19.4
27	0.0	0.0	135.6	0.0	0.0	77.3	0.0	0.0	59.0	0.0	0.0	33.3	0.0	0.0	24.2

Building: **Multi-Family High-rise** **City:** **Buffalo** **HVAC:** **Steam Boiler Only** **Measure:** **Ceiling Insulation**

Base	0			11			19			30			38		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	0.0	0.0	452.9												
19	0.0	0.0	521.7	0.0	0.0	68.8									
30	0.0	0.0	564.7	0.0	0.0	111.7	0.0	0.0	43.0						
38	0.0	0.0	581.3	0.0	0.0	128.3	0.0	0.0	59.6	0.0	0.0	16.6			
49	0.0	0.0	596.8	0.0	0.0	143.9	0.0	0.0	75.1	0.0	0.0	32.1	0.0	0.0	15.5
60	0.0	0.0	606.8	0.0	0.0	153.8	0.0	0.0	85.1	0.0	0.0	42.1	0.0	0.0	25.5

Building: **Multi-Family High-rise** **City:** **Massena** **HVAC:** **Chiller and Boiler with FPFC** **Measure:** **Wall Insulation**

Base	0			11			13			17			19		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	17.9	0.016	61.3												
13	23.2	0.024	80.3	5.3	0.008	19.0									
17	30.5	0.033	106.3	12.6	0.016	45.0	7.3	0.008	26.0						
19	33.1	0.035	115.6	15.2	0.019	54.3	9.9	0.011	35.3	2.6	0.003	9.4			
21	35.3	0.038	123.6	17.4	0.022	62.3	12.1	0.014	43.3	4.8	0.005	17.3	2.2	0.003	8.0
25	38.6	0.041	136.0	20.8	0.024	74.7	15.4	0.016	55.7	8.1	0.008	29.7	5.5	0.005	20.3
27	40.0	0.044	140.9	22.1	0.027	79.6	16.8	0.019	60.6	9.5	0.011	34.6	6.9	0.008	25.3

Building: **Multi-Family High-rise** **City:** **Massena** **HVAC:** **Chiller and Boiler with FPFC** **Measure:** **Ceiling Insulation**

Base	0			11			19			30			38		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	130.3	0.149	481.9												
19	140.4	0.175	556.3	10.1	0.026	74.3									
30	145.5	0.193	601.4	15.2	0.044	119.5	5.1	0.018	45.1						
38	147.3	0.210	619.5	16.9	0.061	137.5	6.8	0.035	63.2	1.8	0.018	18.1			
49	148.8	0.219	635.5	18.4	0.070	153.6	8.3	0.044	79.2	3.2	0.026	34.1	1.5	0.009	16.0
60	149.5	0.228	645.7	19.2	0.079	163.7	9.1	0.053	89.4	4.0	0.035	44.3	2.3	0.018	26.2

Building: **Multi-Family High-rise** **City:** **Massena** **HVAC:** **Steam Boiler Only** **Measure:** **Wall Insulation**

Base	0			11			13			17			19		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	0.0	0.0	68.3												
13	0.0	0.0	89.5	0.0	0.0	21.2									
17	0.0	0.0	118.4	0.0	0.0	50.1	0.0	0.0	28.9						
19	0.0	0.0	128.9	0.0	0.0	60.5	0.0	0.0	39.4	0.0	0.0	10.4			
21	0.0	0.0	137.7	0.0	0.0	69.4	0.0	0.0	48.2	0.0	0.0	19.3	0.0	0.0	8.9
25	0.0	0.0	151.5	0.0	0.0	83.2	0.0	0.0	62.0	0.0	0.0	33.1	0.0	0.0	22.7
27	0.0	0.0	157.0	0.0	0.0	88.7	0.0	0.0	67.5	0.0	0.0	38.6	0.0	0.0	28.2

Building: **Multi-Family High-rise** **City:** **Massena** **HVAC:** **Steam Boiler Only** **Measure:** **Ceiling Insulation**

Base	0			11			19			30			38		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	0.0	0.0	537.0												
19	0.0	0.0	619.9	0.0	0.0	82.8									
30	0.0	0.0	670.2	0.0	0.0	133.1	0.0	0.0	50.3						
38	0.0	0.0	690.3	0.0	0.0	153.3	0.0	0.0	70.4	0.0	0.0	20.1			
49	0.0	0.0	708.1	0.0	0.0	171.1	0.0	0.0	88.3	0.0	0.0	38.0	0.0	0.0	17.9
60	0.0	0.0	719.5	0.0	0.0	182.5	0.0	0.0	99.6	0.0	0.0	49.3	0.0	0.0	29.2

Building: **Multi-Family High-rise** **City:** **NYC** **HVAC:** **Chiller and Boiler with FPFC** **Measure:** **Wall Insulation**

Base	0			11			13			17			19		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	36.2	0.008	35.5												
13	47.2	0.011	46.2	11.0	0.003	10.7									
17	62.4	0.016	61.2	26.2	0.008	25.7	15.2	0.005	15.0						
19	67.9	0.016	66.5	31.7	0.008	30.9	20.6	0.005	20.3	5.5	0.000	5.2			
21	72.4	0.019	71.1	36.2	0.011	35.5	25.2	0.008	24.9	10.0	0.003	9.8	4.5	0.003	4.6
25	79.5	0.019	78.3	43.2	0.011	42.8	32.2	0.008	32.1	17.1	0.003	17.1	11.6	0.003	11.9
27	82.3	0.022	81.0	46.0	0.014	45.5	35.0	0.011	34.8	19.9	0.005	19.8	14.4	0.005	14.6

Building: **Multi-Family High-rise** **City:** **NYC** **HVAC:** **Chiller and Boiler with FPFC** **Measure:** **Ceiling Insulation**

Base	0			11			19			30			38		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	279.9	0.114	285.9												
19	315.5	0.149	333.4	35.6	0.035	47.5									
30	335.8	0.175	361.7	55.9	0.061	75.8	20.3	0.026	28.3						
38	343.6	0.184	373.5	63.7	0.070	87.7	28.1	0.035	40.1	7.8	0.009	11.8			
49	350.4	0.193	382.9	70.5	0.079	97.0	34.9	0.044	49.5	14.6	0.018	21.2	6.7	0.009	9.4
60	354.8	0.202	390.3	74.9	0.088	104.4	39.3	0.053	56.9	18.9	0.026	28.6	11.1	0.018	16.7

Building: **Multi-Family High-rise** **City:** **NYC** **HVAC:** **Steam Boiler Only** **Measure:** **Wall Insulation**

Base	0			11			13			17			19		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	0.0	0.0	39.6												
13	0.0	0.0	51.5	0.0	0.0	11.9									
17	0.0	0.0	68.2	0.0	0.0	28.6	0.0	0.0	16.8						
19	0.0	0.0	74.1	0.0	0.0	34.5	0.0	0.0	22.6	0.0	0.0	5.8			
21	0.0	0.0	79.2	0.0	0.0	39.6	0.0	0.0	27.7	0.0	0.0	10.9	0.0	0.0	5.1
25	0.0	0.0	87.3	0.0	0.0	47.7	0.0	0.0	35.8	0.0	0.0	19.0	0.0	0.0	13.2
27	0.0	0.0	90.3	0.0	0.0	50.7	0.0	0.0	38.8	0.0	0.0	22.1	0.0	0.0	16.2

Building: Multi-Family High-rise **City:** NYC **HVAC:** Steam Boiler Only **Measure:** Ceiling Insulation

Base	0			11			19			30			38		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	0.0	0.0	318.5												
19	0.0	0.0	371.5	0.0	0.0	52.9									
30	0.0	0.0	403.0	0.0	0.0	84.5	0.0	0.0	31.5						
38	0.0	0.0	416.2	0.0	0.0	97.7	0.0	0.0	44.7	0.0	0.0	13.2			
49	0.0	0.0	426.6	0.0	0.0	108.1	0.0	0.0	55.2	0.0	0.0	23.6	0.0	0.0	10.5
60	0.0	0.0	434.9	0.0	0.0	116.3	0.0	0.0	63.4	0.0	0.0	31.8	0.0	0.0	18.7

Building: Multi-Family High-rise **City:** Syracuse **HVAC:** Chiller and Boiler with FPFC **Measure:** Wall Insulation

Base	0			11			13			17			19		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	16.1	0.014	50.6												
13	20.9	0.019	66.1	4.8	0.005	15.5									
17	27.4	0.024	87.7	11.2	0.011	37.1	6.5	0.005	21.6						
19	29.6	0.027	95.5	13.5	0.014	44.9	8.8	0.008	29.4	2.3	0.003	7.8			
21	31.5	0.030	102.0	15.4	0.016	51.4	10.6	0.011	35.9	4.2	0.005	14.3	1.9	0.003	6.4
25	34.4	0.033	112.5	18.3	0.019	61.8	13.5	0.014	46.3	7.0	0.008	24.7	4.8	0.005	16.9
27	35.5	0.033	116.8	19.4	0.019	66.2	14.7	0.014	50.7	8.2	0.008	29.1	5.9	0.005	21.3

Building: Multi-Family High-rise **City:** Syracuse **HVAC:** Chiller and Boiler with FPFC **Measure:** Ceiling Insulation

Base	0			11			19			30			38		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	153.8	0.289	403.0												
19	166.6	0.359	466.0	12.8	0.070	63.0									
30	172.8	0.403	503.8	18.9	0.114	100.8	6.1	0.044	37.8						
38	174.8	0.421	519.9	21.0	0.131	116.9	8.2	0.061	53.9	2.0	0.018	16.1			
49	176.5	0.447	534.9	22.6	0.158	131.9	9.8	0.088	68.9	3.7	0.044	31.1	1.7	0.026	15.0
60	177.5	0.456	543.7	23.7	0.167	140.7	10.9	0.096	77.7	4.7	0.053	39.9	2.7	0.035	23.8

Building: Multi-Family High-rise **City:** Syracuse **HVAC:** Steam Boiler Only **Measure:** Wall Insulation

Base	0			11			13			17			19		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	0.0	0.0	56.4												
13	0.0	0.0	73.7	0.0	0.0	17.3									
17	0.0	0.0	97.7	0.0	0.0	41.3	0.0	0.0	24.1						
19	0.0	0.0	106.5	0.0	0.0	50.1	0.0	0.0	32.8	0.0	0.0	8.7			
21	0.0	0.0	113.6	0.0	0.0	57.2	0.0	0.0	40.0	0.0	0.0	15.9	0.0	0.0	7.2
25	0.0	0.0	125.3	0.0	0.0	68.9	0.0	0.0	51.6	0.0	0.0	27.6	0.0	0.0	18.8
27	0.0	0.0	130.2	0.0	0.0	73.8	0.0	0.0	56.5	0.0	0.0	32.4	0.0	0.0	23.7

Building: Multi-Family High-rise **City:** Syracuse **HVAC:** Steam Boiler Only **Measure:** Ceiling Insulation

Base	0			11			19			30			38		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	0.0	0.0	449.0												
19	0.0	0.0	519.2	0.0	0.0	70.2									
30	0.0	0.0	561.3	0.0	0.0	112.3	0.0	0.0	42.1						
38	0.0	0.0	579.3	0.0	0.0	130.3	0.0	0.0	60.1	0.0	0.0	18.0			
49	0.0	0.0	596.0	0.0	0.0	147.0	0.0	0.0	76.8	0.0	0.0	34.7	0.0	0.0	16.7
60	0.0	0.0	605.8	0.0	0.0	156.8	0.0	0.0	86.5	0.0	0.0	44.4	0.0	0.0	26.5

Building: Multi-Family High-rise **City:** Binghamton **HVAC:** Chiller and Boiler with FPFC **Measure:** Wall Insulation

Base	0			11			13			17			19		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	9.7	0.005	55.6												
13	12.5	0.005	72.8	2.8	0.000	17.2									
17	16.2	0.008	96.9	6.4	0.003	41.3	3.7	0.003	24.1						
19	17.5	0.008	105.5	7.7	0.003	49.9	4.9	0.003	32.7	1.3	0.000	8.6			
21	18.5	0.011	112.7	8.7	0.005	57.1	6.0	0.005	39.9	2.3	0.003	15.8	1.0	0.003	7.2
25	20.0	0.011	123.8	10.3	0.005	68.2	7.5	0.005	51.0	3.9	0.003	26.9	2.6	0.003	18.3
27	20.6	0.011	128.4	10.9	0.005	72.8	8.1	0.005	55.6	4.5	0.003	31.5	3.2	0.003	22.9

Building: **Multi-Family High-rise** **City:** **Binghamton** **HVAC:** **Chiller and Boiler with FPFC** **Measure:** **Ceiling Insulation**

Base	0			11			19			30			38		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	140.8	0.088	420.9												
19	152.9	0.096	489.0	12.1	0.009	68.1									
30	158.9	0.123	531.7	18.1	0.035	110.8	6.0	0.026	42.7						
38	161.0	0.131	548.0	20.2	0.044	127.1	8.2	0.035	59.0	2.1	0.009	16.3			
49	162.8	0.140	562.9	22.0	0.053	142.0	9.9	0.044	73.9	3.9	0.018	31.2	1.8	0.009	14.9
60	163.7	0.140	572.7	23.0	0.053	151.7	10.9	0.044	83.6	4.8	0.018	40.9	2.7	0.009	24.6

Building: **Multi-Family High-rise** **City:** **Binghamton** **HVAC:** **Steam Boiler Only** **Measure:** **Wall Insulation**

Base	0			11			13			17			19		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	0.0	0.0	62.0												
13	0.0	0.0	81.1	0.0	0.0	19.2									
17	0.0	0.0	108.0	0.0	0.0	46.0	0.0	0.0	26.9						
19	0.0	0.0	117.6	0.0	0.0	55.6	0.0	0.0	36.4	0.0	0.0	9.6			
21	0.0	0.0	125.6	0.0	0.0	63.6	0.0	0.0	44.4	0.0	0.0	17.6	0.0	0.0	8.0
25	0.0	0.0	137.9	0.0	0.0	76.0	0.0	0.0	56.8	0.0	0.0	30.0	0.0	0.0	20.4
27	0.0	0.0	143.0	0.0	0.0	81.1	0.0	0.0	61.9	0.0	0.0	35.1	0.0	0.0	25.5

Building: **Multi-Family High-rise** **City:** **Binghamton** **HVAC:** **Steam Boiler Only** **Measure:** **Ceiling Insulation**

Base	0			11			19			30			38		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	0.0	0.0	469.0												
19	0.0	0.0	544.9	0.0	0.0	75.9									
30	0.0	0.0	592.5	0.0	0.0	123.5	0.0	0.0	47.6						
38	0.0	0.0	610.7	0.0	0.0	141.6	0.0	0.0	65.7	0.0	0.0	18.2			
49	0.0	0.0	627.3	0.0	0.0	158.2	0.0	0.0	82.3	0.0	0.0	34.8	0.0	0.0	16.6
60	0.0	0.0	638.1	0.0	0.0	169.1	0.0	0.0	93.2	0.0	0.0	45.6	0.0	0.0	27.4

Building: Multi-Family High-rise City: Poughkeepsie HVAC: Chiller and Boiler with FPFC Measure: Wall Insulation

Base	0			11			13			17			19		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	12.6	0.008	40.5												
13	16.2	0.011	53.5	3.6	0.003	13.0									
17	20.9	0.014	71.9	8.3	0.005	31.4	4.7	0.003	18.4						
19	22.5	0.014	78.6	9.9	0.005	38.1	6.3	0.003	25.1	1.6	0.000	6.7			
21	23.8	0.016	83.8	11.2	0.008	43.4	7.6	0.005	30.3	2.9	0.003	11.9	1.3	0.003	5.2
25	25.7	0.016	92.0	13.1	0.008	51.5	9.5	0.005	38.5	4.8	0.003	20.1	3.2	0.003	13.4
27	26.5	0.016	95.1	13.9	0.008	54.6	10.3	0.005	41.6	5.6	0.003	23.2	4.0	0.003	16.5

Building: Multi-Family High-rise City: Poughkeepsie HVAC: Chiller and Boiler with FPFC Measure: Ceiling Insulation

Base	0			11			19			30			38		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	107.4	0.105	393.0												
19	109.9	0.149	456.3	2.5	0.044	63.4									
30	109.7	0.167	495.1	2.3	0.061	102.1	-0.3	0.018	38.7						
38	109.0	0.175	512.0	1.6	0.070	119.0	-1.0	0.026	55.7	-0.7	0.009	16.9			
49	108.1	0.184	525.4	0.7	0.079	132.5	-1.8	0.035	69.1	-1.6	0.018	30.3	-0.9	0.009	13.4
60	107.3	0.193	533.8	-0.1	0.088	140.9	-2.6	0.044	77.5	-2.4	0.026	38.7	-1.7	0.018	21.8

Building: Multi-Family High-rise City: Poughkeepsie HVAC: Steam Boiler Only Measure: Wall Insulation

Base	0			11			13			17			19		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	0.0	0.0	45.1												
13	0.0	0.0	59.6	0.0	0.0	14.5									
17	0.0	0.0	80.1	0.0	0.0	35.0	0.0	0.0	20.5						
19	0.0	0.0	87.6	0.0	0.0	42.5	0.0	0.0	28.0	0.0	0.0	7.5			
21	0.0	0.0	93.4	0.0	0.0	48.3	0.0	0.0	33.8	0.0	0.0	13.3	0.0	0.0	5.8
25	0.0	0.0	102.5	0.0	0.0	57.4	0.0	0.0	42.9	0.0	0.0	22.4	0.0	0.0	14.9
27	0.0	0.0	105.9	0.0	0.0	60.9	0.0	0.0	46.3	0.0	0.0	25.9	0.0	0.0	18.4

Building: **Multi-Family High-rise** **City:** **Poughkeepsie** **HVAC:** **Steam Boiler Only** **Measure:** **Ceiling Insulation**

Base	0			11			19			30			38		
Measure	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF	kWh/ kSF	kW/ kSF	therm/ kSF
11	0.0	0.0	437.9												
19	0.0	0.0	508.5	0.0	0.0	70.6									
30	0.0	0.0	551.7	0.0	0.0	113.8	0.0	0.0	43.2						
38	0.0	0.0	570.5	0.0	0.0	132.6	0.0	0.0	62.0	0.0	0.0	18.9			
49	0.0	0.0	585.5	0.0	0.0	147.6	0.0	0.0	77.0	0.0	0.0	33.8	0.0	0.0	14.9
60	0.0	0.0	594.8	0.0	0.0	157.0	0.0	0.0	86.3	0.0	0.0	43.2	0.0	0.0	24.3

INFILTRATION REDUCTION

Single-family Residential Infiltration Reduction

	AC Fuel Heat			Heat Pump		AC Electric Heat		Fuel Heat Only			Electric Heat Only	
City	kWh/cfm	kW/cfm	Therm/cfm	kWh/cfm	kW/cfm	kWh/cfm	kW/cfm	kWh/cfm	kW/cfm	Therm/cfm	kWh/cfm	kW/cfm
Albany	1.8	0.006	2.2	34.0	0.002	50.8	0.006	1.1	0.000	2.2	50.1	0.000
Binghamton	1.3	0.004	2.2	35.0	0.002	49.8	0.004	1.1	0.000	2.2	49.5	0.000
Buffalo	1.6	0.004	2.4	38.8	0.005	55.6	0.004	1.3	0.000	2.4	55.2	0.000
MMassena	1.5	0.001	2.7	46.4	0.001	63.0	0.001	1.4	0.000	2.7	62.8	0.000
NYC	2.3	0.004	1.7	21.0	0.003	39.8	0.004	0.8	0.000	1.7	38.4	0.000
Poughkeepsie	1.9	0.004	1.9	24.8	0.003	43.5	0.004	1.0	0.000	1.9	42.7	0.000
Syracuse	1.8	0.003	2.4	37.3	0.003	55.1	0.003	1.2	0.000	2.4	54.6	0.000

Multi-Family Low-rise Infiltration Reduction

	AC Fuel Heat			Heat Pump		AC Electric Heat		Fuel Heat Only			Electric Heat Only	
City	kWh/cfm	kW/cfm	Therm/cfm	kWh/cfm	kW/cfm	kWh/cfm	kW/cfm	kWh/cfm	kW/cfm	Therm/cfm	kWh/cfm	kW/cfm
Albany	1.5	0.004	2.4	33.5	0.004	40.0	0.004	1.4	0.000	2.4	39.9	0.000
Binghamton	1.5	0.003	2.5	32.7	0.003	40.2	0.003	1.6	0.000	2.5	40.3	0.000
Buffalo	1.0	0.003	2.3	31.2	0.002	36.6	0.003	1.1	0.000	2.3	36.7	0.000
MMassena	1.3	0.001	2.7	44.5	0.001	44.6	0.001	1.2	0.000	2.7	44.5	0.000
NYC	1.5	0.003	1.9	21.2	0.003	29.6	0.003	1.1	0.000	1.9	29.2	0.000
Poughkeepsie	1.5	0.002	2.2	24.7	0.003	29.8	0.002	1.1	0.000	2.2	29.5	0.000
Syracuse	1.6	0.004	2.5	34.1	0.004	42.2	0.004	1.6	0.000	2.5	42.2	0.000

Multi-Family High Rise Infiltration Reduction

Impact per unit of infiltration reduction (cfm)

City	kWh/cfm	kW/cfm	Therm/cfm
Albany	-1.1	0.002	7.0
Binghamton	-1.2	0.000	7.1
Buffalo	-1.1	0.002	6.5
MMassena	-0.6	0.002	8.6
NYC	0.0	0.003	5.5
Poughkeepsie	-1.2	0.005	5.6
Syracuse	-1.2	0.006	7.2

Impact per kSF square foot

City	Vintage	kWh/ 1,000 SF	kW/ 1,000SF	Therm/ 1,000SF
Albany	Old	73	0.128	30
Albany	Average	22	0.099	16
Binghamton	Old	64	0.116	33
Binghamton	Average	11	0.085	17
Buffalo	Old	68	0.101	34
Buffalo	Average	20	0.079	19
Massena	Old	66	0.127	30
Massena	Average	20	0.098	17
NYC	Old	118	0.119	29
NYC	Average	56	0.098	17
Syracuse	Old	73	0.195	29
Syracuse	Average	23	0.092	16

Baseline infiltration rate for old building is 1.0 ACH.
Baseline infiltration rate for average building is 0.5 ACH.
Energy savings based on a 15% reduction.

COMMERCIAL CEILING INSULATION UPGRADE

Ceiling Insulation - Assembly

Climate	System	kWh/unit	Summer kW/unit	therm/unit
Albany	AC with electric heat	994	0.000	0.0
	AC with fuel heat	34	0.018	43.2
	Air source heat pump	768	0.000	0.1
	Electric heat only	979	0.032	0.1
	Fuel heat only	11	0.000	43.3
Binghamton	AC with electric heat	964	0.009	0.1
	AC with fuel heat	30	0.038	43.3
	Air source heat pump	843	0.009	0.0
	Electric heat only	961	0.091	0.1
	Fuel heat only	13	0.000	44.2
Buffalo	AC with electric heat	920	0.032	0.0
	AC with fuel heat	25	0.035	41.5
	Air source heat pump	674	0.032	0.1
	Electric heat only	916	0.221	0.1
	Fuel heat only	11	0.000	42.0
Massena	AC with electric heat	1,823	0.050	0.0
	AC with fuel heat	54	0.053	82.1
	Air source heat pump	1,442	0.050	0.1
	Electric heat only	1,842	0.103	0.1
	Fuel heat only	35	0.000	84.3
NYC	AC with electric heat	425	0.000	0.0
	AC with fuel heat	37	0.026	18.4
	Air source heat pump	248	0.000	0.0
	Electric heat only	405	0.021	0.1
	Fuel heat only	0	0.000	20.4
Poughkeepsie	AC with electric heat	1,005	0.047	0.1
	AC with fuel heat	36	0.050	44.3
	Air source heat pump	778	0.047	0.0
	Electric heat only	991	0.012	0.1
	Fuel heat only	15	0.000	44.7
Syracuse	AC with electric heat	789	0.021	0.0
	AC with fuel heat	30	0.044	35.1
	Air source heat pump	789	0.021	0.1
	Electric heat only	778	0.024	0.1
	Fuel heat only	6	0.000	36.1

Ceiling Insulation - Auto Repair

Climate	System	kWh/unit	Summer kW/unit	therm/unit
Albany	AC with electric heat	564	0.000	0.2
	AC with fuel heat	32	0.000	25.2
	Air source heat pump	407	0.000	0.0
	Electric heat only	524	0.019	0.0
	Fuel heat only	16	0.000	24.1
Binghamton	AC with electric heat	489	0.039	0.2
	AC with fuel heat	24	0.000	21.7
	Air source heat pump	316	0.000	0.0
	Electric heat only	441	0.039	0.2
	Fuel heat only	12	0.000	20.0
Buffalo	AC with electric heat	500	0.000	0.0
	AC with fuel heat	23	0.000	20.8
	Air source heat pump	315	0.000	0.0
	Electric heat only	490	0.019	0.0
	Fuel heat only	13	0.000	20.6
Massena	AC with electric heat	585	0.000	0.0
	AC with fuel heat	32	0.000	25.8
	Air source heat pump	377	0.000	0.2
	Electric heat only	564	0.000	0.0
	Fuel heat only	18	0.000	25.6
NYC	AC with electric heat	915	0.000	0.0
	AC with fuel heat	56	0.000	41.2
	Air source heat pump	431	0.000	0.0
	Electric heat only	882	0.000	0.0
	Fuel heat only	33	0.000	40.6
Poughkeepsie	AC with electric heat	754	0.019	0.2
	AC with fuel heat	41	0.019	33.4
	Air source heat pump	532	0.019	0.0
	Electric heat only	748	0.019	0.2
	Fuel heat only	23	0.000	33.8
Syracuse	AC with electric heat	584	0.000	0.0
	AC with fuel heat	34	0.000	26.4
	Air source heat pump	423	0.000	0.0
	Electric heat only	593	0.019	0.0
	Fuel heat only	18	0.000	27.6

Ceiling Insulation - Big Box Retail

Climate	System	kWh/unit	Summer kW/unit	therm/unit
Albany	AC with electric heat	847	0.045	0.0
	AC with fuel heat	-19	0.047	42.5
	Air source heat pump	682	0.045	0.0
	Electric heat only	895	0.011	0.0
	Fuel heat only	2	0.000	43.5
Binghamton	AC with electric heat	740	0.023	0.0
	AC with fuel heat	-33	0.023	38.2
	Air source heat pump	604	0.022	0.0
	Electric heat only	800	0.022	0.0
	Fuel heat only	-3	0.000	40.1
Buffalo	AC with electric heat	707	0.025	0.0
	AC with fuel heat	-31	0.025	36.3
	Air source heat pump	509	0.025	0.0
	Electric heat only	774	0.009	0.0
	Fuel heat only	-5	0.000	38.2
Massena	AC with electric heat	1,213	0.043	0.0
	AC with fuel heat	2	0.044	59.2
	Air source heat pump	1,072	0.043	0.0
	Electric heat only	1,263	-0.022	0.0
	Fuel heat only	18	0.000	60.7
NYC	AC with electric heat	290	0.027	0.0
	AC with fuel heat	-41	0.030	17.1
	Air source heat pump	141	0.027	0.0
	Electric heat only	341	0.008	0.0
	Fuel heat only	-32	0.000	19.0
Poughkeepsie	AC with electric heat	615	0.030	0.0
	AC with fuel heat	-33	0.030	32.2
	Air source heat pump	536	0.030	0.0
	Electric heat only	680	0.014	0.0
	Fuel heat only	-7	0.000	33.9
Syracuse	AC with electric heat	751	0.034	0.0
	AC with fuel heat	-19	0.034	38.1
	Air source heat pump	534	0.034	0.0
	Electric heat only	810	0.014	0.0
	Fuel heat only	-2	0.000	40.3

Ceiling Insulation - Fast Food Restaurant

Climate	System	kWh/unit	Summer kW/unit	therm/unit
Albany	AC with electric heat	1,009	0.000	0.5
	AC with fuel heat	38	0.000	45.5
	Electric heat only	993	0.000	0.5
	Fuel heat only	22	0.000	46.0
Binghamton	AC with electric heat	999	0.000	0.5
	AC with fuel heat	30	0.000	45.5
	Electric heat only	1,023	0.000	0.5
	Fuel heat only	24	0.000	47.0
Buffalo	AC with electric heat	1,066	0.000	0.5
	AC with fuel heat	36	0.000	48.0
	Electric heat only	1,036	0.000	0.5
	Fuel heat only	22	0.000	47.0
Massena	AC with electric heat	1,055	0.000	0.5
	AC with fuel heat	33	0.000	47.0
	Electric heat only	1,074	0.000	0.5
	Fuel heat only	26	0.000	49.5
NYC	AC with electric heat	755	0.000	0.5
	AC with fuel heat	61	0.000	34.0
	Electric heat only	988	0.000	0.5
	Fuel heat only	24	0.000	46.5
Poughkeepsie	AC with electric heat	994	0.050	0.0
	AC with fuel heat	47	0.000	45.5
	Electric heat only	994	0.000	0.5
	Fuel heat only	24	0.000	46.0
Syracuse	AC with electric heat	1,023	0.000	0.5
	AC with fuel heat	43	0.050	46.5
	Electric heat only	1,097	0.000	0.5
	Fuel heat only	27	0.000	50.5

Ceiling Insulation - Full Service Restaurant

Climate	System	kWh/unit	Summer kW/unit	therm/unit
Albany	AC with electric heat	946	0.025	0.3
	AC with fuel heat	51	0.050	42.8
	Electric heat only	941	0.000	0.3
	Fuel heat only	36	0.000	43.3
Binghamton	AC with electric heat	789	0.025	0.0
	AC with fuel heat	42	0.025	35.0
	Electric heat only	790	0.100	0.3
	Fuel heat only	32	0.000	35.5
Buffalo	AC with electric heat	832	0.025	0.3
	AC with fuel heat	43	0.025	37.8
	Electric heat only	797	0.000	0.3
	Fuel heat only	31	0.000	36.8
Massena	AC with electric heat	944	0.050	0.3
	AC with fuel heat	54	0.050	42.5
	Electric heat only	926	0.225	0.0
	Fuel heat only	37	0.000	42.5
NYC	AC with electric heat	698	0.000	0.0
	AC with fuel heat	53	0.000	32.0
	Electric heat only	688	0.000	0.0
	Fuel heat only	29	0.000	32.3
Poughkeepsie	AC with electric heat	852	0.050	0.3
	AC with fuel heat	57	0.025	39.5
	Electric heat only	841	0.000	0.3
	Fuel heat only	40	0.000	39.8
Syracuse	AC with electric heat	915	0.025	0.3
	AC with fuel heat	55	0.025	41.5
	Electric heat only	930	0.025	0.0
	Fuel heat only	39	0.000	43.0

Ceiling Insulation – Grocery

Climate	System	kWh/unit	Summer kW/unit	therm/unit
Albany	AC with electric heat	847	0.045	0.0
	AC with fuel heat	-19	0.047	42.5
	Air source heat pump	682	0.045	0.0
	Electric heat only	895	0.011	0.0
	Fuel heat only	2	0.000	43.5
Binghamton	AC with electric heat	740	0.023	0.0
	AC with fuel heat	-33	0.023	38.2
	Air source heat pump	604	0.022	0.0
	Electric heat only	800	0.022	0.0
	Fuel heat only	-3	0.000	40.1
Buffalo	AC with electric heat	707	0.025	0.0
	AC with fuel heat	-31	0.025	36.3
	Air source heat pump	509	0.025	0.0
	Electric heat only	774	0.009	0.0
	Fuel heat only	-5	0.000	38.2
Massena	AC with electric heat	1,213	0.043	0.0
	AC with fuel heat	2	0.044	59.2
	Air source heat pump	1,072	0.043	0.0
	Electric heat only	1,263	-0.022	0.0
	Fuel heat only	18	0.000	60.7
NYC	AC with electric heat	290	0.027	0.0
	AC with fuel heat	-41	0.030	17.1
	Air source heat pump	141	0.027	0.0
	Electric heat only	341	0.008	0.0
	Fuel heat only	-32	0.000	19.0
Poughkeepsie	AC with electric heat	615	0.030	0.0
	AC with fuel heat	-33	0.030	32.2
	Air source heat pump	536	0.030	0.0
	Electric heat only	680	0.014	0.0
	Fuel heat only	-7	0.000	33.9
Syracuse	AC with electric heat	751	0.034	0.0
	AC with fuel heat	-19	0.034	38.1
	Air source heat pump	534	0.034	0.0
	Electric heat only	810	0.014	0.0
	Fuel heat only	-2	0.000	40.3

Ceiling Insulation – Light Industrial

Climate	System	kWh/unit	Summer kW/unit	therm/unit
Albany	AC with electric heat	929.2	0.023	0.0
	AC with fuel heat	44.6	0.024	44.1
	Air source heat pump	585.4	0.023	0.0
	Electric heat only	937.3	0.000	0.0
	Fuel heat only	51.2	0.000	44.1
Binghamton	AC with electric heat	968.31	0.015	0
	AC with fuel heat	46.13	0.016	45.89
	Air source heat pump	601.99	0.016	0.01
	Electric heat only	976.42	0	0.01
	Fuel heat only	54.68	0	45.86
Buffalo	AC with electric heat	929.55	0.017	0
Buffalo	AC with fuel heat	43.78	0.017	44.23
	Air source heat pump	570.1	0.018	0.01
	Electric heat only	939.85	0	0.02
	Fuel heat only	54.07	0	44.2
Massena	AC with electric heat	1,079.08	0.025	0.01
	AC with fuel heat	48	0.026	50.82
	Air source heat pump	724.88	0.025	0
	Electric heat only	1,087.71	0	0.01
	Fuel heat only	54.87	0	50.86
NYC	AC with electric heat	654.92	0.011	0.01
	AC with fuel heat	54.62	0.012	30.9
	Air source heat pump	344.94	0.01	0.01
	Electric heat only	647.28	0	0.01
	Fuel heat only	49.87	0	30.63
Poughkeepsie	AC with electric heat	828.65	0.016	0
	AC with fuel heat	48.18	0.016	39.47
	Air source heat pump	504.04	0.016	0.01
	Electric heat only	833.7	0	0.02
	Fuel heat only	53.81	0	39.46
Syracuse	AC with electric heat	922.95	0.018	0
	AC with fuel heat	49.54	0.018	43.6
	Air source heat pump	579.35	0.018	0
	Electric heat only	926.66	0	0.01
	Fuel heat only	54.2	0	43.54

Ceiling Insulation – Motel

Climate	System	kWh/unit	Summer kW/unit	therm/unit
Albany	AC with fuel heat	-4.3	0.073	12.9
	AC with electric heat	264.3	0.073	0.0
	Air source heat pump	235.0	0.073	0.0
	Electric heat only	272.9	0.000	0.0
	Fuel heat only	0.3	0.000	13.1
Binghamton	AC with fuel heat	-8.9	-0.013	13.6
	AC with electric heat	276.1	-0.013	0.0
	Air source heat pump	245.4	-0.013	0.0
	Electric heat only	289.3	0.033	0.0
	Fuel heat only	1.1	0.000	13.9
Buffalo	AC with fuel heat	-10.7	-0.007	13.2
	AC with electric heat	264.8	-0.007	0.0
	Air source heat pump	235.2	-0.007	0.0
	Electric heat only	277.7	0.000	0.0
	Fuel heat only	0.5	0.000	13.2
Massena	AC with fuel heat	-5.9	0.067	15.3
	AC with electric heat	314.8	0.067	0.0
	Air source heat pump	292.9	0.067	0.0
	Electric heat only	322.8	0.000	0.0
	Fuel heat only	0.5	0.000	15.3
NYC	AC with fuel heat	-1.8	0.027	8.6
	AC with electric heat	175.6	0.027	0.0
	Air source heat pump	139.9	0.027	0.0
	Electric heat only	182.6	0.000	0.0
	Fuel heat only	0.1	0.000	8.8
Poughkeepsie	AC with fuel heat	-4.8	-0.033	10.9
	AC with electric heat	220.8	-0.033	0.0
	Air source heat pump	188.2	-0.033	0.0
	Electric heat only	230.2	0.000	0.0
	Fuel heat only	0.5	0.000	11.1
Syracuse	AC with fuel heat	-0.4	0.060	12.7
	AC with electric heat	267.5	0.060	0.0
	Air source heat pump	242.0	0.060	0.0
	Electric heat only	270.5	0.000	0.0
	Fuel heat only	0.3	0.000	12.9

Ceiling Insulation - Elementary School

Climate	System	kWh/unit	Summer kW/unit	therm/unit
Albany	AC with electric heat	1,456	0.130	0.1
	AC with fuel heat	121	0.134	59.9
	Air source heat pump	916	0.130	0.1
	Electric heat only	1,411	0.006	0.1
	Fuel heat only	86	0.000	59.8
Binghamton	AC with electric heat	1,369	0.030	0.0
	AC with fuel heat	110	0.030	56.6
	Air source heat pump	813	0.030	0.0
	Electric heat only	1,337	0.006	0.1
	Fuel heat only	85	0.000	56.4
Buffalo	AC with electric heat	1,366	0.360	0.0
	AC with fuel heat	107	0.360	56.7
	Air source heat pump	831	0.360	0.0
	Electric heat only	1,345	0.012	0.1
	Fuel heat only	85	0.044	56.8
Massena	AC with electric heat	1,560	0.134	0.0
	AC with fuel heat	121	0.052	64.1
	Air source heat pump	1030	0.134	0.0
	Electric heat only	1519	-0.002	0.1
	Fuel heat only	83	0.000	64.0
NYC	AC with electric heat	1072	0.206	0.0
	AC with fuel heat	146	0.204	43.1
	Air source heat pump	550	0.208	0.0
	Electric heat only	1,000	0.046	0.1
	Fuel heat only	86	0.098	42.5
Poughkeepsie	AC with electric heat	1371	0.352	0.0
	AC with fuel heat	142	0.352	56.1
	Air source heat pump	842	0.350	0.0
	Electric heat only	1332	0.000	0.1
	Fuel heat only	95	0.000	56.5
Syracuse	AC with electric heat	1326	0.056	0.1
	AC with fuel heat	123	0.054	54.3
	Air source heat pump	799	0.056	0.1
	Electric heat only	1267	-0.014	0.1
	Fuel heat only	79	0.000	53.6

Ceiling Insulation – Religious Worship

Climate	System	kWh/unit	Summer kW/unit	therm/unit
Albany	AC with electric heat	994	0.000	0.0
	AC with fuel heat	34	0.018	43.2
	Air source heat pump	768	0.000	0.1
	Electric heat only	979	0.032	0.1
	Fuel heat only	11	0.000	43.3
Binghamton	AC with electric heat	964	0.009	0.1
	AC with fuel heat	30	0.038	43.3
	Air source heat pump	843	0.009	0.0
	Electric heat only	961	0.091	0.1
	Fuel heat only	13	0.000	44.2
Buffalo	AC with electric heat	920	0.032	0.0
	AC with fuel heat	25	0.035	41.5
	Air source heat pump	674	0.032	0.1
	Electric heat only	916	0.221	0.1
	Fuel heat only	11	0.000	42.0
Massena	AC with electric heat	1,823	0.050	0.0
	AC with fuel heat	54	0.053	82.1
	Air source heat pump	1,442	0.050	0.1
	Electric heat only	1,842	0.103	0.1
	Fuel heat only	35	0.000	84.3
NYC	AC with electric heat	425	0.000	0.0
	AC with fuel heat	37	0.026	18.4
	Air source heat pump	248	0.000	0.0
	Electric heat only	405	0.021	0.1
	Fuel heat only	-5	0.000	20.4
Poughkeepsie	AC with electric heat	1,005	0.047	0.1
	AC with fuel heat	36	0.050	44.3
	Air source heat pump	778	0.047	0.0
	Electric heat only	991	0.012	0.1
	Fuel heat only	15	0.000	44.7
Syracuse	AC with electric heat	789	0.021	0.0
	AC with fuel heat	30	0.044	35.1
	Air source heat pump	789	0.021	0.1
	Electric heat only	778	0.024	0.1
	Fuel heat only	6	0.000	36.1

Ceiling Insulation – Small Office

Climate	System	kWh/unit	Summer kW/unit	therm/unit
Albany	AC with electric heat	649	0.04	0
	AC with fuel heat	28.2	0.04	31
	Air source heat pump	412	0.04	0
	Electric heat only	631.4	0	0
	Fuel heat only	13.6	0	30.4
Binghamton	AC with electric heat	670.2	0.02	0
	AC with fuel heat	24.8	0.02	32
	Air source heat pump	415.6	0.02	0
	Electric heat only	651.8	0	0.2
	Fuel heat only	17.2	0	31.2
Buffalo	AC with electric heat	652.4	0	0
	AC with fuel heat	24.8	0.02	31.2
	Air source heat pump	402.2	0.02	0
	Electric heat only	644.4	0	0
	Fuel heat only	17.4	0	31
Massena	AC with electric heat	787.8	0.04	0
	AC with fuel heat	33.6	0.02	36.8
	Air source heat pump	551.4	0.02	0
	Electric heat only	776.8	0	0
	Fuel heat only	18.4	0	37.2
NYC	AC with electric heat	429.6	0.04	0
	AC with fuel heat	36.8	0.04	20
	Air source heat pump	226.6	0.04	0
	Electric heat only	384.2	0	0
	Fuel heat only	-1.6	0	19.6
Poughkeepsie	AC with electric heat	554.8	0.02	0
	AC with fuel heat	31	0.02	26.4
	Air source heat pump	346.6	0.02	0
	Electric heat only	539.4	0	0
	Fuel heat only	14.4	0	26.2
Syracuse	AC with electric heat	640.4	0.02	0
	AC with fuel heat	33.2	0.04	30.2
	Air source heat pump	401.4	0.04	0
	Electric heat only	622.8	0	0
	Fuel heat only	16.2	0	30

Ceiling Insulation – Small Retail

Climate	System	kWh/unit	Summer kW/unit	therm/unit
Albany	AC with electric heat	1,013	0.063	0.2
	AC with fuel heat	60	0.063	47.2
	Air source heat pump	671	0.063	0.2
	Electric heat only	977	0.000	0.2
	Fuel heat only	38	0.000	46.4
Binghamton	AC with electric heat	1,005	0.031	0.2
	AC with fuel heat	50	0.031	47.3
	Air source heat pump	659	0.047	0.2
	Electric heat only	987	0.016	0.2
	Fuel heat only	40	0.000	46.9
Buffalo	AC with electric heat	998	0.031	0.2
	AC with fuel heat	53	0.031	46.9
	Air source heat pump	602	0.047	0.2
	Electric heat only	982	0.000	0.2
	Fuel heat only	42	0.000	46.9
Massena	AC with electric heat	1,174	0.063	0.2
	AC with fuel heat	63	0.063	54.5
	Air source heat pump	792	0.047	0.0
	Electric heat only	1,152	0.000	0.2
	Fuel heat only	45	0.000	54.1
NYC	AC with electric heat	678	0.016	0.2
	AC with fuel heat	66	0.031	31.6
	Air source heat pump	362	0.031	0.2
	Electric heat only	625	0.000	0.2
	Fuel heat only	24	0.000	30.6
Poughkeepsie	AC with electric heat	836	0.063	0.0
	AC with fuel heat	54	0.047	39.4
	Air source heat pump	511	0.047	0.0
	Electric heat only	800	0.000	0.2
	Fuel heat only	32	0.000	38.4
Syracuse	AC with electric heat	1,026	0.047	0.0
	AC with fuel heat	65	0.047	48.0
	Air source heat pump	660	0.047	0.0
	Electric heat only	1,006	0.000	0.2
	Fuel heat only	46	0.000	47.8

