Table of Revisions/Changes

Revision Number	Addition/ Revision	Issue Date	Effective Date	Measure	Description of Change	Location/Page in TRM
6-24-1	R	7/8/2024	1/1/2025	R/MF Air Leakage Sealing	Revised language in Measure Description and Compliance Efficiency section to clarify eligible applications and minimum requirements.	Pg. 86
6-24-3	R	7/8/2024	1/1/2025	R/MF Clothes Washer	Added provisions to address combination washer-dryers. Updated language in baseline efficiency section and RECS values to 2020 values. Added example calculation for combination units.	Pg. 20
6-24-4	R	7/8/2024	1/1/2025	R/MF Connected Thermostat	Updated default ΔkWh/unit value. Expanded Measure Description to explain the use of different savings algorithms. Removed default values for algorithmic method application.	Pg. 334
6-24-5	R	7/8/2024	1/1/2025	R/MF Insulation – Hot Water and Steam Pipe	Revised language in Measure Description and Compliance Efficiency section to clarify eligible applications and minimum requirements.	Pg. 92
6-24-7	R	7/8/2024	1/1/2025	R/MF Interior and Exterior Lighting	Updated operating hours to reflect results of EM&V study. Added LMI annual hours for NYC distinct from other NY locations.	Pg. 361
6-24-8	R	7/8/2024	1/1/2025	C/I Air Leakage Sealing	Revised language in Measure Description and Compliance Efficiency section to clarify eligible applications and minimum requirements.	Pg. 555
6-24-9	R	7/8/2024	1/1/2025	C/I Electronically Commutated (EC) Motor – HVAC Blower Fan	Modified application of interactive impacts; updated definitions of cooling and heating hours; general maintenance review; language updated for consistency with other TRM measures	Pg. 733
6-24-10	R	7/8/2024	1/1/2025	C/I Electronically Commutated (EC) Motor – Refrigerated Case or Walk-In Cooler/Freezer Evaporator Fan	Combined algorithmic methods for simplicity; updated language in Measure Description for clarity and consistency; updated definition and guidance on default value for nameplate wattage of existing evaporator fan	Pg. 1033

Revision Number	Addition/ Revision	Issue Date	Effective Date	Measure	Description of Change	Location/Page in TRM
6-24-12	R	7/8/2024	1/1/2025	C/I Insulation – Opaque Shell	Revised language in Measure Description section to clarify eligible applications; updated Measure Description to reflect terminology consistent with other TRM measures.	Pg. 573
6-24-13	R	7/8/2024	1/1/2025	C/I Oven, Steamer, Fryer and Griddle	Updated definitions of common variables for clarity; added alternate example calculation to account for fuel-switching and non-fuel switching scenarios.	Pg. 512
6-24-14	R	7/8/2024	1/1/2025	C/I Variable Frequency Drive (VFD) – HVAC Fan and Pump	Significant revision of methodology to eliminate reliance on prototype simulation results and derive savings using fundamental principles and algorithmic approach.	Pg. 956

Note: Revisions, Additions, Corrections and Removals to the measures listed above were undertaken by the Joint Utilities Technical Resource Manual (TRM) Management Committee between April 1, 2024 – June 28, 2024.

BUILDING SHELL

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.

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, and install door sweeps on doors leading to the exterior or an unconditioned space.
- Repair doors and windows leading from conditioned to unconditioned space, including replacement of damaged components (e.g., frame jamb, threshold).
- 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.
$DCFM_{50}$		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 $DCFM_{50}$/SF of 0.50 (i.e., $DCFM_{50}$ = 0.50 x SF).[1]
F_n	19	Value chosen from the range of 17-19 to reflect a conservative estimate of savings.[2]

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[1] Default $DCFM_{50}$/SF of 0.50 is the median value of single-family blower door test data provided by ConEdison, conducted 2018-2020.

[2] LBL, Estimation of Infiltration from Leakage and Climate Indicators, December 1986, pg. 84.

Variable	Value	Notes
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.[3] 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.
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.[4]

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. For all buildings, if a blower door test can be conducted, pre-implementation results will serve as existing conditions.

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 () such that the exterior envelope, as well as interior walls/partitions between conditioned and unconditioned spaces have been inspected and all gaps sealed. See Measure Description for minimum inspection compliance, and examples of air sealing measures.

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[3] Ibid. The value for 2.5 stories was interpolated from presented data.

[4] 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 into the deemed savings shown in Appendix E and vary by building type. See Appendix A for details on prototype building simulation parameters.

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.

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

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

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

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
CF = 0.69, from Summary of Variables and Data Sources table

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

$$\Delta kW = 1 \times \left(\frac{1,300}{19 \times 0.81}\right) \times 0.004 \times 0.69 = 0.34\ kW$$

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

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
6-24-1	7/8/2024

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APPLIANCE

CLOTHES WASHER

Measure Description

This measure covers residential grade clothes washers meeting the criteria established under the ENERGY STAR® Program, Version 8.1, effective April 22, 2021, installed in residential settings.[5] 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.[6]

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.

This measure also includes combination all-in-one washer-dryers as defined in ENERGY STAR® Program, Version 8.1. Combination all-in-one washer-dryers must meet all requirements imposed on residential clothes washers in ENERGY STAR® Program, Version 8.1 and also meet the requirements in Sections 3 and 5 of the ENERGY STAR® Eligibility Criteria for Clothes Dryers[7] applicable for the product type it best matches if it were a stand-alone dryer. Combination all-in-one washer-dryers are exempt from the 80-minute maximum cycle time requirement in Section 3.A of the ENERGY STAR Clothes Dryer specification.

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

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings[8]

Annual Electric Energy Savings

$$\Delta kWh = \Delta kWh_{CW} + \Delta kWh_{CD}$$

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

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[5] ENERGY STAR® Program Requirements Product Specification for Clothes Washers, Eligibility Criteria Version 8.1, April 2021

[6] Efficiency of ENERGY STAR® products: https://www.energystar.gov/products/clothes_washers

[7] ENERGY STAR® Program Requirements Product Specification for Clothes Dryers, Eligibility Criteria Version 1.1, May 2017

[8] Savings calculator for ENERGY STAR® Qualified Appliances (accessed 2/8/2018).

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

Summer Peak Coincident Demand Savings

$$\Delta kW = \frac{\Delta kWh}{(hrs_{CW} + hrs_{CD} \times F_{combo})} \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = \Delta MMBtu_{CW} + \Delta MMBtu_{CD}$$

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

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

where:

ΔkWh = Annual electric energy savings

ΔkW = Peak coincident demand electric savings

ΔMMBtu = Annual fossil fuel energy savings

CW = Clothes Washer

CD = Clothes Dryer

units = Number of measures installed under the program

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

F_{combo} = Combination washer-dryer factor, used to account for presence or absence of combination dryer

hrs_{CW} = Annual run hours of clothes washer

$Cycles_{annual}$ = Number of dryer cycles per year

Load = Average total weight (lbs) of clothes per drying cycle

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_{CD} = 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
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: 0.37	Based on EIA Residential Energy Consumption Survey (RECS) 2020 for Middle Atlantic States.[9]
$ElecSF_{dryer}$	Electric Dryer: 1.0 Gas Dryer: 0 Unknown: 0.68	Based on EIA Residential Energy Consumption Survey (RECS) 2020 for Middle Atlantic States.[10]
$\Delta MMBtu_{wh}$		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: 0.63	Based on EIA Residential Energy Consumption Survey (RECS) 2020 for Middle Atlantic States.[11]
$FuelSF_{dryer}$	Electric Dryer: 0 Gas Dryer: 1.0 Unknown: 0.32	Based on EIA Residential Energy Consumption Survey (RECS) 2020 for Middle Atlantic States.[12]
hrs_{CW}	295	
$Cycles_{annual}$		Lookup based on efficient dryer type in table below.[13]
Load		Lookup based on efficient dryer type in table below.[14]
$F_{elec,baseline}$		Lookup based on efficient dryer type in table below.[15]

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[9] EIA Residential Energy Consumption Survey (RECS) 2020 for Middle Atlantic States, Table HC1.7 ("Unknown" calculated as the number of homes with electric water heating [5.33 million] divided by the total number of homes with electric or gas water heating [5.33 million + 9.00 million]).

[10] EIA Residential Energy Consumption Survey (RECS) 2020 for Middle Atlantic States, Table HC3.7 ("Unknown" calculated as the number of homes with electric dryers [7.50 million] divided by the total number of homes with electric or gas dryers [7.50 million + 3.53 million]).

[11] EIA Residential Energy Consumption Survey (RECS) 2020 for Middle Atlantic States, Table HC1.7 ("Unknown" calculated as the number of homes with gas water heating [9.00 million] divided by the total number of homes with electric or gas water heating [5.33 million + 9.00 million]).

[12] EIA Residential Energy Consumption Survey (RECS) 2020 for Middle Atlantic States, Table HC3.7 ("Unknown" calculated as the number of homes with gas dryers [3.53 million] divided by the total number of homes with electric or gas dryers [7.50 million + 3.53 million]).

[13] Savings calculator for ENERGY STAR® Qualified Appliances (accessed 10/18/2017).

[14] Ibid.

[15] ENERGY STAR® Program Requirements Product Specification for Clothes Dryers, Eligibility Criteria Version 1.1, May 2017.

Variable	Value	Notes
$F_{elec,ee}$		Lookup based on efficient dryer type in table below.[16]
$F_{fuel,baseline}$		Lookup based on efficient dryer type in table below.[17]
$F_{fuel,ee}$		Lookup based on efficient dryer type in table below.[18]
$CEF_{baseline}$		Lookup based on efficient dryer type in table below.[19]
CEF_{ee}		Lookup based on efficient dryer type in table below.[20]
F_{combo}		Use a value of 1.0 for combination appliances. Otherwise, use 0.
hrs_{CD}		Lookup based on efficient dryer type in table below.[21]
CF	0.029	

Integrated Modified Energy Factor, IMEF[22] (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.[23]

Integrated Water Factor, IWF[24] 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[25].

Per Unit Savings[26,27,28,29]

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[16] Ibid.

[17] Ibid.

[18] Ibid.

[19] 10 CFR 430.32 (h)(3).

[20] ENERGY STAR® Program Requirements Product Specification for Clothes Dryers, Eligibility Criteria Version 1.1, May 2017.

[21] Savings calculator for ENERGY STAR® Qualified Appliances (accessed 10/18/2017).

[22] 10 CFR 430 Subpart B, Appendix J2.

[23] ENERGY STAR® Program Requirements Product Specification for Clothes Washers, Eligibility Criteria Version 8.0 February 2018.

[24] 10 CFR 430 Subpart B, Appendix J2.

[25] ENERGY STAR® Program Requirements Product Specification for Clothes Washers, Eligibility Criteria Version 8.1, February 2018.

[26] Savings Calculator for ENERGY STAR® Qualified Appliances (accessed 2/8/2017).

[27] ENERGY STAR® Clothes Washers Key Product Criteria.

[28] ENERGY STAR® Most Efficient 2018, Recognition Criteria Clothes Washers.

[29] 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® 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
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

Key Variables Lookup Table

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*
$Cycles_{annual}$	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
$F_{elec,ee}$	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.[30]

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.[31]

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

The baseline condition for the dryer component of the Combination All-In-One washer-dryer is a standard efficiency, residential grade clothes dryer – applicable for the product type it best matches if it were a stand-alone dryer – with operating specifications as defined in the Key Variables Lookup Table above.

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

ENERGY STAR®[33] and Consortium for Energy Efficiency (CEE)[34] 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

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[30] 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.

[31] 10 CFR 430.32(g)(4).

[32] ENERGY STAR® Program Requirements Product Specification for Clothes Washers.

[33] ENERGY STAR® Most Efficient 2018, Recognition Criteria Clothes Washers.

[34] CEE Super Efficient Home Appliances Initiative, Residential Clothes Washer Specifications.

Product Class	IMEF	IWF
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

The compliance condition for the dryer component of the Combination All-In-One washer-dryer is a residential grade clothes dryer appearing on the ENERGY STAR® qualified products list.

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.[35]

Example Calculation – Standalone Clothes Washer *(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 vented 4 ft^3 dryer is electric. Annual Electric Energy Savings, Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta kWh = \Delta kWh_{CW} + \Delta kWh_{CD}$$

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

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

$$\Delta kW = \frac{\Delta kWh}{(hrs_{CW} + hrs_{CD} \times F_{combo})} \times CF$$

$$\Delta MMBtu = \Delta MMBtu_{CW} + \Delta MMBtu_{CD}$$

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

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

units = 1, from application
ΔkWh_{washer} = 4, from Per Unit Savings Table
ΔkWh_{wh} = 17, from Per Unit Savings Table
$ElecSF_{wh}$ = 0, from Summary of Variables and Data Sources table based on application

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[35] 10 CFR 430 Subpart B, Appendix J2.

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
$Cycles_{annual}$ = 283, from Key Variables Lookup Table based on dryer type from application
Load = 3.00, from Key Variables Lookup Table based on dryer type from application
$F_{elec,baseline}$ = 1.00, from Key Variables Lookup Table based on dryer type from application
$CEF_{baseline}$ = 3.27, from Key Variables Lookup Table based on dryer type from application
$F_{fuel,baseline}$ = 0, from Key Variables Lookup Table based on dryer type from application
$F_{elec,ee}$ = 1.00, from Key Variables Lookup Table based on dryer type from application
CEF_{ee} = 3.45, from Key Variables Lookup Table based on dryer type from application
$F_{fuel,ee}$ = 0, from Key Variables Lookup Table based on dryer type from application
hrs_{CD} = 290, from Key Variables Lookup Table based on dryer type from application
F_{combo} = 0, from application

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

$$\Delta kWh_{CD} = 1 \times 283 \times 3.00 \times \left(\frac{1}{3.27} - \frac{1}{3.45}\right) \times 0 = 0\ kWh$$

$$\Delta kWh = 79 + 0 = 79\ kWh$$

$$\Delta kW = \frac{79}{(295 + 290 \times 0)} \times 0.029 = 0.0078\ kW$$

$$\Delta MMBtu_{CW} = 1 \times [(0.08 \times 1) + (0.29 \times 0)] = 0.08\ MMBtu$$

$$\Delta MMBtu_{CD} = 1 \times 283 \times 8.45 \times \left(\frac{0}{3.27} - \frac{0}{3.45}\right) \times \frac{3{,}412}{1{,}000{,}000} \times 0 = 0$$

$$\Delta MMBtu = 0.08 + 0 = \ 0.08\ MMBtu$$

Example Calculation – Combination Washer-Dryer *(Not to be used as default)*

An existing residential customer installs a 4.8 cubic ft combination all-in-one washer-dryer unit with ventless drying where the water heating fuel type is gas. The washer has an IMEF of 2.76 and an IWF of less than 3.0, making it the same level as a CEE Tier 1 Clothes Washer > 2.5 ft^3. Annual Electric Energy Savings, Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta kWh = \Delta kWh_{CW} + \Delta kWh_{CD}$$

