Table of Revisions/Changes

Revision Number	Addition/ Revision	Issue Date	Effective Date	Measure	Description of Change	Location/Page in TRM
12-23-1	R	1/5/2024	1/1/2025	R/MF Heat Pump Water Heater (HPWH) – Air Source	Measure Description and Baseline Efficiency sections updated to reflect impacts of LL154; method modified to include PPH variable; Compliance Efficiency updated to reflect new ENERGY STAR® standard	Pg. 136
12-23-2	R	1/5/2024	1/1/2025	R/MF Indirect Water Heater	Method modified to include PPH variable; adjustment factor added for heating season only operation	Pg. 149
12-23-3	R	1/5/2024	1/1/2025	R/MF Storage Tank and Instantaneous Domestic Water Heater	Method modified to include PPH variable; Compliance Efficiency updated to reflect new ENERGY STAR® standard	Pg. 155
12-23-4	R	1/5/2024	1/1/2025	R/MF Boiler and Furnace - Combination (Combi) Boiler and Furnace	Method modified to include PPH variable	Pg. 211
12-23-5	R	1/5/2024	1/1/2025	R/MF Heat Pump – Water-to-Air Ground Source (GSHP)	Desuperheater/WWHP method modified to include PPH variable; example calculation for Desuperheater/WWHP added	Pg. 279
12-23-6	R	1/5/2024	1/1/2025	R/MF Thermostatic Radiator Valve (TRV)	Method substantially modified to include hydronic and two-pipe systems, savings with and without system balancing, reliance on alternative source of savings; new method establishes base case consumption, applies ESF based on implementation of hydronic system balancing, and adjust savings based on proportion of radiators modified	Pg. 347
12-23-7	R	1/5/2024	1/1/2025	R/MF Pool Circulator Timer	Method modified to include aboveground pools; low-speed and high-speed hours defaults and approach for establishing revised; modified language in Operating Hours section	Pg. 377
12-23-8	R	1/5/2024	1/1/2025	R/MF Pool Pump	Method for DPPP motor replacement added; WEF definition added; Baseline Efficiencies section modified to reflect DPPP and motor replacement standards	Pg. 382

Revision Number	Addition/ Revision	Issue Date	Effective Date	Measure	Description of Change	Location/Page in TRM
12-23-9	R	1/5/2024	1/1/2025	C/I Indirect Water Heater	Method modified to distinguish water heater setpoint and outlet temperature; adjustment factor added for heating season only operation; GPD assumptions for multifamily aligned with residential measures	Pg. 618
12-23-10	R	1/5/2024	1/1/2025	C/I Instantaneous Water Heater	Method modified to distinguish water heater setpoint and outlet temperature; GPD assumptions for multifamily aligned with residential measures	Pg. 628
12-23-11	R	1/5/2024	1/1/2025	C/I Storage Tank Water Heater	Method modified to distinguish water heater setpoint and outlet temperature; GPD assumptions for multifamily aligned with residential measures	Pg. 636
12-23-12	R	1/5/2024	1/1/2025	C/I Central Domestic Hot Water (DHW) Control	Method modified to distinguish water heater setpoint and outlet temperature; GPD assumptions for multifamily aligned with residential measures; default Operating Hours options added	Pg. 644
12-23-13	R	1/5/2024	1/1/2025	C/I Drain Water Heat Recovery (DWHR)	Method modified to distinguish water heater setpoint and outlet temperature; GPD assumptions for multifamily aligned with residential measures; gas system default efficiency removed	Pg. 657
12-23-14	R	1/5/2024	1/1/2025	C/I Boiler and Furnace - Combination (Combi) Boiler and Furnace	Method modified to distinguish water heater setpoint and outlet temperature; GPD assumptions for multifamily aligned with residential measures	Pg. 704
12-23-15	R	1/5/2024	1/1/2025	C/I Heat Pump – Water-to-Air Ground Source (GSHP) in Systems with Central Pumping	Clarification added regarding system sizing in Measure Description; WWHP method modified to specify outlet temperature; GPD assumptions for multifamily aligned with residential measures; WWHP example calculation added	Pg. 791
12-23-16	R	1/5/2024	1/1/2025	C/I Advanced RTU Control	Method substantially modified to present savings for different control scenarios and rely on alternative source for savings; language regarding control scenarios added to Measure Description; CF, Baseline Efficiency, Compliance Efficiency, Operating Hours, and Example Calculation modified to reflect new method	Pg. 853

Revision Number	Addition/ Revision	Issue Date	Effective Date	Measure	Description of Change	Location/Page in TRM
12-23-17	R	1/5/2024	1/1/2025	C/I Thermostatic Radiator Valve (TRV)	Method substantially modified to include hydronic systems, savings with and without system balancing, reliance on alternative source of savings; new method establishes base case consumption, applies ESF based on implementation of hydronic system balancing, and adjust savings based on proportion of radiators modified	Pg. 892
12-23-18	R	1/5/2024	1/1/2025	C/I Notched and Synchronous Belt	Measure Description and term definitions modified for clarity; Operating Hours section modified to reflect default hours consistent with established facility type run hours	Pg. 939
12-23-19	R	1/5/2024	1/1/2025	C/I Pool Pump	Method for DPPP motor replacement added; WEF definition added; Baseline Efficiencies section modified to reflect DPPP and motor replacement standards	Pg. 951
12-23-20	R	1/5/2024	1/1/2025	Appendix P	R/MF Lighting section modified to address table formatting issue; C/I Compressed Air – Low Pressure Drop Filters EUL and source modified; C/I Advanced RTU Control EUL and source modified;	Pg.1389

Note: Revisions to the measures listed above were undertaken by the Joint Utilities Technical Resource Manual (TRM) Management Committee between October 23, 2023 – January 5, 2024.

DOMESTIC HOT WATER

HEAT PUMP WATER HEATER (HPWH) – AIR SOURCE

Measure Description

This measure covers the installation of electric storage tank water heaters that use heat pump technology to move heat from the air (in conditioned or unconditioned spaces) to the water storage tank and are designed to heat and store potable water at a thermostatically controlled temperature of less than 180°F. It is not intended for equipment delivering process or space heating hot water. It applies to electric heat pump water heaters with a maximum current rating of 24 amperes at an input voltage 250 volts or less, and with a rated storage tank capacity of 120 gallons or less.[1,2]

This measure applies to new construction/major renovation projects and replacement of existing water heaters. Baseline equipment in new construction/major renovation shall be a minimally code compliant, gas-fired storage type water heater where gas service is available and a minimally code compliant, electric storage type water heater elsewhere. Baseline efficiency for replacement of equipment shall be a minimally code compliant system of the same type as the existing equipment. New construction projects in NYC must comply with the provisions of LL154 and reflect an electric baseline beginning in January 2024 in accordance with the LL154 Effectuation Schedule presented in the "New Construction Baselines - NYC Local Low 154 of 2021" section of this TRM's Introduction.

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

Method for Calculating Annual Energy and Peak Coincident Demand Savings

Annual Electric Energy Savings

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

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

[1] ENERGY STAR® Program Requirements Product Specification for Residential Water Heaters, Eligibility Criteria Version 5.0, July 2022.

[2] 10 CFR 430.2.

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

Peak Coincident Demand Savings

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

Annual Fossil Fuel Energy Savings

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

where:

DkWh = Annual electric energy savings
DkW = Peak coincident demand electric savings
DMMBtu = Annual fossil fuel energy savings
$\Delta kWh_{cooling}$ = Annual electric cooling energy savings as a result of interactivity with the building's HVAC system (electric cooling bonus)
$\Delta kWh_{heating}$ = Annual electric heating energy savings as a result of interactivity with the building's HVAC system (electric heating penalty)
units = Number of households addressed by the program
GPD = Gallons per day of delivered hot water per person
PPH = Persons per household served by DHW system
DT_{main} = Average temperature difference between water heater set point temperature and the supply water temperature in water main (°F)
F_{eDHW} = Electric water heating factor, used to exclude baseline electric water heating consumption if no baseline electric water heating is present
F_{FFDHW} = Fossil fuel water heating factor, used to exclude baseline fossil fuel water heating consumption if no baseline fossil fuel fired direct water heating is present
$F_{BoilerDHW}$ = Fossil fuel water heating factor, used to exclude baseline fossil fuel water heating consumption if no baseline fossil fuel fired boiler-driven indirect water heating is present
$_{baseline}$ = Characteristic of baseline condition
$_{ee}$ = Characteristic of energy efficient condition
UEF = Uniform energy factor
F_{derate} = Efficiency derating factor used to account for the degradation of heat pump performance present in systems installed in unconditioned spaces
F_{Loc} = Installation location factor, used to exclude interactive HVAC impacts for systems installed in unconditioned spaces
F_{Cool} = Cooling factor, used to account for the percentage of heat extracted from ambient air by the heat pump water heater that reduces space cooling load

F_{Heat} = Heating factor, used to account for the percentage of heat extracted from ambient air by the heat pump water heater that increases space heating load
$F_{ElecHeat}$ = Electric heating factor, used to exclude electric heating penalty if no electric heating is present
$F_{FuelHeat}$ = Fossil fuel heating factor, used to exclude fossil fuel heating penalty if no fossil fuel heating is present
SEER = Seasonal average energy efficiency ratio over the cooling season, BTU/watthour, (used for average U.S. location/region)
HSPF = Heating seasonal performance factor, BTU/watt-hour, total heating output (supply heat) in BTU (including electric heat) during the heating season / total electric energy heat pump consumed (in watt-hour)
AFUE = Annual fuel utilization efficiency, seasonal energy efficiency for fuel heating equipment
(ΔkW/unit) = Deemed peak coincident demand savings per measure
365 = Days in one year
8.33 = Specific heat of water; energy required (BTU), to heat one gallon of water by one degree Fahrenheit [BTU/(gal-F)]
3,412 = Conversion factor, one kWh equals 3,412 BTU
3.412 = Conversion factor, one watt-hour equals 3.412 BTU
1,000,000 = Conversion factor, one MMBtu equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
GPD	17.2	Average daily hot water usage per person.[3]
PPH		From application. If unknown, use a value of 2.8 for single-family homes[4] and 2.0 for multifamily homes.[5] For sites with multiple water heating systems, PPH shall be allocated proportional to the input heating capacity of each water heater relative to the total input heating capacity of all water heaters.[6]
DT_{main}	T_{set} - T_{main}	Average temperature difference between water heater set point temperature and the supply water temperature in water main (°F).
T_{set}	125	Water heater set point temperature (°F).[7]
T_{main}		Supply water temperature in water main (°F). Lookup in Cold Water Inlet Temperature table below based on nearest city.

[3] Water Research Foundation: Residential End Uses of Water, Version 2, April 2016, pg. 5; 17.2 GPD equated from the report findings indicating an average 2.65 people per household and 45.5 GPD per household.
[4] Residential Statewide Baseline Study of New York State, July 2015. Volume 1: Single-Family Report, Table 9.
[5] Residential Statewide Baseline Study of New York State, July 2015. Volume 2: Multifamily Report, Table 8.
[6] For example, if a home with 6 occupants contains two water heaters with 40 MBH and 50 MBH input capacities and the 40 MBH unit is being replaced with an equivalent capacity unit, the PPH value applied shall be PPH = 6 (occupants) x 40 (MBH) / (40 + 50) (MBH) = 2.7.
[7] 10 CFR 430 Appendix E to Subpart B of Part 430 Uniform Test Method for Measuring the Energy Consumption of Water Heaters, Section 2. Test Conditions, 2.5 Set Point Temperature.

Variable	Value	Notes
F_{eDHW}		Use a value of 1.0 if the water was previously heated with electricity or if it is a new construction home with no gas access. Otherwise, use 0.0.
F_{FFDHW}		Use a value of 1.0 if the water was previously heated directly with fossil fuels or if it is a new construction home with gas access. Otherwise, use 0.0.
$F_{BoilerDHW}$		Use a value of 1.0 if the water was previously heated indirectly with fossil fuels through the boiler system. Otherwise, use 0.0.
$UEF_{baseline}$		Uniform Energy Factor of the baseline condition. See Baseline Efficiencies… section below for details regarding derivation of this input.
UEF_{ee}		Uniform Energy Factor of the energy efficient measure, from application.
F_{derate}		For equipment installed in unconditioned spaces, lookup in Derate Factor table below based on installation location and nearest city. For equipment installed in conditioned spaces, a value of 1.0 shall be used.
F_{Loc}		Use a value of 1.0 if the water heater is installed in a conditioned space. Otherwise, use 0.0.
F_{Cool}		Lookup in HVAC Interactivity table below based on nearest city.
F_{Heat}		Lookup in HVAC Interactivity table below based on nearest city.
$F_{ElecHeat}$		Use a value of 1.0 if the building is electrically heated. Otherwise, use 0.0.
$F_{FuelHeat}$		Use a value of 1.0 if the building is fossil fuel heated. Otherwise, use 0.0.
SEER	13	Assumed efficiency of existing air conditioning system, based on a minimally code compliant, 3-ton, split system AC.[8]
HSPF	Heat Pump: 8.2 Electric Resistance: 3.412	Assumed efficiency of electric heating system, based on a COP of 1.0 for electric resistance heating and a minimally code compliant, 3-ton split system HP for heat pumps.[9]
AFUE		From application. If unknown, lookup from Baseline Efficiencies section based on existing equipment type. For new construction/gut rehab or if equipment type is unknown, assume an 80 MBH gas furnace.

[8] ECCCNYS 2020, Table C403.3.2(1).
[9] ECCCNYS 2020, Table C403.3.2(2).

Variable	Value	Notes
(ΔkW/unit)		Deemed Summer Peak Coincident Demand Savings. Use a value of 0.17 if the water was previously heated with electricity in replacement scenarios and if there is no gas service available in new construction/gut rehab scenarios.[10] Otherwise, use -0.17 for an electric penalty.[11]

Cold Water Inlet Temperature (T_{main})

Supply water main temperatures vary according to climate and are approximately equal to the annual average outdoor temperature plus 6°F.[12] Supply main temperatures based on the annual outdoor temperature are shown below.

City	Annual average outdoor temperature[13] (°F)	T_{main} (°F)
Albany	49.4	55.4
Binghamton	46.8	52.8
Buffalo	49.1	55.1
Massena	45.1	51.1
NYC	54.7	60.7
Poughkeepsie	50.9	56.9
Syracuse	49.0	55.0

Derate Factor

Standard testing conditions for rating of heat pump water heaters require a dry bulb temperature of 67.5°F ± 1°F and a relative humidity of 50% ±2%.[14] The reported efficiency of heat pump water heaters is established at these conditions; however, heat pump efficiency degrades at lower ambient temperatures. The Derate Factor is established to adjust the published efficiency of the qualifying heat pump water heater when the system is installed in semi-conditioned or unconditioned spaces, namely, garages and basements. The values shown below were derived from Table 10 of Residential Heat Pump Water Heater Evaluation: Lab Testing & Energy Use Estimates published by Bonneville Power Administration in 2011[15] and verified via comparison with results from the 2013 NEEA Heat Pump Water Heater Field Study Report.[16] Average values from northwest heating zones 1 (<6,000 HDD), 2 (6,000 – 7,500 HDD) and 3 (>7,500 HDD)[17] from this analysis and comparison were then mapped to representative NY climate regions as shown

[10] "Field Testing of Pre-Production Prototype Heat Pump Water Heaters" Federal Energy Management Program, DOE/EE-0317, May 2007.
[11] "CT HVAC and Water Heater Process and Impact Evaluation and CT Heat Pump Water Heater Impact Evaluation", West Hill Energy and Computing, Final Report R1614/R1613, July 19, 2018.
[12] Burch, Jay and Christensen, Craig, "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory.
[13] Average annual outdoor temperatures taken from NCDC 1991-2020 climate normals.
[14] 10 CFR 430 Subpart B Appendix E.
[15] Residential Heat Pump Water Heater Evaluation: Lab Testing & Energy Use Estimates, Bonneville Power Administration, November 2011.
[16] NEEA Heat Pump Water Heater Field Study Report, Fluid Market Strategies, October 2013.
[17] NW Council Heating/Cooling zone maps.

below.

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

<u>HVAC Interactivity</u>

Because heat pump water heaters operate via the transfer of heat from the ambient air to the water in the storage tank, systems installed in conditioned spaces will interact with the building's HVAC system. The values shown in the table below reflect the percentage of heat extracted from the ambient air by the heat pump that either decreases the building's cooling load (F_{Cool}) or increases the building's heating load (F_{Heat}). These values were derived from Table 12 of Residential Heat Pump Water Heater Evaluation: Lab Testing & Energy Use Estimates published by Bonneville Power Administration in 2011[18] and key operating assumptions specified therein. Average values from northwest heating zones 1 (<6,000 HDD), 2 (6,000 – 7,500 HDD) and 3 (>7,500 HDD)[19] were then mapped to representative NY climate regions and scaled linearly based on regional HDD and CDD. The HDD and CDD values are based on 30-year averages of U.S annual climate normals between 1981 and 2010 using base 65° F.[20]

City	CDD	F_{Cool}	HDD	F_{Heat}
Albany	721	0.26	6,391	0.70
Binghamton	383	0.17	7,200	0.76
Buffalo	607	0.24	6,502	0.70
Massena	406	0.16	8,030	0.84
Poughkeepsie	1017	0.29	4,900	0.65
NYC	745	0.51	6,026	0.49
Syracuse	618	0.25	6,625	0.70

Coincidence Factor (CF)

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

[18] Residential Heat Pump Water Heater Evaluation: Lab Testing & Energy Use Estimates, Bonneville Power Administration, November 2011.
[19] NW Council Heating/Cooling zone maps.
[20] HDD/CDD taken from NCEI 1991-2020 climate normals.

Baseline Efficiencies from which Savings are Calculated

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

The baseline for a fuel switching installation at the end of the appliance effective useful life is the minimally-compliant, state or municipal energy code or federal standard, that is applicable to the measure or system, similar to the existing measure or system, that the consumer would have had installed without the influence of the energy efficiency program. New construction projects in New York City (NYC) are required to adhere to the regulations outlined in Local Law 154 (LL154) and must apply an electric baseline in accordance with the phased effectuation of that legislation.. The LL154 Effectuation Schedule, as detailed in the "New Construction Baselines - NYC Local Law 154 of 2021" section of this TRM's Introduction, provides guidance for compliance.

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

For LMI applications, existing condition baseline shall be established based on nameplate efficiency or efficiency measured through combustion analysis.

$UEF_{baseline}$ shall be calculated as a function of qualifying equipment tank volume (v_t) per federal standards[21] as shown in the table below, using the qualifying equipment capacity and draw pattern. Draw pattern can be established based on the proposed equipment First Hour Rating (FHR), rated in gallons. See First Hour Rating vs. Draw Pattern table below. If FHR is unknown, a Medium draw pattern should be assumed for equipment with rated storage capacity ≤50 gallons and a High draw pattern should be assumed otherwise.[22]

Product Class	Rated Storage Volume and Input Rating	Draw Pattern	$UEF_{baseline}$
Electric Storage Water Heater	≥ 20 gal and ≤ 55 gal	Very Small	0.8808 - (0.0008 x v_t)
		Low	0.9254 - (0.0003 x v_t)
		Medium	0.9307 - (0.0002 x v_t)
		High	0.9349 - (0.0001 x v_t)
	> 55 gal and ≤ 120 gal	Very Small	1.9236 - (0.0011 x v_t)
		Low	2.0440 - (0.0011 x v_t)
		Medium	2.1171 - (0.0011 x v_t)
		High	2.2418 - (0.0011 x v_t)

[21] 10 CFR 430.32(d).
[22] Based on review of typical usage bins for AHRI certified residential water heating equipment. (https://www.ahridirectory.org/ahridirectory/pages/home.aspx)

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

*v_t = tank volume in gallons

First Hour Rating vs. Draw Pattern[23]

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

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

Fossil Fuel Fired Heating System Baseline Efficiencies: Systems Serving Single Units[24]

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

The baseline efficiency for heating systems serving multiple dwelling units is defined by International Energy Conservation Code[25] and subsequently adopted by the Energy Conservation Construction Code of New York State (ECCCNYS) as shown in the table below.

[23] 10 CFR 429.17.
[24] 10 CFR 430.32(e).
[25] ECCCNYS 2020, Table C403.3.2(4) & Table C403.3.2(5).

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

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

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a heat pump water heater meeting minimum performance requirements specified in ENERGY STAR® Program Requirements Product Specification for Residential Water Heaters, Eligibility Criteria Version 5.0.[26] The table below presents minimum UEF ratings for heat pump water heaters required by that standard.

Product Type	UEF
Integrated HPWH	≥ 3.30
Integrated HPWH, 120 Volt / 15 Amp Circuit	≥ 2.20
Split-System HPWH	≥ 2.20

Operating Hours

Water heater run hours are not utilized in the estimation of energy or demand savings, but water

[26] ENERGY STAR® Program Requirements Product Specification for Residential Water Heaters, Eligibility Criteria Version 5.0, July 2022.

heater is assumed to be available for operation 8,760 hours per year.

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

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

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

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

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

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

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

units = 1, from application
GPD = 17.2 from Summary of Variables and Data Source table
PPH = 3, from application
$\Delta T_{main} = T_{set} - T_{main} = 125 - 55.4 = 69.6$
T_{set} from Summary of Variables and Data Sources table
T_{main} from Cold Water Inlet Temperature lookup table based on location from application
F_{eDHW} = 0, from Summary of Variable and Data Sources table based on baseline DHW fuel source from application
UEF_{ee} = 3.5, from application
F_{derate} = 1, from Summary of Variable and Data Sources table based on location from application
F_{Loc} = 1, from Summary of Variable and Data Sources based on location from application

F_{cool} = 0.26, from HVAC Interactivity section based on location from application
SEER = 13, from Summary of Variable and Data Sources table
$F_{ElecHeat}$ = 0, from Summary of Variable and Data Sources table based on location from application
HSPF = N/A, from application
(ΔkW/unit) = -0.17, from Summary of Variables and Data Sources table based on existing water heating system fuel from application
F_{FFDHW} = 1, from Summary of Variables and Data Sources table based on existing water heating system from application
$UEF_{baseline}$ = 0.6483 – (0.0017 x v_t) = 0.6483 – (0.0017 x 40) = 0.5803
$UEF_{baseline}$ equation lookup from Baseline Efficiencies section based on Product Class from baseline application and Rated Storage Volume and Draw Pattern from compliance equipment from application, where Draw Pattern is determined by the First Hour Rating based on application
v_t from application of compliance equipment
$F_{BoilerDHW}$ = 0, from Summary of Variables and Data Sources table based on existing water heating system from application
F_{Heat} = 0.70, from HVAC Interactivity section based on location from application
AFUE = 0.80, from application

$$\Delta kWh_{cooling} = 1 \times \frac{17.2 \times 3 \ \times 365 \times 8.33 \times 69.6}{3{,}412} \times \frac{1}{3.5} \times 1 \times \frac{0.26}{13/3.412} = 62.40\ kWh$$

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

$$\Delta kWh = 1 \times \frac{17.2 \times 3 \times 365 \times 8.33 \times 69.6}{3{,}412} \times \left(0 - \frac{1}{3.5 \times 1}\right) + 62.40 - 0$$
$$= -851.97\ kWh$$

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

$$\Delta MMBtu = 1 \times \frac{17.2 \times 3 \times 365 \times 8.33 \times 69.6}{1{,}000{,}000} \times \left[\frac{1}{0.5803} + 0 - \left(\frac{1}{3.5} \times 1 \times 1 \times \frac{0.7}{0.8}\right)\right]$$
$$= 16.1\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

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

Ancillary Electric Savings Impacts

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

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0	10/15/2010
6-13-3	6/30/2013
11-13-2	11/26/2013
12-17-7	12/31/2017
12-18-3	12/31/2018
2-20-1	2/28/2020
7-21-7	8/30/2021
3-23-19	3/31/2023

12-23-1	1/5/2024

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INDIRECT WATER HEATER

Measure Description

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

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

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

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = N/A$$

Summer Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings

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

where:

DkWh	= Annual electric energy savings
DkW	= Peak coincident demand electric savings
DMMBtu	= Annual fossil fuel energy savings
units	= Number of households addressed by the program
GPD	= Gallons per day of delivered hot water per person
PPH	= Persons per household served by DHW system
DT_{main}	= Average temperature difference between water heater set point temperature and the supply water temperature in water main (°F)
DT_{amb}	= Average temperature difference between water heater set point temperature and

the surrounding ambient air temperature (°F)

baseline	= Characteristic of baseline condition
ee	= Characteristic of rnergy efficient condition
Eff	= Efficiency
UA	= Overall heat loss coefficient (BTU/h-°F)
F_{HS}	= Factor to adjust savings for equipment providing domestic hot water during the heating season only365 = Days in one year
8.33	= Specific heat of water; energy required (BTU), to heat one gallon of water by one degree Fahrenheit [BTU/(gal-F)]
1,000,000	= Conversion factor, one MMBtu equals 1,000,000 BTU
8,760	= Hours in one year

Summary of Variables and Data Sources

Variable	Value	Notes
GPD	17.2	Average daily hot water usage per person.[27]
PPH		From application. If unknown, use a value of 2.8 for single-family homes[28] and 2.0 for multifamily homes.[29] For sites with multiple water heating systems, PPH shall be allocated proportional to the input heating capacity of each water heater relative to the total input heating capacity of all water heaters.[30]
DT_{main}	$T_{set} - T_{main}$	Average temperature difference between water heater set point temperature and the supply water temperature in water main (°F)
DT_{amb}	55 $= T_{set} - T_{amb}$	Average temperature difference between water heater set point temperature and the surrounding ambient air temperature (°F)
T_{set}	125	Water heater set point temperature (°F).[31]
T_{main}		Supply water temperature in water main (°F). Lookup in Cold Water Inlet Temperature table below based on nearest city.
T_{amb}	70	Surrounding ambient air temperature (°F).[32]
$Eff_{baseline}$	0.75	Efficiency of the baseline condition.[33]

[27] Water Research Foundation: Residential End Uses of Water, Version 2, April 2016, pg. 5; 17.2 GPD equated from the report findings indicating an average 2.65 people per household and 45.5 GPD per household.
[28] Residential Statewide Baseline Study of New York State, July 2015. Volume 1: Single-Family Report, Table 9.
[29] Residential Statewide Baseline Study of New York State, July 2015. Volume 2: Multifamily Report, Table 8.
[30] For example, if a home with 6 occupants contains two water heaters with 40 MBH and 50 MBH input capacities and the 40 MBH unit is being replaced with an equivalent capacity unit, the PPH value applied shall be PPH = 6 (occupants) x 40 (MBH) / (40 + 50) (MBH) = 2.7.
[31] 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.
[32] Water heaters are generally located in conditioned or partially conditioned spaces with a typical average temperature of 65°F to 70°F to avoid freezing. A value of 70°F is used for the purposes of estimating tank/ambient air temperature differential, which aligns with standby loss specification testing standards.
[33] 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.

Variable	Value	Notes
Eff_{ee}		Efficiency of energy efficient indirect-system boiler (AFUE), from application.
$UA_{baseline}$	7.85	Overall heat loss coefficient of the baseline condition (BTU/h-°F).[34]
UA_{ee}		Overall heat loss coefficient of the energy efficient measure (BTU/h-°F). Calculate per Qualifying Heat Loss Coefficient section below, based on qualifying equipment standby loss specification, rated in °F/hr. If unknown, assume UA_{ee} = 5.4.[35]
F_{HS}		Use a value of 0.67 for systems that provide DHW during the heating season only and a value of 1.0 for systems providing DHW year round.[36]

Cold Water Inlet Temperature (T_{main})

Supply water main temperatures vary according to climate, and are approximately equal to the annual average outdoor temperature plus 6°F.[37] Supply main temperatures based on the annual outdoor temperature are shown below.

City	Annual average outdoor temperature[38] (°F)	T_{main} (°F)
Albany	49.4	55.4
Binghamton	46.8	52.8
Buffalo	49.1	55.1
Massena	45.1	51.1
NYC	54.7	60.7
Poughkeepsie	50.9	56.9
Syracuse	49.0	55.0

Qualifying Heat Loss Coefficient (UA_{ee})

Indirect-fired water heater storage tanks are tested and rated for standby losses (in °F/hr) at standard testing conditions in accordance with testing standards.[39] The qualifying equipment standby

[34] Based on computation of heat loss coefficients via conversion equations found in 10 CFR 429, 430, and 431 Docket No. EERE-2015-BT-TP-0007, Energy Conservation Program for Consumer Products and Certain Commercial and Industrial Equipment: Test Procedures for Consumer and Commercial Water Heaters. Heat loss coefficient was equated for two minimally code compliant gas storage water heaters found to be the most typical in terms of storage and input capacity, representing storage type water heaters of between 20 and 55 gallon capacity (40 gallon, 40,000 BTU/h assumed) and between 55 and 120 gallon capacity (75 gallon, 76,000 BTU/h assumed). Results of heat loss coefficient evaluation at these two data points agreed to within 0.3%, so the lower of the two was selected to represent the $UA_{baseline}$ term.

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

[36] 0.67 value based on duration of heating season (8 months: October – May) relative to one year (12 months)

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

[38] Average annual outdoor temperatures taken from NCEI 1991-2020 climate normals.

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

loss specification (SL_{ee}), where available, shall be used in the formula below, along with tank volume (v_{ee}) to establish the qualifying equipment heat loss coefficient (UA_{ee}).

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

where:

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

Coincidence Factor (CF)

The prescribed value for the coincidence factor is N/A. This measure is not anticipated to have electric impacts.

Baseline Efficiencies from which Energy Savings are Calculated

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

Compliance Efficiency from which Incentives are Calculated

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

Operating Hours

Water heater run hours are not utilized in the estimation of energy or demand savings, but water heater is assumed to be available for operation for the duration of the operating period (year round or heating season only). Additionally, it is assumed standby losses are incurred over the duration of the operating period.

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

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

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

units = 1, from application

GPD = 17.2, from Summary of Variables and Data Source table

PPH = 5, from application

$\Delta T_{main} = T_{set} - T_{main}$ = 125 – 55.4 = 69.6

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

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

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

Eff_{ee} = 0.90, from application

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

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

UA_{ee} equation from Qualifying Heat Loss Coefficient section

SL_{ee} from application

v_{ee} from application

ΔT_{amb} = 55, from Summary of Variables and Data Sources table

F_{HS} = 1.0, from Summary of Variables and Data Sources table

$$\Delta MMBtu = 1 \times \left[\frac{17.2 \times 5 \times 365 \times 8.33 \times 69.6}{1{,}000{,}000} \times \left(\frac{1}{0.75} - \frac{1}{0.90}\right) + \left(\frac{7.85}{0.75} - \frac{7.44}{0.90}\right) \times \frac{55}{1{,}000{,}000} \times 8{,}760\right] \times 1.0 = 5.10\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

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

Ancillary Electric Savings Impacts

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

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6-13-2	6/30/2013
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7-13-29	7/31/2013
7-13-33	7/31/2013
7-13-34	7/31/2013
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11-13-2	11/26/2013
12-17-4	12/31/2017
12-23-2	1/5/2024

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STORAGE TANK AND INSTANTANEOUS DOMESTIC WATER HEATER

Measure Description

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

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

Instantaneous type units include fossil fuel instantaneous water heaters with a rated input capacity of greater than or equal to 50,000 and less than 200,000 BTU per hour and a manufacturer's specified storage capacity of less than 2 gallons, residential electric instantaneous water heaters with an input of 12 kilowatts or less and a manufacturer's specified storage capacity of less than 2 gallons and residential-duty commercial electric instantaneous water heaters with an input of greater than 12 kilowatts and less than or equal to 56.8 kilowatts and a manufacturer's specified storage capacity of 2 gallons or less.[40]

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

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

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings (Electric Water Heating Only)

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

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

Summer Peak Coincident Demand Savings (Electric Water Heating Only)

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

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

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

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of households addressed by the program
GPD	= Gallons per day of delivered hot water per person
PPH	= Persons per household served by DHW system
ΔT_{main}	= Average temperature difference between water heater set point temperature and the supply water temperature in water main (°F)
ΔT_{amb}	= Average temperature difference between water heater set point temperature and the surrounding ambient air temperature (°F)
$_{baseline}$	= Characteristic of baseline condition
$_{ee}$	= Characteristic of energy efficient condition
UEF	= Uniform energy factor
UA	= Overall heat loss coefficient (BTU/h-°F)
CF	= Coincidence factor
365	= Days in one year
8.33	= Specific heat of water; energy required (BTU), to heat one gallon of water by one degree Fahrenheit [BTU/(gal-F)]
3,412	= Conversion factor, one kWh equals 3,412 BTU
1,000,000	= Conversion factor, one MMBtu equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
GPD	17.2	Average daily hot water usage per person.[41] For residential-duty commercial water heaters, refer to GPD table in the commercial version of this measure.
PPH		From application. If unknown, use a value of 2.8 for single-family homes[42] and 2.0 for multifamily homes.[43] For sites with multiple water heating systems, PPH shall be allocated proportional to the input heating capacity of each water heater relative to the total input heating capacity of all water heaters.[44]
DT_{main}	$T_{set} - T_{main}$	Average temperature difference between water heater set point temperature and the supply water temperature in water main (°F).
DT_{amb}	55 $= T_{set} - T_{amb}$	Average temperature difference between water heater set point temperature and the surrounding ambient air temperature (°F).
T_{set}	125	Water heater set point temperature (°F).[45]
T_{main}		Supply water temperature in water main (°F). Lookup in Cold Water Inlet Temperature table below based on nearest city.
T_{amb}	70	Surrounding ambient air temperature (°F).[46]
$UEF_{baseline}$		Uniform Energy Factor of the baseline condition. See Baseline Efficiencies… section below for details regarding derivation of this input.
UEF_{ee}		Uniform Energy Factor of the energy efficient measure, from application.
$UA_{baseline}$		Overall heat loss coefficient of the baseline condition (BTU/h-°F).[47] For Instantaneous water heaters, set $UA_{baseline} = 0$. For storage type water heaters, set $UA_{baseline} = 7.85$.

[41] Water Research Foundation: Residential End Uses of Water, Version 2, April 2016, pg. 5; 17.2 GPD equated from the report findings indicating an average 2.65 people per household and 45.5 GPD per household.
[42] Residential Statewide Baseline Study of New York State, July 2015. Volume 1: Single-Family Report, Table 9.
[43] Residential Statewide Baseline Study of New York State, July 2015. Volume 2: Multifamily Report, Table 8.
[44] For example, if a home with 6 occupants contains two water heaters with 40 MBH and 50 MBH input capacities and the 40 MBH unit is being replaced with an equivalent capacity unit, the PPH value applied shall be PPH = 6 (occupants) x 40 (MBH) / (40 + 50) (MBH) = 2.7.
[45] 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.
[46] Water heaters are generally located in conditioned or partially conditioned spaces with a typical average temperature of 65°F to 70°F to avoid freezing. A value of 70°F is used for the purposes of estimating tank/ambient air temperature differential, which aligns with standby loss specification testing standards.
[47] Based on computation of heat loss coefficients via conversion equations found in 10 CFR 429, 430, and 431 Docket No. EERE-2015-BT-TP-0007, Energy Conservation Program for Consumer Products and Certain Commercial and Industrial Equipment: Test Procedures for Consumer and Commercial Water Heaters. Heat loss

Variable	Value	Notes
UA_{ee}		Overall heat loss coefficient of the energy efficient measure (BTU/h-°F). For instantaneous water heaters, set UA_{ee} = 0. For storage type water heaters, set UA_{ee} = 5.4.[48]
CF	0.8	

Cold Water Inlet Temperature (T_{main})

Supply water main temperatures vary according to climate, and are approximately equal to the annual average outdoor temperature plus 6°F.[49] Supply main temperatures based on the annual outdoor temperature are shown below.

City	Annual average outdoor temperature[50] (°F)	T_{main} (°F)
Albany	49.4	55.4
Binghamton	46.8	52.8
Buffalo	49.1	55.1
Massena	45.1	51.1
NYC	54.7	60.7
Poughkeepsie	50.9	56.9
Syracuse	49.0	55.0

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.8.[51]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a minimally code compliant water heater of type (storage-type or instantaneous) equivalent to the existing water heater and with tank volume (where applicable), input capacity and draw pattern equivalent to the efficient water heater. For new construction, the baseline condition is a minimally code compliant storage-type water heater with tank volume, input capacity and draw pattern equivalent to the efficient water heater. For all instantaneous water heaters with a storage type baseline, a 40-gallon storage type water heater with input capacity and draw pattern equivalent to the efficient water heater shall be assumed.

coefficient was equated for two minimally code compliant gas storage water heaters found to be the most typical in terms of storage and input capacity, representing storage type water heaters of between 20 and 55 gallon capacity (40 gallon, 40,000 BTU/h assumed) and between 55 and 120 gallon capacity (75 gallon, 76,000 BTU/h assumed). Results of heat loss coefficient evaluation at these two data points agreed to within 0.3%, so the lower of the two was selected to represent the $UA_{baseline}$ term.

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

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

[50] Average annual outdoor temperatures taken from NCEI 1991-2020 climate normals.

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

For LMI applications, existing condition baseline shall be established based on nameplate efficiency or efficiency measured through combustion analysis.

$UEF_{baseline}$ shall be calculated as a function of qualifying equipment tank volume (v_t) for storage type water heaters or looked up for instantaneous water heaters per federal standards from the appropriate table (Residential Water Heaters or Residential-Duty Commercial Water Heaters) below, using the baseline equipment type and efficient case capacity and draw pattern. Draw pattern can be established based on the efficient equipment First Hour Rating (FHR), rated in gallons, for storage type water heaters or Max Gallons per Minute (GPM), rated in gallons/minute, for instantaneous water heaters. See the First Hour Rating vs. Draw Pattern and Max GPM vs. Draw Pattern tables below for storage type and instantaneous water heaters, respectively. If FHR or Max GPM is unknown, a Medium draw pattern should be assumed for storage type water heaters with rated storage capacity ≤ 50 gallons and a High draw pattern should be assumed otherwise.[52]

Residential Water Heaters[53]

Product Class	**Rated Storage Volume and Input Rating**	**Draw Pattern**	**$UEF_{baseline}$**
Gas-Fired Storage Water Heater	≥ 20 gal and ≤ 55 gal	Very Small	$0.3456 - (0.0020 \times v_t^*)$
		Low	$0.5982 - (0.0019 \times v_t)$
		Medium	$0.6483 - (0.0017 \times v_t)$
		High	$0.6920 - (0.0013 \times v_t)$
	> 55 gal and ≤ 100 gal	Very Small	$0.6470 - (0.0006 \times v_t)$
		Low	$0.7689 - (0.0005 \times v_t)$
		Medium	$0.7897 - (0.0004 \times v_t)$
		High	$0.8072 - (0.0003 \times v_t)$
Oil-Fired Storage Water Heater	≤50 gal	Very Small	$0.2509 - (0.0012 \times v_t)$
		Low	$0.5330 – (0.0016 \times v_t)$
		Medium	$0.6078 – (0.0016 \times v_t)$
		High	$0.6815 - (0.0014 \times v_t)$
Electric Storage Water Heater	≥ 20 gal and ≤ 55 gal	Very Small	$0.8808 - (0.0008 \times v_t)$
		Low	$0.9254 - (0.0003 \times v_t)$
		Medium	$0.9307 - (0.0002 \times v_t)$
		High	$0.9349 - (0.0001 \times v_t)$
	> 55 gal and ≤ 120 gal	Very Small	$1.9236 - (0.0011 \times v_t)$
		Low	$2.0440 - (0.0011 \times v_t)$
		Medium	$2.1171 - (0.0011 \times v_t)$
		High	$2.2418 - (0.0011 \times v_t)$
Instantaneous Gas-Fired Water Heater	< 2 gal and > 50,000 BTU/h	Very Small	0.80
		Low	0.81
		Medium	0.81
		High	0.81

[52] Based on review of typical usage bins for AHRI certified residential water heating equipment. (https://www.ahridirectory.org/ahridirectory/pages/home.aspx)
[53] 10 CFR 430.32(d).

Product Class	Rated Storage Volume and Input Rating	Draw Pattern	$UEF_{baseline}$
Instantaneous Electric Water Heater	< 2 gal	Very Small	0.91
		Low	0.91
		Medium	0.91
		High	0.92

*v_t = Rated storage volume (in gallons)

Residential-Duty Commercial Water Heaters[54]

Product Class	Rated Storage Volume and Input Rating	Draw Pattern	$UEF_{baseline}$
Gas-Fired Storage Water Heater	> 75,000 BTU/h and ≤ 105,000 BTU/h and ≤ 120 gal	Very Small	0.2674 - (0.0009 x v_t^*)
		Low	0.5362 - (0.0012 x v_t)
		Medium	0.6002 - (0.0011 x v_t)
		High	0.6597 - (0.0009 x v_t)
Oil-Fired Storage Water Heater	>105,000 BTU/h and ≤140,000 BTU/h and ≤ 120 gal	Very Small	0.2932 – (0.0015 x v_t)
		Low	0.5596 - (0.0018 x v_t)
		Medium	0.6194 – (0.0016 x v_t)
		High	0.6740 – (0.0013 x v_t)
Instantaneous Electric Water Heater	> 12 kW gal and ≤ 55 gal	Very Small	0.80
		Low	0.80
		Medium	0.80
		High	0.80

*v_t = tank volume in gallons

First Hour Rating vs. Draw Pattern (Storage Type Only)[55]

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

Max GPM vs. Draw Pattern (Instantaneous Only)[56]

Max GPM	Draw Pattern
< 1.7 gallons/minute	Very Small
≥ 1.7 and < 2.8 gallons/minute	Low
≥ 2.8 and < 4.0 gallons/minute	Medium
≥ 4.0 gallons/minute	High

Compliance Efficiency from which Incentives are Calculated

[54] 10 CFR 431.110(b).
[55] 10 CFR 429.17.
[56] 10 CFR 429.17.

The compliance condition is an ENERGY STAR® rated fossil fuel or electric storage or instantaneous type water heater as directed by the measure description. Efficient fossil fuel and electric storage tank and instantaneous type water heaters must be eligible under ENERGY STAR® Program Requirements for Residential Water Heaters, Eligibility Criteria Version 5.0, effective July 2022.[57] Minimum UEF qualification for ENERGY STAR® equipment are shown in the table below.

Residential Water Heaters

Product Class	Rated Storage Volume and Input Rating	Draw Pattern	UEF
Gas-Fired Storage Water Heater	> 20 gal and ≤ 55 gal	Medium	≥ 0.81
		High	≥ 0.86
	> 55 gal	Medium	≥ 0.86
		High	≥ 0.80
Instantaneous Gas-Fired Water Heater	N/A	All	≥ 0.95

Product Class[58]	UEF
Integrated HPWH	≥ 3.30
Integrated HPWH, 120 Volt / 15 Amp Circuit	≥ 2.20
Split-System HPWH	≥ 2.20

Residential-Duty Commercial Water Heaters

Product Class	Rated Storage Volume and Input Rating	Draw Pattern	UEF
Gas-Fired Storage Water Heater	> 75,000 BTU/h and ≤ 105,000 BTU/h and ≤ 120 gal	All	≥ 0.86

Operating Hours

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

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

An existing residential customer located near Albany replaces their existing storage tank gas-fired water heater with a high efficiency storage tank gas-fired water heater. The system serves a single-family, detached home with 5 residents. The high efficiency water heater has a tank capacity of 50 gallons and is rated for a medium draw pattern with a UEF of 0.85. Annual

[57] ENERGY STAR® Program Requirements Product Specification for Residential Water Heaters, Eligibility Criteria, Version 5.0, July 18, 2022.

[58] NOTE: Heat pump water heaters shall use the method prescribed for Residential Heat Pump Water Heaters (HPWH) – Air Source in this TRM where feasible.

Electric Energy Savings and Summer Peak Coincident Demand Savings are not applicable. Annual Fossil Fuel Energy Savings are calculated as below.

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

units = 1, from application
GPD = 17.2, from Summary of Variables and Data Source table
PPH = 5, from application
$\Delta T_{main} = T_{set} - T_{main} = 125 - 55.4 = 69.6$
T_{set} from Summary of Variables and Data Sources table
T_{main} from Cold Water Inlet Temperature lookup table based on location from application
$UEF_{baseline} = 0.6483 - (0.0017 \text{ x } v_t) = 0.6483 - (0.0017 \text{ x } 50) = 0.5633$
$UEF_{baseline}$ equation from Residential Water Heaters table based on product class and draw pattern from application
v_t from application
$UEF_{ee} = 0.85$, from application

$$\Delta MMBtu = 1 \times \frac{17.2 \times 5 \times 365 \times 8.33 \times (69.6)}{1{,}000{,}000} \times \left(\frac{1}{(0.5633)} - \frac{1}{0.85}\right) = 10.90\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

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

Ancillary Electric Savings Impacts

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

Gas water heaters with draft inducer fans may introduce additional electric load. Consideration of this effect is not included in this methodology.

References

1. ENERGY STAR® Program Requirements Product Specification for Residential Water Heaters, Eligibility Criteria Version 5.0, July 2022.