Ceiling Insulation – Warehouse

Climate	System	kWh/unit	Summer kW/unit	therm/unit
Albany	AC with electric heat	1,631	0.001	0.0
	AC with fuel heat	13	0.001	65.6
	Air source heat pump	1,215	0.001	0.0
	Electric heat only	1,614	0.000	0.0
	Fuel heat only	0	0.000	65.3
Binghamton	AC with electric heat	1,656	0.037	0.0
	AC with fuel heat	5	0.058	66.7
	Air source heat pump	1,228	0.037	0.0
	Electric heat only	1,650	0.000	0.0
	Fuel heat only	0	0.000	66.7
Buffalo	AC with electric heat	1,584	0.069	0.0
	AC with fuel heat	0	0.084	64.2
	Air source heat pump	1,141	0.069	0.0
	Electric heat only	1,585	0.000	0.0
	Fuel heat only	0	0.000	64.2
Massena	AC with electric heat	1,522	0.001	0.0
	AC with fuel heat	22	0.000	60.4
	Air source heat pump	1,083	0.002	0.0
	Electric heat only	1,501	0.000	0.0
	Fuel heat only	0	0.000	60.5
NYC	AC with electric heat	1,468	0.076	0.0
	AC with fuel heat	48	0.121	60.3
	Air source heat pump	925	0.076	0.0
	Electric heat only	1,416	0.000	0.0
	Fuel heat only	0	0.000	60.1
Poughkeepsie	AC with electric heat	1,612	0.129	0.0
	AC with fuel heat	26	0.132	65.8
	Air source heat pump	1,004	0.129	0.0
	Electric heat only	1,586	0.000	0.0
	Fuel heat only	0	0.000	65.8
Syracuse	AC with electric heat	1,817	0.039	0.0
	AC with fuel heat	21	0.074	72.4
	Air source heat pump	1,409	0.040	0.0
	Electric heat only	1,796	0.000	0.0
	Fuel heat only	0	0.000	72.5

Ceiling Insulation – Community College

Climate	System	kWh/unit	Summer kW/unit	therm/unit
Albany	CV reheat no econ with Air Cooled Chiller	-33	-0.001	4.5
	CV reheat no econ with Water Cooled Chiller	-30	0.000	4.5
	CV reheat econ with Air Cooled Chiller	0	-0.001	4.0
	CV reheat econ with Water Cooled Chiller	-5	0.000	4.0
	VAV reheat econ with Air Cooled Chiller	-6	0.042	2.1
	VAV reheat econ with Water Cooled Chiller	-8	0.043	2.1
Binghamton	CV reheat no econ with Air Cooled Chiller	-32	0.001	3.3
	CV reheat no econ with Water Cooled Chiller	-30	0.001	3.3
	CV reheat econ with Air Cooled Chiller	-2	0.001	3.3
	CV reheat econ with Water Cooled Chiller	-6	0.001	3.2
	VAV reheat econ with Air Cooled Chiller	-3	0.031	2.4
	VAV reheat econ with Water Cooled Chiller	-5	0.026	2.4
Buffalo	CV reheat no econ with Air Cooled Chiller	-32	0.001	4.1
	CV reheat no econ with Water Cooled Chiller	-33	0.011	4.1
	CV reheat econ with Air Cooled Chiller	-1	0.001	3.7
	CV reheat econ with Water Cooled Chiller	-5	0.011	3.7
	VAV reheat econ with Air Cooled Chiller	9	0.034	4.5
	VAV reheat econ with Water Cooled Chiller	8	0.026	4.5

Climate	System	kWh/unit	Summer kW/unit	therm/unit
Massena	CV reheat no econ with Air Cooled Chiller	-36	0.001	4.6
	CV reheat no econ with Water Cooled Chiller	-34	0.001	4.6
	CV reheat econ with Air Cooled Chiller	-1	0.001	4.0
	CV reheat econ with Water Cooled Chiller	-6	0.001	4.0
	VAV reheat econ with Air Cooled Chiller	-1	0.067	2.4
	VAV reheat econ with Water Cooled Chiller	-2	0.046	2.4
NYC	CV reheat no econ with Air Cooled Chiller	-39	0.001	5.8
	CV reheat no econ with Water Cooled Chiller	-30	0.000	5.9
	CV reheat econ with Air Cooled Chiller	12	0.001	4.1
	CV reheat econ with Water Cooled Chiller	2	0.000	4.1
	VAV reheat econ with Air Cooled Chiller	24	0.049	4.7
	VAV reheat econ with Water Cooled Chiller	20	0.032	4.7
Poughkeepsie	CV reheat no econ with Air Cooled Chiller	-42	0.000	6.4
	CV reheat no econ with Water Cooled Chiller	-27	0.001	6.5
	CV reheat econ with Air Cooled Chiller	5	0.000	4.8
	CV reheat econ with Water Cooled Chiller	1	0.001	4.8
	VAV reheat econ with Air Cooled Chiller	22	0.008	9.5
	VAV reheat econ with Water Cooled Chiller	17	0.018	9.5

Climate	System	kWh/unit	Summer kW/unit	therm/unit
Syracuse	CV reheat no econ with Air Cooled Chiller	-33	0.000	4.8
	CV reheat no econ with Water Cooled Chiller	-32	0.001	4.8
	CV reheat econ with Air Cooled Chiller	2	0.000	3.9
	CV reheat econ with Water Cooled Chiller	-3	0.001	3.9
	VAV reheat econ with Air Cooled Chiller	7	0.043	3.6
	VAV reheat econ with Water Cooled Chiller	5	0.030	3.6

Ceiling Insulation – University

Climate	System	kWh/unit	Summer kW/unit	therm/unit
Albany	CV No Econ Air Cooled			
	CV No Econ Water Cooled	-18	0.003	5.6
	CV Econ Air Cooled	-3	0.003	3.3
	CV Econ Water Cooled	-1	0.003	3.3
	VAV Econ Air Cooled	5	0.003	3.0
	VAV Econ Water Cooled	8	0.003	2.8
Binghamton	CV No Econ Air Cooled			
	CV No Econ Water Cooled	-24	0.002	5.9
	CV Econ Air Cooled	-3	0.001	3.6
	CV Econ Water Cooled	-1	0.002	3.7
	VAV Econ Air Cooled	0	0.002	1.9
	VAV Econ Water Cooled	6	0.003	2.7
Buffalo	CV No Econ Air Cooled			
	CV No Econ Water Cooled	-18	0.002	5.9
	CV Econ Air Cooled	-2	0.002	3.6
	CV Econ Water Cooled	-1	0.001	3.1
	VAV Econ Air Cooled	-19	0.002	-2.1
	VAV Econ Water Cooled	-20	0.002	-1.9
Massena	CV No Econ Air Cooled			
	CV No Econ Water Cooled	-24	0.001	5.2
	CV Econ Air Cooled	-1	0.002	3.2
	CV Econ Water Cooled	0	0.001	3.2
	VAV Econ Air Cooled	33	0.002	7.7
	VAV Econ Water Cooled	33	0.001	7.7
NYC	CV No Econ Air Cooled			
	CV No Econ Water Cooled	-15	0.002	4.6
	CV Econ Air Cooled	-1	0.003	2.8
	CV Econ Water Cooled	0	0.002	2.8
	VAV Econ Air Cooled	11	0.003	4.0
	VAV Econ Water Cooled	10	0.002	3.9
Poughkeepsie	CV No Econ Air Cooled			
	CV No Econ Water Cooled	-16	0.002	5.0
	CV Econ Air Cooled	-2	0.001	2.9
	CV Econ Water Cooled	-1	0.002	2.8
	VAV Econ Air Cooled	3	0.001	3.2
	VAV Econ Water Cooled	4	0.001	3.3
Syracuse	CV No Econ Air Cooled			
	CV No Econ Water Cooled	-20	0.002	5.0
	CV Econ Air Cooled	-3	0.002	3.0
	CV Econ Water Cooled	-1	0.002	3.0
	VAV Econ Air Cooled	13	0.002	3.0
	VAV Econ Water Cooled	20	0.057	4.5

Ceiling Insulation – High School

Climate	System	kWh/unit	Summer kW/unit	therm/unit
Albany	CV No Econ Air Cooled	-15	0.000	7.7
	CV No Econ Water Cooled	-12	0.000	7.8
	CV Econ Air Cooled	-11	0.000	7.5
	CV Econ Water Cooled	-8	0.000	7.5
	VAV Econ Air Cooled	-11	0.000	7.5
	VAV Econ Water Cooled	-8	0.000	7.5
Binghamton	CV No Econ Air Cooled	-16	0.000	7.2
	CV No Econ Water Cooled	-12	0.000	7.2
	CV Econ Air Cooled	-12	0.000	7.0
	CV Econ Water Cooled	-8	0.000	7.0
	VAV Econ Air Cooled	-12	0.000	7.0
	VAV Econ Water Cooled	-8	0.000	7.0
Buffalo	CV No Econ Air Cooled	-17	0.000	6.1
	CV No Econ Water Cooled	-12	0.000	6.1
	CV Econ Air Cooled	-16	0.000	5.1
	CV Econ Water Cooled	-9	0.000	6.1
	VAV Econ Air Cooled	-16	0.000	5.1
	VAV Econ Water Cooled	-9	0.000	6.1
Massena	CV No Econ Air Cooled	-16	0.000	7.8
	CV No Econ Water Cooled	-13	0.000	7.8
	CV Econ Air Cooled	-12	0.000	7.7
	CV Econ Water Cooled	-9	0.000	7.7
	VAV Econ Air Cooled	-12	0.000	7.7
	VAV Econ Water Cooled	-9	0.000	7.7
NYC	CV No Econ Air Cooled	-14	0.000	4.1
	CV No Econ Water Cooled	-10	0.000	4.1
	CV Econ Air Cooled	-10	0.000	4.2
	CV Econ Water Cooled	-6	0.000	4.2
	VAV Econ Air Cooled	-10	0.000	4.2
	VAV Econ Water Cooled	-6	0.000	4.2
Poughkeepsie	CV No Econ Air Cooled	-18	0.000	4.3
	CV No Econ Water Cooled	-13	0.000	4.3
	CV Econ Air Cooled	-11	0.000	5.3
	CV Econ Water Cooled	-8	0.000	5.3
	VAV Econ Air Cooled	-11	0.000	5.3
	VAV Econ Water Cooled	-8	0.000	5.3
Syracuse	CV No Econ Air Cooled	-11	0.000	8.1
	CV No Econ Water Cooled	-10	0.000	6.7
	CV Econ Air Cooled	-10	0.000	6.7
	CV Econ Water Cooled	-7	0.000	6.7
	VAV Econ Air Cooled	-10	0.000	6.7
	VAV Econ Water Cooled	-7	0.000	6.7

Ceiling Insulation – Large Retail

Climate	System	kWh/unit	Summer kW/unit	therm/unit
Albany	CV No Econ Air Cooled	-4	0.013	12.0
	CV No Econ Water Cooled	-2	0.008	12.0
	CV Econ Air Cooled	0	0.013	12.1
	CV Econ Water Cooled	1	0.008	12.1
	VAV Econ Air Cooled	-8	0.010	7.9
	VAV Econ Water Cooled	-9	0.007	7.9
Binghamton	CV No Econ Air Cooled	-8	0.005	11.7
	CV No Econ Water Cooled	-5	0.003	11.7
	CV Econ Air Cooled	-2	0.003	11.7
	CV Econ Water Cooled	-1	0.003	11.7
	VAV Econ Air Cooled	-11	0.005	8.1
	VAV Econ Water Cooled	-13	0.003	8.1
Buffalo	CV No Econ Air Cooled	-5	0.003	11.7
	CV No Econ Water Cooled	-4	0.000	11.7
	CV Econ Air Cooled	-1	0.000	11.8
	CV Econ Water Cooled	-1	0.003	11.8
	VAV Econ Air Cooled	-11	0.003	8.6
	VAV Econ Water Cooled	-11	0.000	8.6
Massena	CV No Econ Air Cooled	-3	0.010	13.6
	CV No Econ Water Cooled	-5	0.003	13.6
	CV Econ Air Cooled	0	0.010	13.4
	CV Econ Water Cooled	-1	0.002	13.4
	VAV Econ Air Cooled	-4	0.013	9.9
	VAV Econ Water Cooled	-5	0.003	9.9
NYC	CV No Econ Air Cooled	-5	0.000	7.5
	CV No Econ Water Cooled	-3	0.000	7.5
	CV Econ Air Cooled	1	0.000	7.4
	CV Econ Water Cooled	-1	0.000	7.4
	VAV Econ Air Cooled	-12	0.008	5.9
	VAV Econ Water Cooled	-11	0.005	5.9
Poughkeepsie	CV No Econ Air Cooled	-3	0.005	10.2
	CV No Econ Water Cooled	-4	0.003	10.2
	CV Econ Air Cooled	0	0.005	10.3
	CV Econ Water Cooled	1	0.003	10.3
	VAV Econ Air Cooled	-13	0.005	5.7
	VAV Econ Water Cooled	-12	0.003	5.7
Syracuse	CV No Econ Air Cooled	-4	0.007	11.6
	CV No Econ Water Cooled	-3	0.005	11.6
	CV Econ Air Cooled	1	0.007	11.6
	CV Econ Water Cooled	0	0.005	11.6
	VAV Econ Air Cooled	-9	0.010	8.1
	VAV Econ Water Cooled	-7	0.003	8.1

Ceiling Insulation – Hospital

Climate	System	kWh/unit	Summer kW/unit	therm/unit
Albany	CV No Econ Air Cooled	-51	0.034	9.2
	CV No Econ Water Cooled	-40	0.023	9.2
	CV Econ Air Cooled	11	0.034	7.4
	CV Econ Water Cooled	7	0.023	7.4
	VAV Econ Air Cooled	12	0.044	25.6
	VAV Econ Water Cooled	12	0.028	25.6
Binghamton	CV No Econ Air Cooled	-61	0.017	8.9
	CV No Econ Water Cooled	-56	0.010	8.9
	CV Econ Air Cooled	8	0.017	7.3
	CV Econ Water Cooled	7	0.008	7.4
	VAV Econ Air Cooled	-4	0.023	20.8
	VAV Econ Water Cooled	-4	0.010	20.8
Buffalo	CV No Econ Air Cooled	-58	0.012	9.0
	CV No Econ Water Cooled	-45	0.007	9.0
	CV Econ Air Cooled	4	0.012	7.4
	CV Econ Water Cooled	5	0.007	7.4
	VAV Econ Air Cooled	0	0.017	19.2
	VAV Econ Water Cooled	2	0.011	19.2
Massena	CV No Econ Air Cooled	-59	0.035	11.5
	CV No Econ Water Cooled	-39	0.018	11.5
	CV Econ Air Cooled	10	0.035	9.4
	CV Econ Water Cooled	10	0.017	9.4
	VAV Econ Air Cooled	8	0.043	23.9
	VAV Econ Water Cooled	7	0.019	22.1
NYC	CV No Econ Air Cooled	-40	0.040	5.2
	CV No Econ Water Cooled	-25	0.018	5.2
	CV Econ Air Cooled	19	0.040	4.2
	CV Econ Water Cooled	17	0.018	4.2
	VAV Econ Air Cooled	4	0.047	12.5
	VAV Econ Water Cooled	3	0.019	12.5
Poughkeepsie	CV No Econ Air Cooled	-47	0.016	7.4
	CV No Econ Water Cooled	-35	0.004	7.4
	CV Econ Air Cooled	15	0.016	6.4
	CV Econ Water Cooled	11	0.004	6.4
	VAV Econ Air Cooled	1	-0.065	12.2
	VAV Econ Water Cooled	4	0.014	12.2
Syracuse	CV No Econ Air Cooled	-60	0.030	8.7
	CV No Econ Water Cooled	-46	0.018	8.7
	CV Econ Air Cooled	13	0.029	6.8
	CV Econ Water Cooled	9	0.019	6.8
	VAV Econ Air Cooled	10	0.037	22.3
	VAV Econ Water Cooled	5	0.023	22.3

Ceiling Insulation – Hotel

Climate	System	kWh/unit	Summer kW/unit	therm/unit
Albany	CV No Econ Air Cooled	-220	0.042	4.0
	CV No Econ Water Cooled	-221	0.036	4.0
	CV Econ Air Cooled	-207	0.042	4.1
	CV Econ Water Cooled	-207	0.036	4.1
	VAV Econ Air Cooled	-215	0.036	4.5
	VAV Econ Water Cooled	-215	0.036	4.5
Binghamton	CV No Econ Air Cooled	-380	0.031	4.2
	CV No Econ Water Cooled	-382	0.031	4.3
	CV Econ Air Cooled	-362	0.031	4.3
	CV Econ Water Cooled	-362	0.031	4.3
	VAV Econ Air Cooled	-370	0.031	4.5
	VAV Econ Water Cooled	-370	0.031	4.5
Buffalo	CV No Econ Air Cooled	-334	0.031	3.8
	CV No Econ Water Cooled	-335	0.036	3.8
	CV Econ Air Cooled	-350	0.031	4.0
	CV Econ Water Cooled	-350	0.036	4.0
	VAV Econ Air Cooled	-359	0.031	4.3
	VAV Econ Water Cooled	-358	0.036	4.3
Massena	CV No Econ Air Cooled	-127	0.057	5.1
	CV No Econ Water Cooled	-132	0.057	5.1
	CV Econ Air Cooled	-105	0.057	5.3
	CV Econ Water Cooled	-105	0.057	5.3
	VAV Econ Air Cooled	-111	0.057	6.1
	VAV Econ Water Cooled	-111	0.057	6.1
NYC	CV No Econ Air Cooled	-215	0.062	2.7
	CV No Econ Water Cooled	-215	0.062	2.7
	CV Econ Air Cooled	-201	0.062	2.8
	CV Econ Water Cooled	-202	0.062	2.8
	VAV Econ Air Cooled	-207	0.062	2.0
	VAV Econ Water Cooled	-207	0.062	2.0
Poughkeepsie	CV No Econ Air Cooled	-397	0.042	3.7
	CV No Econ Water Cooled	-400	0.042	3.7
	CV Econ Air Cooled	-379	0.042	3.8
	CV Econ Water Cooled	-379	0.042	3.8
	VAV Econ Air Cooled	-385	0.036	3.5
	VAV Econ Water Cooled	-385	0.036	3.5
Syracuse	CV No Econ Air Cooled	-147	0.047	4.0
	CV No Econ Water Cooled	-149	0.047	4.0
	CV Econ Air Cooled	-131	0.047	4.1
	CV Econ Water Cooled	-131	0.047	4.1
	VAV Econ Air Cooled	-138	0.047	4.4
	VAV Econ Water Cooled	-138	0.052	4.4

Ceiling Insulation – Large Office

Climate	System	kWh/unit	Summer kW/unit	therm/unit
Albany	CV No Econ Water Cooled	155	0.034	45.7
	CV Econ Air Cooled	260	0.040	52.8
	CV Econ Water Cooled	256	0.000	52.5
	VAV Econ Air Cooled	140	0.057	45.1
	VAV Econ Water Cooled	148	0.017	45.1
Buffalo	CV No Econ Air Cooled	106	0.023	35.1
	CV No Econ Water Cooled	75	0.017	35.2
	CV Econ Air Cooled	146	0.000	34.0
	CV Econ Water Cooled	131	0.000	34.1
	VAV Econ Air Cooled	83	0.000	37.3
	VAV Econ Water Cooled	85	0.000	37.3
Binghamton	CV No Econ Air Cooled	198	0.023	42.6
	CV No Econ Water Cooled	194	0.011	42.6
	CV Econ Air Cooled	128	0.029	32.3
	CV Econ Water Cooled	127	0.000	32.4
	VAV Econ Air Cooled	90	0.000	37.4
	VAV Econ Water Cooled	95	0.006	37.4
Massena	CV No Econ Air Cooled	148	0.040	42.3
	CV No Econ Water Cooled	113	0.029	42.4
	CV Econ Air Cooled	153	0.000	34.6
	CV Econ Water Cooled	143	0.000	34.5
	VAV Econ Air Cooled	206	0.000	54.4
	VAV Econ Water Cooled	205	0.000	54.4
NYC	CV No Econ Air Cooled	153	0.046	34.3
	CV No Econ Water Cooled	45	0.023	34.2
	CV Econ Air Cooled	194	0.046	45.2
	CV Econ Water Cooled	178	0.000	45.2
	VAV Econ Air Cooled	23	0.000	10.7
	VAV Econ Water Cooled	39	0.006	10.7
Poughkeepsie	CV No Econ Air Cooled	31	0.051	25.0
	CV No Econ Water Cooled	121	0.006	24.9
	CV Econ Air Cooled	161	0.000	35.7
	CV Econ Water Cooled	153	0.000	35.6
	VAV Econ Air Cooled	125	0.006	32.6
	VAV Econ Water Cooled	124	0.006	32.6
Syracuse	CV No Econ Air Cooled	326	0.046	52.5
	CV No Econ Water Cooled	234	0.023	52.6
	CV Econ Air Cooled	311	0.040	59.5
	CV Econ Water Cooled	298	0.000	59.1
	VAV Econ Air Cooled	134	0.051	44.9
	VAV Econ Water Cooled	147	0.029	45.0

Ceiling Insulation – Dormitory

Climate	System	kWh/unit	Summer kW/unit	therm/unit
Albany	Fan coil with Air Cooled Chiller	70.3	0.064	11.8
	Fan coil with Water Cooled Chiller	91.4	0.058	11.8
	Heat only	16.1	0.004	11.2
Binghamton	Fan coil with Air Cooled Chiller	56.3	0.042	12.4
	Fan coil with Water Cooled Chiller	71.8	0.054	12.4
	Heat only	15.2	0.004	11.9
Buffalo	Fan coil with Air Cooled Chiller	62.2	0.044	12.5
	Fan coil with Water Cooled Chiller	79.1	0.052	12.5
	Heat only	15.4	0.004	12.2
Massena	Fan coil with Air Cooled Chiller	68.2	0.054	14.4
	Fan coil with Water Cooled Chiller	90.7	0.262	14.4
	Heat only	16.5	0.006	14.0
NYC	Fan coil with Air Cooled Chiller	13.0	0.036	10.4
	Fan coil with Water Cooled Chiller	15.3	-0.028	10.4
	Heat only	3.7	0.000	10.3
Poughkeepsie	Fan coil with Air Cooled Chiller	69.7	0.044	10.5
	Fan coil with Water Cooled Chiller	93.7	0.062	10.5
	Heat only	17.1	0.004	10.1
Syracuse	Fan coil with Air Cooled Chiller	72.8	0.060	12.1
	Fan coil with Water Cooled Chiller	94.9	0.066	12.1
	Heat only	16.5	0.004	11.5

Record of Revision

Record of Revision Number	Issue Date
0	10/15/2010
7-13-24	7/31/2013
7-13-25	7/31/2013
7-13-26	7/31/2013

Return to Table of Contents

APPENDIX F

WINDOW AND HIGH PERFORMANCE GLAZING

SINGLE-FAMILY RESIDENTIAL ENERGY STAR® WINDOWS

Albany

Baseline	AC Fuel heat			Heat Pump		AC Electric Heat		Fuel heat Only			Electric Heat Only	
	kWh	kW	Therm	kWh	kW	kWh	kW	kWh	kW	Therm	kWh	kW
1 pane	96.4	0.127	17.0	386.8	0.124	481.6	0.127	7.7	0.000	16.9	393.0	0.000
2 pane	47.7	0.067	5.2	147.3	0.074	167.5	0.067	2.1	0.000	5.2	122.0	0.000
Code	1.3	0.003	3.7	49.3	0.003	81.1	0.003	1.8	0.000	3.7	81.5	0.000

Binghamton

Baseline	AC Fuel heat			Heat Pump		AC Electric Heat		Fuel heat Only			Electric Heat Only	
	kWh	kW	Therm	kWh	kW	kWh	kW	kWh	kW	Therm	kWh	kW
1 pane	75.7	0.104	19.3	420.4	0.107	517.5	0.104	9.3	0.000	19.2	451.1	0.000
2 pane	36.2	0.054	6.1	156.3	0.054	177.3	0.054	2.6	0.000	6.0	143.8	0.000
Code	1.6	0.003	3.9	56.8	0.003	88.2	0.003	2.1	0.000	3.9	88.6	0.000

Buffalo

Baseline	AC Fuel heat			Heat Pump		AC Electric Heat		Fuel heat Only			Electric Heat Only	
	kWh	kW	Therm	kWh	kW	kWh	kW	kWh	kW	Therm	kWh	kW
1 pane	86.5	0.107	20.4	440.2	0.104	553.0	0.107	9.8	0.000	20.4	476.3	0.000
2 pane	43.7	0.060	7.2	176.4	0.057	210.2	0.060	3.4	0.000	7.2	169.9	0.000
Code	1.7	0.003	3.8	54.0	0.003	85.0	0.003	1.9	0.000	3.8	85.1	0.000

Massena

Baseline	AC Fuel heat			Heat Pump		AC Electric Heat		Fuel heat Only			Electric Heat Only	
	kWh	kW	Therm	kWh	kW	kWh	kW	kWh	kW	Therm	kWh	kW
1 pane	84.4	0.111	21.0	490.9	0.117	566.9	0.111	9.6	0.000	20.9	492.0	0.000
2 pane	40.9	0.057	6.5	183.2	0.064	194.4	0.057	2.7	0.000	6.5	156.1	0.000
Code	2.0	0.000	4.4	68.2	0.000	98.5	0.000	2.2	0.000	4.4	98.6	0.000

NYC

Baseline	AC Fuel heat			Heat Pump		AC Electric Heat		Fuel heat Only			Electric Heat Only	
	kWh	kW	Therm	kWh	kW	kWh	kW	kWh	kW	Therm	kWh	kW
1 pane	125.5	0.117	9.2	252.7	0.124	336.0	0.117	4.0	0.000	9.1	214.6	0.000
2 pane	64.5	0.060	1.6	98.7	0.060	106.3	0.060	0.5	0.000	1.5	42.4	0.000
Code	1.1	0.003	2.7	27.4	0.003	59.9	0.003	1.3	0.000	2.7	60.2	0.000

Poughkeepsie

Baseline	AC Fuel heat			Heat Pump		AC Electric Heat		Fuel heat Only			Electric Heat Only	
	kWh	kW	Therm	kWh	kW	kWh	kW	kWh	kW	Therm	kWh	kW
1 pane	86.6	0.104	11.9	277.1	0.117	359.1	0.104	5.5	0.000	11.8	277.8	0.000
2 pane	44.0	0.054	3.2	109.2	0.060	121.1	0.054	1.3	0.000	3.1	78.4	0.000
Code	1.4	0.000	3.4	38.8	0.000	72.3	0.000	1.6	0.000	3.4	72.6	0.000

Syracuse

Baseline	AC Fuel heat			Heat Pump		AC Electric Heat		Fuel heat Only			Electric Heat Only	
	kWh	kW	Therm	kWh	kW	kWh	kW	kWh	kW	Therm	kWh	kW
1 pane	94.5	0.091	18.4	396.4	0.101	510.4	0.091	8.7	0.000	18.3	424.6	0.000
2 pane	47.6	0.064	6.0	153.9	0.067	185.3	0.064	2.6	0.000	5.9	140.4	0.000
Code	1.1	0.003	3.7	48.6	0.000	81.0	0.003	1.8	0.000	3.7	81.8	0.000

MULTI-FAMILY LOW-RISE ENERGY STAR® WINDOWS

Albany

Baseline	AC Fuel heat			Heat Pump		AC Electric Heat		Fuel heat Only			Electric Heat Only	
	kWh	kW	Therm	kWh	kW	kWh	kW	kWh	kW	Therm	kWh	kW
1 pane	148.4	0.228	87.9	1,269.5	0.221	1,668.6	0.228	69.3	0.057	87.9	1,589.5	0.057
2 pane	72.1	0.117	36.3	531.0	0.114	716.9	0.117	31.5	0.057	36.3	676.2	0.057
Code	6.4	0.003	11.3	134.3	0.007	173.4	0.003	6.7	0.003	11.3	173.5	0.003

Binghamton

Baseline	AC Fuel heat			Heat Pump		AC Electric Heat		Fuel heat Only			Electric Heat Only	
	kWh	kW	Therm	kWh	kW	kWh	kW	kWh	kW	Therm	kWh	kW
1 pane	122.3	0.174	99.3	1,426.3	0.168	1,832.4	0.174	61.0	0.007	99.3	1,771.0	0.007
2 pane	57.3	0.091	42.1	605.1	0.087	793.6	0.091	26.0	0.003	42.1	762.2	0.003
Code	6.8	0.003	12.1	137.8	0.003	177.9	0.003	7.3	0.003	12.1	178.3	0.003

Buffalo

Baseline	AC Fuel heat			Heat Pump		AC Electric Heat		Fuel heat Only			Electric Heat Only	
	kWh	kW	Therm	kWh	kW	kWh	kW	kWh	kW	Therm	kWh	kW
1 pane	121.1	0.164	90.8	1,315.5	0.158	1,688.8	0.164	55.1	0.030	90.8	1,622.9	0.030
2 pane	56.3	0.084	37.3	543.2	0.084	701.6	0.084	21.9	0.007	37.3	667.2	0.007
Code	5.6	0.003	12.0	134.9	0.003	173.7	0.003	6.2	0.000	12.0	174.4	0.000

Massena

Baseline	AC Fuel heat			Heat Pump		AC Electric Heat		Fuel heat Only			Electric Heat Only	
	kWh	kW	Therm	kWh	kW	kWh	kW	kWh	kW	Therm	kWh	kW
1 pane	132.4	0.171	100.4	1,389.5	0.168	1,939.0	0.171	63.2	0.027	100.4	1,869.9	0.027
2 pane	62.6	0.091	41.5	538.2	0.091	833.7	0.091	26.0	0.017	41.5	797.0	0.017
Code	5.7	0.003	12.9	170.2	0.003	195.6	0.003	7.3	0.000	12.9	197.0	0.000

NYC

Baseline	AC Fuel heat			Heat Pump		AC Electric Heat		Fuel heat Only			Electric Heat Only	
	kWh	kW	Therm	kWh	kW	kWh	kW	kWh	kW	Therm	kWh	kW
1 pane	184.9	0.188	56.6	830.1	0.184	1,163.5	0.188	61.7	0.000	56.6	1,040.4	0.000
2 pane	94.1	0.097	21.7	347.3	0.094	482.7	0.097	28.2	0.000	21.7	416.8	0.000
Code	4.6	0.003	8.7	84.5	0.003	125.1	0.003	4.3	0.000	8.7	124.8	0.000

Poughkeepsie

Baseline	AC Fuel heat			Heat Pump		AC Electric Heat		Fuel heat Only			Electric Heat Only	
	kWh	kW	Therm	kWh	kW	kWh	kW	kWh	kW	Therm	kWh	kW
1 pane	147.8	0.158	74.3	1,015.5	0.154	1,345.2	0.158	65.1	0.030	74.3	1,262.5	0.030
2 pane	74.1	0.077	30.3	434.3	0.077	589.0	0.077	29.4	0.013	30.3	544.4	0.013
Code	5.8	0.000	11.8	114.4	0.000	147.9	0.000	6.2	0.000	11.8	148.4	0.000

Syracuse

Baseline	AC Fuel heat			Heat Pump		AC Electric Heat		Fuel heat Only			Electric Heat Only	
	kWh	kW	Therm	kWh	kW	kWh	kW	kWh	kW	Therm	kWh	kW
1 pane	147.7	0.225	90.1	1,330.8	0.218	1,689.9	0.225	67.1	0.050	90.1	1,609.5	0.050
2 pane	71.2	0.117	38.1	567.5	0.114	723.8	0.117	29.5	0.034	38.1	682.1	0.034
Code	6.6	0.007	11.7	134.6	0.007	174.6	0.007	7.2	0.000	11.7	175.2	0.000

COMMERCIAL HIGH PERFORMANCE WINDOWS

High-Performance Windows – Assembly

Climate	System	ΔkWh/ 100 SF	ΔkW/ 100 SF	Δtherms/ 100 SF
Albany	AC with electric heat	2,222	0.156	0.0
	AC with fuel heat	270	0.156	86.5
	Air source heat pump	1,951	0.156	0.0
	Electric heat only	1,992	0.000	0.0
	Fuel heat only	0	0.000	86.5
Binghamton	AC with electric heat	2,345	0.156	0.0
	AC with fuel heat	220	0.156	96.6
	Air source heat pump	2,278	0.156	0.0
	Electric heat only	2,163	0.000	0.0
	Fuel heat only	0	0.000	96.6
Buffalo	AC with electric heat	2,169	0.156	0.0
	AC with fuel heat	235	0.156	88.2
	Air source heat pump	1,703	0.156	0.0
	Electric heat only	1,985	0.000	0.0
	Fuel heat only	0	0.000	88.2
Massena	AC with electric heat	4,296	0.156	0.0
	AC with fuel heat	304	0.156	182.9
	Air source heat pump	3,878	0.156	0.0
	Electric heat only	4,083	0.000	0.0
	Fuel heat only	0	0.000	182.9
NYC	AC with electric heat	1,048	0.156	0.0
	AC with fuel heat	389	0.156	30.1
	Air source heat pump	825	0.156	0.0
	Electric heat only	714	0.000	0.0
	Fuel heat only	0	0.000	30.1
Poughkeepsie	AC with electric heat	2,053	0.156	0.0
	AC with fuel heat	262	0.156	83.4
	Air source heat pump	1,861	0.156	0.0
	Electric heat only	1,843	0.000	0.0
	Fuel heat only	0	0.000	83.4
Syracuse	AC with electric heat	1,775	0.156	0.0
	AC with fuel heat	267	0.156	68.7
	Air source heat pump	1,852	0.156	0.0
	Electric heat only	1,541	0.000	0.0
	Fuel heat only	0	0.000	68.7

High-Performance Windows - Big Box Retail

Climate	System	ΔkWh/ 100 SF	ΔkW/ 100 SF	Δtherms/ 100 SF
Albany	AC with electric heat	1,714	0.156	0.0
	AC with fuel heat	294	0.156	68.9
	Air source heat pump	1,520	0.156	0.0
	Electric heat only	1,563	0.000	0.0
	Fuel heat only	0	0.000	68.9
Binghamton	AC with electric heat	1,493	0.156	0.0
	AC with fuel heat	223	0.156	60.4
	Air source heat pump	1,596	0.156	0.0
	Electric heat only	1,324	0.000	0.0
	Fuel heat only	0	0.000	60.4
Buffalo	AC with electric heat	1,794	0.156	0.0
	AC with fuel heat	250	0.156	72.5
	Air source heat pump	1,454	0.156	0.0
	Electric heat only	1,594	0.000	0.0
	Fuel heat only	0	0.000	72.5
Massena	AC with electric heat	1,934	0.156	0.0
	AC with fuel heat	284	0.156	78.0
	Air source heat pump	1,750	0.156	0.0
	Electric heat only	1,751	0.000	0.0
	Fuel heat only	0	0.000	78.0
NYC	AC with electric heat	860	0.156	0.0
	AC with fuel heat	353	0.156	25.0
	Air source heat pump	735	0.156	0.0
	Electric heat only	561	0.000	0.0
	Fuel heat only	0	0.000	25.0
Poughkeepsie	AC with electric heat	1,137	0.156	0.0
	AC with fuel heat	273	0.156	41.0
	Air source heat pump	916	0.156	0.0
	Electric heat only	959	0.000	0.0
	Fuel heat only	0	0.000	41.0
Syracuse	AC with electric heat	1,433	0.156	0.0
	AC with fuel heat	281	0.156	54.0
	Air source heat pump	1,361	0.156	0.0
	Electric heat only	1,292	0.000	0.0
	Fuel heat only	0	0.000	54.0

High-Performance Windows -Fast Food Restaurant

Climate	System	ΔkWh/ 100 SF	ΔkW/ 100 SF	Δtherms/ 100 SF
Albany	AC with electric heat	2,032	0.156	0.0
	AC with fuel heat	298	0.156	81.2
	Air source heat pump	1,504	0.156	0.0
	Electric heat only	1,810	0.000	0.0
	Fuel heat only	0	0.000	81.2
Binghamton	AC with electric heat	2,086	0.156	0.0
	AC with fuel heat	257	0.156	86.0
	Air source heat pump	1,544	0.156	0.0
	Electric heat only	1,814	0.000	0.0
	Fuel heat only	0	0.000	86.0
Buffalo	AC with electric heat	2,302	0.156	0.0
	AC with fuel heat	281	0.156	94.8
	Air source heat pump	1,703	0.156	0.0
	Electric heat only	1,789	0.000	0.0
	Fuel heat only	0	0.000	94.8
Massena	AC with electric heat	2,158	0.156	0.0
	AC with fuel heat	284	0.156	87.1
	Air source heat pump	1,597	0.156	0.0
	Electric heat only	1,845	0.000	0.0
	Fuel heat only	0	0.000	87.1
NYC	AC with electric heat	1,694	0.156	0.2
	AC with fuel heat	382	0.156	64.0
	Air source heat pump	1,254	0.156	0.0
	Electric heat only	1,905	0.000	0.0
	Fuel heat only	0	0.000	64.0
Poughkeepsie	AC with electric heat	1,801	0.156	0.0
	AC with fuel heat	308	0.156	71.9
	Air source heat pump	1,333	0.156	0.0
	Electric heat only	1,927	0.000	0.0
	Fuel heat only	0	0.000	71.9
Syracuse	AC with electric heat	2,066	0.156	0.2
	AC with fuel heat	303	0.156	83.1
	Air source heat pump	1,529	0.156	0.0
	Electric heat only	1,867	0.000	0.0
	Fuel heat only	0	0.000	83.1

High-Performance Windows -Full Service Restaurant

Climate	System	ΔkWh/ 100 SF	ΔkW/ 100 SF	Δtherms/ 100 SF
Albany	AC with electric heat	2,670	0.156	0.0
	AC with fuel heat	380	0.156	108.6
	Air source heat pump	1,976	0.156	0.0
	Electric heat only	2,426	0.000	0.0
	Fuel heat only	0	0.000	108.6
Binghamton	AC with electric heat	2,778	0.156	0.0
	AC with fuel heat	338	0.156	115.2
	Air source heat pump	2,056	0.156	0.0
	Electric heat only	2,614	0.000	0.0
	Fuel heat only	0	0.000	115.2
Buffalo	AC with electric heat	2,977	0.156	0.0
	AC with fuel heat	352	0.156	124.3
	Air source heat pump	2,203	0.156	0.0
	Electric heat only	2,751	0.000	0.0
	Fuel heat only	0	0.000	124.3
Massena	AC with electric heat	2,812	0.156	0.0
	AC with fuel heat	372	0.156	115.5
	Air source heat pump	2,081	0.156	0.0
	Electric heat only	2,618	0.000	0.0
	Fuel heat only	0	0.000	115.5
NYC	AC with electric heat	2,325	0.156	0.0
	AC with fuel heat	449	0.156	91.7
	Air source heat pump	1,721	0.156	0.0
	Electric heat only	2,068	0.000	0.0
	Fuel heat only	0	0.000	91.7
Poughkeepsie	AC with electric heat	2,161	0.156	0.0
	AC with fuel heat	373	0.156	87.6
	Air source heat pump	1,599	0.156	0.0
	Electric heat only	1,921	0.000	0.0
	Fuel heat only	0	0.000	87.6
Syracuse	AC with electric heat	3,060	0.156	0.0
	AC with fuel heat	407	0.156	127.3
	Air source heat pump	2,264	0.156	0.0
	Electric heat only	2,874	0.000	0.0
	Fuel heat only	0	0.000	127.3

High-Performance Windows – Grocery

Climate	System	ΔkWh/ 100 SF	ΔkW/ 100 SF	Δtherms/ 100 SF
Albany	AC with electric heat	1,714	0.156	0.0
	AC with fuel heat	294	0.156	68.9
	Air source heat pump	1,520	0.156	0.0
	Electric heat only	1,563	0.000	0.0
	Fuel heat only	0	0.000	68.9
Binghamton	AC with electric heat	1,493	0.156	0.0
	AC with fuel heat	223	0.156	60.4
	Air source heat pump	1,596	0.156	0.0
	Electric heat only	1,324	0.000	0.0
	Fuel heat only	0	0.000	60.4
Buffalo	AC with electric heat	1,794	0.156	0.0
	AC with fuel heat	250	0.156	72.5
	Air source heat pump	1,454	0.156	0.0
	Electric heat only	1,594	0.000	0.0
	Fuel heat only	0	0.000	72.5
Massena	AC with electric heat	1,934	0.156	0.0
	AC with fuel heat	284	0.156	78.0
	Air source heat pump	1,750	0.156	0.0
	Electric heat only	1,751	0.000	0.0
	Fuel heat only	0	0.000	78.0
NYC	AC with electric heat	860	0.156	0.0
	AC with fuel heat	353	0.156	25.0
	Air source heat pump	735	0.156	0.0
	Electric heat only	561	0.000	0.0
	Fuel heat only	0	0.000	25.0
Poughkeepsie	AC with electric heat	1,137	0.156	0.0
	AC with fuel heat	273	0.156	41.0
	Air source heat pump	916	0.156	0.0
	Electric heat only	959	0.000	0.0
	Fuel heat only	0	0.000	41.0
Syracuse	AC with electric heat	1,433	0.156	0.0
	AC with fuel heat	281	0.156	54.0
	Air source heat pump	1,361	0.156	0.0
	Electric heat only	1,292	0.000	0.0
	Fuel heat only	0	0.000	54.0

High-Performance Windows – Light Industrial

Climate	System	ΔkWh/ 100 SF	ΔkW/ 100 SF	Δtherms/ 100 SF
Albany	AC with electric heat	967	0.156	0.0
	AC with fuel heat	239	0.156	34.6
	Air source heat pump	838	0.156	0.0
	Electric heat only	764	0.000	0.0
	Fuel heat only	0	0.000	34.6
Binghamton	AC with electric heat	1,092	0.156	0.0
	AC with fuel heat	200	0.156	40.4
	Air source heat pump	875	0.156	0.0
	Electric heat only	922	0.000	0.0
	Fuel heat only	0	0.000	40.4
Buffalo	AC with electric heat	1,202	0.156	0.0
	AC with fuel heat	233	0.156	48.3
	Air source heat pump	923	0.156	0.0
	Electric heat only	1,050	0.000	0.0
	Fuel heat only	0	0.000	48.3
Massena	AC with electric heat	1,138	0.156	0.0
	AC with fuel heat	219	0.156	43.6
	Air source heat pump	980	0.156	0.0
	Electric heat only	943	0.000	0.0
	Fuel heat only	0	0.000	43.6
NYC	AC with electric heat	717	0.156	0.0
	AC with fuel heat	318	0.156	19.6
	Air source heat pump	613	0.156	0.0
	Electric heat only	442	0.000	0.0
	Fuel heat only	0	0.000	19.6
Poughkeepsie	AC with electric heat	636	0.156	0.0
	AC with fuel heat	216	0.156	19.6
	Air source heat pump	521	0.156	0.0
	Electric heat only	450	0.000	0.0
	Fuel heat only	0	0.000	19.6
Syracuse	AC with electric heat	974	0.156	0.0
	AC with fuel heat	219	0.156	35.2
	Air source heat pump	837	0.156	0.0
	Electric heat only	781	0.000	0.0
	Fuel heat only	0	0.000	35.2