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

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

$$\Delta kW = \frac{\Delta kWh}{(hrs_{CW} + hrs_{CD} \times F_{combo})} \times CF$$

$$\Delta MMBtu = \Delta MMBtu_{CW} + \Delta MMBtu_{CD}$$

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

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

units = 1, from application
ΔkWh_{washer} = 9, from Per Unit Savings Table, matching the CEE tier level
ΔkWh_{wh} = 35, from Per Unit Savings Table
$ElecSF_{wh}$ = 0, from Summary of Variables and Data Sources table based on application
ΔkWh_{dryer} = 169, from Per Unit Savings Table
$ElecSF_{dryer}$ = 1, from Summary of Variables and Data Sources table based on application
Hrs_{CW} = 295, from Summary of Data Sources and Variables table
CF = 0.029, from Summary of Data Sources and Variables table
$\Delta MMBtu_{wh}$ = 0.16, from Per Unit Savings Table
$FuelSF_{wh}$ = 1, from Summary of Variables and Data Sources table based on application
$\Delta MMBtu_{dryer}$ = 0.65, from Per Unit Savings Table
$FuelSF_{dryer}$ = 0, from Summary of Variables and Data Sources table based on 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
$F_{elec,baseline}$ = 1.00, from Key Variables Lookup Table based on dryer type from application
$CEF_{baseline}$ = 3.73, from Key Variables Lookup Table based on dryer type from application
$F_{fuel,baseline}$ = 0, from Key Variables Lookup Table based on dryer type from application
$F_{elec,ee}$ = 1.00, from Key Variables Lookup Table based on dryer type from application
CEF_{ee} = 3.93, from Key Variables Lookup Table based on dryer type from application
$F_{fuel,ee}$ = 0, from Key Variables Lookup Table based on dryer type from application
hrs_{CD} = 290, from Key Variables Lookup Table based on dryer type from application
F_{combo} = 1, from application

$$\Delta kWh_{CW} = 1 \times [9 + (35 \times 0) + (169 \times 1)] = 218\ kWh$$

$$\Delta kWh_{CD} = 1 \times 283 \times 8.45 \times \left(\frac{1}{3.73} - \frac{1}{3.93}\right) \times 1 = 32.6\ kWh$$

$$\Delta kWh = 218 + 32.6 = 250.6\ kWh$$

$$\Delta kW = \frac{250.6}{(295 + 290 \times 1)} \times 0.029 = 0.012\ kW$$

$$\Delta MMBtu_{CW} = 1 \times [(0.16 \times 1) + (0.65 \times 0)] = 0.16$$

$$\Delta MMBtu_{CD} = 1 \times 283 \times 8.45 \times \left(\frac{0}{3.73} - \frac{0}{3.93}\right) \times \frac{3{,}412}{1{,}000{,}000} \times 0 = 0$$

$$\Delta MMBtu = 0.16 + 0 = \ 0.16\ MMBtu$$

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.

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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
6-24-3	7/8/2024

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HEATING, VENTILATION AND AIR CONDITIONING (HVAC) – CONTROL

CONNECTED THERMOSTAT

Measure Description

This measure covers the installation of ENERGY STAR® qualified connected thermostats applied to single-family and multi-family residential HVAC systems. Utilizing Wi-Fi connections, a connected thermostat provides and receives feedback from users to enhance energy efficiency without compromising comfort. A connected 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 connected 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.[36]

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 connected thermostats are installed. This measure is not applicable to multifamily central heating systems with additional capacity for domestic hot water.

For application of this measure in online marketplace and other point-of-sale rebate programs, an alternative method relying on deemed savings per household is provided. The algorithmic approach is restricted to program delivery mechanisms that allow for the collection of site-specific information. Other programs must use the deemed savings approach rather than defaults applied to the algorithmic method.

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[36] ENERGY STAR® Program Requirements Product Specification for Connected Thermostat Products, Eligibility Criteria Version 1.0, January 2017.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings (Algorithmic)

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

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = units \times \left((kBTU/h)_{in}/unit \times \frac{1}{1{,}000} \times EFLH_{heating} \times ESF_{heating} \times F_{FuelHeat}\right)$$

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings (Deemed)

Annual Electric Energy Savings

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

Summer Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = units \times \Delta MMBtu/unit$$

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
ΔkWh/unit = Annual electric energy savings per household
ΔMMBtu/unit = Annual fossil fuel energy savings per household
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
ΔkWh/unit		Use 152 kWh for thermostats purchased through an electric marketplace program and 32 kWh for thermostats purchased through a gas marketplace program where electric service territory can be verified.[37] If electric/gas service cannot be verified (e.g., for midstream applications), a value of 81 kWh shall be used.[38]

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[37] National Grid 2023 Marketplace Study, June 9, 2023, pg 89

[38] Using Table HC1.7 of EIA RECs 2020, there are 6.84 million housing units that use electric space heating, and 9.88 million housing units that use natural gas space heating.

Variable	Value	Notes
ΔMMBtu/unit		Use 2.3 MMBtu for thermostats purchased through a gas marketplace program and 0 MMBtu otherwise.[39] If electric/gas service cannot be verified (e.g., for midstream applications), a value of 1.4 MMBtu shall be used.[40]
tons/unit		From application.
(kBTU/h)$_{out}$/unit		From application.
(kBTU/h)$_{in}$/unit		From application.
Eff$_{cooling}$		From application. For equipment rated in SEER2, SEER2 rating shall be used.
HSPF		From application. For electric resistance heating and electric furnaces, use 3.4 HSPF if efficiency is unknown. COP must be converted to HSPF using the equivalency HSPF = COP x 3.412. Use HSPF2 for equipment that have an HSPF2 rating.
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.[41]
ESF$_{heating}$	0.08	Energy savings factor for heating.[42]
F$_{ElecCool}$	Electric Cooling: 1 No Electric Cooling: 0 Unknown: 0.43	Based on EIA Residential Energy Consumption Survey (RECS) 2020 for Middle Atlantic States.[43]
F$_{ElecHeat}$	Electric Heating: 1 No Electric Heating: 0 Unknown: 0.19	Based on EIA Residential Energy Consumption Survey (RECS) 2020 for Middle Atlantic States.[44]
F$_{FuelHeat}$	Fossil Fuel Heating: 1 No Fossil Fuel Heating: 0 Unknown: 0.61	Based on EIA Residential Energy Consumption Survey (RECS) 2020 for Middle Atlantic States.[45]

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[39] National Grid 2023 Marketplace Study, June 9, 2023, pg 89

[40] Using Table HC1.7 of EIA RECs 2020, there are 6.84 million housing units that use electric space heating, and 9.88 million housing units that use natural gas space heating.

[41] ENERGY STAR® Program Requirements Product Specification for Connected Thermostat Products, Eligibility Criteria Version 1.0, January 2017, pg. 10.

[42] Ibid.

[43] EIA Residential Energy Consumption Survey (RECS) 2020 for Middle Atlantic States, Table HC7.7 (“Unknown” calculated as the number of homes with central AC divided by the total number of homes).

[44] EIA Residential Energy Consumption Survey (RECS) 2020 for Middle Atlantic States, Table HC6.7 (“Unknown” calculated as the number of homes with electric heat divided by the total number of homes).

[45] EIA Residential Energy Consumption Survey (RECS) 2020 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 non-connected programmable thermostat.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is an HVAC system controlled by an ENERGY STAR® qualified connected thermostat 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 connected 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
$EFLH_{cooling}$ = 358, 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
$EFLH_{heating}$ = 933, 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

$$\Delta kWh = 1 \times \left[\left(2.5 \times \frac{12}{14} \times 358 \times 0.1 \times 1\right) + (0)\right] = 76.71\ kWh$$

$$\Delta MMBtu = 1 \times \left(80 \times \frac{1}{1{,}000} \times 933 \times 0.08 \times 1\right) = 5.97\ MMBtu$$

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.

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Record of Revision

Record of Revision Number	Issue Date
3-18-17	3/29/2018
9-23-8	10/6/2023
6-24-4	7/8/2024

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BUILDING SHELL

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 uninsulated copper, steel, CPVC, or PEX piping with a nominal diameter between 0.50″ and 4.00″. Estimation of energy savings depends 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 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. Domestic 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 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.[46]
$E_{t,fuel}$	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.[47,48]
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).[49]
T_{amb}	DHW: 70 Space Heat: 50	Surrounding average ambient air temperature (°F).[50,51]

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[46] Per 10 CFR 430 Subpart B Appendix E – Uniform Test Method for Measuring the Energy Consumption of Water Heaters: *6.3.2 Recovery Efficiency.*

[47] 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.

[48] 10 CFR 430.32(e)(iii)(A).

[49] 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.

[50] Average annual ambient temperature in unconditioned spaces.

[51] 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: 0.33 Space Heat: 0	Based on EIA Residential Energy Consumption Survey (RECS) 2020 for Middle Atlantic States.[52] "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) 2020 for Middle Atlantic States.[53] "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.[54]
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, steel, CPVC or PEX domestic hot water or space heating piping with a nominal diameter between 0.50″ and 4.00″ 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.[55] Insulation of HDPE piping is not eligible for savings under this measure.[56]

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[52] EIA Residential Energy Consumption Survey (RECS) 2020 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).

[53] EIA Residential Energy Consumption Survey (RECS) 2020 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).

[54] *No source specified – update pending availability and review of applicable references.*

[55] Insulation Institute, 3E Plus® Version 4.1.

[56] HDPE piping was found to have limited savings potential through preliminarily modeling in 3E Plus® Version 4.1.

Pipe Diameter (in)	$(UA/L)_{baseline}$						
	Bare Copper Piping			**Bare Steel Piping**		**Bare CPVC/PEX Piping**	
	Domestic Hot Water	**Hot Water Heat**	**Steam Heat**	**Hot Water Heat**	**Steam Heat**	**Domestic Hot Water**	**Hot Water Heat**
0.50	0.44	0.48	0.53	0.53	0.59	0.39	0.41
0.75	0.54	0.58	0.64	0.65	0.72	0.48	0.50
1.00	0.65	0.70	0.78	0.79	0.88	0.56	0.58
1.25	0.80	0.86	0.96	0.97	1.09	0.69	0.72
1.50	0.90	0.97	1.09	1.10	1.23	0.78	0.81
2.00	1.10	1.19	1.33	1.34	1.51	0.95	0.98
2.50	1.31	1.42	1.58	1.60	1.80	1.07	1.11
3.00	1.57	1.70	1.90	1.92	2.16	1.23	1.27
3.50	1.77	1.92	2.15	2.18	2.45	1.38	1.42
4.00	1.98	2.14	2.40	2.43	2.73	1.52	1.57

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a length of previously uninsulated copper, steel, CPVC, or PEX domestic hot water or space heating hot water/steam distribution piping with added insulation. Where possible, it is recommended that insulation be installed in accordance with ECCCNYS[57], which requires 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.[58]

Pipe Diameter (in)	$(UA/L)_{ee}$											
	Fiberglass						**Rigid Foam/Cellular Glass**					
	0.5 in	**1.0 in**	**1.5 in**	**2.0 in**	**2.5 in**	**3.0 in**	**0.5 in**	**1.0 in**	**1.5 in**	**2.0 in**	**2.5 in**	**3.0 in**
0.50	0.12	0.09	0.08	0.07	0.06	0.06	0.16	0.12	0.10	0.09	0.09	0.08
0.75	0.14	0.10	0.09	0.08	0.07	0.07	0.18	0.14	0.12	0.11	0.10	0.09
1.00	0.16	0.12	0.10	0.09	0.08	0.07	0.21	0.16	0.13	0.12	0.11	0.10
1.25	0.19	0.14	0.11	0.10	0.09	0.08	0.24	0.18	0.15	0.13	0.12	0.11
1.50	0.21	0.15	0.12	0.10	0.09	0.09	0.27	0.20	0.16	0.14	0.13	0.12
2.00	0.25	0.17	0.14	0.12	0.11	0.10	0.32	0.23	0.19	0.16	0.15	0.13
2.50	0.29	0.20	0.16	0.13	0.12	0.11	0.37	0.26	0.21	0.18	0.16	0.15
3.00	0.34	0.23	0.18	0.15	0.13	0.12	0.43	0.30	0.24	0.21	0.18	0.17
3.50	0.38	0.26	0.20	0.17	0.15	0.13	0.47	0.33	0.27	0.23	0.20	0.18

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[57] ECCCNYS 2020, R403.5.3.

[58] Insulation Institute, 3E Plus® Version 4.1.

Pipe Diameter (in)	$(UA/L)_{ee}$											
	Fiberglass						Rigid Foam/Cellular Glass					
	0.5 in	1.0 in	1.5 in	2.0 in	2.5 in	3.0 in	0.5 in	1.0 in	1.5 in	2.0 in	2.5 in	3.0 in
4.00	0.42	0.28	0.22	0.18	0.16	0.14	0.52	0.36	0.29	0.25	0.22	0.20

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. Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated 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
$(UA/L)_{ee}$ = 0.16, from compliance efficiency based on insulation material, 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

$$\Delta kWh = \frac{(0.65 - 0.16)}{0.98 \times 3{,}412} \times 20 \times 55 \times 8{,}760 \times 1.0 = \ 1{,}383.26\ kWh$$

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

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.
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5. EIA Residential Energy Consumption Survey (RECS) 2020 Survey Data for Middle Atlantic States, February 2020.
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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

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1	10/15/2010
7-13-15	7/31/2013
6-18-2	6/26/2018
12-20-1	12/31/2020
3-23-4	3/31/2023
6-24-5	7/8/2024

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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 (GSLs) 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.[59,60] A backstop provision was included in this legislation that would require general service lamps to meet a minimum efficacy of 45 lumens per watt beginning on 1/1/2020 in the absence of a final rule amending GSL standards.[61] Additionally in 2017, final rulings were promulgated expanding GSL and GSIL definitions to eliminate exceptions for certain specialty lamps, reflector lamps and decorative lamps effective 1/1/2020.[62,63] The backstop provision and revised definitions rulings were withdrawn prior to their effectuation date and subsequently reinstated by DOE with phased enforcement between January 2023 and July 2023.[64,65] As such, baseline values for market rate applications of this measure shall apply wattages in accordance with revised GSL and GSIL definitions and the imposed 45 lumen per watt standard established via these rulings. Where existing conditions are available, LMI applications of the primary method prescribed below shall establish baseline wattage aligned with existing conditions.

This measure consists of two methods for estimating energy and demand savings. The primary method represented by the first set of algorithms below is suitable for both market rate and LMI applications. The alternative methodology represented by the second set of algorithms shall be used for LMI applications only. This simplified approach relies on average sampling data to establish wattage and consumption reductions and assumed hours of operation. It is only applicable for LMI projects consisting of 16 LED lamps or fewer. Projects exceeding this limit require a lighting schedule.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

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[59] The maximum rated wattage varies for modified spectrum lamps.
[60] Energy Independence and Security Act of 2007. Pub. L. 110-140. Sec. 321. Efficient Light Bulbs H.R.6 – 86.
[61] 42 U.S.C. 6295(i)(6)(A)(v).
[62] DOE 82 FR 7276.
[63] DOE 82 FR 7322.
[64] DOE 87 FR 27439.
[65] DOE 87 FR 27461.

$$\Delta kWh = units \times \frac{(W_{baseline} - W_{ee})}{1{,}000} \times hrs \times (1 + HVAC_c)$$

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

$$\Delta MMBtu = units \times \frac{(W_{baseline} - W_{ee})}{1{,}000} \times hrs \times HVAC_{ff}$$

Alternate Method for Calculating Annual Energy Savings for LMI Projects[66]

This methodology for claiming savings is an alternate method that is being tested for future use and will be evaluated for use in both Market-Rate and LMI households.