Available from: https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Residential%20Water%20Heaters%20Version%205.0%20Specification%20and%20Partner%20Commitments.pdf
2. 10 CFR 430.2 Definitions.
Available from: https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=78ea8c7c6bf5379d6e0fd2b41e335739&mc=true&n=pt10.3.430&r=PART&ty=HTML#se10.3.430_12
3. 10 CFR 430.32 Energy and water conservation standards and their compliance dates.
Available from: http://www.ecfr.gov/cgi-bin/text-idx?SID=a9921a66f2b4f66a32ec851916b7b9d9&mc=true&node=se10.3.430_132&rgn=div8
4. 10 CFR 431.110 Energy conservation standards and their effective dates.
Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=a69096e892b13c204bbe6da3a92f8111&mc=true&node=se10.3.431_1110&rgn=div8
5. Water Research Foundation: "Residential End Uses of Water, Version 2: Executive Report", April 2016.
Available from: https://www.waterrf.org/research/projects/residential-end-uses-water-version-2
6. Residential Statewide Baseline Study of New York State, July 2015.
Available from: https://www.nyserda.ny.gov/About/Publications/Evaluation-Reports/Building-Stock-and-Potential-Studies/Residential-Statewide-Baseline-Study-of-New-York-State
7. Appendix E to Subpart B of Part 430—Uniform Test Method for Measuring the Energy Consumption of Water Heaters, Section 2. Test Conditions, 2.5 Set Point Temperature.
Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=80dfa785ea350ebeee184bb0ae03e7f0&mc=true&node=ap10.3.430_127.e&rgn=div9
8. 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
9. 10 CFR 429, 430, and 431 Docket No. EERE-2015-BT-TP-0007, Energy Conservation Program for Consumer Products and Certain Commercial and Industrial Equipment: Test Procedures for Consumer and Commercial Water Heaters.
Available from: https://energy.gov/sites/prod/files/2016/08/f33/Water%20Heaters%20Test%20Procedure%20SNOPR.pdf
10. AHRI Directory of Certified Product Performance.
Available from: https://www.ahridirectory.org/ahridirectory/pages/home.aspx
11. Burch, Jay and Craig Christensen; "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory.
Available from: https://www.energystar.gov/ia/partners/prod_development/new_specs/downloads/water_heaters/AlgorithmForMainsWaterTemperature.pdf
12. NOAA National Centers for Environmental Information – NCEI 1991-2020 Climate

Normals.
Available from: https://www.ncdc.noaa.gov/cdo-web/datatools/normals
13. 10 CFR 429.17 Water heaters.
Available from: https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-429

Record of Revision

Record of Revision Number	Issue Date
1	10/15/2010
6-13-1	6/30/2013
7-13-6	7/31/2013
11-13-2	11/26/2013
12-17-5	12/31/2017
3-19-4	3/29/2019
12-23-3	1/5/2024

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HEATING, VENTILATION AND AIR CONDITIONING (HVAC)

BOILER AND FURNACE - COMBINATION (“COMBI”) BOILER AND FURNACE

Measure Description

This measure covers the installation of residential fossil fuel-fired combination or “combi” boilers and furnaces, which are defined as high-efficiency, instantaneous water heaters with a heating designation. Combi-boilers are all-in-one high-efficiency space heating systems with integrated capability for providing instantaneous domestic hot water, while combi-furnaces supply both domestic tankless hot water and forced air heating. These units realize energy savings through increased thermal efficiency and by taking cold water straight from the main supply and heating it as needed, which eliminates the need for a separate hot water storage tank and avoids standby losses. Qualifying equipment must be in accordance with ASHRAE Standard 124-2007 (RA 2016).[59] This measure only applies to systems with modulating/staging capability and no water storage tank.

This measure only captures the fossil fuel savings impacts of combi-boilers and combi-furnaces. While electric combi-boilers exist, more investigation and research are required before an approach for estimating associated energy savings can be developed.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = N/A$$

Summer Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = \Delta MMBtu_{SH} + \Delta MMBtu_{DHW}$$

$$\Delta MMBtu_{SH} = units \times \frac{kBTU/h_{in}}{unit} \times \left(\frac{AFUE_{ee}}{AFUE_{baseline}} - 1\right) \times \frac{EFLH_{heating}}{1,000}$$

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

[59] ASHRAE Standard 124-2007 (RA 2016) – Methods of Testing for Rating Combination Space-Heating and Water-Heating Appliances (ANSI Approved).

where:

ΔkWh = Annual electric energy savings
ΔkW = Peak coincident demand electric savings
$\Delta MMBtu$ = Annual fossil fuel energy savings
$\Delta MMBtu_{DHW}$ = Annual domestic hot water savings associated with installation of a high-efficiency combi-boiler or combi-furnace
$\Delta MMBtu_{SH}$ = Annual space heating savings associated with installation of a high-efficiency combi-boiler or combi-furnace
units = Number of households addressed by the program
$kBTU/h_{in}$ = Space heating fuel input rating
$_{baseline}$ = Characteristic of baseline condition
$_{ee}$ = Characteristic of energy efficient condition
AFUE = Annual fuel utilization efficiency, seasonal energy efficiency for fossil fuel heating equipment
$EFLH_{heating}$ = Heating equivalent full-load hours
GPD = Gallons per day of delivered hot water per person
PPH = Persons per household served by DHW system
ΔT_{main} = Average difference between the cold inlet temperature and the hot water delivery temperature (°F)
RE = Recovery efficiency
UA = Overall heat loss coefficient (BTU/h-°F)
ΔT_{amb} = Average temperature difference between water heater set point temperature and the surrounding ambient air temperature (°F)
8.33 = Specific heat of water; energy required (BTU), to heat one gallon of water by one degree Fahrenheit [BTU/(gal-F)]
365 = Days in one year
1,000 = Conversion factor, one MMBtu equals 1,000 kBTU
8,760 = Hours in one year
1,000,000 = Conversion factor, one MMBtu equals 1,000,000 BTU

Summary of Variables & Data Sources

Variable	Value	Notes/References
$kBTU/h_{in}$		Nominal heating input capacity is the nameplate input rating of the unit in kBTU/h, from application.
$AFUE_{baseline}$		See Baseline Efficiencies section below.
$AFUE_{ee}$		From application.
$EFLH_{heating}$		Lookup based on building type and location in Appendix G.
GPD	17.2	Average daily hot water usage per person.[60]

[60] Water Research Foundation: Residential End Uses of Water, Version 2, April 2016, pg. 5; 17.2 GPD equated from the report findings indicating an average 2.65 people per household and 45.5 GPD per household.

Variable	Value	Notes/References
PPH		From application. If unknown, use a value of 2.8 for single-family homes[61] and 2.0 for multifamily homes.[62] For sites with multiple water heating systems, PPH shall be allocated proportional to the input heating capacity of each water heater relative to the total input heating capacity of all water heaters.[63]
DT_{main}	T_{set} - T_{main}	Average temperature difference between water heater set point temperature and the supply water temperature in water main (°F).
DT_{amb}	55 = T_{set} - T_{amb}	Average temperature difference between water heater set point temperature and the surrounding ambient air temperature (°F).
T_{set}	125	Water heater set point temperature (°F).[64]
T_{main}		Supply water temperature in water main (°F). Lookup in Cold Water Inlet Temperature table below based on nearest city.
T_{amb}	70	Surrounding ambient air temperature (°F).[65]
$RE_{baseline}$	0.75	Gas recovery efficiency.[66]
$UA_{baseline}$	7.85	Overall heat loss coefficient of the baseline condition (BTU/h-°F).[67]

Cold Water Inlet Temperature (T_{main})

Supply water main temperatures vary according to climate and are approximately equal to the annual average outdoor temperature plus 6°F.[68] Supply main temperatures based on the annual outdoor temperature are shown below.

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[61] Residential Statewide Baseline Study of New York State, July 2015. Volume 1: Single-Family Report, Table 9.
[62] Residential Statewide Baseline Study of New York State, July 2015. Volume 2: Multifamily Report, Table 8.
[63] For example, if a home with 6 occupants contains two water heaters with 40 MBH and 50 MBH input capacities and the 40 MBH unit is being replaced with an equivalent capacity unit, the PPH value applied shall be PPH = 6 (occupants) x 40 (MBH) / (40 + 50) (MBH) = 2.7.
[64] 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.
[65] Water heaters are generally located in conditioned or partially conditioned spaces with a typical average temperature of 65°F to 70°F to avoid freezing. A value of 70°F is used for the purposes of estimating tank/ambient air temperature differential, which aligns with standby loss specification testing standards.
[66] Per 10 CFR 430, typical recovery efficiency of a fuel water heater, which is used for the purposes of this measure as a proxy for thermal efficiency, is 0.75. See for example, 10 CFR 430 Subpart B Appendix C1, 5.6.1.1.
[67] Based on computation of heat loss coefficients via conversion equations found in 10 CFR 429, 430, and 431 Docket No. EERE-2015-BT-TP-0007, Energy Conservation Program for Consumer Products and Certain Commercial and Industrial Equipment: Test Procedures for Consumer and Commercial Water Heaters. Heat loss coefficient was calculated for a minimally code compliant fuel storage water heater found to be the most typical in terms of storage and input capacity, representing storage type water heaters of between 20 and 55 gallon capacity (40 gallon, 40,000 BTU/h assumed). Results of heat loss coefficient evaluation for this assumed baseline is used to represent the $UA_{baseline}$ term.
[68] Burch, Jay and Christensen, Craig, "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory.

City	Annual average outdoor temperature[69] (°F)	T_{main} (°F)
Albany	49.4	55.4
Binghamton	46.8	52.8
Buffalo	49.1	55.1
Massena	45.1	51.1
NYC	54.7	60.7
Poughkeepsie	50.9	56.9
Syracuse	49.0	55.0

Coincidence Factor (CF)

The prescribed value for the coincidence factor is N/A. This measure is not anticipated to have electric impacts.

Baseline Efficiencies from which Energy Savings are Calculated

Space Heating Component

The baseline efficiency for the space heating component of residential combi-boilers and combi-furnaces is defined by the Code of Federal Regulations and subsequently adopted by the Energy Conservation Code of New York State, as shown below.

For LMI applications, existing condition baseline shall be established based on nameplate efficiency or efficiency measured through combustion analysis.

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

Fossil Fuel Fired Heating System Baseline Efficiencies: Systems Serving Single Units[70]

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

The baseline efficiency for heating systems serving multiple dwelling units is defined by International Energy Conservation Code[71] and subsequently adopted by the Energy Conservation Construction Code of New York State (ECCCNYS) as shown in the table below.

[69] Average annual outdoor temperatures taken from NCEI 1991-2020 climate normals.
[70] 10 CFR 430.32(e).
[71] ECCCNYS 2020, Table C403.3.2(4) & Table C403.3.2(5).

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

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

Domestic Hot Water Component

The baseline condition is a standard efficiency 40-gallon storage type water heater with a recovery efficiency of 75%[72] and heat loss coefficient of 7.85 BTU/h-°F.[73]

For LMI applications, existing condition baseline shall be established based on nameplate efficiency or efficiency measured through combustion analysis.

[72] Per 10 CFR 430, typical recovery efficiency of a fuel water heater, which is used for the purposes of this measure as a proxy for thermal efficiency, is 0.75. See for example, 10 CFR 430 Subpart B Appendix C1, 5.6.1.1.

[73] Per 10 CFR 430, typical recovery efficiency of a fuel water heater, which is used for the purposes of this measure as a proxy for thermal efficiency, is 0.75. See for example, 10 CFR 430 Subpart B Appendix C1, 5.6.1.1.

[73] Based on computation of heat loss coefficients via conversion equations found in 10 CFR 429, 430, and 431 Docket No. EERE-2015-BT-TP-0007, Energy Conservation Program for Consumer Products and Certain Commercial and Industrial Equipment: Test Procedures for Consumer and Commercial Water Heaters. Heat loss coefficient was calculated for a minimally code compliant fuel storage water heater found to be the most typical in terms of storage and input capacity, representing storage type water heaters of between 20 and 55 gallon capacity (40 gallon, 40,000 BTU/h assumed). Results of heat loss coefficient evaluation for this assumed baseline is used to represent the $UA_{baseline}$ term.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a combi-boiler unit with a heating designation efficiency of 90% AFUE or greater or a combi-furnace unit with a heating designation efficiency of 92% AFUE. Qualifying systems must be equipped with modulating/staging capability and no water storage tank. Units shall be in accordance with ASHRAE Standard 124-2007 (RA 2016).[74]

Operating Hours

Heating equivalent full-load hours were calculated from a DOE-2.2 simulation of prototypical single and multi-family residential buildings. Operating hour assumptions for the prototypical building models are described in Appendix A. The heating EFLH for residential buildings in NY are shown in Appendix G.

Domestic hot water heaters are assumed to be available for operation 8,760 hours per year, and it is assumed standby losses in the baseline case are incurred 8,760 hours per year.

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

A "combi" boiler with 199 kBTU/h and 90% AFUE is installed in a single - family, detached home with 5 residents located near Albany constructed in 1995. The conditions prior to installation include a gas-fired warm air furnace and gas storage tank water heater. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are not applicable. Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta MMBtu = \Delta MMBtu_{SH} + \Delta MMBtu_{DHW}$$

$$\Delta MMBtu_{SH} = units \times \frac{kBTU/h_{in}}{unit} \times \left(\frac{AFUE_{ee}}{AFUE_{baseline}} - 1\right) \times \frac{EFLH_{heating}}{1{,}000}$$

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

units = 1, from application
$(kBTU/h_{in})$/unit = 199, from application
$AFUE_{ee}$ = 0.9, from application
$AFUE_{baseline}$ = 0.80, from Baseline Efficiencies section based on equipment type and size from application
$EFLH_{heating}$ = 978, from Appendix G based on housing type, building vintage, and location from application
GPD = 17.2, from Summary of Variables and Data Source table

[74] ASHRAE Standard 124-2007 (RA 2016) – Methods of Testing for Rating Combination Space-Heating and Water-Heating Appliances (ANSI Approved).

PPH = 5, from application
$\Delta T_{main} = T_{set} - T_{main} = 125 - 55.4 = 69.6$
T_{set} from Summary of Variables and Data Sources table
T_{main} from Cold Water Inlet Temperature lookup table based on location from application
$RE_{baseline} = 0.75$, from Summary of Variables and Data Sources table
$UA_{baseline} = 7.85$, from Summary of Variables and Data Sources table
$\Delta T_{amb} = 55$, from Summary of Variables and Data Sources table

$$\Delta MMBtu_{SH} = 1 \times 199 \times \left(\frac{0.90}{0.80} - 1\right) \times \frac{978}{1,000} = 24.33\ MMBtu$$

$$\Delta MMBtu_{DHW} = 1 \times \left[\frac{17.2 \times 5 \times 365 \times 8.33 \times 69.6}{1,000,000} \times \left(\frac{1}{0.8} - \frac{1}{0.9}\right) + \frac{7.85}{0.75} \times \frac{55}{1,000,000} \times 8,760\right] = 7.57\ MMBtu$$

$$\Delta MMBtu = 24.33 + 7.57 = 31.90\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

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

Ancillary Electric Savings Impacts

High efficiency furnaces may be packaged with high efficiency cooling equipment and/or electronically commutated blower motors, which may provide electricity savings. Draft fans, when present, will increase electricity consumption.

References

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10. ECCCNYS 2020 Table C403.3.2(4): Warm-Air Furnaces And Combination Warm-Air Furnaces/Air-Conditioning Units, Warm-Air Duct Furnaces And Unit Heaters, Minimum Efficiency Requirements & Table C403.2.3(5): Minimum Efficiency Requirements: Gas-And Oil-Fired Boilers.
    Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-[ce]-commercial-energy-efficiency#NYSECC2020P1_CE_Ch04_SecC402
11. CFR 430.32 Energy and water conservation standards and their compliance dates.
    Available from: http://www.ecfr.gov/cgi-bin/text-idx?SID=a9921a66f2b4f66a32ec851916b7b9d9&mc=true&node=se10.3.430_132&rgn=div8

Record of Revision

Record of Revision Number	Issue Date
9-18-16	9/28/2018
12-23-4	1/5/2024

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HEAT PUMP – WATER-TO-AIR GROUND SOURCE (GSHP)

Measure Description

This measure covers the installation of an ENERGY STAR® certified Ground Source Heat Pump (GSHP) system with a closed loop heat exchanger field or an open loop ground water system as permissible by local environmental review.[75] The GSHP system provides heating and cooling for space conditioning by a water-to-air heat pump via a typical air-duct distribution system in a residential home.[76] These systems can optionally have an integrated desuperheater or a dedicated Domestic Hot Water (DHW) water-to-water heat pump (WWHP) that supplements domestic hot water heating in conjunction with space conditioning. Methods for calculating annual DHW energy savings are presented separately below.

This measure applies to GSHPs in residential applications, and where each GSHP unit has its own dedicated loop pump. It does not apply to large GSHP systems with multiple heat pump units with centralized ground loop pumping.

The GSHP analysis associated with this measure is based on several assumptions consistent with best practice design for a quality GSHP installation:

- Current Residential code and Federal standard (Code of Federal Regulations 10 CFR 430.32, ECCCNYS 2020 or local legislation) applicable to the installation should be referenced for correct baseline system and efficiency values.

- Systems shall be sized in accordance with ACCA Manual S based on building loads calculated in accordance with ACCA Manual J.[77,78]

- The building peak heating load in New York typically exceeds the peak cooling load, therefore it is assumed that the GSHP runs at part-load during peak cooling hours.

- The ground loop heat exchanger is adequately sized and installed properly to allow the GSHP to meet the peak heating load without electric resistance auxiliary heat.

- The GSHP is equipped with either a two stage or variable-speed compressor system, a variable speed or constant speed ground loop circulator pump, and a variable-speed blower distribution fan.

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[75] This measure section does not apply to a subset of open loop systems known as standing column wells, since operating temperatures are much different in these applications.

[76] "Residential homes" means detached one- and two-family dwellings and townhouses not more than three stories above-grade in height with a separate means of egress and their accessory structures, and one-family dwellings converted to bed and breakfast dwellings.

[77] ECCCNYS 2020, Section R403.7.

[78] ECCNYS 2020 requires that systems serving multiple dwelling units follow Sections C403 and C404.

- The GSHP efficiency is rated in accordance with ISO 13256-1, and AHRI-certified performance ratings are provided by the manufacturer showing the efficiency and capacity of the unit under full and part load conditions.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Note: The algorithms below address energy impacts associated with space conditioning load only. See the *Methods for Calculating Annual Domestic Hot Water Energy Savings from an Integrated Desuperheater or Dedicated Water-to-Water Heat Pump* section of this measure for estimating DHW savings associated with these systems.

Annual Electric Energy Savings

$$\Delta kWh = \left[\frac{BCL}{1{,}000} \times \left(\frac{1}{EER_{season,baseline}} - \frac{1}{EER_{season,ee}}\right) \times BEFLH_{cooling}\right] + \left[\frac{BHL}{3{,}412} \times \left(\frac{F_{ElecHeat}}{COP_{season,baseline}} - \frac{1}{COP_{season,ee}}\right) \times BEFLH_{heating}\right]$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \frac{BCL}{1{,}000} \times \left(\frac{1}{EER_{peak,baseline}} - \frac{1}{EER_{GSHP,full,ee}}\right) \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = \frac{BHL}{1{,}000{,}000} \times \frac{F_{FuelHeat}}{AFUE_{baseline}} \times BEFLH_{heating}$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
BCL	= Building Cooling Load at design conditions (BTU/h)
BHL	= Building Heating Load at design conditions (BTU/h)
$F_{ElecHeat}$	= Electric heating factor; used to account for the presence or absence of an electric heating system
$F_{FuelHeat}$	= Fossil fuel heating factor; used to account for the presence or absence of a fossil fuel heating system
$_{baseline}$	= Characteristic of baseline condition
$_{ee}$	= Characteristic of energy efficient condition
EER_{season}	= Energy efficiency ratio (BTU/watt-hour) at part-load seasonally adjusted for fan and pump power
EER_{peak}	= Full load energy efficiency ratio (BTU/watt-hour)

$EER_{GSHP,full}$ = Full load energy efficiency ratio (BTU/watt-hour). Refers to Ground Loop Heat Pump (GLHP)-rated condition for closed loop GSHP systems or Ground Water Heat Pump (GWHP)-rated conditions for open loop systems.
COP_{season} = Coefficient of performance, seasonally adjusted for fan and pump power.
AFUE = Annual fuel utilization efficiency, seasonal efficiency for fossil fuel-fired heating equipment
$BEFLH_{cooling}$ = Cooling equivalent full-load hours based on building design load
$BEFLH_{heating}$ = Heating equivalent full-load hours based on building design load
CF = Coincidence Factor
3,412 = Conversion factor, one kWh equals 3,412 BTU
1,000 = Conversion factor, one kW equals 1,000 Watts
1,000,000 = Conversion factor, one MMBtu equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
BCL		Building cooling load at design conditions calculated in accordance with ACCA Manual J, from application.
BHL		Building heating load at design conditions calculated in accordance with ACCA Manual J, from application.
$F_{ElecHeat}$		If the baseline heating system is an electric system, set equal to 1. Otherwise, set equal to 0.
$F_{FuelHeat}$		If the baseline heating system is a fossil fuel system, set equal to 1. Otherwise, set equal to 0.
$EER_{season,baseline}$		Seasonal electric cooling energy efficiency rating of baseline equipment. See SEER values in Baseline Efficiency section below for details.
$EER_{peak,baseline}$		Electric cooling energy efficiency rating of baseline equipment. See EER values in Baseline Efficiency section below for details.
$EER_{season,ee}$		Energy efficiency ratio from the manufacturer's catalog data adjusted to account for applied fan and pump power. See Compliance Efficiency section below for details.
$EER_{GSHP,full,ee}$		Full load energy efficiency ratio at AHRI rated conditions. Corresponds to GLHP-rated condition with fluid temperature of 77ºF for closed loop systems, or GWHP-rated condition with fluid temperature of 59ºF for open loop systems.
$COP_{season,baseline}$		Electric heating energy efficiency rating of baseline equipment. See Baseline Efficiency section below for details.
$COP_{season,ee}$		Coefficient of performance from the manufacturer's catalog data adjusted to account for applied fan and pump power. See Compliance Efficiency section below for details.
$AFUE_{baseline}$		Seasonal fuel energy efficiency of the baseline equipment. See Baseline Efficiency section below for details.
$BEFLH_{cooling}$		Lookup based on building type, vintage and location from the appropriate table in the Operating Hours section below.

Variable	Value	Notes
$BEFLH_{heating}$		Lookup based on building type, vintage and location from the appropriate table in the Operating Hours section below.
CF	0.69	

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.69.[79]

Baseline Efficiencies from which Energy Savings are Calculated

The baselines used in this measure are determined by the type of equipment that would have been installed without the influence of the program supporting the installation of this measure. This allows for an analysis that does not depend on a typical 'like-for-like' replacement scenario.

For LMI applications, existing condition baseline shall be established based on nameplate or measured efficiency.

A GSHP system can be considered a normal replacement scenario for electric resistance heating (with or without a central electric cooling system), an ASHP system (that provides space heating and cooling), or a fossil fuel fired heating system (with or without a central electric cooling system). The tables below provide baseline efficiencies for electric cooling and heating and fossil fuel fired heating systems.

For scenarios where there is new construction or substantial renovation, the baseline is assumed to be a fossil fuel fired warm air furnace of the fuel type most likely to be installed at the project site without the influence of the program with a central air conditioning system.

The baseline efficiency for electric cooling and heating systems is defined by the Code of Federal Regulations as shown in the table below. Baseline efficiency ratings (SEER/SEER2, EER/EER2, HSPF/HSPF2) shall align with the efficiency rating of the efficient equipment.

Electric Cooling and Heating System Baseline Efficiencies (SEER, EER, HSPF)

Product Class	Seasonal Energy Efficiency Ratio (SEER)[80]	Energy Efficiency Ratio (EER)	Heating Seasonal Performance Factor (HSPF)[81]
Split System – Air Conditioner (<45 kBTU/h)	13.0	11.2	N/A

[79] 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.

[80] 10 CFR 430.32(c)(1).

[81] 10 CFR 430.32(c)(1).

Product Class	Seasonal Energy Efficiency Ratio (SEER)[80]	Energy Efficiency Ratio (EER)	Heating Seasonal Performance Factor (HSPF)[81]
Split System – Air Conditioner (≥45 and <65 kBTU/h)	13.0	11.2	N/A
Single Package – Air Conditioner	14.0	11.8	N/A
Split System – Heat Pump (<45 kBTU/h)	14.0	11.8	8.2
Split System – Heat Pump (≥45 and < 65 kBTU/h)	14.0	11.8	8.2
Single Package – Heat Pump (<65 kBTU/h)	14.0	11.8	8.0

<u>Electric Cooling and Heating System Baseline Efficiencies (SEER2, EER2, HSPF2)</u>

Product Class	Seasonal Energy Efficiency Ratio 2 (SEER2)[82]	Energy Efficiency Ratio 2 (EER2)	Heating Seasonal Performance Factor 2 (HSPF2)[83]
Split System – Air Conditioner (<45 kBTU/h)	13.4	11.4	N/A
Split System – Air Conditioner (≥45 and <65 kBTU/h)	13.4	11.4	N/A
Single Package – Air Conditioner	13.4	11.4	N/A
Split System – Heat Pump (<45 kBTU/h)	14.3	11.9	7.5
Split System – Heat Pump (≥45 and < 65 kBTU/h)	14.3	11.9	7.5
Single Package – Heat Pump (<65 kBTU/h)	13.4	11.4	6.7

<u>GSHP System Baseline Efficiencies</u>

[82] 10 CFR 430.32(c)(5).
[83] 10 CFR 430.32(c)(5).

Product Application	Full-Load Rated Heating COP	Full-Load Rated Cooling EER	Adjusted Heating Efficiency ($COP_{season,base}$)	Adjusted Cooling Efficiency ($EER_{season,base}$)
Closed Loop, GLHP-rating	3.2	14.1	2.95	12.99
Open Loop, GWHP-rating	3.7	18.0	3.05	14.71

*Equipment < 135 kBTU/h cooling capacity rated by ISO/ANSI/ASHRAE 13256-1: Baseline system is assumed to be single stage.
**Adjusted values use corrections below for pumping and distribution losses assuming a pumping power of 90 Watts per ton for closed loop and 120 Watts per ton open loop.

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

Fossil Fuel Fired Heating System Baseline Efficiencies: Systems Serving Single Units[84]

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

The baseline efficiency for heating systems serving multiple dwelling units is defined by International Energy Conservation Code[85] and subsequently adopted by the Energy Conservation Construction Code of New York State (ECCCNYS) as shown in the table below.

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

Equipment Type	Size Range	ECCCNYS Minimum Efficiency for Climate Zones 4, 5 and 6
Warm Air Furnace, Gas Fired	< 225 kBTU/h	0.80 AFUE
	≥ 225 kBTU/h	0.80 Et
Warm Air Furnace, Oil Fired	< 225 kBTU/h	0.83 AFUE
	≥ 225 kBTU/h	0.81 Et
Warm Air Unit Heaters, Gas Fired	All Capacities	0.80 Ec
Warm Air Unit Heaters, Oil Fired	All Capacities	0.80 Ec

[84] 10 CFR 430.32(e).
[85] ECCCNYS 2020, Table C403.3.2(4) & Table C403.3.2(5).

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

For scenarios where the baseline heating system is electric resistance heat or an electric furnace, the baseline efficiency is assumed to be a COP of 1.0.

For scenarios where the baseline heating system is a conventional ASHP, additional consideration is given to account for the significant difference between the rating conditions for HSPF and the typical operating conditions in New York State, as shown below:

The HSPF is the AHRI-rated heating seasonal average efficiency expressed in terms of BTU/watt-hour. A seasonally adjusted $COP_{baseline}$ of a conventional air-source heat pump is used in the above equations. This adjusted baseline COP shall be calculated as:

$$COP_{season,baseline} = \frac{HSPF \times F_{HSPF}}{3.412}$$

where:

HSPF = Heating seasonal performance factor of the baseline system
F_{HSPF} = HSPF Climate Adjustment Factor, from table below
3.412 = Conversion factor, one watt-hour equals 3.412 BTU

HSPF Climate Adjustment Factor (F_{HSPF}) for Conventional ASHP Used as a Baseline

City	HSPF < 8.5	HSPF ≥ 8.5
Albany	0.70	0.67
Binghamton	0.68	0.65
Buffalo	0.73	0.70
Massena	0.59	0.56
NYC	0.80	0.78
Poughkeepsie	0.62	0.59

City	HSPF < 8.5	HSPF ≥ 8.5
Syracuse	0.69	0.66

For scenarios where the baseline cooling system is a conventional ASHP, no additional consideration is given to account for the difference between the rating conditions for SEER and the typical operating conditions in New York State, because the differences between the rating conditions and the typical operating conditions are small.

For scenarios where the baseline heating and cooling system is an existing GSHP, the seasonal heating and cooling efficiencies of the baseline equipment code minimum efficiencies that have been adjusted consistent with the methodology provided for efficient equipment described in the *Compliance Efficiency from Which Incentives are Calculated* section below.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is an ENERGY STAR® certified GSHP system as defined in the Measure Description section above. If the GSHP system is closed loop, use the following formulas with the COP and EER values from the GLHP ratings. If the GSHP system is an open loop system, use the following formulas with the COP and EER values from the GWHP ratings. The formulas adjust performance for closed loop systems to an average entering water temperature of approximately 40°F for heating and 77°F for cooling. The open loop formulas adjust performance to an average entering water temperature of 50°F for both heating and cooling[86].

The formulas determine the average seasonal cooling efficiency ($EER_{season,ee}$) and the average seasonal heating efficiency ($COP_{season,ee}$) for a GSHP system with a two-stage or variable speed compressor.

Closed Loop Systems (using GLHP ratings):

$$EER_{season,ee} = \Big(\big(F_{full} \times EER_{GLHP,full} \times 1.09 \times F_{pump,full}\big) + \big(F_{part} \times EER_{GLHP,part} \times F_{pump,part}\big)\Big) \times F_{dist,c}$$

$$COP_{season,ee} = \Big(\big(F_{full} \times COP_{GLHP,full} \times 1.08 \times F_{pump,full}\big) + \big(F_{part} \times COP_{GLHP,part} \times F_{pump,part}\big)\Big) \times F_{dist,h}$$

Open Loop Systems (using GWHP ratings):

$$EER_{season,ee} = \Big(\big(F_{full} \times EER_{GWHP,full} \times F_{pump,full}\big) + \big(F_{part} \times EER_{GWHP,part} \times F_{pump,part}\big)\Big) \times 1.09 \times F_{dist,c}$$

[86] These entering temperatures were selected based on measured data from GSHP sites presented in NYSERDA Report 18-03.

$$COP_{season,ee} = \left(\left(F_{full} \times COP_{GWHP,full} \times F_{pump,full}\right) + \left(F_{part} \times COP_{GWHP,part} \times F_{pump,part}\right)\right) \times F_{dist,h}$$

where:

$COP_{GLHP,full}$ = Rated COP of the unit at GLHP full load heating conditions
$COP_{GLHP,part}$ = Rated COP of the unit at GLHP part load heating conditions
$EER_{GLHP,full}$ = Rated EER of the unit at GLHP full load cooling conditions
$EER_{GLHP,part}$ = Rated EER of the unit at GLHP part load cooling conditions
$COP_{GWHP,full}$ = Rated COP of the unit at GWHP full load heating conditions
$COP_{GWHP,part}$ = Rated COP of the unit at GWHP part load heating conditions
$EER_{GWHP,full}$ = Rated EER of the unit at GWHP full load cooling conditions
$EER_{GWHP,part}$ = Rated EER of the unit at GWHP part load cooling conditions
$F_{dist,c}$ = Factor to adjust the cooling efficiency to account for additional fan power
$F_{dist,h}$ = Factor to adjust the heating efficiency to account for additional fan power
F_{full} = Seasonal weighting factor for full load efficiency
F_{part} = Seasonal weighting factor for part load efficiency
$F_{pump,part}$ = Factor to adjust part load efficiency to account for additional pumping power
$F_{pump,full}$ = Factor to adjust full load efficiency to account for additional pumping power
1.09 = Correction for change in EER[87]
1.08 = Correction for change in COP[88]

Summary of Variables and Data Sources

Variable	Value	Source
$COP_{GLHP,full}$		The rated COP of the unit at GLHP full load (or standard) heating conditions from ASHRAE/ISO 13256-1. This value is certified by AHRI and is available in the product directory. It corresponds to an entering loop temperature of 32°F.
$COP_{GLHP,part}$		The rated COP of the unit at GLHP part load heating conditions from ASHRAE/ISO 13256-1. This value is certified by AHRI and is available in the product directory. It corresponds to an entering loop temperature of 41°F.
$EER_{GLHP,full}$		The rated EER of the unit at GLHP full load (or standard) cooling conditions from ASHRAE/ISO 13256-1. This value is certified by AHRI and is available in the product directory. It corresponds to an entering loop temperature of 77°F.
$EER_{GLHP,part}$		The rated EER of the unit at GLHP part load cooling conditions from ASHRAE/ISO 13256-1. This value is certified by AHRI and is available in the product directory. It corresponds to an entering loop temperature of 68°F.

87 Correction for 9% change in EER as the entering fluid temperature decreases from 77°F to 68°F. The 1% per °F was observed from published performance data as well as in the IGSHPA Design Manual. This factor also applies to the GWHP adjustment from 50°F to 59°F.
88 Correction for 8% change in COP as the entering fluid temperature increases from 32°F to 40°F. The 1% per °F was observed from published performance data as well as in the IGSHPA Design Manual.

Variable	Value	Source
$COP_{GWHP,full}$		The rated COP of the unit at GWHP full load (or standard) heating conditions from ASHRAE/ISO 13256-1. This value is certified by AHRI and is available in the product directory. It corresponds to an entering water temperature of 50°F.
$COP_{GWHP,part}$		The rated COP of the unit at GWHP part load heating conditions from ASHRAE/ISO 13256-1. This value is certified by AHRI and is available in the product directory. It corresponds to an entering water temperature of 50°F.
$EER_{GWHP,full}$		The rated EER of the unit at GWHP full load (or standard) cooling conditions from ASHRAE/ISO 13256-1. This value is certified by AHRI and is available in the product directory. It corresponds to an entering water temperature of 59°F.
$EER_{GWHP,part}$		The rated EER of the unit at GWHP part load cooling conditions from ASHRAE/ISO 13256-1. This value is certified by AHRI and is available in the product directory. It corresponds to an entering water temperature of 59°F.
$F_{dist,c}$		Factor to adjust the cooling efficiency to account for additional fan power that would be required, beyond the fan power corresponding to zero static in rated COP. Choose the appropriate factor from the Distribution Correction Factors table below.
$F_{dist,h}$		Factor to adjust the heating efficiency to account for additional fan power that would be required, beyond the fan power corresponding to zero static in rated COP. Choose the appropriate factor from the Distribution Correction Factors table below.
F_{full}	0.25	Seasonal weighting factor for full load efficiency = 0.25. Based in part on observed mix of low and high stage operation from field testing.[89]
F_{part}	0.75	Seasonal weighting factor for part load efficiency = 0.75. Based in part on observed mix of low and high stage operation from field testing.[90]
$F_{pump,full}$		Factor to adjust the full load efficiency to account for additional pumping power used by the system. Choose the appropriate factor from Pumping Power Adjustment Factor table below.
$F_{pump,part}$		Factor to adjust the part load efficiency to account for additional pumping power used by the system. Choose the appropriate factor from Pumping Power Adjustment Factor table below.

Loop Pumping Power Correction Factor ($F_{pump,full}$ and $F_{pump,part}$)

A correction factor for pumps ($F_{pump,full}$ and $F_{pump,part}$) is required because the rated efficiency values only include the pumping energy associated with the water-side pressure drop through the heat pump unit (typically about 5-10 Watts per nominal ton). Actual pumping power is much higher.

[89] New York State Energy Research and Development Authority (NYSERDA) 2017. "Analysis of Water Furnace Geothermal Heat Pump Sites in New York State with Symphony Monitoring System," NYSERDA Report Number 18-03. Prepared by CDH Energy Corp., Cazenovia, NY. nyserda.ny.gov/publications.

[90] Ibid.

The ASHRAE GSHP Design Guide (Kavanaugh and Rafferty 2015) developed a grading system that assigns scores based on the amount of pumping power per installed ton. For instance, it gives a grade of "A" to system that uses 45 Watts per nominal ton and a grade of "B" to a system that uses 60 Watts per nominal ton.

Analysis of observed pumping power from 45 to 120 Watts/ton was performed to determine the impact of loop pumping power on efficiency. Results are shown in the Pumping Factors table below.[91]

Pumping Power Adjustment Factors
Different factors are required for different loop pumping power levels and loop pump control strategies. For part load performance there are multiple ways to control the pump at low stage:

- the pump can maintain constant flow regardless of compressor stage.
- the pump stages flow in proportion to the compressor capacity.
- the pump can be variable speed and modulate with the variable speed compressor.

A constant speed loop pump results in poor performance since the pump power becomes a relatively larger portion of total power at low stage. Variable speed pumping with a variable speed compressor results in the best performance. The penalty for constant speed pumping is highest for units with variable speed compressors. The last consideration is the low-to-high capacity ratio (CR), which can be calculated as follows:

$$CR = \frac{QC_{GLHP,part}}{QC_{GLHP,full}}$$

where:
CR = Capacity ratio of part-load cooling capacity to full-load heating capacity.
$QC_{GLHP,part}$ = Part-load cooling capacity rating from AHRI certificate.
$QC_{GLHP,full}$ = Full-load heating capacity rating from AHRI certificate.

The values of QC are the rated full and part load performance values from AHRI. Units with two stage compressors typically have a value of CR of approximately 0.75. Units with variable speed compressors typically have a CR of approximately 0.40.

The table below presents the values of $F_{pump,full}$ and $F_{pump,part}$ that correspond to each loop pump arrangement (e.g. pumping control strategy, CR, and pumping power). The full load pumping factors are typically 0.86 to 0.94. Part load factors can range from 0.62 to 0.95 depending on the pumping control strategy, the capacity ratio of the heat pump, and the pumping power. The factor closest to the actual situation should be used.

[91] Henderson, H.I., 2020. White Paper: Savings Calculations for Residential Ground Source Heat Pumps: The Basis for Equivalent Full Load Hours (EFLH) and Seasonal Efficiency Factors. Prepared for the New York State Energy Research and Development Authority (NYSERDA) and the New York State Department of Public Service. Revised in June.

Pumping Factors ($F_{pump,full}$ and $F_{pump,part}$)

Pumping Control Strategy	Capacity Ratio	Pumping Power 45 Watts/ton Clg	45 Watts/ton Htg	60 Watts/ton Clg	60 Watts/ton Htg	75 Watts/ton Clg	75 Watts/ton Htg	90 Watts/ton Clg	90 Watts/ton Htg	105 Watt/ton Clg	105 Watt/ton Htg	120 Watts/ton Clg	120 Watts/ton Htg
Full load ($F_{pump,full}$)		0.94	0.94	0.93	0.92	0.91	0.90	0.89	0.89	0.88	0.87	0.86	0.86
Part load – constant flow pumping ($F_{pump,part}$)	0.75	0.89	0.91	0.86	0.89	0.83	0.86	0.80	0.84	0.78	0.82	0.75	0.80
Part load – constant flow pumping ($F_{pump,part}$)	0.40	0.81	0.85	0.77	0.81	0.72	0.77	0.69	0.74	0.65	0.71	0.62	0.68
Part load – staged pumping ($F_{pump,part}$)	0.75	0.92	0.94	0.89	0.91	0.87	0.89	0.84	0.87	0.82	0.86	0.80	0.84
Part load – staged pumping ($F_{pump,part}$)	0.40	0.92	0.94	0.89	0.91	0.87	0.89	0.84	0.87	0.82	0.86	0.80	0.84
Part load – variable pumping ($F_{pump,part}$)	0.40	0.94	0.95	0.92	0.93	0.90	0.92	0.88	0.90	0.86	0.89	0.84	0.87

Distribution Power Correction

For GSHP systems with an air-duct distribution system, the fan power included in the rated efficiencies corresponds to zero external static pressure and therefore is smaller than would be expected for an actual application. The indoor fan power included in the ISO 13256-1 test procedure is estimated to be approximately 0.15 Watts/cfm for permanent split-capacitor fan motors and 0.11 Watts/cfm for electrically commutated fan motors.[92]

The purpose of the distribution (i.e., fan or pump) correction factor, $F_{dist,h}$ and $F_{dist,c}$ is to determine the equivalent amount of distribution power for the baseline system, such as a fossil fuel fired furnace or boiler, or a heat pump. The correction factor considers the differential distribution power between the GSHP and the baseline system. The Distribution Correction Factors to correct GSHP Seasonal Efficiency for typical baseline scenarios summarized in the table below:

Distribution Correction Factors ($F_{dist,h}$ and $F_{dist,c}$)

	If baseline system is a Furnace with conventional air conditioning	If baseline system is a Boiler with conventional air conditioning	If baseline system is a Central air source heat pump
Heating ($F_{dist,h}$)	0.96	0.96	0.97
Cooling ($F_{dist,c}$)	0.95	0.95	0.95

Note: Based on furnace and boiler ancillary power of 137 Watts

[92] Ibid.

Operating Hours

The Building Equivalent Full Load Hours for heating ($BEFLH_{heating}$) and for cooling ($BEFLH_{cooling}$) in the tables below represent equivalent full load operating hours for HVAC equipment based on 1% design temperature, TMY3 weather data, and the design heating load. For heating, hours from the summer period (June through September) were excluded. For Cooling, the values of EFLH from Appendix G were multiplied by a factor of 1.25 to convert to BEFLH. All values have been adjusted to reflect 30-year NCEI climate normal from 1991 – 2020.