High-Performance Windows –Motel

Climate	System	ΔkWh/ 100 SF	ΔkW/ 100 SF	Δtherms/ 100 SF
Albany	AC with electric heat	1,828	0.156	0.0
	AC with fuel heat	326	0.156	70.1
	Air source heat pump	1,478	0.156	0.0
	Electric heat only	1,572	0.000	0.0
	Fuel heat only	0	0.000	70.1
Binghamton	AC with electric heat	1,863	0.156	0.0
	AC with fuel heat	273	0.156	74.2
	Air source heat pump	1,580	0.156	0.0
	Electric heat only	1,636	0.000	0.0
	Fuel heat only	0	0.000	74.2
Buffalo	AC with electric heat	1,977	0.156	0.0
	AC with fuel heat	298	0.156	78.9
	Air source heat pump	1,489	0.156	0.0
	Electric heat only	1,714	0.000	0.0
	Fuel heat only	0	0.000	78.9
Massena	AC with electric heat	2,382	0.156	0.0
	AC with fuel heat	319	0.156	95.9
	Air source heat pump	2,000	0.156	0.0
	Electric heat only	2,130	0.000	0.0
	Fuel heat only	0	0.000	95.9
NYC	AC with electric heat	1,243	0.156	0.0
	AC with fuel heat	413	0.156	40.0
	Air source heat pump	941	0.156	0.0
	Electric heat only	953	0.000	0.0
	Fuel heat only	0	0.000	40.0
Poughkeepsie	AC with electric heat	1,430	0.156	0.0
	AC with fuel heat	312	0.156	53.0
	Air source heat pump	1,159	0.156	0.0
	Electric heat only	1,202	0.000	0.0
	Fuel heat only	0	0.000	53.0
Syracuse	AC with electric heat	1,748	0.156	0.0
	AC with fuel heat	326	0.156	66.9
	Air source heat pump	1,468	0.156	0.0
	Electric heat only	1,507	0.000	0.0
	Fuel heat only	0	0.000	66.9

High-Performance Windows -Primary School

Climate	System	ΔkWh/ 100 SF	ΔkW/ 100 SF	Δtherms/ 100 SF
Albany	AC with electric heat	1,863	0.000	0.0
	AC with fuel heat	554	0.000	57.6
	Air source heat pump	1,429	0.000	0.0
	Electric heat only	1,332	0.000	0.0
	Fuel heat only	0	0.000	57.6
Binghamton	AC with electric heat	1,971	0.000	0.0
	AC with fuel heat	470	0.000	66.3
	Air source heat pump	1,440	0.000	0.0
	Electric heat only	1,529	0.000	0.0
	Fuel heat only	0	0.000	66.3
Buffalo	AC with electric heat	2,195	0.000	0.0
	AC with fuel heat	531	0.000	74.0
	Air source heat pump	1,556	0.000	0.0
	Electric heat only	1,737	0.000	0.0
	Fuel heat only	0	0.000	74.0
Massena	AC with electric heat	2,072	0.000	0.0
	AC with fuel heat	518	0.000	67.7
	Air source heat pump	1,636	0.000	0.0
	Electric heat only	1,578	0.000	0.0
	Fuel heat only	0	0.000	67.7
NYC	AC with electric heat	1,671	0.000	0.0
	AC with fuel heat	692	0.000	44.4
	Air source heat pump	1,174	0.000	0.0
	Electric heat only	1,050	0.000	0.0
	Fuel heat only	0	0.000	44.4
Poughkeepsie	AC with electric heat	1,380	0.000	0.0
	AC with fuel heat	570	0.000	35.9
	Air source heat pump	1,125	0.000	0.0
	Electric heat only	780	0.000	0.0
	Fuel heat only	0	0.000	35.9
Syracuse	AC with electric heat	1,958	0.000	0.0
	AC with fuel heat	550	0.000	62.3
	Air source heat pump	1,468	0.000	0.0
	Electric heat only	1,438	0.000	0.0
	Fuel heat only	0	0.000	62.3

High-Performance Windows -Religious Worship

Climate	System	ΔkWh/ 100 SF	ΔkW/ 100 SF	Δtherms/ 100 SF
Albany	AC with electric heat	2,222	0.156	0.0
	AC with fuel heat	270	0.156	86.5
	Air source heat pump	1,951	0.156	0.0
	Electric heat only	1,992	0.000	0.0
	Fuel heat only	0	0.000	86.5
Binghamton	AC with electric heat	2,345	0.156	0.0
	AC with fuel heat	220	0.156	96.6
	Air source heat pump	2,278	0.156	0.0
	Electric heat only	2,163	0.000	0.0
	Fuel heat only	0	0.000	96.6
Buffalo	AC with electric heat	2,169	0.156	0.0
	AC with fuel heat	235	0.156	88.2
	Air source heat pump	1,703	0.156	0.0
	Electric heat only	1,985	0.000	0.0
	Fuel heat only	0	0.000	88.2
Massena	AC with electric heat	4,296	0.156	0.0
	AC with fuel heat	304	0.156	182.9
	Air source heat pump	3,878	0.156	0.0
	Electric heat only	4,083	0.000	0.0
	Fuel heat only	0	0.000	182.9
NYC	AC with electric heat	1,048	0.156	0.0
	AC with fuel heat	389	0.156	30.1
	Air source heat pump	825	0.156	0.0
	Electric heat only	714	0.000	0.0
	Fuel heat only	0	0.000	30.1
Poughkeepsie	AC with electric heat	2,053	0.156	0.0
	AC with fuel heat	262	0.156	83.4
	Air source heat pump	1,861	0.156	0.0
	Electric heat only	1,843	0.000	0.0
	Fuel heat only	0	0.000	83.4
Syracuse	AC with electric heat	1,775	0.156	0.0
	AC with fuel heat	267	0.156	68.7
	Air source heat pump	1,852	0.156	0.0
	Electric heat only	1,541	0.000	0.0
	Fuel heat only	0	0.000	68.7

High-Performance Windows -Small Office

Climate	System	ΔkWh/ 100 SF	ΔkW/ 100 SF	Δtherms/ 100 SF
Albany	AC with electric heat	1,169	0.156	0.0
	AC with fuel heat	303	0.156	43.1
	Air source heat pump	829	0.156	0.0
	Electric heat only	855	0.000	0.0
	Fuel heat only	0	0.000	43.1
Binghamton	AC with electric heat	1,225	0.156	0.0
	AC with fuel heat	260	0.156	48.2
	Air source heat pump	842	0.156	0.0
	Electric heat only	948	0.000	0.0
	Fuel heat only	0	0.000	48.2
Buffalo	AC with electric heat	1,300	0.156	0.0
	AC with fuel heat	281	0.156	51.0
	Air source heat pump	877	0.156	0.0
	Electric heat only	1,024	0.000	0.0
	Fuel heat only	0	0.000	51.0
Massena	AC with electric heat	1,349	0.156	0.0
	AC with fuel heat	290	0.156	51.8
	Air source heat pump	1,021	0.156	0.0
	Electric heat only	1,052	0.000	0.0
	Fuel heat only	0	0.000	51.8
NYC	AC with electric heat	942	0.156	0.0
	AC with fuel heat	366	0.156	29.7
	Air source heat pump	639	0.156	0.0
	Electric heat only	581	0.000	0.0
	Fuel heat only	0	0.000	29.7
Poughkeepsie	AC with electric heat	860	0.156	0.0
	AC with fuel heat	282	0.156	29.0
	Air source heat pump	636	0.156	0.0
	Electric heat only	517	0.000	0.0
	Fuel heat only	0	0.000	29.0
Syracuse	AC with electric heat	1,201	0.156	0.0
	AC with fuel heat	310	0.156	44.7
	Air source heat pump	834	0.156	0.0
	Electric heat only	893	0.000	0.0
	Fuel heat only	0	0.000	44.7

High-Performance Windows -Small Retail

Climate	System	ΔkWh/ 100 SF	ΔkW/ 100 SF	Δtherms/ 100 SF
Albany	AC with electric heat	1,704	0.156	0.0
	AC with fuel heat	357	0.156	65.4
	Air source heat pump	1,259	0.156	0.0
	Electric heat only	1,421	0.000	0.0
	Fuel heat only	0	0.000	65.4
Binghamton	AC with electric heat	1,797	0.156	0.0
	AC with fuel heat	320	0.156	72.2
	Air source heat pump	1,294	0.156	0.0
	Electric heat only	1,559	0.000	0.0
	Fuel heat only	0	0.000	72.2
Buffalo	AC with electric heat	1,872	0.156	0.0
	AC with fuel heat	327	0.156	75.2
	Air source heat pump	1,309	0.156	0.0
	Electric heat only	1,635	0.000	0.0
	Fuel heat only	0	0.000	75.2
Massena	AC with electric heat	1,828	0.156	0.0
	AC with fuel heat	329	0.156	71.9
	Air source heat pump	1,433	0.156	0.0
	Electric heat only	1,597	0.000	0.0
	Fuel heat only	0	0.000	71.9
NYC	AC with electric heat	1,260	0.156	0.0
	AC with fuel heat	437	0.156	40.8
	Air source heat pump	886	0.156	0.0
	Electric heat only	929	0.000	0.0
	Fuel heat only	0	0.000	40.8
Poughkeepsie	AC with electric heat	1,085	0.156	0.0
	AC with fuel heat	305	0.156	37.4
	Air source heat pump	821	0.156	0.0
	Electric heat only	819	0.000	0.0
	Fuel heat only	0	0.000	37.4
Syracuse	AC with electric heat	1,810	0.156	0.0
	AC with fuel heat	370	0.156	70.8
	Air source heat pump	1,321	0.156	0.0
	Electric heat only	1,546	0.000	0.0
	Fuel heat only	0	0.000	70.8

High-Performance Windows -Warehouse

Climate	System	ΔkWh/ 100 SF	ΔkW/ 100 SF	Δtherms/ 100 SF
Albany	AC with electric heat	1,828	0.156	0.0
	AC with fuel heat	326	0.156	70.1
	Air source heat pump	1,478	0.156	0.0
	Electric heat only	1,572	0.000	0.0
	Fuel heat only	0	0.000	70.1
Binghamton	AC with electric heat	1,863	0.156	0.0
	AC with fuel heat	273	0.156	74.2
	Air source heat pump	1,580	0.156	0.0
	Electric heat only	1,636	0.000	0.0
	Fuel heat only	0	0.000	74.2
Buffalo	AC with electric heat	1,977	0.156	0.0
	AC with fuel heat	298	0.156	78.9
	Air source heat pump	1,489	0.156	0.0
	Electric heat only	1,714	0.000	0.0
	Fuel heat only	0	0.000	78.9
Massena	AC with electric heat	2,382	0.156	0.0
	AC with fuel heat	319	0.156	95.9
	Air source heat pump	2,000	0.156	0.0
	Electric heat only	2,130	0.000	0.0
	Fuel heat only	0	0.000	95.9
NYC	AC with electric heat	1,243	0.156	0.0
	AC with fuel heat	413	0.156	40.0
	Air source heat pump	941	0.156	0.0
	Electric heat only	953	0.000	0.0
	Fuel heat only	0	0.000	40.0
Poughkeepsie	AC with electric heat	1,430	0.156	0.0
	AC with fuel heat	312	0.156	53.0
	Air source heat pump	1,159	0.156	0.0
	Electric heat only	1,202	0.000	0.0
	Fuel heat only	0	0.000	53.0
Syracuse	AC with electric heat	1,748	0.156	0.0
	AC with fuel heat	326	0.156	66.9
	Air source heat pump	1,468	0.156	0.0
	Electric heat only	1,507	0.000	0.0
	Fuel heat only	0	0.000	66.9

WINDOW FILM

Window Film - Assembly

Climate	System	ΔkWh/ 100 SF	ΔkW/ 100 SF	Δtherms/ 100 SF
Albany	AC with fuel heat	388	0.178	-84.0
Binghamton	AC with fuel heat	333	0.178	-93.2
Buffalo	AC with fuel heat	358	0.178	-82.0
Massena	AC with fuel heat	346	0.178	-100.6
NYC	AC with fuel heat	592	0.178	-58.3
Poughkeepsie	AC with fuel heat	379	0.178	-92.2
Syracuse	AC with fuel heat	426	0.178	-66.0

Window Film - Auto Repair

Climate	System	ΔkWh/ 100 SF	ΔkW/ 100 SF	Δtherms/ 100 SF
Albany	AC with fuel heat	167	0.178	-72.4
Binghamton	AC with fuel heat	138	0.178	-63.0
Buffalo	AC with fuel heat	159	0.178	-67.7
Massena	AC with fuel heat	155	0.178	-74.0
NYC	AC with fuel heat	271	0.178	-77.2
Poughkeepsie	AC with fuel heat	164	0.178	-84.3
Syracuse	AC with fuel heat	169	0.178	-83.5

Window Film - Big Box Retail

Climate	System	ΔkWh/ 100 SF	ΔkW/ 100 SF	Δtherms/ 100 SF
Albany	AC with fuel heat	407	0.178	-54.1
Binghamton	AC with fuel heat	357	0.178	-57.5
Buffalo	AC with fuel heat	378	0.178	-46.4
Massena	AC with fuel heat	370	0.178	-58.5
NYC	AC with fuel heat	538	0.178	-38.6
Poughkeepsie	AC with fuel heat	402	0.178	-47.9
Syracuse	AC with fuel heat	402	0.178	-53.6

Window Film - Fast Food Restaurant

Climate	System	kWh/unit	Summer kW/unit	therm/unit
Albany	AC with fuel heat	290	0.178	-82.9
Binghamton	AC with fuel heat	241	0.178	-84.5
Buffalo	AC with fuel heat	263	0.178	-77.3
Massena	AC with fuel heat	268	0.178	-85.2
NYC	AC with fuel heat	393	0.178	-72.3
Poughkeepsie	AC with fuel heat	282	0.178	-85.0
Syracuse	AC with fuel heat	297	0.178	-75.9

Window Film - Full Service Restaurant

Climate	System	ΔkWh/ 100 SF	ΔkW/ 100 SF	Δtherms/ 100 SF
Albany	AC with fuel heat	296	0.178	-109.1
Binghamton	AC with fuel heat	249	0.178	-111.0
Buffalo	AC with fuel heat	265	0.178	-98.9
Massena	AC with fuel heat	273	0.178	-109.4
NYC	AC with fuel heat	403	0.178	-94.8
Poughkeepsie	AC with fuel heat	297	0.178	-110.2
Syracuse	AC with fuel heat	309	0.178	-98.3

Window Film - Grocery

Climate	System	ΔkWh/ 100 SF	ΔkW/ 100 SF	Δtherms/ 100 SF
Albany	AC with fuel heat	407	0.178	-54.1
Binghamton	AC with fuel heat	357	0.178	-57.5
Buffalo	AC with fuel heat	378	0.178	-46.4
Massena	AC with fuel heat	370	0.178	-58.5
NYC	AC with fuel heat	538	0.178	-38.6
Poughkeepsie	AC with fuel heat	402	0.178	-47.9
Syracuse	AC with fuel heat	402	0.178	-53.6

Window Film – Light Industrial

Climate	System	ΔkWh/ 100 SF	ΔkW/ 100 SF	Δtherms/ 100 SF
Albany	AC with fuel heat	232	0.178	-71.6
Binghamton	AC with fuel heat	175	0.178	-74.1
Buffalo	AC with fuel heat	226	0.178	-62.1
Massena	AC with fuel heat	189	0.178	-76.6
NYC	AC with fuel heat	251	0.178	-68.4
Poughkeepsie	AC with fuel heat	211	0.178	-67.5
Syracuse	AC with fuel heat	211	0.178	-65.7

Window Film - Motel

Climate	System	ΔkWh/ 100 SF	ΔkW/ 100 SF	Δtherms/ 100 SF
Albany	AC with fuel heat	445	0.178	-29.0
Binghamton	AC with fuel heat	396	0.178	-30.0
Buffalo	AC with fuel heat	399	0.178	-27.5
Massena	AC with fuel heat	411	0.178	-32.4
NYC	AC with fuel heat	523	0.178	-19.8
Poughkeepsie	AC with fuel heat	455	0.178	-23.7
Syracuse	AC with fuel heat	426	0.178	-27.1

Window Film - Primary School

Climate	System	ΔkWh/ 100 SF	ΔkW/ 100 SF	Δtherms/ 100 SF
Albany	AC with fuel heat	437	0.000	-105.6
Binghamton	AC with fuel heat	300	0.000	-108.8
Buffalo	AC with fuel heat	382	0.000	-96.8
Massena	AC with fuel heat	383	0.000	-108.7
NYC	AC with fuel heat	555	0.000	-98.0
Poughkeepsie	AC with fuel heat	437	0.000	-107.6
Syracuse	AC with fuel heat	415	0.000	-99.9

Window Film - Small Office

Climate	System	ΔkWh/ 100 SF	ΔkW/ 100 SF	Δtherms/ 100 SF
Albany	AC with fuel heat	388	0.178	-84.0
Binghamton	AC with fuel heat	333	0.178	-93.2
Buffalo	AC with fuel heat	358	0.178	-82.0
Massena	AC with fuel heat	346	0.178	-100.6
NYC	AC with fuel heat	592	0.178	-58.3
Poughkeepsie	AC with fuel heat	379	0.178	-92.2
Syracuse	AC with fuel heat	426	0.178	-66.0

Window Film - Small Retail

Climate	System	ΔkWh/ 100 SF	ΔkW/ 100 SF	Δtherms/ 100 SF
Albany	AC with fuel heat	342	0.178	-73.6
Binghamton	AC with fuel heat	307	0.178	-73.9
Buffalo	AC with fuel heat	307	0.178	-67.7
Massena	AC with fuel heat	290	0.178	-83.6
NYC	AC with fuel heat	448	0.178	-62.5
Poughkeepsie	AC with fuel heat	319	0.178	-70.8
Syracuse	AC with fuel heat	347	0.178	-69.6

Window Film - Warehouse

Climate	System	ΔkWh/ 100 SF	ΔkW/ 100 SF	Δtherms/ 100 SF
Albany	AC with fuel heat	516	0.178	-88.3
Binghamton	AC with fuel heat	421	0.178	-93.5
Buffalo	AC with fuel heat	444	0.178	-80.6
Massena	AC with fuel heat	462	0.178	-82.0
NYC	AC with fuel heat	613	0.178	-83.8
Poughkeepsie	AC with fuel heat	509	0.178	-93.1
Syracuse	AC with fuel heat	525	0.178	-86.1

Window Film - Other

Climate	System	ΔkWh/ 100 SF	ΔkW/ 100 SF	Δtherms/ 100 SF
Albany	AC with fuel heat	360	0.178	-75.7
Binghamton	AC with fuel heat	301	0.178	-78.4
Buffalo	AC with fuel heat	326	0.178	-69.6
Massena	AC with fuel heat	322	0.178	-80.8
NYC	AC with fuel heat	476	0.178	-64.2
Poughkeepsie	AC with fuel heat	353	0.178	-76.9
Syracuse	AC with fuel heat	363	0.178	-70.4

Record of Revision

Record of Revision Number	Issue Date
0	10/15/2010
9-19-9	9/27/2019

Return to Table of Contents

APPENDIX G

EQUIVALENT FULL-LOAD HOURS (EFLH), FOR HEATING AND COOLING

Analysis used to develop parameters for the energy and demand savings calculations are based on DOE-2.2 simulations of a set of prototypical residential buildings. The prototypical simulation models were derived from the residential building prototypes used in the California Database for Energy Efficiency Resources (DEER)[1406] study, with adjustments made for local building practices and climate.

Four separate models were created to represent general vintages of buildings:

1. Built prior to 1940, uninsulated masonry buildings. This vintage is referred to as "Pre-war uninsulated brick "

2. Built prior to 1979 when the NYS Energy Code (known as the Energy Conservation Construction Code of New York State – ECCCNYS) went into effect, poorly insulated wood-frame buildings This vintage is referred to as "Prior to 1979"

3. Built from 1979 through 2006, with insulation conforming to 1980s era building codes (1979 ECCCNYS.) This vintage is referred to as "From 1979 through 2006."

4. Built from 2007 through the present, new construction with insulation conforming to the 2007 ECCCNYS for residential buildings and the New York City Energy Conservative Construction Code (if applicable.) This vintage is referred to as "From 2007 through the present."

Heating equivalent full-load hours for residential buildings were originally calculated from a DOE-2.2 simulation of prototypical residential buildings. The prototype building characteristics are described in Appendix A. The revised heating EFLH are shown below:[1407]

SINGLE-FAMILY DETACHED COOLING EFLH BY VINTAGE AND CITY

City	Old	Average	New
Albany	322	310	279
Binghamton	199	197	158
Buffalo	334	322	276
Massena	258	250	210
NYC	670	649	630
Poughkeepsie	496	470	464
Syracuse	310	296	268

[1406] 2004-2005 Database for Energy Efficiency Resources (DEER) Update Study, Final Report, Itron, Inc. Vancouver, WA. December 2005. Available at www.calmac.org/publications/2004-05_DEER_Update_Final_Report-Wo.pdf

[1407] The original EFLH numbers have been adjusted according to the recommendations contained in the statewide evaluation performed by Opinion Dynamics, New York Statewide Residential Gas High-Efficiency Heating Equipment Programs – Evaluation of 2009-2011 Programs, August 2014. Recommendations regarding EFLH hours located on page 81.

MULTI-FAMILY LOW-RISE COOLING EFLH BY VINTAGE AND CITY

City	Prior to 1979	From 1979 Through 2006	From 2007 Through the Present
Albany	286	295	279
Binghamton	217	219	210
Buffalo	270	274	256
Massena	230	228	218
NYC	507	550	562
Poughkeepsie	397	423	421
Syracuse	265	284	297

MULTI-FAMILY HIGH-RISE COOLING EFLH BY VINTAGE AND CITY[1408]

City	Prior to 1979	From 1979 Through 2006	From 2007 Through the Present
Albany	594	647	782
Binghamton	479	539	684
Buffalo	572	637	773
Massena	532	571	668
NYC	793	843	954
Poughkeepsie	626	669	812
Syracuse	592	665	845

SINGLE-FAMILY DETACHED HEATING EFLH BY VINTAGE AND CITY

City	Old	Average	New
Albany	1,042	978	925
Binghamton	1,086	1,029	963
Buffalo	1,072	1,032	957
Massena	1,125	1,061	1,009
NYC	867	786	725
Poughkeepsie	931	862	807
Syracuse	1,098	1,042	972

MULTI-FAMILY LOW-RISE HEATING EFLH BY VINTAGE AND CITY

City	Pre-war uninsulated brick	Prior to 1979	From 1979 Through 2006	From 2007 Through the Present
Albany	1,111	1,030	1,012	729
Binghamton	1,397	1,320	1,245	899
Buffalo	1,281	1,219	1,215	883
Massena	1,433	1,306	1,326	964
NYC[1409]	999	757	723	503
Poughkeepsie	857	894	868	616
Syracuse	1,395	1,175	1,206	845

[1408] Note, there are no cooling values for the "Pre-war uninsulated brick vintage, due to a typical lack of any central cooling. This vintage assumes one room air conditioner (RAC) within the unit. For the savings calculation method, see the Air Conditioner – Room (RAC) measure listed in the Single and Multi-family Residential Measures section of this manual.

[1409] NYC building only incorporates a higher thermostatic set point of 73°F instead of 70 °F based on reported data. The other cities listed use the thermostatic set-point of 70^0 F. Overheating in Hot Water and Steam-Heated Multi-family Buildings, U.S. Dept. of Energy, Jordan Dentz, Kapil Varshney and Hugh Henderson, October 2013.

MULTI-FAMILY HIGH-RISE HEATING EFLH BY VINTAGE AND CITY

City	Pre-war uninsulated brick	Prior to 1979	From 1979 Through 2006	From 2007 Through the Present
Albany	975	786	626	363
Binghamton	1,102	1,006	831	484
Buffalo	1,181	966	813	471
Massena	1,111	1,016	873	552
NYC[1410]	1,012	526	395	219
Poughkeepsie	922	656	510	291
Syracuse	1,063	889	787	474

[1410] IBID

SMALL COMMERCIAL COOLING EFLH

Building	Albany	Binghamton	Buffalo	Massena	NYC	Poughkeepsie	Syracuse
Assembly	478	436	497	415	669	574	506
Auto Repair	272	244	264	223	426	302	298
Big Box Retail	769	760	826	688	1,279	1,024	831
Fast Food Restaurant	512	501	519	436	645	579	544
Full Service Restaurant	437	514	460	389	574	506	466
Grocery	769	760	826	688	1,279	1,024	831
Light Industrial	400	435	423	370	549	475	429
Motel	734	959	1,084	997	1,233	1,143	1,072
Primary School	297	264	244	257	394	346	274
Religious Worship	227	202	190	204	279	230	246
Small Office	742	714	745	671	955	849	768
Small Retail	642	644	666	599	882	762	678
Warehouse	234	194	212	228	400	284	243
Other	501	572	535	474	736	623	553

LARGE COMMERCIAL COOLING EFLH

Building	System	Albany	Binghamton	Buffalo	Massena	NYC	Poughkeepsie	Syracuse
Community College	CAV econ	585	433	520	509	846	706	609
	CAV noecon	773	586	693	692	1,128	997	811
	VAV econ	470	376	456	353	658	532	455
Dormitory[1411]	Fan Coil*	736	657	752	693	800	760	763
High School	CAV econ	348	304	323	318	466	407	388
	CAV noecon	713	727	741	727	861	787	764
	VAV econ	237	203	215	215	341	289	256
Hospital	CAV econ	1,038	918	1,114	1,038	1,424	1,231	1,147
	CAV noecon	1,728	1,662	1,908	1,730	2,237	1,983	1,906
	VAV econ	961	855	1,026	962	1,217	1,089	1,050
Hotel	CAV econ	2,744	3,078	2,744	2,807	2,918	3,039	3,471
	CAV noecon	2,945	3,270	2,945	3,021	3,108	3,253	3,653
	VAV econ	2,702	3,046	2,702	2,745	2,929	2,937	3,437
Large Office	CAV econ	706	534	587	610	720	713	667
	CAV noecon	1,894	1,786	2,016	1,827	2,250	2,072	2,156
	VAV econ	623	519	504	505	716	670	572

[1411] Dormitories consist of individual rooms with small heating/cooling coils. Constant Air Volume (CAV) or Variable Air Volume (VAV) with Economizers (econ) are not typically used.

Building	System	Albany	Binghamton	Buffalo	Massena	NYC	Poughkeepsie	Syracuse
Large Retail	CAV econ	858	721	849	753	1,068	920	858
	CAV noecon	1,656	1,613	1,763	1,545	1,751	1,670	1,656
	VAV econ	704	594	713	611	886	757	704
University	CAV econ	680	496	610	567	882	706	699
	CAV noecon	936	723	870	811	1,208	1,030	951
	VAV econ	526	432	518	413	690	568	523

SMALL COMMERCIAL HEATING EFLH

Building	Albany	Binghamton	Buffalo	Massena	NYC	Poughkeepsie	Syracuse
Assembly	961	1,006	990	1,158	603	782	903
Auto Repair	3,325	3,455	3,331	3,649	1,910	2,642	3,271
Big Box Retail	554	509	557	620	191	373	522
Fast Food Restaurant	1,426	1,526	1,491	1,690	813	1,120	1,351
Full Service Restaurant	1,502	1,602	1,567	1,746	821	1,162	1,419
Grocery	554	509	557	620	191	373	522
Light Industrial	1,278	1,320	1,188	1,286	714	996	1,200
Motel	1,037	787	789	832	619	603	778
Primary School	1,300	1,290	1,357	1,311	840	1,070	1,236
Religious Worship	954	1,006	978	1,015	722	802	962
Small Office	747	793	760	861	431	589	750
Small Retail	984	1,006	1,020	1,134	545	765	969
Warehouse	916	1,023	940	1,094	452	642	888
Other	1,195	1,156	1,194	1,309	681	917	1,136

LARGE COMMERCIAL HEATING EFLH

Building	System	Albany	Binghamton	Buffalo	Massena	NYC	Poughkeepsie	Syracuse
Community College	CAV econ	1,111	1,072	1,047	1,301	1,431	1,171	1,259
	CAV noecon	1,052	1,042	1,006	1,177	1,268	1,050	1,177
	VAV econ	607	1,161	1,040	606	434	389	554
Dormitory*	Fan Coil*	594	678	753	687	465	507	673
High School	CAV econ	776	782	808	822	901	898	960
	CAV noecon	701	725	741	759	840	829	902
	VAV econ	326	300	384	382	268	303	395
Hospital	CAV econ	3,084	2,847	2,897	2,782	3,366	2,886	3,062
	CAV noecon	2,733	2,423	2,516	2,353	3,137	2,514	2,704
	VAV econ	763	766	642	739	296	481	771
Hotel	CAV econ	1,230	1,177	1,220	1,239	1,077	1,054	1,175
	CAV noecon	962	907	941	1,032	753	794	919
	VAV econ	552	482	518	661	229	376	464

Building	System	Albany	Binghamton	Buffalo	Massena	NYC	Poughkeepsie	Syracuse
Large Office	CAV econ	2,136	2,047	2,020	2,349	2,034	2,142	2,218
	CAV noecon	2,097	1,965	1,976	2,307	2,072	2,133	2,219
	VAV econ	484	476	485	544	291	367	441
Large Retail	CAV econ	2,167	2,148	2,147	2,243	2,101	2,030	2,144
	CAV noecon	2,057	1,983	2,015	2,106	2,033	1,913	2,030
	VAV econ	859	735	777	927	664	632	783
University	CAV econ	1,464	1,573	1,531	1,589	1,191	1,352	1,390
	CAV noecon	1,439	1,438	1,461	1,456	1,104	1,308	1,356
	VAV econ	1,060	569	1,206	1,224	684	761	624

Record of Revision

Record of Revision Number	Issue Date
0	10/15/2010
6-15-8	6/1/2015
1-16-9	12/31/2015

Return to Table of Contents

APPENDIX H

HVAC DISTRIBUTION EFFICIENCIES

Single-family Distribution System Efficiency in Heating Mode, Ducts Located in Unconditioned Basement

Duct total leakage (%)	Duct system R-value (supply and return)	Albany	Binghamton	Buffalo	Massena	NYC	Syracuse
8%	Uninsulated	0.951	0.946	0.947	0.949	0.957	0.949
15%	Uninsulated	0.941	0.936	0.939	0.940	0.946	0.941
20%	Uninsulated	0.936	0.931	0.932	0.933	0.939	0.934
25%	Uninsulated	0.929	0.924	0.925	0.928	0.934	0.929
30%	Uninsulated	0.924	0.919	0.920	0.922	0.926	0.922
8%	R-6	0.980	0.979	0.978	0.978	0.980	0.979
15%	R-6	0.968	0.967	0.967	0.967	0.969	0.967
20%	R-6	0.959	0.959	0.959	0.960	0.962	0.960
25%	R-6	0.953	0.952	0.952	0.951	0.954	0.951
30%	R-6	0.946	0.944	0.944	0.944	0.946	0.944

Single-family Distribution System Efficiency in Cooling Mode, Ducts Located in Unconditioned Basement

Duct total leakage (%)	Duct system R-value (supply and return)	Albany	Binghamton	Buffalo	Massena	NYC	Syracuse
8%	Uninsulated	0.969	0.964	0.958	0.974	0.973	0.975
15%	Uninsulated	0.959	0.952	0.952	0.974	0.967	0.967
20%	Uninsulated	0.956	0.945	0.946	0.968	0.959	0.961
25%	Uninsulated	0.948	0.939	0.938	0.966	0.955	0.956
30%	Uninsulated	0.946	0.938	0.934	0.960	0.948	0.950
8%	R-6	0.985	0.987	0.982	0.985	0.987	0.987
15%	R-6	0.972	0.976	0.968	0.976	0.976	0.977
20%	R-6	0.966	0.964	0.959	0.965	0.970	0.972
25%	R-6	0.960	0.961	0.954	0.959	0.967	0.966
30%	R-6	0.956	0.957	0.948	0.965	0.958	0.960

Residential Distribution System Efficiency in Heating Mode (Attic Ducts)

Duct total leakage (%)	Duct system R-value (supply and return)	Albany	Binghamton	Buffalo	Massena	NYC	Syracuse	Poughkeepsie
8%	Uninsulated	0.777	0.754	0.770	0.759	0.818	0.778	0.779
15%	Uninsulated	0.715	0.692	0.708	0.693	0.761	0.716	0.717
20%	Uninsulated	0.668	0.646	0.662	0.644	0.717	0.670	0.671
25%	Uninsulated	0.619	0.599	0.614	0.592	0.673	0.622	0.623
30%	Uninsulated	0.568	0.549	0.564	0.539	0.626	0.571	0.573
8%	R-6	0.910	0.907	0.910	0.905	0.920	0.911	0.911
15%	R-6	0.851	0.848	0.851	0.843	0.865	0.852	0.851
20%	R-6	0.806	0.804	0.807	0.796	0.823	0.808	0.807
25%	R-6	0.760	0.759	0.762	0.748	0.780	0.762	0.761
30%	R-6	0.712	0.711	0.715	0.698	0.735	0.714	0.714

Residential Distribution System Efficiency in Cooling Mode (Attic Ducts)

Duct total leakage (%)	Duct system R-value (supply and return)	Albany	Binghamton	Buffalo	Massena	NYC	Syracuse	Poughkeepsie
8%	Uninsulated	0.813	0.793	0.820	0.809	0.834	0.811	0.810
15%	Uninsulated	0.755	0.737	0.768	0.753	0.777	0.758	0.753
20%	Uninsulated	0.716	0.698	0.732	0.715	0.737	0.717	0.713
25%	Uninsulated	0.676	0.660	0.694	0.673	0.696	0.677	0.672
30%	Uninsulated	0.637	0.621	0.656	0.634	0.657	0.637	0.632
8%	R-6	0.916	0.914	0.922	0.916	0.919	0.918	0.916
15%	R-6	0.860	0.860	0.870	0.859	0.861	0.862	0.861
20%	R-6	0.821	0.820	0.833	0.819	0.823	0.821	0.821
25%	R-6	0.780	0.780	0.795	0.781	0.782	0.783	0.780
30%	R-6	0.740	0.740	0.761	0.739	0.741	0.742	0.739

Multi-family Distribution System Efficiency in Heating Mode

Duct total leakage (%)	Duct system R-value (supply and return)	Albany	Binghamton	Buffalo	Massena	NYC	Syracuse
8%	Uninsulated	0.821	0.817	0.819	0.813	0.843	0.822
15%	Uninsulated	0.794	0.791	0.793	0.785	0.816	0.795
20%	Uninsulated	0.774	0.773	0.774	0.765	0.797	0.775
25%	Uninsulated	0.754	0.754	0.755	0.744	0.778	0.756
30%	Uninsulated	0.735	0.736	0.735	0.724	0.758	0.736
8%	R-6	0.943	0.944	0.944	0.941	0.949	0.944
15%	R-6	0.913	0.915	0.915	0.909	0.920	0.914
20%	R-6	0.892	0.895	0.894	0.887	0.900	0.893
25%	R-6	0.870	0.874	0.873	0.864	0.879	0.871
30%	R-6	0.848	0.853	0.852	0.841	0.858	0.849

Multi-family Distribution System Efficiency in Cooling Mode

Duct total leakage (%)	Duct system R-value (supply and return)	Albany	Binghamton	Buffalo	Massena	NYC	Syracuse
8%	Uninsulated	0.814	0.797	0.821	0.805	0.859	0.808
15%	Uninsulated	0.792	0.774	0.799	0.776	0.838	0.782
20%	Uninsulated	0.770	0.750	0.781	0.759	0.824	0.767
25%	Uninsulated	0.757	0.739	0.762	0.744	0.810	0.752
30%	Uninsulated	0.738	0.720	0.748	0.726	0.795	0.734
8%	R-6	0.941	0.936	0.945	0.938	0.951	0.939
15%	R-6	0.912	0.909	0.916	0.913	0.929	0.910
20%	R-6	0.893	0.890	0.899	0.889	0.911	0.888
25%	R-6	0.871	0.870	0.879	0.870	0.894	0.870
30%	R-6	0.852	0.851	0.863	0.849	0.876	0.851

Assembly Building Distribution Efficiency Heating

Duct total leakage (%)	Duct system R-value (supply and return)	Albany	Binghamton	Buffalo	Massena	NYC	Syracuse
8%	Uninsulated	0.909	0.923	0.918	0.925	0.857	0.881
15%	Uninsulated	0.879	0.890	0.889	0.890	0.829	0.851
20%	Uninsulated	0.858	0.868	0.867	0.869	0.810	0.831
25%	Uninsulated	0.835	0.848	0.846	0.849	0.793	0.812
30%	Uninsulated	0.816	0.829	0.828	0.829	0.776	0.795
8%	R-6	0.951	0.961	0.959	0.956	0.896	0.915
15%	R-6	0.917	0.930	0.926	0.923	0.863	0.883
20%	R-6	0.895	0.906	0.902	0.901	0.841	0.861
25%	R-6	0.871	0.884	0.879	0.881	0.821	0.840
30%	R-6	0.849	0.862	0.860	0.862	0.801	0.819

Assembly Building Distribution Efficiency Cooling

Duct total leakage (%)	Duct system R-value (supply and return)	Albany	Binghamton	Buffalo	Massena	NYC	Syracuse
8%	Uninsulated	0.870	0.845	0.857	0.869	0.922	0.898
15%	Uninsulated	0.859	0.835	0.846	0.858	0.908	0.887
20%	Uninsulated	0.850	0.825	0.838	0.850	0.897	0.878
25%	Uninsulated	0.840	0.815	0.828	0.840	0.886	0.867
30%	Uninsulated	0.829	0.805	0.817	0.829	0.873	0.856
8%	R-6	0.948	0.930	0.936	0.951	0.986	0.980
15%	R-6	0.932	0.916	0.921	0.936	0.967	0.964
20%	R-6	0.920	0.904	0.909	0.924	0.954	0.951
25%	R-6	0.906	0.891	0.896	0.910	0.939	0.938
30%	R-6	0.892	0.877	0.882	0.896	0.924	0.923

Fast Food Restaurant Distribution Efficiency Heating

Duct total leakage (%)	Duct system R-value (supply and return)	Albany	Binghamton	Buffalo	Massena	NYC	Syracuse
8%	Uninsulated	0.809	0.807	0.804	0.820	0.766	0.805
15%	Uninsulated	0.784	0.784	0.781	0.797	0.734	0.778
20%	Uninsulated	0.766	0.768	0.765	0.780	0.714	0.759
25%	Uninsulated	0.750	0.753	0.749	0.765	0.693	0.742
30%	Uninsulated	0.734	0.739	0.734	0.750	0.675	0.725
8%	R-6	0.901	0.904	0.901	0.905	0.875	0.898
15%	R-6	0.862	0.867	0.864	0.867	0.825	0.858
20%	R-6	0.836	0.844	0.840	0.844	0.794	0.831
25%	R-6	0.813	0.822	0.817	0.822	0.765	0.806
30%	R-6	0.791	0.801	0.796	0.801	0.739	0.783

Fast Food Restaurant Distribution Efficiency Cooling

Duct total leakage (%)	Duct system R-value (supply and return)	Albany	Binghamton	Buffalo	Massena	NYC	Syracuse
8%	Uninsulated	0.853	0.843	0.853	0.845	0.866	0.848
15%	Uninsulated	0.843	0.834	0.843	0.837	0.853	0.839
20%	Uninsulated	0.836	0.827	0.835	0.830	0.844	0.831
25%	Uninsulated	0.827	0.819	0.827	0.822	0.834	0.823
30%	Uninsulated	0.818	0.810	0.817	0.814	0.823	0.814
8%	R-6	0.950	0.950	0.953	0.948	0.945	0.947
15%	R-6	0.933	0.935	0.937	0.932	0.925	0.930
20%	R-6	0.921	0.924	0.925	0.919	0.911	0.917
25%	R-6	0.908	0.912	0.912	0.907	0.896	0.904
30%	R-6	0.895	0.899	0.898	0.894	0.881	0.891

Full Service Restaurant Distribution Efficiency Heating

Duct total leakage (%)	Duct system R-value (supply and return)	Albany	Binghamton	Buffalo	Massena	NYC	Syracuse
8%	Uninsulated	0.816	0.821	0.816	0.819	0.797	0.810
15%	Uninsulated	0.789	0.797	0.791	0.794	0.765	0.782
20%	Uninsulated	0.770	0.781	0.775	0.776	0.743	0.763
25%	Uninsulated	0.753	0.765	0.760	0.759	0.721	0.745
30%	Uninsulated	0.736	0.750	0.745	0.744	0.701	0.728
8%	R-6	0.904	0.910	0.905	0.902	0.893	0.901
15%	R-6	0.866	0.876	0.869	0.866	0.848	0.861
20%	R-6	0.840	0.853	0.847	0.841	0.818	0.834
25%	R-6	0.816	0.832	0.825	0.818	0.789	0.809
30%	R-6	0.794	0.812	0.805	0.797	0.763	0.786

Full Service Restaurant Distribution Efficiency Cooling

Duct total leakage (%)	Duct system R-value (supply and return)	Albany	Binghamton	Buffalo	Massena	NYC	Syracuse
8%	Uninsulated	0.827	0.827	0.840	0.814	0.854	0.821
15%	Uninsulated	0.825	0.826	0.839	0.813	0.845	0.819
20%	Uninsulated	0.821	0.824	0.836	0.811	0.837	0.815
25%	Uninsulated	0.818	0.821	0.832	0.808	0.829	0.812
30%	Uninsulated	0.813	0.817	0.827	0.804	0.820	0.807
8%	R-6	0.959	0.968	0.975	0.955	0.954	0.957
15%	R-6	0.955	0.970	0.975	0.953	0.941	0.952
20%	R-6	0.950	0.968	0.971	0.948	0.931	0.947
25%	R-6	0.943	0.963	0.966	0.942	0.919	0.940
30%	R-6	0.934	0.957	0.958	0.934	0.907	0.931

Small Retail Distribution Efficiency Heating

Duct total leakage (%)	Duct system R-value (supply and return)	Albany	Binghamton	Buffalo	Massena	NYC	Syracuse
8%	Uninsulated	0.657	0.646	0.648	0.670	0.614	0.656
15%	Uninsulated	0.624	0.614	0.617	0.637	0.581	0.623
20%	Uninsulated	0.602	0.594	0.596	0.615	0.559	0.601
25%	Uninsulated	0.582	0.574	0.577	0.594	0.538	0.581
30%	Uninsulated	0.563	0.556	0.559	0.575	0.520	0.562
8%	R-6	0.792	0.787	0.788	0.798	0.767	0.789
15%	R-6	0.742	0.736	0.739	0.748	0.714	0.738
20%	R-6	0.710	0.704	0.707	0.716	0.679	0.705
25%	R-6	0.680	0.674	0.678	0.686	0.648	0.676
30%	R-6	0.652	0.646	0.652	0.659	0.619	0.648