<u>General Purpose LEDs</u>

$$\Delta kWh = units \ \times \left(\frac{\Delta W_{LMI,GP} \times 365}{1{,}000}\right) \times hrs$$

<u>Candelabra LEDs</u>[67]

$$\Delta kWh = units \ \times \Delta kWh_{LMI,Candelbra}$$

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 wattage of lamp and/or fixture (Watts)
hrs = Lighting operating hours
$HVAC_c$ = HVAC interaction factor for annual electric energy consumption

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[66] The average wattage reduction per lamp is taken to be 46 watts for A-lamps and 33 watts for candelabra type lamps. The first lamp operating hours for A-lamps prescribed in the Operating Hours section below were determined from the same study used to derive the standard method operating hours. The additional lower hours for larger quantities of A-lamp LEDs are from various sources.

[67] It is assumed that the ΔkWh per Candelabra lamp is 42.2 kWh. This is derived from an assumed ΔW of 33W per lamp and 3.5 hours of usage per day. The savings associated with candelabra lamps is derived from a baseline lamp wattage that is pre-EISA 2020 adjustments. The 2007 baseline maximum for candelabra lamps in EISA states that the wattage cannot exceed 60 watts.

$HVAC_d$ = HVAC interaction factor at utility summer peak hour
HVACff = HVAC interaction factor for annual fossil fuel consumption (MMBtu/kWh)
CF = Coincidence factor
$\Delta W_{LMI,GP}$ = Wattage reduction per general-purpose lamp (LMI only)
$\Delta kWh_{LMI,Candelabra}$ = Annual electric energy savings per candelabra lamp (LMI only)
1,000 = Conversion factor, one kW equals 1,000 Watts
365 = Days per year

Summary of Variables and Data Sources

Variable	Value	Notes
$W_{baseline}$		Baseline measure watts, from appropriate "Baseline Efficiencies" section below. If applying the primary method in an LMI application, in situ wattage may be used in place of assumed baseline wattage. If the existing wattage is not known for an LMI application, use the "Midstream/Upstream Applications for General Service Lamps" subsection below. For detailed definitions, refer to the NOTE in the "Baseline Efficiency" section.
W_{ee}		Energy efficient measure watts, from application
hrs		Look up in Operating Hours section below based on project type, 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. LMI projects may claim up to 16 LED lamps before requiring a lighting schedule.
$HVAC_c$	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.

Variable	Value	Notes
$\Delta W_{LMI,GP}$	46	Wattage reduction per general-purpose lamp.[68]
$\Delta kWh_{LMI,Candelabra}$	42.2	This is derived from an assumed ΔW of 33W per lamp and 3.5 hours of usage per day.

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.[69] 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

NOTE: For the purposes of establishing baseline efficiencies for this measure, “Downstream” encompasses any program delivery mechanism that allows for the determination of housing type (Market Rate vs. LMI) and, in the case of LMI programs, existing lamp wattage. “Midstream/Upstream” baselines are intended for program delivery mechanisms where housing type cannot be identified or for LMI programs where existing lamp wattage cannot be identified.

Downstream Market Rate Applications for General Service Lamps

In accordance with DOE final rules published in May 2022, baseline wattage for General Service Lamps (GSLs) (as defined in DOE 87 FR 27461)[70] in market rate applications shall be established

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[68] A sampling of recorded pre- and post- wattage of 100 completed EmPower projects, Data reported by a New York City agency (AEA), Inspections completed by Nexant, during a program evaluation (“M&V Evaluation EmPower New York^{SM} Program,” March 2007)., EmPCalc Honeywell Narrative 10_04_16 10 AM.

[69] 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.

[70] DOE 87 FR 27461.

based on a minimum standard efficacy of 45 lumens per watt.[71] Baseline wattage shall be derived as follows:

$$W_{baseline} = \frac{Lumens_{ee}}{45}$$

where:

$W_{baseline}$ = Baseline lamp wattage

$Lumens_{ee}$ = Rated light output of efficient lamp

45 = Minimum lumens per watt standard established by DOE final rule

Downstream Market Rate Applications for Exempt Lamps

A general service lamp, as defined in the Code of Federal Regulations, is a lamp, including but not limited to general service incandescent lamps, compact fluorescent lamps, general service light-emitting diode lamps, and general service organic light emitting diode lamps used in general lighting applications that:

1. Has an ANSI base;
2. Is able to operate at a voltage of 12 volts or 24 volts, at or between 100 to 130 volts, at or between 220 to 240 volts, or of 277 volts for integrated lamps, or is able to operate at any voltage for non-integrated lamps;
3. Has an initial lumen output of greater than or equal to 310 lumens (or 232 lumens for modified spectrum general service incandescent lamps) and less than or equal to 3,300 lumens;
4. Is capable of being operated at voltage range at least partially within 110 and 130 volts.

Certain lamp types were exempt from the original EISA legislation and subsequent final rule amending the definition of GSLs, though several exemptions were discontinued in the latter. For a complete list and definitions of exempt lamp types, as well as discussion of discontinued and maintained exemptions, reference final rules 82 FR 7276 and 82 FR 7322.[72,73]

For products that are not governed by the 45 lumen per watt standard (i.e., do not meet the definition of general service lamp or fall under an exempt product category), the baseline wattage shall be established per ENERGY STAR Watts Equivalent guidance or manufacturer recommended baseline wattage.

Midstream/Upstream Applications for General Service Lamps

Due to lack of availability of customer and existing conditions data in midstream and upstream program delivery mechanisms and the blend of market rate and LMI customer participation in these programs, distinct baseline guidance for these program types that endeavors to account for the proportion of LMI participants across NY state has been developed. The intent of this guidance is a blended baseline applying a 45 lumen per watt standard for market rate participants and an approximated existing condition baseline across the LMI participant population. For the purposes of this exercise, the approximated existing condition baseline for LMI customers was assumed to

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[71] DOE 87 FR 27439.

[72] DOE 82 FR 7276.

[73] DOE 82 FR 7322.

align with baselines established for residential lighting prior to the effectuation of the 45 lumen per watt backstop.

Evaluation of 2021 retail LED bulb sales suggest that approximately 37% of residential LEDs are purchased by LMI customers.[74] As such, the baselines prescribed for midstream and upstream applications in the tables below apply a weighting reflecting 37% LMI and 63% market rate participation.

The baselines established below are applicable to midstream and upstream programs as well as downstream LMI programs where the primary calculation methodology above is utilized and existing lamp wattage cannot be collected. For lamps that are not covered by the tables below, either based on bulb type or lumen output, the manufacturer recommended baseline wattage should be used.

Standard Lamps

Bulb Type (a)	**Lumen Range (b)**	**$W_{baseline}$ (c)**
A-Lamp (A15, A17, A19, A21)	< 310	Use ENERGY STAR Watts Equivalent
	310 – 749	22
	750 – 1,049	35
	1,050 – 1,489	46
	1,490 – 2,600	66
	> 2,600	Use ENERGY STAR Watts Equivalent

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.

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[74] Cadmus & Demand Side Analytics, “Residential Retail Lighting Impact Evaluation Final Report”, Prepared for Central Hudson, April 20, 2022 – Slide 33.

Bulb Type (a)	Base Type (b)	Lumen Range (c)	$W_{baseline}$ (d)
Globe All G (G30, G25, G16.5)	E26 and E17	< 90	Use ENERGY STAR Watts Equivalent
		90 – 179	6
		180 – 249	10
		250 – 349	13
		350 – 749	22
		750 – 1,049	29
		1,050 – 1,489	37
		1,490 – 2,600	55
		> 2,600	Use ENERGY STAR Watts Equivalent
	E12 (Candelabra)	< 90	Use ENERGY STAR Watts Equivalent
		90 – 179	6
		180 – 249	10
		250 – 349	13
		350 – 499	21
		500 – 1,049	33
		> 1,049	Use ENERGY STAR Watts Equivalent
Globe (G40)	E26 (Medium), E17, and E12	< 90	Use ENERGY STAR Watts Equivalent
		90 – 179	6
		180 – 249	10
		250 – 349	13
		350 – 499	21
		500 – 1,049	33
		> 1,049	Use ENERGY STAR Watts Equivalent

Bulb Type (a)	**Base Type (b)**	**Lumen Range (c)**	**$W_{baseline}$ (d)**
Decorative (Shapes B10, B11, B13, BA10, BA11, CA10, C7, C9, F10, F15, ST, S14)	E26 (Medium) and E17	< 70	Use ENERGY STAR Watts Equivalent
		70 – 89	5
		90 – 149	7
		150 – 299	12
		300 – 749	22
		750 – 1,049	29
		1050 – 1,489	37
		1,490 – 2,600	55
		> 2,600	Use ENERGY STAR Watts Equivalent
	Candelabra base E12	< 70	Use ENERGY STAR Watts Equivalent
		70 – 89	5
		90 – 149	7
		150 – 299	12
		300 – 449	20
		450 – 1,049	33
		> 1,049	Use ENERGY STAR Watts Equivalent

Reflector/Flood Lamps

Baseline wattage for reflector and flood type lamps are found in the table 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.

Bulb Type (a)	**Lumen Range (b)**	**$W_{baseline}$ (c)**
R20	200 - 299	15
	300 – 718	24
	719 – 810	29
	811 – 1,002	33
	1,003 – 1,202	39
	1,203 – 1,516	47
	1,517 – 1,733	56
	1,734 – 2,184	64
	> 2,184	75

Bulb Type (a)	**Lumen Range (b)**	**$W_{baseline}$ (c)**
PAR20	200 - 299	15
	300 – 718	22
	719 – 810	29
	811 – 1,002	33
	1,003 – 1,202	39
	1,203 – 1,516	47
	1,517 – 1,733	56
	1,734 – 2,184	64
	> 2,184	75
BR30, BR40, ER40	200 – 299	15
	300 – 399	20
	400 – 649	26
	650 – 1,419	39
	1,420 – 1,789	50
	1,790 – 2,045	60
	2,046 – 2,578	69
	> 2,578	80
ER30	200 – 299	15
	300 – 399	20
	400 – 956	28
	957 – 1183	35
	1184 – 1419	42
	1420 – 1789	50
	1790 – 2045	60
	2046 – 2578	69
	> 2578	80
PAR30, PAR38, R40	639 – 847	25
	848 – 956	31
	957 – 1,183	35
	1,184 – 1,419	42
	1,420 – 1,789	50
	1,790 – 2,045	60
	2,046 – 2,578	69
	> 2,578	80
R14, PAR16, R16	200 – 299	15
	300 – 399	20
	400 – 499	25
	500 – 599	30
	600 – 1,000	35
MR16	< 450	19
	450 – 600	26
	> 600	36

Bulk Type (a)	Lumen Range (b)	$W_{baseline}$ (c)
For any lamps/bulb types for reflector lamps not captured in the criteria above	All	Use ENERGY STAR Watts Equivalent

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	999	2,273	1,125
Binghamton	999	2,273	1,125
Buffalo	999	2,273	1,125
Massena	999	2,273	1,125
NYC	1,752	1,606	1,752
Poughkeepsie	999	2,273	1,125
Syracuse	999	2,273	1,125

NYS cities other than NYC, Interior

Hours of operation for NYS cities other than NYC are taken from an Impact and Process Evaluation Study.[75]

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.[76]

NYC, Exterior

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[75] NMR Group Inc., “ONLINE MARKETPLACE & ELECTRIC RESIDENTIAL CONSUMER PRODUCTS, Impact and Process Evaluation”, June 9, 2023. Table 4-16. Modeled HOU compared to HOU listed in TRMs.

[76] 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.

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.[77]

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 exterior lighting hours derived from on-site lighting inventories of homes in New York City and Westchester County.[78]

LMI LED Table of Hours per Day by Unit Count

The hours per day values prescribed in the table below are intended for use with the Alternate Method for Calculating Annual Energy Savings for LMI Projects established above for General Purpose LEDs. The values in this table are based on the observation that program participants tend to prioritize replacement of the most used bulbs first and, as additional bulbs are replaced, the average hours of use per bulb decreases. For this reason, the hours per day applied to a project replacing 1 -2 bulbs shall be 3.2, while a project replacing 3 – 5 bulbs shall use an hours per day value of 3 and so on.

The values established below reflect the findings and guidance presented in the DOE Residential End-Use Lighting Study, which found average daily hours of use for all residential lamps to be 1.6 nationally and in NY state.[79] These values are consistent with those applied in the EmPower New York program and are subject to change pending future program evaluations.

# of Bulbs	Hours/day (Rest of NY)	Hours/day (NYC)[80]
1 - 2	3.2	5.6
3 - 5	3.0	5.3
6 - 7	2.5	4.4
8 - 9	1.5	2.6
10 - 16	1.0	1.8

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

A residential LMI customer replaces ten 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.

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[77] 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.

[78] 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.

[79] DOE Residential Lighting End-Use Consumption Study: Estimation Framework and Initial Estimates, December 2012; Table 4.1

[80] Hours/Day values in this table reflect a direct linear ratio of the values in the market rate HOU table above for NYC compared to other NY locations (i.e., NYC HOU are adjusted by a factor of 1,752/999 = 1.78).

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

$$\Delta MMBtu = units \times \frac{(W_{baseline} - W_{ee})}{1{,}000} \times hrs \times HVAC_{ff}$$

units = 10, from application
$W_{baseline}$ = 60, from application
W_{ee} = 10, from application
hrs = 999, 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

$$\Delta kWh = 10 \times \frac{(60 - 10)}{1{,}000} \times 999 \times (1 + 0.043) = 521\ kWh$$

$$\Delta kW = 10 \times \frac{(60 - 10)}{1{,}000} \times (1 + 0.073) \times 0.16 = 0.09\ kW$$

$$\Delta MMBtu = 10 \times \frac{(60 - 10)}{1{,}000} \times 999 \times (-0.003) = -1.50\ MMBtu$$

Alternate Method for Calculating Annual Energy Savings for LMI Projects

<u>General Purpose LEDs</u>

$$\Delta kWh = units\ \times \left(\frac{\Delta W_{LMI,GP} \times 365}{1{,}000}\right) \times hrs$$

units = 10, from application
$\Delta W_{LMI,GP}$ = 46, from application
hrs = 1, from Operating Hours section, LMI LED Table of Hours per Day by Unit Count

$$\Delta kWh = 10\ \times \left(\frac{46 \times 365}{1{,}000}\right) \times 1 = 168\ kWh$$

Effective Useful Life (EUL)

For Downstream Market Rate applications, see Appendix P.

For LMI applications relying on existing conditions to serve as baseline, and for the alternative method presented for LMI applications, use 3.3 years.[81]

For Midstream and Upstream applications relying on a blended baseline, use 10.7 years.[82]

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. NMR Group Inc., “ONLINE MARKETPLACE & ELECTRIC RESIDENTIAL CONSUMER PRODUCTS, Impact and Process Evaluation”, June 9, 2023

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[81] The EUL is established based on the expected ratio of lifetime savings to annual savings. Given an incandescent existing condition (with an assumed 1-year remaining useful life), installation of an LED with a 15-year lifetime and an efficacy ratio of 6:1 for LED vs. incandescent technology, the EUL is established as Lifetime Savings/Annual Savings = ((Annual Savings * 1 Year) + (Annual Savings * 1/6 * 14 Years)) / Annual Savings = 1 + 14/6 = 3.3.