Single-Family Detached Cooling $BEFLH_{cooling}$ by Vintage and City

City	Old	Average	New
Albany	465	448	403
Binghamton	254	251	202
Buffalo	508	490	419
Massena	353	342	287
NYC	778	752	731
Poughkeepsie	758	718	709
Syracuse	431	411	373

Multi-Family Low-Rise Cooling $BEFLH_{cooling}$ by Vintage and City

City	Prior to 1979	From 1979 Through 2006	From 2007 Through Present
Albany	413	426	403
Binghamton	277	280	269
Buffalo	411	417	389
Massena	314	311	298
NYC	588	638	652
Poughkeepsie	606	646	643
Syracuse	368	395	413

Single-Family Detached Heating $BEFLH_{heating}$ by Vintage and City

City	Old	Average	New
Albany	1,791	1,681	1,567
Binghamton	2,072	1,947	1,815
Buffalo	2,016	1,892	1,763
Massena	1,957	1,852	1,746
NYC	1,595	1,448	1,296
Poughkeepsie	2,047	1,915	1,778
Syracuse	1,938	1,821	1,701

Multi-Family Low-Rise Heating $BEFLH_{heating}$ by Vintage and City

City	Pre-war uninsu-lated brick	Prior to 1979	From 1979 Through 2006	From 2007 Through pre-sent
Albany	1,802	1,670	1,640	1,182
Binghamton	2,389	2,257	2,130	1,537

City	Pre-war uninsulated brick	Prior to 1979	From 1979 Through 2006	From 2007 Through present
Buffalo	2,111	2,008	2,002	1,455
Massena	2,400	2,187	2,221	1,615
NYC	1,656	1,255	1,199	834
Poughkeepsie	1,459	1,522	1,478	1,048
Syracuse	2,345	1,976	2,027	1,421

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

A closed loop water-to-air GSHP is installed in a single - family, detached home located near Albany and constructed in 1995. The heat pump has variable speed pump controls and a rated heating capacity of 60 kBTUh, with a full load EER of 19, part load EER of 25, full load COP of 3.5 and part load COP of 4.1. The GSHP has 60 watts/ton system pumping power. The home has a building cooling load of 36 kBTUh and the building heating load of 58 kBTUh, and existing HVAC equipment are a split system air conditioner and a gas fired furnace. Annual Electric Energy Savings, Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta kWh = \left[\frac{BCL}{1{,}000} \times \left(\frac{1}{EER_{season,baseline}} - \frac{1}{EER_{season,ee}}\right) \times BEFLH_{cooling}\right] + \left[\frac{BHL}{3{,}412} \times \left(\frac{F_{ElecHeat}}{COP_{season,baseline}} - \frac{1}{COP_{season,ee}}\right) \times BEFLH_{heating}\right]$$

$$\Delta kW = \frac{BCL}{1{,}000} \times \left(\frac{1}{EER_{peak,baseline}} - \frac{1}{EER_{GSHP,full,ee}}\right) \times CF$$

$$\Delta MMBtu = \frac{BHL}{1{,}000{,}000} \times \frac{F_{FuelHeat}}{AFUE_{baseline}} \times BEFLH_{heating}$$

BCL = 36,000, from application

$EER_{season,baseline}$ = 13.0, from Baseline Efficiencies section based on equipment type and size from application

$EER_{season,ee} = ((F_{full} \times EER_{GLHP,full} \times 1.09 \times F_{pump,full}) + (F_{part} \times EER_{GLHP,part} \times F_{pump,part})) \times F_{dist,c}$
= ((0.25 x 19 x 1.09 x 0.93) + (0.75 x 25 x 0.92)) x 0.95 = 20.96

$EER_{season,ee}$ equation from Compliance Efficiency section based on GSHP type

F_{full} from Compliance Efficiency section's Summary of Variables and Data Sources table

$EER_{GLHP,full}$ from application

$F_{pump,full}$ from Pumping Power Adjustment Factors table based on application

F_{part} from Compliance Efficiency section's Summary of Variables and Data Sources table

$EER_{GLHP,part}$ from application
$F_{pump,part}$ from Pumping Power Adjustment Factors table based on application
$F_{dist,c}$ from Distribution Correction Factors based on application
$BEFLH_{cooling}$ = 448, from Operating Hours section tables based on housing type, city, and vintage from application
BHL = 58,000, from application
$F_{ElecHeat}$ = 0, from Summary of Variables and Data Sources table based on existing HVAC from application
$COP_{seaseason,baseline}$ = N/A
$COP_{season,ee}$ = ((F_{full} x $COP_{GLHP,full}$ x 1.08 x $F_{pump,full}$) + (F_{part} x $COP_{GLHP,part}$ x $F_{pump,part}$)) x $F_{dist,h}$
= ((0.25 x 3.5 x 1.08 x 0.92) + (0.75 x 4.1 x 0.93)) x 0.96 = 3.58
$COP_{season,ee}$ equation from Compliance Efficiency section based on GSHP type
$COP_{GLHP,full}$ from application
$F_{pump,full}$ from Pumping Power Adjustment Factors table based on application
$COP_{GLHP,part}$ from application
$F_{pump,part}$ from Pumping Power Adjustment Factors table based on application
$F_{dist,h}$ from Distribution Correction Factors based on application
$BEFLH_{heating}$ = 1,681, from Operating Hours section tables based on housing type, city, and vintage from application
$EER_{peak,baseline}$ = 11.2, from Baseline Efficiencies section based on equipment type and size from application
$EER_{GSHP,full,ee}$ = 19, from application
CF = 0.69, from Summary of Variables and Data Sources table
$F_{FuelHeat}$ = 1, from Summary of Variables and Data Sources table based on existing HVAC from application
$AFUE_{baseline}$ = 0.8, from Baseline Efficiencies section based on equipment type and size from application

$$\Delta kWh = \left[\frac{36{,}000}{1{,}000} \times \left(\frac{1}{13} - \frac{1}{20.96}\right) \times 448\right] + \left[\frac{58{,}000}{3{,}412} \times \left(0 - \frac{1}{3.58}\right) \times 1{,}681\right]$$
$$= -7{,}51\ kWh$$

$$\Delta kW = \frac{36{,}000}{1{,}000} \times \left(\frac{1}{11.2} - \frac{1}{19}\right) \times 0.69 = 0.91\ kW$$

$$\Delta MMBtu = \frac{58{,}000}{1{,}000{,}000} \times \frac{1}{0.8} \times 1{,}681 = 121.87\ MMBtu$$

Methods for Calculating Annual Domestic Hot Water Energy Savings from an Integrated Desuperheater or Dedicated Water-to-Water Heat Pump

GSHP systems can reduce DHW energy consumption by two optional methods: 1) using a GSHP unit with an optional desuperheater or 2) installing an additional water-to-water heat pump (WWHP) dedicated to meeting the DHW load.

When a desuperheater is installed with a GSHP system, the energy consumed by a typical DHW appliance can be reduced. The waste heat from the compressor of the GSHP system is transferred through a heat exchanger to heat or preheat water that is delivered to a storage tank-type water heater. The benefit of the desuperheater varies throughout the year and depends on whether the system is operating in heating mode or cooling mode, and the duration of compressor operation. In the cooling mode, waste heat from the compressor is transferred to heat domestic hot water instead of the closed loop heat exchanger field. In the heating mode water heating is supplied at the heating COP of the heat pump. A desuperheater only heats DHW when the GSHP unit runs to meet the space heating or cooling load.

When a WWHP that is dedicated to DHW is added to the ground loop, the dedicated DHW-WWHP operates in response to the DHW loads, independent of GSHP unit operation to meet space loads. Therefore, the energy savings are more consistent across the year.

In this analysis, installation of a desuperheater is assumed to displace a percentage of the total DHW load, depending on the size of the DHW load. The dedicated WWHP more consistently displaces a larger portion of the DHW load. Electric demand impacts are not considered at this time.

$$\Delta MMBtu_{GSHP-DHW} = \frac{Q_{GSHP-DHW}}{1{,}000{,}000} \times \frac{F_{FFDHW}}{UEF_{baseline}}$$

$$\Delta kWh_{GSHP-DHW} = \frac{Q_{GSHP-DHW}}{3{,}412} \times \left(\frac{F_{EDHW}}{UEF_{baseline}} - \frac{1}{COP_{GSHP-DHW}}\right)$$

$$Q_{GSHP-DHW} = F_{GSHP-DHW} \times GPD \times PPH \times 365 \times 8.33 \times \Delta T_{main}$$

For a desuperheater:

$$F_{GSHP-DHW} = F_{desup}$$

$$COP_{GSHP-DHW} = \frac{COP_{desup}}{F_{desup,htg\ mode}}$$

For a dedicated DHW-WWHP:

When DHW tank has resistance elements,

$$F_{GSHP-DHW} = 0.95$$

OR, when DHW tank is over 80 gallons and has no resistance elements[93]

[93] Based on feedback from NY-GEO on current field practices, if a DHW-WWHP is installed with a large pre-heating tank (e.g., over 80 gallons) it does not need an electric resistance element and can therefore meet 100% of the DHW load.

$$F_{GSHP-DHW} = 1.0$$

$$COP_{GSHP-DHW} = COP_{AHRI,GLHP} \times 0.9$$

where:

$\Delta MMBtu_{GSHP-DHW}$	= Fossil fuel energy displaced by a desuperheater or dedicated DHW-WWHP
$\Delta kWh_{GSHP-DHW}$	= Electricity displaced by desuperheater or dedicated DHW-WWHP operation, considering that desuperheater operation in the heating mode increases energy use
$COP_{AHRI,GLHP}$	= Rated COP for a per ISO13256-2 at GLHP conditions (32°F source, 104°F load)
COP_{desup}	= Overall COP of desuperheater (same as space heating efficiency, use $COP_{season,ee}$ as calculated in Compliance Efficiency section above)
$COP_{GSHP-DHW}$	= Overall annual COP of desuperheater or dedicated DHW-WWHP
F_{desup}	= Fraction of annual DHW load served by a desuperheater
$F_{desup,htg\ mode}$	= Fraction of desuperheater operation that occurs in heating mode
F_{EDHW}	= Factor indicating that baseline DHW system is electric
F_{FFDHW}	= Factor indicating that baseline DHW system is fossil fuel fired
$F_{GSHP-DHW}$	= Fraction of annual DHW load served by a desuperheater or dedicated DHW-WWHP
GPD	= Gallons per day of delivered hot water per person
PPH	= Persons per household served by DHW system
$Q_{GSHP-DHW}$	= Annual DHW load served by desuperheater or dedicated DHW-WWHP, BTU
$UEF_{baseline}$	= Uniform energy factor of baseline DHW appliance (fossil fuel or electric)
ΔT_{main}	= Average temperature difference between water heater set point temperature and the supply water temperature in water main (°F)
0.9	= Correction factor from AHRI rated conditions to 40°F source, 115°F load.
0.95	= Fraction of annual DHW load served by dedicated DHW-WWHP
8.33	= Specific heat of water; energy required (BTU), to heat one gallon of water by one degree Fahrenheit [BTU/(gal-F)]
365	= Days in one year
3,412	= Conversion factor, one kWh equals 3,412 BTU
1,000,000	= Conversion factor, one MMBtu equals 1,000,000 BTU

<u>Summary of Variables and Data Sources</u>

Variable	Value	Notes
COP_{desup}		From application.
F_{desup}		Choose annual desuperheater fraction from table as function of water use (GPD). Fraction of total DHW load met by desuperheater. If no desuperheater is present, set equal to 0.
$F_{desup,htg\ mode}$	0.72 for NYC 0.86 for other cities	Fraction of desuperheater operation that occurs in the heating mode.
F_{EDHW}	1 for electric DHW	Factor indicating baseline DHW is electric.

Variable	Value	Notes
F_{FFDHW}	1 for fossil fuel-fired DHW	Factor indicating baseline DHW is fossil fuel-fired.
GPD	17.2	Average daily hot water usage per person.[94]
PPH		From application. If unknown, use a value of 2.8 for single-family homes[95] and 2.0 for multifamily homes.[96]
T_{main}		Supply water temperature in water main (°F). Lookup in Cold Water Inlet Temperature table below based on nearest city.
T_{set}	130	Water heater set point temperature (°F).[97]
$UEF_{baseline}$		Uniform Energy Factor of the baseline condition. See Baseline Efficiencies section for details regarding derivation of this input.
ΔT_{main}	T_{set} - T_{main}	Average temperature difference between water heater set point temperature and the supply water temperature in water main (°F).

Desuperheater Annual Load Fraction

GPD	Fraction of DHW Load met by Desuperheater (F_{desup}, %)[98]
35	36%
45	30%
55	26%
65	22%

Note: Based on DHW set point of 130°F.

Cold Water Inlet Temperature (T_{main})

Supply water main temperatures vary according to climate and are approximately equal to the annual average outdoor temperature plus 6°F.[99] Supply main temperatures based on the annual outdoor temperature are shown below.

City	Annual average outdoor temperature[100] (°F)	T_{main} (°F)
Albany	49.4	55.4
Binghamton	46.8	52.8

94 Water Research Foundation: Residential End Uses of Water, Version 2, April 2016, pg. 5; 17.2 GPD equated from the report findings indicating an average 2.65 people per household and 45.5 GPD per household.

95 Residential Statewide Baseline Study of New York State, July 2015. Volume 1: Single-Family Report, Table 9.

96 Residential Statewide Baseline Study of New York State, July 2015. Volume 2: Multifamily Report, Table 8.

97 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.

98 Based on an analysis using results from Carlson (1997) combined with bin data for NY cities, as shown in Appendix E of the GSHP White Paper (Henderson 2020). These factors consider the net impact on DHW system, after distribution losses from desuperheater piping. A Geolink report for Albany implied a fraction of 50% with usage of 54 gal/day, ignoring distribution losses.

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

100 Average annual outdoor temperatures taken from NCEI 1991-2020 climate normals.

City	Annual average outdoor temperature[100] (°F)	T_{main} (°F)
Buffalo	49.1	55.1
Massena	45.1	51.1
NYC	54.7	60.7
Poughkeepsie	50.9	56.9
Syracuse	49.0	55.0

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a minimally code compliant water heater of type (storage-type or instantaneous) equivalent to the existing water heater and with tank volume (where applicable), input capacity and draw pattern equivalent to the efficient water heater. For new construction, the baseline condition is a minimally code compliant storage-type water heater with tank volume, input capacity and draw pattern equivalent to the efficient water heater. $UEF_{baseline}$ shall be calculated as a function of qualifying equipment tank volume (v_t) for storage type water heaters. A Medium draw pattern should be assumed for storage type water heaters with rated storage capacity ≤ 50 gallons and a High draw pattern should be assumed otherwise.[101]

Residential Water Heaters[102]

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

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

[102] 10 CFR 430.32(d).

Product Class	Rated Storage Volume and Input Rating	Draw Pattern	$UEF_{baseline}$
		High	0.6815 – (0.0014 x v_t)

*v_t = tank volume in gallons

First Hour Rating vs. Draw Pattern (Storage Type Only)[103]

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

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

A desuperheater is installed with a GSHP system with a seasonal COP of 3.58 in a single-family home in Albany serving 4 residents. The existing gas DHW system has a 50-gallon storage capacity and High draw pattern. Annual Fossil Fuel Energy Savings are calculated as below.

$$COP_{GSHP-DHW} = \frac{COP_{desup}}{F_{desup,htg\ mode}}$$

$$F_{GSHP-DHW} = F_{desup}$$

$$Q_{GSHP-DHW} = F_{GSHP-DHW} \times GPD \times PPH \times 365\ \times 8.33 \times \Delta T_{main}$$

$$\Delta MMBtu_{GSHP-DHW} = \frac{Q_{GSHP-DHW}}{1{,}000{,}000} \times \frac{F_{FFDHW}}{UEF_{baseline}}$$

$$\Delta kWh_{GSHP-DHW} = \frac{Q_{GSHP-DHW}}{3{,}412} \times \left(\frac{F_{EDHW}}{UEF_{baseline}} - \frac{1}{COP_{GSHP-DHW}}\right)$$

COP_{desup} = 3.58, from application
$F_{desup,htg\ mode}$ = 0.86, from Summary of Variables and Data Sources table
F_{desup} = 0.22, from Desuperheater Annual Load Fraction table based on GPD (17.2, from Summary of Variables and Data Sources table) x PPH (4, from application) = 68.8
$\Delta T_{main} = T_{set} - T_{main}$ = 130 - 55.4 = 74.6 °F
T_{set} from Summary of Variables and Data Sources table
T_{main} from Cold Water Inlet Temperature lookup table based on location from application
F_{FFDHW} = 1, from Summary of Variables and Data Sources table
$UEF_{baseline}$ = 0.6920 - (0.0013 x V_t) = 0.6920 - (0.0013 x 50) = 0.6270
$UEF_{baseline}$ equation from Residential Water Heaters table based on product class and draw pattern from application

[103] 10 CFR 429.17.

v_t from application
F_{EDHW} = 0, from Summary of Variables and Data Sources table

$$COP_{GSHP-DHW} = \frac{3.58}{0.86} = 4.16$$

$$F_{GSHP-DHW} = 0.22$$

$$Q_{GSHP-DHW} = 0.22 \times 17.2 \times 4 \times 365 \times 8.33 \times 74.6 = 3{,}433{,}111$$

$$\Delta MMBtu_{GSHP-DHW} = \frac{3{,}433{,}111}{1{,}000{,}000} \times \frac{1}{0.6270} = 5.48\ MMBtu$$

$$\Delta kWh_{GSHP-DHW} = \frac{3{,}433{,}111}{3{,}412} \times \left(\frac{0}{0.6270} - \frac{1}{4.16}\right) = -241.87\ kWh$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

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

Ancillary Electric Savings Impacts

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

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Record of Revision

Record of Revision Number	Issue Date
1	10/15/2010
4-16-1	3/31/2016
6-17-6	6/30/2017
3-18-11	3/29/2018
2-20-3	2/28/2020
7-20-22	7/31/2020
12-23-5	1/5/2024

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HEATING, VENTILATION AND AIR CONDITIONING (HVAC) – CONTROL

THERMOSTATIC RADIATOR VALVE (TRV)

Measure Description

This measure covers the installation of thermostatic radiator valves (TRVs) on one and two pipe steam and hydronic system radiators in multifamily tenant units. TRVs are self-contained, self-operated valves that do not require ancillary power. They provide local control of room temperature by controlling the flow of hot water or steam into the radiator. On a one-pipe steam system the TRVs are installed on the air vent and limit the amount of air escaping the radiator, which in turn limits the amount of steam filling the radiator. On hydronic and two-pipe steam systems, as the room temperature rises the valve head expands, blocking the flow of hot water or steam into the radiator. TRVs are available for a variety of installation conditions utilizing either remote-mounted sensors or integral-mounted sensors by means of remote or integral set point adjustment.

TRVs demonstrate the greatest potential for energy savings and financial viability when overheating is exhibited in zones throughout the system and when combined with other hydronic and steam system best practice improvements. Therefore, prioritization of this measure is recommended in zones where significant overheating is observed and when installed as part of system inspection, balancing and commissioning including, but not limited to: burner tuning, boiler cleaning, recalibration of boiler control set points, inspection and repair/replacement of leaking inlets and air vents, installation of properly sized air vents, main line steam trap repair/replacement, recalibration of system operating pressure, insulation of bare steam lines and installation of radiator orifice plates in two-pipe systems.[104] Separate energy savings factors are prescribed for TRV installation with and without hydronic system balancing. Savings shall be calculated per apartment unit using the method prescribed below.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = N/A$$

Summer Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = units \times \frac{HEI \times SF \times HDD \times ESF}{radiators \times 1{,}000{,}000}$$

where:

[104] US DOE, Thermostatic Radiator Valve Evaluation, January 2015, pg. 25-26.

ΔkWh = Annual electric energy savings
ΔkW = Peak coincident demand electric savings
ΔMMBtu = Annual fossil fuel energy savings
units = Number of TRVs installed
HEI = Building Heating Energy Intensity (BTU/SF/HDD)
SF = Square footage of apartment with TRVs installed
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.
ESF = TRV Energy Savings Factor
radiators = Number of radiators in the apartment with TRVs installed
1,000,000 = Conversion factor, one MMBtu equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
HEI	10.0	Building Heating Energy Intensity is the heating energy consumed in one year (in BTU) divided by total conditioned square footage of the building divided by local annual heating degree days. Default HEI was calculated by multiplying a weighted average of New York City residential building fossil fuel EUI values[105] for steam systems by 0.72 to establish space heating HEI[106], and dividing by New York City HDD.
SF		From application. If unknown, assume 922 square feet based on EIA Residential Energy Consumption Survey (RECS) 2020 for Middle Atlantic States.[107]
HDD		Look up in Heating Degree Days section below based on location.
ESF	TRVs w/o hydronic balancing: 0.095 TRVs w/ hydronic balancing: 0.191	Values based on results of field study of TRV impact in residential buildings implemented with and without hydronic balancing.[108,109]
radiators		From application.

<u>Heating Degree Days</u>

[105] Local Law 84 data via Urban Green Council, Demystifying Steam, February 2019, Table 2: Total Building Floor Area by Heating System Type and Building Size, and Table 3: Baseline Fuel Use and Estimated Savings from Boiler and Distribution Improvements.
[106] Local Law 84 and Local Law 87 as cited in Urban Green Council, Demystifying Steam, February 2019, page 22.
[107] EIA Residential Energy Consumption Survey (RECS) 2020 for Middle Atlantic States, Table HC10.15
[108] ESF for TRVs w/o hydronic balancing taken from lowest % savings from Group A in T. Cholewa, A. Siuta-Olcha, C.A. Balaras
[109] ESF for TRVs w/ hydronic balancing taken from lowest % savings from Group C in T. Cholewa, A. Siuta-Olcha, C.A. Balaras

For the purposes of this measure, Heating Degree Days are defined as the number of degrees that a day's average temperature is below some baseline temperature, which represents the temperature below which buildings need to be heated. The HDD values listed in the table below are based on 30-year averages of U.S annual climate normals for the period of 1991 to 2020 using base 65° F.[110]

City	HDD
Albany	6,391
Binghamton	7,200
Buffalo	6,502
Massena	8,030
NYC	4,900
Poughkeepsie	6,026
Syracuse	6,625

Coincidence Factor (CF)

The prescribed value for the coincidence factor is N/A. This measure is not anticipated to have electric impacts.

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is an existing space heating system with manual control valves at freestanding radiators, convectors, or baseboard heating units.

Compliance Efficiency from which Incentives are Calculated

The measure is defined as the existing radiator, convector, or baseboard heater unit controlled by the thermostatic radiator valve.

Operating Hours

Evaluation of savings associated with installation of TRVs is dependent upon typical heating degree days as specified in the Summary of Variables and Data Sources above.

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

Thermostatic radiator valves are installed on all 4 radiators in a 900 square foot apartment served by a one-pipe steam system in a multifamily building located near Albany. As part of this upgrade, the system undergoes hydronic balancing to improve performance and occupant comfort. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are not applicable. Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta MMBtu = units \times \frac{HEI \times SF \times HDD \times ESF}{radiators \times 1{,}000{,}000}$$

[110] HDD taken from NCEI 1991-2020 climate normals.

units = 4, from application
HEI = 10.0, from Summary of Variables and Data Sources table
SF = 900, from application
HDD = 6,391, from Heating Degree Days table based on location from application
ESF = 0.191, from Summary of Variables and Data Sources table
radiators = 4, from application

$$\Delta MMBtu = 4 \times \frac{10.0 \times 900 \times 6{,}391 \times 0.191}{4 \times 1{,}000{,}000} = 10.99\ MMBtu$$

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

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Record of Revision

Record of Revision Number	Issue Date
1-16-12	12/31/2015
6-17-7	6/30/2017
6-19-8	6/28/2019
7-21-23	8/30/2021
12-23-6	1/5/2024

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Motors and Drives

Pool Circulator Timer

Measure Description

This measure covers the installation of multi-speed timer control on pool water circulation pumps in residential inground and aboveground swimming pools. Pool circulator timers, also known as pool pump controls, adjust the operating speed of pool pumps automatically based on a set operating schedule. This measure is only applicable to pool pump control systems that have the ability to operate a pool pump at two or more speeds based on user presets, a default filtration speed that (when no auxiliary pool loads are operating) is no more than one-half of the motor's maximum rotation speed, and a default setting that returns the pool pump to the lowest user preset speed within one cycle or 24 hours.[111]

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times \frac{60 \times days}{1{,}000} \times \left\{ \left[\frac{GPM_{HS} \times \left(hrs_{baseline,HS} - hrs_{ee,HS} \right)}{EF_{HS}} \right] + \left[\frac{GPM_{LS} \times \left(hrs_{baseline,LS} - hrs_{ee,LS} \right)}{EF_{\mathrm{LS}}} \right] \right\}$$

Summer Peak Coincident Demand Savings

$$\Delta kW = units \times \frac{1}{1{,}000} \times \left(\frac{GPM_{HS}}{EF_{HS}} - \frac{GPM_{LS}}{EF_{\mathrm{LS}}} \right) \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

where:

ΔkWh	= Annual electricity energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
days	= Number of operating days per year
HS	= High speed operation
LS	= Low speed operation
GPM	= Pump flow rate in gallons per minute

[111] Consortium for Energy Efficiency, High Efficiency Residential Swimming Pool Initiative; Pool Pump Control Specification via 81 FR 64580.

baseline	= Characteristic of baseline condition
ee	= Characteristic of energy efficient condition
hrs	= Hours of operation per day
EF	= Pool Pump Energy Factor (Gal/Wh)
CF	= Coincidence factor
60	= Minutes in one hour
1,000	= Conversion factor, one kW equals 1,000 watts

Summary of Variables and Data Sources

Variable	Value	Notes
GPM_{HS}		From application or look up in Gallons per Minute and Energy Factor table below.
GPM_{LS}		From application or look up in Gallons per Minute and Energy Factor table below.
$hrs_{baseline,HS}$		From application. If unknown, calculate as: $$hrs_{baseline,HS} = \frac{V_{pool} \times N_{turnover}}{GPM_{HS} \times 60}$$ where: V_{pool} = Volume of pool, in gallons. From application. If unknown, assume 22,000 for inground pools[112] and 10,364 for aboveground pools.[113] $N_{turnover}$ = Number of turnovers per day, where a turnover is a full cycling of pool water through the pool filter. From application. If unknown, use 2 per day.[114]
$hrs_{baseline,LS}$		From application. If unknown, use 0 as default.[115]
$hrs_{ee,HS}$		From application. If unknown, use 2 as default.[116]

[112] Savings Calculator for ENERGY STAR® Certified Inground Pool Pumps (accessed 11/01/2023)
[113] Based on a circular 21' diameter pool with 4' water depth, based on market research.
[114] Savings Calculator for ENERGY STAR® Certified Inground Pool Pumps (accessed 11/01/2023). Assumed number of turnovers per day in cool climates.
[115] California Energy Commission, Technical Support Document - Energy Efficiency Program for Dedicated-Purpose Pool Pumps, February 20, 2020: Table 7.3.8 Daily Operating Hour Calculation for Self-Priming and Non-Self-Priming Pool Filter Pumps
[116] Ibid

Variable	Value	Notes
$hrs_{ee,LS}$		From application. If unknown, calculate as: $$hrs_{ee,LS} = \frac{V_{pool} \times N_{turnover} - (2 \times GPM_{HS} \times 60)}{GPM_{LS} \times 60}$$ where: V_{pool} = Volume of pool, in gallons. From application. If unknown, assume 22,000 for inground pools[117] and 10,364 for aboveground pools.[118] $N_{turnover}$ = Number of turnovers per day, where a turnover is a full cycling of pool water through the pool filter. From application. If unknown, use 2 per day.[119]
EF_{HS}		From application or look up in Gallons per Minute and Energy Factor Table below based on nameplate pump horsepower.
EF_{LS}		From application or look up in Gallons per Minute and Energy Factor Table below based on nameplate pump horsepower.
days		From application. If unknown, use 122 as default, based on 4 months of operation per year.[120]
CF	0.362	

Gallons per Minute and Energy Factor

Default values for EF and GPM are found in the table below, based on nameplate horsepower.[121] Pump Performance Curve C is assumed for ENERGY STAR pumps. The pump curve compares the total head in feet of water to the flow rate of the water for a given pump at a given motor speed.

Pump Type and Variable	**Nameplate Horsepower at High Speed**				
	1.65 hhp (3 HP)	**1.25 hhp (2.5 HP)**	**1.18 hhp (2 HP)**	**0.95 hhp (1.65 HP)**	**0.72 hhp (1-1.4 HP)**
EF_{HS}	2.0	2.2	2.3	2.3	2.5
GPM_{HS}	102	93	89	78	76
EF_{LS}	6.1	6.0	6.5	6.7	6.8
GPM_{LS}	51.0	45.7	44.8	41.8	40.3

[117] Savings Calculator for ENERGY STAR® Certified Inground Pool Pumps (accessed 11/01/2023)
[118] Based on a circular 21' diameter pool with 4' water depth, based on market research.
[119] Savings Calculator for ENERGY STAR® Certified Inground Pool Pumps (accessed 11/01/2023). Assumed number of turnovers in cool climates.
[120] Savings Calculator for ENERGY STAR® Certified Inground Pool Pumps (accessed 11/01/2023). Assumed pool operation in cool climates.
[121] Savings Calculator for ENERGY STAR® Certified Inground Pool Pumps (accessed 11/01/2023). Single speed conventional pump Energy Factor and Flow rate used as a proxy for high speed. Variable-speed pump Low Energy Factor and Low Flow used as a proxy for low speed.

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.362.[122]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition for this measure is a multi or variable speed pool pump without a pool circulator timer as defined in the Measure Description.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a multi or variable speed pool pump equipped with a pool circulator timer as defined in the Measure Description.

Operating Hours

Daily hours of operation shall be taken from application or use defaults recommended in the Summary of Variables and Data Sources above. Annual operating days shall be taken from application or use 122 days per year. It is assumed that a pool is in use for 4 months per year given New York's average climate.[123]

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

An existing residential customer installs a pool circulator timer on a 2 hp inground pool pump at their home near NYC. Prior to installation, the pump operated at high speed for 8 hours per day to achieve 2 turnovers. Following installation, the pump operates on high speed for 2 hours per day and low speed for 10 hours per day to achieve the desired number of turnovers. The pool is in use 124 days per year. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

$$\Delta kWh = units \times \frac{60 \times days}{1{,}000} \times \left\{\left[\frac{GPM_{HS} \times \left(hrs_{baseline,HS} - hrs_{ee,HS}\right)}{EF_{HS}}\right] + \left[\frac{GPM_{LS} \times \left(hrs_{baseline,LS} - hrs_{ee,LS}\right)}{EF_{\mathrm{LS}}}\right]\right\}$$

$$\Delta kW = units \times \frac{1}{1{,}000} \times \left(\frac{GPM_{HS}}{EF_{HS}} - \frac{GPM_{LS}}{EF_{\mathrm{LS}}}\right) \times CF$$

units = 1, from application
GPM_{HS} = 89, from Gallons per minute and Energy Factor table

[122] Standards Driven Market Transformation; 20 Year Multifaceted Intervention Leads to DOE Pool Pump Standard, ACEEE, pg. 5-6.
[123] Savings Calculator for ENERGY STAR® Certified Inground Pool Pumps (accessed 11/01/2023). Assumed pool operation in cool climates.

GPM_{LS} = 44.8, from Gallons per minute and Energy Factor table
$hrs_{baseline,HS}$ = 8, from application
$hrs_{baseline,LS}$ = 0, from application
$hrs_{ee,HS}$ = 2, from application
$hrs_{ee,LS}$ = 10, from application
EF_{HS} = 2.3, from Gallons per minute and Energy Factor table
EF_{LS} = 6.5, from Gallons per minute and Energy Factor table
days = 124, from application
CF = 0.362, from Summary of Variables and Data sources table

$$\Delta kWh = 1 \times \frac{60 \times 124}{1{,}000} \times \left\{ \left[\frac{89 \times (8-2)}{2.3} \right] + \left[\frac{44.8 \times (0-10)}{6.5} \right] \right\} = 1{,}214.59\ kWh$$

$$\Delta kW = 1 \times \frac{1}{1{,}000} \times \left(\frac{89}{2.3} - \frac{44.8}{6.5} \right) \times 0.362 = 0.012\ kW$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

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

Ancillary Electric Savings Impacts

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

References

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2. Savings Calculator for ENERGY STAR® Certified Inground Pool Pumps, April 2020.
   Available from: https://www.energystar.gov/productfinder/product/certified-pool-pumps/results#
3. California Energy Commission, Technical Support Document - Energy Efficiency Program for Dedicated-Purpose Pool Pumps, February 20, 2020
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4. Standards Driven Market Transformation; 20 Year Multifaceted Intervention Leads to DOE Pool Pump Standard, ACEEE, pg. 5-6.
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Record of Revision

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7-20-4	7/31/2020
12-23-7	1/5/2024

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POOL PUMP

Measure Description

This measure covers the installation of ENERGY STAR® qualified residential inground and aboveground pool pumps and dedicated-purpose pool pump motor replacements. Pool pump speeds vary based on the pump's operation. Filtration, for example, only requires half the flow rate of running a pool cleaner. Conventional pool pumps, with only one speed, are set to run at the higher speeds required of the pool cleaner and waste energy during filtration operation by running faster than necessary. An ENERGY STAR® certified pool pump can run at different speeds and be programmed to match the pool operation with its appropriate pool pump speed. The energy saved is considerable; reducing pump speed by one-half allows the pump to use just one-eighth as much energy.[124] After January 1, 2019, all pool pumps must be rated according to Weighted Energy Factor (WEF).

This measure is applicable to single-phase self-priming (inground) and non-self-priming (aboveground) pool pumps with a Rated Hydraulic Horsepower (hhp) rating of >0 and <2.5 hhp. While pressure cleanser booster pumps are eligible under ENERGY STAR® qualified product criteria, there was a critical lack of information regarding ENERGY STAR® calculations and assumptions pertaining to this equipment available at the time of publication of this measure. The measure scope will be expanded as more information becomes available. This measure is not applicable to community pools in multifamily housing complexes.

This measure is also applicable to Dedicated Purpose Pool Pump motor replacement for motors with rated horsepower up to 5 hp.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings for Pool Pump Installation

$$\Delta kWh = units \times days \times \frac{V_{pool}}{1{,}000} \times N_{turnover} \times \left[\frac{1}{WEF_{baseline}} - \frac{1}{WEF_{ee}}\right]$$

Annual Electric Energy Savings for Dedicated-Purpose Pool Pump Motor Replacement

$$\Delta kWh = units \times days \times \frac{V_{pool}}{1{,}000} \times N_{turnover} \times \frac{1}{WEF_{baseline}} \times \left[\frac{1}{Eff_{baseline,DPPP}} - \frac{1}{Eff_{ee,DPPP}}\right]$$

Summer Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fuel Energy Savings

[124] ENERGY STAR® Pool Pumps Product Page

$$\Delta MMBtu = N/A$$

Note: Although pump hp is not applied directly within algorithms, it must be known to establish baseline and compliance efficiency values.

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fuel energy savings
units	= Number of measures installed under the program
days	= Number of operating days per year
$_{baseline}$	= Baseline condition or measure
$_{ee}$	= Energy efficient condition or measure
WEF	= Pool Pump Weighted Energy Factor (kgal/kWh)
V_{pool}	= Volume of pool, in gallons
$N_{turnover}$	= Number of turnovers per day, where a turnover is a full cycling of pool water through the pool filter
$_{DPPP}$	= Specification of the Dedicated-Purpose Pool Pump motor
Eff	= Motor efficiency
hhp	= Rated Hydraulic Horsepower (hhp) of qualifying pump motor
1,000	= Conversion factor, one kgal equals 1,000 gallons

Summary of Variables and Data Sources

Variable	Value	Notes
V_{pool}		From application. If unknown, assume 22,000 for inground pools[125] and 10,364 for aboveground pools.[126]
$N_{turnover}$		From application. If unknown, use 2 per day.[127]
WEF_{ee}		From application, or look up and/or calculate based on Compliance Efficiency section below, based on Rated Hydraulic Horsepower (hhp).
hhp		From application.
$WEF_{baseline}$		Look up and/or calculate based on Baseline Efficiencies section below, based on Rated Hydraulic Horsepower (hhp)
$Eff_{baseline,DPPP}$		Look up in Baseline Efficiencies section below based on hp of replacement motor.
$Eff_{ee,DPPP}$		From application.
days		From application. If unknown, use 122.[128]

[125] Savings Calculator for ENERGY STAR® Certified Inground Pool Pumps (accessed 11/01/2023).
[126] Based on a circular 21' diameter pool with 4' water depth, based on market research.
[127] Savings Calculator for ENERGY STAR® Certified Inground Pool Pumps (accessed 11/01/2023). Assumed number of turnovers per day in cool climates.
[128] Savings Calculator for ENERGY STAR® Certified Inground Pool Pumps (accessed 11/01/2023). Assumed pool operation in cool climates.

Weighted Energy Factor (WEF) (kgal/kWh) is a measurement of pump efficiency based on performance at one or two operating points, which are uniquely defined for each Dedicated Purpose Pool Pump (DPPP) variety and speed configuration. The performance measurements at different operating points are weighted to represent real world use. WEF is measured in thousand gallons per kilowatt hour (kgal/kWh). See the DOE Test Procedure for Dedicated Purpose Pool Pumps for additional calculation details.[129]

Coincidence Factor (CF)

The prescribed value for the coincidence factor is N/A. This measure is not anticipated to have peak kW impacts.

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition for pool pump installations is a non-ENERGY STAR® qualified pool pump. The values for baseline WEF shall be calculated per the table below, based on pump type and Rated Hydraulic Horsepower (hhp).[130] Pump Performance Curve C is assumed for pool pumps. The pump curve compares the total head in feet of water to the flow rate of the water for a given pump at a given motor speed.

Pump Type	Size	Baseline WEF
Self-Priming (Inground)	hhp ≤ 0.13	5.55
Self-Priming (Inground)	0.13 < hhp < 0.711	-1.30 x ln (hhp) + 2.90
Self-Priming (Inground)	0.711 ≤ hhp < 2.5	-2.30 x ln (hhp) + 6.59
Non-Self-Priming (Aboveground)	hhp ≤ 0.13	4.60
Non-Self-Priming (Aboveground)	0.13 < hhp < 2.5	-0.85 x ln (hhp) + 2.87

The baseline efficiency for Dedicated Purpose Pool Pump motor replacements is established based on the rated horsepower of the replacement motor per the table below.[131]

DPPP Motor HP	Baseline Efficiency
< 0.5	0.66
≥ 0.5 and < 1.0	0.72
≥ 1.0 and ≤ 5.0	0.80

Compliance Efficiency from which Incentives are Calculated

The compliance condition for pool pump installations is an ENERGY STAR® qualified single-phase, self-priming (inground) or non-self-priming (aboveground) pool pump with a Rated Hydraulic Horsepower (hhp) rating of >0 and <2.5 hhp. Pumps must have a WEF (in kgal/kWh) equal

[129] 10 CFR 431.464(b)
[130] Table G-3: Standards for Dedicated-Purpose Pool Pumps, Replacement Pool Pump Motors, California Title 20 via NYS Appliance Standards.
[131] Table G-4: Standards for Replacement Dedicated-Purpose Pool Pump Motors Manufactured on or After July 19, 2021, California Title 20 via NYS Appliance Standards.

to or greater than the WEF equations in the table below based on pump type and Rated Hydraulic Horsepower (hhp).[132] Pump Performance Curve C is assumed for ENERGY STAR® pumps. The pump curve compares the total head in feet of water to the flow rate of the water for a given pump at a given motor speed.

Pump Type	Size	Compliance WEF
Self-Priming (Inground)	hhp ≤ 0.13	13.40
Self-Priming (Inground)	0.13 < hhp < 0.711	-2.45 x ln (hhp) + 8.40
Self-Priming (Inground)	0.711 ≤ hhp < 2.5	-2.45 x ln (hhp) + 8.40
Non-Self-Priming (Aboveground)	hhp ≤ 0.13	4.92
Non-Self-Priming (Aboveground)	0.13 < hhp < 2.5	-1.00 x ln (hhp) + 3.85

The compliance condition for Dedicated Purpose Pool Pump motor replacements is a motor with rated horsepower less than or equal to 5 hp with rated efficiency exceeding the baseline efficiency prescribed in the Baseline Efficiencies section above.

Operating Hours

Annual operating days shall be taken from application or use 122 days per year. It is assumed that a pool is in use for 4 months per year given New York's average climate.[133]

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

An ENERGY STAR® qualified self-priming variable frequency drive (VFD) inground pool pump with a Rated Hydraulic Horsepower of 2 hhp is installed at a single-family home near Albany. The pump has a WEF of 9.3 and conducts two turnovers per day. The pool is 21,000 gallons and operational for 122 days per year. Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings are calculated as below.

$$\Delta kWh = units \times days \times \frac{V_{pool}}{1{,}000} \times N_{turnover} \times \left[\frac{1}{WEF_{baseline}} - \frac{1}{WEF_{ee}}\right]$$

units = 1, from application
days = 122, from application
V_{pool} = 21,000, from application
WEF_{ee} = 9.3, from application
$N_{turnover}$ = 2, from application
$WEF_{baseline}$ = 5.0, from Baseline Efficiency from which Incentives are Calculated

$$\Delta kWh = 1 \times 122 \times \frac{21{,}000}{1{,}000} \times 2 \times \left[\frac{1}{5.0} - \frac{1}{9.3}\right] = 473.83\ kWh$$

[132] ENERGY STAR® Program Requirements Product Specification for Pool Pumps, Eligibility Criteria Version 3.1, July 2021.
[133] Savings Calculator for ENERGY STAR® Certified Inground Pool Pumps (accessed 11/01/2023). Assumed pool operation in cool climates.

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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6-18-20	6/30/2018
9-18-6	9/28/2018
12-20-4	12/31/2020
12-21-8	1/28/2022
12-23-8	1/5/2024

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DOMESTIC HOT WATER

INDIRECT WATER HEATER

Measure Description

This measure covers the installation of a fossil fuel fired indirect water heater in which the stored water is heated via hot water or steam produced by a fossil fuel boiler rather than direct input from electric elements or fossil fuel burners. In such a system, a heat exchanger separates the potable water in the water heater from the boiler water. This measure applies to small commercial indirect systems comprising a boiler with input heating capacity less than 300,000 BTU/h and greater than or equal to 4,000 BTU/h per gallon of stored water.[134]

This measure estimates savings associated with the delivery of potable hot water only and assumes the installation of zone priority controls to interrupt demand for space heating until domestic hot water demand is met. Larger equipment as well as equipment where zone priority control is not feasible shall be treated under a custom application.

The baseline assumption for indirect water heaters is a minimally code compliant tank type water heater or an indirect system with a minimally code compliant boiler, based on actual existing conditions. For new construction, a tank type baseline shall be assumed.

Method for Calculating Annual Energy and Peak Coincidence Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = N/A$$

Summer Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings

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

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

[134] 10 CFR 431.102.

GPD/unit	= Gallons per day of delivered hot water per water heater
DT_{main}	= Average temperature difference between delivered hot water temperature and the supply water temperature in water main (°F)
DT_{amb}	= Average temperature difference between water heater set point temperature and the surrounding ambient air temperature (°F)
$_{baseline}$	= Characteristic of baseline condition
$_{ee}$	= Characteristic of energy efficient condition
Eff	= Efficiency
UA	= Overall heat loss coefficient (BTU/h-°F)
F_{HS}	= Factor to adjust savings for equipment providing domestic hot water during the heating season only
365	= Days in one year
8.33	= Specific heat of water; energy required (BTU), to heat one gallon of water by one degree Fahrenheit [BTU/(gal-F)]
1,000,000	= Conversion factor, one MMBtu equals 1,000,000 BTU
8,760	= Hours in one year

Summary of Variables and Data Sources

Variable	Value	Notes
GPD/unit		From application, or lookup/calculate based on building type, square footage, and occupancy from GPD table below. If based on values per the table below, divide result by number of units installed.
DT_{main}	$T_{del} – T_{main}$	Average temperature difference between delivered hot water temperature and the supply water temperature in water main (°F).
DT_{amb}	$T_{set} – T_{amb}$	Average temperature difference between water heater set point temperature and the surrounding ambient air temperature (°F).
T_{del}	125	Delivered hot water temperature (°F).[135]
T_{set}		Water heater set point temperature (°F), per application or use 140°F as a default.[136]
T_{main}		Supply water temperature in water main (°F). Lookup in Cold Water Inlet Temperature table below based on nearest city. (°F).
T_{amb}	70	Surrounding ambient air temperature (°F).[137]
$Eff_{baseline}$		Efficiency of baseline condition. Lookup in Baseline Efficiencies section below.

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[135] Aligned with residential measure set point temperature to normalize default GPD across sectors.
[136] Per OSHA recommendations for prevention of Legionella bacterial growth. (https://www.osha.gov/SLTC/legionnairesdisease/control_prevention.html)
[137] Water heaters are generally located in conditioned or partially conditioned spaces with a typical average temperature of 65°F to 70°F to avoid freezing. A value of 70°F is used for the purposes of estimating tank/ambient air temperature differential, which aligns with standby loss specification testing standards.

Variable	Value	Notes
Eff_{ee}		Efficiency of energy efficient indirect-system boiler (AFUE) from application.
$UA_{baseline}$		Overall heat loss coefficient of the baseline condition (BTU/h-°F). Calculate based on baseline standby loss per the Baseline Heat Loss Coefficient section below.
UA_{ee}		Overall heat loss coefficient of the energy efficient measure (BTU/h-°F). Calculate based on energy efficient standby loss per the Qualifying Heat Loss Coefficient section below.
F_{HS}		Use a value of 0.67 for systems that provide DHW during the heating season only and a value of 1.0 for systems providing DHW year round.[138]

Gallons per Day (GPD)

The average daily hot water usage, expressed in gallons per day, for several commercial facility types is tabulated below. Daily hot water usage can be calculated based on the GPD and site-specific metric in the Rate column, or default values can be referenced directly from the GPD column.

Building Type	GPD	Rate	Notes/Assumptions	Source
Assembly	239	7.02 GPD per 1,000 SF	Assumes 10% hot water, 34,000 SF	EIA[139]: Public Assembly
Auto Repair	25	4.89 GPD per 1,000 SF	Assumes 10% hot water, 5,150 SF	EIA: Other
Big Box Retail	448	3.43 GPD per 1,000 SF	Assumes 10% hot water, 130,500 SF	EIA: Mercantile
Community College	1,520	1.9 GPD per person	Assumes 800 students	NREL[140]: School with Showers
Dormitory	8,600	17.2 GPD per resident	Assumes 500 residents	Water Research Foundation[141]
Elementary School	250	0.5 GPD per student	Assumes 500 students	NREL: School
Fast Food Restaurant	500	500 GPD per restaurant		FSTC[142]: Quick Service
Full-Service Restaurant	2,500	2,500 GPD per restaurant		FSTC: Full Service
Grocery	172	3.43 GPD per 1,000 SF	Assumes 10% hot water, 50,000 SF	EIA: Mercantile
High School	1,520	1.9 GPD per person	Assumes 800 students	NREL: School with Showers

[138] 0.67 value based on duration of heating season (8 months: October – May) relative to one year (12 months)
[139] U.S. Energy Information Administration, 2012 Commercial Buildings Energy Consumption Survey: Water Consumption in Large Buildings, Table WD1. Daily water consumption in large commercial buildings, 2012.
[140] National Renewable Energy Laboratory, Saving Energy in Commercial Buildings: Domestic Hot Water Assessment Guidelines, Table 1. Hot Water Use By Building Type, June 2011.
[141] Water Research Foundation: Residential End Uses of Water, Version 2, April 2016.
[142] Improving Commercial Kitchen Hot Water System Performance, Design Guide – Energy Efficient Heating, Delivery and Use, Table 1. Typical hot water system cost for restaurants, March 2010.