Small Retail Distribution Efficiency Cooling

Duct total leakage (%)	Duct system R-value (supply and return)	Albany	Binghamton	Buffalo	Massena	NYC	Syracuse
8%	Uninsulated	0.825	0.822	0.825	0.816	0.838	0.817
15%	Uninsulated	0.818	0.817	0.819	0.809	0.827	0.810
20%	Uninsulated	0.812	0.812	0.813	0.804	0.818	0.804
25%	Uninsulated	0.805	0.806	0.807	0.798	0.809	0.797
30%	Uninsulated	0.798	0.800	0.800	0.791	0.799	0.790
8%	R-6	0.932	0.934	0.935	0.927	0.931	0.928
15%	R-6	0.921	0.926	0.924	0.917	0.915	0.916
20%	R-6	0.912	0.918	0.916	0.908	0.904	0.907
25%	R-6	0.903	0.910	0.907	0.899	0.891	0.897
30%	R-6	0.892	0.902	0.897	0.889	0.879	0.887

Other Building Distribution Efficiency Heating

Duct total leakage (%)	Duct system R-value (supply and return)	Albany	Binghamton	Buffalo	Massena	NYC	Syracuse
8%	Uninsulated	0.798	0.799	0.797	0.809	0.759	0.788
15%	Uninsulated	0.769	0.771	0.770	0.780	0.727	0.759
20%	Uninsulated	0.749	0.753	0.751	0.760	0.707	0.739
25%	Uninsulated	0.730	0.735	0.733	0.742	0.686	0.720
30%	Uninsulated	0.712	0.719	0.717	0.725	0.668	0.703
8%	R-6	0.887	0.891	0.888	0.890	0.858	0.876
15%	R-6	0.847	0.852	0.850	0.851	0.813	0.835
20%	R-6	0.820	0.827	0.824	0.826	0.783	0.808
25%	R-6	0.795	0.803	0.800	0.802	0.756	0.783
30%	R-6	0.772	0.780	0.778	0.780	0.731	0.759

Other Building Distribution Efficiency Cooling

Duct total leakage (%)	Duct system R-value (supply and return)	Albany	Binghamton	Buffalo	Massena	NYC	Syracuse
8%	Uninsulated	0.844	0.834	0.844	0.836	0.870	0.846
15%	Uninsulated	0.836	0.828	0.837	0.829	0.858	0.839
20%	Uninsulated	0.830	0.822	0.831	0.824	0.849	0.832
25%	Uninsulated	0.823	0.815	0.824	0.817	0.840	0.825
30%	Uninsulated	0.815	0.808	0.815	0.810	0.829	0.817
8%	R-6	0.947	0.946	0.950	0.945	0.954	0.953
15%	R-6	0.935	0.937	0.939	0.935	0.937	0.941
20%	R-6	0.926	0.929	0.930	0.925	0.925	0.931
25%	R-6	0.915	0.919	0.920	0.915	0.911	0.920
30%	R-6	0.903	0.909	0.909	0.903	0.898	0.908

Record of Revision

Record of Revision Number	Issue Date
0	10/15/2010
7-13-27	7/31/2013

Return to Table of Contents

APPENDIX I

COOL ROOF

Building Type	City	Unit	kWh/unit	kW/unit	MMBtu/unit
Assembly	Albany	1,000 sq ft roof area	138	0.128	-1.60
	Binghamton	1,000 sq ft roof area	123	0.128	-1.60
	Buffalo	1,000 sq ft roof area	119	0.128	-1.60
	Massena	1,000 sq ft roof area	135	0.128	-1.90
	NYC	1,000 sq ft roof area	168	0.128	-1.10
	Poughkeepsie	1,000 sq ft roof area	163	0.128	-1.35
	Syracuse	1,000 sq ft roof area	150	0.128	-1.80
Auto Repair	Albany	1,000 sq ft roof area	77	0.128	-2.30
	Binghamton	1,000 sq ft roof area	66	0.128	-2.02
	Buffalo	1,000 sq ft roof area	65	0.128	-2.00
	Massena	1,000 sq ft roof area	78	0.128	-2.33
	NYC	1,000 sq ft roof area	116	0.128	-2.08
	Poughkeepsie	1,000 sq ft roof area	95	0.128	-2.19
	Syracuse	1,000 sq ft roof area	89	0.128	-2.19
Big Box Retail	Albany	1,000 sq ft roof area	155	0.128	-1.10
	Binghamton	1,000 sq ft roof area	146	0.128	-1.05
	Buffalo	1,000 sq ft roof area	132	0.128	-1.00
	Massena	1,000 sq ft roof area	150	0.128	-1.40
	NYC	1,000 sq ft roof area	187	0.128	-0.60
	Poughkeepsie	1,000 sq ft roof area	183	0.128	-0.85
	Syracuse	1,000 sq ft roof area	165	0.128	-1.20
Fast Food	Albany	1,000 sq ft roof area	117	0.128	-2.80
	Binghamton	1,000 sq ft roof area	101	0.128	-2.60
	Buffalo	1,000 sq ft roof area	101	0.128	-2.40
	Massena	1,000 sq ft roof area	124	0.128	-2.50
	NYC	1,000 sq ft roof area	170	0.128	-1.90
	Poughkeepsie	1,000 sq ft roof area	143	0.128	-2.35
	Syracuse	1,000 sq ft roof area	131	0.128	-2.80
Full Service Restaurant	Albany	1,000 sq ft roof area	279	0.128	-4.70
	Binghamton	1,000 sq ft roof area	112	0.128	-4.35
	Buffalo	1,000 sq ft roof area	233	0.128	-4.00
	Massena	1,000 sq ft roof area	282	0.128	-4..0
	NYC	1,000 sq ft roof area	344	0.128	-3.00
	Poughkeepsie	1,000 sq ft roof area	160	0.128	-3.85
	Syracuse	1,000 sq ft roof area	307	0.128	-4.70
Grocery	Albany	1,000 sq ft roof area	155	0.128	-1.10
	Binghamton	1,000 sq ft roof area	146	0.128	-1.05
	Buffalo	1,000 sq ft roof area	132	0.128	-1.00
	Massena	1,000 sq ft roof area	150	0.128	-1.40
	NYC	1,000 sq ft roof area	187	0.128	-0.60
	Poughkeepsie	1,000 sq ft roof area	183	0.128	-0.85
	Syracuse	1,000 sq ft roof area	165	0.128	-1.20

Building Type	City	Unit	kWh/unit	kW/unit	MMBtu/unit
Light Industrial	Albany	1,000 sq ft roof area	90	0.128	-2.00
	Binghamton	1,000 sq ft roof area	62	0.128	-1.90
	Buffalo	1,000 sq ft roof area	74	0.128	-1.80
	Massena	1,000 sq ft roof area	87	0.128	-2.10
	NYC	1,000 sq ft roof area	118	0.128	-1.40
	Poughkeepsie	1,000 sq ft roof area	94	0.128	-1.70
	Syracuse	1,000 sq ft roof area	102	0.128	-2.00
Motel	Albany	1,000 sq ft roof area	225	0.128	-1.00
	Binghamton	1,000 sq ft roof area	196	0.128	-0.88
	Buffalo	1,000 sq ft roof area	224	0.128	-1.13
	Massena	1,000 sq ft roof area	238	0.128	-0.63
	NYC	1,000 sq ft roof area	232	0.128	-1.09
	Poughkeepsie	1,000 sq ft roof area	207	0.128	-1.11
	Syracuse	1,000 sq ft roof area	250	0.128	-1.10
Primary School	Albany	1,000 sq ft roof area	196	0.624	-2.90
	Binghamton	1,000 sq ft roof area	145	0.086	-2.80
	Buffalo	1,000 sq ft roof area	152	0.426	-2.70
	Massena	1,000 sq ft roof area	191	0.116	-3.20
	NYC	1,000 sq ft roof area	270	0.652	-2.20
	Poughkeepsie	1,000 sq ft roof area	225	0.474	-2.55
	Syracuse	1,000 sq ft roof area	202	0.506	-3.30
Religious	Albany	1,000 sq ft roof area	138	0.128	-1.60
	Binghamton	1,000 sq ft roof area	123	0.128	-1.80
	Buffalo	1,000 sq ft roof area	120	0.128	-1.56
	Massena	1,000 sq ft roof area	135	0.128	-1.95
	NYC	1,000 sq ft roof area	168	0.128	-1.03
	Poughkeepsie	1,000 sq ft roof area	163	0.128	-1.97
	Syracuse	1,000 sq ft roof area	150	0.128	-1.88
Small Office	Albany	1,000 sq ft roof area	151	0.128	-1.20
	Binghamton	1,000 sq ft roof area	128	0.128	-1.15
	Buffalo	1,000 sq ft roof area	130	0.128	-1.10
	Massena	1,000 sq ft roof area	152	0.128	-1.40
	NYC	1,000 sq ft roof area	169	0.128	-0.80
	Poughkeepsie	1,000 sq ft roof area	164	0.128	-1.00
	Syracuse	1,000 sq ft roof area	157	0.128	-1.40
Small Retail	Albany	1,000 sq ft roof area	175	0.128	-1.70
	Binghamton	1,000 sq ft roof area	160	0.128	-1.60
	Buffalo	1,000 sq ft roof area	143	0.128	-1.50
	Massena	1,000 sq ft roof area	164	0.128	-2.10
	NYC	1,000 sq ft roof area	203	0.128	-1.20
	Poughkeepsie	1,000 sq ft roof area	195	0.128	-1.45
	Syracuse	1,000 sq ft roof area	184	0.128	-1.80
Warehouse	Albany	1,000 sq ft roof area	393	0.128	-4.84
	Binghamton	1,000 sq ft roof area	324	0.128	-5.64
	Buffalo	1,000 sq ft roof area	300	0.128	-4.47
	Massena	1,000 sq ft roof area	402	0.128	-4.74
	NYC	1,000 sq ft roof area	454	0.128	-3.86
	Poughkeepsie	1,000 sq ft roof area	464	0.128	-6.37
	Syracuse	1,000 sq ft roof area	440	0.128	-5.22

Building Type	City	Unit	kWh/unit	kW/unit	Therm/unit
Other	Albany	1,000 sq ft roof area	188	0.128	-2.50
	Binghamton	1,000 sq ft roof area	142	0.128	-2.19
	Buffalo	1,000 sq ft roof area	149	0.128	-2.02
	Massena	1,000 sq ft roof area	175	0.128	-2.30
	NYC	1,000 sq ft roof area	211	0.128	-1.67
	Poughkeepsie	1,000 sq ft roof area	188	0.128	-2.10
	Syracuse	1,000 sq ft roof area	193	0.128	-2.33

Record of Revision

Record of Revision Number	Issue Date
0	10/15/2010

Return to Table of Contents

APPENDIX J

COMMERCIAL HVAC UNIT SAVINGS

AIR SIDE ECONOMIZER

Building Type	City	System Type	Unit	KWh/unit
Assembly	Albany	Air-Side Economizer	ton	39
	Binghamton	Air-Side Economizer	ton	36
	Buffalo	Air-Side Economizer	ton	45
	Massena	Air-Side Economizer	ton	33
	NYC	Air-Side Economizer	ton	27
	Poughkeepsie	Air-Side Economizer	ton	33
	Syracuse	Air-Side Economizer	ton	42
Big Box Retail	Albany	Air-Side Economizer	ton	165
	Binghamton	Air-Side Economizer	ton	152
	Buffalo	Air-Side Economizer	ton	167
	Massena	Air-Side Economizer	ton	138
	NYC	Air-Side Economizer	ton	152
	Poughkeepsie	Air-Side Economizer	ton	159
	Syracuse	Air-Side Economizer	ton	165
Fast Food	Albany	Air-Side Economizer	ton	49
	Binghamton	Air-Side Economizer	ton	47
	Buffalo	Air-Side Economizer	ton	53
	Massena	Air-Side Economizer	ton	44
	NYC	Air-Side Economizer	ton	39
	Poughkeepsie	Air-Side Economizer	ton	44
	Syracuse	Air-Side Economizer	ton	49
Full Service Restaurant	Albany	Air-Side Economizer	ton	38
	Binghamton	Air-Side Economizer	ton	35
	Buffalo	Air-Side Economizer	ton	41
	Massena	Air-Side Economizer	ton	32
	NYC	Air-Side Economizer	ton	31
	Poughkeepsie	Air-Side Economizer	ton	35
	Syracuse	Air-Side Economizer	ton	38
Light Industrial	Albany	Air-Side Economizer	ton	45
	Binghamton	Air-Side Economizer	ton	39
	Buffalo	Air-Side Economizer	ton	38
	Massena	Air-Side Economizer	ton	33
	NYC	Air-Side Economizer	ton	25
	Poughkeepsie	Air-Side Economizer	ton	35
	Syracuse	Air-Side Economizer	ton	54
Primary School	Albany	Air-Side Economizer	ton	49
	Binghamton	Air-Side Economizer	ton	44
	Buffalo	Air-Side Economizer	ton	52
	Massena	Air-Side Economizer	ton	38
	NYC	Air-Side Economizer	ton	42
	Poughkeepsie	Air-Side Economizer	ton	46
	Syracuse	Air-Side Economizer	ton	41

Building Type	City	System Type	Unit	KWh/unit
Small Office	Albany	Air-Side Economizer	ton	202
	Binghamton	Air-Side Economizer	ton	195
	Buffalo	Air-Side Economizer	ton	195
	Massena	Air-Side Economizer	ton	188
	NYC	Air-Side Economizer	ton	186
	Poughkeepsie	Air-Side Economizer	ton	194
	Syracuse	Air-Side Economizer	ton	186
Small Retail	Albany	Air-Side Economizer	ton	107
	Binghamton	Air-Side Economizer	ton	101
	Buffalo	Air-Side Economizer	ton	113
	Massena	Air-Side Economizer	ton	95
	NYC	Air-Side Economizer	ton	95
	Poughkeepsie	Air-Side Economizer	ton	101
	Syracuse	Air-Side Economizer	ton	111
Religious	Albany	Air-Side Economizer	ton	9
	Binghamton	Air-Side Economizer	ton	10
	Buffalo	Air-Side Economizer	ton	7
	Massena	Air-Side Economizer	ton	6
	NYC	Air-Side Economizer	ton	6
	Poughkeepsie	Air-Side Economizer	ton	7
	Syracuse	Air-Side Economizer	ton	6
Warehouse	Albany	Air-Side Economizer	ton	3
	Binghamton	Air-Side Economizer	ton	5
	Buffalo	Air-Side Economizer	ton	2
	Massena	Air-Side Economizer	ton	4
	NYC	Air-Side Economizer	ton	2
	Poughkeepsie	Air-Side Economizer	ton	4
	Syracuse	Air-Side Economizer	ton	7
Other	Albany	Air-Side Economizer	ton	71
	Binghamton	Air-Side Economizer	ton	66
	Buffalo	Air-Side Economizer	ton	71
	Massena	Air-Side Economizer	ton	61
	NYC	Air-Side Economizer	ton	61
	Poughkeepsie	Air-Side Economizer	ton	66
	Syracuse	Air-Side Economizer	ton	70

CLOSE APPROACH COOLING TOWERS

Building Type	City	System Type	kWh/ton	kW/ton
Dormitory	Albany	Fan coil with Water Cooled Chiller	6.7	0.003
	Binghamton	Fan coil with Water Cooled Chiller	5.5	0.003
	Buffalo	Fan coil with Water Cooled Chiller	5.6	0.004
	Massena	Fan coil with Water Cooled Chiller	5.9	0.047
	NYC	Fan coil with Water Cooled Chiller	7.7	-0.006
	Poughkeepsie	Fan coil with Water Cooled Chiller	8.0	0.003
	Syracuse	Fan coil with Water Cooled Chiller	6.8	0.003

ECONOMIZER

Building Type	City	System type	kWh/ton	kW/ton
High School	Albany	CV no econ	5.7	0
		CV econ	1.8	0
		VAV econ	2.3	0
	Binghamton	CV no econ	5.9	0
		CV econ	2.2	0
		VAV econ	2.4	0
	Buffalo	CV no econ	5.6	0
		CV econ	1.8	0
		VAV econ	1.8	0
	Massena	CV no econ	5.9	0
		CV econ	1.8	0
		VAV econ	1.8	0
	NYC	CV no econ	6.3	0
		CV econ	2.3	0
		VAV econ	3.2	0
	Syracuse	CV no econ	5.9	0
		CV econ	2.2	0
		VAV econ	2.4	0
	Poughkeepsie	CV no econ	5.9	0
		CV econ	2.2	0
		VAV econ	2.4	0
Hospital	Albany	CV no econ	14.0	0
		CV econ	9.0	0
		VAV econ	7.0	0
	Binghamton	CV no econ	14.0	0
		CV econ	8.0	0
		VAV econ	6.0	0
	Buffalo	CV no econ	14.0	0
		CV econ	8.0	0
		VAV econ	6.0	0
	Massena	CV no econ	13.0	0
		CV econ	8.0	0
		VAV econ	6.0	0
	NYC	CV no econ	16.0	0
		CV econ	10.0	0
		VAV econ	7.0	0
	Syracuse	CV no econ	15.0	0
		CV econ	9.5	0
		VAV econ	7.0	0
	Poughkeepsie	CV no econ	14.0	0
		CV econ	9.0	0
		VAV econ	6.0	0

Building Type	City	System type	kWh/ton	kW/ton
Hotel	Albany	CV no econ	11.8	0
		CV econ	2.8	0
		VAV econ	3.5	0
	Binghamton	CV no econ	12.4	0
		CV econ	3.0	0
		VAV econ	3.5	0
	Buffalo	CV no econ	14.0	0
		CV econ	3.4	0
		VAV econ	3.6	0
	Massena	CV no econ	10.4	0
		CV econ	3.1	0
		VAV econ	3.9	0
	NYC	CV no econ	10.4	0
		CV econ	3.1	0
		VAV econ	3.9	0
	Syracuse	CV no econ	12.9	0
		CV econ	3.1	0
		VAV econ	3.6	0
	Poughkeepsie	CV no econ	11.1	0
		CV econ	3.0	0
		VAV econ	11.8	0

Building Type	City	System type	kWh/ton	kW/ton
Large Office	Albany	CV no econ	12.0	0
		CV econ	5.0	0
		VAV econ	7.0	0
	Binghamton	CV no econ	11.0	0
		CV econ	5.0	0
		VAV econ	5.0	0
	Buffalo	CV no econ	11.0	0
		CV econ	5.0	0
		VAV econ	6.0	0
	Massena	CV no econ	12.0	0
		CV econ	5.0	0
		VAV econ	5.0	0
	NYC	CV no econ	14.0	0
		CV econ	5.0	0
		VAV econ	7.0	0
	Poughkeepsie	CV no econ	13.0	0
		CV econ	5.0	0
		VAV econ	7.0	0
	Syracuse	CV no econ	11.0	0
		CV econ	5.0	0
		VAV econ	7.0	0

Building Type	City	System type	kWh/ton	kW/ton
Large Retail	Albany	CV no econ	9.3	0
		CV econ	4.2	0
		VAV econ	6.3	0
	Binghamton	CV no econ	9.6	0
		CV econ	3.8	0
		VAV econ	4.9	0
	Buffalo	CV no econ	9.5	0
		CV econ	4.3	0
		VAV econ	5.6	0
	Massena	CV no econ	9.1	0
		CV econ	3.8	0
		VAV econ	6.0	0
	NYC	CV no econ	10.9	0
		CV econ	4.8	0
		VAV econ	8.6	0
	Poughkeepsie	CV no econ	9.8	0
		CV econ	4.2	0
		VAV econ	7.1	0
	Syracuse	CV no econ	9.1	0
		CV econ	4.0	0
		VAV econ	7.3	0
University	Albany	CV no econ	5.6	0
		CV econ	3.6	0
		VAV econ	4.1	0
	Binghamton	CV no econ	5.0	0
		CV econ	3.2	0
		VAV econ	3.3	0
	Buffalo	CV no econ	5.0	0
		CV econ	3.1	0
		VAV econ	3.8	0
	Massena	CV no econ	5.1	0
		CV econ	3.0	0
		VAV econ	3.8	0
	NYC	CV no econ	6.6	0
		CV econ	3.9	0
		VAV econ	5.7	0
	Poughkeepsie	CV no econ	6.7	0
		CV econ	3.6	0
		VAV econ	4.5	0
	Syracuse	CV no econ	5.4	0
		CV econ	3.5	0
		VAV econ	4.1	0

Building Type	City	System type	kWh/ton	kW/ton
Other	Albany	CV no econ	9.7	0
		CV econ	4.4	0
		VAV econ	5.0	0
	Binghamton	CV no econ	9.6	0
		CV econ	4.2	0
		VAV econ	4.2	0
	Buffalo	CV no econ	9.9	0
		CV econ	4.3	0
		VAV econ	4.5	0
	Massena	CV no econ	9.3	0
		CV econ	4.1	0
		VAV econ	4.4	0
	NYC	CV no econ	10.7	0
		CV econ	4.9	0
		VAV econ	5.9	0
	Poughkeepsie	CV no econ	10.3	0
		CV econ	4.6	0
		VAV econ	5.3	0
	Syracuse	CV no econ	9.7	0
		CV econ	4.5	0
		VAV econ	5.1	0

Record of Revision

Record of Revision Number	Issue Date
0	10/15/2010

Return to Table of Contents

APPENDIX K

VARIABLE FREQUENCY DRIVES

Unit energy (kWh) savings for VFDs were estimated by building type, HVAC type and city using DOE-2.2 simulations of the prototype buildings with built-up HVAC systems. The simulations were run for each of the three built-up system types (CV no economizer, CV with economizer, and VAV with economizer) and the results were weighted according to the HVAC system weights shown in Appendix B. The results for each prototype are shown by measure and location below:

Community College

Climate	Measure Unit Savings (kWh/hp)					
	CW Pump	CHW Pump	HW Pump	Return Fan	Supply Fan	Tower Fan
Albany	606	683	497	429	452	216
Binghamton	716	682	496	510	534	256
Buffalo	663	631	460	471	495	237
Massena	553	835	383	390	412	197
NYC	419	399	290	293	312	150
Poughkeepsie	464	441	321	325	346	165
Syracuse	539	513	373	380	402	193

Dormitory

Climate	Measure Unit Savings (kWh/hp)			
	CW Pump	CHW Pump	HW Pump	Tower Fan
Albany	961	453	386	190
Binghamton	963	453	386	143
Buffalo	964	453	386	152
Massena	966	451	388	166
NYC	965	453	393	266
Poughkeepsie	962	450	387	244
Syracuse	966	452	388	204

High School

Climate	Measure Unit Savings (kWh/hp)					
	CW Pump	CHW Pump	HW Pump	Return Fan	Supply Fan	Tower Fan
Albany	350	232	60	513	674	203
Binghamton	359	234	58	509	661	169
Buffalo	358	233	53	511	660	176
Massena	357	238	65	518	663	187
NYC	327	231	44	531	707	241
Poughkeepsie	348	232	54	522	699	209
Syracuse	346	236	59	527	692	210

Hospital

Climate	Measure Unit Savings (kWh/hp)					
	CW Pump	CHW Pump	HW Pump	Return Fan	Supply Fan	Tower Fan
Albany	2,053	1,665	1,142	1,645	1,860	413
Binghamton	2,053	1,687	1,142	1,549	1,681	380
Buffalo	2,053	1,678	1,142	1,591	1,731	416
Massena	2,053	1,689	1,142	1,537	1,588	395
NYC	2,053	1,713	1,142	1,801	2,137	574
Poughkeepsie	2,053	1,718	1,142	1,694	1,977	487
Syracuse	2,053	1,671	1,142	1,618	1,796	415

Hotel

Climate	Measure Unit Savings (kWh/hp)					
	CW Pump	CHW Pump	HW Pump	Return Fan	Supply Fan	Tower Fan
Albany	73	1,740	6,559	326	250	1,571
Binghamton	73	1,745	6,554	284	211	1,423
Buffalo	75	1,764	6,551	321	247	1,583
Massena	72	1,802	6,499	284	188	1,377
NYC	75	1,925	6,603	332	242	1,525
Poughkeepsie	73	2,198	6,563	286	201	1,475
Syracuse	74	1,854	6,556	295	209	1,497

Large Retail

Climate	Measure Unit Savings (kWh/hp)					
	CW Pump	CHW Pump	HW Pump	Return Fan	Supply Fan	Tower Fan
Albany	1,049	3,421	3,287	1,085	1,282	280
Binghamton	1,059	3,481	3,241	1,074	1,266	217
Buffalo	1,062	3,462	3,270	1,082	1,272	240
Massena	1,053	3,448	3,246	1,080	1,257	251
NYC	1,020	3,310	3,411	1,091	1,310	396
Poughkeepsie	1,036	3,385	3,361	1,093	1,306	341
Syracuse	1,054	3,429	3,298	1,089	1,289	296

Office

Climate	Measure Unit Savings (kWh/hp)					
	CW Pump	CHW Pump	HW Pump	Return Fan	Supply Fan	Tower Fan
Albany	1,334	1,231	981	1,286	1,646	269
Binghamton	1,315	1,195	905	1,156	1,463	233
Buffalo	1,299	1,196	938	1,154	1,467	255
Massena	1,382	1,258	981	1,315	1,625	248
NYC	1,183	1,176	845	1,258	1,605	407
Poughkeepsie	1,208	1,165	742	1,240	1,606	344
Syracuse	1,295	1,213	1,005	1,236	1,578	292

University

Climate	Measure Unit Savings (kWh/hp)					
	CW Pump	CHW Pump	HW Pump	Return Fan	Supply Fan	Tower Fan
Albany	687	767	570	669	747	231
Binghamton	701	757	571	591	621	185
Buffalo	696	760	573	623	642	216
Massena	705	754	579	673	718	195
NYC	668	802	550	850	1,038	308
Poughkeepsie	683	775	558	789	959	261
Syracuse	680	771	572	685	738	251

For the city, measure, and building type combinations not addressed above, use data supplied by National Grid shown below. The unit savings estimates are based on data developed by NSTAR for the Massachusetts TRM[1412]. These values were trued up to National Grid evaluation studies by computing the ratio of the savings by VFD application from the National Grid Massachusetts Energy Initiative program evaluation to the average value by application across the NSTAR data. This adjustment factor was then applied to each of the NSTAR values. The adjusted savings are shown below.

[1412] NSTAR VFD savings taken from Chan, T. *Formulation of a Prescriptive Incentive for the VFD and Motors and VFD Impact Tables at NSTAR*, June, 2010

Measure Unit Savings (kWh/hp)

Building Type	Exh fan	CT fan	CHW pump	Boiler FW pump	HW pump	MAF	Return fan	Supply fan	WLHP circ pump
Elm/HSchool	1,968			1,492		2,088			1,334
Grocery	1,726	392	398	1,275	752	1,368	924	1,007	1,711
Health*	1,863			1,812		1,842			1,912
Hotel/Motel	1,740			1,694		2,067			1,788
Multi-Family**	1,768			1,806		1,892	902	1,025	1,934
Offices	1,840			1,440		2,054			1,685
Restaurant	1,899	424	381	1,526	916	1,613	936	1,059	1,845
Retail	1,707			1,504		1,469			1,561
University/College	2,011			1,788		1,976			1,594
Warehouse	1,828	195	199	1,545	934	1,982	823	936	1,468

*Health includes hospital building types
**Multi-family includes dormitory building types

Peak demand savings were taken from the NSTAR data, as shown below:

Measure Unit Demand Savings (kW/hp)

Building Type	Exh fan	CT fan	CHW pump	Boiler FW pump	HW pump	MAF	Return fan	Supply fan	WLHP circ pump
Elm/HSchool	0.411	-0.025	0.061	0.498	0.498	0.119	0.111	0.070	0.300
Grocery	0.284	-0.025	0.061	0.498	0.498	0.119	0.111	0.070	0.194
Health*	0.119	-0.025	0.061	0.498	0.498	0.119	0.111	0.070	0.061
Hotel/Motel	0.119	-0.025	0.061	0.498	0.498	0.119	0.111	0.070	0.061
Multi-Family**	0.119	-0.025	0.061	0.498	0.498	0.119	0.111	0.070	0.061
Offices	0.119	-0.025	0.061	0.498	0.498	0.119	0.111	0.070	0.061
Restaurant	0.284	-0.025	0.061	0.498	0.498	0.119	0.111	0.070	0.194
Retail	0.119	-0.025	0.061	0.498	0.498	0.119	0.111	0.070	0.061
University/College	0.119	-0.025	0.061	0.498	0.498	0.119	0.111	0.070	0.061
Warehouse	0.119	-0.025	0.061	0.498	0.498	0.284	0.111	0.070	0.061

*Health includes hospital building types
**Multi-family includes dormitory building types

Record of Revision

Record of Revision Number	Issue Date
0	10/15/2010
6-19-13	6/28/2019

Return to Table of Contents

APPENDIX L

MINIMUM MOTOR EFFICIENCY – ECCCNYS

The energy savings baseline efficiency for all normal replacement motors rebated after the new standards take effect is shown below:

TABLE C405.7(1)
MINIMUM NOMINAL FULL-LOAD EFFICIENCY FOR NEMA DESIGN A, NEMA DESIGN B, AND *IEC DESIGN N MOTORS* (EXCLUDING FIRE PUMP) ELECTRIC MOTORS AT 60 HZ[a, b]

MOTOR HORSEPOWER (STANDARD KILOWATT EQUIVALENT)	NOMINAL FULL-LOAD EFFICIENCY (%) AS OF JUNE 1, 2016							
	2 Pole		4 Pole		6 Pole		8 Pole	
	Enclosed	Open	Enclosed	Open	Enclosed	Open	Enclosed	Open
1 (0.75)	77.0	77.0	85.5	85.5	82.5	82.5	75.5	75.5
1.5 (1.1)	84.0	84.0	86.5	86.5	87.5	86.5	78.5	77.0
2 (1.5)	85.5	85.5	86.5	86.5	88.5	87.5	84.0	86.5
3 (2.2)	86.5	85.5	89.5	89.5	89.5	88.5	85.5	87.5
5 (3.7)	88.5	86.5	89.5	89.5	89.5	89.5	86.5	88.5
7.5 (5.5)	89.5	88.5	91.7	91.0	91.0	90.2	86.5	89.5
10 (7.5)	90.2	89.5	91.7	91.7	91.0	91.7	89.5	90.2
15 (11)	91.0	90.2	92.4	93.0	91.7	91.7	89.5	90.2
20 (15)	91.0	91.0	93.0	93.0	91.7	92.4	90.2	91.0
25 (18.5)	91.7	91.7	93.6	93.6	93.0	93.0	90.2	91.0
30 (22)	91.7	91.7	93.6	94.1	93.0	93.6	91.7	91.7
40 (30)	92.4	92.4	94.1	94.1	94.1	94.1	91.7	91.7
50 (37)	93.0	93.0	94.5	94.5	94.1	94.1	92.4	92.4
60 (45)	93.6	93.6	95.0	95.0	94.5	94.5	92.4	93.0
75 (55)	93.6	93.6	95.4	95.0	94.5	94.5	93.6	94.1
100 (75)	94.1	93.6	95.4	95.4	95.0	95.0	93.6	94.1
125 (90)	95.0	94.1	95.4	95.4	95.0	95.0	94.1	94.1
150 (110)	95.0	94.1	95.8	95.8	95.8	95.4	94.1	94.1
200 (150)	95.4	95.0	96.2	95.8	95.8	95.4	94.5	94.1
250 (186)	95.8	95.0	96.2	95.8	95.8	95.8	95.0	95.0
300 (224)	95.8	95.4	96.2	95.8	95.8	95.8		
350 (261)	95.8	95.4	96.2	95.8	95.8	95.8		
400 (298)	95.8	95.8	96.2	95.8				
450 (336)	95.8	96.2	96.2	96.2				
500 (373)	95.8	96.2	96.2	96.2				

Record of Revision

Record of Revision Number	Issue Date
0	10/15/2010

Return to Table of Contents

APPENDIX M

GUIDELINES FOR EARLY REPLACEMENT CONDITION

Getting Started

The full manual, beginning in Section 2, explains the concepts of the tables and their use, and the choices offered to PAs. It also contains various instructions on such matters as data retention and the tracking database. This first section contains the immediate directions to get a quick start on the simplest case. These tables can only be used regarding the proposed replacement of equipment that has not reached its prescribed Effective Useful Life (EUL). Two other conditions are pertinent to use of this page:

The PA accepts agrees to use the assumptions for each measure regarding the typical relationship between incremental costs and savings and the full costs and savings of replacing the older (but pre-EUL) equipment with the high efficiency equipment promoted by the program. The measures in question are listed in Table M-1 *without* an "a" or a "b" superscript.

If these conditions are met, the fundamental steps for calculation would be as follows:

- Calculate the full costs of replacing the old equipment with the program measure, including labor.
- Calculate the full first year savings of the program measure using the existing equipment as the baseline, assume such savings through the EUL of the new equipment, monetize the savings per the prescribed annual Long Run Avoided Costs (LRACs) estimates, and calculate the present value of this stream of monetized savings using Staff's discount rate. This present value is referred to herein as the Inflated Benefits.[1413]
- Estimate the remaining useful life (RUL) of the old equipment in place.
- Turn to the measure-specific costs and savings tables of the measure in question (the measures are grouped by the EUL on Table M-1).
- Go down each table to the row for the estimated RUL and find the percentage adjustment factor in the column for the measure.
- Multiply the Inflated Benefits by the benefits factor.
- Multiply the full costs by the costs factor.
- For Total Resources Cost (TRC) analysis, use the two products from steps 6 and 7.
- For first year savings to report against approved program goals, use the full savings.

Introduction

In the EEPS Order issued on October 18, 2010 (p.9),[1414] the Commission stated, regarding TRC analysis of early replacements in individual projects, that it was ". . . directing Staff to develop a new approach, based on the dual baseline approach, which provides consistency between the treatment of savings and costs. The Director of the Office of Energy Efficiency and Environment is directed to compile and provide simplifying lookup tables, which provide early

[1413] "Inflated Benefits" is simply a concept designed to be an intermediate step in the computation of estimated dual baseline benefits, using the tables in this Appendix. It does not imply an assumption that the old equipment, absent the program, would have continued in use through the life of the new equipment.

[1414] Case 07-M-0548, Order Approving Consolidation and Revision of Technical Manuals (issued October 18, 2010).

replacement method energy savings consistent with the dual baseline concept as an attachment to the consolidated Technical Manual (TM)." Staff was also directed "to develop a consistent cost estimation approach which reflects the concept that the costs of making a high efficiency early replacement will avoid an end-of useful-life replacement with minimally code compliant equipment."

Early Replacement vs. Normal Replacement

Early replacement is defined in the Order as the replacement of equipment before it reaches its Effective Useful Life (EUL), whereas end-of-life or normal replacement refers to the replacement of equipment that has reached or passed the end of its measure-prescribed EUL. The crucial difference between end-of-life replacement and early replacement is that end-of-life/normal uses "incremental" costs and savings while early replacement uses "full" values:

- *Incremental savings* is defined as the annual energy use of the currently-on-the-market standard, minimally compliant equipment minus the annual energy use of the high efficiency equipment subsidized by the program.
- *Full savings* is defined as the annual energy use of the old equipment in place minus the annual energy use of the high efficiency equipment subsidized by the program.
- *Incremental cost* is defined as the full cost of new efficient equipment minus the cost of the currently-on-the-market standard, minimally-compliant equipment, plus the time value penalty (the present value cost of a dollar amount increases with earlier spending, see below).
- *Full cost* is simply the cost (including installation) of the new efficient equipment.

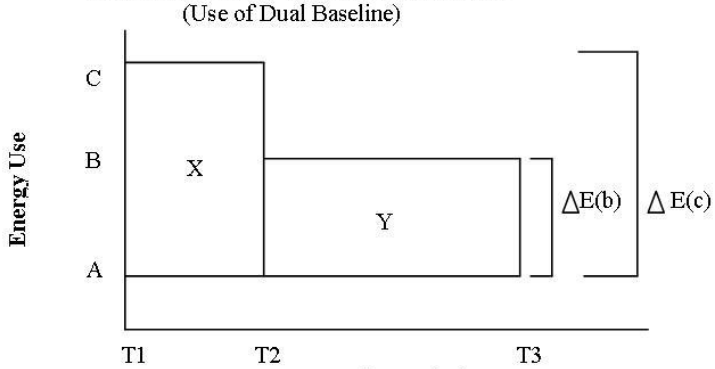
Early replacement not only accelerates savings to the electric grid but also allows PAs to claim greater first-year annual savings toward their annual energy goals because full savings are reported as the first-year savings. *If a PA cannot substantiate that the age of the equipment in place is less than its EUL and therefore a case of early replacement,* the replacement must be screened as normal (end of life) replacement, with the incremental savings reported as the first-year savings toward approved program goals.

In both normal and early replacement conditions, the establishment of the correct baseline is critical in accurately estimating gross energy and demand impacts. However, while the TM addresses the establishment of the baseline for normal replacement conditions, it rarely addresses the establishment of baselines for early replacement conditions. This Appendix M provides two sets of lookup tables and guidance designed to simplify the complex mathematical analysis of dual-baseline cases and reduce PA data needs. The first set of tables, for *typical* early replacement measure conditions as developed by TecMarket Works, reflects data, discussed below, that PAs might find it difficult to obtain. The second set of tables requires PAs to provide these data but still simplifies the calculations.

The standard early replacement condition, illustrated in Figure 1, involves a customer who replaces equipment before it reaches the end of its EUL. That is, the equipment is fully functioning and would continue to function for some period of time; referred to as the remaining useful life (RUL). However, the customer is induced by the program to replace this existing equipment with more efficient equipment. It is assumed that at the end of the RUL, absent the program, the customer would have installed equipment that would meet the existing efficiency

code or appliance standard, i.e., equipment that represents the market average efficiency or the efficiency that had become the industry standard (referred to as the *code/standard equipment*).

Figure 1. The Early Replacement Condition
(Use of Dual Baseline)



C = Energy use of pre-existing measure
B = Energy use of code/standard measure
A = Energy use of new efficient measure
T1 = Date on which new efficient measure is installed
T2 = Date on which existing measure was expected to have failed
T3 = Date on which the new efficient measure is expected to fail
T3—T1= Expected effective useful life (EUL) of the new efficient measure
T2—T1= Expected remaining useful life (RUL) of the pre-existing measure
T3 - T2 = Expected remaining EUL of the new efficient measure
Δ E(c) = The full savings defined as C - A
Δ E(b) = The incremental savings defined as B - A

Energy savings in this example would consist of two portions. The customer would have experienced the full savings defined by Area **X** (energy use C-A for the RUL period T2-T1). At the end of the RUL, the savings for the period T3-T2 would be reduced to incremental savings defined by area **Y**. To carry out these calculations, information on two (dual) baselines is required, the energy use of the pre-existing equipment and the energy use of code/standard equipment. Information on energy use for the high efficiency equipment provided through the program will also be required.

The cost would also have to be calculated in a manner consistent with early replacement. In normal replacement situations, one would use the incremental cost that is defined as the cost of the new efficient equipment minus the cost of the code/standard equipment. In the early replacement case, the incremental cost is calculated in a slightly different manner. This calculation recognizes that, while the customer purchased efficient equipment with the assistance of the program, it would have purchased code/standard equipment at some time in the future, i.e., at the end of the RUL, had the program not existed.

Thus, one would first have to determine the full cost of the new efficient equipment (including the installation labor) at T1 *and* the full cost of the code/standard equipment (including the installation labor) at T2. The incremental costs would then be calculated as the cost of the new efficient equipment minus the present value (PV) of the cost that is avoided in the future for the code/standard equipment. Figure 2 presents a case in which the RUL is 4 years and, absent the

program, the code/standard equipment would have been installed in the fifth year. This calculation differs from the normal/end of life replacement incremental cost in adding the time value of money for spending earlier.

Figure 1. Incremental Cost Calculation for an Early Replacement of Equipment with an RUL of Four Years

Year	PV with Program	PV without Program
1	Full cost of high efficient equipment	0
2	0	0
3	0	0
4	0	0
5	0	Full cost of Code/Standard Equipment

The two key inputs necessary for these calculations, the energy use and the cost of the code/standard equipment, may not be readily available to PA field staff and are subject to change before the end of the equipment's RUL in the absence of a program. Note that the first set of tables in this Appendix M is based on current codes and standards. If a PA can document the needed energy use and cost data, it can choose to use the second set of tables. Both sets of tables are based on a "ratio approach".

The Ratio Approach to the Dual Baseline with the Lookup Tables

This approach focuses on the ratio of incremental savings to full savings[1415] and the ratio of incremental costs to full costs. These ratios, shown at the top of the attached tables, determine the factors that PAs can use to adjust the savings and cost data they do have. The first set of tables, the measure-specific set, allows the early replacement calculations to be performed in a manner that only requires the program administrator to have the Remaining Useful Life (RUL) of the equipment in place and the full savings and costs of the project. The ratios in the first set of tables (M-2 through M-19) were developed by TecMarket Works. The second set of tables (M-29 through M-38), the non-measure-specific set, requires the program administrators to provide their own incremental costs and savings ratios (based on the code/standard equipment). To use the second set of tables, PAs must match ratios that they have calculated to corresponding ratios in the tables.

The source of these two ratios for the first set of tables is the Database for Energy Efficient Resources (DEER), most recently updated by Itron for the California Public Utility Commission in 2009. Among other things, DEER contains energy use and costs for selected energy-efficient technologies and equipment in the residential and nonresidential sectors. DEER also contains the same information for typical equipment, those commonly installed in the marketplace.

To use either set of tables PAs will need to calculate the first-year annual savings as the annual energy use of the old equipment in place minus the annual energy use of the high efficiency equipment (the full savings). These full savings are then counted for each year of the EUL as is

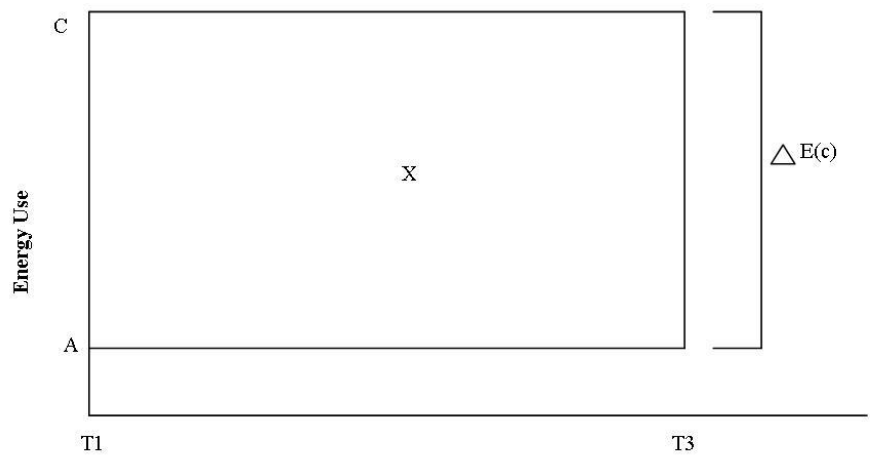
[1415] The savings values ratios are not lifecycle present values but are rather the line segments in Figure 1 on the vertical axis: (B – A) divided by (C – A).

represented as area *X* in Figure 3. For each year of the EUL (T3 – T1) of the new equipment, the full kWh or therm savings are converted to dollar benefits by multiplying them by the Commission's avoided costs estimates for that year. As a preliminary step in using the tables, the PAs will calculate this "inflated lifecycle benefits" as the present value of the stream of full savings benefits for the EUL of the new equipment.