[82] Midstream and Upstream methods use the same approach, but apply a blended weighting, in alignment with the blended baseline weighting. Applying the same weighting as used to establish blended baselines for Midstream and Upstream applications (37% LMI and 63% Market Rate) to assumed downstream market rate and LMI application lifetimes (15 years and 3.3 years, respectively).

Available from: <Link will be added once available>

4. 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
5. Energy Savings Forecast of Solid-State Lighting in General Illumination Applications, US Department of Energy, December 2019, pg. 82.
   Available from: https://www.energy.gov/sites/prod/files/2020/02/f72/2019_ssl-energy-savings-forecast.pdf
6. Electronic Code of Federal Regulations, Title 10: Energy, PART 430—ENERGY CONSERVATION PROGRAM FOR CONSUMER PRODUCTS, Subpart C—Energy and Water Conservation Standards.
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7. Energy Efficiency and Renewable Energy Office, Energy Conservation Program: Energy Conservation Standards for General Service Lamps; Final Rule (DOE 82 FR 7276), January 19, 2017.
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8. Energy Efficiency and Renewable Energy Office, Energy Conservation Program: Energy Conservation Standards for General Service Lamps; Final Rule (DOE 82 FR 7322), January 19, 2017.
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9. Energy Efficiency and Renewable Energy Office, Energy Conservation Program: Definitions for General Service Lamps; Final Rule (DOE 87 FR 27461), May 9, 2022.
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11. Cadmus & Demand Side Analytics, “Residential Retail Lighting Impact Evaluation Final Report”, Prepared for Central Hudson, April 20, 2022.
12. DOE, Residential Lighting End-Use Consumption Study: Estimation Framework and Initial Estimates, December 2012.
    Available from:
    https://www1.eere.energy.gov/buildings/publications/pdfs/ssl/2012_residential-lighting-study.pdf

Record of Revision

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1	10/15/2010
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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
3-22-5	4/29/2022
6-22-19	12/30/2022
3-23-11	3/31/2023
6-23-8	7/14/2023
6-24-7	7/8/2024

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BUILDING SHELL

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.

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, and install door sweeps on doors leading to the exterior or an unconditioned space.
- Repair doors and windows leading from conditioned to unconditioned space, including replacement of damaged components (e.g., frame jamb, threshold).
- 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. Blower door test results can only be used if it is deemed that the test is reliable, such as but not limited to confirmation that all openings to the exterior can be verified closed during pre- and post-implementation testing. 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

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

$$\Delta kWh_{cooling} = \frac{\left[\dfrac{(CFM_{75}/SF)_{baseline} - (CFM_{75}/SF)_{ee}}{F_{n,cooling} \times F_h}\right] \times SF \times LM \times 1.08 \times CDD \times 24}{Eff_{ElecCool} \times 1,000}$$

$$\Delta kWh_{heating} = \frac{\left[\frac{(CFM_{75}/SF)_{baseline} - (CFM_{75}/SF)_{ee}}{F_{n,heating} \times F_h}\right] \times SF \times 1.08 \times HDD \times 24 \times F_{ElecHeat}}{HSPF \times 1{,}000}$$

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[83]

$F_{n,cooling}$ = 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[84] (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)

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[83] ECCCNYS 2020 C402.5 Air leakage – thermal envelope (Mandatory).

[84] ECCCNYS 2020 C406.9 Reduced air infiltration.

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)
$F_{ElecHeat}$ = 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[85]
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.[86]
$(CFM_{75}/SF)_{ee}$		From application, results from blower door test. If post -implementation blower door test results are unavailable, use 0.25 CFM_{75}/SF as default.[87,88,89]
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.

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[85] 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.
[86] ECCCNYS 2020 C402.5 Air leakage – thermal envelope (Mandatory).
[87] ECCCNYS 2020 C406.9 Reduced air infiltration.
[88] U.S. Army Corps of Engineers Air Leakage Test Protocol for Building Envelopes, Version 3, May 11, 2012, p. 7
[89] 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.[90] 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.
$\mathrm{Eff}_{ElecCool}$		From application. SEER or IEER shall be used, based on nameplate rating metric of existing equipment. For equipment rated in SEER2, SEER2 rating shall be used.
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. For equipment rated in HSPF2, HSPF2 rating shall be used.
EER		From application. For equipment rated in EER2, EER2 rating shall be used. If unknown, baseline EER is established as follows[91]: $EER = (1.12 \times \mathrm{Eff}_{\mathrm{ElecCool}}) - (0.02 \times {\mathrm{Eff}_{\mathrm{ElecCool}}}^2)$
$\mathrm{Eff}_{heating}$		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	

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[90] LBL, Exegesis of Proposed ASHRAE Standard 119: Air Leakage Performance for Detached Single-Family Residential Buildings, M. Sherman, July 1986, pg. 12.

[91] DOE, Building America House Simulation Protocols, October 2010; for equipment rated in SEER2, replace SEER with SEER2 and EER with EER2 in the derivation formula.

Infiltration-Leakage Ratio, Climate Zone

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 tables below based on climate zone and shielding class, as defined below, based on application.[92]

Shielding Class[93]:

(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[94]

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

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[92] 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.

[93] ASHRAE Handbook – Fundamentals, 2017. Chapter 16 Ventilation and Infiltration, Section 10 Simplified Models of Residential Ventilation and Infiltration, Table 5 Local Shelter Classes.

[94] ASHRAE Journal, Dehumidification and Cooling Loads From Ventilation Air, Lewis Harriman, November 1997.

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.

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.[95]

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.[96] For all buildings, if a blower door test can be conducted, pre-implementation results will serve as existing conditions.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is the application of air leakage sealing treatments to an existing building envelope such that the exterior envelope, as well as interior walls/partitions between conditioned and unconditioned spaces have been inspected and all gaps sealed. Compliance flow rate CFM_{75}/SF shall come from blower door testing. If post-implementation blower-door results are unavailable, use default of 0.25 CFM_{75}/SF. For all buildings, if a blower door test can be conducted, post-implementation results will serve as efficient condition.

See Measure Description for minimum inspection compliance, and examples of air sealing measures.

Operating Hours

Effective heating and cooling hours associated with benefits of air sealing are established via the Heating and Cooling Degree Days table below.

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[95] C&I Unitary HVAC Load Shape Project Final Report, KEMA, 2011, Table 0-5: NY - Inland and NY - Urban/Coastal.

[96] ECCCNYS 2020 C402.5 Air leakage – thermal envelope (Mandatory).

Heating and Cooling Degree Days[97]

City	HDD	CDD
Albany	6,391	721
Binghamton	7,200	383
Buffalo	6,502	607
Massena	8,030	406
NYC	4,900	1017
Poughkeepsie	6,026	745
Syracuse	6,625	618

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 and the location has a HDD of 6,682 and a CDD of 602. 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

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[97] HDD/CDD taken from NCEI 1991-2020 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

$$\Delta kWh_{cooling} = \frac{\left[\frac{0.44 - 0.27}{34 \times 0.719}\right] \times 15{,}000 \times 6.8 \times 1.08 \times 602 \times 24}{13 \times 1{,}000} = 851.39$$

$$\Delta kWh_{heating} = \frac{\left[\frac{0.44 - 0.27}{28 \times 0.719}\right] \times 15{,}000 \times 1.08 \times 6{,}682 \times 24 \times 0}{N/A \times 1{,}000} = 0$$

$$\Delta kWh = 851 + 0 = 851\ kWh$$

$$\Delta kW = \frac{\left[\frac{0.44 - 0.27}{34 \times 0.719}\right] \times 15{,}000 \times 6.8 \times 1.08}{10.8 \times 1{,}000} \times 0.477$$
$$= 0.034\ kW$$

$$\Delta MMBtu = \frac{\left[\frac{0.44 - 0.27}{28 \times 0.719}\right] \times 15{,}000 \times 1.08 \times 6{,}682 \times 24 \times 1}{0.82 \times 1{,}000{,}000} = 26.75\ MMBtu$$

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.

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3-21-11	4/9/2021
6-24-8	7/8/2024

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HEATING, VENTILATION AND AIR CONDITIONING (HVAC)

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

$$\Delta kWh = \left(\Delta kWh_{heating} + \Delta kWh_{cooling}\right) \times (1 + HVAC_c)$$

$$\Delta kWh_{cooling} = units\ \times \frac{\left(W_{baseline} \times ESF_{cooling}\right)}{1{,}000} \times LF \times hrs_{cooling}$$

$$\Delta kWh_{heating} = units\ \times \frac{\left(W_{baseline} \times ESF_{heating}\right)}{1{,}000} \times LF \times hrs_{heating}$$

Summer Peak Coincident Demand Savings

$$\Delta kW = units\ \times \frac{\left(W_{baseline} \times ESF_{cooling}\right)}{1{,}000} \times LF \times (1 + HVAC_d) \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = units\ \times \frac{\left(W_{baseline} \times ESF_{heating}\right)}{1{,}000} \times LF \times hrs_{heating} \times HVAC_{ff}$$

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
$hrs_{cooling}$ = Total system operating hours in cooling mode, including shoulder months
$hrs_{heating}$ = Total system operating hours in heating mode, including shoulder months
$HVAC_c$ = 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
$W_{baseline}$		From application.
$ESF_{heating}$	0.23	US Department of Energy.[98]
$ESF_{cooling}$	0.38	US Department of Energy.[99]
LF	0.9	US Department of Energy.[100]
$hrs_{cooling}$		From application. If unknown, see operating hours section below.
$hrs_{heating}$		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.[101]

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.

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[98] US DOE, Evaluation of Retrofit Variable-Speed Furnace Fan Motors, January 2014, Section 4: Discussion, pg. 23.
[99] Ibid.
[100] Used to reflect that motors do not typically run at 100% of rated power.
[101] *No source specified – update pending availability and review of applicable references.*

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.

Operating Hours

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).

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 1,200 hours during the cooling season and 3,000 hours during the heating season. Annual Electric Energy Savings, Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta kWh = \left(\Delta kWh_{heating} + \Delta kWh_{cooling}\right) \times (1 + HVAC_c)$$

$$\Delta kWh_{cooling} = units \times \frac{\left(W_{baseline} \times ESF_{cooling}\right)}{1{,}000} \times LF \times hrs_{cooling}$$

$$\Delta kWh_{heating} = units \times \frac{\left(W_{baseline} \times ESF_{heating}\right)}{1{,}000} \times LF \times hrs_{heating}$$

$$\Delta kW = units \times \frac{\left(W_{baseline} \times ESF_{cooling}\right)}{1{,}000} \times LF \times (1 + HVAC_d) \times CF$$

$$\Delta MMBtu = units \times \frac{\left(W_{baseline} \times ESF_{heating}\right)}{1{,}000} \times LF \times hrs_{heating} \times HVAC_{ff}$$

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
$hrs_{cooling}$ = 1,200, from application
$hrs_{heating}$ = 3,000, 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

$$\Delta kWh_{cooling} = 1 \times \frac{(500 \times 0.38)}{1,000} \times 0.9 \times 1,200 = 205.2\ kWh$$

$$\Delta kWh_{heating} = 1 \times \frac{(500 \times 0.23)}{1,000} \times 0.9 \times 3,000 = 310.5\ kWh$$

$$\Delta kWh = (205.2 + 310.5) \times (1 + 0.070) = 551.8\ kWh$$

$$\Delta kW = 1 \times \frac{(500 \times 0.38)}{1,000} \times 0.9 \times (1 + 0.200) \times 0.8 = 0.164\ kW$$

$$\Delta MMBtu = 1 \times \frac{(500 \times 0.23)}{1,000} \times 0.9 \times 3,000 \times (-0.004) = -1.24\ MMBtu$$

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

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1-16-14	12/31/2015
6-18-13	6/26/2018
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REFRIGERATION

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.[102]

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times \left(\frac{W_{EFan}}{1{,}000}\right) \times F_{PA} \times ESF \times hrs \times \left(1 + \frac{1}{COP_{ref}}\right)$$

Summer Peak Coincident Demand Savings

$$\Delta kW = units \times \left(\frac{W_{EFan}}{1{,}000}\right) \times F_{PA} \times ESF \times CF \times \left(1 + \frac{1}{COP_{ref}}\right)$$

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 fan motors installed under the program
W_{EFan} = Nameplate wattage of existing evaporator fan motor
F_{PA} = Power adjustment factor
ESF = Reduction of load by replacing evaporator fan motor
hrs = Evaporator fan motor annual operating hours
COP_{ref} = Coefficient of performance of refrigeration equipment
CF = Coincidence factor
1,000 = Conversion factor, one kW equals 1,000 W

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[102] 10 CFR 431.306.

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. If unavailable, use the wattage of the EC fan motor divided by (1 – ESF).
F_{PA}	0.601	Oak Ridge National Laboratory.[103]
hrs	Refrigerated Case: 8,573 Walk-In - On/Off Control: 5,571 Walk-In - Multistep Control: 6,062 Walk-In - No Cooler Control: 8,567	Refrigerated Case: PG&E.[104] Walk-In: Based on refrigeration control type.[105]
ESF	Refrigerated Case (replacing SP motor): 0.44 Refrigerated Case (replacing PSC motor): 0.30 Walk-In: 0.65	Refrigerated Case: US DOE.[106] Walk-In: Based on numerous pre and post meter readings conducted by NRM and supported by RLW Analytics evaluation.[107]
COP_{ref}		From application, using method detailed in Calculating Coefficient of Performance of Refrigeration Equipment section below. If requisite information is unavailable, use default of 2.87 for coolers and 1.62 for freezers.[108] 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	

Calculating Coefficient of Performance of Refrigeration Equipment (COP_{ref})

The method below shall be applied to establish the COP of refrigeration equipment for use in this measure. If condenser efficiency is unknown, use 0.20 kW/ton for freezers and 0.16 kW/ton for coolers to reflect condenser load.[109]

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[103] Oak Ridge National Laboratory, Q-Sync Motors in Commercial Refrigeration: Preliminary Test Results and Projected Benefits, September 2015, page 5.

[104] PG&E Work Paper PGE3PREF124 Revision 2. Average of operating hours of medium temperature applications and low temperature applications.

[105] 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.

[106] 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.

[107] Small Business Services, Custom Measure Impact Evaluation, RLW Analytics, Inc., March 2007.

[108] Based on CDH Energy evaluation of actual refrigeration system performance for several commercially available compressors, dated 09/06/2017. Values presented reflect unweighted average efficiencies of all evaluated systems, with additional 0.20 kW/ton for freezers and 0.16 kW/ton for coolers to reflect condenser load.

[109] Ibid

$$COP_{ref} = \frac{\frac{12}{3.413}}{(\mathrm{Comp_{eff}} + \mathrm{Cond_{eff}})}$$

where:

$\mathrm{Comp_{eff}}$ = Efficiency of the cooler/freezer compressor (kW/Ton)
$\mathrm{Cond_{eff}}$ = Efficiency of the cooler/freezer condenser (kW/Ton)
12 = kBtu/ton
3.413 = BTUs in one watt-hour of electricity

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 1.0.[110]

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 manufactured before January 1, 2009.