Building Type	GPD	Rate	Notes/Assumptions	Source
Hospital	16,938	54.42 GPD per 1,000 SF	Assumes 40% hot water, 250,000 SF	EIA: Health Care, Inpatient
Hotel	9,104	45.52 GPD per 1,000 SF	Assumes 40% hot water, 200,000 SF	EIA: Lodging
Large Office	550	1.1 GPD per person	Assumes 500 people	NREL: Office
Large Retail	446	3.43 GPD per 1,000 SF	Assumes 10% hot water, 130,000 SF	EIA: Mercantile
Light Industrial	489	4.89 GPD per 1,000 SF	Assumes 10% hot water, 100,000 SF	EIA: Other
Motel	1,366	45.52 GPD per 1,000 SF	Assumes 40% hot water, 30,000 SF	EIA: Lodging
Multifamily High-Rise	3,440	34.4 GPD per unit	Assumes 100 units, 2 people per unit	Multifamily Baseline Study[143]
Multifamily Low-Rise	413	34.4 GPD per unit	Assumes 12 units, 2 people per unit	Multifamily Baseline Study
Refrigerated Warehouse	86	0.93 GPD per 1,000 SF	Assumes 10% hot water, 92,000 SF	EIA: Warehouse and Storage
Religious	77	7.02 GPD per 1,000 SF	Assumes 10% hot water, 11,000 SF	EIA: Public Assembly
Small Office	110	1.1 GPD per person	Assumes 100 people	NREL: Office
Small Retail	27	3.43 GPD per 1,000 SF	Assumes 10% hot water, 8,000 SF	EIA: Mercantile
University	1,000	0.5 GPD per student	Assumes 2,000 students	NREL: School
Warehouse	465	0.93 GPD per 1,000 SF	Assumes 10% hot water, 500,000 SF	EIA: Warehouse and Storage
Other	Calculate	4.89 GPD per 1,000 SF	Assumes 10% hot water	EIA: Other

Cold Water Inlet Temperature (T_{main})

Supply water main temperatures vary according to climate and are approximately equal to the annual average outdoor temperature plus 6°F.[144] Supply main temperatures based on the annual outdoor temperature are shown below.

City	Annual average outdoor temperature[145] (°F)	T_{main} (°F)
Albany	49.4	55.4
Binghamton	46.8	52.8
Buffalo	49.1	55.1
Massena	45.1	51.1
NYC	54.7	60.7
Poughkeepsie	50.9	56.9
Syracuse	49.0	55.0

Baseline Heat Loss Coefficient ($UA_{baseline}$)

143 Residential Statewide Baseline Study of New York State, July 2015. Volume 2: Multifamily Report, Table 8.

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

145 Average annual outdoor temperatures taken from NCEI 1991-2020 climate normals.

$UA_{baseline}$ is calculated from the assumed equipment standby loss specification ($SL_{baseline}$), which is determined per minimum effective federal standards for commercial gas storage type water heaters (see Baseline Standby Losses section below).[146]

$$UA_{baseline} = \frac{SL_{baseline}}{70}$$

where:

$SL_{baseline}$ = Standby heat loss (BTU/h) specification. For the baseline condition ($SL_{baseline}$), use the intermediate standby loss equation from the Baseline Standby Losses section below.

70 = Temperature difference associated with standby loss specification (°F)[147]

<u>Baseline Standby Losses ($SL_{baseline}$)</u>

Standby losses ($SL_{baseline}$) for commercial gas storage type water heaters:[148]

$$SL_{baseline} = \frac{Q_{baseline}}{800} + 110\sqrt{v_{baseline}}$$

where:

$v_{baseline}$ = Baseline tank volume (gal), equal to the storage capacity of the efficient equipment

$Q_{baseline}$ = Baseline input capacity (BTU/h), equal to the input capacity of the efficient equipment

<u>Qualifying Heat Loss Coefficient (UA_{ee})</u>

Indirect water heater storage tanks are tested and rated for standby losses (in °F/hr or BTU/h) at standard testing conditions in accordance with testing standards.[149]

For equipment with standby losses rated in °F/hr, the qualifying equipment standby loss specification (SL_{ee}) shall be used in the formula below, along with tank volume (v_{ee}) to establish the qualifying equipment heat loss coefficient (UA_{ee}).

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

where:

UA_{ee} = Overall heat loss coefficient (BTU/h-°F) of the energy efficient condition

SL_{ee} = Standby loss specification (°F/hr) of the energy efficient condition

v_{ee} = Rated storage capacity (gallons) of the energy efficient condition

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[146] 10 CFR 429, 430, and 431 Docket No. EERE-2015-BT-TP-0007, Energy Conservation Program for Consumer Products and Certain Commercial and Industrial Equipment: Test Procedures for Consumer and Commercial Water Heaters.

[147] Ibid.

[148] Ibid.

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

70 = Temperature difference associated with standby loss specification (°F)[150]
8.33 = Specific heat of water; energy required (BTU), to heat one gallon of water by one degree Fahrenheit [BTU/(gal-F)]

For equipment with standby losses rated in BTU/h, the qualifying equipment standby loss specification (SL_{ee}) shall be used in the formula below to establish the qualifying equipment heat loss coefficient (UA_{ee})

$$UA_{ee} = \frac{SL_{ee}}{70}$$

where:
UA_{ee} = Overall heat loss coefficient (BTU/h-°F) of the energy efficient condition
SL_{ee} = Standby loss specification (BTU/h) of the energy efficient condition
70 = Temperature difference associated with standby loss specification (°F)[151]

Coincidence Factor (CF)

The prescribed value for the coincidence factor is N/A. This measure is not anticipated to have electric impacts.

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a minimally code compliant fossil fuel storage type or indirect water heater (based on actual existing conditions) with efficiency per the Energy Conservation Construction Code of New York State[152] as shown in the table below. Heat loss coefficient of the baseline condition shall be established as indicated in the Baseline Heat Loss Coefficient section above. Measure is only applicable to small commercial (<300,000 BTU/h) equipment in applications with zone priority control. Baseline tank volume and input capacity shall be set equal to the energy efficient condition. For new construction, a tank type baseline shall be assumed.

Equipment Type/Size	Efficiency
Tank Type: All Sizes	0.80 E_t
Gas-Fired Hot Water Boiler: < 300,000 BTU/h	0.82 AFUE
Oil-Fired Hot Water Boiler: < 300,000 BTU/h	0.84 AFUE
Gas-Fired Steam Boiler, All Except Natural Draft: < 300,000 BTU/h	0.80 AFUE
Gas-Fired Steam Boiler, Natural Draft: < 300,000 BTU/h	0.80 AFUE
Oil-Fired Steam Boiler: < 300,000 BTU/h	0.82 AFUE

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a small commercial (<300,000 BTU/h) fossil fuel-fired indirect water

[150] 10 CFR 429, 430, and 431 Docket No. EERE-2015-BT-TP-0007, Energy Conservation Program for Consumer Products and Certain Commercial and Industrial Equipment: Test Procedures for Consumer and Commercial Water Heaters.
[151] Ibid.
[152] ECCCNYS 2020, Table C403.3.3(5) and Table C404.2.

heater as defined in the Measure Description section. The efficiency of the compliant equipment must exceed the efficiency of the baseline equipment.

Operating Hours

Water heater run hours are not utilized in the estimation of energy or demand savings, but water heater is assumed to be available for operation for the duration of the operating period (year-round or heating season only). Additionally, it is assumed standby losses are incurred over the duration of the operating period.

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

A gas-fired storage type water heater is replaced with an indirect water heater tank with an input capacity of 150 kBtu/h and storage capacity of 60 gallons in a commercial facility located near Albany. The building's hot water demand is 200 gallons per day and water heater set point temperature is 145ºF. The boiler has a 90% energy efficiency rating and a standby loss rating of 0.56 ºF/hr and provides service hot water year-round. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are not applicable. Annual Fossil Fuel Energy Savings are calculated as below.

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

units =1
GPD/unit = 200, from application
$DT_{main} = T_{del} - T_{main} = 125 - 55.4 = 69.6$
    T_{del} from Summary of Variables and Data Sources table
    T_{main} from Cold Water Inlet Temperature table based on location from application
$DT_{amb} = T_{set} - T_{amb} = 145 - 70 = 75$
    T_{set} from application
    T_{amb} from Summary of Variables and Data Sources table
$Eff_{baseline} = 0.82$, from Baseline Efficiency section based on application
$Eff_{ee} = 0.9$, from application
$UA_{baseline} = SL_{baseline} / 70 = 962 / 70 = 13.74$
    $UA_{baseline}$ equation from Baseline Heat Loss Coefficient section
    $SL_{baseline} = Q_{baseline} / 800 + 100 \text{ x } (v_{baseline})^{1/2} = 150{,}000 / 800 + 100 \text{ x } (60)^{1/2} = 962$
    $SL_{baseline}$ equation from Baseline Standby Losses section
    $Q_{baseline}$ from application based on efficient equipment
    $v_{baseline}$ from application based on efficient equipment
$UA_{ee} = SL_{ee} / 70 \text{ x } v_{ee} \text{ x } 8.33 = 0.56 / 70 \text{ x } 60 \text{ x } 8.33 = 4.00$
    UA_{ee} equation from Qualifying Heat Loss Coefficient section
    SL_{ee} from application
    v_{ee} from application
$F_{HS} = 1.0$, from Summary of Variables and Data Sources table

$$\Delta MMBtu = 1 \times \left[\frac{200 \times 365 \times 8.33 \times 69.6}{1{,}000{,}000} \times \left(\frac{1}{0.82} - \frac{1}{0.9}\right) + \left(\frac{13.74}{0.82} - \frac{4.00}{0.9}\right) \times \frac{75}{1{,}000{,}000} \times 8{,}760\right] \times 1.0 = 12.68\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

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

Ancillary Electric Savings Impacts

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

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Record of Revision

Record of Revision Number	Issue Date
1	10/15/2010
3-18-14	3/29/2018
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INSTANTANEOUS WATER HEATER

Measure Description

This measure covers the installation of high-efficiency fossil fuel and electric instantaneous water heaters, which heat water but contain no more than one gallon of water per 4,000 BTU/h of input. It is applicable to fossil fuel-fired instantaneous water heaters with a rated input greater than 200,000 BTU/h and electric instantaneous water heaters with a rated input greater than 12 kW.[153] This measure applies to potable hot water delivery only; it is not applicable to hot water heaters used for process loads or space heating.

This measure applies to the replacement of existing storage type water heaters using the same heating fuel (fossil fuel or electric) as the efficient case. The replacement of existing instantaneous water heaters is ineligible due to limited savings. For new construction, this measure assumes baseline to be a standard efficiency water heater using the same heating fuel (fossil fuel or electric) as the efficient case.

This measure applies to commercial grade water heaters only. For residential-duty water heaters installed in commercial settings, the Residential Storage Tank and Instantaneous Domestic Water Heater methodology detailed in this document shall be employed utilizing typical GPD values as defined in the "Gallons per Day (GPD)" section below.

Method for Calculating Annual Energy and Peak Coincidence Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times \left[\frac{GPD/unit \times 365 \times 8.33 \times \Delta T_{main}}{3{,}412} \times \left(\frac{1}{E_{t,baseline}} - \frac{1}{E_{t,ee}} \right) + \frac{UA_{baseline} \times \Delta T_{amb} \times 8{,}760}{E_{t,baseline} \times 3{,}412} \right]$$

Summer Peak Coincident Demand Savings

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

Annual Fossil Fuel Energy Savings

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

[153] 10 CFR 431.102.

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
GPD	= Gallons per day of delivered hot water per water heater
ΔT_{main}	= Average temperature difference between delivered hot water temperature and the supply water temperature in water main (°F)
ΔT_{amb}	= Average temperature difference between water heater set point temperature and the surrounding ambient air temperature (°F)
$_{baseline}$	= Characteristic of baseline condition
$_{ee}$	= Characteristic of energy efficient condition
E_t	= Thermal efficiency
UA	= Overall heat loss coefficient (BTU/h-°F)
CF	= Coincidence factor
365	= Days in one year
8.33	= Specific heat of water; energy required (BTU), to heat one gallon of water by one degree Fahrenheit [BTU/(gal-F)]
3,412	= Conversion factor, one kWh equals 3,412 BTU
1,000,000	= Conversion factor, one MMBtu equals 1,000,000 BTU
8,760	= Hours in one year

Summary of Variables and Data Sources

Variable	Value	Notes
GPD/unit		From application, or lookup based on building type in GPD table below. If based on values per the table below, divide result by number of units installed.
DT_{main}	T_{del} - T_{main}	Average temperature difference between delivered hot water temperature and the supply water temperature in water main (°F).
DT_{amb}	T_{set} - T_{amb}	Average temperature difference between water heater set point temperature and the surrounding ambient air temperature (°F).
T_{del}	125	Delivered hot water temperature (°F).[154]
T_{set}		Water heater set point temperature (°F). From application, or use 140°F.[155]
T_{main}		Supply water temperature in water main (°F). Lookup in Cold Water Inlet Temperature table below based on nearest city.

[154] Aligned with residential measure set point temperature to normalize default GPD across sectors.
[155] Per OSHA recommendations for prevention of Legionella bacterial growth. (https://www.osha.gov/SLTC/legionnairesdisease/control_prevention.html)

Variable	Value	Notes
T_{amb}	70	Surrounding ambient air temperature (°F).[156]
$E_{t,baseline}$	Electric: 0.98 Fossil Fuel: 0.80	Thermal efficiency of the baseline condition.[157,158]
$E_{t,ee}$		Thermal efficiency for energy efficient measure, from application.
$UA_{baseline}$		Overall heat loss coefficient of the baseline condition, calculate based on baseline standby loss per the Overall Heat Loss Coefficient section below.
CF	0.8	

<u>Gallons per Day (GPD)</u>

The average daily hot water usage, expressed in gallons per day, for several commercial facility types is tabulated below. Daily hot water usage can be calculated based on the GPD and site-specific metric in the Rate column, or default values can be referenced directly from the GPD column.

Building Type	GPD	Rate	Notes/Assumptions	Source
Assembly	239	7.02 GPD per 1,000 SF	Assumes 10% hot water, 34,000 SF	EIA[159]: Public Assembly
Auto Repair	25	4.89 GPD per 1,000 SF	Assumes 10% hot water, 5,150 SF	EIA: Other
Big Box Retail	448	3.43 GPD per 1,000 SF	Assumes 10% hot water, 130,500 SF	EIA: Mercantile
Community College	1,520	1.9 GPD per person	Assumes 800 students	NREL[160]: School with Showers
Dormitory	8,600	17.2 GPD per resident	Assumes 500 residents	Water Research Foundation[161]
Elementary School	250	0.5 GPD per student	Assumes 500 students	NREL: School
Fast Food Restaurant	500	500 GPD per restaurant		FSTC[162]: Quick Service
Full-Service Restaurant	2,500	2,500 GPD per restaurant		FSTC: Full Service

[156] Water heaters are generally located in conditioned or partially conditioned spaces with a typical average temperature of 65°F to 70°F to avoid freezing. A value of 70°F is used for the purposes of estimating tank/ambient air temperature differential, which aligns with standby loss specification testing standards.
[157] Fuel: 10 CFR 431.110 (a).
[158] Electric: Per 10 CFR 430 Subpart B Appendix E – Uniform Test Method for Measuring the Energy Consumption of Water Heaters: *6.3.2 Recovery Efficiency*.
[159] U.S. Energy Information Administration, 2012 Commercial Buildings Energy Consumption Survey: Water Consumption in Large Buildings, Table WD1. Daily water consumption in large commercial buildings, 2012.
[160] National Renewable Energy Laboratory, Saving Energy in Commercial Buildings: Domestic Hot Water Assessment Guidelines, Table 1. Hot Water Use By Building Type, June 2011.
[161] Water Research Foundation: Residential End Uses of Water, Version 2, April 2016.
[162] Food Service Technology Center, Design Guide – Energy Efficient Heating, Delivery and Use, Table 1. Typical hot water system cost for restaurants, March 2010.

Grocery	172	3.43 GPD per 1,000 SF	Assumes 10% hot water, 50,000 SF	EIA: Mercantile
High School	1,520	1.9 GPD per person	Assumes 800 students	NREL: School with Showers
Hospital	16,938	54.42 GPD per 1,000 SF	Assumes 40% hot water, 250,000 SF	EIA: Health Care, Inpatient
Hotel	9,104	45.52 GPD per 1,000 SF	Assumes 40% hot water, 200,000 SF	EIA: Lodging
Large Office	550	1.1 GPD per person	Assumes 500 people	NREL: Office
Large Retail	446	3.43 GPD per 1,000 SF	Assumes 10% hot water, 130,000 SF	EIA: Mercantile
Light Industrial	489	4.89 GPD per 1,000 SF	Assumes 10% hot water, 100,000 SF	EIA: Other
Motel	1,366	45.52 GPD per 1,000 SF	Assumes 40% hot water, 30,000 SF	EIA: Lodging
Multifamily High-Rise	3,440	34.4 GPD per unit	Assumes 100 units, 2 people per unit	Multifamily Baseline Study[163]
Multifamily Low-Rise	413	34.4 GPD per unit	Assumes 12 units, 2 people per unit	Multifamily Baseline Study
Refrigerated Warehouse	86	0.93 GPD per 1,000 SF	Assumes 10% hot water, 92,000 SF	EIA: Warehouse and Storage
Religious	77	7.02 GPD per 1,000 SF	Assumes 10% hot water, 11,000 SF	EIA: Public Assembly
Small Office	110	1.1 GPD per person	Assumes 100 people	NREL: Office
Small Retail	27	3.43 GPD per 1,000 SF	Assumes 10% hot water, 8,000 SF	EIA: Mercantile
University	1,000	0.5 GPD per student	Assumes 2,000 students	NREL: School
Warehouse	465	0.93 GPD per 1,000 SF	Assumes 10% hot water, 500,000 SF	EIA: Warehouse and Storage
Other	Calculate	4.89 GPD per 1,000 SF	Assumes 10% hot water	EIA: Other

Cold Water Inlet Temperature (T_{main})

Supply water main temperatures vary according to climate, and are approximately equal to the annual average outdoor temperature plus 6°F.[164] Supply main temperatures based on the annual outdoor temperature are shown below.

[163] Residential Statewide Baseline Study of New York State, July 2015. Volume 2: Multifamily Report, Table 8.
[164] Burch, Jay and Christensen, Craig, "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory.

City	Annual average outdoor temperature[165] (°F)	T_{main} (°F)
Albany	49.4	55.4
Binghamton	46.8	52.8
Buffalo	49.1	55.1
Massena	45.1	51.1
NYC	54.7	60.7
Poughkeepsie	50.9	56.9
Syracuse	49.0	55.0

Overall Heat Loss Coefficient ($UA_{baseline}$)

Tank overall heat loss coefficient is calculated from the equipment standby loss specification. To calculate $UA_{baseline}$, use the appropriate intermediate standby loss equation from the Baseline Standby Losses section below.

$$UA = \frac{SL}{70}$$

where:

SL = Standby heat loss (BTU/h). For the baseline condition ($SL_{baseline}$), use the appropriate intermediate standby loss equation from the Baseline Standby Losses section below.

70 = Temperature difference associated with standby loss specification (°F)[166]

Baseline Standby Losses ($SL_{baseline}$)

Standby losses ($SL_{baseline}$) for large electric storage type water heaters (> 12kW and > 20 gallons):[167]

$$SL_{baseline} = \frac{\left(0.30 + \frac{27}{v_{baseline}}\right)}{100} \times 70 \times v_{baseline} \times 8.33$$

where:

$v_{baseline}$ = Baseline tank volume (gal). If unknown, assume 150 gallons.

70 = Temperature difference associated with standby loss specification (°F)[168]

8.33 = Specific heat of water; energy required (BTU), to heat one gallon of water by one degree Fahrenheit [BTU/(gal-F)]

Standby losses ($SL_{baseline}$) for large oil and gas storage type water heaters (> 75,000 BTU/h input

[165] Average annual outdoor temperatures taken from NCEI 1991-2020 climate normals.

[166] 10 CFR 429, 430, and 431 Docket No. EERE-2015-BT-TP-0007, Energy Conservation Program for Consumer Products and Certain Commercial and Industrial Equipment: Test Procedures for Consumer and Commercial Water Heaters.

[167] Ibid.

[168] 10 CFR 429, 430, and 431 Docket No. EERE-2015-BT-TP-0007, Energy Conservation Program for Consumer Products and Certain Commercial and Industrial Equipment: Test Procedures for Consumer and Commercial Water Heaters.

capacity (Q) and storage size > 1 gallon per 4000 BTU/h):[169]

$$SL_{baseline} = \frac{Q_{baseline}}{800} + 110\sqrt{v_{baseline}}$$

where:

$v_{baseline}$ = Baseline tank volume (gal). If unknown, assume 150 gallons.
$Q_{baseline}$ = Baseline input capacity (BTU/h). If unknown, assume 200,000 BTU/h.

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.8.[170]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a standard efficiency fossil fuel or electric storage type water heater (fuel type equivalent to the efficient case) with tank volume and input capacity equivalent to those of the existing equipment, UA value calculated as prescribed above and a thermal efficiency of 0.80 (fossil fuel) or 0.98 (electric). For new construction, assume the baseline condition consists of a 100-gallon storage type water heater with an input capacity of 200,000 BTU/h.[171]

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a fossil fuel or electric instantaneous water heater as defined in the Measure Description section above. Fossil fuel tankless water heaters must meet the minimum qualifying efficiency for ENERGY STAR® certification of a thermal efficiency greater than or equal to 0.94.[172] Electric tankless water heaters must meet or exceed the efficiency of the baseline condition with a thermal efficiency greater than or equal to 0.98.

Effective Useful Life (EUL)

See Appendix P.

Operating Hours

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

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

A 250 kBTU/h, 150 gallon gas-fired storage tank water heater in a commercial facility located near Albany is replaced with a 380 kBTU/h gas-fired instantaneous water heater with a 95%

[169] Ibid.
[170] *No source specified – update pending availability and review of applicable references.*
[171] Based on the average storage size and capacity of AHRI-certified commercial storage type water heaters per the ARHI Directory. (https://www.ahridirectory.org/Search/SearchHome)
[172] ENERGY STAR® Commercial Water Heater Key Product Criteria.

rated thermal efficiency. The facility has a hot water demand of 1,000 gallons per day and a hot water set point temperature of 145ºF. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are not applicable. Annual Fossil Fuel Energy Savings are calculated as below.

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

GPD/unit = 1,000, from application

$DT_{main} = T_{del} - T_{main} = 125 - 55.4 = 69.6$

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

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

$E_{t,baseline}$ = 0.8, from Summary of Variables and Data Sources table based on type from application

$E_{t,ee}$ = 0.95, from application

$UA_{baseline} = SL_{baseline} / 70 = 1{,}537 / 70 = 21.96$

$UA_{baseline}$ equation from Overall Heat Loss Coefficient section

$SL_{baseline} = Q_{baseline} /800 + 100 \text{ x } (v_{baseline})^{1/2} = 250{,}000/800 + 100 \text{ x } (150)^{1/2} = 1{,}537$

$SL_{baseline}$ equation from Baseline Standby Losses section based on equipment type from application

$Q_{baseline}$ from application

$v_{baseline}$ from application

$DT_{amb} = T_{set} - T_{amb} = 145 - 70 = 75$

T_{set} from application

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

$$\Delta MMBtu = 1 \times \left[\frac{1{,}000 \times 365 \times 8.33 \times 69.6}{1{,}000{,}000} \times \left(\frac{1}{0.8} - \frac{1}{0.95}\right) + \frac{21.96 \times 75 \times 8{,}760}{0.8 \times 1{,}000{,}000}\right] = 59.80\ MMBtu$$

Ancillary Fossil Fuel Savings Impacts

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

Ancillary Electric Savings Impacts

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

References

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   Available from: https://www.govinfo.gov/content/pkg/CFR-2013-title10-vol3/pdf/CFR-2013-title10-vol3-part431.pdf
2. 10 CFR Appendix E to Subpart B of Part 430—Uniform Test Method for Measuring the Energy Consumption of Water Heaters, Section 2. Test Conditions, 2.5 Set Point Temperature.
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   Available from: https://www.osha.gov/SLTC/legionnairesdisease/control_prevention.html
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10. NOAA National Centers for Environmental Information – NCEI 1991-2020 Climate Normals.
    Available from: https://www.ncdc.noaa.gov/cdo-web/datatools/normals
11. 10 CFR 429, 430, and 431 Docket No. EERE-2015-BT-TP-0007, Energy Conservation Program for Consumer Products and Certain Commercial and Industrial Equipment: Test Procedures for Consumer and Commercial Water Heaters.

Available from: https://energy.gov/sites/prod/files/2016/08/f33/Water%20Heaters%20Test%20Procedure%20SNOPR.pdf
12. ENERGY STAR® Commercial Water Heater Key Product Criteria
Available from: https://www.energystar.gov/products/water_heaters/commercial_water_heaters/key_product_criteria
13. Residential Statewide Baseline Study of New York State, July 2015.
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Record of Revision

Record of Revision Number	Issue Date
6-18-20	6/26/2018
3-21-13	4/9/2021
12-23-10	1/5/2024

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STORAGE TANK WATER HEATER

Measure Description

This measure covers the installation of fossil fuel and electric storage tank water heaters designed to heat and store water at a thermostatically controlled temperature. This measure applies to potable hot water delivery only; it is not applicable to hot water heaters used for process loads or space heating.

Storage type units include commercial fossil fuel storage water heaters with a nominal input of greater than 75,000 BTU/h and less than 4,000 BTU/h per gallon of stored water and commercial electric storage water heaters with a nominal input of greater than 12 kilowatts and less than 4,000 BTU/h per gallon of stored water.[173]

This measure applies to replacement of existing storage type water heaters using the same heating fuel (fossil fuel or electric) as the efficient case. For new construction, this measure assumes baseline to be a standard efficiency water heater using the same heating fuel (fossil fuel or electric) as the efficient equipment.

This measure applies to commercial grade water heaters only. For residential-duty water heaters installed in commercial settings, the Residential Storage Tank and Instantaneous Domestic Water Heater methodology detailed in this document shall be employed utilizing typical GPD values as defined in the "Gallons per Day (GPD)" section below.

Method for Calculating Annual Energy and Peak Coincidence Demand Savings

Annual Electric Energy Savings (Electric Equipment Only)

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

Summer Peak Coincident Demand Savings (Electric Equipment Only)

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

Annual Fossil Fuel Energy Savings (Fossil Fuel Equipment Only)

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

where:

DkWh = Annual electric energy savings
DkW = Peak coincident demand electric savings

[173] 10 CFR 431.102.

DMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
GPD/unit	= Gallons per day of delivered hot water per water heater
ΔT_{main}	= Average temperature difference between delivered hot water temperature and the supply water temperature in water main (°F)
ΔT_{amb}	= Average temperature difference between water heater set point temperature and the surrounding ambient air temperature (°F)
$_{baseline}$	= Characteristic of baseline condition
$_{ee}$	= Characteristic of energy efficient condition
E_t	= Thermal efficiency
UA	= Overall heat loss coefficient (BTU/h-°F)
CF	= Coincidence factor
365	= Days in one year
8.33	= Specific heat of water; energy required (BTU), to heat one gallon of water by one degree Fahrenheit [BTU/(gal-F)]
3,412	= Conversion factor, one kWh equals 3,412 BTU
1,000,000	= Conversion factor, one MMBtu equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
GPD/unit		From application, or lookup/calculate based on building type, square footage, and occupancy from GPD table below. If based on values per the table below, divide result by number of units installed.
DT_{main}	T_{del} - T_{main}	Average temperature difference between delivered hot water temperature and the supply water temperature in water main (°F).
DT_{amb}	T_{set} - T_{amb}	Average temperature difference between water heater set point temperature and the surrounding ambient air temperature (°F).
T_{del}	125	Delivered hot water temperature (°F).[174]
T_{set}		Water heater set point temperature (°F), per application or use 140°F as a default.[175]
T_{main}		Supply water temperature in water main (°F). Lookup in Cold Water Inlet Temperature table below based on nearest city.
T_{amb}	70	Surrounding ambient air temperature (°F).[176]
$E_{t,baseline}$	Electric: 0.98	Thermal efficiency of the baseline

[174] Aligned with residential measure set point temperature to normalize default GPD across sectors.
[175] Per OSHA recommendations for prevention of Legionella bacterial growth. (https://www.osha.gov/SLTC/legionnairesdisease/control_prevention.html)
[176] Water heaters are generally located in conditioned or partially conditioned spaces with a typical average temperature of 65°F to 70°F to avoid freezing. A value of 70°F is used for the purposes of estimating tank/ambient air temperature differential, which aligns with standby loss specification testing standards.

Variable	Value	Notes
	Fossil Fuel: 0.80	condition.[177,178]
$E_{t,ee}$		Thermal efficiency for energy efficient measure, from application.
$UA_{baseline}$		Overall heat loss coefficient of the baseline condition (BTU/h-°F). Calculate based on baseline standby loss per the Overall Heat Loss Coefficient section below.
UA_{ee}		Overall heat loss coefficient of the energy efficient measure (BTU/h-°F). Calculate based on energy efficient standby loss per the Overall Heat Loss Coefficient section below.
CF	0.8	

<u>Gallons per Day (GPD)</u>

The average daily hot water usage, expressed in gallons per day, for several commercial facility types is tabulated below. Daily hot water usage can be calculated based on the GPD and site-specific metric in the Rate column, or default values can be referenced directly from the GPD column.

Building Type	GPD	Rate	Notes/Assumptions	Source
Assembly	239	7.02 GPD per 1,000 SF	Assumes 10% hot water, 34,000 SF	EIA[179]: Public Assembly
Auto Repair	25	4.89 GPD per 1,000 SF	Assumes 10% hot water, 5,150 SF	EIA: Other
Big Box Retail	448	3.43 GPD per 1,000 SF	Assumes 10% hot water, 130,500 SF	EIA: Mercantile
Community College	1,520	1.9 GPD per person	Assumes 800 students	NREL[180]: School with Showers
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Elementary School	250	0.5 GPD per student	Assumes 500 students	NREL: School
Fast Food Restaurant	500	500 GPD per restaurant		FSTC[182]: Quick Service

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[181] Water Research Foundation: Residential End Uses of Water, Version 2, April 2016.
[182] Food Service Technology Center, Design Guide – Energy Efficient Heating, Delivery and Use, Table 1. Typical hot water system cost for restaurants, March 2010.

Building Type	GPD	Rate	Notes/Assumptions	Source
Full-Service Restaurant	2,500	2,500 GPD per restaurant		FSTC: Full Service
Grocery	172	3.43 GPD per 1,000 SF	Assumes 10% hot water, 50,000 SF	EIA: Mercantile
High School	1,520	1.9 GPD per person	Assumes 800 students	NREL: School with Showers
Hospital	16,938	54.42 GPD per 1,000 SF	Assumes 40% hot water, 250,000 SF	EIA: Health Care, Inpatient
Hotel	9,104	45.52 GPD per 1,000 SF	Assumes 40% hot water, 200,000 SF	EIA: Lodging
Large Office	550	1.1 GPD per person	Assumes 500 people	NREL: Office
Large Retail	446	3.43 GPD per 1,000 SF	Assumes 10% hot water, 130,000 SF	EIA: Mercantile
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Motel	1,366	45.52 GPD per 1,000 SF	Assumes 40% hot water, 30,000 SF	EIA: Lodging
Multifamily High-Rise	3,440	34.4 GPD per unit	Assumes 100 units, 2 people per unit	Multifamily Baseline Study[183]
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Refrigerated Warehouse	86	0.93 GPD per 1,000 SF	Assumes 10% hot water, 92,000 SF	EIA: Warehouse and Storage
Religious	77	7.02 GPD per 1,000 SF	Assumes 10% hot water, 11,000 SF	EIA: Public Assembly
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Other	Calculate	4.89 GPD per 1,000 SF	Assumes 10% hot water	EIA: Other

Cold Water Inlet Temperature (T_{main})

Supply water main temperatures vary according to climate, and are approximately equal to the annual average outdoor temperature plus 6°F.[184] Supply main temperatures based on the annual outdoor temperature are shown below.

[183] Residential Statewide Baseline Study of New York State, July 2015. Volume 2: Multifamily Report, Table 8.
[184] Burch, Jay and Christensen, Craig, "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory.

City	Annual average outdoor temperature[185] (°F)	T_{main} (°F)
Albany	49.4	55.4
Binghamton	46.8	52.8
Buffalo	49.1	55.1
Massena	45.1	51.1
NYC	54.7	60.7
Poughkeepsie	50.9	56.9
Syracuse	49.0	55.0

Overall Heat Loss Coefficient ($UA_{baseline}$ and UA_{ee})

Tank overall heat loss coefficient is calculated from the equipment standby loss specification. For UA_{ee}, the manufacturer specified standby loss shall be applied directly to the UA formula below. To calculate $UA_{baseline}$, use the appropriate intermediate standby loss equation from the Baseline Standby Losses section below.

$$UA = \frac{SL}{70}$$

where:

SL = Standby heat loss (BTU/h), from application for the energy efficient measure (SL_{ee}). For the baseline condition ($SL_{baseline}$), use the appropriate intermediate standby loss equation from the Baseline Standby Losses section below.

70 = Temperature difference associated with standby loss specification (°F).[186]

Baseline Standby Losses ($SL_{baseline}$)

Standby losses ($SL_{baseline}$) for commercial electric storage type water heaters:[187]

$$SL_{baseline} = \frac{\left(0.30 + \frac{27}{v_{baseline}}\right)}{100} \times 70 \times v_{baseline} \times 8.33$$

where:

$v_{baseline}$ = Baseline tank volume (gal), equal to the storage capacity of the efficient equipment

70 = Temperature difference associated with standby loss specification (°F)[188]

[185] Average annual outdoor temperatures taken from NCEI 1991-2020 climate normals.

[186] 10 CFR 429, 430, and 431 Docket No. EERE-2015-BT-TP-0007, Energy Conservation Program for Consumer Products and Certain Commercial and Industrial Equipment: Test Procedures for Consumer and Commercial Water Heaters.

[187] Ibid.

[188] 10 CFR 429, 430, and 431 Docket No. EERE-2015-BT-TP-0007, Energy Conservation Program for Consumer Products and Certain Commercial and Industrial Equipment: Test Procedures for Consumer and Commercial Water Heaters.

8.33 = Specific heat of water; energy required (BTU), to heat one gallon of water by one degree Fahrenheit [BTU/(gal-F)]

Standby losses ($SL_{baseline}$) for commercial gas storage type water heaters:[189]

$$SL_{baseline} = \frac{Q_{baseline}}{800} + 110\sqrt{v_{baseline}}$$

where:

$v_{baseline}$ = Baseline tank volume (gal), equal to the storage capacity of the efficient equipment

$Q_{baseline}$ = Baseline input capacity (BTU/h), equal to the input capacity of the efficient equipment

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.8.[190]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition for replacement measures is a standard efficiency fossil fuel or electric storage type water heater (based on proposed conditions) with tank volume and input capacity equivalent to the efficient case, UA value calculated as prescribed above and a thermal efficiency of 0.80 (fossil fuel) or 0.98 (electric).

For LMI applications, existing condition baseline shall be established based on nameplate efficiency or efficiency measured through combustion analysis.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a fossil fuel or electric storage type water heater as defined in the Measure Description section above, which exceeds the efficiency of the baseline equipment.

Operating Hours

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

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

A gas storage tank water heater is installed in a commercial facility located near Albany. The facility has a hot water demand of 500 gallons per day. The storage tank water heater has a storage capacity of 100 gallons, an input capacity of 200 kBTU/h and an efficiency rating of

[189] 10 CFR 429, 430, and 431 Docket No. EERE-2015-BT-TP-0007, Energy Conservation Program for Consumer Products and Certain Commercial and Industrial Equipment: Test Procedures for Consumer and Commercial Water Heaters.

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

97%. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are not applicable. Annual Fossil Fuel Energy Savings are calculated as below.

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

units = 1
GPD/unit = 500, from application
$DT_{main} = T_{del} - T_{main} = 125 - 55.4 = 69.6$
T_{del} from Summary of Variables and Data Sources table
T_{main} from Cold Water Inlet Temperature table based on location from application
$E_{t,baseline}$ = 0.8, from Summary of Variables and Data Sources table based on type from application
$E_{t,ee}$ = 0.97, from application

$$\Delta MMBtu = 1 \times \frac{500 \times 365 \times 8.33 \times 69.6}{1{,}000{,}000} \times \left(\frac{1}{0.8} - \frac{1}{0.97}\right) = 23.18\ \ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

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

Ancillary Electric Savings Impacts

High-efficiency water heaters may incorporate a draft fan, which increases electricity consumption. Additionally, reduction in standby heat losses will have a negligible impact on space heating and cooling when the water heater is located in conditioned space. Consideration of these effects is not included in this methodology.

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1	10/15/2010
12-17-10	12/31/2017

12-23-11	1/5/2024

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DOMESTIC HOT WATER (DHW) – CONTROL

CENTRAL DOMESTIC HOT WATER (DHW) CONTROL

Measure Description

This measure is applicable to the installation of temperature modulation and demand controls on central domestic hot water (DHW) systems with recirculation. Temperature modulation controls reduce circulator pump energy and recirculation heat losses by modulating DHW system supply temperatures according to a set schedule, activating recirculation when supply water drops below the set point. Demand controls limit energy consumption by activating recirculation loops based on demand. DHW demand controls must monitor calls for hot water and return water temperature, activating recirculation when demand is detected or return water has dropped below a prescribed temperature. Temperature modulation and demand controls achieve savings without significant interruptions to instantaneous hot water availability.

This measure is not applicable to new construction or gut rehab installations.[191] This measure is not applicable in facilities where twenty-four-hour recirculation and delivered hot water temperature is required by code. DHW demand control systems shall be installed by a qualified contractor complying with all relevant construction and safety codes and standards.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = \Delta kWh_{pump} + \Delta kWh_{HW}$$

$$\Delta kWh_{pump} = \frac{hp \times 0.746}{Eff_{pump}} \times LF \times hrs_{recirc,baseline} \times ESF_{pump}$$

$$\Delta kWh_{HW} = \frac{GPD \times 365 \times 8.33 \times \Delta T_{main}}{3{,}412} \times \frac{F_{DHW,elec}}{E_{t,elec}} \times \frac{hrs_{recirc,baseline}}{8{,}760} \times ESF_{HW}$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \frac{\Delta kWh}{hrs_{recirc,baseline}} \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = \frac{GPD \times 365 \times 8.33 \times \Delta T_{main}}{1{,}000{,}000} \times \frac{F_{DHW,fuel}}{E_{t,fuel}} \times \frac{hrs_{recirc,baseline}}{8{,}760} \times ESF_{HW}$$

where:

[191] ECCCNYS 2020 C404.7 and NYSPC 607.2.

ΔkWh	= Annual electricity energy savings
ΔkW	= Peak coincident demand electric savings
$\Delta MMBtu$	= Annual fossil fuel energy savings
hp	= Total recirculation system pump horsepower
Eff	= Efficiency
$_{pump}$	= Property of circulator pump
LF	= Load Factor
$hrs_{recirc,baseline}$	= Annual hours of operation of recirculation system in the baseline condition
ESF	= Energy savings factor
GPD	= Gallons per day
ΔT_{main}	= Average temperature difference between delivered hot water temperature and the supply water temperature in water main (ºF)
E_t	= Thermal efficiency
$_{elec}$	= Property of electrical central DHW system
$_{fuel}$	= Property of fossil fuel central DHW system
$_{HW}$	= Hot water
$F_{DHW,elec}$	= Electric water heating factor
$F_{DHW,fuel}$	= Fossil fuel water heating factor
CF	= Coincidence Factor
0.746	= Conversion factor (kW/hp), 746 watts equals one electric horsepower
8.33	= Specific heat of water; energy required (BTU), to heat one gallon of water by one degree Fahrenheit [BTU/(gal-F)]
8,760	= Hours in one year
365	= Days in one year
3,412	= Conversion factor, one kWh equals 3,412 BTU
1,000,000	= Conversion factor, one MMBtu equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
hp		From application.
Eff_{pump}	PSC Pump: 0.60 ECM Pump: 0.80	PSC pump efficiency.[192] ECM pump efficiency.[193] If unknown, use a value of 0.80.
LF	0.9	Assumed value to reflect that motors do not typically run at 100% of rated power.
$hrs_{recirc,baseline}$		From application. If unknown, see Operating Hours section below.
GPD		From application, or lookup/calculate based on building type, square footage, and occupancy from GPD table below.

[192] US DOE, Energy Savings Potential and Opportunities for High-Efficiency Electric Motors in Residential and Commercial Equipment, Table 2.1 Summary of Single-Phase AC Induction Motor Characteristics - Efficiency of the baseline condition is taken as the average full load efficiency rating range for a PSC motor.
[193] ACHR News, Comparing Motor Technologies, December 2009.

Variable	Value	Notes
ΔT_{main}	$T_{del} - T_{main}$	Average temperature difference between delivered hot water temperature and the supply water temperature in water main (ºF).
T_{del}	125	Delivered hot water temperature (°F).[194]
T_{main}		Supply water temperature in water main (ºF). Lookup in Cold Water Inlet Temperature table below based on nearest city.
$E_{t,elec}$	0.98	Thermal efficiency of electric water heater.[195]
$E_{t,fuel}$	0.80	Thermal efficiency of fossil fuel water heater.[196]
ESF_{pump}	0.87	Minnesota Department of Commerce.[197]
ESF_{HW}		Lookup based on control type in the Energy Savings Factor section below.
$F_{DHW,elec}$		Use a value of 1.0 if the affected DHW system is electric. Otherwise, use 0.0.
$F_{DHW,fuel}$		Use a value of 1.0 if the affected DHW system is fossil fuel-fired. Otherwise, use 0.0.
CF	0.8	

<u>Gallons per Day (GPD)</u>

The average daily hot water usage, expressed in gallons per day, for several commercial facility types is tabulated below. Daily hot water usage can be calculated based on the GPD and site-specific metric in the Rate column, or default values can be referenced directly from the GPD column.

Building Type	GPD	Rate	Notes/Assumptions	Source
Assembly	239	7.02 GPD per 1,000 SF	Assumes 10% hot water, 34,000 SF	EIA[198]: Public Assembly
Auto Repair	25	4.89 GPD per 1,000 SF	Assumes 10% hot water, 5,150 SF	EIA: Other
Big Box Retail	448	3.43 GPD per 1,000 SF	Assumes 10% hot water, 130,500 SF	EIA: Mercantile
Community College	1,520	1.9 GPD per person	Assumes 800 students	NREL[199]: School with Showers
Dormitory	8,600	17.2 GPD per resident	Assumes 500 residents	Water Research Foundation[200]
Elementary School	250	0.5 GPD per student	Assumes 500 students	NREL: School

[194] Aligned with residential measure set point temperature to normalize default GPD across sectors.
[195] Per 10 CFR 430 Subpart B Appendix E – Uniform Test Method for Measuring the Energy Consumption of Water Heaters: *6.3.2 Recovery Efficiency*.
[196] Per 10 CFR 431.110(a).
[197] Center for Energy and Environment, Evaluation of New DHW System Controls in Hospitality and Commercial Buildings, Prepared for Minnesota Department of Commerce, Division of Energy Resources, June 30, 2018, pg. 12.
[198] U.S. Energy Information Administration, 2012 Commercial Buildings Energy Consumption Survey: Water Consumption in Large Buildings, Table WD1. Daily water consumption in large commercial buildings, 2012.
[199] National Renewable Energy Laboratory, Saving Energy in Commercial Buildings: Domestic Hot Water Assessment Guidelines, Table 1. Hot Water Use By Building Type, June 2011.
[200] Water Research Foundation: Residential End Uses of Water, Version 2, April 2016.

Building Type	GPD	Rate	Notes/Assumptions	Source
Fast Food Restaurant	500	500 GPD per restaurant		FSTC[201]: Quick Service
Full-Service Restaurant	2,500	2,500 GPD per restaurant		FSTC: Full Service
Grocery	172	3.43 GPD per 1,000 SF	Assumes 10% hot water, 50,000 SF	EIA: Mercantile
High School	1,520	1.9 GPD per person	Assumes 800 students	NREL: School with Showers
Hospital	16,938	54.42 GPD per 1,000 SF	Assumes 40% hot water, 250,000 SF	EIA: Health Care, Inpatient
Hotel	9,104	45.52 GPD per 1,000 SF	Assumes 40% hot water, 200,000 SF	EIA: Lodging
Large Office	550	1.1 GPD per person	Assumes 500 people	NREL: Office
Large Retail	446	3.43 GPD per 1,000 SF	Assumes 10% hot water, 130,000 SF	EIA: Mercantile
Light Industrial	489	4.89 GPD per 1,000 SF	Assumes 10% hot water, 100,000 SF	EIA: Other
Motel	1,366	45.52 GPD per 1,000 SF	Assumes 40% hot water, 30,000 SF	EIA: Lodging
Multifamily High-Rise	3,440	34.4 GPD per unit	Assumes 100 units, 2 people per unit	Multifamily Baseline Study[202]
Multifamily Low-Rise	413	34.4 GPD per unit	Assumes 12 units, 2 people per unit	Multifamily Baseline Study
Refrigerated Warehouse	86	0.93 GPD per 1,000 SF	Assumes 10% hot water, 92,000 SF	EIA: Warehouse and Storage
Religious	77	7.02 GPD per 1,000 SF	Assumes 10% hot water, 11,000 SF	EIA: Public Assembly
Small Office	110	1.1 GPD per person	Assumes 100 people	NREL: Office
Small Retail	27	3.43 GPD per 1,000 SF	Assumes 10% hot water, 8,000 SF	EIA: Mercantile
University	1,000	0.5 GPD per student	Assumes 2,000 students	NREL: School
Warehouse	465	0.93 GPD per 1,000 SF	Assumes 10% hot water, 500,000 SF	EIA: Warehouse and Storage
Other	Calculate	4.89 GPD per 1,000 SF	Assumes 10% hot water	EIA: Other

Cold Water Inlet Temperature (T_{main})

Supply water main temperatures vary according to climate, and are approximately equal to the annual average outdoor temperature plus 6°F.[203] Supply main temperatures based on the annual outdoor temperature are shown below.