In cases of early replacement under the ratio approach, it is these inflated lifecycle benefits that must be adjusted using the appropriate *inflated lifecycle benefits adjustment factor*. For a given measure with a given EUL, RUL and ratio of incremental savings to full savings, the inflated lifecycle benefits adjustment factor is the ratio (presented as a percentage) of the present value of the dual baseline lifecycle benefits (X+Y) illustrated in Figure 1 to the present value of the inflated lifecycle benefits illustrated in Figure 3.

PAs can obtain these factors from either the set of DEER-based tables or from the set of PA-based tables if a PA can calculate its own incremental savings to full savings ratios.

Figure 3. Inflated Lifecycle Benefits



△E(c) = C - A
C = Energy use of pre-existing equipment
A = Energy use of the efficient equipment rebated through program
T1 = Date on which new efficient equipment is installed
T3 = Date on which the new efficient equipment is expected to fail
T3 - T1 = EUL of new efficient equipment

Under the Commission requirement of consistent treatment of savings and costs, the full costs[1416] must also be adjusted downward. PAs can obtain the *full cost adjustment factors* from either the DEER-based Tables based on typical ratios of incremental cost to full cost or from the PA-based Tables if a PA can calculate its own incremental cost to full cost ratios. The DEER-based set of lookup tables runs from M-2 through M-28. Of these, M-2 through M-10 cover benefits, M-11 through M-19 costs, and M-20 through M-28 adjusted EULs. The PA-based set of lookup tables

[1416] Full costs include the capital cost of the new efficient equipment plus installation cost.

runs from M-29 through M-47. Of these, M-29 through M-37 cover benefits, M-38 all costs (only the RUL matters, not the EUL), and M-39 through M-47adjusted EULs.

DEER-Based Look-Up Tables

The first set of tables includes look-up tables M-2 through M-10, which present the *Inflated Lifecycle Benefit Adjustment Factors*. The tables are based primarily on data contained in the California 2009 DEER. For each qualified equipment type, the median ratio of incremental savings to the full savings was calculated. These ratios along with the RULs, ranging from 1 year to the EUL minus 1 year, are shown in the look-up tables and are used to derive the factors needed to adjust the inflated lifecycle benefits.

Tables M-11 through M-19 present the *full cost adjustment factors*, for the same equipment addressed in Tables M-2 through M-10, for the same RUL ranges. For each qualified equipment type, the median ratio of incremental costs to the full costs was calculated.

To use these tables of typical ratios, a PA must have gathered the following four pieces of information:

- the EUL of the new efficient equipment,
- the RUL of the old equipment in place,
- the full savings of the equipment (annual energy use of the old equipment in place minus the annual energy of the high efficiency equipment supported by the program), and
- the full costs (including installation)

The EUL for a given measure is obtained from Table M-1, which is a compilation of the EULs for all the relevant measures in the consolidated Technical Manual effective January 1, 2011 that could qualify for early replacement[1417]. The RUL[1418], the full savings, and the full costs are provided by the program implementer. Note that documentation for PA estimates of these data must be retained for possible Staff review. Table M-1 also presents the normal replacement baseline equipment against which each of the 29 measures covered in this table is compared. Note that the lookup tables apply only to the 23 measures without an ***a*** or ***b*** designation in Table M-1.

Table M-1. Early Replacement Measures, EULs, and Baselines

[1417] Early replacement is inappropriate for such equipment as wall insulation, right sizing, setback thermostats, and sub-metering since nothing is being replaced. Lighting equipment has also been excluded since it is expected to be treated as pre-qualified.

[1418] Upon request, Staff will provide a suggested questionnaire to assist in the determination of the RUL.

Measures	EUL	Normal Replacement Baseline
Heat Pump Water Heater: Residential	10	Code Electric Storage Water Heater
Room Air Conditioner: Residential	10	EPACT Room Air Conditioner
Clothes Washer: Single Family: Residential	11	EPACT Clothes Washer
ENERGY STAR Dishwashers: Residential	11	EPACT Dishwasher
Water Heater: Gas: Residential	11	Code Gas Storage Water Heater
Energy Star Dehumidifier: Residential[a]	12	Standard Efficiency Dehumidifier
Refrigerators: Nonresidential	12	EPACT Refrigerator
Indirect Water Heaters: Residential	13	Code Gas Storage Water Heater
Water Heater: Electric: Residential	13	Code Electric Storage Water Heater
Clothes Washer: Multi-Family Residential	14	EPACT Clothes Washer
Air Compressor Upgrade: Nonresidential	15	Standard Efficiency Rotary Screw Compressor
Central Air Conditioning: Residential	15	Code Central AC with gas heat
Central Air Source Heat Pumps: Residential	15	Code Central Air Source Heat Pump
Cool Roof: Nonresidential[a]	15	Standard Roof
Cooling Tower: Nonresidential[a]	15	Standard Efficiency Cooling Tower
Efficient Air-Cooled Refrigeration Condenser: Nonresidential[a]	15	Standard Efficiency Refrigeration Condenser
Indirect Water Heaters: Nonresidential	15	Code Gas Storage Water Heater
Motors: Nonresidential[b]	15	EISA Minimum Efficiency Motor
Packaged Air Conditioners (Central AC): Nonresidential	15	Code Packaged Air Conditioner
Packaged Air Source Heat Pumps (CAC Cooling Only): Nonresidenti	15	Code Packaged Air Source Heat Pump
Water Heaters: Nonresidential (Gas & Electric)	15	Code Storage Water Heater
Refrigerators: Residential	17	EPACT Refrigerator
Chillers: Nonresidential	20	Code Chiller
Gas Furnaces and Boilers: Nonresidential	20	Code Furnace and Boiler
High Efficiency Gas Furnaces: Residential	20	Code Furnace
High Performance Glazing: Nonresidential[b]	20	Code Glazing
High Performance Windows (Gas Heating Only): Residential	20	Code Window
Instantaneous Water Heater: Residential	20	Code Storage Water Heater
Gas Boilers: Residential	25	Code Boiler

EPACT refers to efficiency standards promulgated by the Energy Policy and Conservation Act of 2005

EISA refers to efficiency standards promulgated by the Energy Independence and Security Act of 2007

Code refers to New York State Construction codes, which reference ASHRAE standards.

For measures assigned an **a**, the efficiency of the old in place unit is still the common practice or no new standards have been adopted, i.e., the baseline for the full savings and the incremental savings are the same. As a result, the ratio of incremental to full savings is near 1.0, meaning that a PA can claim the full savings for the entire EUL of the new equipment (areas X and Y in Figure 4). Therefore, the lookup tables do not apply.

For these measures assigned a **b**, the high efficiency equipment subsidized by the program is consistent with current code or standards. For these measures, the incremental savings are zero and thus the ratio of incremental to full savings is 0.0.This means that a PA can claim full savings for only the RUL (area X in Figure 5), after which the high-efficiency replacement would have occurred anyway. Therefore, the lookup tables do not apply.

Figure 4. Efficiency of the Old In Place Unit Is Still the Common Practice Or No New Standards

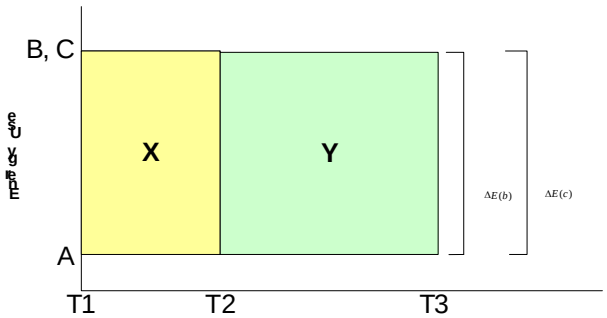
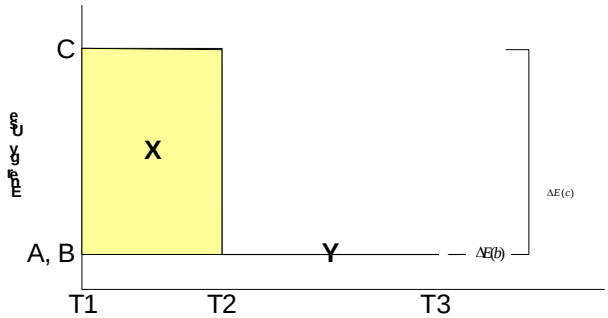


Figure 5. High Efficiency Equipment Subsidized by the Program Is Consistent with Current Code Or Standards



$\Delta E(c)$ = C - A

$\Delta E(b)$ = B - A

C = Energy use of pre-existing equipment
B = Energy use of equipment that meets code
A = Energy use of the efficient equipment rebated through program
T1 = Date on which new efficient equipment is installed
T2 = Date on which existing equipment was expected to have failed
T3= Date on which the new efficient equipment is expected to fail
T3 – T1 = Expected effective useful life (EUL) of the new efficient equipment
T2 – T1 = Expected remaining useful life (RUL) of the pre-existing equipment
T3 – T2 = Expected remaining EUL of the new efficient equipment

After obtaining the four pieces of information listed above, the program implementer can determine the appropriate inflated lifecycle benefits adjustment factor by which to multiply the inflated lifecycle benefits and the full cost adjustment factor by which to multiply the full costs. These adjusted inflated lifecycle benefits and adjusted full costs are to be used in the TRC ratio in the screening of measures in specific projects.

4.1.1 Table Organization

The DEER-Based Tables are divided into two groups:

- Inflated Lifecycle Benefit Adjustment Factors (Tables M-2 through M-10)
- Full-Cost Adjustment Factor (Tables M-11 through M-19)

Each set of tables addresses the same 23 measures or varieties of measures grouped by the EUL.

In each table, the left *column* contains the RULs from 1 year through the EUL minus 1 year. For example, Table M-5 presents Inflated Lifecycle Benefit Adjustment Factors for measures with an EUL of 15 years. Therefore, Table M-5 contains RULs from 1 through 14.

- The *first row* of each table contains the names of each measure addressed in the table.
- The *second row* of each table indicates whether the measure is residential, non-residential or both.
- The *third row* of each table lists the median ratio associated with each measure. For Tables M-2 through M-10 and Tables M-20 through M-28, the ratio is the ratio of the incremental savings to the full savings for each measure. For Tables M-11 through M-19, the ratio is the ratio of the incremental costs to the full costs for each measure.

The remaining *cells* in the matrix contain:

- For Tables M-2 through M-10, the cells contain the Inflated Lifecycle Benefit Adjustment Factors
- For Tables M-11 through M-19, the cells contain the Full-Cost Adjustment Factors

4.1.2 Example

Consider the following example for a group of five measures, residential and non-residential air conditioners (central ACs/packaged units) covering four levels of efficiency, each with an EUL of 15 years:

- non-residential domestic electric water heaters (service hot water),
- non-residential domestic gas water heaters,
- non-residential indirect water heaters, and
- non-residential air compressors.

Table M-5 presents the inflated lifecycle benefits adjustment factors for these five measures. For central air conditioners, the program implementer must determine the SEER of the new efficient unit, estimate the RUL for the old unit in place, and select the appropriate lifecycle benefits adjustment factor. For example, if the SEER of the new efficient unit is 17 and the estimated RUL is 4 years, Table M-5 shows that the *inflated lifecycle benefits adjustment factor* is 0.63. Thus, the inflated lifecycle benefits should be multiplied by 0.63.

For a central air conditioner with a SEER of 17 and an estimated RUL of 4 years, Table M-14 shows that the *full-cost adjustment factor* is 0.44. Thus, the full cost of the new efficient central air conditioner should be multiplied by the full-cost adjustment factor of 0.44.

4.1.3 Trends on the Lookup Tables and Calculation of Ratios

This section discusses the directions in which RULs and the savings and costs ratios affect the adjustment factors, and illustrates how the ratios are calculated.

- *Tables M-2 through M-10*: The longer the RUL is, the larger the share of the inflated lifecycle benefits that a PA can claim. Also, the greater the ratio of incremental savings to full savings; the larger the share of the inflated lifecycle benefits that a PA can claim. Consider the following example of equipment with an EUL of 10 years and annual kWh use of 2,000 kWh that is removed in its 6th year (RUL=4 years) and replaced with an energy efficient version of the equipment with an annual kWh use of 1,400 kWh. The full savings are 600 kWh (2,000 - 1,400). It is assumed that in four years the customer would have installed equipment that, at a minimum, met the current efficiency code of annual energy use. The ratio will change depending on the efficiency of the code/standard equipment:
    - If the kWh use associated with code/standard is 1,600 kWh, then the incremental savings = (1,600 – 1,400) or 200 and the ratio = (200/600) or 0.33.
    - If the kWh use associated with code/standard is 1800 kWh, then the incremental savings = (1,800 – 1,400) or 400 and the ratio = (400/600) or 0.67.

A less strict code (one that allows higher consumption) allows a PA to claim a larger share of the inflated lifecycle benefits. In other words, the higher the kWh use associated with the code/standard equipment, the more the program is accomplishing in avoiding standard equipment.

- *Tables M-11 through M-19*: The longer the RUL is, the larger the share of the unadjusted costs for a PA to include (larger time value penalty). Also, the greater the ratio of incremental costs to full costs is, the larger the share of the unadjusted costs for a PA to include. Continuing with the above example, assume that the full cost of the energy efficient equipment is $2,000. It is assumed that in four years the customer would have installed code/standard equipment. The ratio will change depending on the cost of the code/standard equipment:

    - If the full cost of the minimally compliant equipment is $1,400, then the incremental cost = $600 and the ratio = ($600/$2,000) or 0.30.

    - If the full cost of the minimally compliant equipment is $1,800, then the incremental cost = $200 and the ratio = ($200/$2,000) or 0.10.

- The higher cost of the minimally compliant equipment, which lowers the incremental cost, allows a PA to take into account a smaller portion of the full cost of the efficient measure when calculating a TRC. In other words, the higher the cost of the minimally compliant equipment that the customer would have incurred without the program, the lower the cost of the program.

4.2. PA-Based Look-Up Tables

If a PA is able to calculate its own ratio of the incremental savings to full savings and/or the ratio of incremental costs to full cost, then they may choose to use the second set of tables. If a PA chooses to use its own savings ratio and/or cost ratio, it should identify the ratio in the appropriate tables (M-29 through M-47) that is closest to the one(s) it developed. These 19 tables are for the most part organized and interpreted in the same manner as Tables M-2 through M-28. The only exceptions are that the ratios range[1419] from 0.95 to .05 in increments of 0.05, and there are no measure designations. To use these tables, a PA will still need to gather the same four pieces of information needed to use the first set of tables:

- the EUL of the new efficient equipment,
- the RUL of the old equipment in place,
- the full savings of the equipment (annual energy use of the old equipment in place minus the annual energy of the high efficiency equipment supported by the program), and
- the full costs (including installation)

Additionally, the PA will need documented estimates of incremental costs and savings in order to calculate:

- The ratio of incremental savings to full savings, and/or
- The ratio of incremental costs to full cost

[1419] The lookup tables do not apply to measures that have a ratio of *incremental savings to full savings* or a ratio of *incremental costs to full costs* of 1.0 or 0.0 for the same reasons provided earlier in Section 2.1.

Note that all documentation for PA estimates of this data must be retained for Staff review, in accordance with Guidance Document EE-08, dated March 31, 2014. This guidance document can be found at:
www3.dps.ny.gov/W/PSCWeb.nsf/All/31D14D1DDC55FB2185257B240062B398?OpenDocument

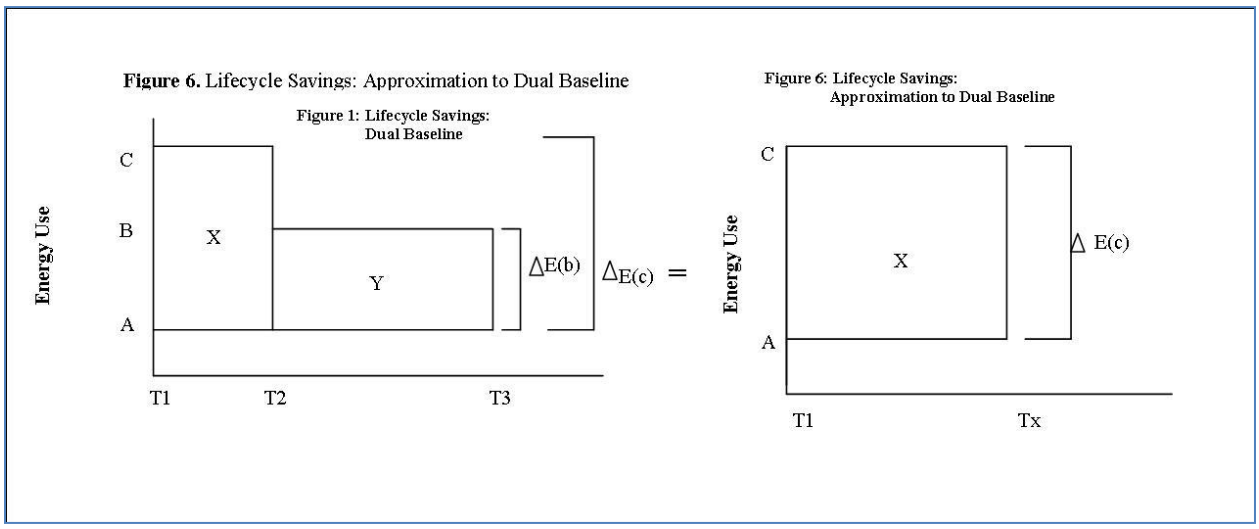
Program-Tracking Database Requirements

The program tracking databases are maintained by the PAs for the purposes of current reporting and future impact evaluations. The Impact Evaluation section has many fields not used for current reporting. The Department of Public Service hereby adds, for cases of early replacement, six additional required variables.

Type of Installation (TRC Approach)[1420] ,

- The *Adjusted Full Savings* (full savings multiplied by the full-savings adjustment factor),
- The *Adjusted Full Cost* (full cost multiplied by the full-cost adjustment factor),
- The Ratio of Incremental Savings to Full Savings,
- The Ratio of Incremental Costs to Full Costs, and
- The *Adjusted EUL* (discussed below)

The Adjusted EUL is defined as that period of years over which the full savings would be claimed such that it matches the present value dollar benefits of the underlying dual baseline. That is, the EUL of the new equipment in Figure 6 below, represented by **Tx – T1**, is adjusted so that the present value of lifecycle benefits represented by area **X** in Figure 6 is equivalent to the present value of the lifecycle benefits represented by the sum of areas **X** and **Y** in Figure 1.



The longer the RUL is, the larger the adjusted EUL. This follows the same logic as the case of the *inflated lifecycle benefit adjustment factors* except that the result is an adjusted EUL (that

[1420] ER=Early Replacement; NR=Normal Replacement; SC=Special Circumstance; AO=Add On. Add on refers to adding something, which replaces nothing. Examples include adding controls to a boiler that had none, or adding insulation where there was none or some. Add-on measures are modeled at full costs and full savings for the length of their EULs. The full savings are reported toward first-year goals.

portion of the EUL for which the PV of using the full savings would equal the PV of the dual baseline savings).

PAs can obtain the adjusted EULs from the DEER-Based Tables based on typical ratios of incremental savings to full savings or from the PA-Based Tables if a PA can calculate its own savings ratios. The adjusted EUL is not used for TRC screening, but for the program's tracking database. The tables are organized in the same way as the earlier tables. The only difference is that the cells in the matrix contain adjusted EULs in years. Tables M-20 through M-28 contain DEER-Based adjusted EULs while Tables M-39 through M-47 contain PA-Based adjusted EULs.

Table M-2. Inflated Lifecycle Benefit Adjustment Factors: Residential Boilers

	Boiler-G
	Res
	Median Ratio of Incremental Savings to Full Savings
	0.15
RUL	Artificial Lifecycle Benefit Adjustment Factors
1	20%
2	26%
3	32%
4	37%
5	42%
6	47%
7	52%
8	56%
9	60%
10	64%
11	68%
12	68%
13	71%
14	75%
15	78%
16	81%
17	84%
18	86%
19	89%
20	91%
21	94%
22	94%
23	96%
24	98%
EUL =	25

Table M-3. Inflated Lifecycle Benefit Adjustment Factors: Chillers, Furnaces, Non-Res Boilers, and High Performance Windows

	Chiller: Air Cooled Recip and Screw	Chiller: Water Cooled Recip	Chiller: Water Cooled Screw < 150 ton	Chiller: Water Cooled Screw 150-300 ton	Chiller: Water Cooled Screw > 300 ton	Chiller: Water Cooled Centrifugal < 150 ton	Chiller: Water Cooled Centrifugal 150-300 ton	Chiller: Water Cooled Centrifugal > 300 ton	Boiler-G	Furnace-G (AFUE 90)	Furnace-G (AFUE 92)	Furnace-G (AFUE 94)	Furnace-G (AFUE 96)	High Performance Windows-G
	Non-Res	Non-Res	Non-Res	Non-Res	Non-Res	Non-Res	Non-Res	Non-Res	Non-Res	Res/Non-Res	Res/Non-Res	Res/Non-Res	Res/Non-Res	Res
	Median Ratio of Incremental Savings to Full Savings													
	0.50	0.15	0.37	0.31	0.69	0.58	0.38	0.31	0.27	0.44	0.48	0.51	0.54	0.63
RUL	Artificial Lifecycle Benefit Adjustment Factors													
1	53%	23%	42%	36%	72%	63%	42%	36%	35%	47%	53%	53%	58%	68%
2	58%	29%	47%	42%	72%	63%	47%	42%	35%	53%	58%	58%	63%	68%
3	63%	36%	53%	47%	76%	67%	53%	47%	41%	58%	58%	63%	63%	72%
4	63%	42%	58%	53%	76%	72%	58%	53%	47%	63%	63%	68%	68%	72%
5	67%	47%	58%	58%	80%	72%	58%	58%	53%	63%	68%	68%	72%	76%
6	72%	53%	63%	58%	80%	76%	63%	58%	58%	68%	68%	72%	72%	80%
7	72%	53%	67%	63%	84%	76%	67%	63%	63%	72%	72%	76%	76%	80%
8	76%	58%	72%	67%	84%	80%	72%	67%	68%	72%	76%	76%	80%	84%
9	80%	63%	72%	72%	87%	84%	72%	72%	68%	76%	76%	80%	80%	84%
10	80%	67%	76%	76%	87%	84%	76%	76%	72%	80%	80%	80%	84%	87%
11	84%	72%	80%	76%	91%	87%	80%	76%	76%	80%	84%	84%	84%	87%
12	87%	76%	84%	80%	91%	87%	84%	80%	80%	84%	84%	87%	87%	91%
13	87%	80%	84%	84%	94%	91%	84%	84%	84%	87%	87%	87%	87%	91%
14	91%	84%	87%	87%	94%	91%	87%	87%	84%	87%	91%	91%	91%	94%
15	91%	87%	91%	87%	94%	94%	91%	87%	87%	91%	91%	91%	94%	94%
16	94%	91%	91%	91%	97%	94%	91%	91%	91%	94%	94%	94%	94%	94%
17	94%	91%	94%	94%	97%	97%	94%	94%	94%	94%	94%	94%	97%	97%
18	97%	94%	97%	97%	97%	97%	97%	97%	97%	97%	97%	97%	97%	97%
19	100%	97%	97%	97%	100%	100%	97%	97%	97%	97%	97%	100%	100%	100%
EUL =	20													

Table M-4. Inflated Lifecycle Benefit Adjustment Factors: Residential Refrigerators

	Refrigerator-E
	Res
	Median Ratio of Incremental Savings to Full Savings
	0.11
RUL	Artificial Lifecycle Benefit Adjustment Factors
1	17%
2	25%
3	32%
4	39%
5	46%
6	52%
7	58%
8	64%
9	69%
10	74%
11	79%
12	79%
13	84%
14	88%
15	92%
16	96%
EUL =	17

Table M-5. Inflated Lifecycle Benefit Adjustment Factors: Central Air Conditioners, Air Source Heat Pumps, Non-Res Water Heaters, Indirect Water Heaters, and Air Compressor Upgrades

	Central Air conditioner (SEER 14)	Central Air conditioner (SEER 15)	Central Air conditioner (SEER 16)	Central Air conditioner (SEER 17)	Central Air conditioner (SEER 18)	DHW-E	DHW-G	Indirect Water Heater-G	Air Compressor Upgrade-E
	Res/Non-Res	Res/Non-Res	Res/Non-Res	Res/Non-Res	Res/Non-Res	Non-Res	Non-Res	Non-Res	Non-Res
	Median Ratio of Incremental Savings to Full Savings								
	0.19	0.31	0.38	0.44	0.48	0.60	0.21	0.34	0.48
RUL	Artificial Lifecycle Benefit Adjustment Factors								
1	27%	35%	50%	50%	56%	63%	35%	42%	50%
2	35%	43%	50%	56%	56%	69%	35%	49%	56%
3	43%	50%	56%	56%	63%	69%	42%	49%	63%
4	50%	56%	56%	63%	69%	75%	49%	56%	69%
5	56%	63%	63%	69%	69%	75%	56%	63%	69%
6	56%	63%	69%	69%	75%	80%	63%	69%	75%
7	63%	69%	75%	75%	75%	80%	63%	69%	75%
8	69%	75%	75%	80%	80%	86%	69%	75%	80%
9	75%	80%	80%	80%	86%	86%	75%	80%	86%
10	80%	80%	86%	86%	86%	91%	80%	86%	86%
11	86%	86%	86%	91%	91%	91%	86%	86%	91%
12	91%	91%	91%	91%	91%	95%	91%	91%	91%
13	91%	95%	95%	95%	95%	95%	91%	96%	95%
14	95%	95%	95%	95%	95%	100%	96%	96%	95%
EUL =	15								

Table M-6. Inflated Lifecycle Benefit Adjustment Factors: Multi-Family Clothes Washers

RUL	Clothes Washer-G
	MF Res
	Median Ratio of Incremental Savings to Full Savings
	0.39
	Artificial Lifecycle Benefit Adjustment Factors
1	45%
2	52%
3	59%
4	59%
5	66%
6	72%
7	72%
8	78%
9	84%
10	84%
11	90%
12	95%
13	95%
EUL =	14

Table M-7. Inflated Lifecycle Benefit Adjustment Factors: Residential Electric and Indirect Water Heaters

RUL	DHW-E	Indirect Water Heater-G
	Res	Res
	Median Ratio of Incremental Savings to Full Savings	
	0.60	0.34
	Artificial Lifecycle Benefit Adjustment Factors	
1	69%	46%
2	69%	46%
3	69%	54%
4	76%	62%
5	76%	62%
6	83%	69%
7	83%	76%
8	89%	82%
9	89%	82%
10	94%	89%
11	94%	94%
12	100%	94%
EUL =	13	

Table M-8. Inflated Lifecycle Benefit Adjustment Factors: Non-Res Refrigerators

RUL	Refrigerator-E
	Non-Res
	Median Ratio of Incremental Savings to Full Savings
	0.34
	Artificial Lifecycle Benefit Adjustment Factors
1	41%
2	50%
3	58%
4	58%
5	66%
6	73%
7	81%
8	81%
9	87%
10	94%
11	94%
EUL =	12

Table M-9. Inflated Lifecycle Benefit Adjustment Factors: Clothes Washers, Dishwashers, and Residential Gas Water Heaters

RUL	Clothes Washer-E	Dishwasher-E	DHW-G
	Res	Res	Res
	Median Ratio of Incremental Savings to Full Savings		
	0.39	0.33	0.21
	Artificial Lifecycle Benefit Adjustment Factors		
1	43%	43%	33%
2	53%	53%	43%
3	62%	53%	43%
4	62%	62%	52%
5	70%	70%	61%
6	78%	78%	70%
7	78%	78%	78%
8	86%	86%	86%
9	93%	93%	86%
10	93%	93%	93%
EUL =	11		

Table M-10. Inflated Lifecycle Benefit Adjustment Factors: Heat Pump Water Heaters and Room A/C

RUL	Heat Pump Water Heater-E	Room Air Conditioner-E
	Res	Res
	Median Ratio of Incremental Savings to Full Savings	
	0.87	0.25
	Artificial Lifecycle Benefit Adjustment Factors	
1	92%	36%
2	92%	47%
3	92%	57%
4	92%	57%
5	92%	66%
6	92%	75%
7	100%	84%
8	100%	84%
9	100%	92%
EUL =	10	

Table M-11. Full-Cost Adjustment Factors: Residential Boilers

RUL	Boiler-G Res Median Ratio of Incremental Cost to Full Cost 0.16 Full Cost Adjustment Factors
1	20%
2	25%
3	28%
4	32%
5	36%
6	39%
7	42%
8	45%
9	48%
10	51%
11	53%
12	56%
13	58%
14	60%
15	62%
16	64%
17	66%
18	68%
19	70%
20	71%
21	73%
22	74%
23	75%
24	77%
EUL =	25

Table M-12. Full-Cost Adjustment Factors: Chillers, Furnaces, Non-Res Boilers, and High Performance Windows

	Chiller: Air Cooled Recip and Screw	Chiller: Water Cooled Recip	Chiller: Water Cooled Screw < 150 ton	Chiller: Water Cooled Screw 150-300 ton	Chiller: Water Cooled Screw > 300 ton	Chiller: Water Cooled Centrifugal < 150 ton	Chiller: Water Cooled Centrifugal 150-300 ton	Chiller: Water Cooled Centrifugal > 300 ton	Boiler-G	Furnace-G (AFUE 90)	Furnace-G (AFUE 92)	Furnace-G (AFUE 94)	Furnace-G (AFUE 96)	High Performance Windows-G
	Non-Res	Non-Res	Non-Res	Non-Res	Non-Res	Non-Res	Non-Res	Non-Res	Non-Res	Res/Non-Res	Res/Non-Res	Res/Non-Res	Res/Non-Res	Res
	Median Ratio of Incremental Cost to Full Cost													
	0.18	0.03	0.16	0.13	0.12	0.21	0.24	0.33	0.48	0.28	0.31	0.34	0.36	0.10
RUL	Full Cost Adjustment Factors													
1	22%	8%	20%	18%	17%	25%	28%	36%	51%	32%	35%	37%	39%	15%
2	26%	13%	25%	22%	21%	29%	32%	40%	53%	35%	38%	41%	42%	19%
3	30%	17%	28%	26%	25%	33%	35%	43%	56%	39%	41%	44%	45%	23%
4	34%	22%	32%	30%	29%	36%	39%	46%	58%	42%	44%	47%	48%	27%
5	37%	26%	36%	33%	33%	40%	42%	49%	60%	45%	47%	50%	51%	31%
6	41%	30%	39%	37%	36%	43%	45%	51%	62%	48%	50%	52%	54%	35%
7	44%	33%	42%	40%	40%	46%	48%	54%	64%	51%	53%	55%	56%	38%
8	47%	37%	45%	43%	43%	49%	50%	56%	66%	53%	55%	57%	58%	41%
9	49%	40%	48%	46%	46%	51%	53%	59%	68%	56%	57%	59%	60%	44%
10	52%	43%	51%	49%	48%	54%	56%	61%	70%	58%	60%	61%	63%	47%
11	54%	46%	53%	52%	51%	56%	58%	63%	71%	60%	62%	63%	64%	50%
12	57%	49%	56%	54%	54%	58%	60%	65%	73%	62%	64%	65%	66%	53%
13	59%	52%	58%	57%	56%	61%	62%	67%	74%	64%	66%	67%	68%	55%
14	61%	54%	60%	59%	58%	63%	64%	68%	75%	66%	67%	69%	70%	57%
15	63%	57%	62%	61%	61%	65%	66%	70%	77%	68%	69%	70%	71%	60%
16	65%	59%	64%	63%	63%	66%	68%	72%	78%	69%	71%	72%	73%	62%
17	67%	61%	66%	65%	65%	68%	69%	73%	79%	71%	72%	73%	74%	64%
18	69%	63%	68%	67%	66%	70%	71%	74%	80%	73%	74%	75%	76%	66%
19	70%	65%	70%	69%	68%	71%	73%	76%	81%	74%	75%	76%	77%	67%
EUL =	20													

Table M-13. Full-Cost Adjustment Factors: Residential Refrigerators

	Refrigerator-E
	Res
	Median Ratio of Incremental Cost to Full Cost
	0.12
RUL	Full Cost Adjustment Factors
1	17%
2	21%
3	25%
4	29%
5	33%
6	36%
7	40%
8	43%
9	46%
10	48%
11	51%
12	54%
13	56%
14	58%
15	61%
16	63%
EUL =	17

Table M-14. Full-Cost Adjustment Factors: Central Air Conditioners, Air Source Heat Pumps, Non-Res Water Heaters, Indirect Water Heaters, and Air Compressor Upgrades

	Central Air Conditioner/Air Source Heat Pumps (SEER 14)	Central Air Conditioner/Air Source Heat Pumps (SEER 15)	Central Air Conditioner/Air Source Heat Pumps (SEER 16)	Central Air Conditioner/Air Source Heat Pumps (SEER 17)	Central Air Conditioner/Air Source Heat Pumps (SEER 18)	DHW-E	DHW-G	Indirect Water Heater-G	Air Compressor Upgrade-E
	Res/Non-Res	Res/Non-Res	Res/Non-Res	Res/Non-Res	Res/Non-Res	Non-Res	Non-Res	Non-Res	Non-Res
	Median Ratio of Incremental Cost to Full Cost								
	0.10	0.20	0.26	0.31	0.37	0.25	0.22	0.93	0.46
RUL	Full Cost Adjustment Factors								
1	15%	24%	30%	35%	40%	29%	26%	93%	49%
2	19%	28%	34%	38%	43%	33%	30%	94%	51%
3	23%	32%	37%	41%	46%	36%	34%	94%	54%
4	27%	35%	40%	44%	49%	39%	37%	94%	56%
5	31%	39%	43%	47%	52%	43%	40%	95%	59%
6	35%	42%	46%	50%	54%	46%	43%	95%	61%
7	38%	45%	49%	53%	57%	48%	46%	95%	63%
8	41%	48%	52%	55%	59%	51%	49%	95%	65%
9	44%	51%	54%	57%	61%	54%	52%	96%	67%
10	47%	53%	57%	60%	63%	56%	54%	96%	68%
11	50%	56%	59%	62%	65%	58%	57%	96%	70%
12	53%	58%	61%	64%	67%	61%	59%	96%	72%
13	55%	60%	63%	66%	69%	63%	61%	97%	73%
14	57%	62%	65%	67%	70%	65%	63%	97%	74%
EUL =	15								

Table M-15. Full-Cost Adjustment Factors: Multi-Family Clothes Washers

	Clothes Washer-G
	MF Res
	Median Ratio of Incremental Cost to Full Cost
	0.24
RUL	Full Cost Adjustment Factors
1	28%
2	32%
3	35%
4	39%
5	42%
6	45%
7	48%
8	50%
9	53%
10	56%
11	58%
12	60%
13	62%
EUL =	14

Table M-16. Full-Cost Adjustment Factors: Residential Electric and Indirect Water Heaters

RUL	DHW-E	Indirect Water Heater-G
	Res	Res
	Median Ratio of Incremental Cost to Full Cost	
	0.25	0.93
	Full Cost Adjustment Factors	
1	29%	93%
2	33%	94%
3	36%	94%
4	39%	94%
5	43%	95%
6	46%	95%
7	48%	95%
8	51%	95%
9	54%	96%
10	56%	96%
11	58%	96%
12	61%	96%
EUL =	13	

Table M-17. Full-Cost Adjustment Factors: Non-Residential Refrigerators

RUL	Refrigerator-E
	Non-Res
	Median Ratio of Incremental Cost to Full Cost
	0.05
	Full Cost Adjustment Factors
1	10%
2	15%
3	19%
4	23%
5	27%
6	31%
7	35%
8	38%
9	41%
10	44%
11	47%
EUL =	12

Table M-18. Full-Cost Adjustment Factors: Clothes Washers, Dishwashers, and Residential Gas Water Heaters

RUL	Clothes Washer-E	Dishwasher-E	DHW-G
	Res	Res	Res
	Median Ratio of Incremental Cost to Full Cost		
	0.24	0.06	0.22
	Full Cost Adjustment Factors		
1	28%	11%	26%
2	32%	16%	30%
3	35%	20%	34%
4	39%	24%	37%
5	42%	28%	40%
6	45%	32%	43%
7	48%	35%	46%
8	50%	39%	49%
9	53%	42%	52%
10	56%	45%	54%
EUL =	11		

Table M-19. Full-Cost Adjustment Factors: Heat Pump Water Heaters and Room A/C

RUL	Heat Pump Water Heater-E	Room Air Conditioner-E
	Res	Res
	Median Ratio of Incremental Cost to Full Cost	
	0.77	0.23
	Full Cost Adjustment Factors	
1	78%	27%
2	79%	31%
3	80%	34%
4	81%	38%
5	82%	41%
6	83%	44%
7	84%	47%
8	85%	50%
9	86%	52%
EUL =	10	

Table M-20. Adjusted EULs: Residential Boilers

RUL	Boiler-G Res Median Ratio of Incremental Savings to Full Savings 0.15 Adjusted EULs in Years
1	3
2	4
3	5
4	6
5	7
6	8
7	9
8	10
9	11
10	12
11	13
12	13
13	14
14	15
15	16
16	17
17	18
18	19
19	20
20	21
21	22
22	22
23	23
24	24
EUL =	25

Table M -21. Adjusted EULs: Chillers, Furnaces, Non-Residential Boilers, and High Performance Windows

	Chiller: Air Cooled Recip and Screw	Chiller: Water Cooled Recip	Chiller: Water Cooled Screw < 150 ton	Chiller: Water Cooled Screw 150-300 ton	Chiller: Water Cooled Screw > 300 ton	Chiller: Water Cooled Centrifugal < 150 ton	Chiller: Water Cooled Centrifugal 150-300 ton	Chiller: Water Cooled Centrifugal > 300 ton	Boiler-G	Furnace-G (AFUE 90)	Furnace-G (AFUE 92)	Furnace-G (AFUE 94)	Furnace-G (AFUE 96)	High Performance Windows-G
	Non-Res	Non-Res	Non-Res	Non-Res	Non-Res	Non-Res	Non-Res	Non-Res	Non-Res	Res/Non-Res	Res/Non-Res	Res/Non-Res	Res/Non-Res	Res
	Median Ratio of Incremental Savings to Full Savings													
	0.50	0.15	0.37	0.31	0.69	0.58	0.38	0.31	0.27	0.44	0.48	0.51	0.54	0.63
RUL	Adjusted EULs in Years													
1	8	3	6	5	12	10	6	5	5	7	8	8	9	11
2	9	4	7	6	12	10	7	6	5	8	9	9	10	11
3	10	5	8	7	13	11	8	7	6	9	9	10	10	12
4	10	6	9	8	13	12	9	8	7	10	10	11	11	12
5	11	7	9	9	14	12	9	9	8	10	11	11	12	13
6	12	8	10	9	14	13	10	9	9	11	11	12	12	14
7	12	8	11	10	15	13	11	10	10	12	12	13	13	14
8	13	9	12	11	15	14	12	11	11	12	13	13	14	15
9	14	10	12	12	16	15	12	12	11	13	13	14	14	15
10	14	11	13	13	16	15	13	13	12	14	14	14	15	16
11	15	12	14	13	17	16	14	13	13	14	15	15	15	16
12	16	13	15	14	17	16	15	14	14	15	15	16	16	17
13	16	14	15	15	18	17	15	15	15	16	16	16	16	17
14	17	15	16	16	18	17	16	16	15	16	17	17	17	18
15	17	16	17	16	18	18	17	16	16	17	17	17	18	18
16	18	17	17	17	19	18	17	17	17	18	18	18	18	18
17	18	17	18	18	19	19	18	18	18	18	18	18	19	19
18	19	18	19	19	19	19	19	19	19	19	19	19	19	19
19	20	19	19	19	20	20	19	19	19	19	19	20	20	20
EUL =	20													

Table M-22. Adjusted EULs: Residential Refrigerators

RUL	Refrigerator-E
	Res
	Median Ratio of Incremental Savings to Full Savings
	0.11
	Adjusted EULs in Years
1	2
2	3
3	4
4	5
5	6
6	7
7	8
8	9
9	10
10	11
11	12
12	12
13	13
14	14
15	15
16	16
EUL =	17

Table M-23. Adjusted EULs: Central Air Conditioners, Air Source Heat Pumps, Non-Res Water Heaters, Indirect Water Heaters, and Air Compressor Upgrades

RUL	Central Air Conditioner/Air Source Heat Pumps (SEER 14)	Central Air Conditioner/Air Source Heat Pumps (SEER 15)	Central Air Conditioner/Air Source Heat Pumps (SEER 16)	Central Air Conditioner/Air Source Heat Pumps (SEER 17)	Central Air Conditioner/Air Source Heat Pumps (SEER 18)	DHW-E	DHW-G	Indirect Water Heater-G	Air Compressor Upgrade-E
	Res/Non-Res	Res/Non-Res	Res/Non-Res	Res/Non-Res	Res/Non-Res	Non-Res	Non-Res	Non-Res	Non-Res
	Median Ratio of Incremental Savings to Full Savings								
	0.19	0.31	0.38	0.44	0.48	0.60	0.21	0.34	0.48
	Adjusted EULs in Years								
1	3	4	6	6	7	8	4	5	6
2	4	5	6	7	7	9	4	6	7
3	5	6	7	7	8	9	5	6	8
4	6	7	7	8	9	10	6	7	9
5	7	8	8	9	9	10	7	8	9
6	7	8	9	9	10	11	8	9	10
7	8	9	10	10	10	11	8	9	10
8	9	10	10	11	11	12	9	10	11
9	10	11	11	11	12	12	10	11	12
10	11	11	12	12	12	13	11	12	12
11	12	12	12	13	13	13	12	12	13
12	13	13	13	13	13	14	13	13	13
13	13	14	14	14	14	14	13	14	14
14	14	14	14	14	14	15	14	14	14
EUL =	15								

TABLE M-24. ADJUSTED EULS: MULTI-FAMILY CLOTHES WASHERS

RUL	Clothes Washer-G
	MF Res
	Median Ratio of Incremental Savings to Full Savings
	0.39
	Adjusted EULs in Years
1	5
2	6
3	7
4	7
5	8
6	9
7	9
8	10
9	11
10	11
11	12
12	13
13	13
EUL =	14

TABLE M-25. ADJUSTED EULS: RESIDENTIAL ELECTRIC AND GAS INDIRECT WATER HEATERS

RUL	DHW-E	Indirect Water Heater-G
	Res	Res
	Median Ratio of Incremental Savings to Full Savings	
	0.60	0.34
	Adjusted EULs in Years	
1	8	5
2	8	5
3	8	6
4	9	7
5	9	7
6	10	8
7	10	9
8	11	10
9	11	10
10	12	11
11	12	12
12	13	12
EUL =	13	

TABLE M-26. ADJUSTED EULS: NON-RESIDENTIAL REFRIGERATORS

RUL	Refrigerator-E
	Non-Res
	Median Ratio of Incremental Savings to Full Savings
	0.34
	Adjusted EULs in Years
1	4
2	5
3	6
4	6
5	7
6	8
7	9
8	9
9	10
10	11
11	11
EUL =	12

Table M-27. Adjusted EULs: Clothes Washers, Dishwashers, and Residential Gas Water Heaters

RUL	Clothes Washer-E	Dishwasher-E	DHW-G
	Res	Res	Res
	Median Ratio of Incremental Savings to Full Savings		
	0.39	0.33	0.21
	Adjusted EULs in Years		
1	4	4	3
2	5	5	4
3	6	5	4
4	6	6	5
5	7	7	6
6	8	8	7
7	8	8	8
8	9	9	9
9	10	10	9
10	10	10	10
EUL =	11		