Compliance Efficiency from which Incentives are Calculated

The compliance case is a retrofitted 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.[111]

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.

$$\Delta kWh = units \times \left(\frac{W_{EFan}}{1{,}000}\right) \times F_{PA} \times ESF \times hrs \times \left(1 + \frac{1}{COP_{ref}}\right)$$

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[110] *No source specified – update pending availability and review of applicable references.*
[111] Cadmus, Commercial Refrigeration, Loadshape Project, October 2015

$$\Delta kW = units \times \left(\frac{W_{EFan}}{1{,}000}\right) \times F_{PA} \times ESF \times CF \times \left(1 + \frac{1}{COP_{ref}}\right)$$

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 = 6,062, from Summary of Variables and Data Sources table based on refrigeration control type from application
ESF = 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

$$\Delta kWh = 1 \times \left(\frac{126.5}{1{,}000}\right) \times 0.601 \times 0.65 \times 6{,}062 \times \left(1 + \frac{1}{3.2}\right) = 393.2\ kWh$$

$$\Delta kW = 1 \times \left(\frac{126.5}{1{,}000}\right) \times 0.601 \times 0.65 \times 1.0 \times \left(1 + \frac{1}{3.2}\right) = 0.065\ kW$$

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

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

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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
6-24-10	7/8/2024

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BUILDING SHELL

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.

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 ($\geq$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[112] California Energy Commission, 2013 Building Energy Efficiency Standards.[113]
$F_{ElecCool}$		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. For equipment rated in SEER2, SEER2 rating shall be used.
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. For equipment rated in HSPF2, HSPF2 rating shall be used.
EER		From application. For equipment rated in EER2, EER2 rating shall be used.
$Eff_{FuelHeat}$		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.[114]

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[112] Thermal Design and Code Compliance for Cold-Formed Steel Walls, 2015, American Iron and Steel Institute, pg. 17.

[113] 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.

[114] 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 condition is a building envelope with insufficient insulation (i.e., not compliant with all applicable construction code requirements). Because existing insufficient insulation is used to establish baseline for this measure, there is no distinction in the approach for baseline determination between market-rate and LMI applications. 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.

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[115] 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[116]

City	HDD	CDD
Albany	6,391	721
Binghamton	7,200	383
Buffalo	6,502	607
Massena	8,030	406
NYC	4,900	1017
Poughkeepsie	6,026	745
Syracuse	6,625	618

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.

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[115] ECCCNYS 2020, Section C503 Building Thermal Envelope.

[116] HDD/CDD taken from NCEI 1991-2020 climate normal using a 65 °F balance point.

Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

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

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

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

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

$R_{baseline}$ = 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 = 745, from Operating Hours section based on city
HDD = 6,026, 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

$$\Delta kWh_{cooling} = \frac{\left(\frac{1}{13.5} - \frac{1}{13.5 + 16.5}\right) \times 2{,}000 \times (1 - 0.07) \times 745 \times 24 \times 1.0}{1{,}000 \times 15} = 98.14$$

$$\Delta kWh_{heating} = \frac{\left(\frac{1}{13.5} - \frac{1}{13.5 + 16.5}\right) \times 2{,}000 \times (1 - 0.07) \times 6{,}026 \times 24 \times 1.0}{1{,}000 \times 11} = 850.21$$

$$\Delta kWh = 98.14 + 850.21 = 948.35\ kWh$$

$$\Delta kW = \frac{\left(\frac{1}{13.5} - \frac{1}{13.5 + 16.5}\right) \times 2{,}000 \times (1 - 0.07) \times 1.0}{1{,}000 \times 12} \times 0.477 = 0.006\ kW$$

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

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Record of Revision

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3-21-12	4/9/2021
6-24-12	7/8/2024

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APPLIANCE

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.[117]

- Convection Ovens[118] - 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.[119]
- Rack Ovens[120] - 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[121] - 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[122] - This measure includes gas and electric commercial deep-fat fryers. A deep-fat fryer is an appliance, including a cooking vessel, 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. 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.

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[117] ENERGY STAR® Commercial Food Service Equipment Calculator (accessed 2/26/2018).

[118] ENERGY STAR® Program Requirements Product Specification for Commercial Ovens, Eligibility Criteria, Version 3.0., April 2022.

[119] PG&E Work Paper PGECOFST101 Revision 6, Table 12, pg. 18.

[120] ENERGY STAR® Program Requirements Product Specification for Commercial Ovens, Eligibility Criteria Version 3.0, April 2022.

[121] ENERGY STAR® Program Requirements for Commercial Steam Cookers, Eligibility Criteria Version 1.2, August 2003.

[122] ENERGY STAR® Program Requirements Product Specification for Commercial Fryers, Eligibility Criteria Final Version 3.0. October 2016.

- Griddles[123] - 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 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.[124]

This measure is limited to non-fuel switching and gas-to-electric scenarios. For gas to electric fuel switching scenarios, use $BTU_{baseline}$ values in the fossil fuel equations and the BTU_{ee} values in the electric equations.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings (Electric Equipment Only)

$$\begin{aligned}\Delta kWh = units \times days \times \frac{1}{3{,}412} \\ \times \{[(BTU_{DailyPreheat,baseline} + BTU_{DailyIdle,baseline} + BTU_{Cooking,baseline}) \\ \times F_{elec,baseline}] \\ - [(BTU_{DailyPreheat,ee} + BTU_{DailyIdle,ee} + BTU_{Cooking,ee}) \times F_{elec,ee}]\}\end{aligned}$$

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)

$$\begin{aligned}\Delta MMBtu = units \times days \times \frac{1}{1{,}000{,}000} \\ \times \{[(BTU_{DailyPreheat,baseline} + BTU_{DailyIdle,baseline} + BTU_{Cooking,baseline}) \\ \times F_{ff,baseline}] \\ - [(BTU_{DailyPreheat,ee} + BTU_{DailyIdle,ee} + BTU_{Cooking,ee}) \times F_{ff,ee}]\}\end{aligned}$$

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[123] ENERGY STAR® Program Requirements for Commercial Griddles, Eligibility Criteria Version 1.2, January 2011.

[124] PG&E Work Paper PGECOFST117 Revision 5, Table 9, pg. 11-12, where 1 pizza equals 0.76 lbs.

where:

$$BTU_{DailyPreheat,baseline} = N_{preheat} \times BTU_{preheat,baseline}$$

$$BTU_{DailyPreheat,ee} = N_{preheat} \times BTU_{preheat,ee}$$

$$BTU_{DailyIdle,baseline} = BTU/h_{idle,baseline} \times \left[hrs - N_{preheat} \times hrs_{preheat,baseline} - \left(\frac{lbs}{(lbs/hr)_{baseline}}\right)\right]$$

$$BTU_{DailyIdle,ee} = BTU/h_{idle,ee} \times \left[hrs - N_{preheat} \times hrs_{preheat,ee} - \left(\frac{lbs}{(lbs/hr)_{ee}}\right)\right]$$

$$BTU_{Cooking,baseline} = lbs \times Q_{food} \times \frac{1}{Eff_{baseline}}$$

$$BTU_{Cooking,ee} = lbs \times Q_{food} \times \frac{1}{Eff_{ee}}$$

When applying default ΔBTU$_{preheat}$, ΔBTU$_{idle}$ and ΔBTU$_{cooking}$ values from the Default Values table below in place of calculated values, the following equations shall be used:

Annual Electric Energy Savings (Electric Equipment Only)

$$\Delta kWh = units \times days \times \frac{1}{3{,}412} \times \left(\Delta BTU_{preheat} + \Delta BTU_{idle} + \Delta BTU_{Cooking}\right) \times F_{elec,baseline}$$

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)

$$\Delta MMBtu = units \times days \times \frac{1}{1{,}000{,}000} \times \left(\Delta BTU_{preheat} + \Delta BTU_{idle} + \Delta BTU_{Cooking}\right) \times F_{ff,baseline}$$

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.

where:

ΔkWh = Annual electric energy savings
ΔkW = Peak coincident demand electric savings
$\Delta MMBtu$ = Annual fossil fuel energy savings
$BTU_{DailyPreheat}$ = Total Daily Preheat energy usage
$BTU_{DailyIdle}$ = Total Daily Idle energy usage
$BTU_{Cooking}$ = Total Daily Cooking energy usage
$\Delta BTU_{preheat}$ = 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
F_{elec} = Factor for presence of electric equipment in the baseline situation
F_{ff} = Factor for presence of gas equipment
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, as defined by ENERGY STAR® program requirements or relevant standard for each equipment 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
days		From application or look up based on facility type in Operating Hours section below.
$F_{elec,baseline}$		For baseline/existing electric equipment, set to 1. Otherwise, 0.
$F_{elec,ee}$		For compliant/efficient electric equipment, set to 1. Otherwise, 0.
$F_{ff,baseline}$		For baseline/existing gas equipment, set to 1. Otherwise, 0.
$F_{ff,ee}$		For compliant/efficient gas equipment, set to 1. Otherwise, 0.
hrs		From application or look up based on facility type in Operating Hours section below.
$N_{preheat}$	1	Pacific Gas and Electric.[125]

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[125] Shared assumption from all PG&E Work Papers referenced in this measure.

Variable	Value	Notes
$BTU_{preheat,baseline}$		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.
$BTU/h_{idle,ee}$		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 and are not suitable for fuel switching scenarios.

Equipment	$\Delta BTU_{preheat}$	ΔBTU_{idle}	$\Delta BTU_{cooking}$
Convection Oven, Electric, Full Size	580	1,365 x hrs -1,708	3,250
Convection Oven, Electric, Half Size	649	102 x hrs -1,000	1,553
Convection Oven, Gas, Full Size	3,647	3,100 x hrs -4,673	2,470
Convection Oven, Gas, Half Size	2,625	3,500 x hrs -11,842	27,778
Conveyor Oven, Gas	8,662	13,000 x hrs -55,144	124,405
Rack Oven, Gas, Double Rack	24,251	35,000 x hrs -179,550	397,692
Rack Oven, Gas, Single Rack	12,233	18,000 x hrs -89,017	176,250
Steamer, Electric	4,197	14,581 x hrs -10,792	19,385
Steamer, Gas	8,539	27,378 x hrs -23,156	42,368
Fryer, Electric, Standard	648	1,365 x hrs -3,791	10,988
Fryer, Electric, Large Vat	1,194	853 x hrs -1,911	15,268
Fryer, Gas	6,331	5,000 x hrs -15,381	73,286

Equipment	**$\Delta BTU_{preheat}$**	**ΔBTU_{idle}**	**$\Delta BTU_{cooking}$**
Fryer, Gas, Large Vat	5,000	4,000 x hrs -8,556	73,286
Griddle, Electric	6,828	1,638 x hrs -7,451	5,220
Griddle, Gas	6,000	5,100 x hrs -49,875	23,438

Common Variables[126]

Equipment	**Value**		
	$hrs_{preheat}$	**lbs**	**Q_{food} (BTU/lb)**
Convection Oven, Electric, Full Size	0.14[127]	100	250
Convection Oven, Electric, Half Size	0.14[128]	100	250
Convection Oven, Gas, Full Size	0.14[129]	100	250
Convection Oven, Gas, Half Size	0.18[130]	100	250
Conveyor Oven, Gas	0.25[131]	190	250
Rack Oven, Gas, Double Rack	0.33[132]	1,200[133]	235
Rack Oven, Gas, Single Rack	0.33[134]	600	235
Steamer, Electric	0.22[135]	100	105
Steamer, Gas	0.22[136]	100	105
Fryer, Electric, Standard	0.14[137]	150	570
Fryer, Electric, Large Vat	0.14[138]	150	570
Fryer, Gas, Standard	0.23[139]	150	570
Fryer, Gas, Large Vat	0.23[140]	150	570
Griddle, Electric	0.25[141]	100	475
Griddle, Gas	0.25[142]	100	475

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.9.[143]

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[126] ENERGY STAR® Commercial Food Service Equipment Calculator (accessed 2/26/2018), unless otherwise noted.
[127] California TF, Work Paper SWFS001-02, pg. 7.
[128] California TF, Work Paper SWFS001-02, pg. 7.
[129] California TF, Work Paper SWFS001-02, pg. 11.
[130] California TF, Work Paper SWFS001-02, pg. 18.
[131] California TF, Work Paper SWFS008-01, pg. 7, where 1 pizza equals 0.76 lbs.
[132] California TF, Work Paper SWFS014-02, pg. 7.
[133] Ibid.
[134] Ibid, pg. 8.
[135] California TF, Work Paper SWFS005-02, pg. 9.
[136] California TF, Work Paper SWFS005-02, pg. 13.
[137] California TF, Work Paper SWFS011-03, pg, 8.
[138] Ibid.
[139] California TF, Work Paper SWFS011-03, pg, 12.
[140] Ibid.
[141] California TF Work Paper SWFS004 Revision 1, pg. 7.
[142] California TF Work Paper SWFS004 Revision 1, pg. 10.
[143] 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.[144]

Equipment	$BTU_{preheat,baseline}$ (BTU)	$BTUh_{idle,baseline}$ (BTU/h)	$(lbs/hr)_{baseline}$	$Eff_{baseline}$
Convection Oven, Electric, Full Size	5,323[145]	5,459[146]	90	0.71[147]
Convection Oven, Electric, Half Size	3,037[148]	3,412[149]	45	0.71[150]
Convection Oven, Gas, Full Size	13,096[151]	12,000[152]	83	0.46[153]
Convection Oven, Gas, Half Size[154]	6,000	12,000	45	0.42
Conveyor Oven, Gas[155]	48,662	70,000	114	0.33
Rack Oven, Gas, Double Rack	90,009[156]	30,000[157]	250	0.52[158]
Rack Oven, Gas, Single Rack	54,817[159]	25,000[160]	130	0.48[161]
Steamer, Electric	5,186[162]	455 x no. pans[163]	23.3 x no. pans	0.50[164]

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[144] ENERGY STAR® Commercial Food Service Equipment Calculator (accessed 2/26/2018).
[145] California TF, Work Paper SWFS001-02, pg. 7.
[146] NYS Appliances Standards prescribe ENERGY STAR® Program Requirements Product Specification for Commercial Ovens Eligibility Criteria Version 3.0
[147] Ibid.
[148] California TF, Work Paper SWFS001-02, pg. 7.
[149] NYS Appliances Standards prescribe ENERGY STAR® Program Requirements Product Specification for Commercial Ovens Eligibility Criteria Version 2.2
[150] Ibid.
[151] California TF, Work Paper SWFS001-02, pg. 11.
[152] NYS Appliances Standards prescribe ENERGY STAR® Program Requirements Product Specification for Commercial Ovens Eligibility Criteria Version 2.2
[153] Ibid.
[154] California TF, Work Paper SWFS001-02, pg. 11.
[155] California TF, Work Paper SWFS008-02, pg. 7, where 1 pizza equals 0.76 lbs.
[156] California TF, Work Paper SWFS014-02, pg. 8.
[157] NYS Appliances Standards prescribe ENERGY STAR® Program Requirements Product Specification for Commercial Ovens Eligibility Criteria Version 2.2
[158] Ibid.
[159] California TF, Work Paper SWFS014-02, pg. 7.
[160] NYS Appliances Standards prescribe ENERGY STAR® Program Requirements Product Specification for Commercial Ovens Eligibility Criteria Version 2.2
[161] Ibid.
[162] California TF, Work Paper SWFS005-02, pg. 9.
[163] NYS Appliances Standards prescribe ENERGY STAR® Program Requirements for Commercial Steam Cookers V1.2
[164] Ibid.