City	Annual average outdoor temperature[204] (°F)	T_{main} (°F)
Albany	49.4	55.4

[201] Food Service Technology Center, Design Guide – Energy Efficient Heating, Delivery and Use, Table 1. Typical hot water system cost for restaurants, March 2010.
[202] Residential Statewide Baseline Study of New York State, July 2015. Volume 2: Multifamily Report, Table 8.
[203] Burch, Jay and Christensen, Craig, "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory.
[204] Average annual outdoor temperatures taken from NCEI 1991-2020 climate normals.

City	Annual average outdoor temperature[204] (°F)	T_{main} (°F)
Binghamton	46.8	52.8
Buffalo	49.1	55.1
Massena	45.1	51.1
NYC	54.7	60.7
Poughkeepsie	50.9	56.9
Syracuse	49.0	55.0

Energy Savings Factor

The hot water energy savings factor (ESF_{HW}) is dependent on the installed control type.

Control Type	ESF_{HW}	Notes
Demand Control	0.07	NREL[205]
Temperature Modulation	0.02	NREL[206]
Demand Control and Temperature Modulation	0.15	NREL[207]

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.8.[208]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition for this measure is a central DHW recirculation system running in continuous operation.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a central DHW recirculation system with a control system that regulates circulator pump operation based on demand, temperature or both. Recirculation system controls must be installed by a qualified contractor complying with all relevant construction and safety codes and standards.

Operating Hours

Operating hours for continuous recirculation hours will be 8,760.

For systems with heating season recirculation only, hours based on location per the table below shall be used. Hours values below were developed from NOAA hourly normals[209] by assuming a 65ºF balance point temperature and summing dry bulb hours below the balance point.

[205] NREL, Control Strategies to Reduce the Energy Consumption of Central Domestic Hot Water Systems, June 2016.

[206] Ibid.

[207] Ibid.

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

[209] NOAA National Centers for Environmental Information – NCEI 1991 - 2020 Hourly Normals.

City	hrs
Albany	6,587
Binghamton	7,214
Buffalo	6,727
Massena	7,138
NYC	5,920
Poughkeepsie	6,481
Syracuse	6,671

For systems with recirculation coincident with facility operation, the values found in the table below may be used based on facility type.

Facility Type	Operating Hours (hrs/yr)	Facility Type	Operating Hours (hrs/yr)
Auto Related*	2,810	Manufacturing Facility	2,857
Automotive / Transportation Service or Repair Facility (24/7)	8,760	Medical Offices	3,748
Bakery	2,854	Motion Picture Theatre	1,954
Banks	3,748	Multi-Family (Common Areas)	7,665
Church	1,955	Museum	3,748
College– Cafeteria**	2,713	Nursing Homes	5,840
College – Classes	2,586	Office (General Office Types)**	3,013
College - Dormitory	3,066	Parking Garages	4,368
Commercial Condos***	3,100	Parking Garages (24/7)	7,717
Convenience Stores	6,376	Parking Lots	4,100
Convention Center	1,954	Penitentiary	5,477
Court House	3,748	Performing Arts Theatre	2,586
Dining: Bar Lounge/Leisure	4,182	Police / Fire Stations (24 Hr)	7,665
Dining: Cafeteria / Fast Food	6,456	Post Office	3,748
Dining: Family	4,182	Pump Stations	1,949
Entertainment	1,952	Refrigerated Warehouse	2,602
Exercise Center	5,836	Religious Building	1,955
Fast Food Restaurants	6,376	Restaurants	4,182
Fire Station (Unmanned)	1,953	Retail	3,463
Food Stores	4,055	School / University	2,187
Gymnasium	2,586	Schools (Jr./Sr. High)	2,187
Hospitals	7,674	Schools (Preschool/ Elementary)	2,187
Hospitals / Health Care	7,666	Schools (Technical/ Vocational)	2,187
Industrial - 1 Shift	2,857	Small Services	3,750
Industrial - 2 Shift	4,730	Sports Arena	1,954

Facility Type	Operating Hours (hrs/yr)	Facility Type	Operating Hours (hrs/yr)
Industrial - 3 Shift	6,631	Town Hall	3,748
Laundromats	4,056	Transportation	6,456
Library	3,748	Warehouse (Not Refrigerated)	2,602
Light Manufacturers**	2,613	Waste Water Treatment Plant	6,631
Lodging (Hotels/Motels)	3,064	Workshop	3,750
Mall Concourse	4,833		

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

Temperature modulation and demand controls are installed on a gas fired, central domestic hot water system with recirculation in a commercial facility located near Albany. The recirculation pump is run by a 1/4 horsepower EC motor and is in continuous operation year round. The facility has a demand of 750 gallons of water per day and a hot water set point temperature of 145ºF. Annual Electric Energy Savings, Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta kWh = \Delta kWh_{pump} + \Delta kWh_{HW}$$

$$\Delta kWh_{pump} = \frac{hp \times 0.746}{Eff_{pump}} \times LF \times hrs_{recirc,baseline} \times ESF_{pump}$$

$$\Delta kWh_{HW} = \frac{GPD \times 365 \times 8.33 \times \Delta T_{main}}{3{,}412} \times \frac{1}{E_{t,elec}} \times \frac{hrs_{recirc,baseline}}{8{,}760} \times ESF_{HW}$$

$$\Delta kW = \frac{\Delta kWh}{hrs_{recirc,baseline}} \times CF$$

$$\Delta MMBtu = \frac{GPD \times 365 \times 8.33 \times \Delta T_{main}}{1{,}000{,}000} \times \frac{1}{E_{t,fuel}} \times \frac{hrs_{recirc,baseline}}{8{,}760} \times ESF_{HW}$$

hp = 0.25, from application
Eff_{pump} = 0.8, from Summary of Variables and Data Sources table based on pump type from application
LF = 0.9, from Summary of Variables and Data Sources table
$hrs_{recirc,baseline}$ = 8,760, from application
ESF_{pump} = 0.87, from Summary of Variables and Data Sources table
GPD = 750, from application
$DT_{main} = T_{del} – T_{main}$ = 125 – 55.4 = 69.6
T_{del} from Summary of Variables and Data Sources table
T_{main} from Cold Water Inlet Temperature table based on location from application
$E_{t,fuel}$ = 0.80, from Summary of Variables and Data Sources table based on equipment from application

ESF_{HW} = 0.15, based on Energy Savings Factor table based on application
CF = 0.8

$$\Delta kWh_{pump} = \frac{0.25 \times 0.746}{0.8} \times 0.9 \times 8{,}760 \times 0.87 = 1{,}637.60\ kWh$$

$$\Delta kWh = \Delta kWh_{pump} + 0 = 1{,}637.60 + 0 = 1{,}637.60\ kWh$$

$$\Delta kW = \frac{1{,}637.60}{8{,}760} \times 0.8 = 0.149\ kW$$

$$\Delta MMBtu = \frac{750 \times 365 \times 8.33 \times 69.6}{1{,}000{,}000} \times \frac{1}{0.8} \times \frac{8{,}760}{8{,}760} \times 0.15 = 29.76\ MMBtu$$

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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3-20-8	3/30/2020
6-22-9	9/2/2022
12-23-12	1/5/2024

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DRAIN WATER HEAT RECOVERY (DWHR)

Measure Description

This measure covers the installation of drain water heat recovery systems on a main waste drain in commercial applications. Drain water heat recovery (DWHR) systems are drainage heat exchangers that recover heat from drain greywater to preheat cold water entering the water heater. By preheating cold water entering the storage tank, the water heater consumes less energy to heat the water to the desired temperature.

This measure is only applicable to buildings with storage type water heaters.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings (Electric Water Heating Only)

$$\Delta kWh = units \times \frac{GPD \times 365 \times 8.33 \times \Delta T_{main}}{3{,}412} \times \frac{1}{E_{t,elec}} \times ESF$$

Summer Peak Coincident Demand Savings (Electric Water Heating Only)

$$\Delta kW = units \times \frac{UA \times \Delta T_{amb}}{3{,}412} \times \frac{1}{E_{t,elec}} \times ESF \times CF$$

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

$$\Delta MMBtu = units \times \frac{GPD \times 365 \times 8.33 \times \Delta T_{main}}{1{,}000{,}000} \times \frac{1}{E_{t,fuel}} \times ESF$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
GPD	= Gallons per day
DT_{main}	= Average temperature difference between delivered hot water temperature and the supply water temperature in water main (°F)
DT_{amb}	= Average temperature difference between water heater set point temperature and the surrounding ambient air temperature (°F)
UA	= Overall heat loss coefficient (BTU/h-°F)
ESF	= Energy savings factor
E_t	= Water heater thermal efficiency
$_{elec}$	= Property of electrical central DHW system
$_{fuel}$	= Property of fossil fuel central DHW system
CF	= Coincidence factor
365	= Days in one year

8.33 = Specific heat of water; energy required (BTU), to heat one gallon of water by one degree Fahrenheit [BTU/(gal-F)]
3,412 = Conversion factor, one kWh equals 3,412 BTU
1,000,000 = Conversion factor, one MMBtu equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
GPD		From application, or lookup/calculate based on building type, square footage and occupancy from GPD table below.
DT_{main}	$T_{del} - T_{main}$	Average temperature difference between delivered hot water temperature and the supply water temperature in water main (°F).
DT_{amb}	$T_{set} - T_{amb}$	Average temperature difference between water heater set point temperature and the surrounding ambient air temperature (°F).
T_{del}	125	Delivered hot water temperature (°F).[210]
T_{set}		From application.
T_{main}		Supply water temperature in water main (°F). Lookup in Cold Water Inlet Temperature table below based on nearest city.
T_{amb}	70	Surrounding ambient air temperature (°F).[211]
$E_{t,elec}$	0.98	From application. If unknown, use default thermal efficiency of typical electric storage type water heater provided.[212]
$E_{t,fuel}$		From application.
UA	7.85	Overall heat loss coefficient of the baseline condition (BTU/h-°F).[213]
ESF	0.25	Oak Ridge National Laboratory.[214]

[210] Aligned with residential measure set point temperature to normalize default GPD across sectors.
[211] Water heaters are generally located in conditioned or partially conditioned spaces with a typical average temperature of 65°F to 70°F to avoid freezing. A value of 70°F is used for the purposes of estimating tank/ambient air temperature differential, which aligns with standby loss specification testing standards.
[212] Per 10 CFR 431 Subpart G, Appendix B 5.7.1.
[213] Based on computation of heat loss coefficients via conversion equations found in 10 CFR 429, 430, and 431 Docket No. EERE-2015-BT-TP-0007, Energy Conservation Program for Consumer Products and Certain Commercial and Industrial Equipment: Test Procedures for Consumer and Commercial Water Heaters. Heat loss coefficient was equated for two minimally code compliant gas storage water heaters found to be the most typical in terms of storage and input capacity, representing storage type water heaters of between 20 and 55 gallon capacity (40 gallon, 40,000 BTU/h assumed) and between 55 and 120 gallon capacity (75 gallon, 76,000 BTU/h assumed). Results of heat loss coefficient evaluation at these two data points agreed to within 0.3%, so the lower of the two was selected to represent the $UA_{baseline}$ term.
[214] GFX Evaluation, Oak Ridge National Laboratory, August 2000, lower end of the energy savings range (25-30%). Savings are assumed to be comparable to residential application.

Variable	Value	Notes
CF	0.8	

Cold Water Inlet Temperature (T_{main})

Supply water main temperatures vary according to climate and are approximately equal to the annual average outdoor temperature plus 6°F.[215] Supply main temperatures based on the annual outdoor temperature are shown below.

City	Annual average outdoor temperature[216] (°F)	T_{main} (°F)
Albany	49.4	55.4
Binghamton	46.8	52.8
Buffalo	49.1	55.1
Massena	45.1	51.1
NYC	54.7	60.7
Poughkeepsie	50.9	56.9
Syracuse	49.0	55.0

Gallons per Day (GPD)

The average daily hot water usage, expressed in gallons per day, for several commercial facility types is tabulated below. Daily hot water usage can be calculated based on the GPD and site-specific metric in the Rate column, or default values can be referenced directly from the GPD column.

Building Type	GPD	Rate	Notes/Assumptions	Source
Assembly	239	7.02 GPD per 1,000 SF	Assumes 10% hot water, 34,000 SF	EIA[217]: Public Assembly
Auto Repair	25	4.89 GPD per 1,000 SF	Assumes 10% hot water, 5,150 SF	EIA: Other
Big Box Retail	448	3.43 GPD per 1,000 SF	Assumes 10% hot water, 130,500 SF	EIA: Mercantile
Community College	1,520	1.9 GPD per person	Assumes 800 students	NREL[218]: School with Showers
Dormitory	8,600	17.2 GPD per resident	Assumes 500 residents	Water Research Foundation[219]
Elementary School	250	0.5 GPD per student	Assumes 500 students	NREL: School

[215] Burch, Jay and Christensen, Craig, "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory.
[216] Average annual outdoor temperatures taken from NCEI 1991-2020 climate normals.
[217] U.S. Energy Information Administration, 2012 Commercial Buildings Energy Consumption Survey: Water Consumption in Large Buildings, Table WD1. Daily water consumption in large commercial buildings, 2012.
[218] National Renewable Energy Laboratory, Saving Energy in Commercial Buildings: Domestic Hot Water Assessment Guidelines, Table 1. Hot Water Use By Building Type, June 2011.
[219] Water Research Foundation: Residential End Uses of Water, Version 2, April 2016.

Building Type	GPD	Rate	Notes/Assumptions	Source
Fast Food Restaurant	500	500 GPD per restaurant		FSTC[220]: Quick Service
Full-Service Restaurant	2,500	2,500 GPD per restaurant		FSTC: Full Service
Grocery	172	3.43 GPD per 1,000 SF	Assumes 10% hot water, 50,000 SF	EIA: Mercantile
High School	1,520	1.9 GPD per person	Assumes 800 students	NREL: School with Showers
Hospital	16,938	54.42 GPD per 1,000 SF	Assumes 40% hot water, 250,000 SF	EIA: Health Care, Inpatient
Hotel	9,104	45.52 GPD per 1,000 SF	Assumes 40% hot water, 200,000 SF	EIA: Lodging
Large Office	550	1.1 GPD per person	Assumes 500 people	NREL: Office
Large Retail	446	3.43 GPD per 1,000 SF	Assumes 10% hot water, 130,000 SF	EIA: Mercantile
Light Industrial	489	4.89 GPD per 1,000 SF	Assumes 10% hot water, 100,000 SF	EIA: Other
Motel	1,366	45.52 GPD per 1,000 SF	Assumes 40% hot water, 30,000 SF	EIA: Lodging
Multifamily High-Rise	3,440	34.4 GPD per unit	Assumes 100 units, 2 people per unit	Multifamily Baseline Study[221]
Multifamily Low-Rise	413	34.4 GPD per unit	Assumes 12 units, 2 people per unit	Multifamily Baseline Study
Refrigerated Warehouse	86	0.93 GPD per 1,000 SF	Assumes 10% hot water, 92,000 SF	EIA: Warehouse and Storage
Religious	77	7.02 GPD per 1,000 SF	Assumes 10% hot water, 11,000 SF	EIA: Public Assembly
Small Office	110	1.1 GPD per person	Assumes 100 people	NREL: Office
Small Retail	27	3.43 GPD per 1,000 SF	Assumes 10% hot water, 8,000 SF	EIA: Mercantile
University	1,000	0.5 GPD per student	Assumes 2,000 students	NREL: School
Warehouse	465	0.93 GPD per 1,000 SF	Assumes 10% hot water, 500,000 SF	EIA: Warehouse and Storage
Other	Calculate	4.89 GPD per 1,000 SF	Assumes 10% hot water	EIA: Other

Coincidence Factor (CF)

[220] Food Service Technology Center, Design Guide – Energy Efficient Heating, Delivery and Use, Table 1. Typical hot water system cost for restaurants, March 2010.
[221] Residential Statewide Baseline Study of New York State, July 2015. Volume 2: Multifamily Report, Table 8.

The prescribed value for the coincidence factor is 0.8.[222]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a storage type water heater without a DWHR system in a commercial application.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a storage type water heater equipped with DWHR on the main waste drainage line in a commercial application. DWHR units shall comply with CSA B55.2 and shall be tested in accordance with CSA B55.1. Potable water-side pressure loss of DWHR units shall be less than 3 psi.[223]

Operating Hours

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

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

A drain water heat recovery system is installed in a small commercial facility located near Albany. The facility has an electric water heater with a demand of 300 gallons of water per day and a set point temperature of 140ºF. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

$$\Delta kWh = units \times \frac{GPD \times 365 \times 8.33 \times \Delta T_{main}}{3{,}412} \times \frac{1}{E_{t,elec}} \times ESF$$

$$\Delta kW = units \times \frac{UA \times \Delta T_{amb}}{3{,}412} \times \frac{1}{E_{t,elec}} \times ESF \times CF$$

units = 1, from application
GPD = 300, from application
$DT_{main} = T_{del} - T_{main} = 125 - 55.4 = 69.6$
T_{del} from Summary of Variables and Data Sources table
T_{main} from Cold Water Inlet Temperature table based on location from application
$E_{t,elec}$ = 0.98, from Summary of Variables and Data Sources table
ESF = 0.25, from Summary of Variables and Data Sources table
UA = 7.85, from Summary of Variables and Data Sources table
$DT_{amb} = T_{set} - T_{amb} = 140 - 70 = 70$
T_{set} from application

[222] *No source specified – update pending availability and review of applicable references.*
[223] ECCCNYS 2020, Section R403.5.4 Drain Water Recovery Units.

T_{amb} from Summary of Variables and Data Sources table
CF = 0.8, from Summary of Variables and Data Sources table

$$\Delta kWh = 1 \times \frac{300 \times 365 \times 8.33 \times 69.6}{3{,}412} \times \frac{1}{0.98} \times 0.25 = 4{,}746.50\ kWh$$

$$\Delta kW = 1 \times \frac{7.85 \times 70}{3{,}412} \times \frac{1}{0.98} \times 0.25 \times 0.8 = 0.0329\ kW$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

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

Ancillary Electric Savings Impacts

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

References

1. 10 CFR 430.2 Definitions.
   Available from: https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=78ea8c7c6bf5379d6e0fd2b41e335739&mc=true&n=pt10.3.430&r=PART&ty=HTML#se10.3.430_12
2. 10 CFR 430.32 Energy and water conservation standards and their compliance dates.
   Available from: http://www.ecfr.gov/cgi-bin/text-idx?SID=a9921a66f2b4f66a32ec851916b7b9d9&mc=true&node=se10.3.430_132&rgn=div8
3. GFX Evaluation, Oak Ridge National Laboratory, August 2000.
   Available from: http://gfxtechnology.com/Duluth-Triplex.pdf
4. 10 CFR 429, 430, and 431 Docket No. EERE-2015-BT-TP-0007, Energy Conservation Program for Consumer Products and Certain Commercial and Industrial Equipment: Test Procedures for Consumer and Commercial Water Heaters.
   Available from: https://energy.gov/sites/prod/files/2016/08/f33/Water%20Heaters%20Test%20Procedure%20SNOPR.pdf
5. AHRI Directory of Certified Product Performance.
   Available from: https://www.ahridirectory.org/ahridirectory/pages/home.aspx
6. Burch, Jay and Craig Christensen; "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory.
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e=pdf
7. NOAA National Centers for Environmental Information – NCEI 1991-2020 Climate Normals.
Available from: https://www.ncdc.noaa.gov/cdo-web/datatools/normals
8. 10 CFR 429.17 Water heaters.
Available from: https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-429
9. ECCCNYS 2020 Section R403.5.4 Drain Water Heat Recovery Units.
Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-re-residential-energy-efficiency
10. 10 CFR 431 Subpart G – Commercial Water Heaters, Hot Water Supply Boilers and Unfired Hot Water Storage Tanks, Appendix B - Uniform Test Method for Measuring the Standby Loss of Electric Storage Water Heaters and Storage-Type Instantaneous Water Heaters.
Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=e0518d0e0be-fdd3d0f69d20f62691096&mc=true&node=pt10.3.431&rgn=div5#ap10.3.431_1110.b
11. Residential Statewide Baseline Study of New York State, July 2015.
Available from: https://www.nyserda.ny.gov/About/Publications/Evaluation-Reports/Building-Stock-and-Potential-Studies/Residential-Statewide-Baseline-Study-of-New-York-State

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3-21-14	4/9/2021
12-23-13	1/5/2024

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HEATING, VENTILATION AND AIR CONDITIONING (HVAC)

BOILER AND FURNACE - COMBINATION ("COMBI") BOILER AND FURNACE

Measure Description

This measure covers the installation of fossil fuel combination (or "combi") boilers and furnaces, which are defined as high-efficiency, instantaneous water heaters with a heating designation. Combi-boilers are all-in-one high-efficiency space heating systems with integrated capability for providing instantaneous domestic hot water, while combi-furnaces supply both domestic tankless hot water and forced air heating. These units realize energy savings through increased thermal efficiency and by taking cold water straight from the main supply and heating it as needed, which eliminates the need for a separate hot water storage tank and avoids standby losses. Qualifying equipment must be in accordance with ASHRAE Standard 124-2007 (RA 2016).[224] This measure only applies to systems with modulating/staging capability and no water storage tank.

This measure only captures the fossil fuel savings impacts of combi-boilers and combi-furnaces. While electric combi-boilers exist, more investigation and research is required before an approach for estimating associated energy savings can be developed.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = N/A$$

Summer Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = \Delta MMBtu_{SH} + \Delta MMBtu_{DHW}$$

$$\Delta MMBtu_{SH} = units \times \frac{kBTU/h_{in}}{unit} \times \left(\frac{Eff_{ee}}{Eff_{baseline}} - 1\right) \times \frac{EFLH_{heating}}{1{,}000}$$

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

where:

[224] ASHRAE Standard 124-2007 (RA 2016) – Methods of Testing for Rating Combination Space-Heating and Water-Heating Appliances (ANSI Approved).

ΔkWh = Annual electric energy savings
ΔkW = Peak coincident demand electric savings
$\Delta MMBtu$ = Annual fossil fuel energy savings
$\Delta MMBtu_{SH}$ = Annual space heating savings associated with installation of a high-efficiency combi-boiler or combi-furnace
$\Delta MMBtu_{DHW}$ = Annual domestic hot water savings associated with installation of a high-efficiency combi-boiler or combi-furnace
units = Number of measures installed under the program
$kBTU/h_{in}$ = Space heating fuel input rating
$_{baseline}$ = Characteristic of baseline condition
$_{ee}$ = Characteristic of energy efficient condition
Eff = Energy efficiency (0-100%)
$EFLH_{heating}$ = Heating equivalent full-load hours
GPD/unit = Gallons per day of delivered hot water per "combi" unit
ΔT_{main} = Average temperature difference between delivered hot water temperature and the supply water temperature in water main (°F)
E_t = Water heating designation thermal efficiency
UA = Overall heat loss coefficient (BTU/h-°F)
ΔT_{amb} = Average temperature difference between water heater set point temperature and the surrounding ambient air temperature (°F)
8.33 = Specific heat of water; energy required (BTU), to heat one gallon of water by one degree Fahrenheit [BTU/(gal-F)]
365 = Days in one year
1,000 = Conversion factor, one MMBtu equals 1,000 kBTU
8,760 = Hours in one year
1,000,000 = Conversion factor, one MMBtu equals 1,000,000 BTU

Summary of Variables & Data Sources

Variable	Value	Notes/References
$kBTUh_{in}$		Nominal heating input capacity is the nameplate input rating of the unit in kBTU/hr, from application.
$Eff_{baseline}$		See Baseline Efficiencies section below.
Eff_{ee}		From application.
$EFLH_{heating}$		Lookup based on building type and location in Appendix G.
GPD/unit		From application, or lookup/calculate based on building type, square footage and occupancy from GPD table below. If based on values per the table below, divide result by number of units installed.
DT_{main}	T_{del} - T_{main}	Average temperature difference between delivered hot water temperature and the supply water temperature in water main (°F).
DT_{amb}	T_{set} - T_{amb}	Average temperature difference between water heater set point temperature and the surrounding ambient air temperature (°F).

Variable	Value	Notes/References
T_{del}	125	Delivered hot water temperature (°F).[225]
T_{set}		Water heater set point temperature (°F). From application. If unknown use 140°F.[226]
T_{main}		Supply water temperature in water main (°F). Lookup in Cold Water Inlet Temperature table below based on nearest city.
T_{amb}	70	Surrounding ambient air temperature (°F).[227]
$E_{t,baseline}$	0.80	Water heating designation thermal efficiency of the baseline condition.[228]
$UA_{baseline}$	7.85	Overall heat loss coefficient of the baseline condition (BTU/h-°F).[229]

Gallons per Day (GPD)

The average daily hot water usage, expressed in gallons per day, for several commercial facility types is tabulated below. Daily hot water usage can be calculated based on the GPD and site-specific metric in the Rate column, or default values can be referenced directly from the GPD column.

Building Type	GPD	Rate	Notes/Assumptions	Source
Assembly	239	7.02 GPD per 1,000 SF	Assumes 10% hot water, 34,000 SF	EIA[230]: Public Assembly
Auto Repair	25	4.89 GPD per 1,000 SF	Assumes 10% hot water, 5,150 SF	EIA: Other
Big Box Retail	448	3.43 GPD per 1,000 SF	Assumes 10% hot water, 130,500 SF	EIA: Mercantile
Community College	1,520	1.9 GPD per person	Assumes 800 students	NREL[231]: School with Showers
Dormitory	8,600	17.2 GPD per resident	Assumes 500 residents	Water Research Foundation[232]

[225] Aligned with residential measure set point temperature to normalize default GPD across sectors.
[226] Per OSHA recommendations for prevention of Legionella bacterial growth. (https://www.osha.gov/SLTC/etools/hospital/hazards/leg/leg.html)
[227] Water heaters are generally located in conditioned or partially conditioned spaces with a typical average temperature of 65°F to 70°F to avoid freezing. A value of 70°F is used for the purposes of estimating tank/ambient air temperature differential, which aligns with standby loss specification testing standards.
[228] 10 CFR 431.110 (a).
[229] Based on computation of heat loss coefficients via conversion equations found in 10 CFR 429, 430, and 431 Docket No. EERE-2015-BT-TP-0007, Energy Conservation Program for Consumer Products and Certain Commercial and Industrial Equipment: Test Procedures for Consumer and Commercial Water Heaters. Heat loss coefficient was calculated for a minimally code compliant fuel storage water heater found to be the most typical in terms of storage and input capacity, representing storage type water heaters of between 20 and 55 gallon capacity (40 gallon, 40,000 Btu/h assumed). Results of heat loss coefficient evaluation for this assumed baseline is used to represent the $UA_{baseline}$ term.
[230] U.S. Energy Information Administration, 2012 Commercial Buildings Energy Consumption Survey: Water Consumption in Large Buildings, Table WD1. Daily water consumption in large commercial buildings, 2012
[231] National Renewable Energy Laboratory, Saving Energy in Commercial Buildings: Domestic Hot Water Assessment Guidelines, Table 1. Hot Water Use By Building Type, June 2011.
[232] Water Research Foundation: Residential End Uses of Water, Version 2, April 2016.

Building Type	GPD	Rate	Notes/Assumptions	Source
Elementary School	250	0.5 GPD per student	Assumes 500 students	NREL: School
Fast Food Restaurant	500	500 GPD per restaurant		FSTC[233]: Quick Service
Full-Service Restaurant	2,500	2,500 GPD per restaurant		FSTC: Full Service
Grocery	172	3.43 GPD per 1,000 SF	Assumes 10% hot water, 50,000 SF	EIA: Mercantile
High School	1,520	1.9 GPD per person	Assumes 800 students	NREL: School with Showers
Hospital	16,938	54.42 GPD per 1,000 SF	Assumes 40% hot water, 250,000 SF	EIA: Health Care, Inpatient
Hotel	9,104	45.52 GPD per 1,000 SF	Assumes 40% hot water, 200,000 SF	EIA: Lodging
Large Office	550	1.1 GPD per person	Assumes 500 people	NREL: Office
Large Retail	446	3.43 GPD per 1,000 SF	Assumes 10% hot water, 130,000 SF	EIA: Mercantile
Light Industrial	489	4.89 GPD per 1,000 SF	Assumes 10% hot water, 100,000 SF	EIA: Other
Motel	1,366	45.52 GPD per 1,000 SF	Assumes 40% hot water, 30,000 SF	EIA: Lodging
Multifamily High-Rise	3,440	34.4 GPD per unit	Assumes 100 units, 2 people per unit	Multifamily Baseline Study[234]
Multifamily Low-Rise	413	34.4 GPD per unit	Assumes 12 units, 2 people per unit	Multifamily Baseline Study
Refrigerated Warehouse	86	0.93 GPD per 1,000 SF	Assumes 10% hot water, 92,000 SF	EIA: Warehouse and Storage
Religious	77	7.02 GPD per 1,000 SF	Assumes 10% hot water, 11,000 SF	EIA: Public Assembly
Small Office	110	1.1 GPD per person	Assumes 100 people	NREL: Office
Small Retail	27	3.43 GPD per 1,000 SF	Assumes 10% hot water, 8,000 SF	EIA: Mercantile
University	1,000	0.5 GPD per student	Assumes 2,000 students	NREL: School
Warehouse	465	0.93 GPD per 1,000 SF	Assumes 10% hot water, 500,000 SF	EIA: Warehouse and Storage
Other	Calculate	4.89 GPD per 1,000 SF	Assumes 10% hot water	EIA: Other

[233] Food Service Technology Center, Design Guide – Energy Efficient Heating, Delivery and Use, Table 1. Typical hot water system cost for restaurants, March 2010.
[234] Residential Statewide Baseline Study of New York State, July 2015. Volume 2: Multifamily Report, Table 8.

Cold Water Inlet Temperature (T_{main})
Supply water main temperatures vary according to climate and are approximately equal to the annual average outdoor temperature plus 6°F.[235] Supply main temperatures based on the annual outdoor temperature are shown below.

City	Annual average outdoor temperature[236] (°F)	T_{main} (°F)
Albany	49.4	55.4
Binghamton	46.8	52.8
Buffalo	49.1	55.1
Massena	45.1	51.1
NYC	54.7	60.7
Poughkeepsie	50.9	56.9
Syracuse	49.0	55.0

Coincidence Factor (CF)

The prescribed value for the coincidence factor is N/A. This measure is not anticipated to have electric impacts.

Baseline Efficiencies from which Energy Savings are Calculated

Space Heating Component
The baseline condition for the space heating component of combi-boilers and combi-furnaces shall be consistent with code requirements for commercial fossil fuel-fired furnaces and boilers defined by the Code of Federal Regulations (CFR) and subsequently adopted by the Energy Conservation Construction Code of New York State. The table below establishes the prescribed baseline efficiency values for combi-furnaces and combi-boilers by input capacity. For combi-furnaces < 225 kBTU/h, selection of efficiency rating (AFUE or E_t) should align with the rating specification of the qualifying equipment.

For LMI applications, existing condition baseline shall be established based on nameplate efficiency or efficiency measured through combustion analysis.

Equipment Type	Size Range	ECCCNYS Minimum Efficiency for Climate Zones 4, 5 and 6
Warm Air Furnace, Gas Fired	< 225 kBTU/h	0.80 AFUE or 0.80 E_t
	≥ 225 kBTU/h	0.80 Et
Warm Air Furnace, Oil Fired	< 225 kBTU/h	0.83 AFUE or 0.80 E_t
	≥ 225 kBTU/h	0.81 Et
Warm Air Unit Heaters, Gas Fired	All Capacities	0.80 Ec

[235] Burch, Jay and Christensen, Craig, "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory.
[236] Average annual outdoor temperatures taken from NCDC 1991-2020 climate normals.

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

<u>Domestic Hot Water Component</u>
The baseline condition is a standard efficiency storage type water heater with a thermal efficiency of 80%[237] and heat loss coefficient of 7.85 BTU/hr-°F.[238]

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a combi-boiler unit with a heating designation efficiency of 90% AFUE, E_t or E_c or greater or a combi-furnace unit with a heating designation efficiency of 92% AFUE or E_t or greater. Qualifying systems must be equipped with modulating/staging capability and no water storage tank. Units shall be in accordance with ASHRAE Standard 124-2007 (RA 2016).[239]

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[237] 10 CFR 431.110 (a).
[238] Based on computation of heat loss coefficients via conversion equations found in 10 CFR 429, 430, and 431 Docket No. EERE-2015-BT-TP-0007, Energy Conservation Program for Consumer Products and Certain Commercial and Industrial Equipment: Test Procedures for Consumer and Commercial Water Heaters. Heat loss coefficient was calculated for a minimally code compliant gas storage water heater found to be the most typical in terms of storage and input capacity, representing storage type water heaters of between 20 and 55 gallon capacity (40 gallon, 40,000 Btu/h assumed). Results of heat loss coefficient evaluation for this assumed baseline is used to represent the $UA_{baseline}$ term.
[239] ASHRAE Standard 124-2007 (RA 2016) – Methods of Testing for Rating Combination Space-Heating and Water-Heating Appliances (ANSI Approved).

Operating Hours

Heating equivalent full-load hours were calculated from a DOE-2.2 simulation of prototypical commercial buildings. Operating hour assumptions for the prototypical building models are described in Appendix A. The heating EFLH for commercial buildings in NY are shown in Appendix G.

Domestic hot water heaters are assumed to be available for operation 8,760 hours per year, and it is assumed standby losses in the baseline case are incurred 8,760 hours per year.

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

A "combi" boiler with 199 kBTU/h and 95% AFUE is installed in a small office building located near Albany. The conditions prior to installation include a gas-fired warm air furnace and gas-fired storage type water heater. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are not applicable. Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta MMBtu = \Delta MMBtu_{SH} + \Delta MMBtu_{DHW}$$

$$\Delta MMBtu_{SH} = units \times \frac{kBTU/h_{in}}{unit} \times \left(\frac{Eff_{ee}}{Eff_{baseline}} - 1\right) \times \frac{EFLH_{heating}}{1{,}000}$$

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

units = 1, from application
($kBTU/h_{in}$)/unit = 199, from application
Eff_{ee} = 0.9, from application
$Eff_{baseline}$ = 0.80, from Baseline Efficiencies section based on equipment type and size from application
$EFLH_{heating}$ = 747, from Appendix G based on HVAC system, building type, and location from application
GPD/unit = 110, from Gallons per Day table based on building type from application
$\Delta T_{main} = T_{del} - T_{main} = 125 - 55.4 = 69.6$
T_{del} from Summary of Variables and Data Sources table
T_{main} from Cold Water Inlet Temperature lookup table based on location from application
$UA_{baseline}$ = 7.85, from Summary of Variables and Data Sources table
$E_{t,baseline}$ = 0.8, from Summary of Variables and Data Sources table
$\Delta T_{amb} = T_{set} - T_{amb} = 140 - 70 = 70$
T_{set} from Summary of Variables and Data Sources table
T_{amb} from Summary of Variables and Data Sources table

$$\Delta MMBtu_{SH} = 1 \times 199 \times \left(\frac{0.95}{0.80} - 1\right) \times \frac{747}{1{,}000} = 27.87\ MMBtu$$

$$\Delta MMBtu_{DHW} = 1 \times \left[\frac{110 \times 365 \times 8.33 \times 69.6}{1{,}000{,}000} \times \left(\frac{1}{0.8} - \frac{1}{0.95}\right) + \frac{7.85}{0.8} \times \frac{70}{1{,}000{,}000} \times\ 8{,}760\right] = 10.61\ MMBtu$$

$$\Delta MMBtu = 27.87 + 10.61 = 38.48\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

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

Ancillary Electric Savings Impacts

High efficiency furnaces may be packaged with high efficiency cooling equipment and/or electronically commutated blower motors, which may provide electricity savings. Draft fans, when present, will increase electricity consumption.

References

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Record of Revision

Record of Revision Number	Issue Date
3-19-12	3/29/2019
12-23-14	1/5/2024

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Heat Pump – Water-to-Air Ground Source (GSHPs) in Systems with Central Pumping

Measure Description

This measure covers the installation of multiple ENERGY STAR® certified Ground Source Heat Pump (GSHP) units combined into a system with a closed loop ground heat exchanger field and with central pumping. The GSHP units are water-to-air heat pumps with ducting to provide space heating and cooling to individual zones within a commercial building, including multifamily. The system can optionally include water-to-water heat pumps for domestic water heating. Methods for calculating annual DHW energy savings are presented separately below.

This measure applies to GSHPs in building applications with multiple heat pump units served by centralized ground loop pumping. The calculations only consider simple baseline conditions with separate zone-by-zone space heating and cooling equipment. They do not consider baseline conditions with centralized air handlers serving multiple zones, with terminal reheat, or with other forms of variable air volume terminals. Further, this measure only applies to single-owner facilities with closely-grouped buildings and does not consider multi-owner district, community, or shared loop systems with multiple levels of pumping and loop flow control.

The GSHP analysis associated with this measure is based on several assumptions consistent with best practice design for a quality GSHP installation:

- Building heating and cooling loads shall be calculated, and systems shall be sized in accordance with applicable federal, state, local and municipal codes and standards.

- GSHP units shall be sized in accordance with zone loads calculated with appropriate commercial load calculations, such as from the 2017 ASHRAE Fundamentals.[240]

- The ground loop heat exchanger is adequately sized and installed properly to allow the GSHP to meet the peak heating and peak cooling loads. The peak heating and cooling loads pertain to the total of zone loads established above.

- The design loop pumping power must be less than 60 Watts per nominal installed ton[241], or 7.5 HP per 100 tons, which corresponds to a grade of “B” according to the ASHRAE GSHP Design Guide (Kavanaugh and Rafferty 2015).

- The GSHP efficiency is rated in accordance with ISO 13256-1, and AHRI-certified performance ratings are provided by the manufacturer showing the efficiency and capacity of the unit under full and part load conditions.

This measure applies for the following types of GSHP central pumping options:

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[240] 2017 ASHRAE Fundamentals Handbook, Chapter 18. Non-residential heating and cooling loads.
[241] The nominal tons are based on the rated cooling capacity at full load GLHP conditions as per ISO Standard 13256-1.

- Traditional variable speed control that varies pump speed to maintain differential pressure based on a sensor installed at a remotely located GSHP unit,
- Staged (two-speed) pumping control,
- “Sensorless” variable speed control where internal pump controls are used to approximately maintain constant pressure across the pump, or
- Hybrid options that combine central loop variable speed pumping with individual cartridge[242] circulators on each heat pump unit.

For the first 3 options, only the central pumping energy is calculated with no pumping adjustment to the heat pump efficiency ($F_{pump,full}$ & $F_{pump,part}$ should be set to 1.0). For the hybrid option, both central pumping energy as well as an adjustment to heat pump efficiency are required ($F_{pump,full}$ & $F_{pump,part}$ come from the table below).

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Note: The algorithms below address energy impacts associated with space conditioning load only. See the *Methods for Calculating Annual Domestic Hot Water Energy Savings from a Dedicated Water-to-Water Heat Pump* section of this measure for estimating DHW savings associated with these systems.

Annual Electric Energy Savings

$$\Delta kWh = \left[\frac{BCL}{1{,}000} \times \left(\frac{F_{ElecCool}}{EER_{season,baseline}} - \frac{1}{EER_{season,ee}}\right) \times BEFLH_{cooling}\right] + \left[\frac{BHL}{3{,}412} \times \left(\frac{F_{ElecHeat}}{COP_{season,baseline}} - \frac{1}{COP_{season,ee}}\right) \times BEFLH_{heating} - \left[F_{pump,avg} \times kW_{pump,design} \times 8760\right]\right]$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \frac{BCL}{1{,}000} \times \left(\frac{F_{ElecCool}}{EER_{peak,baseline}} - \frac{1}{EER_{GSHP,full,,ee}}\right) \times CF - kW_{pump,design}$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = \frac{BHL}{1{,}000{,}000} \times \frac{F_{FuelHeat}}{AFUE_{baseline}} \times BEFLH_{heating}$$

where:

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

[242] Cartridge circulators are inline, self-contained pumps or circulators.

$\Delta MMBtu$ = Annual fossil fuel energy savings
AFUE = Annual fuel utilization efficiency, seasonal efficiency for fuel heat equipment
$_{baseline}$ = Characteristic of baseline condition
BCL = Building Cooling "Block" Load at design conditions (BTU/h)
$BEFLH_{cooling}$ = Cooling equivalent full-load hours based on building design load
$BEFLH_{heating}$ = Heating equivalent full-load hours based on building design load
BHL = Building Heating "Block" Load at design conditions (BTU/h)
CF = Coincidence Factor
COP = Coefficient of performance, ratio of output energy/input energy
COP_{season} = Coefficient of performance on a seasonal basis. Adjusted to account for fan and pump power.
$_{ee}$ = Characteristic of energy efficient condition
EER = Energy efficiency ratio (BTU/watt-hour)
$EER_{GSHP,full}$ = Full load energy efficiency ratio (BTU/watt-hours). Refers to GLHP-rated condition for closed loop GSHP systems.
EER_{season} = Energy efficiency ratio (BTU/watt-hour) at part-load seasonally-adjusted for fan and pump power, for baseline conditions or for energy efficient case, BTU/watt-hour
$F_{ElecCool}$ = Electric cooling factor; used to account for the presence or absence of an electric cooling system
$F_{ElecHeat}$ = Electric heating factor; used to account for the presence or absence of an electric heating system
$F_{FuelHeat}$ = Fossil fuel heating; used to account for the presence or absence of a fossil fuel heating system
$_{peak}$ = Peak rating condition
SEER = Seasonal average energy efficiency ratio over the cooling season, BTU/watt-hour, (used for average U.S. location/region)
$kW_{pump,\ design}$ = Pumping power at the design or full speed loop flowrate, kW
$F_{pump,\ avg}$ = Average pumping power percentage over the year, % or fraction
8760 = Number of hours in a year
3,412 = Conversion factor, one kWh equals 3,412 BTU
1,000 = Conversion factor, one kW equals 1,000 Watts
1,000,000 = Conversion factor, (BTU/MMBtu), one MMBtu equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
BCL		Building cooling block load at design conditions determined by appropriate commercial load estimating method. Block load is the simultaneous or coincident peak load of all thermal zones (2017 ASHRAE Fundamentals, Chapter 18).
BHL		Building heating load at design conditions determined by appropriate commercial load estimating method. Block load is the simultaneous or coincident peak load of all zones (2017 ASHRAE Fundamentals, Chapter 18).
$F_{ElecCool}$		If an electric cooling system is present, set equal to 1. Otherwise, set equal to 0.

Variable	Value	Notes
$F_{ElecHeat}$		If an electric heating system is present, set equal to 1. Otherwise, set equal to 0.
$F_{FuelHeat}$		If a fossil fuel-fired heating system is present, set equal to 1. Otherwise, set equal to 0.
$EER_{season,baseline}$		Seasonal electric cooling energy efficiency rating of baseline equipment. See Baseline Efficiency section below for details.
$EER_{peak,baseline}$		Electric cooling energy efficiency rating of baseline equipment. See Baseline Efficiency section below for details.
$EER_{season,ee}$		Energy efficiency ratio from the manufacturer's catalog data AHRI ratings adjusted to account for applied fan and pump power. See Compliance Efficiency section below for details.
$EER_{GSHP,full}$		Full load energy efficiency ratio at AHRI rated conditions. Corresponds to GLHP-rated condition with fluid temperature of 77ºF for closed loop systems.
$AFUE_{baseline}$		Annual fuel utilization efficiency, seasonal energy efficiency for fuel heating equipment. See Baseline Efficiency section below for details.
$COP_{season,baseline}$		Electric heating energy efficiency rating of baseline equipment. See Baseline Efficiency section below for details.
$COP_{season,ee}$		Coefficient of performance (ratio of heat delivered to energy input to the heat pump unit) from the manufacturer's catalog data adjusted to account for applied fan and pump power. See Compliance Efficiency section below for details.
$BEFLH_{cooling}$		Lookup based on building type, vintage and location from table below.
$BEFLH_{heating}$		Lookup based on building type, vintage and location from table below.
$kW_{pump,design}$		The power consumption of the pump motor (and variable speed drive) when the central loop pump provides the design or full speed flowrate, kW.
$F_{pump,avg}$		The average pumping power across the year, lookup based on diversity and bypass flow from table below.