Table M-28. Adjusted EULs: Heat Pump Water Heaters and Room A/C

	Heat Pump Water Heater-E	Room Air Conditioner-E
	Res	Res
	Median Ratio of Incremental Savings to Full Savings	
	0.87	0.25
RUL	Adjusted EULs in Years	
1	9	3
2	9	4
3	9	5
4	9	5
5	9	6
6	9	7
7	10	8
8	10	8
9	10	9
EUL =	10	

Table M-29. Inflated Lifecycle Benefit Adjustment Factors for PA-Supplied Ratios of Incremental Savings to Full Savings for a 25 Year EUL

	Savings																		
RU	**0.0**	**0.1**	**0.1**	**0.2**	**0.2**	**0.3**	**0.3**	**0.4**	**0.4**	**0.5**	**0.5**	**0.6**	**0.6**	**0.7**	**0.7**	**0.8**	**0.8**	**0.9**	**0.9**
1	14	14	20	26	32	37	42	42	47	52	60	64	68	71	78	81	86	91	96
2	20	20	26	32	37	42	42	47	52	56	60	64	71	75	78	84	86	91	96
3	26	26	32	37	42	42	47	52	56	60	64	68	71	75	81	84	89	91	96
4	32	32	37	42	47	47	52	56	60	64	68	71	75	78	81	86	89	94	96
5	37	37	42	47	47	52	56	60	64	68	68	71	75	81	84	86	89	94	96
6	42	42	47	52	52	56	60	64	64	68	71	75	78	81	84	86	91	94	96
7	47	47	52	52	56	60	64	64	68	71	75	78	81	84	86	89	91	94	98
8	52	52	56	56	60	64	64	68	71	75	75	78	81	84	86	89	91	94	98
9	56	56	60	60	64	68	68	71	75	75	78	81	84	86	89	91	94	96	98
1	60	60	64	64	68	68	71	75	75	78	81	84	84	86	89	91	94	96	98
1	64	64	68	68	71	71	75	75	78	81	81	84	86	89	89	91	94	96	98
1	64	68	68	71	75	75	78	78	81	81	84	86	86	89	91	94	94	96	98
1	68	71	71	75	75	78	78	81	81	84	86	86	89	91	91	94	96	96	98
1	71	75	75	78	78	81	81	84	84	86	86	89	89	91	94	94	96	98	98
1	75	78	78	81	81	81	84	84	86	86	89	89	91	91	94	96	96	98	98
1	78	81	81	81	84	84	86	86	89	89	89	91	91	94	94	96	96	98	98
1	81	84	84	84	86	86	86	89	89	91	91	91	94	94	96	96	98	98	100
1	84	86	86	86	89	89	89	91	91	91	94	94	94	96	96	96	98	98	100
1	86	89	89	89	89	91	91	91	91	94	94	94	96	96	96	98	98	98	100
2	89	89	91	91	91	91	94	94	94	94	96	96	96	96	98	98	98	98	100
2	91	91	94	94	94	94	94	96	96	96	96	96	98	98	98	98	98	100	100
2	94	94	94	96	96	96	96	96	96	96	98	98	98	98	98	98	100	100	100
2	96	96	96	96	96	98	98	98	98	98	98	98	98	98	98	100	100	100	100
2	98	98	98	98	98	98	98	98	98	100	100	100	100	100	100	100	100	100	100
EUL	**2**																		

Table M-30. Inflated Lifecycle Benefit Adjustment Factors for PA-Supplied Ratios of Incremental Savings to Full Savings for a 20 Year EUL

	Savings Ratio																		
RUL	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95
1	16%	16%	23%	29%	29%	36%	42%	47%	47%	53%	58%	63%	67%	72%	76%	80%	87%	91%	94%
2	23%	23%	29%	29%	36%	42%	47%	47%	53%	58%	63%	67%	72%	76%	80%	84%	87%	91%	97%
3	29%	29%	36%	36%	42%	47%	47%	53%	58%	63%	67%	67%	72%	76%	80%	84%	87%	91%	97%
4	36%	36%	42%	42%	47%	53%	53%	58%	63%	63%	67%	72%	76%	80%	84%	87%	91%	94%	97%
5	42%	42%	47%	47%	53%	53%	58%	63%	63%	67%	72%	76%	76%	80%	84%	87%	91%	94%	97%
6	47%	47%	53%	53%	58%	58%	63%	63%	67%	72%	72%	76%	80%	84%	84%	87%	91%	94%	97%
7	47%	53%	53%	58%	63%	63%	67%	67%	72%	72%	76%	80%	80%	84%	87%	91%	91%	94%	97%
8	53%	58%	58%	63%	63%	67%	67%	72%	76%	76%	80%	80%	84%	87%	87%	91%	94%	94%	97%
9	58%	63%	63%	67%	67%	72%	72%	76%	76%	80%	80%	84%	84%	87%	91%	91%	94%	97%	97%
10	63%	67%	67%	72%	72%	72%	76%	76%	80%	80%	84%	84%	87%	87%	91%	94%	94%	97%	97%
11	67%	72%	72%	72%	76%	76%	80%	80%	84%	84%	84%	87%	87%	91%	91%	94%	94%	97%	97%
12	72%	76%	76%	76%	80%	80%	80%	84%	84%	87%	87%	87%	91%	91%	94%	94%	97%	97%	100%
13	76%	80%	80%	80%	84%	84%	84%	87%	87%	87%	91%	91%	91%	94%	94%	94%	97%	97%	100%
14	80%	84%	84%	84%	84%	87%	87%	87%	87%	91%	91%	91%	94%	94%	94%	97%	97%	97%	100%
15	84%	84%	87%	87%	87%	87%	91%	91%	91%	91%	94%	94%	94%	94%	97%	97%	97%	97%	100%
16	87%	87%	91%	91%	91%	91%	91%	94%	94%	94%	94%	94%	97%	97%	97%	97%	97%	100%	100%
17	91%	91%	91%	94%	94%	94%	94%	94%	94%	94%	97%	97%	97%	97%	97%	97%	100%	100%	100%
18	94%	94%	94%	94%	94%	97%	97%	97%	97%	97%	97%	97%	97%	97%	97%	100%	100%	100%	100%
19	97%	97%	97%	97%	97%	97%	97%	97%	97%	97%	100%	100%	100%	100%	100%	100%	100%	100%	100%
EUL =	20																		

Table M-31. Inflated Lifecycle Benefit Adjustment Factors for PA-Supplied Ratios of Incremental Savings to Full Savings for a 17 Year EUL

	Savings Ratio																		
RUL	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95
1	17%	17%	25%	25%	32%	39%	39%	46%	52%	52%	58%	64%	69%	74%	79%	84%	88%	92%	96%
2	25%	25%	32%	32%	39%	39%	46%	52%	52%	58%	64%	69%	69%	74%	79%	84%	88%	92%	96%
3	32%	32%	39%	39%	46%	46%	52%	52%	58%	64%	64%	69%	74%	79%	79%	84%	88%	92%	96%
4	32%	39%	39%	46%	52%	52%	58%	58%	64%	64%	69%	74%	74%	79%	84%	88%	88%	92%	96%
5	39%	46%	46%	52%	52%	58%	58%	64%	69%	69%	74%	74%	79%	84%	84%	88%	92%	92%	96%
6	46%	52%	52%	58%	58%	64%	64%	69%	69%	74%	74%	79%	79%	84%	88%	88%	92%	96%	96%
7	52%	58%	58%	64%	64%	69%	69%	69%	74%	74%	79%	79%	84%	84%	88%	92%	92%	96%	96%
8	58%	64%	64%	69%	69%	69%	74%	74%	79%	79%	79%	84%	84%	88%	88%	92%	92%	96%	96%
9	64%	69%	69%	69%	74%	74%	74%	79%	79%	84%	84%	84%	88%	88%	92%	92%	96%	96%	100%
10	69%	74%	74%	74%	79%	79%	79%	84%	84%	84%	88%	88%	88%	92%	92%	92%	96%	96%	100%
11	74%	79%	79%	79%	79%	84%	84%	84%	84%	88%	88%	88%	92%	92%	92%	96%	96%	96%	100%
12	79%	79%	84%	84%	84%	84%	88%	88%	88%	88%	92%	92%	92%	92%	96%	96%	96%	96%	100%
13	84%	84%	88%	88%	88%	88%	88%	92%	92%	92%	92%	92%	96%	96%	96%	96%	96%	100%	100%
14	88%	88%	88%	92%	92%	92%	92%	92%	92%	92%	96%	96%	96%	96%	96%	96%	100%	100%	100%
15	92%	92%	92%	92%	92%	96%	96%	96%	96%	96%	96%	96%	96%	96%	96%	100%	100%	100%	100%
16	96%	96%	96%	96%	96%	96%	96%	96%	96%	96%	100%	100%	100%	100%	100%	100%	100%	100%	100%
EUL =	17																		

Table M-32. Inflated Lifecycle Benefit Adjustment Factors for PA-Supplied Ratios of Incremental Savings to Full Savings for a 15 Year EUL

	Savings Ratio																		
RUL	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95
1	19%	19%	27%	27%	35%	35%	43%	43%	50%	56%	56%	63%	69%	75%	75%	80%	86%	91%	95%
2	19%	27%	27%	35%	43%	43%	50%	50%	56%	56%	63%	69%	69%	75%	80%	86%	86%	91%	95%
3	27%	35%	35%	43%	43%	50%	50%	56%	63%	63%	69%	69%	75%	80%	80%	86%	91%	91%	95%
4	35%	43%	43%	50%	50%	56%	56%	63%	63%	69%	69%	75%	75%	80%	86%	86%	91%	95%	95%
5	43%	50%	50%	56%	56%	63%	63%	63%	69%	69%	75%	75%	80%	80%	86%	91%	91%	95%	95%
6	50%	56%	56%	63%	63%	63%	69%	69%	75%	75%	75%	80%	80%	86%	86%	91%	91%	95%	95%
7	56%	63%	63%	63%	69%	69%	69%	75%	75%	80%	80%	80%	86%	86%	91%	91%	95%	95%	100%
8	63%	69%	69%	69%	75%	75%	75%	80%	80%	80%	86%	86%	86%	91%	91%	91%	95%	95%	100%
9	69%	75%	75%	75%	75%	80%	80%	80%	80%	86%	86%	86%	91%	91%	91%	95%	95%	95%	100%
10	75%	75%	80%	80%	80%	80%	86%	86%	86%	86%	91%	91%	91%	91%	95%	95%	95%	95%	100%
11	80%	80%	86%	86%	86%	86%	86%	91%	91%	91%	91%	91%	95%	95%	95%	95%	95%	100%	100%
12	86%	86%	86%	91%	91%	91%	91%	91%	91%	91%	95%	95%	95%	95%	95%	95%	100%	100%	100%
13	91%	91%	91%	91%	91%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	100%	100%	100%	100%
14	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	100%	100%	100%	100%	100%	100%	100%	100%	100%
EUL =	15																		

Table M-33. Inflated Lifecycle Benefit Adjustment Factors for PA-Supplied Ratios of Incremental Savings to Full Savings for a 14 Year EUL

	Savings Ratio																		
RUL	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95
1	10%	19%	19%	28%	37%	37%	45%	45%	52%	52%	59%	66%	66%	72%	78%	84%	84%	90%	95%
2	19%	28%	28%	37%	37%	45%	45%	52%	59%	59%	66%	66%	72%	78%	78%	84%	90%	90%	95%
3	28%	37%	37%	45%	45%	52%	52%	59%	59%	66%	66%	72%	72%	78%	84%	84%	90%	95%	95%
4	37%	45%	45%	52%	52%	59%	59%	59%	66%	66%	72%	72%	78%	78%	84%	90%	90%	95%	95%
5	45%	52%	52%	59%	59%	59%	66%	66%	72%	72%	72%	78%	78%	84%	84%	90%	90%	95%	95%
6	52%	59%	59%	59%	66%	66%	66%	72%	72%	78%	78%	78%	84%	84%	90%	90%	95%	95%	100%
7	59%	66%	66%	66%	72%	72%	72%	78%	78%	78%	84%	84%	84%	90%	90%	90%	95%	95%	100%
8	66%	72%	72%	72%	72%	78%	78%	78%	78%	84%	84%	84%	90%	90%	90%	95%	95%	95%	100%
9	72%	72%	78%	78%	78%	78%	84%	84%	84%	84%	90%	90%	90%	90%	95%	95%	95%	95%	100%
10	78%	78%	84%	84%	84%	84%	84%	90%	90%	90%	90%	90%	95%	95%	95%	95%	95%	100%	100%
11	84%	84%	84%	90%	90%	90%	90%	90%	90%	90%	95%	95%	95%	95%	95%	95%	100%	100%	100%
12	90%	90%	90%	90%	90%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	100%	100%	100%	100%
13	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	100%	100%	100%	100%	100%	100%	100%	100%	100%
EUL =	14																		

Table M-34. Inflated Lifecycle Benefit Adjustment Factors for PA-Supplied Ratios of Incremental Savings to Full Savings for a 13 Year EUL

	Savings Ratio																		
RUL	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95
1	11%	20%	20%	30%	30%	39%	39%	47%	55%	55%	62%	62%	69%	76%	76%	83%	89%	89%	94%
2	20%	30%	30%	39%	39%	47%	47%	55%	55%	62%	62%	69%	69%	76%	83%	83%	89%	94%	94%
3	30%	39%	39%	47%	47%	55%	55%	55%	62%	62%	69%	69%	76%	76%	83%	89%	89%	94%	94%
4	39%	47%	47%	55%	55%	55%	62%	62%	69%	69%	69%	76%	76%	83%	83%	89%	89%	94%	94%
5	47%	55%	55%	55%	62%	62%	62%	69%	69%	76%	76%	76%	83%	83%	89%	89%	94%	94%	100%
6	55%	62%	62%	62%	69%	69%	69%	76%	76%	76%	83%	83%	83%	89%	89%	89%	94%	94%	100%
7	62%	69%	69%	69%	69%	76%	76%	76%	76%	83%	83%	83%	89%	89%	89%	94%	94%	94%	100%
8	69%	69%	76%	76%	76%	76%	83%	83%	83%	83%	89%	89%	89%	89%	94%	94%	94%	94%	100%
9	76%	76%	83%	83%	83%	83%	83%	89%	89%	89%	89%	89%	94%	94%	94%	94%	94%	100%	100%
10	83%	83%	83%	89%	89%	89%	89%	89%	89%	89%	94%	94%	94%	94%	94%	94%	100%	100%	100%
11	89%	89%	89%	89%	89%	94%	94%	94%	94%	94%	94%	94%	94%	94%	94%	100%	100%	100%	100%
12	94%	94%	94%	94%	94%	94%	94%	94%	94%	94%	100%	100%	100%	100%	100%	100%	100%	100%	100%
EUL =	13																		

Table M-35. Inflated Lifecycle Benefit Adjustment Factors for PA-Supplied Ratios of Incremental Savings to Full Savings for a 12 Year EUL

	Savings Ratio																		
RUL	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95
1	11%	22%	22%	32%	32%	41%	41%	50%	50%	58%	58%	66%	66%	73%	81%	81%	87%	94%	94%
2	22%	32%	32%	41%	41%	41%	50%	50%	58%	58%	66%	66%	73%	73%	81%	87%	87%	94%	94%
3	32%	41%	41%	41%	50%	50%	58%	58%	66%	66%	66%	73%	73%	81%	81%	87%	87%	94%	94%
4	41%	50%	50%	50%	58%	58%	58%	66%	66%	73%	73%	73%	81%	81%	87%	87%	94%	94%	100%
5	50%	58%	58%	58%	66%	66%	66%	73%	73%	73%	81%	81%	81%	87%	87%	87%	94%	94%	100%
6	58%	66%	66%	66%	66%	73%	73%	73%	73%	81%	81%	81%	87%	87%	87%	94%	94%	94%	100%
7	66%	66%	73%	73%	73%	73%	81%	81%	81%	81%	87%	87%	87%	87%	94%	94%	94%	94%	100%
8	73%	73%	81%	81%	81%	81%	81%	87%	87%	87%	87%	87%	94%	94%	94%	94%	94%	100%	100%
9	81%	81%	81%	87%	87%	87%	87%	87%	87%	87%	94%	94%	94%	94%	94%	94%	100%	100%	100%
10	87%	87%	87%	87%	87%	94%	94%	94%	94%	94%	94%	94%	94%	94%	94%	100%	100%	100%	100%
11	94%	94%	94%	94%	94%	94%	94%	94%	94%	94%	100%	100%	100%	100%	100%	100%	100%	100%	100%
EUL =	12																		

Table M-36. Inflated Lifecycle Benefit Adjustment Factors for PA-Supplied Ratios of Incremental Savings to Full Savings for an 11 Year EUL

	Savings Ratio																		
RUL	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95
1	12%	23%	23%	34%	34%	34%	43%	43%	53%	53%	62%	62%	70%	70%	78%	86%	86%	93%	93%
2	23%	34%	34%	34%	43%	43%	53%	53%	62%	62%	62%	70%	70%	78%	78%	86%	86%	93%	93%
3	34%	43%	43%	43%	53%	53%	53%	62%	62%	70%	70%	70%	78%	78%	86%	86%	93%	93%	100%
4	43%	53%	53%	53%	62%	62%	62%	70%	70%	70%	78%	78%	78%	86%	86%	86%	93%	93%	100%
5	53%	62%	62%	62%	62%	70%	70%	70%	70%	78%	78%	78%	86%	86%	86%	93%	93%	93%	100%
6	62%	62%	70%	70%	70%	70%	78%	78%	78%	78%	86%	86%	86%	86%	93%	93%	93%	93%	100%
7	70%	70%	78%	78%	78%	78%	78%	86%	86%	86%	86%	86%	93%	93%	93%	93%	93%	100%	100%
8	78%	78%	78%	86%	86%	86%	86%	86%	86%	86%	93%	93%	93%	93%	93%	93%	100%	100%	100%
9	86%	86%	86%	86%	86%	93%	93%	93%	93%	93%	93%	93%	93%	93%	93%	100%	100%	100%	100%
10	93%	93%	93%	93%	93%	93%	93%	93%	93%	93%	100%	100%	100%	100%	100%	100%	100%	100%	100%
EUL =	11																		

Table M-37. Inflated Lifecycle Benefit Adjustment Factors for PA-Supplied Ratios of Incremental Savings to Full Savings for a 10 Year EUL

	Savings Ratio																		
RUL	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95
1	13%	25%	25%	25%	36%	36%	47%	47%	57%	57%	57%	66%	66%	75%	75%	84%	84%	92%	92%
2	25%	36%	36%	36%	47%	47%	47%	57%	57%	66%	66%	66%	75%	75%	84%	84%	92%	92%	100%
3	36%	47%	47%	47%	57%	57%	57%	66%	66%	66%	75%	75%	75%	84%	84%	84%	92%	92%	100%
4	47%	57%	57%	57%	57%	66%	66%	66%	66%	75%	75%	75%	84%	84%	84%	92%	92%	92%	100%
5	57%	57%	66%	66%	66%	66%	75%	75%	75%	75%	84%	84%	84%	84%	92%	92%	92%	92%	100%
6	66%	66%	75%	75%	75%	75%	75%	84%	84%	84%	84%	84%	92%	92%	92%	92%	92%	100%	100%
7	75%	75%	75%	84%	84%	84%	84%	84%	84%	84%	92%	92%	92%	92%	92%	92%	100%	100%	100%
8	84%	84%	84%	84%	84%	92%	92%	92%	92%	92%	92%	92%	92%	92%	92%	100%	100%	100%	100%
9	92%	92%	92%	92%	92%	92%	92%	92%	92%	92%	100%	100%	100%	100%	100%	100%	100%	100%	100%
EUL =	10																		

Table M-38. Full Cost Adjustment Factors

	Cost Ratio																		
RUL	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95
1	10%	15%	19%	24%	29%	34%	38%	43%	48%	53%	57%	62%	67%	72%	76%	81%	86%	91%	95%
2	15%	19%	24%	28%	33%	37%	42%	46%	51%	55%	60%	64%	69%	73%	78%	82%	87%	91%	96%
3	19%	23%	28%	32%	36%	40%	45%	49%	53%	57%	62%	66%	70%	74%	79%	83%	87%	91%	96%
4	23%	27%	31%	35%	39%	43%	48%	52%	56%	60%	64%	68%	72%	76%	80%	84%	88%	92%	96%
5	27%	31%	35%	39%	43%	46%	50%	54%	58%	62%	66%	69%	73%	77%	81%	85%	89%	92%	96%
6	31%	35%	38%	42%	46%	49%	53%	56%	60%	64%	67%	71%	75%	78%	82%	85%	89%	93%	96%
7	35%	38%	42%	45%	48%	52%	55%	59%	62%	66%	69%	73%	76%	79%	83%	86%	90%	93%	97%
8	38%	41%	45%	48%	51%	54%	58%	61%	64%	67%	71%	74%	77%	80%	84%	87%	90%	93%	97%
9	41%	44%	48%	51%	54%	57%	60%	63%	66%	69%	72%	75%	78%	81%	85%	88%	91%	94%	97%
10	44%	47%	50%	53%	56%	59%	62%	65%	68%	71%	74%	77%	80%	82%	85%	88%	91%	94%	97%
11	47%	50%	53%	56%	58%	61%	64%	67%	69%	72%	75%	78%	81%	83%	86%	89%	92%	94%	97%
12	50%	53%	55%	58%	61%	63%	66%	68%	71%	74%	76%	79%	82%	84%	87%	89%	92%	95%	97%
13	53%	55%	58%	60%	63%	65%	68%	70%	73%	75%	78%	80%	83%	85%	88%	90%	93%	95%	98%
14	55%	57%	60%	62%	65%	67%	69%	72%	74%	76%	79%	81%	83%	86%	88%	91%	93%	95%	98%
15	57%	60%	62%	64%	66%	69%	71%	73%	75%	78%	80%	82%	84%	87%	89%	91%	93%	96%	98%
16	60%	62%	64%	66%	68%	70%	72%	75%	77%	79%	81%	83%	85%	87%	89%	92%	94%	96%	98%
17	62%	64%	66%	68%	70%	72%	74%	76%	78%	80%	82%	84%	86%	88%	90%	92%	94%	96%	98%
18	64%	66%	68%	69%	71%	73%	75%	77%	79%	81%	83%	85%	87%	89%	90%	92%	94%	96%	98%
19	66%	67%	69%	71%	73%	75%	76%	78%	80%	82%	84%	86%	87%	89%	91%	93%	95%	96%	98%
20	67%	69%	71%	73%	74%	76%	78%	79%	81%	83%	85%	86%	88%	90%	91%	93%	95%	97%	98%
21	69%	71%	72%	74%	76%	77%	79%	81%	82%	84%	85%	87%	89%	90%	92%	94%	95%	97%	98%
22	71%	72%	74%	75%	77%	78%	80%	82%	83%	85%	86%	88%	89%	91%	92%	94%	95%	97%	98%
23	72%	74%	75%	77%	78%	80%	81%	82%	84%	85%	87%	88%	90%	91%	93%	94%	96%	97%	99%
24	74%	75%	76%	78%	79%	81%	82%	83%	85%	86%	88%	89%	90%	92%	93%	94%	96%	97%	99%
EUL =	25																		

Table M-39. Adjusted EULs for a 25 Year EUL

	Savings Ratio																		
RUL	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95
1	2	2	3	4	5	6	7	7	8	9	11	12	13	14	16	17	19	21	23
2	3	3	4	5	6	7	7	8	9	10	11	12	14	15	16	18	19	21	23
3	4	4	5	6	7	7	8	9	10	11	12	13	14	15	17	18	20	21	23
4	5	5	6	7	8	8	9	10	11	12	13	14	15	16	17	19	20	22	23
5	6	6	7	8	8	9	10	11	12	13	13	14	15	17	18	19	20	22	23
6	7	7	8	9	9	10	11	12	12	13	14	15	16	17	18	19	21	22	23
7	8	8	9	9	10	11	12	12	13	14	15	16	17	18	19	20	21	22	24
8	9	9	10	10	11	12	12	13	14	15	15	16	17	18	19	20	21	22	24
9	10	10	11	11	12	13	13	14	15	15	16	17	18	19	20	21	22	23	24
10	11	11	12	12	13	13	14	15	15	16	17	18	18	19	20	21	22	23	24
11	12	12	13	13	14	14	15	15	16	17	17	18	19	20	20	21	22	23	24
12	12	13	13	14	15	15	16	16	17	17	18	19	19	20	21	22	22	23	24
13	13	14	14	15	15	16	16	17	17	18	19	19	20	21	21	22	23	23	24
14	14	15	15	16	16	17	17	18	18	19	19	20	20	21	22	22	23	24	24
15	15	16	16	17	17	17	18	18	19	19	20	20	21	21	22	23	23	24	24
16	16	17	17	17	18	18	19	19	20	20	20	21	21	22	22	23	23	24	24
17	17	18	18	18	19	19	19	20	20	21	21	21	22	22	23	23	24	24	25
18	18	19	19	19	20	20	20	21	21	21	22	22	22	23	23	23	24	24	25
19	19	20	20	20	20	21	21	21	21	22	22	22	23	23	23	24	24	24	25
20	20	20	21	21	21	21	22	22	22	22	23	23	23	23	24	24	24	24	25
21	21	21	22	22	22	22	22	23	23	23	23	23	24	24	24	24	24	25	25
22	22	22	22	23	23	23	23	23	23	23	24	24	24	24	24	24	25	25	25
23	23	23	23	23	23	24	24	24	24	24	24	24	24	24	24	25	25	25	25
24	24	24	24	24	24	24	24	24	24	25	25	25	25	25	25	25	25	25	25
EUL =	25																		

Table M-40. Adjusted EULs for a 20 Year EUL

	Savings Ratio																		
RUL	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95
1	2	2	3	4	4	5	6	7	7	8	9	10	11	12	13	14	16	17	18
2	3	3	4	4	5	6	7	7	8	9	10	11	12	13	14	15	16	17	19
3	4	4	5	5	6	7	7	8	9	10	11	11	12	13	14	15	16	17	19
4	5	5	6	6	7	8	8	9	10	10	11	12	13	14	15	16	17	18	19
5	6	6	7	7	8	8	9	10	10	11	12	13	13	14	15	16	17	18	19
6	7	7	8	8	9	9	10	10	11	12	12	13	14	15	15	16	17	18	19
7	7	8	8	9	10	10	11	11	12	12	13	14	14	15	16	17	17	18	19
8	8	9	9	10	10	11	11	12	13	13	14	14	15	16	16	17	18	18	19
9	9	10	10	11	11	12	12	13	13	14	14	15	15	16	17	17	18	19	19
10	10	11	11	12	12	12	13	13	14	14	15	15	16	16	17	18	18	19	19
11	11	12	12	12	13	13	14	14	15	15	15	16	16	17	17	18	18	19	19
12	12	13	13	13	14	14	14	15	15	16	16	16	17	17	18	18	19	19	20
13	13	14	14	14	15	15	15	16	16	16	17	17	17	18	18	18	19	19	20
14	14	15	15	15	15	16	16	16	16	17	17	17	18	18	18	19	19	19	20
15	15	15	16	16	16	16	17	17	17	17	18	18	18	18	19	19	19	19	20
16	16	16	17	17	17	17	17	18	18	18	18	18	19	19	19	19	19	20	20
17	17	17	17	18	18	18	18	18	18	18	19	19	19	19	19	19	20	20	20
18	18	18	18	18	18	19	19	19	19	19	19	19	19	19	19	20	20	20	20
19	19	19	19	19	19	19	19	19	19	19	20	20	20	20	20	20	20	20	20
EUL =	20																		

Table M-41. Adjusted EULs for a 17 Year EUL

	Savings Ratio																		
RUL	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95
1	2	2	3	3	4	5	5	6	7	7	8	9	10	11	12	13	14	15	16
2	3	3	4	4	5	5	6	7	7	8	9	10	10	11	12	13	14	15	16
3	4	4	5	5	6	6	7	7	8	9	9	10	11	12	12	13	14	15	16
4	4	5	5	6	7	7	8	8	9	9	10	11	11	12	13	14	14	15	16
5	5	6	6	7	7	8	8	9	10	10	11	11	12	13	13	14	15	15	16
6	6	7	7	8	8	9	9	10	10	11	11	12	12	13	14	14	15	16	16
7	7	8	8	9	9	10	10	10	11	11	12	12	13	13	14	15	15	16	16
8	8	9	9	10	10	10	11	11	12	12	12	13	13	14	14	15	15	16	16
9	9	10	10	10	11	11	11	12	12	13	13	13	14	14	15	15	16	16	17
10	10	11	11	11	12	12	12	13	13	13	14	14	14	15	15	15	16	16	17
11	11	12	12	12	12	13	13	13	13	14	14	14	15	15	15	16	16	16	17
12	12	12	13	13	13	13	14	14	14	14	15	15	15	15	16	16	16	16	17
13	13	13	14	14	14	14	14	15	15	15	15	15	16	16	16	16	16	17	17
14	14	14	14	15	15	15	15	15	15	15	16	16	16	16	16	16	17	17	17
15	15	15	15	15	15	16	16	16	16	16	16	16	16	16	16	17	17	17	17
16	16	16	16	16	16	16	16	16	16	16	17	17	17	17	17	17	17	17	17
EUL =	17																		

Table M-42. Adjusted EULs for a 15 Year EUL

	Savings Ratio																		
RUL	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95
1	2	2	3	3	4	4	5	5	6	7	7	8	9	10	10	11	12	13	14
2	2	3	3	4	5	5	6	6	7	7	8	9	9	10	11	12	12	13	14
3	3	4	4	5	5	6	6	7	8	8	9	9	10	11	11	12	13	13	14
4	4	5	5	6	6	7	7	8	8	9	9	10	10	11	12	12	13	14	14
5	5	6	6	7	7	8	8	8	9	9	10	10	11	11	12	13	13	14	14
6	6	7	7	8	8	8	9	9	10	10	10	11	11	12	12	13	13	14	14
7	7	8	8	8	9	9	9	10	10	11	11	11	12	12	13	13	14	14	15
8	8	9	9	9	10	10	10	11	11	11	12	12	12	13	13	13	14	14	15
9	9	10	10	10	10	11	11	11	11	12	12	12	13	13	13	14	14	14	15
10	10	10	11	11	11	11	12	12	12	12	13	13	13	13	14	14	14	14	15
11	11	11	12	12	12	12	12	13	13	13	13	13	14	14	14	14	14	15	15
12	12	12	12	13	13	13	13	13	13	13	14	14	14	14	14	14	15	15	15
13	13	13	13	13	13	14	14	14	14	14	14	14	14	14	14	15	15	15	15
14	14	14	14	14	14	14	14	14	14	14	15	15	15	15	15	15	15	15	15
EUL =	15																		

Table M-43. Adjusted EULs for a 14 Year EUL

	Savings Ratio																		
RUL	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95
1	1	2	2	3	4	4	5	5	6	6	7	8	8	9	10	11	11	12	13
2	2	3	3	4	4	5	5	6	7	7	8	8	9	10	10	11	12	12	13
3	3	4	4	5	5	6	6	7	7	8	8	9	9	10	11	11	12	13	13
4	4	5	5	6	6	7	7	7	8	8	9	9	10	10	11	12	12	13	13
5	5	6	6	7	7	7	8	8	9	9	9	10	10	11	11	12	12	13	13
6	6	7	7	7	8	8	8	9	9	10	10	10	11	11	12	12	13	13	14
7	7	8	8	8	9	9	9	10	10	10	11	11	11	12	12	12	13	13	14
8	8	9	9	9	9	10	10	10	10	11	11	11	12	12	12	13	13	13	14
9	9	9	10	10	10	10	11	11	11	11	12	12	12	12	13	13	13	13	14
10	10	10	11	11	11	11	11	12	12	12	12	12	13	13	13	13	13	14	14
11	11	11	11	12	12	12	12	12	12	12	13	13	13	13	13	13	14	14	14
12	12	12	12	12	12	13	13	13	13	13	13	13	13	13	13	14	14	14	14
13	13	13	13	13	13	13	13	13	13	13	14	14	14	14	14	14	14	14	14
EUL =	14																		

Table M-44. Adjusted EULs for a 13 Year EUL

	Savings Ratio																		
RUL	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95
1	1	2	2	3	3	4	4	5	6	6	7	7	8	9	9	10	11	11	12
2	2	3	3	4	4	5	5	6	6	7	7	8	8	9	10	10	11	12	12
3	3	4	4	5	5	6	6	6	7	7	8	8	9	9	10	11	11	12	12
4	4	5	5	6	6	6	7	7	8	8	8	9	9	10	10	11	11	12	12
5	5	6	6	6	7	7	7	8	8	9	9	9	10	10	11	11	12	12	13
6	6	7	7	7	8	8	8	9	9	9	10	10	10	11	11	11	12	12	13
7	7	8	8	8	8	9	9	9	9	10	10	10	11	11	11	12	12	12	13
8	8	8	9	9	9	9	10	10	10	10	11	11	11	11	12	12	12	12	13
9	9	9	10	10	10	10	10	11	11	11	11	11	12	12	12	12	12	13	13
10	10	10	10	11	11	11	11	11	11	11	12	12	12	12	12	12	13	13	13
11	11	11	11	11	11	12	12	12	12	12	12	12	12	12	12	13	13	13	13
12	12	12	12	12	12	12	12	12	12	12	13	13	13	13	13	13	13	13	13
EUL =	13																		

Table M-45. Adjusted EULs for a 12 Year EUL

	Savings Ratio																		
RUL	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95
1	1	2	2	3	3	4	4	5	5	6	6	7	7	8	9	9	10	11	11
2	2	3	3	4	4	4	5	5	6	6	7	7	8	8	9	10	10	11	11
3	3	4	4	4	5	5	6	6	7	7	7	8	8	9	9	10	10	11	11
4	4	5	5	5	6	6	6	7	7	8	8	8	9	9	10	10	11	11	12
5	5	6	6	6	7	7	7	8	8	8	9	9	9	10	10	10	11	11	12
6	6	7	7	7	7	8	8	8	8	9	9	9	10	10	10	11	11	11	12
7	7	7	8	8	8	8	9	9	9	9	10	10	10	10	11	11	11	11	12
8	8	8	9	9	9	9	9	10	10	10	10	10	11	11	11	11	11	12	12
9	9	9	9	10	10	10	10	10	10	10	11	11	11	11	11	11	12	12	12
10	10	10	10	10	10	11	11	11	11	11	11	11	11	11	11	12	12	12	12
11	11	11	11	11	11	11	11	11	11	11	12	12	12	12	12	12	12	12	12
EUL =	12																		

Table M-46. Adjusted EULs for a 11 Year EUL

	Savings Ratio																		
RUL	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95
1	1	2	2	3	3	3	4	4	5	5	6	6	7	7	8	9	9	10	10
2	2	3	3	3	4	4	5	5	6	6	6	7	7	8	8	9	9	10	10
3	3	4	4	4	5	5	5	6	6	7	7	7	8	8	9	9	10	10	11
4	4	5	5	5	6	6	6	7	7	7	8	8	8	9	9	9	10	10	11
5	5	6	6	6	6	7	7	7	7	8	8	8	9	9	9	10	10	10	11
6	6	6	7	7	7	7	8	8	8	8	9	9	9	9	10	10	10	10	11
7	7	7	8	8	8	8	8	9	9	9	9	9	10	10	10	10	10	11	11
8	8	8	8	9	9	9	9	9	9	9	10	10	10	10	10	10	11	11	11
9	9	9	9	9	9	10	10	10	10	10	10	10	10	10	10	11	11	11	11
10	10	10	10	10	10	10	10	10	10	10	11	11	11	11	11	11	11	11	11
EUL =	11																		

Table M-47. Adjusted EULs for a 10 Year EUL

	Savings Ratio																		
RUL	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95
1	1	2	2	2	3	3	4	4	5	5	5	6	6	7	7	8	8	9	9
2	2	3	3	3	4	4	4	5	5	6	6	6	7	7	8	8	9	9	10
3	3	4	4	4	5	5	5	6	6	6	7	7	7	8	8	8	9	9	10
4	4	5	5	5	5	6	6	6	6	7	7	7	8	8	8	9	9	9	10
5	5	5	6	6	6	6	7	7	7	7	8	8	8	8	9	9	9	9	10
6	6	6	7	7	7	7	7	8	8	8	8	8	9	9	9	9	9	10	10
7	7	7	7	8	8	8	8	8	8	8	9	9	9	9	9	9	10	10	10
8	8	8	8	8	8	9	9	9	9	9	9	9	9	9	9	10	10	10	10
9	9	9	9	9	9	9	9	9	9	9	10	10	10	10	10	10	10	10	10
EUL =	10																		

Record of Revision

Record of Revision Number	Issue Date
0	10/15/2010
5-11-1	5/6/2011

Return to Table of Contents

APPENDIX N

SPECIAL CIRCUMSTANCE

Introduction

In its October 18, 2010 order[1421], the Commission defined early replacement as replacement of equipment prior to the end of its prescribed effective-useful life and directed Staff to develop a dual baseline method for estimating the benefits and costs of early replacement that provides consistency between the treatment of savings and costs. The order also directed Staff to provide simplifying lookup tables for early replacement energy savings consistent with the dual baseline concept. The dual baseline methods and lookup tables have been developed and are provided in Appendix M of the Technical Manual.

The October 18, 2010 Order also introduced the concept of "special circumstance" replacements: the replacement of equipment operated by customers who are influenced by initial costs more than by life cycle economics. These customers include those with insufficient capital, a split incentive (such as a landlord incurring cost to provide a tenant benefit), short time horizons, and/or other factors which tend to prevent long range economic decision-making regarding the installation of high efficiency equipment. The Commission applied the concept of special circumstance replacements only to commercial and industrial machinery and multi-family central systems,[1422] and only to equipment well past its prescribed effective useful life. The order specifically excluded lighting equipment from special circumstance replacement.

The Commission established a general outline for determining eligibility for special circumstance replacement treatment including:

Equipment age significantly exceeds its effective useful-life;
Energy consumption significantly exceeds that of current high efficiency models;
There is a history of significant repair or replacement with used equipment;
The prospective next repair or replacement is likely to be much less expensive than replacement with new higher efficiency machinery.

The order directed Staff to develop more detailed criteria and a method for adapting dual baseline screening for early replacement to special circumstance replacements, with consultation with the Evaluation Advisory Group (EAG) that includes the program administrators (PAs). In dual baseline analysis, the savings for the first baseline are calculated against the replaced equipment, while the savings for the second baseline are calculated against the current standards/codes minimums or, in the absence of such, common practice.

[1421] Case 07-M-0548, Energy Efficiency Portfolio Standard (EEPS), Order Approving Consolidation and Revision of Technical Manuals (issued October 18, 2010).
[1422] What "multi-family central systems" includes is clarified in detail in the Case 07-M-0548, Energy Efficiency Portfolio Standard (EEPS), Order Approving Modifications to the Technical Manual (issued July 18, 2011), pp 15 - 16.

In the July 18, 2011 order,[1423] the Commission approved Staff's proposals regarding detailing the first two criteria for eligibility:[1424]

> **Age Rule**: The equipment to be replaced must be aged at least 125% of it is prescribed effective-useful life in cases where the age of the equipment can be determined to this extent.[1425] If the equipment is determined to be less than 125% of its EUL, it's not eligible for SC treatment regardless of consumption or any other factor
>
> **Energy Use Rule**: Applies **only** in cases in which the age of the existing equipment cannot be determined relative to 125%; existing equipment of most types must consume at least 20% more energy than the new high efficiency equipment to do the same amount of work, and at least 35% more for chillers.

In the July 18 Order, the Commission also approved Staff's proposal to define the first baseline, the hypothetical period for which the old equipment in place would have continued in use absent the program (the Default Functional Period or DFP) as 25% of the program efficient measure's EUL.[1426]

The July 18, 2011 order also directed Staff to post directions and lookup tables for Special Circumstance replacement as a counterpart to those in Appendix M for early replacement. For the interim period, PAs were permitted to use the tables in Appendix M for Special Circumstances for costs. [1427] However, Appendix N includes tables for special circumstance replacement that PAs must now use.

For equipment that qualifies as special circumstance, the dual baseline method described in Appendix M will be applied for special circumstance TRC screening. The dual baseline situation that characterizes the special circumstance situation, illustrated in Figure 1, involves a customer who replaces fully functioning equipment aged at least 25% beyond its official EUL. The equipment hypothetically would have continued to function for some period of time, the DFP. However, the customer is induced by the program to replace this existing equipment with more efficient equipment. It is assumed that at the end of the DFP, absent the program, the customer would have installed equipment that would meet the existing efficiency code or appliance standard, or common practice (referred to as the *code/standard equipment*).

[1423] Ibid.

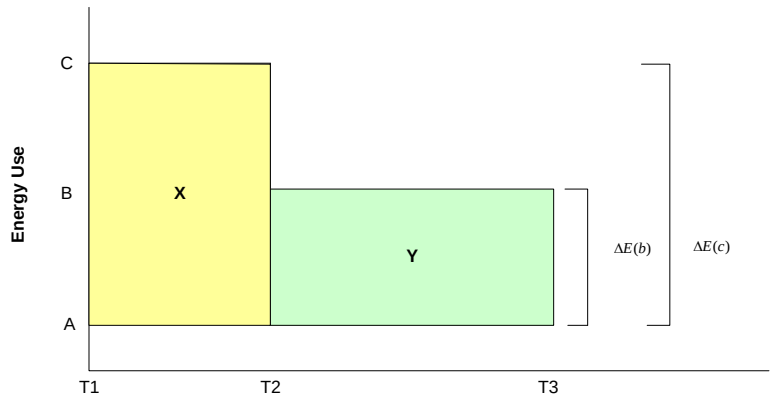
[114] While the first two require definition of "significant," the third and fourth do not require or lend themselves to additional detail. The Commission also approved Staff's proposed relationship between the first two, i.e., energy consumption is considered only if age relative to 125% cannot be determined.

[1425] It is not necessary to determine the exact age of the equipment as long as it can be determined to be at least 125% of the effective-useful life.

[1426] The Order also included a comprehensive list of measures and associated EULs that should be used in cases where the special circumstance measure matches a measure in the Order. In cases where there is no match, PAs must propose and document the EUL.

[1427] Program administrators were required to research and calculate their own savings ratios and to use the second set of tables (not the DEER-based tables), as consumption of the old equipment in place may differ between early and special circumstance replacement -- the baseline existing equipment is pre EUL versus 125% past it, potentially with widely varying efficiency. For costs, the comparison is between current high efficiency versus standards/code or common practice in any case.

Figure 2. The Special Circumstance Condition



$\Delta E(c)$ = C - A
$\Delta E(b)$ = B - A
C = Energy use of pre-existing equipment
B = Energy use of equipment that meets code
A = Energy use of the efficient equipment rebated through program
T1 = Date on which new efficient equipment is installed
T2 = Date on which existing equipment was expected to have failed
T3= Date on which the new efficient equipment is expected to fail
T3 – T1 = Expected effective useful life (EUL) of the new efficient equipment
T2 – T1 = Expected period of time in which the pre-existing equipment would have continued to function, referred to as the default functional period (DFP)
T3 – T2 = Expected remaining EUL of the new efficient equipment

Energy savings in this example would consist of two portions. The customer would have experienced the ***full*** savings represented by the line segment C-A for the DFP period T2-T1, Area **X**. At the end of the DFP, the savings for the period T3-T2 would be reduced to ***incremental*** savings represented by the line segment B – A, area **Y**. To carry out these calculations, information on the energy use of code/standard equipment is required. Information on energy use of the existing equipment and the high efficiency equipment provided through the program is also required, but much more available and routinely needed.