Equipment	$BTU_{preheat,baseline}$ (BTU)	$BTUh_{idle,baseline}$ (BTU/h)	$(lbs/hr)_{baseline}$	$Eff_{baseline}$
Steamer, Gas	18,833[165]	2,100 x no. pans[166]	23.3 x no. pans	0.38[167]
Fryer, Electric, Standard	5,971[168]	3,412[169]	65	0.80[170]
Fryer, Electric, Large Vat	10,577[171]	3,753[172]	100	0.80[173]
Fryer, Gas, Standard	16,609[174]	9,000[175]	60	0.50[176]
Fryer, Gas, Large Vat	27,000[177]	12,000[178]	100	0.50[179]
Griddle, Electric	2,275 x griddle area*[180]	1,365 x griddle area*	5.83 x griddle area*	0.65
Griddle, Gas	3,500 x griddle area*[181]	3,500 x griddle area*	4.17 x griddle area*	0.32

*Griddle area in square feet

Compliance Efficiency from which Incentives are Calculated

The compliance condition is ENERGY STAR® food service equipment 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. Preheat energy and all values are reported from referenced California TF workpaper sources.

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[165] California TF, Work Paper SWFS005-02, pg. 13.
[166] NYS Appliances Standards prescribe ENERGY STAR® Program Requirements for Commercial Steam Cookers V1.2
[167] Ibid.
[168] California TF, Work Paper SWFS011-02, pg. 8.
[169] NYS Appliances Standards prescribe ENERGY STAR ® Program Requirements for Commercial Fryers V2.0
[170] Ibid.
[171] California TF, Work Paper SWFS011-02, pg. 8.
[172] NYS Appliances Standards prescribe ENERGY STAR ® Program Requirements for Commercial Fryers V2.0
[173] Ibid.
[174] California TF, Work Paper SWFS011-02, pg. 11.
[175] NYS Appliances Standards prescribe ENERGY STAR ® Program Requirements for Commercial Fryers V2.0
[176] Ibid.
[177] California TF, Work Paper SWFS011-02, pg. 11.
[178] NYS Appliances Standards prescribe ENERGY STAR ® Program Requirements for Commercial Fryers V2.0
[179] Ibid.
[180] California TF, Work Paper SWFS004-01, pg. 7.
[181] California TF, Work Paper SWFS004-01, pg. 7.

Equipment	$BTU_{preheat,ee}$ (BTU)	$BTU/h_{idle,ee}$ (BTU/h)	$(lbs/hr)_{ee}$	Eff_{ee}
Convection Oven, Electric, Full Size	4,743[182]	4,776[183]	90	0.76[184]
Convection Oven, Electric, Half Size	2,388[185]	3,412[186]	49	0.71[187]
Convection Oven, Gas, Full Size	9,449[188]	9,500[189]	86	0.49[190]
Convection Oven, Gas, Half Size[191]	3,375	8,500	55	0.45
Conveyor Oven, Gas[192]	40,000	57,000	167	0.42
Rack Oven, Gas, Double Rack	65,758[193]	30,000[194]	250	0.52[195]
Rack Oven, Gas, Single Rack	42,584[196]	25,000[197]	130	0.48[198]
Steamer, Electric	989[199]	455 x no. pans[200]	16.7 x no. pans	0.69[201]
Steamer, Gas	10,294[202]	2,100 x no. pans[203]	20.0 x no. pans	0.52[204]

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[182] California TF, Work Paper SWFS001-02, pg. 7.
[183] NYS Appliances Standards prescribe ENERGY STAR® Program Requirements Product Specification for Commercial Ovens, Eligibility Criteria, Version 3.0
[184] Ibid.
[185] California TF, Work Paper SWFS001-02, pg. 7.
[186] NYS Appliances Standards prescribe ENERGY STAR® Program Requirements Product Specification for Commercial Ovens, Eligibility Criteria, Version 3.0
[187] Ibid.
[188] California TF, Work Paper SWFS001-02, pg. 11.
[189] ENERGY STAR® Program Requirements Product Specification for Commercial Ovens, Eligibility Criteria, Version 3.0
[190] Ibid.
[191] California TF, Work Paper SWFS001-02, pg. 11.
[192] California TF, Work Paper SWFS008-02, pg. 7, where 1 pizza equals 0.76 lbs.
[193] California TF, Work Paper SWFS014-02, pg. 8.
[194] NYS Appliances Standards prescribe ENERGY STAR® Program Requirements Product Specification for Commercial Ovens, Eligibility Criteria, Version 3.0
[195] Ibid.
[196] California TF, Work Paper SWFS014-02, pg. 8.
[197] NYS Appliances Standards prescribe ENERGY STAR® Program Requirements Product Specification for Commercial Ovens, Eligibility Criteria, Version 3.0
[198] Ibid.
[199] California TF, Work Paper SWFS005-02, pg. 9.
[200] NYS Appliances Standards prescribe ENERGY STAR® Program Requirements for Commercial Steam Cookers V1.2
[201] Con Edison 2023 program minimum qualifying specifications
[202] California TF, Work Paper SWFS005-02, pg. 13.
[203] NYS Appliances Standards prescribe ENERGY STAR® Program Requirements for Commercial Steam Cookers V1.2
[204] Con Edison 2023 program minimum qualifying specifications

Equipment	$BTU_{preheat,ee}$ (BTU)	$BTU/h_{idle,ee}$ (BTU/h)	$(lbs/hr)_{ee}$	Eff_{ee}
Fryer, Electric, Standard	5,323[205]	2,730[206]	70	0.83[207]
Fryer, Electric, Large Vat	9,383[208]	3,753[209]	110	0.87[210]
Fryer, Gas, Standard	10,278[211]	7,100[212]	65	0.56[213]
Fryer, Gas, Large Vat	22,000[214]	9,600[215]	110	0.62[216]
Griddle, Electric	1,137 x griddle area*[217]	6,141 x griddle area*[218]	6.67 x griddle area*	0.77[219]
Griddle, Gas	2,500 x griddle area*[220]	5,600 x griddle area*[221]	7.5 x griddle area*	0.52[222]

* Griddle area in square feet

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.[223]

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

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[205] California TF, Work Paper SWFS011-02, pg. 8.
[206] NYS Appliances Standards prescribe ENERGY STAR ® Program Requirements for Commercial Fryers V3.0
[207] Ibid.
[208] California TF, Work Paper SWFS011-02, pg. 8.
[209] NYS Appliances Standards prescribe ENERGY STAR ® Program Requirements for Commercial Fryers V3.0
[210] Ibid.
[211] California TF, Work Paper SWFS011-02, pg. 11.
[212] Con Edison 2023 program minimum qualifying specifications
[213] Ibid.
[214] California TF, Work Paper SWFS011-02, pg. 11.
[215] Con Edison 2023 program minimum qualifying specifications
[216] Ibid.
[217] California TF Work Paper SWFS004-01, pg. 7.
[218] Con Edison 2023 program minimum qualifying specifications
[219] Ibid.
[220] California TF Work Paper SWFS004 -01, pg. 10.
[221] Con Edison 2023 program minimum qualifying specifications.
[222] Ibid.
[223] California Energy Commission, Characterizing the Energy Efficiency Potential of Gas-Fired Commercial Foodservice Equipment, Appendix E.

Facility Type	hours/day	days/year
Motel	20	365
Primary School	5	180
Secondary School	8	180
Office	12	250
University	11	283

Example Calculation – Non Fuel-Switching *(Not to be used as default)*

A full-size electric convection oven with 90 lb/hr capacity, 3,470 $BTU_{preheat}$, 4,400 BTU/h_{idle} and 76% 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.

$$\Delta kWh = units \times days \times \frac{1}{3{,}412} \times \{[(BTU_{DailyPreheat,baseline} + BTU_{DailyIdle,baseline} + BTU_{Cooking,baseline}) \times F_{elec,baseline}] - [(BTU_{DailyPreheat,ee} + BTU_{DailyIdle,ee} + BTU_{Cooking,ee}) \times F_{elec,ee}]\}$$

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

where:

$$BTU_{DailyPreheat,baseline} = N_{preheat} \times BTU_{preheat,baseline}$$

$$BTU_{DailyPreheat,ee} = N_{preheat} \times BTU_{preheat,ee}$$

$$BTU_{DailyIdle,baseline} = BTU/h_{idle,baseline} \times \left[hrs - N_{preheat} \times hrs_{preheat,baseline} - \left(\frac{lbs}{(lbs/hr)_{baseline}}\right)\right]$$

$$BTU_{DailyIdle,ee} = BTU/h_{idle,ee} \times \left[hrs - N_{preheat} \times hrs_{preheat,ee} - \left(\frac{lbs}{(lbs/hr)_{ee}}\right)\right]$$

$$BTU_{cooking,baseline} = lbs \times Q_{food} \times \frac{1}{Eff_{baseline}}$$

$$BTU_{cooking,ee} = lbs \times Q_{food} \times \frac{1}{Eff_{ee}}$$

units = 1, from application
days = 320 days/year, from application
$F_{elec,baseline}$ = 1, from Summary of Variables and Data Sources, assuming electric baseline
$F_{elec,ee}$ = 1, from Summary of Variables and Data Sources

$N_{preheat}$ = 1, from Summary of Variables and Data Sources

$BTU_{preheat,baseline}$ = 5,323 BTU, from Baseline Efficiencies from which Energy Savings are calculated

$BTU_{preheat,ee}$ = 3,470 BTU, from application

$BTU/h_{idle,baseline}$ = 5,459 BTU, from Baseline Efficiencies from which Energy Savings are calculated

$BTU/h_{idle,ee}$ = 4,400 BTU, from application

$Hrs_{preheat,baesline}$ = 0.14, from Common Variables

$Hrs_{preheat,ee}$ = 0.14, from Common Variables

Hrs = 12 hours/day, from application

lbs = 100 lbs, from Common Variables

$(lbs/hr)_{baseline}$ = 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

$Eff_{baseline}$ = 0.71, from Baseline Efficiencies from which Energy Savings are calculated

Eff_{ee} = 0.76, from application

CF = 0.9, from Summary of Variables and Data Sources

$$BTU_{DailyPreheat,baseline} = 1 \times 5{,}323 = 5{,}323$$

$$BTU_{DailyPreheat,ee} = 1 \times 3{,}470 = 3{,}470$$

$$BTU_{DailyIdle,baseline} = 5{,}459 \times \left[12 - 1 \times 0.14 - \left(\frac{100}{90}\right)\right] = 58{,}678.18$$

$$BTU_{DailyIdle,ee} = 4{,}400 \times \left[12 - 1 \times 0.14 - \left(\frac{100}{90}\right)\right] = 47{,}295.11$$

$$BTU_{cooking,baseline} = 100 \times 250 \times \frac{1}{0.71} = 35{,}211.27$$

$$BTU_{cooking,ee} = 100 \times 250 \times \frac{1}{0.76} = 32{,}894.74$$

$$\Delta kWh = units \times days \times \frac{1}{3{,}412} \times \{[(5{,}323 + 58{,}678 + 35{,}211) \times 1] - [(3{,}470 + 47{,}295 + 32{,}895) \times 1]\}$$

$$\Delta kWh = 1 \times 320 \times \frac{1}{3{,}412} \times (99212 - 83660) = 1{,}459\ kWh$$

$$\Delta kW = \frac{1{,}459}{(320 \times 12)} \times 0.9 = 0.34\ kW$$

Example Calculation – Fuel Switching *(Not to be used as default)*

A hospital near Albany is changing their gas oven for an electric half-size convection oven. Annual Electric Energy Savings, Summer Peak Coincident Demand Savings, and Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta kWh = units \times days \times \frac{1}{3{,}412} \times \{[(BTU_{DailyPreheat,baseline} + BTU_{DailyIdle,baseline} + BTU_{Cooking,baseline}) \times F_{elec,baseline}] - [(BTU_{DailyPreheat,ee} + BTU_{DailyIdle,ee} + BTU_{Cooking,ee}) \times F_{elec,ee}]\}$$

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

$$\Delta MMBtu = units \times days \times \frac{1}{1{,}000{,}000} \times \{[(BTU_{DailyPreheat,baseline} + BTU_{DailyIdle,baseline} + BTU_{Cooking,baseline}) \times F_{ff,baseline}] - [(BTU_{DailyPreheat,ee} + BTU_{DailyIdle,ee} + BTU_{Cooking,ee}) \times F_{ff,ee}]\}$$

where:

$$BTU_{DailyPreheat,baseline} = N_{preheat} \times BTU_{preheat,baseline}$$

$$BTU_{DailyPreheat,ee} = N_{preheat} \times BTU_{preheat,ee}$$

$$BTU_{DailyIdle,baseline} = BTU/h_{idle,baseline} \times \left[hrs - N_{preheat} \times hrs_{preheat,baseline} - \left(\frac{lbs}{(lbs/hr)_{baseline}}\right)\right]$$

$$BTU_{DailyIdle,ee} = BTU/h_{idle,ee} \times \left[hrs - N_{preheat} \times hrs_{preheat,ee} - \left(\frac{lbs}{(lbs/hr)_{ee}}\right)\right]$$

$$BTU_{cooking,baseline} = lbs \times Q_{food} \times \frac{1}{Eff_{baseline}}$$

$$BTU_{cooking,ee} = lbs \times Q_{food} \times \frac{1}{Eff_{ee}}$$

units = 1, from application
days = 365 days/year, from Operating Hours based on Facility type
$F_{elec,baseline}$ = 0, from Summary of Variables and Data Sources
$F_{elec,ee}$ = 1, from Summary of Variables and Data Sources
$F_{ff,baseline}$ = 1, from Summary of Variables and Data Sources
$F_{ff,ee}$ = 0, from Summary of Variables and Data Sources
$N_{preheat}$ = 1, from Summary of Variables and Data Sources