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.69 in multifamily applications[243] and 0.8 in commercial and industrial applications.[244]

Baseline Efficiencies from which Energy Savings are Calculated

[243] 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.

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

The baselines used in this measure are determined by the type of equipment that would have been installed without the influence of the program supporting the installation of this measure. This allows for an analysis that does not depend on a typical ‘like-for-like’ replacement scenario.

For LMI applications, existing condition baseline shall be established based on nameplate or measured efficiency.

Tables are provided below to show the baseline efficiencies for appropriate Electric Heating and Cooling System Baseline Efficiencies, and appropriate Fossil Fuel Fired Heating System Baseline Efficiencies.

Federal energy conservation standards[245] effective January 1, 2018 for small, large and very large package air conditioning and heating equipment are more stringent than NYS and NYC codes. These cases are denoted with footnotes in the table below.

Electric Cooling System Baseline Efficiencies

Unitary Air Conditioners				
Equipment Type	**Size Category (Cooling Capacity)**	**Heating Section Type**	**Subcategory or Rating Condition**	**Baseline Efficiency**
Air conditioners (air cooled)	< 65,000 BTU/h (single phase)	All	Split System	11.2 EER 13.0 SEER 11.4 EER2 13.4 SEER2
			Single Package	11.8 EER 14.0 SEER 11.4 EER2 13.4 SEER2
Through-the-wall (air cooled)	≤ 30,000 BTU/h (single phase)	All	Split System	10.6 EER 12.0 SEER
			Single Package	10.6 EER 12.0 SEER
Small-duct high-velocity (air cooled)	< 65,000 BTU/h (single phase)	All	Split System	9.9 EER 11.0 SEER

245 10 CFR 431.97 (Table 3).

Unitary Air Conditioners				
Equipment Type	**Size Category (Cooling Capacity)**	**Heating Section Type**	**Subcategory or Rating Condition**	**Baseline Efficiency**
Air conditioners (air cooled)	≥ 65,000 BTU/h and < 135,000 BTU/h[246]	Electric Resistance (or None)	Split System and Single Package	11.2 EER 12.9 IEER
		All Other	Split System and Single Package	11.0 EER 12.7 IEER
	≥ 135,000 BTU/h and < 240,000 BTU/h	Electric Resistance (or None)	Split System and Single Package	11.0 EER 12.4 IEER
		All Other	Split System and Single Package	10.8 EER 12.2 IEER
	≥ 240,000 BTU/h and < 760,000 BTU/h	Electric Resistance (or None)	Split System and Single Package	10.0 EER 11.6 IEER
		All Other	Split System and Single Package	9.8 EER 11.4 IEER
	≥ 760,000 BTU/h	Electric Resistance (or None)	Split System and Single Package	9.7 EER 11.2 IEER
		All Other	Split System and Single Package	9.5 EER 11.0 IEER

<u>Electric Cooling and Heating System Baseline Efficiencies for Package Terminal Equipment</u>

Equipment Type	**Size Category (Input)**	**Subcategory or Rating Condition**	**Minimum Efficiency ECCCNYS[247]**
PTAC (Cooling Mode) Standard Size	All Capacities	95°F db Outdoor Air	EER = 14.0 - (0.300 × Cap/1,000)
PTAC (Cooling Mode) Replacements/ Nonstandard Size[248]	All Capacities	95°F db Outdoor Air	EER = 10.9 - (0.213 × Cap/1,000)

[246] For equipment with ≥65,000 BTU/h and <135,000 BTU/h cooling capacity, IEER values are taken from 10 CFR 431.97 (Table 3).
[247] "Cap" = The rated cooling capacity of the project in BTU/h. If the unit's capacity is less than 7,000 BTU/h, use 7,000 BTU/h in the calculation. If the unit's capacity is greater than 15,000 BTU/h, use 15,000 BTU/h in the calculations."
[248] Replacement/Nonstandard size units must be factory labeled as follows: "MANUFACTURED FOR REPLACEMENT APPLICATIONS ONLY; NOT TO BE INSTALLED IN NEW CONSTRUCTION PROJECTS." Replacement/Nonstandard size efficiencies apply only to units being installed in existing sleeves having an external wall opening of less than 16 in. high or less than 42 in. wide and having a cross-sectional area less than 670 in.

Equipment Type	Size Category (Input)	Subcategory or Rating Condition	Minimum Efficiency ECCCNYS[247]
PTHP (Cooling Mode) Standard Size	All Capacities	95°F db Outdoor Air	EER = 14.0 - (0.300 × Cap/1,000)
PTHP (Cooling Mode) Replacements/ Non-standard Size	All Capacities	95°F db Outdoor Air	EER = 10.8 - (0.213 × Cap/1,000)
PTHP (Heating Mode) Standard Size	All Capacities	—	NYS: COP = 3.2 – (0.026 × Cap/1,000) NYC: COP = 3.7 – (0.052 × Cap/1,000)
PTHP (Heating Mode) Replacements/ Non-standard Size	All Capacities	—	COP = 2.9 - (0.026 × Cap/1,000)

Fossil Fuel Fired Heating System Baseline Efficiencies: Systems Serving Single Units [249]

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

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

Equipment Type	Size Range	ECCCNYS Minimum Efficiency for Climate Zones 4, 5 and 6
Warm Air Furnace, Gas Fired	< 225 kBTU/h	0.80 AFUE
	≥ 225 kBTU/h	0.80 Et
Warm Air Furnace, Oil Fired	< 225 kBTU/h	0.83 AFUE
	≥ 225 kBTU/h	0.81 Et
Warm Air Unit Heaters, Gas Fired	All Capacities	0.80 Ec
Warm Air Unit Heaters, Oil Fired	All Capacities	0.80 Ec

[249] 10 CFR 430.32(e).

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

For scenarios where the baseline heating system is electric resistance heat, the baseline seasonal efficiency is assumed to be a COP of 1.0. For scenarios with PTHPs as the baseline heating system, we assume the rated heating efficiency is derated[250] to account for mix of electric resistance and PTHP operation:

$$COP_{season,baseline} = COP_{rated} \times F_{PTHP}$$

Where F_{PTHP} = 0.55 for NYC and 0.45 for upstate locations

For cooling, the seasonal average efficiency ($EER_{season,base}$), should be set to the values of SEER for residential equipment or IEER for commercial packaged equipment, as appropriate. For PTAC or PTHP systems use rated EER times a factor of 1.15.[251]

For scenarios where there is new construction or substantial renovation, the baseline is assumed to be a gas fired warm air furnace with a central air conditioning system when natural gas service is available at the project site.

Replacement of room air conditioners is not addressed in this analysis. To capture savings associated with removal of room air conditioners, refer to the Air Conditioner – Room (RAC) Recycling measure in the Single and Multi-Family Residential Measures section of this TRM.

[250] As per Tables 11 and 12 from NYSERDA report "High-Performance Packaged Terminal Heat Pump Market and Development Research", Report 18-27, October 2018 completed by Taitem Engineering. Effective annual COP with resistance heat backup are 1.76 in NYC and 1.32 in Syracuse with a change-over temperature of 35°F. This equates to derating factors of 0.55 for NYC and 0.45 for Upstate NY assuming a rated COP of 3.2 in NYC and 3.0 upstate.

[251] 1.15 is the typical ratio of SEER and EER (or IEER and EER) given in the tables above.

Central Loop Pumping Energy Use for GSHP Systems

In larger GSHP systems with centralized pumping, the loop flow is modulated in response to the building load (or the number of GSHP units operating). Each GSHP unit typically has a two-way (or ON/OFF) valve that restricts loop flow through the unit when it is off.[252] As a result, less loop flow is required at lightly-load conditions when fewer GSHP units are operating, so pumping power is significantly reduced.

The factor $F_{pump,avg}$ indicates the average fraction of the design or full power across the year. The design power is defined as the electric power required to provide the design or maximum loop flow rate ($kW_{pump,design}$). The table below provides values of $F_{pump,avg}$ based on climate cities as well as various design and operating factors. The operating factors include the type of pumping system, the amount of load diversity and the amount of bypass flow in the loop. This table was developed using a bin analysis as described in a White Paper.[253] These design and operating factors are discussed below:

- The type of loop flow modulation can include: 1) Traditional variable speed drive (VSD) driven pump controlled to maintain the differential pressure difference at a remote location in the system, 2) a staged pumping system, or 3) a sensorless VSD pump that maintains a constant pressure difference across the pump without using a pressure sensor (see the White Paper).
- Variable speed loops may require that some bypass flow be provided so that the loop pumps can continue to operate even when all the heat pumps are off. Bypass flow can be provided by leaving off two-way valves on some heat pump units or by providing fixed bypass plumbing from the supply to the return side of the loop. The % of bypass flow affects the minimum allowable flow (and therefore the minimum pumping power). The table includes bypass flows ranging from 30 to 60%.
- The load diversity in the system also affects the pumping energy use. Since each heat pump is sized to meet the local zone loads, it is unlikely that every heat pump unit will be operating at the same time, even at design conditions. The table considers the case with modest diversity (e.g., 80/90% of the maximum loop flow at cooling / heating design conditions) as well as the case with more diversity (e.g., 60/70% of the maximum loop flow at cooling / heating design conditions). The design loop flow can often be less than the theoretical maximum flow with every heat pump operating, which effects the diversity factor. We recommend that modest diversity (80/90%) be used when the design loop flow is less than the maximum theoretical flow. Otherwise use 60/70% diversity. The White Paper provides further guidance on situations where load diversity is likely to occur.

[252] If the GSHP unit is dual-stage or variable speed, then a modulating valve should be used to maintain a constant loop temperature difference across the unit.

[253] Henderson, H. 2020. White Paper Savings Calculations for Large Ground Source Heat Pumps with Central Pumping, For application in Multi-Family Buildings and Other Commercial Applications. Prepared for the New York State Energy Research and Development Authority (NYSERDA) and the New York State Department of Public Service. November.

Tables for $F_{pump,avg}$ Based on Location and Other Factors

	Albany	Bing-hamton	Buffalo	Massena	New York City	Pough-keepsie	Syracuse
	Bypass Flow = 30% (10% min Power) & Diversity = 80%/90%						
Traditional VSD	18.1%	19.5%	19.5%	18.6%	19.2%	20.7%	19.1%
Two-Stage	42.6%	42.9%	43.1%	41.6%	40.9%	44.5%	43.0%
Sensorless VSD	19.0%	20.5%	20.5%	19.5%	20.1%	21.7%	20.0%
	Bypass Flow = 40% (13% min Power) & Diversity = 80%/90%						
Traditional VSD	19.7%	21.1%	21.1%	20.4%	20.7%	22.4%	20.6%
Two-Stage	42.6%	42.9%	43.1%	41.6%	40.9%	44.5%	43.0%
Sensorless VSD	20.7%	22.2%	22.1%	21.4%	21.8%	23.5%	21.7%
	Bypass Flow = 50% (22% min Power) & Diversity = 80%/90%						
Traditional VSD	25.6%	26.8%	26.7%	26.3%	26.2%	28.0%	26.2%
Two-Stage	42.6%	42.9%	43.1%	41.6%	40.9%	44.5%	43.0%
Sensorless VSD	26.8%	28.1%	28.0%	27.6%	27.5%	29.4%	27.5%
	Bypass Flow = 60% (33% min Power) & Diversity = 80%/90%						
Traditional VSD	34.3%	35.4%	35.2%	35.0%	34.7%	36.5%	34.8%
Two-Stage	42.6%	42.9%	43.1%	41.6%	40.9%	44.5%	43.0%
Sensorless VSD	36.1%	37.2%	37.0%	36.8%	36.4%	38.3%	36.5%
	Bypass Flow = 30% (10% min Power) & Diversity = 60%/70%						
Traditional VSD	13.0%	13.7%	13.7%	13.4%	13.4%	14.7%	13.4%
Two-Stage	34.0%	35.1%	35.1%	35.0%	34.2%	36.6%	33.8%
Sensorless VSD	13.7%	14.4%	14.4%	14.1%	14.1%	15.4%	14.1%
	Bypass Flow = 40% (13% min Power) & Diversity = 60%/70%						
Traditional VSD	15.2%	15.9%	15.8%	15.6%	15.5%	16.8%	15.5%
Two-Stage	34.0%	35.1%	35.1%	35.0%	34.2%	36.6%	33.8%
Sensorless VSD	16.0%	16.7%	16.6%	16.4%	16.2%	17.6%	16.3%
	Bypass Flow = 50% (22% min Power) & Diversity = 60%/70%						
Traditional VSD	22.4%	22.9%	22.8%	22.8%	22.6%	23.7%	22.6%
Two-Stage	34.0%	35.1%	35.1%	35.0%	34.2%	36.6%	33.8%
Sensorless VSD	23.5%	24.1%	23.9%	23.9%	23.7%	24.9%	23.7%
	Bypass Flow = 60% (33% min Power) & Diversity = 60%/70%						
Traditional VSD	32.6%	32.8%	32.7%	32.8%	32.7%	33.5%	32.7%
Two-Stage	34.0%	35.1%	35.1%	35.0%	34.2%	36.6%	33.8%
Sensorless VSD	34.3%	34.5%	34.3%	34.5%	34.4%	35.2%	34.3%

Compliance Efficiency from which Incentives are Calculated

The compliance condition is an ENERGY STAR® certified GSHP heat pump system as defined in the Measure Description section above. The formulas adjust performance for closed loop systems to an average entering water temperature for both heating and for cooling. For small residential systems the average entering temperatures are approximately 40°F for heating and 77°F for cooling. For large GSHP systems, the user must specify the average entering water temperature for heating ($EWT_{avg,h}$) as well as for cooling ($EWT_{avg,c}$). Temperatures for large buildings are typically 5 to 15°F higher than the residential / small systems averages in heating and 10 to 20°F higher than the residential / small systems averages in cooling. Some loop sizing software can provide the average values. If only the design temperatures from the ground loop sizing calculations are known (EWT_{max} and EWT_{min}), then an approximate assumption would be:

$EWT_{avg,h} = EWT_{min} + 10°F$

$EWT_{avg,c} = EWT_{max} - 10°F$

The formulas determine the average seasonal cooling efficiency ($EER_{season,ee}$) and the average seasonal heating efficiency ($COP_{season,ee}$) for a GSHP system with a two-stage or variable speed compressor. For single-stage units the part load values are omitted and $F_{full} = 1$ & $F_{part} = 0$

$$EER_{season,ee} = \Big[\Big(F_{full} \times EER_{GLHP,full} \times \Big(1 + 0.01 \times \big(77 - EWT_{avg,c}\big)\Big) \times F_{pump,full}\Big) + \Big(F_{part} \times EER_{GLHP,part} \times \Big(1 + 0.01 \times \big(68 - EWT_{avg,c}\big)\Big) \times F_{pump,part}\Big)\Big] \times F_{dist,c}$$

$$COP_{season,ee} = \Big[\Big(F_{full} \times COP_{GLHP,full} \times \Big(1 + 0.01 \times \big(EWT_{avg,h} - 32\big)\Big) \times F_{pump,full}\Big) + \Big(F_{part} \times COP_{GLHP,part} \times \Big(1 + 0.01 \times \big(EWT_{avg,h} - 41\big)\Big) \times F_{pump,part}\Big)\Big] \times F_{dist,h}$$

where:

$COP_{GLHP,full}$	= Rated COP of the unit at GLHP full load heating conditions
$COP_{GLHP,part}$	= Rated COP of the unit at GLHP part load heating conditions
$EER_{GLHP,full}$	= Rated EER of the unit at GLHP full load cooling conditions
$EER_{GLHP,part}$	= Rated EER of the unit at GLHP part load cooling conditions
$EWT_{avg,h}$	= The average entering loop temperature in the heating season
$EWT_{avg,c}$	= The average entering loop temperature in the cooling season
$F_{dist,c}$	= Factor to adjust the cooling efficiency to account for additional fan power
$F_{dist,h}$	= Factor to adjust the heating efficiency to account for additional fan power
F_{full}	= Seasonal weighting factor for full load efficiency
F_{part}	= Seasonal weighting factor for part load efficiency
$F_{pump, part}$	= Factor to adjust part load efficiency to account for additional pumping power
$F_{pump,full}$	= Factor to adjust full load efficiency to account for additional pumping power
0.01	= Correction for fractional change in EER or COP per each 1°F in entering loop temperature[254]

[254] Correction for % change in EER or COP as the entering fluid temperature changes by 1°F. Observed from published performance data as well as in the IGSHPA Design Manual.

Summary of Variables and Data Sources

Variable	Value	Source
$COP_{GLHP,full}$		The rated COP of the unit at GLHP full load (or standard) heating conditions from ASHRAE/ISO 13256-1. This value is certified by AHRI and is available in the product directory. It corresponds to an entering loop temperature of 32°F.
$COP_{GLHP,part}$		The rated COP of the unit at GLHP part load heating conditions from ASHRAE/ISO 13256-1. This value is certified by AHRI and is available in the product directory. It corresponds to an entering loop temperature of 41°F.
$EER_{GLHP,full}$		The rated EER of the unit at GLHP full load (or standard) cooling conditions from ASHRAE/ISO 13256-1. This value is certified by AHRI and is available in the product directory. It corresponds to an entering loop temperature of 77°F.
$EER_{GLHP,part}$		The rated EER of the unit at GLHP part load cooling conditions from ASHRAE/ISO 13256-1. This value is certified by AHRI and is available in the product directory. It corresponds to an entering loop temperature of 68°F.
$EWT_{avg,h}$		The average entering loop temperature in the heating season, typically between 45 and 55°F for larger GSHP systems.
$EWT_{avg,c}$		The average entering loop temperature in the cooling season, typically between 60 and 80°F for larger GSHP systems.
EWT_{min}		The minimum expected entering loop temperature in the heating season, from the ground loop sizing calculations.
EWT_{max}		The maximum expected entering loop temperature in the cooling season, from the ground loop sizing calculations.
$F_{dist,c}$		Factor to adjust the cooling efficiency to account for additional fan power that would be required, beyond the fan power corresponding to zero static in rated COP. Choose the appropriate factor from the Distribution Correction Factors table below.
$F_{dist,h}$		Factor to adjust the heating efficiency to account for additional fan power that would be required, beyond the fan power corresponding to zero static in rated COP. Choose the appropriate factor from the Distribution Correction Factors table below.
F_{full}	0.25	Seasonal weighting factor for full load efficiency = 0.25, for two-stage and variable speed GSHP units. Based in part on observed mix of low and high stage operation from field testing.[255] For single stage use 1.0.
F_{part}	0.75	Seasonal weighting factor for part load efficiency = 0.75, for two-stage and variable speed GSHP units. Based in part on observed mix of low and high stage operation from field testing.[256] For single stage use 0.

[255] New York State Energy Research and Development Authority (NYSERDA) 2017. “Analysis of Water Furnace Geothermal Heat Pump Sites in New York State with Symphony Monitoring System,” NYSERDA Report Number 18-03. Prepared by CDH Energy Corp., Cazenovia, NY. nyserda.ny.gov/publications.
[256] Ibid.

Variable	Value	Source
$F_{pump,full}$		Factor to adjust the full load efficiency to account for additional pumping power used by the system. Choose the appropriate factor from Pumping Power Adjustment Factor table below.
$F_{pump,part}$		Factor to adjust the part load efficiency to account for additional pumping power used by the system. Choose the appropriate factor from Pumping Power Adjustment Factor table below.

Loop Pumping Power Correction Factor ($F_{pump,full}$ and $F_{pump,part}$)
These correction factors are not required when centralized pumping is used with two-way valves on each heat pump. In that case set $F_{pump,full}$ and $F_{pump,part}$ to 1.0.

If the GSHP system includes central loop pumps AND also uses cartridge circulators on each GSHP unit (instead of two-way valves), then these correction factors must be applied. The discussion of pumping Watts below only applies to the cartridge circulator/pump and NOT to the central pumps.

A correction factor for cartridge pumps ($F_{pump,full}$ and $F_{pump,part}$) is required because the rated efficiency values only include the pumping energy associated with the water-side pressure drop through the heat pump unit (typically about 5-10 Watts per nominal ton). Actual pumping power is much higher. The ASHRAE GSHP Design Guide (Kavanaugh and Rafferty 2015) developed a grading system that assigns scores based on the amount of pumping power per installed ton. For instance, it gives a grade of "A" to system that uses 45 Watts per nominal ton and a grade of "B" to a system that uses 60 Watts per nominal ton.

Analysis of observed pumping power from 45 to 75 Watts/ton was performed to determine the impact of loop pumping power on efficiency. Results are shown in the Pumping Factors table below.

Pumping Power Adjustment Factors for Cartridge Pumps on each GSHP unit
Different factors are required for different loop pumping power levels and loop pump control strategies. For part load performance there are multiple ways to control the pump at low stage:

- the pump can maintain constant flow regardless of compressor stage.
- the pump stages flow in proportion to the compressor capacity.
- the pump can be variable speed and modulate with the variable speed compressor.

A constant speed loop pump with a staged or variable speed GSHP unit results in poor performance since the pump power becomes a relatively larger portion of total power at low stage. Variable speed pumping with a variable speed compressor results in the best performance. The penalty for constant speed pumping is highest for units with variable speed compressors. The last consideration is the low-to-high capacity ratio (CR), which can be calculated as follows:

$$CR = \frac{QC_{GLHP,part}}{QC_{GLHP,full}}$$

where:

CR = Capacity ratio of part-load cooling capacity to full-load heating capacity.
$QC_{GLHP,part}$ = Part-load cooling capacity rating from AHRI certificate.
$QC_{GLHP,full}$ = Full-load heating capacity rating from AHRI certificate.

The values of QC are the rated full and part load performance values from AHRI. Units with two stage compressors typically have a value of CR of approximately 0.75. Units with variable speed compressors typically have a CR of approximately 0.40.

The table below presents the values of $F_{pump,full}$ and $F_{pump,part}$ that correspond to each loop pump arrangement (e.g. pumping control strategy, CR, and pumping power). Single stage GSHP units only require the full load factor, while staged and variable speed GSHP units require both full and part load factors. The full load pumping factors are typically 0.86 to 0.94. Part load factors can range from 0.77 to 0.94 depending on the pumping control strategy, the capacity ratio of the heat pump, and the pumping power. The factor closest to the actual situation should be used.

Pumping Factors ($F_{pump,full}$ and $F_{pump,part}$)

Pumping Control Strategy	Capacity Ratio	45 Watts/ton		60 Watts/ton		75 Watts/ton	
		Clg	Htg	Clg	Htg	Clg	Htg
Full load ($F_{pump,full}$)		0.94	0.94	0.93	0.92	0.91	0.90
Part load – constant flow pumping ($F_{pump,part}$)	0.75	0.89	0.91	0.86	0.89	0.83	0.86
Part load – constant flow pumping ($F_{pump,part}$)	0.40	0.81	0.85	0.77	0.81	0.72	0.77
Part load – staged pumping ($F_{pump,part}$)	0.75	0.92	0.94	0.89	0.91	0.87	0.89
Part load – staged pumping ($F_{pump,part}$)	0.40	0.92	0.94	0.89	0.91	0.87	0.89
Part load – variable pumping ($F_{pump,part}$)	0.40	0.94	0.95	0.92	0.93	0.90	0.92

Distribution Power Correction

For GSHP systems with an air-duct distribution system, the fan power included in the rated efficiencies corresponds to zero external static pressure and therefore is smaller than would be expected for an actual application. The indoor fan power included in the ISO 13256-1 test procedure is estimated to be approximately 0.15 Watts/cfm for permanent split-capacitor fan motors and 0.11 Watts/cfm for electrically commutated fan motors.[257]

The purpose of the distribution (i.e., fan or pump) correction factor, $F_{dist,h}$ and $F_{dist,c}$ is to determine the equivalent amount of distribution power for the baseline system, such as a fuel fired furnace

[257] Ibid.

or boiler. The correction factor considers the differential distribution power between the GSHP and the baseline system. The Distribution Correction Factors to correct GSHP Seasonal Efficiency for typical baseline scenarios summarized in the table below:

Distribution Correction Factors ($F_{dist,h}$ and $F_{dist,c}$)

	If baseline system is a Furnace with conventional air conditioning	If baseline system is a Boiler with conventional air conditioning	If baseline system is a Central air source heat pump
Heating ($F_{dist,h}$)	0.96	0.96	0.97
Cooling ($F_{dist,c}$)	0.95	0.95	0.95

Note: Based on furnace and boiler ancillary power of 137 Watts

Operating Hours

The Building Equivalent Full Load Hours for heating ($BEFLH_{heating}$) and for cooling ($BEFLH_{cooling}$) in the tables below represent building equivalent full load operating hours for HVAC equipment based on the design heating and cooling loads (i.e., "Block Loads"). The table includes BEFLH values for small commercial buildings as well as low and high-rise multifamily buildings. These values were developed in a White Paper based on EnergyPlus simulation runs from a NYSERDA simulation project focused on commercial and multifamily buildings (Henderson 2021b). BEFLH values are given by climate zone and by building vintage for each building type. Large commercial buildings have been excluded from the table since baseline HVAC systems in those buildings (e.g., VAV systems) are not adequately considered in this measure. For facility types not listed, central-pumped GSHP measures shall be addressed via custom analysis.

Facility Type	**CZ***	**BEFLH Heating**			**BEFLH Cooling**		
		Pre-1980	**Post-1980**	**NC**	**Pre-1980**	**Post-1980**	**NC**
Office – Low-Rise (≤3 floors)	4A	351	537	285	1,000	1,186	984
	5A	545	793	505	634	778	786
	6A	599	790	521	495	641	672
Grocery	4A	1,029	1,055	1,269	609	622	656
	5A	1,206	1,204	1,447	358	343	506
	6A	1,130	1,130	1,344	277	263	355
Hotel – Small (≤4 floors)	4A	386	916	649	1,956	2,141	2,056
	5A	619	1,127	893	1,916	1,958	1,818
	6A	502	942	919	1,650	1,760	1,625

Facility Type	CZ*	BEFLH Heating			BEFLH Cooling		
		Pre-1980	Post-1980	NC	Pre-1980	Post-1980	NC
Restaurant	4A	1,153	1,236	778	767	788	1,141
	5A	1,481	1,508	1,183	545	547	808
	6A	1,413	1,386	1,142	381	417	663
Stand Alone Retail	4A	760	779	579	705	705	941
	5A	987	983	858	466	440	662
	6A	969	970	838	362	363	617
School	4A	550	558	178	552	632	1,160
	5A	688	729	394	362	394	885
	6A	690	709	275	327	323	818
Warehouse	4A	875	876	637	243	230	498
	5A	1,161	1,159	915	97	93	276
	6A	1,049	1,047	972	82	77	247
Multifamily (≤7 floors)	4A	1,332	1,324	1,100	900	935	987
	5A	1,713	1,668	1,320	631	666	497
	6A	1,449	1,393	1,450	453	470	542
Multifamily (>7 and ≤20 floors)	4A	1,242	1,216	1,144	965	1,007	1,192
	5A	1,625	1,563	1,391	693	738	638
	6A	1,375	1,301	1,406	494	523	697
Multifamily - Brick (>7 and ≤20 floors)	4A	1,431	1,317	1,198	1,141	1,074	1,212
	5A	1,793	1,668	1,430	752	777	639
	6A	1,606	1,382	1,478	573	572	699

* Climate Zones (CZ) shall be mapped to standard weather stations/cities as follows:

- 4A: NYC
- 5A: Albany, Buffalo, Poughkeepsie, Syracuse
- 6A: Binghamton, Massena

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

Several GSHP units are installed at a low-rise office building located near Albany (climate zone 5A) constructed in 1975. The units are combined into a system with a closed loop ground heat exchanger field with centralized pumping. The system is of hybrid design, combining traditional central loop variable speed pumping with individual cartridge circulators on each heat pump unit. Each heat pump has a full load EER of 19, part load EER of 25, full load COP of 3.5 and part load COP of 4.1. The GSHPs have 45 watts/ton system pumping power. The building has a total cooling load of 720 kBTUh and total heating load of 1,000 kBTUh. The baseline HVAC equipment comprise 20-ton packaged gas furnace/RTU AC units. The minimum expected temperature entering the loop in the heating season is 60ºF and the maximum expected temperature entering the loop in the cooling season is 60ºF. At full speed flowrate, the pump motor and variable speed drive draw 0.5 kW. The design loop flow is less than maximum theoretical flow, and when heat pumps are in off position, bypass flow is configured to 60% of design flowrate. Annual Electric Energy Savings, Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta kWh = \left[\frac{BCL}{1{,}000} \times \left(\frac{F_{ElecCool}}{EER_{season,baseline}} - \frac{1}{EER_{season,ee}}\right) \times BEFLH_{cooling}\right] + \left[\frac{BHL}{3{,}412} \times \left(\frac{F_{ElecHeat}}{COP_{season,baseline}} - \frac{1}{COP_{season,ee}}\right) \times BEFLH_{heating} - \left[F_{pump,avg} \times kW_{pump,design} \times 8760\right]\right]$$

$$\Delta kW = \frac{BCL}{1{,}000} \times \left(\frac{F_{ElecCool}}{EER_{peak,baseline}} - \frac{1}{EER_{GSHP,full,,ee}}\right) \times CF - kW_{pump,design}$$

$$\Delta MMBtu = \frac{BHL}{1{,}000{,}000} \times \frac{F_{FuelHeat}}{AFUE_{baseline}} \times BEFLH_{heating}$$

BCL = 720,000, from application
$F_{ElecCool}$ = 1, from Summary of Variables and Data Sources table based on baseline HVAC from application
$EER_{season,baseline}$ = 11.4, from Baseline Efficiencies section based on equipment type and size from application
$EER_{season,ee}$ = ((F_{full} x $EER_{GLHP,full}$ x (1 + 0.01 x (77 – $EWT_{avg,c}$)) x $F_{pump,full}$) + (F_{part} x $EER_{GLHP,part}$ (1 + 0.01 x (68 – $EWT_{avg,c}$)) x $F_{pump,part}$)) x $F_{dist,c}$
= ((0.25 x 19 x (1 + 0.01 x (77 - 50)) x 0.93) + (0.75 x 25 x (1 + 0.01 x (68- 50) x 0.92)) x 0.95 = 24.67
$EER_{season,ee}$ equation from Compliance Efficiency section based on GSHP type
F_{full} from Compliance Efficiency section's Summary of Variables and Data Sources table
$EER_{GLHP,full}$ from application
$EWT_{avg,c}$ = EWT_{min} - 10°F = 60 - 10 = 50ºF
$EWT_{avg,c}$ equation from compliance efficiency section
EWT_{min} from application
$F_{pump,full}$ from Pumping Power Adjustment Factors table based on application
F_{part} from Compliance Efficiency section's Summary of Variables and Data Sources table
$EER_{GLHP,part}$ from application
$F_{pump,part}$ from Pumping Factors table based on application
$F_{dist,c}$ from Distribution Correction Factors based on application
$BEFLH_{cooling}$ = 634, from Operating Hours section based on location, Facility Type and construction year from application
BHL = 1,000,000, from application
$F_{ElecHeat}$ = 0, from Summary of Variables and Data Sources table based on existing HVAC from application
$COP_{seaseason,baseline}$ = N/A
$COP_{season,ee}$ = ((F_{full} x $COP_{GLHP,full}$ x (1 + 0.01 x ($EWT_{avg,h}$ – 32)) x $F_{pump,full}$) + (F_{part} x $COP_{GLHP,part}$ x (1 + 0.01 x ($EWT_{avg,h}$ – 41)) x $F_{pump,part}$)) x $F_{dist,h}$

= ((0.25 x 3.5 x (1 + 0.01 x (70- 32)) x 0.92) + (0.75 x 4.1 x (1 + 0.01 x (70 - 41)) x 0.93)) x 0.96 = 4.61

$COP_{season,ee}$ equation from Compliance Efficiency section based on GSHP type

$COP_{GLHP,full}$ from application

$EWT_{avg,h} = EWT_{min} + 10°F = 60 + 10 = 70°F$

$EWT_{avg,h}$ equation from compliance efficiency section

EWT_{min} from application

$F_{pump,full}$ from Pumping Power Adjustment Factors table based on application

$COP_{GLHP,part}$ from application

$F_{pump,part}$ from Pumping Power Adjustment Factors table based on application

$F_{dist,h}$ from Distribution Correction Factors based on application

$BEFLH_{heating}$ = 545, from Operating Hours section based on location, Facility Type and construction year from application

$F_{pump,avg}$ = 0.343, from Central Loop Pumping Energy Use for GSHP Systems section based on Bypass Flow, Diversity, type of loop flow modulation, and location from application

$kW_{pump,design}$ = 0.5, from application

$EER_{peak,baseline}$ = 9.8, from Baseline Efficiencies section based on equipment type and size from application

$EER_{GSHP,full,ee}$ = 19, from application

CF = 0.8, from Summary of Variables and Data Sources table based on application

$F_{FuelHeat}$ = 1, from Summary of Variables and Data Sources table based on existing HVAC from application

$AFUE_{baseline}$ = 0.8, from Baseline Efficiencies section based on equipment type and size from application

$$\begin{aligned}\Delta kWh = &\left[\frac{720{,}000}{1{,}000} \times \left(\frac{1}{11.4} - \frac{1}{24.67}\right) \times 634\right] \\ &+ \left[\frac{1{,}000{,}000}{3{,}412} \times \left(0 - \frac{1}{4.61}\right) \times 545 - [0.343 \times 0.5 \times 8760]\right] \\ &= -14{,}612.35\ kWh\end{aligned}$$

$$\Delta kW = \frac{720{,}000}{1{,}000} \times \left(\frac{1}{9.8} - \frac{1}{19}\right) \times 0.8 - 0.5 = 27.96\ kW$$

$$\Delta MMBtu = \frac{1{,}000{,}000}{1{,}000{,}000} \times \frac{1}{0.8} \times 545 = 681.25\ MMBtu$$

Methods for Calculating Annual Domestic Hot Water Energy Savings from a Dedicated Water-to-Water Heat Pump

GSHP systems can meet DHW loads by installing a water-to-water heat pump (WWHP) dedicated to meeting the DHW load.

When a WWHP that is dedicated to DHW is added to the ground loop, the DHW-WWHP operates in response to the DHW loads, independently of GSHP units' operation to meet space loads. Therefore, the energy savings are more consistent across the year.

In this analysis the DHW-WWHP displaces nearly all the DHW load. Electric demand impacts are not considered at this time.

$$\Delta MMBtu_{DHW-WWHP} = \frac{Q_{DHW-WWHP}}{1{,}000{,}000} \times \frac{F_{FFDHW}}{UEF_{baseline}}$$

$$\Delta kWh_{DHW-WWHP} = \frac{Q_{DHW-WWHP}}{3{,}412} \times \left(\frac{F_{EDHW}}{UEF_{baseline}} - \frac{1}{COP_{DHW-WWHP}}\right)$$

$$Q_{DHW-WWHP} = 1.1 \times GPD/unit \ \times 365 \ \times 8.33 \ \times \ \Delta T_{main}$$

$$COP_{DHW-WWHP} = COP_{AHRI,GLHP} \times 0.95$$

where:

$\Delta MMBtu_{DHW-WWHP}$ = Fossil fuel energy displaced by dedicated DHW-WWHP
$\Delta kWh_{DHW-WWHP}$ = Electricity savings from dedicated DHW-WWHP operation
$COP_{AHRI,GLHP}$ = Rated COP per ISO13256-2 at GLHP conditions (32°F source-side, 104°F load-side)
$COP_{DHW-WWHP}$ = Overall annual COP of dedicated DHW-WWHP
F_{EDHW} = Factor indicating that baseline DHW system is electric
F_{FFDHW} = Factor indicating that baseline DHW system is fossil fuel fired
GPD/unit = Gallons per day consumption, for DHW system per installed unit
$Q_{DHW-WWHP}$ = Annual DHW load served by dedicated DHW-WWHP, BTU
$UEF_{baseline}$ = Uniform energy factor of baseline DHW appliance (gas or electric). For commercial systems use AFUE or Et in place of UEF, as appropriate.
ΔT_{main} = Average temperature difference between delivered hot water temperature and the supply water temperature in water main (°F)
0.95 = Correction factor from AHRI rated conditions to 50-60°F source-side, 120-130°F load-side.
1.1 = Factor to increase DHW load served by DHW-WWHP to account for 10% tank losses (that are embedded in UEF).
8.33 = Specific heat of water; energy required (BTU), to heat one gallon of water by one degree Fahrenheit [BTU/(gal-F)]
365 = Days in one year
3,412 = Conversion factor, one kWh equals 3,412 BTU
1,000,000 = Conversion factor (BTU/MMBtu), one therm equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
F_{EDHW}	1 for electric DHW	Factor indicating baseline DHW is electric
F_{FFDHW}	1 for gas-fired DHW	Factor indicating baseline DHW is fossil fuel-fired
GPD/unit		From application, or lookup/calculate based on building type, square footage, and occupancy from GPD table below. If based on values per the table below, divide result by number of units installed.
T_{main}		Supply water temperature in water main (°F). Lookup in Cold Water Inlet Temperature table below based on nearest city.
T_{del}	125	Delivered hot water temperature (°F).[258]
$UEF_{baseline}$		Uniform Energy Factor of the baseline condition. See Baseline Efficiencies section for details regarding derivation of this input.
ΔT_{main}	T_{del} - T_{main}	Average temperature difference between delivered hot water temperature and the supply water temperature in water main (°F).
$COP_{AHRI,GLHP}$		From application.

Hot Water Consumption for Commercial and Multifamily Building Applications

Building Type	GPD	Rate	Notes/Assumptions	Source
Assembly	239	7.02 GPD per 1,000 SF	Assumes 10% hot water, 34,000 SF	EIA[259]: Public Assembly
Auto Repair	25	4.89 GPD per 1,000 SF	Assumes 10% hot water, 5,150 SF	EIA: Other
Big Box Retail	448	3.43 GPD per 1,000 SF	Assumes 10% hot water, 130,500 SF	EIA: Mercantile
Community College	1,520	1.9 GPD per person	Assumes 800 students	NREL[260]: School with Showers
Dormitory	8,600	17.2 GPD per resident	Assumes 500 residents	Water Research Foundation[261]
Elementary School	250	0.5 GPD per student	Assumes 500 students	NREL: School
Fast Food Restaurant	500	500 GPD per restaurant		FSTC[262]: Quick Service

258 Aligned with residential measure set point temperature to normalize default GPD across sectors.
259 U.S. Energy Information Administration, 2012 Commercial Buildings Energy Consumption Survey: Water Consumption in Large Buildings, Table WD1. Daily water consumption in large commercial buildings, 2012.
260 National Renewable Energy Laboratory, Saving Energy in Commercial Buildings: Domestic Hot Water Assessment Guidelines, Table 1. Hot Water Use by Building Type, June 2011.
261 Water Research Foundation: Residential End Uses of Water, Version 2, April 2016.
262 Improving Commercial Kitchen Hot Water System Performance, Design Guide – Energy Efficient Heating, Delivery and Use, Table 1. Typical hot water system cost for restaurants, March 2010.

Building Type	GPD	Rate	Notes/Assumptions	Source
Full-Service Restaurant	2,500	2,500 GPD per restaurant		FSTC: Full Service
Grocery	172	3.43 GPD per 1,000 SF	Assumes 10% hot water, 50,000 SF	EIA: Mercantile
High School	1,520	1.9 GPD per person	Assumes 800 students	NREL: School with Showers
Hospital	16,938	54.42 GPD per 1,000 SF	Assumes 40% hot water, 250,000 SF	EIA: Health Care, Inpatient
Hotel	9,104	45.52 GPD per 1,000 SF	Assumes 40% hot water, 200,000 SF	EIA: Lodging
Large Office	550	1.1 GPD per person	Assumes 500 people	NREL: Office
Large Retail	446	3.43 GPD per 1,000 SF	Assumes 10% hot water, 130,000 SF	EIA: Mercantile
Light Industrial	489	4.89 GPD per 1,000 SF	Assumes 10% hot water, 100,000 SF	EIA: Other
Motel	1,366	45.52 GPD per 1,000 SF	Assumes 40% hot water, 30,000 SF	EIA: Lodging
Multifamily High-Rise	3,440	34.4 GPD per unit	Assumes 100 units, 2 people per unit	Multifamily Baseline Study[263]
Multifamily Low-Rise	413	34.4 GPD per unit	Assumes 12 units, 2 people per unit	Multifamily Baseline Study
Refrigerated Warehouse	86	0.93 GPD per 1,000 SF	Assumes 10% hot water, 92,000 SF	EIA: Warehouse and Storage
Religious	77	7.02 GPD per 1,000 SF	Assumes 10% hot water, 11,000 SF	EIA: Public Assembly
Small Office	110	1.1 GPD per person	Assumes 100 people	NREL: Office
Small Retail	27	3.43 GPD per 1,000 SF	Assumes 10% hot water, 8,000 SF	EIA: Mercantile
University	1,000	0.5 GPD per student	Assumes 2,000 students	NREL: School
Warehouse	465	0.93 GPD per 1,000 SF	Assumes 10% hot water, 500,000 SF	EIA: Warehouse and Storage
Other	Calculate	4.89 GPD per 1,000 SF	Assumes 10% hot water	EIA: Other

Cold Water Inlet Temperature (T_{main})

Supply water main temperatures vary according to climate and are approximately equal to the annual average outdoor temperature plus 6°F.[264] Supply main temperatures based on the annual outdoor temperature are shown below.

[263] Residential Statewide Baseline Study of New York State, July 2015. Volume 2: Multifamily Report, Table 8.

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

City	Annual average outdoor temperature[265] (°F)	T_{main} (°F)
Albany	49.4	55.4
Binghamton	46.8	52.8
Buffalo	49.1	55.1
Massena	45.1	51.1
NYC	54.7	60.7
Poughkeepsie	50.9	56.9
Syracuse	49.0	55.0

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a minimally code compliant water heater of type (storage-type or instantaneous) equivalent to the existing water heater and with tank volume (where applicable), input capacity and draw pattern equivalent to the efficient water heater. For new construction, the baseline condition is a minimally code compliant storage-type water heater with tank volume, input capacity and draw pattern equivalent to the efficient water heater. $UEF_{baseline}$ shall be calculated as a function of qualifying equipment tank volume (vt) for storage type water heaters. A Medium draw pattern should be assumed for storage type water heaters with rated storage capacity ≤ 50 gallons and a High draw pattern should be assumed otherwise.[266]

Residential Water Heaters[267]

Product Class	Rated Storage Volume and Input Rating	Draw Pattern	Uniform Energy Factor
Gas-Fired Storage Water Heater	≥ 20 gal and ≤ 55 gal	Very Small	0.3456 - (0.0020 x vt*)
		Low	0.5982 - (0.0019 x vt)
		Medium	0.6483 - (0.0017 x vt)
		High	0.6920 - (0.0013 x vt)
	> 55 gal and ≤ 100 gal	Very Small	0.6470 - (0.0006 x vt)
		Low	0.7689 - (0.0005 x vt)
		Medium	0.7897 - (0.0004 x vt)
		High	0.8072 - (0.0003 x vt)

[265] Average annual outdoor temperatures taken from NCEI 1991-2020 climate normals.
[266] Based on review of typical usage bins for AHRI certified residential water heating equipment. (https://www.ahridirectory.org/ahridirectory/pages/home.aspx).
[267] 10 CFR 430.32(d).