The costs also have to be calculated in a manner consistent with the special circumstance case. In normal replacement situations, one would use the incremental cost that is defined as the cost of the new efficient equipment minus the cost of the code/standard equipment. In the special circumstance case, the incremental cost is calculated in a slightly different manner, which recognizes, in the absence of the program, the customer would not have purchased any equipment until the future end of the DFP.

Thus, one would first have to determine the full cost of the new efficient equipment at T1 *and* the full cost of the code/standard equipment (both including the installation labor) at T2 (assuming no change in real costs). The incremental costs would then be calculated as the cost of the new efficient equipment installed now (left column in Figure 2) minus the present value (PV) of the cost that is avoided in the future for the code/standard equipment (right column Figure 2). Figure 2 presents a case in which the DFP is 4 years and, absent the program, the code/standard equipment would have been installed in the fifth year. This calculation differs from the normal/end of life replacement incremental cost in adding the time value of money for spending the money earlier.

Figure 3. Incremental Cost Calculation for Special Circumstance Cases with a DFP of Four Years

Year	PV With Program	PV Without Program
1	Full Cost of High Efficient Equipment	0
2	0	0
3	0	0
4	0	0
5	0	Full Cost of Code/Standard Equipment

The Ratio Approach to the Dual Baseline with the Lookup Tables

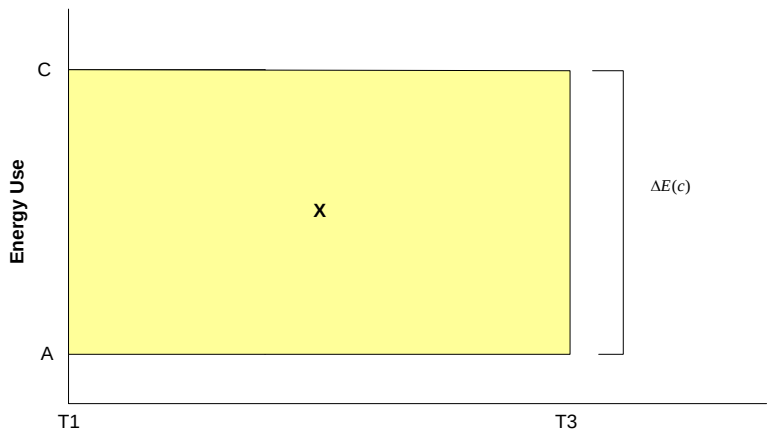
As in Appendix M, this approach focuses on the ratio of incremental energy savings to full energy savings[1428] and the ratio of incremental costs to full costs. These ratios, shown at the top of the columns in Tables N-1 through N-2, determine the factors that PAs can use to adjust the savings and cost data. These first two tables require the program administrators to provide their own incremental costs and savings ratios (based on the code/standard equipment). To use these tables, PAs must match the ratios that they have calculated to the nearest corresponding ratios in these tables

To use Table N-1 for benefits, PAs will need to calculate the full annual savings as the annual energy use of the old equipment in place minus the annual energy use of the high efficiency equipment. These full savings are then counted for each year of the EUL as is represented as area *X* in Figure 3. For each year of the EUL (T3 – T1) of the new equipment, the full kWh or therm savings are converted to dollar benefits by multiplying them by the Commission's avoided costs estimates for that year[1429].

Figure 5. Inflated Lifecycle Benefits

[1428] The savings values ratios are not area present values but are rather the line segments in Figure 1 on the vertical axis: (B – A) divided by (C – A).

[1429] The tables are not territory-specific, but statewide. This is because only the LRAC growth rates matter, not the absolute values, and the growth rates for the various zones are almost identical in the LRACs in use.



$\Delta E(c)$ = C - A
C = Energy use of pre-existing equipment
A = Energy use of the efficient equipment rebated through program
T1 = Date on which new efficient equipment is installed
T3 = Date on which the new efficient equipment is expected to fail
T3 – T1 = EUL of new efficient equipment

As a preliminary step in using Table N-1, and valid only for that purpose, the PAs will calculate this "inflated lifecycle benefits" for kWh, peak kW, and/or therms as the present value of the stream of full savings benefits for the EUL of the new equipment.[1430]

In cases of special circumstance under the ratio approach, it is these inflated lifecycle benefits that must be adjusted using the appropriate *inflated lifecycle benefits adjustment factor*. For a given measure with a given EUL/DFP and ratio of incremental savings to full savings, the inflated lifecycle benefits adjustment factor is the ratio (presented as a percentage) of the present value of the dual baseline lifecycle benefits (X+Y) illustrated in Figure 1 to the present value of the inflated lifecycle benefits illustrated in Figure 3.

Under the Commission requirement of consistent treatment of savings and costs, the full costs[1431] must also be adjusted downward. Using research on the costs of standard/code equipment, a PA can calculate the ratios of incremental costs to full costs and obtain the *full cost adjustment factors* from Table N-2. If a PA cannot obtain or chooses not to seek the data necessary to calculate the cost ratios, it can use the ratios and adjustment factors from Tables M-11 through M-19 in Appendix M in cases in which the measures match.

Note that all documentation for PA costs and savings estimates and ratios must be retained for possible Staff or ex post evaluator review.

Look-Up Tables

Tables N-1 and N-2 have been prepared so that PAs can obtain the Inflated Lifecycle Benefit and the Full Cost adjustment factors. For Inflated Lifecycle Benefits Adjustment Factors, PAs must

[1430] Usually, the ratio of incremental kWh savings to full kWh saving would be the same as the ratio of incremental peak kW demand reduction to full peak kW demand reduction, which implies using the same ratio and adjustment factor for both. However, with some measure types, such as cooling, PAs may benefit from calculating different ratios of incremental to full for kWh and kW. A PA can choose to use higher 0.05 increment kW ratios if it can calculate and document them with retention.

[1431] Full costs include the capital cost of the new efficient equipment plus installation cost.

calculate their own savings ratios. If PAs are able to calculate their own ratios of incremental costs to full costs, they may prefer to use Table N-2. However, as discussed above, in some cases PAs may use the tables in Appendix M to obtain cost ratios and adjustment factors.

For Tables N-1 and N-2, a PA should identify the 0.05 increment ratios that are closest to those it developed. The ratios range from 0.95 to .05 in increments of 0.05, and there are no measure designations.

Note that ratios of 1.0 and 0.0 are not included in the tables. For some measures, the efficiency of the old in place unit is still the common practice or no new standards have been adopted, i.e., the baseline for the full savings and the incremental savings are the same. As a result, the ratio of incremental to full savings is near 1.0, meaning that a PA can claim the full savings for the entire EUL of the new equipment (areas X and Y in Figure 4). Therefore, the lookup tables do not apply. For other measures, the high efficiency equipment subsidized by the program is consistent with current code or standards. For these measures, the incremental savings are zero and thus the ratio of incremental to full savings is 0.0.This means that a PA can claim full savings for only the RUL (area X in Figure 5), after which the high-efficiency replacement would have occurred anyway. Therefore, the lookup tables do not apply.

Figure 4. Efficiency of the Old In Place Unit Is Still the Common Practice Or No New Standards

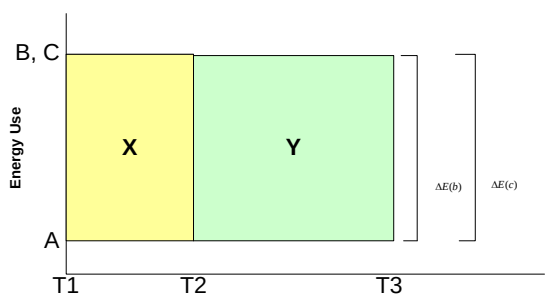
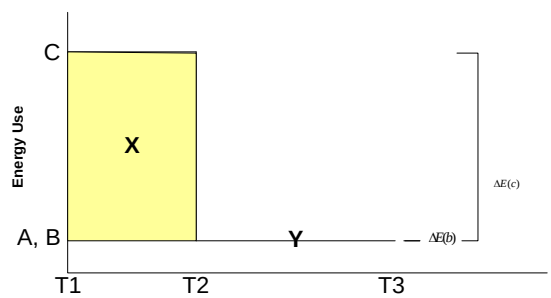


Figure 5. High Efficiency Equipment Subsidized by the Program Is Consistent with Current Code Or Standards



$\Delta E(c)$ = C - A

$\Delta E(b)$ = B - A

C = Energy use of pre-existing equipment
B = Energy use of equipment that meets code
A = Energy use of the efficient equipment rebated through program
T1 = Date on which new efficient equipment is installed
T2 = Date on which existing equipment was expected to have failed
T3= Date on which the new efficient equipment is expected to fail
T3 – T1 = Expected effective useful life (EUL) of the new efficient equipment
T2 – T1 = Expected remaining useful life (RUL) of the pre-existing equipment
T3 – T2 = Expected remaining EUL of the new efficient equipment

To use the tables, a PA must gather the following four pieces of information:

- the EUL of the type of equipment,
- the DFP of the old equipment in place (just 25% of the EUL),
- the full savings of the equipment (annual energy use of the old equipment in place minus the annual energy of the high efficiency equipment supported by the program), and
- the full costs (including installation)

Additionally, a PA will need documented estimates, based on equipment minimally compliant with standards/codes or common practice, of incremental savings and costs in order to calculate:

- The ratio of incremental savings to full savings, and
- The ratio of incremental costs to full cost

Again, note that for the costs, PAs can use the Tables in Appendix M where measures match.

Table Organization

Table N-1 contains the Inflated Lifecycle Benefit Adjustment Factors while Table N-2 contains the Full-Cost Adjustment Factors.

In Table N-1, the first row is the ratio of incremental savings to full savings while in Table N-2 the first row is the ratio of incremental to full cost. In both tables, the first two columns identify the EULs and corresponding DFPs:

- 25 Years/6
- 20 Years/5
- 14 to 17 Years/4
- 10 to 13 Years/3

The remaining columns present the respective adjustment factors by ratio of

- Table 1: Incremental savings to full savings
- Table 2: Incremental costs to full costs

Program-Tracking Database Requirements

The program tracking databases contain information for each measure installation which the PAs are required to maintain for the purposes of current reporting and future impact evaluation, the latter requiring many fields not used for current reporting. The following seven additional required variables, as were first required in Appendix M,[1432] are being added by Staff through the Evaluation Advisory Group process[1433]:

- Type of Installation (TRC Approach)[1434] ,
- The Full Savings (kWh or therms),
- If electric, the on-peak demand reductions associated with the Full Savings,
- The *Adjusted Full Cost* (full cost multiplied by the full-cost adjustment factor),
- The Ratio of Incremental Savings to Full Savings,

[1432] Note that item #2 above is a correction of item #2 in Section 5 of Appendix M. Furthermore, item #3 is now required in addition to those variables listed in Section 5 of Appendix M. Those using Appendix M should take note of these changes.

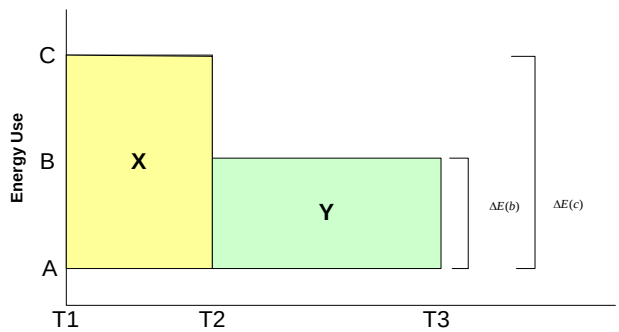
[1433] Note that for cases of normal replacement and add-on, the variables 2 through 7 should be coded as "n/a" (not applicable).

[1434] ER=Early Replacement; NR=Normal Replacement; SC=Special Circumstance; AO=Add On. Add on refers to adding something that replaces nothing. Examples include adding controls to a boiler that had none, or adding insulation where there was none or some. Add-on measures are modeled at full costs and full savings for the length of their EULs. The full savings are reported toward first-year goals.

- The Ratio of Incremental Costs to Full Costs, and
- The *Adjusted EUL* (discussed below).

The Adjusted EUL is defined as that period of years over which the present value benefits of the full savings would approximate the present value dollar benefits of the underlying dual baseline. Figure 6 shows the Adjusted EUL Tx, reduced from the actual EUL T3 such that the lifecycle savings over the period Tx – T1 approximates the lifecycle savings over the period T3 – T1 in Figure 1 (repeated from above). The longer the DFP is, the longer the adjusted EUL, owing to more years at full savings.

Figure 1. Lifecycle Savings: Dual Baseline



=

Figure 6: Lifecycle Savings: Approximation to Dual Baseline

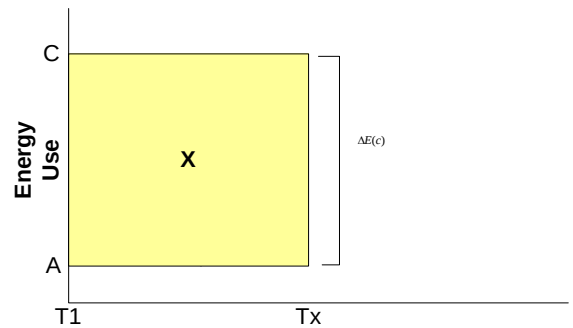


Table N-3 presents the adjusted EULs in years for each possible ratio (in 0.05 increments). In Table N-3, the first row is the incremental to full savings ratio and the first two columns identify the EULs and corresponding DFPs. The adjusted EUL is not used for TRC screening, but only for the program's tracking database. Table N-3 is organized in the same way as the Table N-1. Note that Tables N-1 through N-3 are also available in Excel.

Example

Consider the following example. Suppose a PA finds in place equipment with an EUL of 17 years whose age is determined to be 22 years. The five years over the EUL is greater than 25% of the EUL (17/4 = 4.25 which rounds to 4, which is also the DFP). The equipment is eligible for special circumstance treatment if it also meets criteria #3 and #4. The PA has determined that the ratio of incremental savings to full savings is 0.65 and the ratio of incremental costs to full costs is 0.40. To find the Inflated Lifecycle Benefits Adjustment Factors, the Full Cost Adjustment Factors, and the Adjusted EUL for this measure, the PA must go to Table N-1 and identify the row for measures with an EUL of 17 years and a DFP of 4 years. Next, they must identify the column with an incremental savings to full savings ratio of 0.65. The value in the intersection of this row and this column is 0.75, which is the Inflated Lifecycle Benefits Adjustment Factor. Using Table N-3, the same procedure would be followed to obtain the Adjusted EUL of 10 years.

To find the Full Cost Adjustment Factor, the PA would go to Table N-2, find the row with a 4-year DFP and the column with a ratio of 0.40. The value in the cell is 0.52, which is the Full Cost Adjustment Factor. As discussed above, in some cases PAs may use the tables in Appendix M to obtain cost ratios and adjustment factors.

The next step is to multiply the inflated benefits by the benefits factor and the full costs by the costs factor. For Total Resources Cost (TRC) analysis, ratio the two products, benefits/costs. For first year savings to report against approved program goals, for special circumstances replacements PAs would use the full savings, the first baseline of the existing equipment versus the high efficiency program measure.

Table N-1. Inflated Lifecycle Benefit Adjustment Factors for PA-Supplied Ratios of Incremental Savings to Full Savings, by DFP, for kWh, kW, and Therm Savings

	DFP	Median Ratio of Incremental Savings to Full Savings																		
		0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95
		Inflated Lifecycle Benefit Adjustment Factors																		
25 Year EUL	6	42%	42%	47%	52%	52%	56%	60%	64%	64%	68%	71%	75%	78%	81%	84%	86%	91%	94%	96%
20 Year EUL	5	42%	42%	47%	47%	53%	53%	58%	63%	63%	67%	72%	76%	76%	80%	84%	87%	91%	94%	97%
17 to 14 Year EUL	4	35%	43%	43%	50%	50%	56%	56%	63%	63%	69%	69%	75%	75%	80%	86%	86%	91%	95%	95%
13 to 10 EUL	3	32%	41%	41%	41%	50%	50%	58%	58%	66%	66%	66%	73%	73%	81%	81%	87%	87%	94%	94%

Table N-2. Full Cost Adjustment Factors for PA-Supplied Ratios of Incremental Cost to Full Cost, by DFP

	DFP	Median Ratio of Incremental Cost to Full Cost																		
		0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95
		Full Cost Adjustment Factors																		
25 Year EUL	6	31%	35%	38%	42%	46%	49%	53%	56%	60%	64%	67%	71%	75%	78%	82%	85%	89%	93%	96%
20 Year EUL	5	27%	31%	35%	39%	43%	46%	50%	54%	58%	62%	66%	69%	73%	77%	81%	85%	89%	92%	96%
17 to 14 Year EUL	4	23%	27%	31%	35%	39%	43%	48%	52%	56%	60%	64%	68%	72%	76%	80%	84%	88%	92%	96%
13 to 10 EUL	3	19%	23%	28%	32%	36%	40%	45%	49%	53%	57%	62%	66%	70%	74%	79%	83%	87%	91%	96%

Table N-3. Adjusted EULs, by DFP

	DFP	Median Ratio of Incremental Savings to Full Savings																		
		0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95
		Adjusted EULs in Years																		
25 Year EUL	6	6	7	7	8	8	9	9	10	10	11	11	12	12	13	14	14	15	16	16
20 Year EUL	5	6	6	7	7	8	8	9	10	10	11	12	13	13	14	15	16	17	18	19
17 to 14 Year EUL	4	4	5	5	6	6	7	7	8	8	9	9	10	10	11	12	12	13	14	14
13 to 10 EUL	3	3	4	4	4	5	5	6	6	7	7	7	8	8	9	9	10	10	11	11

Record of Revision

Record of Revision Number	Issue Date
0	10/15/2010

Return to Table of Contents

APPENDIX O

COMMERCIAL AND INDUSTRIAL LIGHTING POLICY

INTRODUCTION

On January 12, 2011 Staff issued a SAPA Notice, in part on proposals to implement directives in the Commission's October 18, 2010 order in Case 07-M-0548 regarding benefit/cost analysis for Special Circumstance customers in Energy Efficiency Portfolio Standard (EEPS) programs.[1435] In its 2/28/11 comments, National Grid sought clarification regarding: whether field staff must determine the age of lighting fixtures in place and how to treat lighting replacement where the age of the fixture in place is past its prescribed effective useful life (EUL). With regard to these lighting issues, the Commission in its July 18, 2011 order in the EEPS proceeding directed[1436] "the Implementation Advisory Group to attempt to resolve the issues of determining the age of lighting equipment and the correct approach for valuing savings from lighting replacements[1437] under the mechanism we provided for modifying the Consolidated Technical Manual [CTM] in our June 20, 2011 Order in this proceeding."[1438]

Regarding commercial and industrial lighting issues,[1439] the technical manual, effective 1/1/11 [*as modified September 2012]*, states: "The baseline condition is assumed to be the existing *[and operational]* lighting fixture in *[all applications other than new construction or extensive renovations which trigger the building code*]." This makes the savings baseline and costs for TRC analysis independent of the age of the operational fixture. This approach reflects the frequent impracticality of determining the age of lighting fixtures

Absent this provision, replacement of fixtures in place which are either (1) irreparable (unusable and not economic to repair) or, (2) operating and not demonstrably younger than their EUL (in short, broken or past EUL) would be treated as normal/end of life replacement: modeled with incremental costs and with incremental savings for the full EUL of the new measure, including for first year scorecard reporting.[1440] Fixtures in place in working order and demonstrably aged below their EUL would get early replacement treatment which, for most non-lighting measures, would mean dual baseline treatment per Appendix M. Appendix M, however, excludes lighting from such treatment.[1441] Therefore, the conventional early replacement modeling of full costs and full savings would still apply, with the full savings against the old fixture in place modeled for the full EUL of the new equipment and reported as first year scorecard savings.

[1435] SAPA 07-M-0548SP30 - Proceeding on Motion of the Commission Regarding an Energy Efficiency Portfolio Standard.

[1436] Case 07-M-0548, Order Approving Modifications to the Technical Manual, pp. 16-17.

[1437] Savings are related to the type of lamp used in the fixture.

[1438] New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs, October 15, 2010, p. 109, www.dps.ny.gov/Tech ManualNYRevised10-15-10.pdf

[1439] C&I lighting includes multi-family building common areas for the purposes of this paper.

[1440] Incremental means the costs and consumption of the high efficiency model promoted by the program minus the costs and consumption of the standard efficiency level alternative – Federal minimum appliance standards, State building codes or, in the absence of codes and standards, the common practice.

[1441] Appendix M, posted with Technical Manual, see footnote #5, p. 10.

In compliance with instructions stated in the July 18, 2011 Order, this appendix prescribes principles for C&I lighting replacements, both replacements of operational fixtures and irreparable fixtures, addressing:

- Replacements for which incentive funding is precluded, as a practical matter of presumptive TRC failure by definition,
- Inputs for TRC ratio calculations,
- Age determination requirements (none), and
- Values for reporting as first year annualized savings against targets approved in orders (the same as the first year savings modeled in the TRC analysis).

THE OVERALL PRINCIPLES

If a lighting fixture of any age is operational, replacement is early replacement. The full savings against the fixture in place[1442], will be reported as first year savings and modeled for the full EUL of the replacement measure in TRC screening. Costs will be full costs, the total costs of the replacement, as is usual for early replacement analysis outside Appendix M.[1443]

For irreparable lighting fixtures, normal/end of life rules apply: incremental savings and costs between the common practice and the high efficiency measures promoted by EEPS are used for TRC analysis; incremental savings are used for first year scorecard savings; and no age determination is required.

DISCUSSION BY TYPE OF EQUIPMENT REPLACED

The lighting upgrades considered here are; screw-in incandescent fixtures (which will evolve toward use of halogen lamps)[1444] replaced with CFL or LED fixtures. Linear fluorescent T12 or standard T8 replaced with Super T8s, T5s or LEDs.[1445] The fixtures in place may be either in good working order (early replacement) or irreparable (normal replacement).

Baselines: Screw-In Fixtures

Screw-in fixtures are expected to continue to accommodate the least efficient lamp types which still meet the national lighting standards established under the Energy Independence and Security Act of 2007 (EISA).Therefore, the baseline choice for early or normal replacement with any pin-based fixtures remains screw-in fixtures: either to keep a working fixture in place or to replace an irreparable one with a new screw-in fixture. Once the EISA standard is phased-in for a particular lamp size the least efficient lamp technology meeting the standard would normally be considered the baseline. Incandescent lamps, however, are expected to remain in inventories for sale and are reportedly being stockpiled. A screw-in fixture can house, for baseline consumption relative to CFLs, either incandescent or halogen lamps. Therefore, baselines will be based upon deemed

[1442] The full savings differs from incremental savings in subtracting the consumption of the fixture supported by the program from the consumption of the fixture in place, not from the consumption of the current common alternative.
[1443] If passing the TRC, however, is a concern, PAs may choose to document an age past the EUL to be able to model the incremental costs used re: normal replacement as opposed to the full costs usual for early replacement.
[1444] Halogen lamps consume approximately 72% as much as incandescent lamps. Whereas the TRM reports a delta of watts consumption of 2.53 between CFLs and incandescent lamps, the delta would be approximately 1.55 for CFLs against halogen lamps. This means that 1.55 times the CFL wattage is the savings delta against a halogen lamp.
[1445] Speaking only of the types whose replacement are usual subjects of EEPS programs, thus not including high intensity discharge (HID) fixtures, metal halide, high pressure sodium, mercury vapor, *or CFLs or LEDs yet*. Perhaps at some point it will be cost effective to replace CFLs with LED lamps.

years, for each wattage range, in which installation of the new common practice technology, halogen lamps, is more likely than installation of stockpiled incandescent lamps.[1446] Until reconsideration (based on studies in progress and program experience) in March 2015, incandescent lamps will remain the baseline.

For fixtures compatible with incandescent and halogen lamps, TRC analysis of a measure or project may be occurring before the deemed switch year or after it. Analysis done before the estimated switch year will entail two baselines of consumption during the EUL of the screw-in alternative to CFL.[1447] The first baseline will be incandescent lamp consumption until the beginning of the deemed switch year,[1448] the second baseline being halogen lamp consumption. In future TRC analysis after the deemed switch dates, the baseline for incremental savings will be halogen lamps against CFLs throughout.

Baselines: Linear Fluorescent Fixtures

For early replacement of an operational T12 fixture, the baseline relative to super T8s is simply the consumption of the T12 lamp. For normal replacement of an irreparable T12 fixture, the baseline, until reconsideration (based on studies in progress and program experience) in March 2015, is the consumption of a T12. At some point, customers will no longer be installing relatively inefficient T12 fixtures in significant numbers as lamp availability decreases[1449] and therefore standard T8s will be the common practice and thus the suitable linear fluorescent baseline for consideration of appropriate super T8s and T5s.

ELIGIBILITY FOR REBATES

The next issue is potential cost-effectiveness and thus measures' eligibility for rebates. Incentives for CFL (and potentially for LED lamp) pin fixtures, as needed and if cost- effective, may continue to be appropriate for some years to come.[1450] Incandescent/halogen fixtures may remain in use indefinitely, with halogens being less expensive upfront as well as more familiar looking than CFLs or LED lamps. Replacement of screw-in fixtures with new screw-in fixtures may continue, and thus incentives for replacement with higher efficiency technologies make sense.

Turning to rebate-eligibility of linear fluorescent fixtures, since installation of T12 fixtures will be unlikely at some point and replacement of a standard T8 fixture with a standard T8 fixture would yield no savings. At that point, savings will exist and cost-effective incentives will be payable only for installation of super T8s (or T5s) in watts-saving configurations. Super T8s produce more lumens per watt and have improved color rendering and a longer rated life, but since ratepayers should not pay for extra lumens, incentives should be paid only for projects which reduce the overall wattage of fixtures relative to standard T8s.

COSTS TO BE MODELED

[1446] While in reality the technology mixes will shift gradually, the baselines as executed here will require selection of the year in which the probable majority choice will switch.
[1447] Screw-in LEDs are unlikely in the C&I context in which quality concerns require LED fixtures.
[1448] While incandescent lamps installed before the switch year may remain in use during it, this would probably be for a short time given the usual heavy C&I usage. Additionally, fractional year modeling is not practical.
[1449] This will not happen often enough to justify ratepayer subsidy of all replacements to avoid the occasional instance. Retrogression from T8 to T12 is particularly unlikely.
[1450] This is also applicable for screw-in CFLs for incandescent/halogen fixtures.

The last issue is costs to be modeled in TRC screening. For early replacement of operational, screw-in incandescent/halogen fixtures, the TRC screening would as usual include the full *costs* of the replacement, additionally owing to the indefinite remaining life of the fixture in place, and to the continued availability of inexpensive screw-in fixtures usable for halogen. Since most equipment replaced will be in working order, the full-costs case will be the most common, but with incremental costs for normal replacement of irreparable fixtures.

Turning to costs to be modeled for linear fluorescent fixtures, operational standard T8s can remain in place for some years, and therefore full costs for early replacement are fully appropriate. If age past the EUL is documented, however, PAs may model incremental costs for normal replacement. Also as a case of normal replacement, since irreparable standard T8 fixtures can be replaced with like, the modeling of incremental costs for super T8 fixtures is justified.

Record of Revision

Record of Revision Number	Issue Date
0	10/15/2010
3-3-1	3/14/2013

Return to Table of Contents

APPENDIX P

EFFECTIVE USEFUL LIFE (EUL)

SINGLE AND MULTI-FAMILY RESIDENTIAL MEASURES

Category	Single and Multi-family Residential Measures	Sector	EUL (years)	Source
Appliance	Air Purifier	Residential	9	ENERGY STAR® Calc[1451]
	Clothes Dryer	Residential	14	ENERGY STAR® M&I Scoping Report[1452]
	Clothes Washer	Residential	11	DEER 2014 EUL ID: Appl-EffCW
	Dehumidifier	Residential	12	ENERGY STAR® Calc[1453]
	Dishwasher	Residential	11	DEER 2014 EUL ID: Appl-EffDW
	Fireplace	Residential	15	DOE[1454]
	Refrigerator and Freezer	Residential	14	DEER 2014 EUL ID: Appl-ESRefg
	Soundbar	Residential	7	RPP Product Analysis[1455]
	Advanced Power Strip (APS)	Residential	8	DEER 2014 EUL ID: Plug-OccSens
Appliance Control	Air Conditioner - Room (RAC) Recycling	Residential	3	DEER 2014 EUL ID: HV-RAC-RUL

[1451] Savings Calculator for ENERGY STAR® Qualified Appliances (last updated October 2016) Available from: https://www.energystar.gov/buildings/facility-owners-and-managers/existing-buildings/save-energy/purchase-energy-saving-products

[1452] ENERGY STAR® Market & Industry Scoping Report: Residential Clothes Dryer, November 2011.

[1453] ENERGY STAR® Dehumidifier Calculator https://www.energystar.gov/ia/partners/promotions/cool_change/downloads/CalculatorConsumerDehumidifier.xls

[1454] Technical Support Document: Energy Conservation Program for Consumer Products: Energy Conservation Standards for Hearth Products. Chapters 7 and 8. Department of Energy (DOE). January 30, 2015, pg 2-12 https://www.regulations.gov/document?D=EERE-2014-BT-STD-0036-0002

[1455] Retail Products Platform Product Analysis, Last Updated May 25, 2016. Available from: https://drive.google.com/file/d/0B9Fd3ckbKJp5OEpWSHg1eksyZ1U/view

Category	Single and Multi-family Residential Measures	Sector	EUL (years)	Source
Appliance Recycling	Dehumidifier Recycling	Residential	3	Assumes same RUL as RAC
	Refrigerator Recycling	Residential	5	DEER 2014 EUL ID: Appl-RecRef
	Freezer Recycling	Residential	4	DEER 2014 EUL ID: Appl-RecFrzr
	Air Conditioner – Room (RAC) Cover and Gap Sealer	Residential	3	See note below[1456]
Building Shell	Air Leakage Sealing	Residential	15	GDS[1457]
	Insulation – Hot Water and Steam Pipe	Residential	15	GDS[1458]
	Insulation – Opaque Shell	Residential	25	GDS[1459]
	Storm Window	Residential	20	DOE[1460]
	Window	Residential	20	DEER 2014 EUL ID: BS-Win
	Window - Film	Residential	10	DEER 2014 EUL ID: GlazDaylt-WinFilm
	Heat Pump Water Heater (HPWH)	Residential	10	DEER 2014 EUL ID: WtrHt-HtPmp
Domestic Hot Water (DHW)	Indirect Water Heater	Residential	11	DEER 2014 EUL ID: WtrHt-Res-Gas
	Storage Water Heater - Gas	Residential	15	PA Consulting Group[1461]
	Storage Water Heater - Electric	Residential	13	DEER 2014 EUL ID: WtrHt-Res-Elec
	Instantaneous Water Heater	Residential	20	DEER 2014 EUL ID: WtrHt-Instant-Res
	Solar Pool Heater	Residential	15	DOE[1462]

[1456] Average/typical manufacturer warranty period for AC covers
[1457] GDS Associates, Inc., Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures, June 2007, Table 1 – Residential Measures
[1458] Ibid.
[1459] Ibid.
[1460] https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-22864rev2.pdf
[1461] PA Consulting Group Inc., Focus on Energy Evaluation Business Programs: Measure Life Study, final report dated August 25, 2009. Available from: https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
[1462] https://www.energy.gov/energysaver/solar-swimming-pool-heaters

Category	Single and Multi-family Residential Measures	Sector	EUL (years)	Source
DHW - Control	Low-Flow – Faucet Aerator	Residential	10	DEER 2014 EUL ID: WtrHt-WH-Aertr
	Low-Flow – Showerhead	Residential	10	DEER 2014 EUL ID: WtrHt-WH-Shrhd
	Thermostatic Shower Restriction Valve	Residential	10	UPC[1463]
	Air Conditioner – Central (CAC)	Residential	15	DEER 2014 EUL ID: HV-ResAC
Heating, Ventilation and Air Conditioning (HVAC)	Air Conditioner – Room (RAC)	Residential	12	GDS[1464]
	Air Conditioner – PTAC	Residential	15	DEER 2014 EUL ID: HVAC-PTAC
	Boiler, Hot Water – Steel Water Tube	Residential	24	ASHRAE Handbook, 2015
	Boiler, Hot Water – Steel Fire Tube	Residential	25	ASHRAE Handbook, 2015
	Boiler, Hot Water – Cast Iron	Residential	35	ASHRAE Handbook, 2015
	Boiler, Steam – Steel Water Tube	Residential	30	ASHRAE Handbook, 2015
	Boiler, Steam – Steel Fire Tube	Residential	25	ASHRAE Handbook, 2015
	Boiler, Steam – Cast Iron	Residential	30	ASHRAE Handbook, 2015
	Boiler and Furnace - Combination (“Combi”) Boiler	Residential	22	DOE[1465]
	Boiler and Furnace - Combination (“Combi”) Furnace	Residential	20	DEER 2014[1466] EUL ID: HVAC-Frnc
	Duct Sealing and Insulation	Residential	18	DEER 2014 EUL ID: HV-DuctSeal
	Electronically Commutated (EC) Motor – HVAC Blower Fan	Residential	15	DEER 2014 EUL ID: Motors-fan
	Electronically Commutated (EC) Motor – Hydronic Circulator Pump	Residential	15	DEER 2014 EUL ID: Motors-pump

[1463] UPC certification under the International Association of Plumbing and Mechanical Officials standard IGC 244-2007a. A standard that includes a lifecycle test consisting of 10,000 cycles without fail. 10,000 cycles is the equivalent of three users showering daily for more than nine years.
[1464] GDS Associates, Inc., Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures, June 2007, Table 1 – Residential Measures
[1465] Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Furnaces, February 10, 2015, Table 8.2.17. Product definition of furnaces includes electric boilers with firing rates of less than 300,000 BTU/h
Available from: https://energy.mo.gov/sites/energy/files/technical-support-document---residential-furances_doe.pdf
[1466] Based on DEER value for high efficiency boiler and instantaneous water heater

Category	Single and Multi-family Residential Measures	Sector	EUL (years)	Source
Heating, Ventilation and Air Conditioning (HVAC)	Energy and Heat Recovery Ventilator	Residential	14	PA Consulting Group[1467]
	Furnace, Gas Fired	Residential	22	DOE[1468,1469]
	Gas Heat Pump	Residential	15	DEER 2014 EUL ID: HV-Res HP
	Heat Pump - Air Source (ASHP)	Residential	15	DEER 2014 EUL ID: HV-Res HP
	Heat Pump – Ground Source (GSHP)	Residential	25	ASHRAE[1470]
	Heat Pump – PTHP	Residential	15	DEER 2014 EUL ID: HVAC-PTHP
	Refrigerant Charge Correction & Tune-Up – Air Conditioner and Heat Pump	Residential	10	DEER 2014 EUL ID: HV-RefChrg
	Tune-Up - Boiler	Residential	5	DEER 2014 EUL ID: BlrTuneup
	Tune-Up - Furnace	Residential	5	DEER 2014 EUL ID: BlrTuneup
	Unit Heater, Gas Fired	Residential	13	ASHRAE Handbook, 2015
	Adaptive Photonic Control	Residential	EUL = Retrofitted motor RUL = Retrofitted motor EUL – (Current Year – Mfr. Year) **Default = 5**	DEER 2014 EUL ID: Motors-fan
HVAC - Control	Outdoor Temperature Setback Control for Hydronic Boiler	Residential	EUL = Boiler RUL = Boiler EUL – (Current Year – Mfr. Year) **Default = 5**	N/A

[1467] PA Consulting Group Inc., Focus on Energy Evaluation Business Programs: Measure Life Study, final report dated August 25, 2009. Available from: https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf

[1468] U.S. DOE. "Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Furnaces" and "Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Commercial Warm Air Furnaces." August 30, 2016. Available from: https://www.regulations.gov/document?D=EERE-2014-BT-STD-0031-0217

[1469] U.S. DOE. "Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Commercial Warm Air Furnaces." December 30, 2015. Available from: https://www.regulations.gov/document?D=EERE-2013-BT-STD-0021-0050

[1470] ASHRAE: Owning and Operating Cost Database, Equipment Life/Maintenance Cost Survey: https://xp20.ashrae.org/publicdatabase/system_service_life.asp?selected_system_type=1

Category	Single and Multi-family Residential Measures	Sector	EUL (years)	Source
HVAC - Control	Steam Trap – Low Pressure Space Heating	Residential	6	DEER 2014 EUL ID: HVAC-StmTrp
	Submetering	Multifamily	10	NYSERDA[1471]
	Thermostat – All Types	Residential	11	DEER 2014 EUL ID: HVAC-ProgTStats
	Thermostatic Radiator Valve – One Pipe Steam Radiator	Multifamily	15	DOE[1472]
	Smart Thermostatic Radiator Enclosure	Residential	15	DEER 2014 EUL ID: Motors-fan[1473]
	LED Lamp	Residential	Rated Life listed by ENERGY STAR® or default to 15,000 hrs/ annual lighting operating hrs or 15 yrs if rated lifetime or annual operating hours are not known	ENERGY STAR® Lamps[1474]
Lighting	LED Lamp Light Fixture	Residential LED (Interior)	50,000 hours	DLC[1475]
			Residential	Rated Life listed by ENERGY STAR or default to 25,000 hrs/ annual lighting operating hrs or 15 yrs if rated lifetime or annual operating hours are not known

[1471] NYSERDA Residential Electric Submetering Manual
[1472] U.S. DOE, "Thermostatic Radiator Valve Evaluation", January 2015, Table 4. pg. 16
[1473] Based on assumed EUL of integrated fan, which is expected to be the first component to fail
[1474] ENERGY STAR® Program Requirements Product Specification for Lamps (Light Bulbs) V2.1, June 2017, p. 19 (Capped at 20 years). https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V2.1%20Final%20Specification.pdf
[1475] Placed on the Qualified Products List by the Design Light Consortium (DLC) 50,000 hours, according to the appropriate Application Category as specified in the DLC's Product Qualification Criteria, Technical Requirement Table version 4.4 or higher

Category	Single and Multi-family Residential Measures		Sector	EUL (years)	Source
Lighting	Light Fixture Bi-Level Lighting	LED (Exterior)	Residential	Rated Life listed by ENERGY STAR or default to 35,000 hrs/ annual lighting operating hrs or 15 yrs if rated lifetime or annual operating hours are not known	ENERGY STAR® Fixtures[1476]
		LED (Inseparable)	Residential	Rated Life listed by ENERGY STAR or default to 50,000 hrs/ annual lighting operating hrs or 15 yrs if rated lifetime or annual operating hours are not known	ENERGY STAR® Fixtures
		Multifamily Common Area	15	ComEd[1477]	ENERGY STAR® Fixtures
Lighting Control	Pool Pump		Residential	10	DEER 2014 EUL ID: OutD-PoolPump
Motors and Drives	Pool Circulator Timer		Residential	10	DEER 2014 EUL ID: OutD-PoolPump
	Heat Pump Pool Heater		Residential	15	DEER 2014 EUL ID: HV-Res HP
Other	Pool Heater		Residential	8	DOE[1478]
	Solar Pool Heater		Residential	15	DOE[1479]

[1476] ENERGY STAR® Program Requirements Product Specification for Luminaires (Light Fixtures) V2.2, August 2019, p. 18 (Capped at 20 years).
https://www.energystar.gov/sites/default/files/Luminaires%20V2.2%20Final%20Specification.pdf
[1477] ComEd Luminaire Level Lighting Control IPA Program Impact Evaluation Report prepared by Navigant Available from:
http://ilsagfiles.org/SAG_files/Evaluation_Documents/ComEd/ComEd_EPY9_Evaluation_Reports_Final/ComEd_PY9_LLLC_IPA_Program_Impact_Evaluation_Report_2018-06-05_Final.pdf
[1478] DOE, Chapter 8, Life-Cycle Cost and Payback Period Analyses, Table 8.75 Available from:
https://www.regulations.gov/document?D=EERE-2006-STD-0129-0170
[1479] https://www.energy.gov/energysaver/solar-swimming-pool-heaters

COMMERCIAL AND INDUSTRIAL MEASURES

Category	Commercial & Industrial Measures	Sector	EUL (years)	Source
Agricultural Equipment	High Speed Fans	C&I	10	PG&E[1480]
	Milk Pre-Cooler Heat Exchanger	C&I	15	PA Consulting Group[1481]
	Refrigeration Heat Recovery	C&I	14	DEER 2014 EUL ID: HVAC-ChlrComp-Ag
	Scroll Compressor	C&I	12	DEER 2014 EUL ID: RefgWrhs-ScrollComp
Agricultural Equipment - Control	Engine Block Heater Timer	C&I	8	See note below[1482]
	Variable Speed Drive Milk Pump Plate Cooler	C&I	15	PA Consulting Group[1483]
	Variable Speed Drive Vacuum Pump	C&I	15	PA Consulting Group[1484]
Appliance	Clothes Dryer	C&I	14	ENERGY STAR®M&I Report[1485]
	Clothes Washer	C&I	11	DEER 2014 EUL ID: Appl-EffCW
	Cooking Equipment[1486]	C&I	12	DEER 2014 EUL IDs: Various
	Dishwasher	C&I	10 – Under Counter 15 – Single Door 20 – Conveyor Type 10 – Pots, Pans & Utensils	ENERGY STAR®Calc[1487]
	Ice Maker	C&I	10	DEER 2014 EUL ID: Cook-IceMach
	Refrigerator and Freezer	C&I	12	DEER 2014 EUL ID: Cook-SDRef
Appliance - Control	Advanced Power Strip (APS)	C&I	8	DEER 2014 EUL ID: Plug-OccSens
	Vending Machine and Novelty Cooler Control	C&I	5	DEER 2014 EUL ID: Plug-VendCtrler

[1480] PG&E Work Paper PGE3PAGR117, October 12, 2017
[1481] PA Consulting Group Inc., Focus on Energy Evaluation Business Programs: Measure Life Study, final report dated August 25, 2009. Available from: https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
[1482] Based on EUL's for Advanced Power Strips
[1483] PA Consulting Group Inc., Focus on Energy Evaluation Business Programs: Measure Life Study, final report dated August 25, 2009. Available from: https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
[1484] PA Consulting Group Inc., Focus on Energy Evaluation Business Programs: Measure Life Study, final report dated August 25, 2009. Available from: https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
[1485] ENERGY STAR® Market & Industry Scoping Report: Residential Clothes Dryer, November 2011.
[1486] Applicable to all kitchen cooking equipment not otherwise listed
[1487] ENERGY STAR® Savings Calculator for ENERGY STAR® Certified Commercial Kitchen Equipment www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx?5da4-3d90&5da4-3d90

Category	Commercial & Industrial Measures	Sector	EUL (years)	Source
Appliance Recycling	Air Conditioner – Room (RAC)	C&I	9	DEER 2014 EUL ID: HV-RAC-ES
Building Shell	Air Leakage Sealing	C&I	15	GDS[1488]
	Cool Roof	C&I	15	DEER 2014 EUL ID: BldgEnv-CoolRoof
	Insulation - Hot Water and Steam Pipe	C&I	15	GDS[1489]
	Insulation - Opaque Shell	C&I	30	ET & CEC[1490]
	Window - Film	C&I	10	DEER 2014 EUL ID: GlazDaylt-WinFilm
	Window - Glazing	C&I	20	DEER 2014 EUL ID: BS-Win
	Air Curtains	C&I	15	DEER 2014 EUL ID: Motors-fan
Compressed Air	Air Compressor	C&I	13	Other State TRMs[1491]
	Engineered Air Nozzle	C&I	15	Wisconsin PSC[1492]
	No Air Loss Water Drain	C&I	13	MA Measure Life Study[1493]
	Refrigerated Air Dryer	C&I	13	Other State TRMs [1494]
	Compressed Air Heat Recovery	C&I	13	Other State TRMs [1495]
	Flow Controller	C&I	13	Other State TRMs [1496]
	Low Pressure Drop Filter	C&I	5	Other State TRMs [1497]
Domestic Hot Water (DHW)	Heat Pump Water Heater (HPWH)	C&I	10	DEER EUL ID: WtrHt-HtPmp
	Indirect Water Heater	C&I	15	DEER 2014 EUL ID: WtrHt-Com
	Instantaneous Water Heater	C&I	20	DEER 2014 EUL ID: WtrHt-Instant-Com
	Storage Tank Water Heater	C&I	15	DEER 2014 EUL ID: WtrHt-Com

[1488] GDS Associates, Inc., Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures, June 2007, Table 1 – Residential Measures
[1489] GDS Associates, Inc., Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures, June 2007, Table 1 – Residential Measures
[1490] Energy Trust uses 30 years for commercial applications. CEC uses 30 years for insulation in Title 24 analysis.
[1491] Based on a review of TRM assumptions from Ohio (August 2010), Massachusetts (October 2015), Illinois (February 2017) and Vermont (December 2018). Estimates range from 10 to 15 years.
[1492] PA Consulting Group (2009). *Business Programs: Measure Life Study*. Prepared for State of Wisconsin Public Service Commission
[1493] Measure Life Study prepared for The Massachusetts Joint Utilities, Energy & Resource Solutions, 2005 http://www.ers-inc.com/wp-content/uploads/2018/04/Measure-Life-Study_MA-Joint-Utilities_ERS.pdf
[1494] Based on a review of TRM assumptions from Ohio (August 2010), Massachusetts (October 2015), Illinois (February 2017) and Vermont (December 2018). Estimates range from 10 to 15 years.
[1495] Ibid.
[1496] Ibid.
[1497] Ibid.