$BTU_{preheat,baseline}$ = 6,000 BTU, from Baseline Efficiencies from which Energy Savings are calculated
$BTU_{preheat,ee}$ = 2,388 BTU, from application
$BTU/h_{idle,baseline}$ = 12,000 BTU, from Baseline Efficiencies from which Energy Savings are calculated
$BTU/h_{idle,ee}$ = 3,412 BTU, from application
$Hrs_{preheat,baesline}$ = 0.18, from Common Variables
$Hrs_{preheat,ee}$ = 0.14, from Common Variables
Hrs = 11 hours/day, from Operating Hours based on Facility type
lbs = 100 lbs, from Common Variables
$(lbs/hr)_{baseline}$ = 45 lbs/hr, from Baseline Efficiencies from which Energy Savings are calculated
$(lbs/hr)_{ee}$ = 45, from application
Q_{food} = 250 BTU/lb, from Common Variables
$Eff_{baseline}$ = 0.42, from Baseline Efficiencies from which Energy Savings are calculated
Eff_{ee} = 0.71, from application
CF = 0.9, from Summary of Variables and Data Sources

$$BTU_{DailyPreheat,baseline} = 1 \times 6{,}000 = 6{,}000$$

$$BTU_{DailyPreheat,ee} = 1 \times 2{,}388 = 2{,}388$$

$$BTU_{DailyIdle,baseline} = 12{,}000 \times \left[11 - 1 \times 0.18 - \left(\frac{100}{45}\right)\right] = 103{,}173.33$$

$$BTU_{DailyIdle,ee} = 3{,}412 \times \left[11 - 1 \times 0.14 - \left(\frac{100}{45}\right)\right] = 29{,}472.10$$

$$BTU_{cooking,baseline} = 100 \times 250 \times \frac{1}{0.42} = 59{,}523.81$$

$$BTU_{cooking,ee} = 100 \times 250 \times \frac{1}{0.71} = 35{,}211.27$$

$$\Delta kWh = units \times days \times \frac{1}{3{,}412} \times \{[(6{,}000 + 103{,}173 + 59{,}524) \times 0] - [(2{,}388 + 29{,}472 + 35{,}211) \times 1]\}$$

$$\Delta kWh = 1 \times 365 \times \frac{1}{3{,}412} \times (0 - 67{,}071) = -7{,}175\ kWh$$

$$\Delta kW = \frac{-7{,}175}{(365 \times 11)} \times 0.9 = -1.6\ kW$$

$$\begin{aligned}\Delta MMBtu = 1 \times 365 \times \frac{1}{1{,}000{,}000} \\ \times \{[(6{,}000 + 103{,}173 + 59{,}524) \times 1] \\ - [(2{,}388 + 29{,}472 + 35{,}211) \times 0]\}\end{aligned}$$

$$\Delta MMBtu = 1 \times 365 \times \frac{1}{1{,}000{,}000} \times (168{,}697 - 0) = 61.6\ MMBtu$$

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

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   https://www.energystar.gov/sites/default/files/asset/document/ENERGY%20STAR%20Version%203.0%20Commercial%20Ovens%20Final%20Specification.pdf?_gl=1*tuw2y1*_ga*Mjc4Mzg4OTEuMTY5Mjg4NzI2Mw..*_ga_S0KJTVVLQ6*MTY5MzMzMzcxNS41LjEuMTY5MzMzMzg3MS4wLjAuMA
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Record of Revision

Record of Revision Number	Issue Date
3-18-18	3/29/2018
3-20-4	3/30/2020
12-21-11	1/28/2022
6-24-13	7/8/2024

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MOTORS AND DRIVES

VARIABLE FREQUENCY DRIVE (VFD) – HVAC FAN AND PUMP

Measure Description

This measure covers the installation of Variable Frequency Drives (VFDs) applied to HVAC fans and pumps in commercial and industrial buildings. Applications covered by this method include supply fans, return fans, exhaust fans, chilled water pumps, and heating hot water pumps. VFDs allow for the speed of the fan or pump to be adjusted to maintain the desired system flow rate and/or pressure based on varying system demand, reducing motor energy consumption. This requires a system with varying loads and appropriate controls like two-way valves or Variable Air Volume (VAV) boxes.

Distinct methods are provided for application of Variable Frequency Drives (VFDs) to HVAC fans and pump motors. This measure does not address other applications, which should be evaluated via a custom analysis method.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings *(HVAC Fan Applications)*

Annual Electric Energy Savings

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

$$kWh_{baseline} = 0.746 \times hp \times \frac{LF}{Eff_{motor}} \times hrs \times \sum_{0\%}^{100\%} (\%FF \times PLR_{baseline})$$

$$kWh_{ee} = 0.746 \times hp \times \frac{LF}{Eff_{motor}} \times hrs \times \sum_{0\%}^{100\%} (\%FF \times PLR_{ee})$$

Summer Peak Coincident Demand Savings

$$\Delta kW = (kW_{baseline} - kW_{ee})$$

$$kW_{baseline} = 0.746 \times hp \times \frac{LF}{Eff_{motor}} \times PLR_{peak,baseline}$$

$$kW_{ee} = 0.746 \times hp \times \frac{LF}{Eff_{motor}} \times PLR_{peak,ee}$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings *(HVAC Pump Applications)*

Annual Electric Energy Savings

$$\Delta kWh = \frac{hp \times 0.746 \times LF}{Eff_{motor}} \times hrs \times ESF$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \frac{hp \times 0.746 \times LF}{Eff_{motor}} \times DSF \times CF$$

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
$_{baseline}$ = Characteristic of baseline condition
$_{ee}$ = Characteristic of the efficient condition
hp = Rated horsepower of controlled motor
LF = Motor load factor at design flow rate
Eff_{motor} = Rated full-load efficiency of controlled motor
hrs = Annual motor run hours
%FF = Percentage of run-hours spent within a given flow fraction range
PLR = Part load ratio at a given flow fraction range based on fan and control type
PLR_{peak} = Part load ratio during summer peak period based on fan and control type
ESF = Energy Savings Factor
DSF = Demand Savings Factor
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.
LF		From application. If actual load factor is unknown, assume 65%.[224]

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[224] Lawrence Berkeley National Laboratory, and Resource Dynamics Corporation. (2008). “Improving Motor and Drive System Performance; A Sourcebook for Industry”. U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy. Golden, CO: National Renewable Energy Laboratory.

Variable	Value	Notes
Eff_{motor}		From application. If unknown, lookup from Appendix L based on motor type (open or enclosed), number of poles (2, 4 or 6) and horsepower.
hrs		From application. If actual hours are unknown, lookup based on motor application, building type, and location in the Operating Hours section below.
%FF		If known, apply flow fraction percentages at 10% usage bins consistent with ranges specified in the Default Fan Duty Cycle table below. Otherwise, values from the Default Fan Duty Cycle table may be applied. In that case, Default Average PLR by Control and Fan Type values are provided below that may be substituted for the sigma function in the algorithms above.
$PLR_{baseline}$		If applying known flow fraction percentages, lookup in the Part Load Ratios table below based on baseline fan and control type. Otherwise, Default Average PLR by Control and Fan Type values are provided below that may be substituted for the sigma function in the algorithms above.
PLR_{ee}		If applying known flow fraction percentages, lookup in the Part Load Ratios table below based on efficient fan and control type. Otherwise, Default Average PLR by Control and Fan Type values are provided below that may be substituted for the sigma function in the algorithms above.
$PLR_{peak,baseline}$		Lookup in the Part Load Ratios table below based on baseline fan and control type and flow fraction at summer peak, if known. If flow fraction is unknown, assume PLR at 90% load.
$PLR_{peak,ee}$		Lookup in the Part Load Ratios table below based on efficient fan and control type and flow fraction at summer peak, if known. If flow fraction is unknown, assume PLR at 90% load.
ESF		Lookup based on Pump Type in the Energy and Demand Savings Factors table below.
DSF		Lookup based on Pump Type in the Energy and Demand Savings Factors table below.
CF	Pumps: 0.55	Peak coincident demand savings for fan applications take into account load ratio at system peak; therefore, no coincidence factor is applied.

Default Average PLR by Control and Fan Type ($\sum_{0\%}^{100\%}(\%FF \times PLR_{baseline})$)

Fan/Control Type	Average PLR
No Control or Bypass Damper	1.00
Discharge Dampers	0.80

Fan/Control Type	Average PLR
Outlet Damper, Bl & Airfoil Fans	0.78
Inlet Damper Box	0.69
Inlet Guide Vane, Bl & Airfoil Fans	0.63
Inlet Vane Dampers	0.53
Outlet Damper, FC Fans	0.53
Eddy Current Drives	0.49
Inlet Guide Vane, FC Fans	0.39
VFD with duct static pressure controls	0.30
VFD with low/no duct static pressure	0.27

Default Fan Duty Cycle[225]

Flow Fraction (% of Design CFM)	Percent of Time at Flow Fraction (%FF)
0% to 10%	0.0%
10% to 20%	1.0%
20% to 30%	5.5%
30% to 40%	15.5%
40% to 50%	22.0%
50% to 60%	25.0%
60% to 70%	19.0%
70% to 80%	8.5%
80% to 90%	3.0%
90% to 100%	0.5%

Part Load Ratios by Control and Fan Type and Flow Fraction (PLR)

Fan/Control Type	Flow Fraction									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
No Control or Bypass Damper	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Discharge Dampers	0.46	0.55	0.63	0.70	0.77	0.83	0.88	0.93	0.97	1.00
Outlet Damper, Bl & Airfoil Fans	0.53	0.53	0.57	0.64	0.72	0.80	0.89	0.96	1.02	1.05
Inlet Damper Box	0.56	0.6	0.62	0.64	0.66	0.69	0.74	0.81	0.92	1.07
Inlet Guide Vane, Bl & Airfoil Fans	0.53	0.56	0.57	0.59	0.60	0.62	0.67	0.74	0.85	100
Inlet Vane Dampers	0.38	0.40	0.42	0.44	0.48	0.53	0.60	0.70	0.83	0.99
Outlet Damper, FC Fans	0.22	0.26	0.30	0.37	0.45	0.54	0.65	0.77	0.91	1.06
Eddy Current Drives	0.17	0.20	0.25	0.32	0.41	0.51	0.63	0.76	0.90	1.04
Inlet Guide Vane, FC Fans	0.21	0.22	0.23	0.26	0.31	0.39	0.49	0.63	0.81	1.04

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[225] Default Fan Duty Cycle Based on 2012 ASHRAE Handbook; HVAC Systems and Equipment, page 45.11, Figure 12.

Fan/Control Type	Flow Fraction									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
VFD with duct static pressure controls	0.09	0.10	0.11	0.15	0.20	0.29	0.41	0.57	0.76	1.01
VFD with low/no duct static pressure	0.05	0.06	0.09	0.12	0.18	0.27	0.39	0.55	0.75	1.00

Energy and Demand Savings Factors226

Pump Type	ESF	DSF
Chilled Water Pump	0.633	0.46
Hot Water Pump	0.652	0.00

Coincidence Factor (CF)

Peak coincident demand savings for fan applications take into account load ratio at system peak; therefore, no coincidence factor is applied. For pump applications, the prescribed value for the coincidence factor is 0.55.[227]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a supply, return, or exhaust air fan or a chilled or hot water pump motor without a VFD installed. Baseline control type shall be established based on the existing motor control strategy.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a supply, return, or exhaust air fan or a chilled or hot water pump motor equipped with a VFD. The application must have a variable load and installation is to include the necessary controls. Savings are based on application of VFDs to a range of baseline load conditions including no control, inlet guide vanes, outlet guide vanes and throttling valves.

Operating Hours

Annual motor operating hours shall be taken from application when available. If unknown, the hours from the table below based on Facility Type and motor application shall be applied.

VFD Operating Hours for Fan Motors by Building Type (hrs)[228]

Facility Type	Albany	Binghamton	Buffalo	Massena	NYC	Poughkeepsie	Syracuse
Auto Related	6,781	7,230	6,779	8,044	5,641	6,456	6,906
Bakery	4,877	5,200	4,875	5,785	4,057	4,643	4,967

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[226] United Illuminating Company and Connecticut Light & Power Company. 2012. Connecticut Program Savings Document – 8 th Edition for 2013 Program Year. Orange, CT; energy and demand savings constants were derived using a temperature bin spreadsheet and typical heating, cooling, and fan load profiles. Note, these values have been adjusted from the source data to remove the embedded load factor.

[227] UI and CL&P Program Saving Documentation for 2009 Program Year, Table 1.1.1; HVAC - Variable Frequency Drives – Pumps.

[228] Scaled from Connecticut's 2022 Program Savings Document – 19th edition by comparing Total Cooling and Heating Degree Days.

Facility Type	**Albany**	**Binghamton**	**Buffalo**	**Massena**	**NYC**	**Poughkeepsie**	**Syracuse**
Banks, Financial Centers	5,828	6,214	5,826	6,914	4,849	5,549	5,936
Church	3,689	3,933	3,688	4,376	3,069	3,512	3,757
College — Cafeteria	6,162	6,570	6,160	7,310	5,127	5,867	6,276
College - Classes/ Administrative	6,331	6,750	6,329	7,510	5,267	6,028	6,448
College - Dormitory	4,048	4,316	4,047	4,802	3,368	3,854	4,123
Commercial Condos	8,760	8,760	8,760	8,760	7,696	8,760	8,760
Convenience Stores	5,499	5,863	5,497	6,523	4,575	5,236	5,600
Convention Center	8,760	8,760	8,760	8,760	7,696	8,760	8,760
Court House	5,828	6,214	5,826	6,914	4,849	5,549	5,936
Dining: Bar Lounge/ Leisure	5,559	5,927	5,557	6,594	4,625	5,293	5,662
Dining: Cafeteria / Fast Food	6,162	6,570	6,160	7,310	5,127	5,867	6,276
Dining: Family	5,559	5,927	5,557	6,594	4,625	5,293	5,662
Exercise Center	6,059	6,460	6,057	7,187	5,040	5,769	6,171
Fast Food Restaurants	6,059	6,460	6,057	7,187	5,040	5,769	6,171
Fire Station (Unmanned)	6,162	6,570	6,160	7,310	5,127	5,867	6,276
Food Stores	4,048	4,316	4,047	4,802	3,368	3,854	4,123
Gymnasium	4,800	5,117	4,798	5,694	3,993	4,570	4,888
Hospitals	6,059	6,460	6,057	7,187	5,040	5,769	6,171
Hospitals / Health Care	8,760	8,760	8,760	8,760	7,629	8,731	8,760
Industrial - 1 Shift	8,760	8,760	8,760	8,760	7,629	8,731	8,760
Industrial - 2 Shift	4,877	5,200	4,875	5,785	4,057	4,643	4,967
Industrial - 3 Shift	7,151	7,624	7,148	8,482	5,949	6,808	7,283
Laundromats	8,760	8,760	8,760	8,760	7,696	8,760	8,760
Library	5,499	5,863	5,497	6,523	4,575	5,236	5,600
Light Manufacturers	6,059	6,460	6,057	7,187	5,040	5,769	6,171
Lodging (Hotels/ Motels)	4,877	5,200	4,875	5,785	4,057	4,643	4,967
Mall Concourse	3,613	3,852	3,612	4,286	3,006	3,440	3,680
Manufacturing Facility	4,953	5,281	4,951	5,875	4,121	4,716	5,044
Medical Offices	4,877	5,200	4,875	5,785	4,057	4,643	4,967
Motion Picture Theatre	5,064	5,399	5,062	6,007	4,213	4,821	5,157
Multi-Family (Common Areas)	6,059	6,460	6,057	7,187	5,040	5,769	6,171
Museum	4,048	4,316	4,047	4,802	3,368	3,854	4,123
Nursing Homes	6,059	6,460	6,057	7,187	5,040	5,769	6,171
Office (General Office Types)	8,760	8,760	8,760	8,760	7,696	8,760	8,760
Office/Retail	5,064	5,399	5,062	6,007	4,213	4,821	5,157
Parking Garages & Lots	5,064	5,399	5,062	6,007	4,213	4,821	5,157
Penitentiary	6,781	7,230	6,779	8,044	5,641	6,456	6,906
Performing Arts Theatre	8,760	8,760	8,760	8,760	7,696	8,760	8,760