Product Class	Rated Storage Volume and Input Rating	Draw Pattern	Uniform Energy Factor
Oil-fired Storage Water Heater	≤50 gal	Very Small	0.2509 − (0.0012 × vt)
		Low	0.5330 − (0.0016 × vt)
		Medium	0.6078 − (0.0016 × vt)
		High	0.6815 − (0.0014 × vt)
Electric Storage Water Heater	≥ 20 gal and ≤ 55 gal	Very Small	0.8808 - (0.0008 x vt)
		Low	0.9254 - (0.0003 x vt)
		Medium	0.9307 - (0.0002 x vt)
		High	0.9349 - (0.0001 x vt)
	> 55 gal and ≤ 120 gal	Very Small	1.9236 - (0.0011 x vt)
		Low	2.0440 - (0.0011 x vt)
		Medium	2.1171 - (0.0011 x vt)
		High	2.2418 - (0.0011 x vt)

*v_t = tank volume in gallons

Commercial Water Heaters for Central Systems

Commercial Equipment Type	Efficiency Level
Tank Type: All Sizes	0.80 Et
Gas-Fired Hot Water Boiler: < 300,000 BTU/h	0.82 AFUE
Oil-Fired Hot Water Boiler: < 300,000 BTU/h	0.84 AFUE
Gas-Fired Steam Boiler, All Except Natural Draft: < 300,000 BTU/h	0.80 AFUE
Gas-Fired Steam Boiler, Natural Draft: < 300,000 BTU/h	0.80 AFUE
Oil-Fired Steam Boiler: < 300,000 BTU/h	0.82 AFUE

First Hour Rating vs. Draw Pattern (Storage Type Only)[268]

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

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

A water-to-water heat pump is being installed with a GSHP with GLHP COP of 3.5 at a low-rise office building located near Albany (climate zone 5A). The existing DHW system is a gas-fired storage water heater that has a 50-gallon capacity and Medium draw pattern. Annual Electric Energy Savings, Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are calculated as below.

$$COP_{DHW-WWHP} = COP_{AHRI,GLHP} \times 0.95$$

$$Q_{DHW-WWHP} = 1.1 \times GPD/unit \ \times 365 \ \times 8.33 \ \times \ \Delta T_{main}$$

[268] 10 CFR 429.17.

$$\Delta MMBtu_{DHW-WWHP} = \frac{Q_{DHW-WWHP}}{1{,}000{,}000} \times \frac{F_{FFDHW}}{UEF_{baseline}}$$

$$\Delta kWh_{DHW-WWHP} = \frac{Q_{DHW-WWHP}}{3{,}412} \times \left(\frac{F_{EDHW}}{UEF_{baseline}} - \frac{1}{COP_{DHW-WWHP}}\right)$$

$COP_{AHRI,GLHP}$ = 3.5, from application
$COP_{DHW-WWHP}$ = 3.325
vt = 50, from application
F_{EDHW} = 0, from Summary of Variable and Data Sources table based on baseline DHW fuel source from application
F_{FFDHW} = 1, from Summary of Variable and Data Sources table based on baseline DHW fuel source from application
GPD/unit = 110, GPD/unit equation based on Hot Water Consumption for Commercial and Multifamily Building Applications table
ΔT_{main} = T_{del} - T_{main} = 125 - 55.4 = 69.6 °F
T_{del} from Summary of Variables and Data Sources table
T_{main} from Cold Water Inlet Temperature lookup table based on location from application
$UEF_{baseline}$ = 0.6483 - (0.0017 x v_t) = 0.6483 - (0.0017 x 50) = 0.5633
$UEF_{baseline}$ equation lookup from Baseline Efficiencies section based on Product Class from baseline application and Rated Storage Volume
v_t = 50, from application

$$COP_{DHW-WWHP} = 3.5 \times 0.95 = 3.325$$

$$Q_{DHW-WWHP} = 1.1 \times 110 \times 365 \times 8.33 \times 69.6 = 25{,}605{,}454$$

$$\Delta MMBtu_{DHW-WWHP} = \frac{25{,}605{,}454}{1{,}000{,}000} \times \frac{1}{0.5633} = 45.46\ MMBtu$$

$$\Delta kWh_{DHW-WWHP} = \frac{25{,}605{,}454}{3{,}412} \times \left(\frac{0}{0.5633} - \frac{1}{3.325}\right) = -2{,}257.00\ kWh$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

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

Ancillary Electric Savings Impacts

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

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Record of Revision

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7-21-14	8/30/2021
12-23-15	1/5/2024

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HEATING, VENTILATION AND AIR CONDITIONING (HVAC) – CONTROL

ADVANCED RTU CONTROL

Measure Description

This measure covers the installation of Advanced Rooftop Unit (RTU) Control on a single-zone, constant volume, rooftop HVAC unit with a single-speed supply fan and functioning economizer. Advanced RTU Control consists of integrated demand-controlled ventilation (DCV) and optional two or three-speed supply fan control enabled via variable frequency drive. DCV systems determine occupancy using a CO2 sensor and reduce heating and cooling loads by modulating outdoor air intake to meet ventilation requirements. Variable-speed fan motors reduce the fan speed for first stage cooling and ventilation. This measure is only eligible in retrofit applications or where DCV and variable speed fan control are not required by code.

This measure applies to one of three control scenarios:

- Scenario 1: DCV
- Scenario 2: DCV and two-speed supply fan control (40% in ventilation mode, 90% in heating and cooling modes) – applicable for multi-speed fan control scenarios.
- Scenario 3: DCV and three-speed supply fan control (40% in ventilation mode, 75% in first stage heating and cooling modes, 90% in second stage heating and cooling modes) – applicable for VFD control scenarios.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

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

$$\Delta kWh_{cooling} = tons \times (\Delta kWh/ton)_{cooling}$$

$$\Delta kWh_{heating} = tons \times (\Delta kWh/ton)_{heating} \times F_{ElecHeat}$$

Summer Peak Coincident Demand Savings

$$\Delta kW = tons \times (\Delta\, kW/ton) \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = kBTUh_{out} \times (\Delta MMBtu/kBTUh) \times F_{FuelHeat}$$

where:

ΔkWh	= Annual electricity energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
$\Delta kWh_{cooling}$	= Annual electricity cooling energy savings

$\Delta kWh_{heating}$ = Annual electricity heating energy savings
tons = Tons of air conditioning supplied by RTU, based on nameplate data
$kBTUh_{out}$ = Output capacity of RTU furnace (kBTU/h)
$(\Delta kWh/ton)_{cooling}$ = Annual electricity cooling energy savings per ton of air conditioning
$(\Delta kWh/ton)_{heating}$ = Annual electricity heating energy savings per ton of air conditioning
$(\Delta kW/ton)$ = Peak coincident demand electric savings per ton of air conditioning
$(\Delta MMBtu/kBTUh)$ = Annual fossil fuel energy savings per kBTUh output heating capacity
$F_{ElecHeat}$ = Electric heating factor, used to account for the presence or absence of an electric heating system
$F_{FuelHeat}$ = Fuel heating factor, used to account for the presence or absence of a fossil fuel heating system
CF = Coincidence Factor

Summary of Variables and Data Sources

Variable	Value	Notes
tons		From application.
$(\Delta kWh/ton)_{cooling}$		Lookup from Electric Cooling Savings $(\Delta kWh/ton)_{cooling}$ table below based on location and control scenario.
$(\Delta kWh/ton)_{heating}$		Lookup from Electric Heating Savings $(\Delta kWh/ton)_{heating}$ table below based on location and control scenario.
$(\Delta kW/ton)$		Lookup from Peak Demand Electric Savings $(\Delta kW/ton)$ table below based on location and control scenario.
$(\Delta MMBtu/kBTUh)$		Lookup from Fuel Savings $(\Delta MMBtu/kBTUh)$ table below based on location and control scenario.
$F_{ElecHeat}$		Use a value of 1.0 if the heating section of the retrofitted RTU is electric. Otherwise, use 0.0.
$F_{FuelHeat}$		Use a value of 1.0 if the heating section of the retrofitted RTU is fossil fuel fired. Otherwise, use 0.0.
CF	0.8	

Electric Cooling Savings $(\Delta kWh/ton)_{cooling}$[269]

City->	Albany			Binghamton			Buffalo			Massena		
Control Scenario->	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*
Assembly	44.0	132.4	150.3	23.4	70.3	79.8	37.1	111.5	126.5	24.8	74.5	84.6
Assisted Living	7.5	497.1	518.5	4.0	264.1	275.4	6.3	418.5	436.5	4.2	279.9	292.0
College	46.3	351.4	378.5	24.6	186.7	201.1	39.0	295.9	318.6	26.1	197.9	213.1

269 Deemed savings calculated based on IL TRM V11 (4.4.41 Advanced Rooftop Controls (ARC), pg. 466) values for Chicago, adjusted by the ratio of Cooling Degree Days for each listed NY city and Chicago, based on NCEI 1991 – 2020 Climate Normals using base 65º balance point as detailed in “Advanced RTU Control – Weather Normalized DCV Savings.xlsx”

City->	Albany			Binghamton			Buffalo			Massena		
Control Scenario->	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*
Conditioned Storage	3.0	304.1	346.4	1.6	161.5	184.0	2.5	256.0	291.6	1.7	171.2	195.0
Convenience Store	42.7	788.6	836.6	22.7	418.9	444.4	36.0	664.0	704.3	24.1	444.1	471.1
Garage	16.4	413.5	491.2	8.7	219.7	260.9	13.8	348.1	413.5	9.3	232.8	276.6
Grocery	37.6	416.6	434.7	20.0	221.3	230.9	31.6	350.7	365.9	21.2	234.6	244.8
Manufacturing Facility	7.7	652.0	691.1	4.1	346.3	367.1	6.5	548.9	581.8	4.3	367.1	389.2
Office Low Rise	14.7	912.6	969.2	7.8	484.8	514.8	12.4	768.3	815.9	8.3	513.9	545.7
Religious Building	5.4	766.0	881.6	2.9	406.9	468.3	4.5	644.9	742.2	3.0	431.4	496.5
Restaurant	12.8	491.7	523.0	6.8	261.2	277.8	10.7	413.9	440.3	7.2	276.9	294.5
Retail Department Store	29.5	597.4	641.4	15.6	317.4	340.7	24.8	503.0	540.0	16.6	336.4	361.2
Retail Strip Mall	28.2	628.6	659.8	15.0	333.9	350.5	23.7	529.2	555.5	15.9	354.0	371.5

City->	NYC			Poughkeepsie			Syracuse		
Control Scenario->	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*
Assembly	62.1	186.7	212.0	45.5	136.8	155.3	37.7	113.5	128.8
Assisted Living	10.6	701.2	731.3	7.8	513.6	535.7	6.5	426.1	444.4
College	65.3	495.7	533.9	47.9	363.1	391.1	39.7	301.2	324.4
Conditioned Storage	4.2	428.9	488.6	3.1	314.2	357.9	2.6	260.6	296.9
Convenience Store	60.3	1,112.4	1,180.1	44.2	814.9	864.4	36.6	676.0	717.1
Garage	23.2	583.3	692.8	17.0	427.3	507.5	14.1	354.4	421.0
Grocery	53.0	587.6	613.1	38.8	430.5	449.1	32.2	357.1	372.6
Manufacturing Facility	10.9	919.6	974.8	8.0	673.7	714.1	6.6	558.8	592.4
Office Low Rise	20.8	1,287.3	1,367.0	15.2	943.0	1,001.4	12.6	782.3	830.7
Religious Building	7.6	1,080.5	1,243.6	5.6	791.5	911.0	4.6	656.6	755.7
Restaurant	18.0	693.5	737.7	13.2	508.1	540.4	10.9	421.4	448.3
Retail Department Store	41.5	842.7	904.7	30.4	617.3	662.7	25.2	512.1	549.7
Retail Strip Mall	39.7	886.7	930.6	29.1	649.5	681.7	24.1	538.8	565.5

Electric Heating Savings $(\Delta kWh/ton)_{heating}$[270]

City->	Albany			Binghamton			Buffalo			M
Control Scenario->	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*	*1*
Assembly	875.6	900.3	900.3	986.4	1,014.2	1,014.2	890.8	915.9	915.9	1,100.1
Assisted Living	96.2	48.1	12.0	108.3	54.2	13.5	97.8	48.9	12.2	120.8
College	776.9	739.9	715.3	875.2	833.6	805.9	790.4	752.8	727.7	976.1
Conditioned Storage	271.3	135.7	111.0	305.6	152.9	125.0	276.0	138.0	112.9	340.8
Convenience Store	530.3	406.9	382.3	597.5	458.5	430.6	539.5	414.0	388.9	666.3
Garage	48.1	36.1	36.1	54.2	40.7	40.7	48.9	36.7	36.7	60.4
Grocery	805.6	745.4	733.5	907.6	839.8	826.3	819.6	758.4	746.2	1,012.2
Manufacturing Facility	48.1	36.1	36.1	54.2	40.7	40.7	48.9	36.7	36.7	60.4
Office Low Rise	300.6	108.3	84.2	338.6	122.0	94.8	305.8	110.1	85.6	377.7
Religious Building	96.2	108.3	132.3	108.3	122.0	149.0	97.8	110.1	134.6	120.8
Restaurant	300.6	216.4	192.3	338.6	243.8	216.7	305.8	220.2	195.7	377.7
Retail Department Store	276.5	156.3	132.3	311.5	176.1	149.0	281.3	159.1	134.6	347.4
Retail Strip Mall	252.5	192.3	180.3	284.5	216.7	203.2	256.9	195.7	183.5	317.3

City->	NYC			Poughkeepsie			Syracuse		
Control Scenario->	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*
Assembly	671.3	690.3	690.3	825.6	848.9	848.9	907.6	933.2	933.2
Assisted Living	73.7	36.9	9.2	90.7	45.3	11.3	99.7	49.8	12.4
College	595.7	567.3	548.4	732.5	697.6	674.5	805.3	767.0	741.5
Conditioned Storage	208.0	104.0	85.1	255.8	127.9	104.6	281.2	140.7	115.0
Convenience Store	406.6	312.0	293.1	500.0	383.7	360.4	549.7	421.8	396.2
Garage	36.9	27.7	27.7	45.3	34.0	34.0	49.8	37.4	37.4
Grocery	617.7	571.5	562.3	759.6	702.9	691.6	835.1	772.7	760.3
Manufacturing Facility	36.9	27.7	27.7	45.3	34.0	34.0	49.8	37.4	37.4
Office Low Rise	230.5	83.0	64.5	283.4	102.1	79.4	311.6	112.2	87.3
Religious Building	73.7	83.0	101.4	90.7	102.1	124.7	99.7	112.2	137.1
Restaurant	230.5	165.9	147.5	283.4	204.1	181.4	311.6	224.4	199.4
Retail Department Store	212.0	119.9	101.4	260.7	147.4	124.7	286.6	162.1	137.1
Retail Strip Mall	193.6	147.5	138.3	238.1	181.4	170.0	261.8	199.4	186.9

[270] Deemed savings calculated based on IL TRM V11 (4.4.41 Advanced Rooftop Controls (ARC), pg. 466) values for Chicago, adjusted by the ratio of Heating Degree Days for each listed NY city and Chicago, based on NCEI 1991 – 2020 Climate Normals using base 65º balance point as detailed in “Advanced RTU Control – Weather Normalized DCV Savings.xlsx”

Peak Demand Electric Savings (ΔkW/ton)[271]

City->	Albany			Binghamton			Buffalo			Massena		
Control Scenario->	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*
Assembly	0.074	0.108	0.108	0.039	0.057	0.057	0.062	0.091	0.091	0.041	0.061	0.061
Assisted Living	0.018	0.064	0.064	0.010	0.034	0.034	0.015	0.054	0.054	0.010	0.036	0.036
College	0.006	0.077	0.077	0.003	0.041	0.041	0.005	0.065	0.065	0.003	0.043	0.043
Conditioned Storage	0.005	0.071	0.071	0.003	0.038	0.038	0.004	0.060	0.060	0.003	0.040	0.040
Convenience Store	0.045	0.337	0.337	0.024	0.179	0.179	0.038	0.284	0.284	0.026	0.190	0.190
Garage	0.009	0.045	0.045	0.005	0.024	0.024	0.008	0.038	0.038	0.005	0.026	0.026
Grocery	0.029	0.069	0.069	0.015	0.036	0.036	0.025	0.058	0.058	0.016	0.039	0.039
Manufacturing Facility	0.005	0.253	0.253	0.003	0.135	0.135	0.004	0.213	0.213	0.003	0.143	0.143
Office Low Rise	0.008	0.296	0.296	0.004	0.157	0.157	0.006	0.249	0.249	0.004	0.167	0.167
Religious Building	0.000	0.348	0.348	0.000	0.185	0.185	0.000	0.293	0.293	0.000	0.196	0.196
Restaurant	0.029	0.139	0.139	0.015	0.074	0.074	0.025	0.117	0.117	0.016	0.078	0.078
Retail Department Store	0.036	0.103	0.103	0.019	0.055	0.055	0.030	0.087	0.087	0.020	0.058	0.058
Retail Strip Mall	0.039	0.164	0.164	0.021	0.087	0.087	0.033	0.138	0.138	0.022	0.092	0.092

City->	NYC			Poughkeepsie			Syracuse		
Control Scenario->	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*
Assembly	0.104	0.152	0.152	0.076	0.111	0.111	0.063	0.092	0.092
Assisted Living	0.025	0.091	0.091	0.019	0.066	0.066	0.015	0.055	0.055
College	0.008	0.109	0.109	0.006	0.080	0.080	0.005	0.066	0.066
Conditioned Storage	0.007	0.100	0.100	0.005	0.073	0.073	0.004	0.061	0.061
Convenience Store	0.064	0.476	0.476	0.047	0.349	0.349	0.039	0.289	0.289
Garage	0.013	0.064	0.064	0.010	0.047	0.047	0.008	0.039	0.039
Grocery	0.041	0.097	0.097	0.030	0.071	0.071	0.025	0.059	0.059
Manufacturing Facility	0.007	0.358	0.358	0.005	0.262	0.262	0.004	0.217	0.217

[271] Deemed savings calculated based on IL TRM V11 (4.4.41 Advanced Rooftop Controls (ARC), pg. 466) values for Chicago, adjusted by the ratio of Cooling Degree Days for each listed NY city and Chicago, based on NCEI 1991 – 2020 Climate Normals using base 65º balance point as detailed in “Advanced RTU Control – Weather Normalized DCV Savings.xlsx”

City->	NYC			Poughkeepsie			Syracuse		
Control Scenario->	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*
Office Low Rise	0.011	0.418	0.418	0.008	0.306	0.306	0.007	0.254	0.254
Religious Building	0.000	0.490	0.490	0.000	0.359	0.359	0.000	0.298	0.298
Restaurant	0.041	0.196	0.196	0.030	0.143	0.143	0.025	0.119	0.119
Retail Department Store	0.051	0.145	0.145	0.037	0.106	0.106	0.031	0.088	0.088
Retail Strip Mall	0.056	0.231	0.231	0.041	0.169	0.169	0.034	0.140	0.140

Fuel Savings (ΔMMBtu/kBTUh)[272]

City->	Albany			Binghamton			Buffalo			Massena		
Control Scenario->	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*
Assembly	0.72	0.74	0.74	0.81	0.83	0.83	0.73	0.75	0.75	0.90	0.92	0.92
Assisted Living	0.08	0.04	0.01	0.09	0.05	0.01	0.08	0.04	0.01	0.10	0.05	0.01
College	0.64	0.60	0.58	0.72	0.68	0.66	0.65	0.62	0.59	0.80	0.76	0.73
Conditioned Storage	0.22	0.11	0.09	0.25	0.12	0.10	0.23	0.11	0.09	0.28	0.14	0.11
Convenience Store	0.43	0.33	0.31	0.49	0.37	0.35	0.44	0.34	0.32	0.54	0.42	0.39
Garage	0.04	0.03	0.03	0.05	0.03	0.03	0.04	0.03	0.03	0.05	0.04	0.04
Grocery	0.68	0.62	0.61	0.76	0.70	0.69	0.69	0.64	0.63	0.85	0.79	0.77
Manufacturing Facility	0.04	0.03	0.03	0.05	0.03	0.03	0.04	0.03	0.03	0.05	0.04	0.04
Office Low Rise	0.25	0.09	0.07	0.28	0.10	0.08	0.26	0.09	0.07	0.32	0.11	0.09
Religious Building	0.08	0.09	0.11	0.09	0.10	0.12	0.08	0.09	0.11	0.10	0.11	0.14
Restaurant	0.25	0.18	0.16	0.28	0.20	0.18	0.26	0.18	0.16	0.32	0.23	0.20
Retail Department Store	0.23	0.13	0.11	0.26	0.15	0.12	0.24	0.13	0.11	0.29	0.16	0.14
Retail Strip Mall	0.21	0.16	0.15	0.24	0.18	0.17	0.22	0.16	0.15	0.27	0.20	0.19

City->	NYC			Poughkeepsie			Syracuse		
Control Scenario->	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*
Assembly	0.55	0.56	0.56	0.67	0.69	0.69	0.74	0.76	0.76
Assisted Living	0.06	0.03	0.01	0.08	0.04	0.01	0.08	0.04	0.01
College	0.49	0.46	0.45	0.60	0.57	0.55	0.66	0.63	0.61
Conditioned Storage	0.17	0.09	0.07	0.21	0.10	0.09	0.23	0.11	0.09

[272] Deemed savings calculated based on IL TRM V11 (4.4.41 Advanced Rooftop Controls (ARC), pg. 466) values for Chicago, adjusted by the ratio of Heating Degree Days for each listed NY city and Chicago, based on NCEI 1991 – 2020 Climate Normals using base 65º balance point as detailed in "Advanced RTU Control – Weather Normalized DCV Savings.xlsx"

City->	NYC			Poughkeepsie			Syracuse		
Control Scenario->	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*
Convenience Store	0.33	0.26	0.24	0.41	0.31	0.29	0.45	0.34	0.32
Garage	0.03	0.02	0.02	0.04	0.03	0.03	0.04	0.03	0.03
Grocery	0.52	0.48	0.47	0.64	0.59	0.58	0.70	0.65	0.64
Manufacturing Facility	0.03	0.02	0.02	0.04	0.03	0.03	0.04	0.03	0.03
Office Low Rise	0.19	0.07	0.05	0.24	0.09	0.07	0.26	0.09	0.07
Religious Building	0.06	0.07	0.09	0.08	0.09	0.10	0.08	0.09	0.11
Restaurant	0.19	0.14	0.12	0.24	0.17	0.15	0.26	0.19	0.17
Retail Department Store	0.18	0.10	0.09	0.22	0.12	0.10	0.24	0.14	0.11
Retail Strip Mall	0.16	0.12	0.12	0.20	0.15	0.14	0.22	0.17	0.16

Coincidence Factor (CF)

The prescribed coincidence factor for this measure is 0.8.[273]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline case for this measure is a single-zone, constant volume, rooftop HVAC unit with a single-speed supply fan and functioning economizer with no occupancy-based ventilation controls.

Compliance Efficiency from which Incentives are Calculated

The compliance case for this measure is the installation of Advanced RTU Controls, as defined in the Measure Description, on a single-zone, constant volume, rooftop HVAC unit with a single-speed supply fan and functioning economizer.

The efficient condition must comply with all applicable provisions of federal, state, local and municipal mechanical/ventilation, and construction code, including but not limited to section C403.2.6.1 of ECCCNYS and section 402 of NYS Mechanical Code.

Operating Hours

HVAC system operating hours are embedded into the deemed savings shown in the savings tables above.

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

Advanced RTU Control comprising demand control ventilation and two-speed supply fan control (Scenario 2) is installed on a 10 ton constant volume, rooftop HVAC unit with a single-speed supply fan at a small office building located near Albany. The RTU is equipped with a gas furnace with 140 kBTU/h output capacity. Annual Electric Energy Savings, Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are calculated as below.

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

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

$$\Delta kWh_{cooling} = tons \times (\Delta kWh/ton)_{cooling}$$

$$\Delta kWh_{heating} = tons \times (\Delta kWh/ton)_{heating} \times F_{ElecHeat}$$

$$\Delta kW = tons \times (\Delta\, kW/ton) \times CF$$

$$\Delta MMBtu = kBTUh_{out} \times (\Delta MMBtu/kBTUh) \times F_{FuelHeat}$$

tons = 10, from application
$(\Delta kWh/ton)_{cooling}$ = 912.6, from Electric Cooling Savings $(\Delta kWh/ton)_{cooling}$ table
$(\Delta kWh/ton)_{heating}$ = 108.3, from Electric Heating Savings $(\Delta kWh/ton)_{heating}$ table
(ΔkW/ton) = 0.296, from Peak Demand Electric Savings (ΔkW/ton) table
$kBTUh_{out}$ = 140, from application
(ΔMMBtu/kBTUh) = 0.09 from Fuel Savings (ΔMMBtu/kBTUh) table
$F_{ElecHeat}$ = 0, from Summary of Variables and Data Sources table based on application
$F_{FuelHeat}$ = 1, from Summary of Variables and Data Sources table based on application
CF = 0.8, from Summary of Variables and Data Sources table

$$\Delta kWh_{cooling} = 10 \times 912.6 = 9{,}126.00\ kWh$$

$$\Delta kWh_{heating} = 10 \times 108.3 \times 0 = 0\ kWh$$

$$\Delta kWh = 9{,}126.00 + 0 = 9{,}126.00\ kWh$$

$$\Delta kW = 10 \times .296 \times 0.8 = 2.368\ kW$$

$$\Delta MMBtu = 140 \times 0.09 \times 1 = 12.6\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

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

Ancillary Electric Savings Impacts

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

References

1. ECCCNYS 2020; C403.2.2 Ventilation.
   Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-[ce]-commercial-energy-efficiency#NYSECC2020P1_CE_Ch04_SecC403
2. NYSMC 2020 402 Natural Ventilation.
   Available from: https://codes.iccsafe.org/content/NYSMC2020P1/chapter-4-ventilation
3. Advanced Rooftop Control (ARC) Retrofit: Field-Test Results, PNNL22656. U.S. Department of Energy, July 2013.
   Available from: https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-22656.pdf
4. Advanced RTU Control – Weather Normalized DCV Savings.xlsx
   Available from: *To be published on DMM.*

Record of Revision

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7-20-13	7/31/2020
7-21-16	8/30/2021
9-23-3	10/31/2023
12-23-16	1/5/2024

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THERMOSTATIC RADIATOR VALVE (TRV)

Measure Description

This measure covers the installation of thermostatic radiator valves (TRVs) on one and two pipe steam and hydronic system radiators in commercial facilities. TRVs are self-contained, self-operated valves that do not require ancillary power. They provide local control of room temperature by controlling the flow of hot water or steam into the radiator. On a one-pipe steam system the TRVs are installed on the air vent and limit the amount of air escaping the radiator, which in turn limits the amount of steam filling the radiator. On hydronic and two-pipe steam systems, as the room temperature rises the valve head expands, blocking the flow of hot water or steam into the radiator. TRVs are available for a variety of installation conditions utilizing either remote-mounted sensors or integral-mounted sensors by means of remote or integral set point adjustment. This measure is not applicable to district or municipal steam systems.

TRVs demonstrate the greatest potential for energy savings and financial viability when overheating is exhibited in zones throughout the system and when combined with other hydronic and steam system best practice improvements. Therefore, prioritization of this measure is recommended in zones that are overheated by 3°F or greater[274] and when installed as part of system inspection, balancing and commissioning including, but not limited to: burner tuning, boiler cleaning, recalibration of boiler control set points, inspection and repair/replacement of leaking inlets and air vents, installation of properly sized air vents, main line steam trap repair/replacement, recalibration of system operating pressure, insulation of bare steam lines and installation of radiator orifice plates in two-pipe systems.[275] Separate energy savings factors are prescribed for TRV installation with and without hydronic system balancing.

Method for Calculating Annual Energy Savings and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = N/A$$

Summer Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = units \times \frac{kBTU/h_{in} \times EFLH_{heating} \times ESF}{radiators \times 1{,}000}$$

where:

ΔkWh = Annual electric energy savings

[274] NYSERDA, Thermostatic Radiator Valve (TRV) Demonstration Project, Report No. 95-14, September 1995, pg. 5-1.

[275] US DOE, Thermostatic Radiator Valve Evaluation, January 2015, pg. 25 – 26.

ΔkW	= Peak coincident demand electric savings
$\Delta MMBtu$	= Annual fossil fuel energy savings
units	= Number of TRVs installed
$kBTU/h_{in}$	= Total nameplate capacity fuel input rating (kBTU/h) of boiler system
$EFLH_{heating}$	= Heating equivalent full-load hours
ESF	= TRV Energy Savings Factor
radiators	= Total number of radiators in the space heating system
1,000	= Conversion factor, one MMBtu equals 1,000 kBTU

Summary of Variables and Data Source

Variable	Value	Notes
$kBTU/h_{in}$		From application.
$EFLH_{heating}$		From application. If unknown, look up based on building type and location in Appendix G.
ESF	TRVs w/o hydronic balancing: 0.095 TRVs w/ hydronic balancing: 0.191	Values based on results of field study of TRV impact in residential buildings implemented with and without hydronic balancing.[276,277]
radiators		From application.

Coincidence Factor (CF)

The prescribed value for the coincidence factor is N/A. Thismeasure is not anticipated to have electric impacts.

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is an existing space heating system with manual control valves at freestanding radiators, convectors, or baseboard heating units.

Compliance Efficiency from which Savings are Calculated

The measure is defined as the existing radiator, convector, or baseboard heater unit controlled by the thermostatic radiator valve.

Operating Hours

Equipment heating and cooling equivalent full load hours shall be taken from the application. If unknown, default EFLH by facility type and location can be found in Appendix G.

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

[276] Results of multifamily impact evaluation used as a proxy to estimate commercial facility savings – ESF for TRVs w/o hydronic balancing taken from lowest % savings from Group A in T. Cholewa, A. Siuta-Olcha, C.A. Balaras

[277] Results of multifamily impact evaluation used as a proxy to estimate commercial facility savings – ESF for TRVs w/ hydronic balancing taken from lowest % savings from Group C in T. Cholewa, A. Siuta-Olcha, C.A. Balaras

Thermostatic radiator valves are installed on 20 of the 40 one-pipe steam radiators in a primary school building located near Albany served by a steam boiler with 1,500 kBTU/h input capacity. As part of this upgrade, the system undergoes hydronic balancing to improve performance and occupant comfort. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are not applicable. Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta MMBtu = units \times \frac{kBTU/h_{in} \times EFLH_{heating} \times ESF}{radiators \times 1{,}000}$$

units = 20, from application
$kBTU/h_{in}$ = 1,500, from application
$EFLH_{heating}$ = 1,240, based on building type and location from Appendix G.
ESF = 0.191, from Summary of Variables and Data Sources table
radiators = 40, from application

$$\Delta MMBtu = 20 \times \frac{1{,}500 \times 1{,}240 \times 0.191}{40 \times 1{,}000} = 177.63\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

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

Ancillary Electric Savings Impacts

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

References

1. NYSERDA, Thermostatic Radiator Valve (TRV) Demonstration Project, Report No. 95-14, September 1995.
   Available from: https://digital.library.unt.edu/ark:/67531/metadc620708/m2/1/high_res_d/119941.pdf
2. US DOE, Thermostatic Radiator Valve Evaluation, January 2015.
   Available from: https://www.nrel.gov/docs/fy15osti/63388.pdf
3. T. Cholewa, A. Siuta-Olcha, C.A. Balaras, Actual Energy Savings from the Use of Thermostatic Radiator Valves in Residential Buildings–Long Term Field Evaluation, Energy and Buildings, July 2017.
   Available from: https://www.sciencedirect.com/science/article/pii/S0378778817305820?viewFullText=true#bib0100

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12-18-16	12/28/2018
12-23-17	1/5/2024

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MOTORS AND DRIVES

NOTCHED AND SYNCHRONOUS BELT

Measure Description

This measure covers the replacement of smooth V-belts in electric HVAC fan motors with notched or synchronous belts. V-belts between the motor and the supply air fan and/or return air fan are typical in larger packaged and split HVAC systems to provide flexibility in the placement of the motor relative to the load. A notched belt has grooves or notches that run perpendicular to the belt's length, which reduces the bending resistance of the belt. Notched belts can use the same pulleys as cross-section standard V-belts. They run cooler, last longer, and are about 2% more efficient than standard V-belts. Synchronous belts (also called cogged, timing, positive-drive, or high-torque drive belts) are toothed and require the installation of mating grooved sprockets. These belts operate with a consistent efficiency of 98% and maintain their efficiency over a wide load range.[278]

Estimated savings are based upon the improved transfer of the motor shaft energy to the fan by replacing a smooth V-belt with a notched belt or synchronous belt in a belt drive system. Savings assume equivalent fan motor specifications and operating hours between the baseline and efficient case and are expressed per converted fan motor.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times \frac{hp \times 0.746}{Eff_{motor}} \times RLF \times \left(\frac{1}{Eff_{baseline}} - \frac{1}{Eff_{ee}}\right) \times hrs$$

Summer Peak Coincident Demand Savings

$$\Delta kW = units \times \frac{hp \times 0.746}{Eff_{motor}} \times RLF \times \left(\frac{1}{Eff_{baseline}} - \frac{1}{Eff_{ee}}\right) \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = units \times \frac{hp \times 0.746}{Eff_{motor}} \times RLF \times \left(\frac{1}{Eff_{baseline}} - \frac{1}{Eff_{ee}}\right) \times hrs$$

where:

ΔkWh = Annual electric energy savings
ΔkW = Peak coincident demand electric savings
ΔMMBtu = Annual fossil fuel energy savings
units = Number of fan motors converted to notched or synchronous belts

[278] U.S. DOE, Motor Tip Sheet #5, Replace V-Belts with Notched or Synchronous Belt Drives, DOE/GO-102012-3740, November 2012.

hp	= Horsepower per converted fan motor
RLF	= Rated load factor
$Eff_{baseline}$	= Mechanical energy transfer efficiency of smooth V-belts
Eff_{ee}	= Mechanical energy transfer efficiency of notched or synchronous belts
Eff_{motor}	= Efficiency of fan motor in converted system (assumed equivalent between base-line and efficient case)
hrs	= Annual fan motor run hours
CF	= Coincidence factor
0.746	= Conversion factor (kW/hp), 746 watts equals one horsepower

Summary of Variables and Data Sources

Variable	Value	Notes
hp		Rated horsepower of the converted fan motor, from application.
Eff_{motor}		Full-load efficiency of the converted fan motor, from application. If unknown look up from Appendix L based on motor type (open or enclosed), number of poles (2, 4 or 6) and horsepower. If motor characteristics are unknown, assume 0.93.[279]
RLF		Percent of rated motor load at normal operation. (RLF = hp_{avg}/hp_{rated}), from application. If unknown, assume 0.75.[280]
hrs		Annual fan motor run hours, from application. If unknown, look up based on facility type in the Operating Hours section below.
$Eff_{baseline}$	0.93	US DOE.[281]
Eff_{ee}	Notched: 0.95 Synchronous: 0.98	Use default value based upon efficient belt type from application for notched[282] and synchronous[283] belt drives.
CF	0.8	

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.8.[284]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is an electric HVAC fan motor equipped with a smooth V-belt drive system.

279 Table 2 of Premium-Efficiency Motors, Energy Innovators Initiative Technical Fact Sheet, Office of Energy Efficiency of Natural Resources Canada. Average efficiency of 75% load premium motors 5-50 hp.
280 U.S. DOE, Determining Electric Motor Load and Efficiency, p. 1; assumes system is designed to maximize efficiency.
281 U.S. DOE, Motor Tip Sheet #5, Replace V-Belts with Notched or Synchronous Belt Drives, DOE/GO-102012-3740, November 2012.
282 Ibid. 2% better than standard V-belt.
283 Ibid.
284 *No source specified – update pending availability and review of applicable references.*

Compliance Efficiency from which Incentives are Calculated

The energy efficient condition is an electric HVAC fan motor equipped with a notched or synchronous belt drive system.

Operating Hours

Annual fan motor run hours shall come from application. If unknown, look up operating hours by facility type from the table below, aligned with facility operating hours as defined in the Commercial and Industrial Interior and Exterior Lamps and Fixtures measure.

Facility Type	Hours (hrs/yr)	Facility Type	Hours (hrs/yr)
Auto Related*	2,810	Manufacturing Facility	2,857
Automotive / Transportation Service or Repair Facility (24/7)	8,760	Medical Offices	3,748
Bakery	2,854	Motion Picture Theatre	1,954
Banks	3,748	Multi-Family (Common Areas)	7,665
Church	1,955	Museum	3,748
College – Cafeteria**	2,713	Nursing Homes	5,840
College – Classes	2,586	Office (General Office Types)**	3,013
College - Dormitory	3,066	Parking Garages	4,368
Commercial Condos***	3,100	Parking Garages (24/7)	7,717
Convenience Stores	6,376	Parking Lots	4,100
Convention Center	1,954	Penitentiary	5,477
Court House	3,748	Performing Arts Theatre	2,586
Dining: Bar Lounge/Leisure	4,182	Police / Fire Stations (24 Hr)	7,665
Dining: Cafeteria / Fast Food	6,456	Post Office	3,748
Dining: Family	4,182	Pump Stations	1,949
Entertainment	1,952	Refrigerated Warehouse	2,602
Exercise Center	5,836	Religious Building	1,955
Fast Food Restaurants	6,376	Restaurants	4,182
Fire Station (Unmanned)	1,953	Retail	3,463
Food Stores	4,055	School / University	2,187
Gymnasium	2,586	Schools (Jr./Sr. High)	2,187
Hospitals	7,674	Schools (Preschool/Elementary)	2,187
Hospitals / Health Care	7,666	Schools (Technical/Vocational)	2,187
Industrial - 1 Shift	2,857	Small Services	3,750
Industrial - 2 Shift	4,730	Sports Arena	1,954
Industrial - 3 Shift	6,631	Town Hall	3,748
Laundromats	4,056	Transportation	6,456
Library	3,748	Warehouse (Not Refrigerated)	2,602
Light Manufacturers**	2,613	Waste Water Treatment Plant	6,631
Lodging (Hotels/Motels)	3,064	Workshop	3,750

Facility Type	Hours (hrs/yr)	Facility Type	Hours (hrs/yr)
Mall Concourse	4,833		

* New car showrooms and Big Box retail stores with evening and/or weekend hours should use the Facility Type "Retail" for lighting operating hours.
** Lighting operating hours data from the 2008 California DEER Update study
*** Lighting operating hours data for offices used

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

A smooth V-belt driving a 92% efficient 10 hp HVAC fan motor that operates 4,000 hours hours per year is replaced with a notched belt in an assembly building near Albany. The building is equipped with central air conditioning with electric heat. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

$$\Delta kWh = units \times \frac{hp \times 0.746}{Eff_{motor}} \times RLF \times \left(\frac{1}{Eff_{baseline}} - \frac{1}{Eff_{ee}}\right) \times hrs$$

$$\Delta kW = units \times \frac{hp \times 0.746}{Eff_{motor}} \times RLF \times \left(\frac{1}{Eff_{baseline}} - \frac{1}{Eff_{ee}}\right) \times CF$$

units = 1, from application
hp = 10, from application
Eff_{motor} = 0.92, from application
RLF = 0.75, default from Summary of Variables and Data Sources
hrs = 4,000 hours, from application
$Eff_{baseline}$ = 0.92, default from Summary of Variables and Data Sources
Eff_{ee} = 0.95, from Summary of Variables and Data Sources
CF=0.8

$$\Delta kWh = 1 \times \frac{10 \times 0.746}{0.92} \times 0.75 \times \left(\frac{1}{0.92} - \frac{1}{0.95}\right) \times 4{,}000 = 834.99\ kWh$$

$$\Delta kW = 1 \times \frac{10 \times 0.746}{0.92} \times 0.75 \times \left(\frac{1}{0.92} - \frac{1}{0.95}\right) \times 0.8 = 0.17\ kW$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

High efficiency belt drive systems reject less heat into the conditioned space increasing space heating requirements. The HVAC interaction factors as a function of the location and HVAC system type are shown in Appendix D.

Ancillary Electric Savings Impacts

High efficiency belt drive systems reject less heat into the conditioned space increasing space heating requirements while decreasing cooling load. The HVAC interaction factors as a function of the location and HVAC system type are shown in Appendix D.

References

1. U.S. DOE, Motor Tip Sheet #5, Replace V-Belts with Notched or Synchronous Belt Drives, DOE/GO-102012-3740, November 2012.
   Available from: https://www.nrel.gov/docs/fy13osti/56012.pdf
2. Office of Energy Efficiency of Natural Resources Canada, Energy Innovators Initiative Technical Fact Sheet, Premium-Efficiency Motors.
   Available from: https://publications.gc.ca/collections/Collection/M144-21-2003E.pdf
3. U.S. DOE, Determining Electric Motor Load and Efficiency
   Available from: https://energy.gov/sites/prod/files/2014/04/f15/10097517.pdf

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POOL PUMP

Measure Description

This measure covers the installation of ENERGY STAR® qualified commercial inground pool pumps and dedicated-purpose pool pump motor replacements. Pool pump speeds vary based on the pump's operation. Filtration, for example, only requires half the flow rate of running a pool cleaner. Conventional pool pumps, with only one speed, are set to run at the higher speeds required of the pool cleaner and waste energy during filtration operation by running faster than necessary. An ENERGY STAR® certified pool pump can run at different speeds and be programmed to match the pool operation with its appropriate pool pump speed. The energy saved is considerable; reducing pump speed by one-half allows the pump to use just one-eighth as much energy.[285] After January 1, 2019, all pool pumps must be rated according to Weighted Energy Factor (WEF).

This measure is applicable to single-phase self-priming pool pumps with a Rated Hydraulic Horsepower (hhp) rating of >0 and <2.5 hhp. While pressure cleanser booster pumps are eligible under ENERGY STAR® qualified product criteria, there was a critical lack of information regarding ENERGY STAR® calculations and assumptions pertaining to this equipment available at the time of publication of this measure. The measure scope will be expanded as more information becomes available. This measure is applicable to all pool facilities except those that fall under the NY health code Subpart 6-1: a single-family swimming pool, or other bathing facility, a spa pool or a floating tank.[286]

This measure is also applicable to Dedicated Purpose Pool Pump motor replacement for motors with rated horsepower up to 5 hp.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings for Pool Pump Installation

$$\Delta kWh = units \times \frac{days}{1{,}000} \times V_{pool} \times N_{turnover} \times \left[\frac{1}{WEF_{baseline}} - \frac{1}{WEF_{ee}}\right]$$

Annual Electric Energy Savings for Dedicated-Purpose Pool Pump Motor Replacement

$$\Delta kWh = units \times days \times \frac{V_{pool}}{1{,}000} \times N_{turnover} \times \frac{1}{WEF_{baseline}} \times \left[\frac{1}{Eff_{baseline,DPPP}} - \frac{1}{Eff_{ee,DPPP}}\right]$$

Summer Peak Coincident Demand Savings

$$\Delta kW = N/A$$

285 ENERGY STAR® Pool Pumps Product Page

286 SubPart6-1.3, Swimming pools, New York Codes, Rules, and Regulations.

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

Note- Although pump hp is not applied directly within algorithms, it must be known to establish baseline and compliance efficiency values.

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
days	= Number of operating days per year
$_{baseline}$	= Characteristic of baseline condition
$_{ee}$	= Characteristic of energy efficient condition
WEF	= Pool Pump Weighted Energy Factor (kgal/kWh)
V_{pool}	= Volume of pool, in gallons
$N_{turnover}$	= Number of turnovers per day, where a turnover is a full cycling of pool water through the pool filter
$_{DPPP}$	= Specification of the Dedicated-Purpose Pool Pump motor
Eff	= Motor efficiency
hhp	= Rated Hydraulic Horsepower (hhp) of qualifying pump motor
1,000	= Conversion factor, one kgal equals 1,000 gallons

Summary of Variables and Data Sources

Variable	Value	Notes
V_{pool}		From application. If unknown, assume 22,000.[287]
$N_{turnover}$		From application. If unknown, use 4 per day.[288]
WEF_{ee}		From application or look up and/or calculate based on Compliance Efficiency section below, based on Rated Hydraulic Horsepower (hhp).
hhp		From application.
$WEF_{baseline}$		Look up and/or calculate based on Baseline Efficiencies section below, based on Rated Hydraulic Horsepower (hhp).
$Eff_{baseline,DPPP}$		Look up in Baseline Efficiencies section below based on hp of replacement motor.
$Eff_{ee,DPPP}$		From application.
days		From application.

Weighted Energy Factor (WEF) (kgal/kWh) is a measurement of pump efficiency based on performance at one or two operating points, which are uniquely defined for each Dedicated Purpose Pool Pump (DPPP) variety and speed configuration. The performance measurements at different

[287] Savings Calculator for ENERGY STAR® Certified Inground Pool Pumps (accessed 11/1/2023).
[288] SubPart6-1.11 Treatment, Swimming pools, New York Codes, Rules, and Regulations.

operating points are weighted to represent real world use. WEF is measured in thousand gallons per kilowatt hour (kgal/kWh). See the DOE Test Procedure for Dedicated Purpose Pool Pumps for additional calculation details.[289]

Coincidence Factor (CF)

The prescribed value for the coincidence factor is N/A. This measure is not anticipated to have peak kW impacts.

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition for pool pump installations is a non-ENERGY STAR® qualified pool pump. The values for baseline WEF shall be calculated per the table below, based on pump type and Rated Hydraulic Horsepower (hhp).[290] Pump Performance Curve C is assumed for pool pumps. The pump curve compares the total head in feet of water to the flow rate of the water for a given pump at a given motor speed.

Pump Type	Size	Baseline WEF
Self-Priming (Inground)	hhp ≤ 0.13	5.55
Self-Priming (Inground)	0.13 < hhp < 0.711	-1.30 x ln (hhp) + 2.90
Self-Priming (Inground)	0.711 ≤ hhp < 2.5	-2.30 x ln (hhp) + 6.59

The baseline efficiency for Dedicated Purpose Pool Pump motor replacements is established based on the rated horsepower of the replacement motor per the table below.[291]

DPPP Motor HP	Baseline Efficiency
< 0.5	0.66
≥ 0.5 and < 1.0	0.72
≥ 1.0 and ≤ 5.0	0.80

Compliance Efficiency from which Incentives are Calculated

The compliance condition for pool pump installations is an ENERGY STAR® qualified single-phase self-priming pool pump with a Rated Hydraulic Horsepower (hhp) rating of >0 and <2.5 hhp. Pumps must have a WEF (in kgal/kWh) equal to or greater than the WEF equations in the table below based on pump type and Rated Hydraulic Horsepower (hhp).[292] Pump Performance Curve C is assumed for ENERGY STAR® pumps. The pump curve compares the total head in feet of water to the flow rate of the water for a given pump at a given motor speed.