Category	Commercial & Industrial Measures	Sector	EUL (years)	Source
DHW - Control	Drain Water Heat Recovery (DWHR)	C&I	30	2019 Title 24[1498]
	Low-Flow – Faucet Aerator	C&I	10	DEER 2014 EUL ID: WtrHt-WH-Aertr
	Low-Flow – Pre-Rinse Spray Valve (PRSV)	C&I	5	GDS
	Low-Flow – Salon Valve	C&I	10	DEER 2014 EUL ID: WtrHt-WH-Shrhd
	Low-Flow – Showerhead	C&I	10	DEER 2014 EUL ID: WtrHt-WH-Shrhd
	Central DHW Control	C&I	15	NREL[1499]
Heating, Ventilation and Air Conditioning (HVAC)	Air Conditioner – PTAC	C&I	15	DEER 2014 EUL ID: HVAC-PTAC
	Air Conditioner – Unitary	C&I	15	DEER 2014 EUL ID: HVAC-airAC
	Boiler and Furnace - Combination ("Combi") Boiler	C&I	22	DOE[1500]
	Boiler and Furnace - Combination ("Combi") Furnace	C&I	20	DEER 2014[1501] EUL ID: HVAC-Frnc
	Boiler, Hot Water – Steel Water Tube	C&I	24	ASHRAE Handbook, 2015
	Boiler, Hot Water – Steel Fire Tube	C&I	25	ASHRAE Handbook, 2015
	Boiler, Hot Water – Cast Iron	C&I	35	ASHRAE Handbook, 2015
	Boiler, Steam – Steel Water Tube	C&I	30	ASHRAE Handbook, 2015
	Boiler, Steam – Steel Fire Tube	C&I	25	ASHRAE Handbook, 2015
	Boiler, Steam – Cast Iron	C&I	30	ASHRAE Handbook, 2015
	Chiller – Air & Water Cooled	C&I	20	DEER 2014 EUL ID: HVAC-Chlr
	Chiller – Cooling Tower	C&I	15	DEER 2014 EUL ID: HVAC-ClTwrPkgSys
	Condensing Unit Heater	C&I	18	Ecotope[1502]
	Duct Sealing and Insulation	C&I	18	DEER 2014 EUL ID: HVAC-DuctSeal
	Electronically Commutated (EC) Motor - HVAC Blower Fan	C&I	15	DEER 2014 EUL ID: Motors-Fan

[1498] 2019 Title 24, Part 6 CASE Report. "Drain Water Heat Recovery – Final Report." Available from: http://title24stakeholders.com/wp-content/uploads/2017/09/2019-T24-CASE-Report_DWHR_Final_September-2017.pdf
[1499] https://www.nrel.gov/docs/fy16osti/64541.pdf
[1500] Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Furnaces, February 10, 2015, Table 8.2.17
Available from: https://energy.mo.gov/sites/energy/files/technical-support-document---residential-furances_doe.pdf
[1501] Based on DEER value for high efficiency boiler and instantaneous water heater
[1502] Ecotope Natural Gas Efficiency and Conservation Measure Resource Assessment (2003)

Category	Commercial & Industrial Measures	Sector	EUL (years)	Source
Heating, Ventilation and Air Conditioning (HVAC)	Electronically Commutated (EC) Motor – Hydronic Circulator Pump	C&I	15	DEER 2014 EUL ID: Motors-pump
	Economizer –Dual Enthalpy Air Side	C&I	10	DEER 2014 EUL ID: HVAC-addEcono
	Furnace, Gas Fired	C&I	23	DOE[1503,1504]
	Gas Heat Pump	C&I	15	DEER 2014 EUL ID: HV-Res HP
	Heat Pump – Unitary & Applied	C&I	15	DEER 2014 EUL ID: HVAC-airHP
	Heat Pump – PTHP	C&I	15	DEER 2014 EUL ID: HVAC-PTHP
	Heat Pump – Water Source (WSHP)	C&I	25	ASHRAE[1505]
	High Volume Low Speed Fan	C&I	15	PA Consulting Group[1506]
	Infrared Heater	C&I	17	GDS[1507]
	Refrigerant Charge Correction & Tune Up – Air Conditioner and Heat Pump	C&I	10	DEER 2014 EUL ID: HVAC-RefChg
	Tune-Up – Boiler	C&I	5	DEER 2014 EUL ID: BlrTuneup
	Tune-Up – Chiller System	C&I	5	WI EUL DB[1508]
	Tune-Up – Furnace	C&I	5	DEER 2014 EUL ID: BlrTuneup
	Variable Refrigerant Flow (VRF) System	C&I	15	DEER 2014 EUL ID: HVAC-VSD-pump
	Unit Heater, Gas Fired	C&I	13	ASHRAE Handbook, 2015

[1503] U.S. DOE. "Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Furnaces" and "Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Commercial Warm Air Furnaces." August 30, 2016. Available from: https://www.regulations.gov/document?D=EERE-2014-BT-STD-0031-0217

[1504] U.S. DOE. "Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Commercial Warm Air Furnaces." December 30, 2015. Available from: https://www.regulations.gov/document?D=EERE-2013-BT-STD-0021-0050

[1505] ASHRAE Owning and Operating Cost Database
Available from: https://xp20.ashrae.org/publicdatabase/system_service_life.asp?selected_system_type=1

[1506] PA Consulting Group Inc., Focus on Energy Evaluation Business Programs: Measure Life Study, final report dated August 25, 2009. Available from: https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf

[1507] GDS Associates, Inc. "Natural Gas Efficiency Potential Study." DTE Energy. July 29, 2016. Available from: https://www.michigan.gov/documents/mpsc/DTE_2016_NG_ee_potential_study_w_appendices_vFINAL_554360_7.pdf

[1508] Wisconsin Public Service Commission: Equipment Useful Life Database, 2013
Excerpt available from: https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf

Category	Commercial & Industrial Measures	Sector	EUL (years)	Source
HVAC – Control	Adaptive Photonic Control	C&I	EUL = Retrofitted motor RUL = Retrofitted motor EUL – (Current Year – Mfr. Year) **Default = 5**	DEER 2014 EUL ID: Motors-fan
	Direct Digital Control (DDC) System	C&I	15	DEER 2014 EUL ID: HVAC-EMS
	Demand Control Ventilation (DCV)	C&I	15	DEER 2014 EUL ID: HVAC-VSD-DCV
	Energy Management System	C&I	15	DEER 2014 EUL ID: HVAC-EMS
	Energy Management System – Guest Room	C&I	15	DEER 2014 EUL ID: HVAC-EMS
	Boiler Economizer	C&I	EUL = Boiler RUL = Boiler EUL – (Current Year – Mfr. Year) **Default = 5**	GDS[1509]
	Kitchen Demand Ventilation Control	C&I	15	PG&E[1510]
	Outdoor Temperature Setback Control for Hydronic Boiler	C&I	EUL = Boiler RUL = Boiler EUL – (Current Year – Mfr. Year) **Default = 5**	N/A
	Steam Trap – Low-Pressure Space Heating	C&I	6	DEER 2014 EUL ID: HVAC-StmTrp
	Thermostat – Programmable Thermostat – Wi-Fi (Communicating)	C&I	11	DEER 2014 EUL ID: HVAC-ProgTStats
	Thermostatic Radiator Valve	C&I	15	DOE[1511]
	Advanced Rooftop Control	C&I	EUL = RUL of Existing RTU = RTU EUL – (Current Year – Year of Mfr.) **Default = 5**	N/A

[1509] Natural Gas Energy Efficiency Potential in Massachusetts, GDS Associates, 2009. Available from: http://ma-eeac.org/wordpress/wp-content/uploads/5_Natural-Gas-EE-Potenial-in-MA.pdf
[1510] PG&E Work Paper WPSDGENRCC0019, June 15, 2012
[1511] U.S. DOE. "Thermostatic Radiator Valve Evaluation." January 2015. Available from: https://www.nrel.gov/docs/fy15osti/63388.pdf

Category	Commercial & Industrial Measures		Sector	EUL (years)	Source
Lighting	Light Fixture	LED Fixture (DLC)	C&I	50,000 hrs /annual lighting operating hrs or 15 yrs if annual operating hrs are not known	DLC[1512]
	Light Fixture	LED Fixture (Interior)	C&I	Rated Life listed by ENERGY STAR or default to 25,000 hrs/annual lighting operating hrs or 15 yrs if rated lifetime or annual operating hrs are not known	ENERGY STAR®[1513]
		LED Fixture (Exterior)	C&I	Rated Life listed by ENERGY STAR or default to 35,000 hrs/annual lighting operating hrs or 15 yrs if rated lifetime or annual operating hrs are not known	ENERGY STAR®[1514]
		LED Fixture (Inseparable)	C&I	Rated Life listed by ENERGY STAR or default to 50,000/annual lighting operating hrs or 15 yrs if rated lifetime or annual operating hrs are not known	ENERGY STAR®[1515]
		LED Fixture (Uncertified)	C&I	Rated Life listed by ENERGY STAR or default to 25,000 hrs /annual lighting operating hrs or 15 yrs if rated lifetime or annual operating hrs are not known	Uncertified

[1512] 50,000 hours per L_{70} requirements prescribed by the DLC's Product Qualification Criteria, Technical Requirement Table version 4.4

[1513] Placed on the Qualified Fixture List by ENERGY STAR®, according to the appropriate luminaire classification as specified in the ENERGY STAR® Program requirements for Luminaires, version 2.1. Divided by estimated annual use, but capped at 20 years regardless (consistent with C&I redecoration and business type change patterns

[1514] Placed on the Qualified Fixture List by ENERGY STAR®, according to the appropriate luminaire classification as specified in the ENERGY STAR® Program requirements for Luminaires, version 2.1. Divided by estimated annual use, but capped at 20 years regardless (consistent with C&I redecoration and business type change patterns

[1515] Placed on the Qualified Fixture List by ENERGY STAR®, according to the appropriate luminaire classification as specified in the ENERGY STAR® Program requirements for Luminaires, version 2.1. Divided by estimated annual use, but capped at 20 years regardless (consistent with C&I redecoration and business type change patterns

Category	Commercial & Industrial Measures	Sector	EUL (years)	Source
Lighting	LED Lamp	C&I	50,000 hours	DLC[1516]
			Rated Life listed by ENERGY STAR or default to 15,000 hrs /annual lighting operating hrs or 15 yrs if rated lifetime or annual operating hrs are not known	ENERGY STAR®
	Refrigerated Case LED	C&I	16	DEER 2014 EUL ID: GrocDisp-FixtLtg-LED
	Lighting Power Density (LPD)	C&I	15	GDS[1517]
Lighting - Control	Bi-Level Lighting	C&I	15	ComEd[1518]
	Integrated Interior Lighting Control	C&I	15	ComEd[1519]
	Non-Integrated Interior Lighting Control	C&I	10	GDS[1520]
	Plug-Load Occupancy Sensor	C&I	8	DEER[1521]
Motors and Drives	Motor (incl. PEI Pumps)	C&I	15	DEER 2014 EUL ID: Motors-HiEff
	Notched & Synchronous Belt	C&I	5	DEER 2014 EUL ID: HV-CoggedBelt
	Pool Pump	C&I	10	DEER 2014 EUL ID: OutD-PoolPump
	Variable Frequency Drive (VFD) – Fan and Pump	C&I	15	DEER 2014 EUL ID: HVAC-VSDSupFan
	Elevator Modernization	C&I	15	DEER 2014[1522]

[1516] Placed on the Qualified Products List by the Design Light Consortium (DLC) 50,000 hours, according to the appropriate Application Category as specified in the DLC's Product Qualification Criteria, Technical Requirement Table version 4.4 or higher

[1517] Measure Life Report, Residential and Commercial/Industrial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007. As directed in the Interior and Exterior Lighting measure, new construction projects may be evaluated based on LPD. This value is provided for use with new construction LPD projects only.
Available from: https://energy.mo.gov/sites/energy/files/measure-life-report-2007.pdf

[1518] ComEd Luminaire Level Lighting Control IPA Program Impact Evaluation Report prepared by Navigant
Available from:
http://ilsagfiles.org/SAG_files/Evaluation_Documents/ComEd/ComEd_EPY9_Evaluation_Reports_Final/ComEd_PY9_LLLC_IPA_Program_Impact_Evaluation_Report_2018-06-05_Final.pdf

[1519] ComEd Luminaire Level Lighting Control IPA Program Impact Evaluation Report prepared by Navigant
Available from:
http://ilsagfiles.org/SAG_files/Evaluation_Documents/ComEd/ComEd_EPY9_Evaluation_Reports_Final/ComEd_PY9_LLLC_IPA_Program_Impact_Evaluation_Report_2018-06-05_Final.pdf

[1520] Measure Life Report, Residential and Commercial/Industrial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.
Available from: https://energy.mo.gov/sites/energy/files/measure-life-report-2007.pdf

[1521] DEER value for lighting occupancy sensors

[1522] Assumes same EUL as VFD measure.

Category	Commercial & Industrial Measures	Sector	EUL (years)	Source
Other	Heat Pump Pool Heater	C&I	15	DEER 2014 EUL ID: HV-Res HP
	High Efficiency Transformer	C&I	32	DOE[1523]
	High Frequency Battery Charger	C&I	15	PG&E[1524]
	High Viscosity Industrial Lubricant	C&I	10	ExxonMobil
	Pool Heater	C&I	8	DOE[1525]
	Solar Pool Cover	C&I	5	CALMAC[1526]
Process Equipment	Steam Trap – Other Applications	C&I	6	DEER 2014 EUL ID: HVAC-StmTrp
	Ozone Laundry	C&I	10	PG&E[1527]
	Process Exhaust Filtration	C&I	15	CIBSE[1528]
Refrigeration	Air-Cooled Refrigeration Condenser	C&I	15	DEER 2014 EUL ID: GrocSys-Cndsr
	Automatic Door Closer for Walk-In Cooler/Freezer	C&I	8	DEER 2014 EUL ID: GrocWlkIn-DrClsr
	Cooler and Freezer Door Gasket	C&I	4	DEER 2014 EUL ID: GrocWlkIn-StripCrtn, GrocWlkIn-WDrGask
	Cooler and Freezer Door Strip	C&I	4	DEER 2014 EUL ID: GrocWlkIn-StripCrtn, GrocWlkIn-WDrGask
	EC Motor – Refrigerated Case or Walk-In Cooler/Freezer Evaporator Fan	C&I	15	DEER 2014 EUL ID: GrocDisp-FEvapFanMtr
	Equipment (Condenser, Compressor, and Sub-cooling)	C&I	15	DEER 2014 EUL ID: GrocSys-MechSubcl
	Evaporator Fan Motor – with Permanent Magnet Synchronous Motor (PMSM)	C&I	15	DEER 2014 EUL ID: GrocDisp-FEvapFanMtr
	Refrigerated Case Door	C&I	12	DEER 2014 EUL ID: GrocDisp-FixtDoors
	Refrigerated Case Night Cover	C&I	5	DEER 2014 EUL ID: GrocDisp-DispCvrs

[1523] https://www.federalregister.gov/documents/2019/06/18/2019-12761/energy-conservation-program-energy-conservation-standards-for-distribution-transformers
[1524] https://www.kannahconsulting.com/wp-content/uploads/2016/08/2010-10-11_Battery_Charger_Title_20_CASE_Report_v2-2-2.pdf, pg 43
[1525] DOE, Chapter 8, Life-Cycle Cost and Payback Period Analyses, Table 8.75 Available from: https://www.regulations.gov/document?D=EERE-2006-STD-0129-0170
[1526] http://www.calmac.org/publications/PoolCoverReport_2015_Final_Report_Appendices.pdf
[1527] PG&E Work Paper PGECOAPP123, August 22, 2017
[1528] Chartered Institution of Building Services Engineers. "Probabilistic Estimation of Service Life." An industrial ventilation system consists of a fan and a set of filters; Fan and Filter EUL are 15 to 20 years depending on type. http://www.cibse.org/knowledge/cibse-technical-symposium-2011/probabilistic-estimation-of-service-life.

Category	Commercial & Industrial Measures	Sector	EUL (years)	Source
Refrigeration - Control	Anti-Condensation Heater Control	C&I	12	DEER 2014 EUL ID: GrocDisp-ASH
	Condenser Pressure and Temperature Control	C&I	15	DEER 2014 EUL ID: GrocSys-Cndsr
	Evaporator Fan Control	C&I	16	DEER 2014 EUL ID: Groc-WlkIn-WEvapFMtrCtrl
	Floating Head Pressure Control	C&I	10	PA Consulting Group [1529]

Common References

1. DEER 2014 EUL
   Available from:
   http://www.deeresources.com/files/DEER2013codeUpdate/download/DEER2014-EUL-table-update_2014-02-05.xlsx
2. GDS Associates, Inc., Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures, June 2007
   Available from:
   https://library.cee1.org/system/files/library/8842/CEE_Eval_MeasureLifeStudyLights%2526HVACGDS_1Jun2007.pdf

Record of Revision

Record of Revision Number	Issue Date
EUL's originally listed in July 18, 2011 Order	7/18/2011
Additional EUL's posted on web site	Subsequent to 7/18/2011 Order
7-13-28	7/31/2013
6-14-1	6/19/2014
6-14-2	6/19/2014
6-15-4	6/1/2015
6-16-2	6/30/2016
1-17-8	12/31/2016
6-17-16	6/30/2017
9-17-11	9/30/2017
12-17-17	12/31/2017
3-18-21	3/31/2018
6-18-23	6/30/2018
9-18-21	9/30/2018
12-18-17	12/28/2018
3-19-16	3/29/2019
6-19-14	6/30/2019
9-19-10	9/30/2019

[1529] PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study. Final Report." August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf

Record of Revision Number	Issue Date
12-19-17	12/23/2019
3-20-17	3/30/2020
7-20-20	7/31/2020
12-20-12	12/31/2020
3-21-18	3/31/2021
7-21-21	8/30/2021

Return to Table of Contents

APPENDIX Q

PEAK LOAD SHAPE FACTORS

NATURAL GAS

The peak gas definition is based on the program-induced change in the average daily gas flow in which the distribution system, on average, reaches its pumping/consumption capacity such that as the temperature falls lower (or the heating degree days go higher) gas consumption does not increase. Setting the peak gas definition for this condition means that the gas peak is calculated to reflect the decreased cubic feet of natural gas expected to not flow through the distribution system during the 24-hour period as a result of the impacts of the gas energy efficiency program.

NATURAL GAS PEAK SAVINGS DEFINITION

Up State: The number of therms saved during a day, a 24 hour period starting at 10:00AM, in which the average temperature is minus nine -9°F (-22.8 ^{o}C).

Downstate: The number of therms saved during a day, a 24 hour period starting at 10:00AM, in which the average temperature is zero^{o}F (-17.8^{o}C).

PEAK-DAY GAS IMPACT CALCULATION METHODOLOGY

A peak day gas demand impact methodology was created to convert annual energy savings to peak day gas demand reductions.

1. Define the statewide peak period
2. Extract the load shape curves for each customer segment, building type and equipment end-use type
3. Compute ratios of gas consumption during this peak period to gas consumption throughout the entire year (i.e. "peak load shape factors")

Hourly load shapes were developed for each hour of the year (8,760 hours total). A load shape provides the hourly percentage of annual load for a specific end use, meaning that the sum of hourly fractions over one year will result in one therm of gas energy consumption. These load shapes leverage the United States Department of Energy (DOE) residential and commercial prototypical models and are categorized by customer segment and equipment end-use type (i.e. total facility, heating, hot water, and interior equipment). Each energy efficiency measure within each program was assigned to one of these load shapes.

Peak load shape factors for the winter peak period were then calculated using the formula**:**

$$\boldsymbol{Peak\ Load\ Shape\ Factor = \sum_{i}^{n} Hourly\ Fractional\ Load_i}$$

$$\boldsymbol{PLSF = HFL_{Hour\ 1} + HFL_{Hr\ 2} + HFL_{Hr\ 3} + HFL_{Hr\ 4} \ldots + HFL_{Hr\ 23} + HFL_{Hr\ 24}}$$

where i = the hour during peak period for n hours

The proxy winter peak period definition was determined to be the 24 hours starting 10:00 AM February 19th, 2015 to 10:00 AM February 20th, 2015, a Thursday and Friday respectively, but implemented using TMY3 weather file. This results in 1 day (or 24 hours) of winter peak period.

The sum of the hourly fractional load during these hours, taken from the appropriate customer segment and equipment end-use type load shape, multiplied by the annual therms savings for a particular energy efficiency measure, will equal the peak day gas demand impact. Said in another way, PLSF/1, or simply the PLSF, is equal to the percentage of a measure's energy savings that occur on a single peak day.

$$\boldsymbol{Peak\ Day\ Impact\ Savings} = \frac{\boldsymbol{Peak\ Load\ Shape\ Factor\ \times\ Annual\ Therm\ Savings}}{\boldsymbol{Peak\ Period\ Days}}$$

The PLSF value is assigned based on Building Segment & End-Use Category in the following table:

Peak Load Shape Factors – Con Ed				
Building Segment	**Total Facility (Gas)**	**Heating (Gas)**	**Hot Water (Gas)**	**Interior Equipment (Gas)**
Single Family - Res	0.0202	0.0272	0.0033	-
Small Multi-Family - Res	0.0202	0.0272	0.0033	-
Large Multi-Family - Res	0.0202	0.0272	0.0033	-
NYPA - Res	0.0202	0.0272	0.0033	-
Large Office	0.0130	0.0131	0.0042	-
Small Office	0.0130	0.0131	0.0042	-
Restaurant	0.0089	0.0159	0.0034	0.0027
Large Retail	0.0188	0.0188	-	-
Small Retail	0.0192	0.0192	-	-
Grocery	0.0130	0.0138	0.0030	0.0027
Warehouse/Industrial	0.0245	0.0245	-	-
Education	0.0159	0.0164	0.0050	0.0036
Hospital	0.0067	0.0073	0.0035	0.0027
Nursing Home/Lodging	0.0040	0.0090	0.0034	0.0027
Miscellaneous/Entertainment	0.0100	0.0176	0.0033	0.0027
Multi-Family - Common Area	0.0420	0.0420	0.0033	-
NYPA – Com	0.0130	0.0131	0.0042	-
Boiler EMS Impact Load Shape – Res	-	0.0082	-	-
Smart Thermostat Impact Load Shape - Res	-	0.0070	-	-

References

1. Navigant Gas Peak Day Analysis Memo - May 23, 2019
   Available from:
   http://documents.dps.ny.gov/public/MatterManagement/MatterFilingItem.aspx?FilingSeq=264172&MatterSeq=48457

Record of Revision

Record of Revision Number	Issue Date
7-21-25	8/30/2021

Return to Table of Contents

FORMS

TYPICAL MEASURE HEADINGS

Measure Name _____

Measure Description _____

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$\Delta kWh = units \times (savings\ equation)$

Summer Peak Coincident Demand Savings

$\Delta kW = units \times (savings\ equation) \times CF$

Annual Fossil Fuel Energy Savings

$\Delta MMBtu = units \times (savings\ equation)$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
CF	= Coincidence factor

Summary of Variables and Data Sources

Variable	Value	Notes

Coincidence Factor (CF)

The prescribed value for the coincidence factor is _____

Baseline Efficiencies from which Energy Savings are Calculated

_____

Compliance Efficiency from which Incentives are Calculated

_____

Operating Hours

_____

Effective Useful Life (EUL)

Years: _____

Source: _____

Ancillary Fossil Fuel Savings Impacts

_____

Ancillary Electric Savings Impacts

_____

References

1. _____

Record of Revision (example)

Record of Revision Number	Issue Date
(example) 8-26-2014	(example) 8/29/2014

Record of Revision

Record of Revision Number	Issue Date
0	12/10/2014

Return to Table of Contents

GLOSSARY

ABBREVIATIONS, ACRONYMS, AND EQUATION VARIABLES	
$\overline{COP}$	Average coefficient of performance
$\overline{\Delta T}$	Average temperature difference
$\overline{EER}$	Seasonal average energy efficiency ratio over the cooling season BTU/watt-hour, (used for a particular climate/building)
ΔkW	Peak coincident demand electric savings
ΔkWh	Annual electric energy savings
ΔMMBtu	Annual fossil fuel energy savings
ΔH_{vap}	Heat of vaporization (latent heat), in BTU/lb, at system operating pressure (psig)
ΔP	Pressure drop at nominal airflow
ΔQ	Heat difference/loss
ΔR	Difference in R-value between cellulose insulation and existing insulation
ΔT	Temperature difference
Δ	Change, difference, or savings
A	Amperage
AC	Air conditioning
ACCA	Air Conditioning Contractors of America
ACEEE	American Council for an Energy-Efficient Economy
ACL	Actual cooling load (BTU/h) based on Manual J calculation
ACH	Air change per hour
AFUE	Annual fuel utilization efficiency, seasonal energy efficiency for fuel heating equipment
AHAM	Association of Home Appliance Manufacturers
AHL	Actual heating load (BTU/h) based on Manual J calculation
AHRI	Air Conditioning Heating and Refrigeration Institute
AHU	Air handling unit
AIA	American Institute of Architects
AIR_{loss}	Air loss percentage in a compressed air line
ANSI	American National Standards Institute
APU	Auxiliary power unit
area	Extent of space or surface
ARI	Air-Conditioning & Refrigeration Institute
ARRA	American Recovery and Reinvestment Act of 2009
ASHP	Air source heat pump
ASHRAE	American Society of Heating, Refrigeration, and Air Conditioning Engineers

EnergyPlus™	Whole building energy simulation program that engineers, architects, and researchers use to model both energy consumption—for heating, cooling, ventilation, lighting and plug and process loads—and water use in buildings.
HPRXML	Heat Pump Ready eXtensible Markup Language
HES	Home Energy Score
HPXML	Home Performance eXtensible Markup Language
Manual J8	The 8th edition of Air Conditioning Contractors of America's (ACCA) residential HVAC heating and cooling load calculation method.
NEEP ccASHP Database	Northeast Energy Efficiency Partnerships Cold Climate Heat Pump Database
OpenStudio®	Cross-platform (Windows, Mac, and Linux) collection of software tools to support whole building energy modeling using EnergyPlus™ and advanced daylight analysis using Radiance. OpenStudio® is an open source (LGPL) project to facilitate community development, extension, and private sector adoption of new energy modeling tools and data standards.
Realization Rate	The rate of actual observed savings from a measure or measures against the estimated savings of the same measure calculated during submission of the project.
Typical meteorological year edition 3 (TMY3)	A collection of standardized meteorological data at an hourly level derived from 1020 weather sites across the U.S. from a sampling period of 1991-2005.
baseline	Characteristic of baseline condition
BLDC	Brushless DC electric motor
BG&E	Baltimore Gas and Electric
BTU	British Thermal Unit
BTU/h	British Thermal Units per hour
CAC	Central air conditioner
CADR	Clean Air Delivery Rate (CFM)
Capacity	Cooling output rating, in BTU/h
CAV	Constant air volume
CBECS	Commercial Buildings Energy Consumption Survey

CDD	Cooling degree days - The number of degrees that a day's average temperature is above some baseline temperature, which represents the temperature above which buildings need to be cooled. The baseline temperature is typically 65°F, but may vary based on application.
CEC	State of California Energy Commission
CEE	Consortium for Energy Efficiency
CEF	Combined energy factor (lb/kWh)
CEER	Combined Energy Efficiency Ratio
CF	Coincidence factor
CFL	Compact fluorescent lamp
CFM	Cubic foot per minute
CFM/watt	Ventilating efficiency ratio, rated at 0.01’’ static pressure in cubic feet per minute per watt
CHW	Chilled water
CHWP	Chilled water pump
CLH	Cooling load hours
CM	Case motor
CMU	Concrete masonry
$Comp_{eff}$	Efficiency of the cooler/freezer compressor (kW/Ton)
COP	Coefficient of performance, ratio of output energy/input energy
cows	Number of milking cows on farm
CR	Collector Rating (Btu/ft^2-day)
CV	Constant volume
CW	Condenser water
CWP	Condenser water pump
Cycle	Compressor duty cycle
$Cycles_{annual}$	Number of dryer cycles per year
D	Demand
days	Number of operating days per year
DC	Direct current
DCV	Demand controlled ventilation
DEER	Database for Energy Efficiency Resources, California
DF	Demand diversity factor
DFP	Default functional period
DHW	Domestic hot water
Dia	Diameter
DLC	DesignLights Consortium®
DOAS	Dedicated outdoor air system
DOE 2.2	US DOE building energy simulation, and cost calculation tool
DPS	Department of Public Service, New York State
DSF	Demand savings factor
DWHR	Drain Water Heat Recovery
DX	Direct expansion
ECCC NYC	Energy Conservation Construction Code of New York City

ECCC NYS	Energy Conservation Construction Code of New York State
EC	Electronically commutated
Econ	Economizer
Ecotope	Ecotope Consulting, Redlands, CA
ee	Characteristic of energy efficient condition
EEPS	Energy Efficiency Portfolio Standard
EER	Energy efficiency ratio under peak conditions
EF	Energy factor
Eff	Efficiency
E_c	Combustion efficiency
Efficiency Vermont	State of Vermont Energy and Efficiency Initiatives
E_t	Thermal efficiency
EFLH	Equivalent full-load hours
EIA	Energy Information Administration, US
EISA	Energy Independence and Security Act (EISA) of 2007
ElecSF	Electric Savings Factor
ENERGY STAR®	U.S. Environmental Protection Agency voluntary program
Energy Trust	Energy Trust of Oregon, Inc.
EPA	Environmental Protection Agency (EPA), US
EPACT	Energy Policy and Conservation Act of 2005
EPDM	Ethylene propylene diene monomer roofing membrane
ERV	Energy recovery ventilation
ESF	Energy savings factor
ESF/psid	Percent savings per psid pressure drop reduction
EUL	Effective useful life
EFan	Evaporator fan
Exh	Exhaust
F	Factor
$F_{ElecCool}$	Electric cooling factor; used to account for the presence or absence of an electric cooling system
F_{CR}	Condensate Return Factor, used to account for the proportion of energy lost that is returned to the system via condensate line
$F_{control}$	Control type factor
$F_{discharge}$	Discharge coefficient
F_{derate}	Aggregate derating factor
$F_{ElecHeat}$	Electric heating factor; used to account for the presence or absence of an electric heating system
F_{elec}	Percentage of energy consumed that is derived from electricity
$F_{FuelHeat}$	Fuel heating factor; used to account for the presence or absence of a fossil fuel heating system
F_{faucet}	Faucets per household factor
F_{failed}	Percentage of steam traps that fail annually

F_{gas}	Percentage of energy consumed that is derived from gas
F_h	Zone correction for blower door infiltration rate to natural air changes
F_{hrs}	Percentage of annual hours that steam traps are failed
F_{Loss}	Steam loss adjustment factor
F_n	Height correction for blower door infiltration rate to natural air changes
$F_{opening}$	Effectiveness of opening factor
F_{peak}	Peak operation factor
F_{regen}	Regenerative breaking factor; used account for fraction of run hours regenerative braking produces energy savings
F_{VFD}	Factor to account for reduced consumption resultant from VFD control
FE	Rated efficiency of fireplace
FEMP	Federal Energy Management Program
FL	Full-load chiller efficiency under peak conditions
FLH	Full-load hours
Flow	Nozzle flow
FPFC	Four pipe fan coil
ft	Foot
ft^2	Square feet
ft^3	Cubic feet
FuelSF	Fuel Savings Factor
GasSF	Gas Savings Factor
GDS	GDS Associates, Marietta, GA
Glazing area	Aperture area of glazing
GLHP	Ground Loop Heat Pump
GPD	Gallons Per Day
GPM	Gallons Per Minute
GSHP	Ground Source Heat Pump
GWHP	Ground Water Heat Pump
ΔH_{vap}	Heat of vaporization (latent heat), in BTU/lb
$H_2O_{savings}$	Water savings
HDD	Heating degree days - The number of degrees that a day's average temperature is below some baseline temperature, which represents the temperature below which buildings need to be heated. The baseline temperature is typically 65°F, but may vary based on application.
HDD	Heating Degree Days based on location
$heating_{annual}$	Annual heating consumption of building
HEI	Building Heating Energy Intensity
HID	High intensity discharge lamp
hp	Horsepower
hp_{max}	Maximum motor horsepower
hp_{peak}	Horsepower at which motor achieves peak efficiency
HP	High performance
hrs	Hours
$hrs_{operating}$	Operating hours

HSPF	Heating seasonal performance factor, BTU/watt-hour, total heating output (supply heat) in BTU (including electric heat) during the heating season / total electric energy heat pump consumed (in watt-hour)
ht	Height
HVAC	Heating, ventilation, and air conditioning
$HVAC_c$	HVAC interaction factor for annual electric energy consumption
$HVAC_d$	HVAC interaction factor at utility summer peak hour
$HVAC_{ff}$	HVAC interaction factor for annual fossil fuel consumption
HW	Hot water
HWRF	Hot Water Reduction Factor
HWUF	Hot Water Usage Factor, a measure of efficiency of baseline system (gal/lb)
hx	Heat Exchanger
IECC	International Energy Conservation Code
IEER	Integrated energy efficiency ratio
IESNA	Illuminating engineering Society of North America
IHR	Ice Harvest Rate (lbs/day)
IPLV	Integrated Part-Load Value, a performance characteristic, typically of a chiller capable of capacity modulation.
k	Thermal conductivity
$kBTU/h_{in}$	Input rating (kBTU/h)
$kBTU/h_{out}$	Output rating (kBTU/h)
kgal	Thousand gallons
kSF	Thousand square feet
kW	kilowatts
kW/CFM	Air compressor kW per CFM air delivery at 100 psi
l	Length
lb	Pounds
LBNL	Lawrence Berkeley National Laboratory
leakage	Estimate of percent of units not installed in service territory
LED	Light emitting diode
LEED	Leadership in Energy and Environmental Design
LF	Load Factor
Load	Average total weight (lbs) of clothes per drying cycle
$Loss_{steam}$	Hourly steam loss per failed trap (lb/hr)
LPD	Lighting power density
LRAC	Long-run avoided cost
LSAF	Load shape adjustment factor
MEC	Metropolitan Energy Center
MMBtu	Unit of heat
min	Minutes
MPH	Wind speed, in miles per hour
NACH	Natural Air Changes
NAECA	National Appliance Energy Conservation Act of 1987
NBI	New Buildings Institute

NCEI	National Centers for Environmental Information
NEA	National Energy Alliances
NEAT	National Energy Audit Tool
NEMA	National Electrical Manufacturers Association
NREL	National Renewable Energy Laboratory
NRM	National Resource Management
NSTAR	Operating company of Northeast utilities
NWPPC	Northwest Power Planning Council
NWRTF	Northwest Regional Technical Forum
NY DPS	New York State Department of Public Service
NYISO	New York Independent System Operator
NYSERDA	New York State Energy Research and Development Authority
^{o}F	Degrees Fahrenheit
OCW	Overweight of counterbalance as a fraction of elevator car capacity
OSA	Outdoor supply air
Pa	Pascals, the standard unit of pressure or stress in the International system of units (SI)
PA Consulting	PA Consulting Group
PF	Power factor
Phase	Number of phases in a motor (1 or 3) Single Phase is a type of motor with low horsepower that operates on 120 or 240 volts, often used in residential appliances. Three phase is a motor with a continuous series of three overlapping AC cycles offset by 120 degrees. Three-phase is typically used in commercial applications.
PLR	Power loss reduction
PNNL	Pacific Northwest National Laboratory
PSC	Public Service Commission, New York State
PSF	Proper sizing factor
p_{atm}	Atmospheric pressure (lbs per square inch)
psig	Gauge pressure (lbs per square inch)
psia	Absolute steam pressure (psi)
PSZ	Packaged single zone
PTAC	Package terminal air conditioner
PTHP	Packaged terminal heat pump
Q	Heat
$Q_{reduced}$	Reduced heat
Q_{reject}	Total heat rejection
Q_{wind}	Air flow entering doorway due to wind
$Q_{thermal}$	Air flow entering doorway due to thermal factors
r	Radius
RA	Return air
RAC	Room air conditioner
RE	Recovery efficiency
RECS	Residential Energy Consumption Survey

RegenSF	Savings Factor for regenerative braking system
RESNET	Residential Energy Services Network
RH	Reduced heat
RLF	Rated load factor
RPM	Revolutions per minute
R-value	A measure of thermal resistance particular to each material
S	Savings
SAPA	State Administrative Procedure Act
SBC	System Benefit Charge
SCFM	Standard cubic feet per minute @ 68 ºF and 14.7 psi standard condition
SEER	Seasonal average energy efficiency ratio over the cooling season, BTU/watt-hour, (used for average U.S. location/region)
sens	Sensible effectiveness of heat exchanger
SF	Square foot
SHGC	Solar heat gain coefficient
SL	Standby heat loss
Staff	NYS Department of Public Service Staff
standby	Standby Power (watts)
T	Temperature
TAF	Temperature adjustment factor
TDA	Total Display Area (ft^2)
TDEC	Total Daily Energy Consumption
TEFC	Totally enclosed fan cooled
th	Thickness
therm	Unit of heat
THR	Total heat rejection
$Throttle_{fac}$	Throttle factor
TMY	Typical meteorological year
tons	Tons of air conditioning
tons/unit	Tons of air conditioning per unit, based on nameplate data
total	Total effectiveness of heat exchanger
TRC	Total Resources Cost
TRF	Thermal Regain Factor
TRM	Technical Resource Manual
UA	Overall heat loss coefficient (BTU/h-ºF)
UA/L	Overall heat loss coefficient per unit length (BTU/hºF-ft)
UEF	Uniform Energy Factor
unit	Measure
units	Number of measures installed under the program
UPC	Uniform Plumbing Code under the International Association of Plumbing and Mechanical Officials
US DOE	United States Department of Energy
US EPA	United States Environmental Protection Agency
U-value	Measure of heat loss in a building element/overall heat transfer co-efficient

V	Volt
v	Volume
VAV	Variable air volume
VSD	Variable speed drive
W	watts
W_{ctrl}	Total wattage of controlled lighting (watts)
WEF	Weighted Energy Factor
Wisconsin PSC	State of Wisconsin Public Service Commission
WUF	Washer Utilization Factor, a measure of the runtime of a typical laundry facility (lbs laundry/lbs capacity)

EQUATION CONVERSION FACTORS	
$\pi/4$	Orifice area development factor
0.000584	Conversion factor used in DOE test procedure
0.00132	Electric efficient storage type water heater replacing standard storage tank water heater. NAECA referenced as function of storage volume.
0.0019	Natural gas efficient storage type water heater replacing standard storage tank water heater. NAECA referenced as function of storage volume.
0.005	Savings factor per change in psi
0.284	Conversion factor, one kW equals 0.284 ton
0.293	Conversion factor, one BTU/h equals 0.293071 watt
0.473	Conversion factor (liters/pint)
0.05	Regression coefficient for the average speed of a VSD and processed milk units
0.67	Natural gas water heater Energy Factor
0.746	Conversion factor (kW/hp), 746 watts equals one electric horsepower
0.93	Specific heat of milk (Btu/lb·˚F)
0.97	Electric resistance water heater Energy Factor
0.97	An empirically derived constant in the Grashof equation
1.08	Specific heat of air × density of inlet air @ 70ºF × 60 min/hr
1.6	Typical refrigeration system kW/ton
1.7729	Regression constant for the average speed of a VSD and processed milk units
2	Air flow rate of milking unit (CFM)
3.412	Conversion factor, one watt-hour equals 3.412 BTU
3.517	Conversion factor, one ton equals 3.517 kilowatts
4.5	Density of inlet air at 70ºF x 60 min/hr, in lb-min/ft^3-hr
5.202	Conversion factor from inches of water to pounds per square ft (lb/sq.ft)
8.33	Energy required (BTU's), to heat one gallon of water by one degree Fahrenheit
10	Conversion factor, one MMBtu equals 10 therms
12	(kBTU/h)/ton of air conditioning capacity
24	Hours in one day
60	An empirically derived constant in the Grashof's equation (lb_m/ in$^{0.06}$-lb$^{0.97}$-hr)
60	Minutes in one hour
67.5	Ambient air temperature °F
88	Conversion factor, one mile per hour equals 88 feet per minute
91	Days in winter months
100	Conversion factor, one therm equals 100 kBTU
274	Days in non-winter months.
365	Days in one year
459.67	Conversion factor, Fahrenheit to Rankine
3,412	Conversion factor, one kWh equals 3,412 BTU
8,760	Hours in one year
1,000	Conversion factor, one kW equals 1,000 watts

1,000	Conversion factor, one MMBtu equals 1,000 kBTU
12,000	Conversion factor, one ton equals 12,000 BTU/h
33,000	Conversion factor ((ft-lb/min)/hp), 33,000 foot-pounds per minute equals one electric horsepower
1,000,000	Conversion factor, one MMBtu equals 1,000,000 BTU

Record of Revision

Record of Revision Number	Issue Date
0	12/10/2014
6-15-4	6/1/2014
1-17-9	12/31/2016
6-17-17	6/30/2017
9-17-12	9/30/2017
12-17-18	12/31/2017
3-18-22	3/29/2018
6-19-15	6/30/2019
3-20-18	3/30/2020
7-21-25	8/30/2021

Return to Table of Contents