Facility Type	Albany	Binghamton	Buffalo	Massena	NYC	Poughkeepsie	Syracuse
Police / Fire Stations (24 Hr)	6,059	6,460	6,057	7,187	5,040	5,769	6,171
Post Office	7,158	7,632	7,156	8,491	5,955	6,815	7,290
Pump Stations	5,064	5,399	5,062	6,007	4,213	4,821	5,157
Refrigerated Warehouse	2,367	2,523	2,366	2,807	1,969	2,253	2,410
Religious Building	3,806	4,058	3,805	4,515	3,166	3,624	3,876
Residential (Except Nursing Homes)	3,689	3,933	3,688	4,376	3,069	3,512	3,757
Restaurants	4,048	4,316	4,047	4,802	3,368	3,854	4,123
Retail	5,559	5,927	5,557	6,594	4,625	5,293	5,662
School / University	5,499	5,863	5,497	6,523	4,575	5,236	5,600
Schools (Jr./Sr. High)	6,331	6,750	6,329	7,510	5,267	6,028	6,448
Schools (Preschool/ Elementary)	2,367	2,523	2,366	2,807	1,969	2,253	2,410
Schools (Technical/ Vocational)	4,067	4,336	4,066	4,824	3,383	3,872	4,142
Small Services	5,384	5,740	5,382	6,386	4,479	5,126	5,483
Sports Arena	5,064	5,399	5,062	6,007	4,213	4,821	5,157
Entertainment	6,059	6,460	6,057	7,187	5,040	5,769	6,171
Town Hall	6,059	6,460	6,057	7,187	5,040	5,769	6,171
Transportation	6,781	7,230	6,779	8,044	5,641	6,456	6,906
Warehouse (Not Refrigerated)	3,806	4,058	3,805	4,515	3,166	3,624	3,876
Waste Water Treatment Plant	2,367	2,523	2,366	2,807	1,969	2,253	2,410
Workshop	4,877	5,200	4,875	5,785	4,057	4,643	4,967

VFD Operating Hours for Chilled Water Pumps by Building Type (hrs)[229]

Facility Type	Albany	Binghamton	Buffalo	Massena	NYC	Poughkeepsie	Syracuse
Auto Related	1,269	674	1,069	715	1,791	1,312	1,089
Bakery	913	485	769	514	1,288	944	783
Banks, Financial Centers	2,405	1,277	2,026	1,354	3,393	2,486	2,063
Church	691	367	582	389	975	714	593
College — Cafeteria	1,154	613	972	650	1,628	1,193	990
College - Classes/ Administrative	2,075	1,102	1,748	1,168	2,927	2,145	1,780
College - Dormitory	3,374	1,792	2,842	1,899	4,760	3,488	2,895
Commercial Condos	3,935	2,089	3,314	2,215	5,551	4,068	3,376
Convenience Stores	1,030	547	867	580	1,453	1,065	884
Convention Center	3,935	2,089	3,314	2,215	5,551	4,068	3,376
Court House	2,405	1,277	2,026	1,354	3,393	2,486	2,063
Dining: Bar Lounge/ Leisure	1,041	553	877	586	1,469	1,077	893
Dining: Cafeteria / Fast Food	1,154	613	972	650	1,628	1,193	990
Dining: Family	1,041	553	877	586	1,469	1,077	893
Exercise Center	1,135	603	956	639	1,601	1,173	973

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[229] Scaled from Connecticut's 2022 Program Savings Document – 19th edition by comparing Cooling Degree Days.

Facility Type	Albany	Binghamton	Buffalo	Massena	NYC	Poughkeepsie	Syracuse
Fast Food Restaurants	1,135	603	956	639	1,601	1,173	973
Fire Station (Unmanned)	1,154	613	972	650	1,628	1,193	990
Food Stores	3,374	1,792	2,842	1,899	4,760	3,488	2,895
Gymnasium	899	477	757	506	1,268	929	771
Hospitals	1,135	603	956	639	1,601	1,173	973
Hospitals / Health Care	6,762	3,591	5,696	3,807	8,760	6,990	5,802
Industrial - 1 Shift	6,762	3,591	5,696	3,807	8,760	6,990	5,802
Industrial - 2 Shift	913	485	769	514	1,288	944	783
Industrial - 3 Shift	913	485	769	514	1,288	944	783
Laundromats	913	485	769	514	1,288	944	783
Library	1,030	547	867	580	1,453	1,065	884
Light Manufacturers	1,135	603	956	639	1,601	1,173	973
Lodging (Hotels/ Motels)	913	485	769	514	1,288	944	783
Mall Concourse	677	359	570	381	955	700	581
Manufacturing Facility	2,652	1,408	2,234	1,493	3,742	2,742	2,275
Medical Offices	913	485	769	514	1,288	944	783
Motion Picture Theatre	948	503	799	534	1,337	980	813
Multi-Family (Common Areas)	1,135	603	956	639	1,601	1,173	973
Museum	3,374	1,792	2,842	1,899	4,760	3,488	2,895
Nursing Homes	1,135	603	956	639	1,601	1,173	973
Office (General Office Types)	3,935	2,089	3,314	2,215	5,551	4,068	3,376
Office/Retail	948	503	799	534	1,337	980	813
Parking Garages & Lots	948	503	799	534	1,337	980	813
Penitentiary	1,269	674	1,069	715	1,791	1,312	1,089
Performing Arts Theatre	3,935	2,089	3,314	2,215	5,551	4,068	3,376
Police / Fire Stations (24 Hr)	1,135	603	956	639	1,601	1,173	973
Post Office	2,442	1,297	2,057	1,375	3,445	2,524	2,095
Pump Stations	948	503	799	534	1,337	980	813
Refrigerated Warehouse	1,846	980	1,555	1,039	2,604	1,908	1,584
Religious Building	713	379	601	401	1,006	737	612
Residential (Except Nursing Homes)	691	367	582	389	975	714	593
Restaurants	3,374	1,792	2,842	1,899	4,760	3,488	2,895
Retail	1,041	553	877	586	1,469	1,077	893
School / University	1,030	547	867	580	1,453	1,065	884
Schools (Jr./Sr. High)	2,075	1,102	1,748	1,168	2,927	2,145	1,780
Schools (Preschool/ Elementary)	1,846	980	1,555	1,039	2,604	1,908	1,584
Schools (Technical/ Vocational)	761	404	641	429	1,074	787	653

Facility Type	Albany	Binghamton	Buffalo	Massena	NYC	Poughkeepsie	Syracuse
Small Services	1,910	1,014	1,609	1,075	2,695	1,975	1,639
Sports Arena	948	503	799	534	1,337	980	813
Entertainment	1,135	603	956	639	1,601	1,173	973
Town Hall	1,135	603	956	639	1,601	1,173	973
Transportation	1,269	674	1,069	715	1,791	1,312	1,089
Warehouse (Not Refrigerated)	713	379	601	401	1,006	737	612
Waste Water Treatment Plant	1,846	980	1,555	1,039	2,604	1,908	1,584
Workshop	913	485	769	514	1,288	944	783

VFD Operating Hours for Hot Water Pumps by Building Type (hrs)[230]

Facility Type	Albany	Binghamton	Buffalo	Massena	NYC	Poughkeepsie	Syracuse
Auto Related	2,684	3,023	2,730	3,372	2,058	2,531	2,782
Bakery	1,931	2,175	1,964	2,426	1,480	1,820	2,001
Banks, Financial Centers	6,082	6,851	6,187	7,642	4,663	5,734	6,304
Church	1,460	1,644	1,485	1,834	1,119	1,376	1,513
College — Cafeteria	2,440	2,748	2,482	3,065	1,870	2,300	2,529
College - Classes/ Administrative	6,991	7,876	7,113	8,760	5,360	6,592	7,247
College - Dormitory	4,141	4,665	4,213	5,203	3,175	3,905	4,293
Commercial Condos	8,760	8,760	8,760	8,760	7,256	8,760	8,760
Convenience Stores	2,177	2,452	2,215	2,735	1,669	2,053	2,257
Convention Center	8,760	8,760	8,760	8,760	7,256	8,760	8,760
Court House	6,082	6,851	6,187	7,642	4,663	5,734	6,304
Dining: Bar Lounge/ Leisure	2,201	2,479	2,239	2,765	1,687	2,075	2,281
Dining: Cafeteria / Fast Food	2,440	2,748	2,482	3,065	1,870	2,300	2,529
Dining: Family	2,201	2,479	2,239	2,765	1,687	2,075	2,281
Exercise Center	2,398	2,702	2,440	3,014	1,839	2,262	2,486
Fast Food Restaurants	2,398	2,702	2,440	3,014	1,839	2,262	2,486
Fire Station (Unmanned)	2,440	2,748	2,482	3,065	1,870	2,300	2,529
Food Stores	4,141	4,665	4,213	5,203	3,175	3,905	4,293
Gymnasium	1,899	2,140	1,932	2,387	1,456	1,791	1,969
Hospitals	2,398	2,702	2,440	3,014	1,839	2,262	2,486
Hospitals / Health Care	8,760	8,760	8,760	8,760	7,256	8,760	8,760
Industrial - 1 Shift	8,760	8,760	8,760	8,760	7,256	8,760	8,760
Industrial - 2 Shift	1,931	2,175	1,964	2,426	1,480	1,820	2,001
Industrial - 3 Shift	2,831	3,189	2,880	3,557	2,170	2,669	2,934
Laundromats	3,745	4,218	3,810	4,705	2,871	3,531	3,882
Library	2,177	2,452	2,215	2,735	1,669	2,053	2,257
Light Manufacturers	2,398	2,702	2,440	3,014	1,839	2,262	2,486
Lodging (Hotels/ Motels)	1,931	2,175	1,964	2,426	1,480	1,820	2,001
Mall Concourse	1,430	1,611	1,455	1,797	1,097	1,349	1,483
Manufacturing Facility	5,329	6,003	5,421	6,695	4,085	5,024	5,523
Medical Offices	1,931	2,175	1,964	2,426	1,480	1,820	2,001
Motion Picture Theatre	2,004	2,258	2,039	2,518	1,537	1,890	2,077

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[230] Scaled from Connecticut's 2022 Program Savings Document – 19th edition by comparing Heating Degree Days.

Facility Type	**Albany**	**Binghamton**	**Buffalo**	**Massena**	**NYC**	**Poughkeepsie**	**Syracuse**
Multi-Family (Common Areas)	2,398	2,702	2,440	3,014	1,839	2,262	2,486
Museum	4,141	4,665	4,213	5,203	3,175	3,905	4,293
Nursing Homes	2,398	2,702	2,440	3,014	1,839	2,262	2,486
Office (General Office Types)	8,760	8,760	8,760	8,760	7,256	8,760	8,760
Office/Retail	2,004	2,258	2,039	2,518	1,537	1,890	2,077
Parking Garages & Lots	2,004	2,258	2,039	2,518	1,537	1,890	2,077
Penitentiary	2,684	3,023	2,730	3,372	2,058	2,531	2,782
Performing Arts Theatre	8,760	8,760	8,760	8,760	7,256	8,760	8,760
Police / Fire Stations (24 Hr)	2,398	2,702	2,440	3,014	1,839	2,262	2,486
Post Office	5,735	6,460	5,835	7,206	4,397	5,407	5,944
Pump Stations	2,004	2,258	2,039	2,518	1,537	1,890	2,077
Refrigerated Warehouse	5,216	5,876	5,307	6,554	3,999	4,918	5,407
Religious Building	1,506	1,697	1,532	1,892	1,155	1,420	1,561
Residential (Except Nursing Homes)	1,460	1,644	1,485	1,834	1,119	1,376	1,513
Restaurants	4,141	4,665	4,213	5,203	3,175	3,905	4,293
Retail	2,201	2,479	2,239	2,765	1,687	2,075	2,281
School / University	2,177	2,452	2,215	2,735	1,669	2,053	2,257
Schools (Jr./Sr. High)	6,991	7,876	7,113	8,760	5,360	6,592	7,247
Schools (Preschool/ Elementary)	5,216	5,876	5,307	6,554	3,999	4,918	5,407
Schools (Technical/ Vocational)	1,610	1,813	1,638	2,023	1,234	1,518	1,669
Small Services	6,072	6,840	6,177	7,629	4,655	5,725	6,294
Sports Arena	2,004	2,258	2,039	2,518	1,537	1,890	2,077
Entertainment	2,398	2,702	2,440	3,014	1,839	2,262	2,486
Town Hall	2,398	2,702	2,440	3,014	1,839	2,262	2,486
Transportation	2,684	3,023	2,730	3,372	2,058	2,531	2,782
Warehouse (Not Refrigerated)	1,506	1,697	1,532	1,892	1,155	1,420	1,561
Waste Water Treatment Plant	5,216	5,876	5,307	6,554	3,999	4,918	5,407
Workshop	1,931	2,175	1,964	2,426	1,480	1,820	2,001

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

A 10 hp HVAC supply fan with a rated motor efficiency of 85% and outlet damper control is equipped with a VFD with duct static pressure controls 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.

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

$$kWh_{baseline} = 0.746 \times hp \times \frac{LF}{Eff_{motor}} \times hrs \times \sum_{0\%}^{100\%} (\%FF \times PLR_{baseline})$$

$$kWh_{ee} = 0.746 \times hp \times \frac{LF}{Eff_{motor}} \times hrs \times \sum_{0\%}^{100\%} (\%FF \times PLR_{ee})$$

$$\Delta kW = (kW_{baseline} - kW_{ee})$$

$$kW_{baseline} = 0.746 \times hp \times \frac{LF}{Eff_{motor}} \times PLR_{peak,baseline}$$

$$kW_{ee} = 0.746 \times hp \times \frac{LF}{Eff_{motor}} \times PLR_{peak,ee}$$

hp = 10, from application
LF = 0.65, from Summary of Variables and Data Sources table
Eff_{motor} = 0.85, from application
hrs = 5,267, from Operating Hours section based on motor application and facility type

$\sum_{0\%}^{100\%}(\%FF \times PLR_{baseline})$ = 0.78, from Default Average PLR table based on fan and baseline control type
$\sum_{0\%}^{100\%}(\%FF \times PLR_{ee})$ = 0.30, from Default Average PLR table based on fan and efficient control type
$PLR_{peak,baseline}$ = 1.02, from Part Load Ratios table based on fan and baseline control type at 90% load
$PLR_{peak,ee}$ = 0.76, from Part Load Ratios table based on fan and efficient control type at 90% load

$$kWh_{baseline} = 0.746 \times 10 \times \frac{0.65}{0.85} \times 5{,}267 \times 0.78 = 23{,}436\ kWh$$

$$kWh_{ee} = 0.746 \times 10 \times \frac{0.65}{0.85} \times 5{,}267 \times 0.30 = 9{,}014\ kWh$$

$$\Delta kWh = (23{,}436 - 9{,}014) = 14{,}422\ kWh$$

$$kW_{baseline} = 0.746 \times 10 \times \frac{0.65}{0.85} \times 1.02 = 5.8\ kW$$

$$kW_{ee} = 0.746 \times 10 \times \frac{0.65}{0.85} \times 0.76 = 4.3\ kW$$

$$\Delta kW = (5.8 - 4.3) = 1.5\ kW$$

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.

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Record of Revision

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