[289] 10 CFR 431.464(b)
[290] Table G-3: Standards for Dedicated-Purpose Pool Pumps, Replacement Pool Pump Motors, California Title 20 via NYS Appliance Standards.
[291] Table G-4: Standards for Replacement Dedicated-Purpose Pool Pump Motors Manufactured on or After July 19, 2021, California Title 20 via NYS Appliance Standards.
[292] ENERGY STAR® Program Requirements Product Specification for Pool Pumps, Eligibility Criteria Version 3.1, July 2021.

Pump Type	Size	Compliance WEF
Self-Priming (Inground)	hhp ≤ 0.13	13.40
Self-Priming (Inground)	0.13 < hhp < 0.711	-2.45 x ln (hhp) + 8.40
Self-Priming (Inground)	0.711 ≤ hhp < 2.5	-2.45 x ln (hhp) + 8.40

The compliance condition for Dedicated Purpose Pool Pump motor replacements is a motor with rated horsepower less than or equal to 5 hp with rated efficiency exceeding the baseline efficiency prescribed in the Baseline Efficiencies section above.

Operating Hours

The annual operating days shall be taken from application. While in use, the energy efficient pump cycles through pool water at a default rate of 6 hours per turnover as mandated by the NY Codes and Regulations.[293]

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

An ENERGY STAR® qualified self-priming multi-speed inground pool pump with a Rated Hydraulic Horsepower of 1.65 hhp and 9.0 WEF is replacing a single-speed unit at a community college near Albany. The pump remains in operation for 90 days during the swimming season and conducts 4 turnovers per day. The volume of the swimming pool is 22,000 gallons. Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings are calculated as below.

$$\Delta kWh = units \times days \times \frac{V_{pool}}{1{,}000} \times N_{turnover} \times \left[\frac{1}{WEF_{baseline}} - \frac{1}{WEF_{ee}}\right]$$

units = 1, from application
V_{pool} = 22,000, from application
$N_{turnover}$ = 4, from application
WEF_{ee} = 9.0, from application
hhp = 1.65, from application.
$WEF_{baseline}$ = 5.4, from Baseline Efficiency from which Incentives are Calculated
days = 90, from application

$$\Delta kWh = 1 \times 90 \times \frac{22{,}000}{1{,}000} \times 4 \times \left[\frac{1}{5.4} - \frac{1}{9.0}\right] = 586.67\ kWh$$

Effective Useful Life (EUL)

See Appendix P.

[293] Subpart 6-1.11 Treatment, Swimming pools, New York Codes, Rules and Regulations.

Ancillary Fossil Fuel Savings Impacts

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

Ancillary Electric Savings Impacts

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

References

1. ENERGY STAR® Pool Pumps Product Page
   Available from: https://www.energystar.gov/products/pool_pumps#:~:text=An%20ENERGY%20STAR%20certified%20pool,one%2Deighth%20as%20much%20energy
2. ENERGY STAR® Pool Pump Fact Sheet, January 2018.
   Available from: https://www.energystar.gov/sites/default/files/asset/document/Pool-Pumps_FactSheet_012318_0.pdf
3. SubPart6-1, Swimming pools, New York Codes, Rules and Regulations.
   Available from: https://regs.health.ny.gov/content/subpart-6-1-swimming-pools
4. Savings Calculator for ENERGY STAR® Certified Inground Pool Pumps, May 2020.
   Available from: https://www.energystar.gov/productfinder/downloads/Pool_Pump_Calculator_2020.05.05_FINAL.xlsx
5. 10 CFR 431.464 Test procedure for the measurement of energy efficiency, energy consumption, and other performance factors of pumps.
   Available from: https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-431
6. NYSERDA NY State Appliance and Equipment Current Standards.
   Available from: https://www.nyserda.ny.gov/All-Programs/New-York-State-Appliance-and-Equipment-Efficiency-Standards/Current-Standards
7. CA Title 20 1605.1. Federal and State Standards for Federally Regulated Appliances
   Available from: https://govt.westlaw.com/calregs/Document/ID496BE335CCE11EC9220000D3A7C4BC3?viewType=FullText&originationContext=documenttoc&transitionType=CategoryPageItem&contextData=(sc.Default)
8. ENERGY STAR® Program Requirements Product Specification for Pool Pumps, Eligibility Criteria Version 3.1, July 2021.
   Available from: https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%203.1%20Pool%20Pumps%20Final%20Specification_0.pdf

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APPENDIX P

EFFECTIVE USEFUL LIFE (EUL)

SINGLE AND MULTI-FAMILY RESIDENTIAL MEASURES

Category	Single and Multi-family Residential Measures	Sector	EUL (years)	Source
Appliance	Air Purifier	Residential	9	ENERGY STAR® Calc[294]
	Clothes Dryer (incl. Heat Pump Clothes Dryer)	Residential	14	ENERGY STAR® M&I Scoping Report[295]
	Clothes Washer	Residential	11	DEER 2014 EUL ID: Appl-EffCW
	Dehumidifier	Residential	12	ENERGY STAR® Calc[296]
	Dishwasher	Residential	11	DEER 2014 EUL ID: Appl-EffDW
	Fireplace	Residential	15	DOE[297]
	Induction Cooktop	Residential	16	DEER 2014 EUL ID: Appl-Elec_Cooking
	Refrigerator and Freezer	Residential	14	DEER 2014 EUL ID: Appl-ESRefg
	Soundbar	Residential	7	RPP Product Analysis[298]
Appliance Control	Advanced Power Strip (APS)	Residential	8	DEER 2014 EUL ID: Plug-OccSens
Appliance Recycling	Air Conditioner - Room (RAC) Recycling	Residential	3	DEER 2014 EUL ID: HV-RAC-RUL
	Dehumidifier Recycling	Residential	3	Assumes same RUL as RAC

[294] Savings Calculator for ENERGY STAR® Qualified Appliances (last updated October 2016). https://www.energystar.gov/buildings/facility-owners-and-managers/existing-buildings/save-energy/purchase-energy-saving-products
[295] ENERGY STAR® Market & Industry Scoping Report: Residential Clothes Dryer, November 2011.
[296] ENERGY STAR® Dehumidifier Calculator. https://www.energystar.gov/ia/partners/promotions/cool_change/downloads/CalculatorConsumerDehumidifier.xls
[297] Technical Support Document: Energy Conservation Program for Consumer Products: Energy Conservation Standards for Hearth Products. Chapters 7 and 8. Department of Energy (DOE). January 30, 2015, pg. 2-12. https://www.regulations.gov/document?D=EERE-2014-BT-STD-0036-0002
[298] Retail Products Platform Product Analysis, Last Updated May 25, 2016. https://www.energystar.gov/sites/default/files/asset/document/ESPPM_Increasing%20the%20Volume%20on%20Sound%20Bars_Littlehales.pdf

Category	Single and Multi-family Residential Measures	Sector	EUL (years)	Source
	Refrigerator Recycling	Residential	5	DEER 2014 EUL ID: Appl-RecRef

Category	Single and Multi-family Residential Measures	Sector	EUL (years)	Source
Appliance Recycling	Freezer Recycling	Residential	4	DEER 2014 EUL ID: Appl-RecFrzr
Building Shell	Air Conditioner – Room (RAC) Cover and Gap Sealer	Residential	3	See note below[299]
	Air Leakage Sealing	Residential	15	GDS[300]
	Attic Access Insulation & Sealing	Residential	15	GDS[301]
	Insulation – Hot Water and Steam Pipe	Residential	15	GDS[302]
	Insulation – Opaque Shell	Residential	25	GDS[303]
	Plastic Window Insulation	Residential	1	See Note[304]
	Storm Window	Residential	20	DOE[305]
	Window	Residential	20	DEER 2014 EUL ID: BS-Win
	Window - Film	Residential	10	DEER 2014 EUL ID: Glaz-Daylt-WinFilm
Domestic Hot Water (DHW)	Heat Pump Water Heater (HPWH)	Residential	10	DEER 2014 EUL ID: WtrHt-HtPmp
	Indirect Water Heater	Residential	11	DEER 2014 EUL ID: WtrHt-Res-Gas
	Storage Water Heater - Gas	Residential	15	PA Group[306]
	Storage Water Heater - Electric	Residential	13	DEER 2014 EUL ID: WtrHt-Res-Elec
	Instantaneous Water Heater	Residential	20	DEER 2014 EUL ID: WtrHt-Instant-Res
DHW - Control	Low-Flow – Faucet Aerator	Residential	10	DEER 2014 EUL ID: WtrHt-WH-Aertr
	Low-Flow – Showerhead	Residential	10	DEER 2014 EUL ID: WtrHt-WH-Shrhd

299 Average/typical manufacturer warranty period for AC covers.
300 GDS Associates, Inc., Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures, June 2007, Table 1 – Residential Measures.
301 Ibid.
302 Ibid.
303 Ibid.
304 1 year is assumed to be the EUL since plastic window insulation comes in the form of single-use kits that are disposed of when the heating season ends.
305 https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-22864rev2.pdf
306 PA Consulting Group Inc., Focus on Energy Evaluation Business Programs: Measure Life Study, final report dated August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf

Category	Single and Multi-family Residential Measures	Sector	EUL (years)	Source
	Thermostatic Shower Valve	Residential	10	UPC[307]

[307] UPC certification under the International Association of Plumbing and Mechanical Officials standard IGC 244-2007a. A standard that includes a lifecycle test consisting of 10,000 cycles without fail. 10,000 cycles is the equivalent of three users showering daily for more than nine years.

Category	Single and Multi-family Residential Measures	Sector	EUL (years)	Source
Heating, Ventilation and Air Conditioning (HVAC)	Air Conditioner – Central (CAC)	Residential	15	DEER 2014 EUL ID: HV-ResAC
	Air Conditioner – Room (RAC)	Residential	12	GDS[308]
	Air Conditioner – PTAC	Residential	15	DEER 2014 EUL ID: HVAC-PTAC
	Boiler, Hot Water – Steel Water Tube	Residential	24	ASHRAE Handbook, 2015
	Boiler, Hot Water – Steel Fire Tube	Residential	25	ASHRAE Handbook, 2015
	Boiler, Hot Water – Cast Iron	Residential	35	ASHRAE Handbook, 2015
	Boiler, Steam – Steel Water Tube	Residential	30	ASHRAE Handbook, 2015
	Boiler, Steam – Steel Fire Tube	Residential	25	ASHRAE Handbook, 2015
	Boiler, Steam – Cast Iron	Residential	30	ASHRAE Handbook, 2015
	Boiler and Furnace - Combination ("Combi") Boiler	Residential	22	DOE[309]
	Boiler and Furnace - Combination ("Combi") Furnace	Residential	20	DEER 2014[310] EUL ID: HVAC-Frnc
	Duct Sealing and Insulation	Residential	18	DEER 2014 EUL ID: HV-DuctSeal
	Electronically Commutated (EC) Motor – HVAC Blower Fan	Residential	15	DEER 2014 EUL ID: Motors-fan
	Electronically Commutated (EC) Motor – Hydronic Circulator Pump	Residential	15	DEER 2014 EUL ID: Motors-pump

[308] GDS Associates, Inc., Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures, June 2007, Table 1 – Residential Measures.
[309] Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Furnaces, February 10, 2015, Table 8.2.17. Product definition of furnaces includes electric boilers with firing rates of less than 300,000 BTU/h.
https://energy.mo.gov/sites/energy/files/technical-support-document---residential-furances_doe.pdf
[310] Based on DEER value for high efficiency boiler and instantaneous water heater.

Category	Single and Multi-family Residential Measures	Sector	EUL (years)	Source
Heating, Ventilation and Air Conditioning (HVAC)	Energy and Heat Recovery Ventilator	Residential	14	PA Consulting Group[311]
	Furnace, Gas Fired	Residential	22	DOE[312,313]
	Gas Heat Pump	Residential	15	DEER 2014 EUL ID: HV-Res HP
	Heat Pump - Air Source (ASHP) and Air-to-Water (AWHP)	Residential	15	DEER 2014 EUL ID: HV-Res HP
	Heat Pump – Ground Source (GSHP)	Residential	25	ASHRAE[314]
	Heat Pump – PTHP	Residential	15	DEER 2014 EUL ID: HVAC-PTHP
	Refrigerant Charge Correction & Tune-Up – Air Conditioner and Heat Pump	Residential	10	DEER 2014 EUL ID: HV-RefChrg
	Tune-Up - Boiler	Residential	5	DEER 2014 EUL ID: BlrTuneup
	Tune-Up - Furnace	Residential	5	DEER 2014 EUL ID: BlrTuneup
	Unit Heater, Gas Fired	Residential	13	ASHRAE Handbook, 2015
HVAC - Control	Adaptive Photonic Control	Residential	EUL = Retrofitted motor RUL = Retrofitted motor EUL – (Current Year – Mfr. Year) **Default = 5**	DEER 2014 EUL ID: Motors-fan
	Advanced Boiler Control	Residential	EUL = Boiler RUL = Boiler EUL –	N/A

311 PA Consulting Group Inc., Focus on Energy Evaluation Business Programs: Measure Life Study, final report dated August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf

312 U.S. DOE. "Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Furnaces" and "Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Commercial Warm Air Furnaces." August 30, 2016. https://www.regulations.gov/document?D=EERE-2014-BT-STD-0031-0217

313 U.S. DOE. "Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Commercial Warm Air Furnaces." December 30, 2015. https://www.regulations.gov/document?D=EERE-2013-BT-STD-0021-0050

314 ASHRAE: Owning and Operating Cost Database, Equipment Life/Maintenance Cost Survey: https://xp20.ashrae.org/publicdatabase/system_service_life.asp?selected_system_type=1

Category	Single and Multi-family Residential Measures	Sector	EUL (years)	Source
			(Current Year – Mfr. Year) **Default = 5**	

Category	Single and Multi-family Residential Measures	Sector	EUL (years)	Source
HVAC - Control	Outdoor Temperature Setback Control for Hydronic Boiler	Residential	EUL = Boiler RUL = Boiler EUL – (Current Year – Mfr. Year) **Default = 5**	N/A
	Steam Trap – Low Pressure Space Heating	Residential	6	DEER 2014 EUL ID: HVAC-StmTrp
	Submetering	Multifamily	10	NYSERDA[315]
	Thermostat – All Types	Residential	11	DEER 2014 EUL ID: HVAC-ProgTStats
	Thermostatic Radiator Valve – One Pipe Steam Radiator	Multifamily	15	DOE[316]
	Smart Thermostatic Radiator Enclosure	Residential	15	DEER 2014 EUL ID: Motors-fan[317]
Lighting[318]	LED Lamp	Residential	Rated Life listed by ENERGY STAR® or default to 15,000 hrs/ annual lighting operating hrs or 15 yrs if rated lifetime or annual operating hours are not known	ENERGY STAR® Lamps[319]

[315] NYSERDA Residential Electric Submetering Manual.
[316] U.S. DOE, "Thermostatic Radiator Valve Evaluation", January 2015, Table 4. pg. 16.
[317] Based on assumed EUL of integrated fan, which is expected to be the first component to fail.
[318] In response to codification of a 45 lm/W backstop requirement for general service lamps (GSLs), EULs for select lighting measures are currently under review by the TRM Management Committee. Revisions will take effect concurrent with other action taken in response to the imposed GSL standard in the V10 NY TRM filing. https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=4
[319] ENERGY STAR® Program Requirements Product Specification for Lamps (Light Bulbs) V2.1, June 2017, pg. 19 (Capped at 20 years). https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V2.1%20Final%20Specification.pdf

Category	Single and Multi-family Residential Measures		Sector	EUL (years)	Source
Lighting[320]	Light Fixture	LED (Interior)	Residential	Rated Life listed by DLC or default to 50,000 hrs/ annual lighting operating hrs or 15 yrs if rated lifetime or annual operating hours are not known	DLC[321]
				Rated Life listed by ENERGY STAR or default to 25,000 hrs/ annual lighting operating hrs or 15 yrs if rated lifetime or annual operating hours are not known	ENERGY STAR® Fixtures[322]

[320] In response to codification of a 45 lm/W backstop requirement for general service lamps (GSLs), EULs for select lighting measures are currently under review by the TRM Management Committee. Revisions will take effect concurrent with other action taken in response to the imposed GSL standard in the V10 NY TRM filing. https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=4

[321] Placed on the Qualified Products List by the Design Light Consortium (DLC) 50,000 hours, according to the appropriate Application Category as specified in the DLC's Product Qualification Criteria, Technical Requirement Table version 4.4 or higher.

[322] ENERGY STAR® Program Requirements Product Specification for Luminaires (Light Fixtures) V2.2, August 2019, pg. 18 (Capped at 20 years). https://www.energystar.gov/sites/default/files/Luminaires%20V2.2%20Final%20Specification.pdf

Category	Single and Multi-family Residential Measures		Sector	EUL (years)	Source
	Light Fixture	LED (Exterior)	Residential	Rated Life listed by ENERGY STAR or default to 35,000 hrs/ annual lighting operating hrs or 15 yrs if rated lifetime or annual operating hours are not known	ENERGY STAR® Fixtures[323]
Lighting[324]	Light Fixture	LED (Inseparable)	Residential	Rated Life listed by ENERGY STAR or default to 50,000 hrs/ annual lighting operating hrs or 15 yrs if rated lifetime or annual operating hours are not known	ENERGY STAR® Fixtures
Lighting Control	Bi-Level Lighting		Multifamily Common Area	15	ComEd[325]
	Connected Lighting		Residential	3	GE and Philips Hue Bridge[326]
Motors and Drives	Pool Pump		Residential	10	DEER 2014 EUL ID: OutD-PoolPump
	Pool Circulator Timer		Residential	10	DEER 2014 EUL ID: OutD-PoolPump

323 Ibid.

324 In response to codification of a 45 lm/W backstop requirement for general service lamps (GSLs), EULs for select lighting measures are currently under review by the TRM Management Committee. Revisions will take effect concurrent with other action taken in response to the imposed GSL standard in the V10 NY TRM filing. https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=4

325 ComEd Luminaire Level Lighting Control IPA Program Impact Evaluation Report prepared by Navigant. https://www.ilsag.info/wp-content/uploads/SAG_files/Evaluation_Documents/ComEd/ComEd_EPY9_Evaluation_Reports_Final/ComEd_PY9_LLLC_IPA_Program_Impact_Evaluation_Report_2018-06-05_Final.pdf

326 Cync by General Electric Limited Warranty for Smart Bulbs and Light Strips. https://www.gelighting.com/smart-home/warranty and Philips End of Support Policy: End of Support Policy | Philips Hue (philips-hue.com)

Category	Single and Multi-family Residential Measures	Sector	EUL (years)	Source
Other	Heat Pump Pool Heater	Residential	15	DEER 2014 EUL ID: HV-Res HP
	Pool Heater	Residential	8	DOE[327]
	Solar Pool Heater	Residential	15	DOE[328]

[327] DOE, Chapter 8, Life-Cycle Cost and Payback Period Analyses, Table 8.75. https://www.regulations.gov/document?D=EERE-2006-STD-0129-0170

[328] https://www.energy.gov/energysaver/solar-swimming-pool-heaters

COMMERCIAL AND INDUSTRIAL MEASURES

Category	Commercial & Industrial Measures	Sector	EUL (years)	Source
Agricultural Equipment	High Speed Fans	C&I	10	PG&E[329]
	Livestock Waterer	C&I	10	PA Consulting Group[330]
	Milk Pre-Cooler Heat Exchanger	C&I	15	Ibid
	Refrigeration Heat Recovery	C&I	14	DEER 2014 EUL ID: HVAC-ChlrComp-Ag
	Scroll Compressor	C&I	12	DEER 2014 EUL ID: RefgWrhs-ScrollComp
Agricultural Equipment - Control	Engine Block Heater Timer	C&I	8	See note below[331]
	Variable Speed Drive Milk Pump Plate Cooler	C&I	15	PA Consulting Group[332]
	Variable Speed Drive Vacuum Pump	C&I	15	PA Consulting Group[333]
Appliance	Air Purifier	C&I	9	ENERGY STAR® Calc[334]
	Clothes Dryer	C&I	14	ENERGY STAR®M&I Report[335]
	Clothes Washer	C&I	11	DEER 2014 EUL ID: Appl-EffCW
	Cooking Equipment[336]	C&I	12	DEER 2014 EUL IDs: Various
	Dehumidifier	C&I	12	ENERGY STAR® Calc[337]

[329] PG&E Work Paper PGE3PAGR117, October 12, 2017.
[330] PA Consulting Group Inc., Focus on Energy Evaluation Business Programs: Measure Life Study, final report dated August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
[331] Based on EUL's for Advanced Power Strips.
[332] PA Consulting Group Inc., Focus on Energy Evaluation Business Programs: Measure Life Study, final report dated August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
[333] PA Consulting Group Inc., Focus on Energy Evaluation Business Programs: Measure Life Study, final report dated August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
[334] Savings Calculator for ENERGY STAR® Qualified Appliances (last updated October 2016). https://www.energystar.gov/buildings/facility-owners-and-managers/existing-buildings/save-energy/purchase-energy-saving-products
[335] ENERGY STAR® Market & Industry Scoping Report: Residential Clothes Dryer, November 2011.
[336] Applicable to all kitchen cooking equipment not otherwise listed.
[337] ENERGY STAR® Dehumidifier Calculator. https://www.energystar.gov/ia/partners/promotions/cool_change/downloads/CalculatorConsumerDehumidifier.xls

Category	Commercial & Industrial Measures	Sector	EUL (years)	Source
	Dishwasher	C&I	10 – Under Counter 15 – Single Door 20 – Conveyor Type 10 – Pots, Pans & Utensils	ENERGY STAR®Calc[338]

[338] ENERGY STAR® Savings Calculator for ENERGY STAR® Certified Commercial Kitchen Equipment. www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx?5da4-3d90&5da4-3d90

Category	Commercial & Industrial Measures	Sector	EUL (years)	Source
Appliance	Fireplace	C&I	15	DOE[339]
	Ice Maker	C&I	10	DEER 2014 EUL ID: Cook-IceMach
	Induction Cooktop	C&I	16	DEER 2014 EUL ID: Appl-Elec_Cooking
	Refrigerator and Freezer	C&I	12	DEER 2014 EUL ID: Cook-SDRef
Appliance - Control	Advanced Power Strip (APS)	C&I	8	DEER 2014 EUL ID: Plug-OccSens
	Vending Machine and Novelty Cooler Control	C&I	5	DEER 2014 EUL ID: Plug-VendCtrler
Appliance Recycling	Air Conditioner – Room (RAC)	C&I	3	DEER 2014 EUL ID: HV-RAC-RUL
Building Shell	Air Curtains	C&I	15	DEER 2014 EUL ID: Motors-fan
	Air Leakage Sealing	C&I	15	GDS[340]
	Insulation - Hot Water and Steam Pipe	C&I	15	GDS[341]
	Insulation - Opaque Shell	C&I	30	ET & CEC[342]
	Window - Film	C&I	10	DEER 2014 EUL ID: GlazDaylt-WinFilm
	Window - Glazing	C&I	20	DEER 2014 EUL ID: BS-Win
Compressed Air	Air Compressor	C&I	13	Other State TRMs[343]
	Engineered Air Nozzle	C&I	15	Wisconsin PSC[344]

[339] Technical Support Document: Energy Conservation Program for Consumer Products: Energy Conservation Standards for Hearth Products. Chapters 7 and 8. Department of Energy (DOE). January 30, 2015, pg. 2-12. https://www.regulations.gov/document?D=EERE-2014-BT-STD-0036-0002
[340] GDS Associates, Inc., Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures, June 2007, Table 1 – Residential Measures.
[341] GDS Associates, Inc., Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures, June 2007, Table 1 – Residential Measures.
[342] Energy Trust uses 30 years for commercial applications. CEC uses 30 years for insulation in Title 24 analysis.
[343] Based on a review of TRM assumptions from Ohio (August 2010), Massachusetts (October 2015), Illinois (February 2017) and Vermont (December 2018). Estimates range from 10 to 15 years. Cited TRMs are reviewed annually for updates and potential to replace TRM citations with primary reference material.
[344] PA Consulting Group (2009). *Business Programs: Measure Life Study*. Prepared for State of Wisconsin Public Service Commission.

Category	Commercial & Industrial Measures	Sector	EUL (years)	Source
	No Air Loss Water Drain	C&I	13	MA Measure Life Study[345]
	Refrigerated Air Dryer	C&I	13	Other State TRMs [346]
	Compressed Air Heat Recovery	C&I	13	Other State TRMs [347]
	Flow Controller	C&I	13	Other State TRMs [348]

[345] Measure Life Study prepared for The Massachusetts Joint Utilities, Energy & Resource Solutions, 2005. http://www.ers-inc.com/wp-content/uploads/2018/04/Measure-Life-Study_MA-Joint-Utilities_ERS.pdf

[346] Based on a review of TRM assumptions from Ohio (August 2010), Massachusetts (October 2015), Illinois (February 2017) and Vermont (December 2018). Estimates range from 10 to 15 years. Cited TRMs are reviewed annually for updates and potential to replace TRM citations with primary reference material.

[347] Ibid.

[348] Ibid.

Category	Commercial & Industrial Measures	Sector	EUL (years)	Source
Compressed Air	Low Pressure Drop Filter	C&I	10	Navigant EUL Report [349]
Domestic Hot Water (DHW)	Heat Pump Water Heater (HPWH)	C&I	15	DEER 2014 EUL ID: WtrHt-Com
	Indirect Water Heater	C&I	15	DEER 2014 EUL ID: WtrHt-Com
	Instantaneous Water Heater	C&I	20	DEER 2014 EUL ID: WtrHt-Instant-Com
	Storage Tank Water Heater	C&I	15	DEER 2014 EUL ID: WtrHt-Com
DHW - Control	DHW Temperature Turndown	C&I	RUL of DHW System **Default = 5**	N/A
	Drain Water Heat Recovery (DWHR)	C&I	30	2019 Title 24[350]
	Low-Flow – Faucet Aerator	C&I	10	DEER 2014 EUL ID: WtrHt-WH-Aertr
	Low-Flow – Pre-Rinse Spray Valve (PRSV)	C&I	5	GDS
	Low-Flow – Salon Valve	C&I	10	DEER 2014 EUL ID: WtrHt-WH-Shrhd
	Low-Flow – Showerhead	C&I	10	DEER 2014 EUL ID: WtrHt-WH-Shrhd
	Central DHW Control	C&I	15	NREL[351]
Heating, Ventilation and Air Conditioning (HVAC)	Air Conditioner – PTAC	C&I	15	DEER 2014 EUL ID: HVAC-PTAC
	Air Conditioner – Unitary	C&I	15	DEER 2014 EUL ID: HVAC-airAC

[349] Navigant ComEd Effective Useful Life Research Report. https://www.icc.illinois.gov/docket/P2017-0312/documents/287811/files/501915.pdf
[350] 2019 Title 24, Part 6 CASE Report. "Drain Water Heat Recovery – Final Report." http://title24stakeholders.com/wp-content/uploads/2017/09/2019-T24-CASE-Report_DWHR_Final_September-2017.pdf
[351] https://www.nrel.gov/docs/fy16osti/64541.pdf

Category	Commercial & Industrial Measures	Sector	EUL (years)	Source
	Boiler and Furnace - Combination ("Combi") Boiler	C&I	22	DOE[352]
	Boiler and Furnace -Combination ("Combi") Furnace	C&I	20	DEER 2014[353] EUL ID: HVAC-Frnc
	Boiler, Hot Water – Steel Water Tube	C&I	24	ASHRAE Handbook, 2015
	Boiler, Hot Water – Steel Fire Tube	C&I	25	ASHRAE Handbook, 2015
	Boiler, Hot Water – Cast Iron	C&I	35	ASHRAE Handbook, 2015

[352] Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Furnaces, February 10, 2015, Table 8.2.17. https://energy.mo.gov/sites/energy/files/technical-support-document---residential-furances_doe.pdf

[353] Based on DEER value for high efficiency boiler and instantaneous water heater.

Category	Commercial & Industrial Measures	Sector	EUL (years)	Source
Heating, Ventilation and Air Conditioning (HVAC)	Boiler, Steam – Steel Water Tube	C&I	30	ASHRAE Handbook, 2015
	Boiler, Steam – Steel Fire Tube	C&I	25	ASHRAE Handbook, 2015
	Boiler, Steam – Cast Iron	C&I	30	ASHRAE Handbook, 2015
	Chiller – Air & Water Cooled	C&I	20	DEER 2014 EUL ID: HVAC-Chlr
	Chiller – Cooling Tower	C&I	15	DEER 2014 EUL ID: HVAC- ClTwrPkgSys
	Condensing Unit Heater	C&I	18	Ecotope[354]
	Duct Sealing and Insulation	C&I	18	DEER 2014 EUL ID: HVAC-DuctSeal
	Economizer –Dual Enthalpy Air Side	C&I	10	DEER 2014 EUL ID: HVAC-addEcono
	Electronically Commutated (EC) Motor - HVAC Blower Fan	C&I	15	DEER 2014 EUL ID: Motors-Fan
	Electronically Commutated (EC) Motor – Hydronic Circulator Pump	C&I	15	DEER 2014 EUL ID: Motors-pump
	Energy and Heat Recovery Ventilator	C&I	14	PA Consulting Group[355]
	Furnace, Gas Fired	C&I	23	DOE[356,357]
	Gas Heat Pump	C&I	15	DEER 2014 EUL ID: HV-Res HP
	Heat Pump – Unitary & Applied	C&I	15	DEER 2014 EUL ID: HVAC-airHP
	Heat Pump – PTHP	C&I	15	DEER 2014

354 Ecotope Natural Gas Efficiency and Conservation Measure Resource Assessment (2003).
355 PA Consulting Group Inc., Focus on Energy Evaluation Business Programs: Measure Life Study, final report dated August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
356 U.S. DOE. "Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Furnaces" and "Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Commercial Warm Air Furnaces." August 30, 2016. https://www.regulations.gov/document?D=EERE-2014-BT-STD-0031-0217
357 U.S. DOE. "Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Commercial Warm Air Furnaces." December 30, 2015. https://www.regulations.gov/document?D=EERE-2013-BT-STD-0021-0050

Category	Commercial & Industrial Measures	Sector	EUL (years)	Source
				EUL ID: HVAC-PTHP
	Heat Pump – Ground Source (GSHP)	C&I	25	ASHRAE[358]
	High Volume Low Speed Fan	C&I	15	PA Consulting Group[359]
	Infrared Heater	C&I	17	GDS[360]

[358] ASHRAE Owning and Operating Cost Database. https://xp20.ashrae.org/publicdatabase/system_service_life.asp?selected_system_type=1
[359] PA Consulting Group Inc., Focus on Energy Evaluation Business Programs: Measure Life Study, final report dated August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
[360] GDS Associates, Inc. “Natural Gas Efficiency Potential Study.” DTE Energy. July 29, 2016. https://www.michigan.gov/documents/mpsc/DTE_2016_NG_ee_potential_study_w_appendices_vFINAL_554360_7.pdf

Category	Commercial & Industrial Measures	Sector	EUL (years)	Source
Heating, Ventilation and Air Conditioning (HVAC)	Refrigerant Charge Correction & Tune Up – Air Conditioner and Heat Pump	C&I	10	DEER 2014 EUL ID: HVAC-Ref-Chg
	Tune-Up – Boiler	C&I	5	DEER 2014 EUL ID: BlrTuneup
	Tune-Up – Chiller System	C&I	5	WI EUL DB[361]
	Tune-Up – Furnace	C&I	5	DEER 2014 EUL ID: BlrTuneup
	Variable Refrigerant Flow (VRF) System	C&I	15	DEER 2014 EUL ID: HVAC-VSD-pump
	Unit Heater, Gas Fired	C&I	13	ASHRAE Handbook, 2015
HVAC – Control	Adaptive Photonic Control	C&I	EUL = Retrofitted motor RUL = Retrofitted motor EUL – (Current Year – Mfr. Year) **Default = 5**	DEER 2014 EUL ID: Motors-fan
	Advanced Rooftop Control	C&I	16	NYSERDA[362]
	Direct Digital Control (DDC) System	C&I	15	DEER 2014 EUL ID: HVAC-EMS
	Demand Control Ventilation (DCV)	C&I	15	DEER 2014 EUL ID: HVAC-VSD-DCV
	Energy Management System	C&I	15	DEER 2014 EUL ID: HVAC-EMS
	Energy Management System – Guest Room	C&I	15	DEER 2014 EUL ID: HVAC-EMS
	Boiler Economizer	C&I	EUL = Boiler RUL = Boiler EUL – (Current	GDS[363]

[361] Wisconsin Public Service Commission: Equipment Useful Life Database, 2013. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
[362] NYSERDA Methodology Appendix: Assessment of Energy Efficiency and Electrification Potential in New York State Residential and Commercial Buildings study (revised April 2023), Table 3-11: HVAC Controls https://www.nyserda.ny.gov/-/media/Project/Nyserda/Files/Publications/building-stock-potential-studies/AppendixAMethodologyNYSEEandElectrificationPotentialStudyApril2023-acc.pdf
[363] Natural Gas Energy Efficiency Potential in Massachusetts, GDS Associates, 2009. https://ma-eeac.org/wp-content/uploads/5_Natural-Gas-EE-Potenial-in-MA.pdf

Category	Commercial & Industrial Measures	Sector	EUL (years)	Source
			Year – Mfr. Year) **Default = 5**	
	Kitchen Demand Ventilation Control	C&I	15	PG&E[364]
	Outdoor Temperature Setback Control for Hydronic Boiler	C&I	EUL = Boiler RUL = Boiler EUL – (Current Year – Mfr. Year) **Default = 5**	N/A
	Steam Trap – Low-Pressure Space Heating	C&I	6	DEER 2014 EUL ID: HVAC-StmTrp

[364] PG&E Work Paper WPSDGENRCC0019, June 15, 2012.

Category	Commercial & Industrial Measures		Sector	EUL (years)	Source
HVAC – Control	Steam Trap Monitoring System – Low-Pressure Space Heating		C&I	15	DEER 2014 EUL ID: HVAC-EMS
	Thermostat – Programmable Thermostat – Wi-Fi (Communicating)		C&I	11	DEER 2014 EUL ID: HVAC-ProgTStats
	Thermostatic Radiator Valve		C&I	15	DOE[365]
Lighting[366]	Light Fixture	LED Fixture (DLC)	C&I	50,000 hrs /annual lighting operating hrs or 15 yrs if annual operating hrs are not known	DLC[367]
		LED Fixture (Interior)	C&I	Rated Life listed by ENERGY STAR or default to 25,000 hrs/annual lighting operating hrs or 15 yrs if rated lifetime or annual operating hrs are not known	ENERGY STAR®[368]

365 U.S. DOE. "Thermostatic Radiator Valve Evaluation." January 2015. https://www.nrel.gov/docs/fy15osti/63388.pdf

366 In response to codification of a 45 lm/W backstop requirement for general service lamps (GSLs), EULs for select lighting measures are currently under review by the TRM Management Committee. Revisions will take effect concurrent with other action taken in response to the imposed GSL standard in the V10 NY TRM filing. https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=4

367 50,000 hours per L_{70} requirements prescribed by the DLC's Product Qualification Criteria, Technical Requirement Table version 4.4.

368 Placed on the Qualified Fixture List by ENERGY STAR®, according to the appropriate luminaire classification as specified in the ENERGY STAR® Program with C&I redecoration and business type change patterns).

Category	Commercial & Industrial Measures		Sector	EUL (years)	Source
		LED Fixture (Exterior)	C&I	Rated Life listed by ENERGY STAR or default to 35,000 hrs/annual lighting operating hrs or 15 yrs if rated lifetime or annual operating hrs are not known	ENERGY STAR®[369]
		LED Fixture (Inseparable)	C&I	Rated Life listed by ENERGY STAR or default to 50,000/annual lighting operating hrs or 15 yrs if rated lifetime or annual operating hrs are not known	ENERGY STAR®[370]

[369] Ibid. requirements for Luminaires, version 2.1. Divided by estimated annual use, but capped at 20 years regardless (consistent
[370] Ibid.

Category	Commercial & Industrial Measures		Sector	EUL (years)	Source
Lighting[371]	Light Fixture	LED Fixture (Uncertified)	C&I	Rated Life listed by ENERGY STAR or default to 25,000 hrs /annual lighting operating hrs or 15 yrs if rated lifetime or annual operating hrs are not known	Uncertified
	LED Lamp		C&I	50,000 hours	DLC[372]
				Rated Life listed by ENERGY STAR or default to 15,000 hrs /annual lighting operating hrs or 15 yrs if rated lifetime or annual operating hrs are not known	ENERGY STAR®
	LED Exit Signs & Open Signs		C&I	16	DEER 2014 EUL ID: LED-sign
	Refrigerated Case LED		C&I	16	DEER 2014 EUL ID: GrocDisp-FixtLtg-LED
	Lighting Power Density (LPD)		C&I	15	GDS[373]
	Bi-Level Lighting		C&I	15	ComEd[374]

[371] In response to codification of a 45 lm/W backstop requirement for general service lamps (GSLs), EULs for select lighting measures are currently under review by the TRM Management Committee. Revisions will take effect concurrent with other action taken in response to the imposed GSL standard in the V10 NY TRM filing. https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=4

[372] Placed on the Qualified Products List by the Design Light Consortium (DLC) 50,000 hours, according to the appropriate Application Category as specified in the DLC's Product Qualification Criteria, Technical Requirement Table version 4.4 or higher.

[373] Measure Life Report, Residential and Commercial/Industrial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007. As directed in the Interior and Exterior Lighting measure, new construction projects may be evaluated based on LPD. This value is provided for use with new construction LPD projects only. https://energy.mo.gov/sites/energy/files/measure-life-report-2007.pdf

[374] ComEd Luminaire Level Lighting Control IPA Program Impact Evaluation Report prepared by Navigant. https://www.ilsag.info/wp-

Category	Commercial & Industrial Measures	Sector	EUL (years)	Source
Lighting - Control	Integrated Interior Control	C&I	15	ComEd[375]
	Non-Integrated Interior Control	C&I	10	GDS[376]
	Plug-Load Occupancy Sensor	C&I	8	DEER[377]
Motors and Drives	Motor (incl. PEI Pumps)	C&I	15	DEER 2014 EUL ID: Motors-HiEff
	Notched & Synchronous Belt	C&I	5	DEER 2014 EUL ID: HV-CoggedBelt
Motors and Drives	Pool Pump	C&I	10	DEER 2014 EUL ID: OutD-Pool-Pump
	Variable Frequency Drive (VFD) – Fan and Pump	C&I	15	DEER 2014 EUL ID: HVAC-VSDSupFan
	Elevator Modernization	C&I	15	DEER 2014[378]
Other	Building Operator Certification	C&I	13	ComEd[379]
	Heat Pump Pool Heater	C&I	15	DEER 2014 EUL ID: HV-Res HP
	High Efficiency Transformer	C&I	32	DOE[380]
	High Frequency Battery Charger	C&I	15	PG&E[381]
	High Viscosity Industrial Lubricant	C&I	10	ExxonMobil[382]
	Pool Heater	C&I	8	DOE[383]

content/uploads/SAG_files/Evaluation_Documents/ComEd/ComEd_EPY9_Evaluation_Reports_Final/ComEd_PY9_LLLC_IPA_Program_Impact_Evaluation_Report_2018-06-05_Final.pdf

[375] Ibid.

[376] Measure Life Report, Residential and Commercial/Industrial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007. https://energy.mo.gov/sites/energy/files/measure-life-report-2007.pdf

[377] DEER value for lighting occupancy sensors.

[378] Assumes same EUL as VFD measure.

[379] Average measure life of capital measures from the ComEd CY2020 evaluation.

[380] https://www.federalregister.gov/documents/2019/06/18/2019-12761/energy-conservation-program-energy-conservation-standards-for-distribution-transformers

[381] https://www.kannahconsulting.com/wp-content/uploads/2016/08/2010-10-11_Battery_Charger_Title_20_CASE_Report_v2-2-2.pdf, pg. 43.

[382] Information presented in the ExxonMobil study is confidential.

[383] DOE, Chapter 8, Life-Cycle Cost and Payback Period Analyses, Table 8.75. https://www.regulations.gov/document?D=EERE-2006-STD-0129-0170

Category	Commercial & Industrial Measures	Sector	EUL (years)	Source
	Solar Pool Cover	C&I	5	CALMAC[384]
Process Equipment	Steam Trap – Other Applications	C&I	6	DEER 2014 EUL ID: HVAC-StmTrp
	Steam Trap Monitoring System – Other Applications	C&I	15	DEER 2014 EUL ID: HVAC-EMS
	Ozone Laundry	C&I	10	PG&E[385]
	Process Exhaust Filtration	C&I	15	CIBSE[386]
Refrigeration	Air-Cooled Refrigeration Condenser	C&I	15	DEER 2014 EUL ID: GrocSys-Cndsr
	Automatic Door Closer for Walk-In Cooler/Freezer	C&I	8	DEER 2014 EUL ID: GrocWlkIn-DrClsr
	Cooler and Freezer Door Gasket	C&I	4	DEER 2014 EUL ID: GrocWlkIn-StripCrtn, GrocWlkIn-WDrGask
	Cooler and Freezer Door Strip	C&I	4	DEER 2014 EUL ID: GrocWlkIn-StripCrtn, GrocWlkIn-WDrGask
	EC Motor – Refrigerated Case or Walk-In Cooler/Freezer Evaporator Fan	C&I	15	DEER 2014 EUL ID: GrocDisp-FEvapFanMtr

[384] http://www.calmac.org/publications/PoolCoverReport_2015_Final_Report_Appendices.pdf
[385] PG&E Work Paper PGECOAPP123, August 22, 2017.
[386] Chartered Institution of Building Services Engineers. "Probabilistic Estimation of Service Life." An industrial ventilation system consists of a fan and a set of filters; Fan and Filter EUL are 15 to 20 years depending on type. https://www.cibse.org/knowledge-research/knowledge-portal/probabilistic-estimation-of-service-life

Category	Commercial & Industrial Measures	Sector	EUL (years)	Source
Refrigeration	Equipment (Condenser, Compressor, and Sub-cooling)	C&I	15	DEER 2014 EUL ID: GrocSys-MechSubcl
	Evaporator Fan Motor – with Permanent Magnet Synchronous Motor (PMSM)	C&I	15	DEER 2014 EUL ID: GrocDisp-FEvapFanMtr
	Refrigerated Case Door	C&I	12	DEER 2014 EUL ID: GrocDisp-FixtDoors
	Refrigerated Case Night Cover	C&I	5	DEER 2014 EUL ID: GrocDisp-DispCvrs
	Refrigeration Condenser Coil Cleaning	C&I	1	Based on measure compliance requirements
Refrigeration - Control	Anti-Condensation Heater Control	C&I	12	DEER 2014 EUL ID: GrocDisp-ASH
	Condenser Pressure and Temperature Control	C&I	15	DEER 2014 EUL ID: GrocSys-Cndsr
	Evaporator Fan Control	C&I	16	DEER 2014 EUL ID: Groc-WlkIn-WEvapFMtrCtrl
	Floating Head Pressure Control	C&I	10	PA Consulting Group [387]

Common References

1. DEER 2014 EUL.
   Available from: http://www.deeresources.com/files/DEER2013codeUpdate/download/DEER2014-EUL-table-update_2014-02-05.xlsx
2. GDS Associates, Inc., Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures, June 2007.
   Available from: https://library.cee1.org/system/files/library/8842/CEE_Eval_MeasureLifeStudyLights%2526HVACGDS_1Jun2007.pdf

[387] PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study. Final Report." August 25, 2009.
https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf

Record of Revision

Record of Revision Number	Issue Date
EUL's originally listed in July 18, 2011 Order	7/18/2011
Additional EUL's posted on web site	Subsequent to 7/18/2011 Order
7-13-28	7/31/2013
6-14-1	6/19/2014
6-14-2	6/19/2014
6-15-4	6/1/2015
6-16-2	6/30/2016
1-17-8	12/31/2016
6-17-16	6/30/2017
9-17-11	9/30/2017
12-17-17	12/31/2017
3-18-21	3/31/2018
6-18-23	6/30/2018
9-18-21	9/30/2018
12-18-17	12/28/2018
3-19-16	3/29/2019
6-19-14	6/30/2019
9-19-10	9/30/2019
12-19-17	12/23/2019
3-20-17	3/30/2020
7-20-20	7/31/2020
12-20-12	12/31/2020
3-21-18	3/31/2021
7-21-21	8/30/2021
12-21-25	1/28/2022
6-22-13	9/2/2022
3-23-21	3/31/2023
6-23-16	7/14/2023
9-23-5	10/31/2023
12-23-20	1/5/2024

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