Table of Revisions/Changes

Revision Number	Addition/ Revision	Issue Date	Effective Date	Measure	Description of Change	Location/Page in TRM
3-22-04	R	4/29/2022	1/1/2023	R/MF EC Motor for Hydronic System Circulator Pump	Updated Calculation Methodology; Added language to exclude application to GSHP; Added Reference to source material; Heating hours table updated	Pg. 210
3-22-05	R	4/29/2022	1/1/2023	R/MF Interior and Exterior Lighting	Added methodology for LMI projects; Expanded Lumen Ranges in Wattage Tables	Pg. 320
3-22-08	R	4/29/2022	1/1/2023	C/I EC Motor for Hydronic System Circulator Pump	Updated Calculation Methodology; Added language to exclude application to GSHP; Added Reference to source material; Heating hours table updated	Pg. 670
3-22-09	R	4/29/2022	1/1/2023	R/MF Heat Pump Pool Heater	Removed references to indoor pools; Removed Demand Savings algorithm; Updated Example Calculation; Updated Ambient Air Temperature and Pressure table	Pg. 341
3-22-10	R	4/29/2022	1/1/2023	C/I Heat Pump Pool Heater	Removed references to indoor pools; Removed Demand Savings algorithm; Updated Example Calculation; Updated Ambient Air Temperature and Pressure table	Pg. 880

Note: Revisions and additions to the measures listed above were undertaken by the Joint Utilities Technical Resource Manual (TRM) Management Committee between January 28, 2022 – April 29, 2022.

Heating, Ventilation and Air Conditioning (HVAC)

Electronically Commutated (EC) Motor – Hydronic Circulator Pump

Measure Description

This measure covers the retrofit of standard efficiency permanent split capacitor (PSC) motors with electronically commutated (EC) motors in hydronic distribution circulators in residential heating and cooling systems, excluding Ground Source Heat Pump ground loops. A circulator pump is a specific type of pump used to circulate liquids in a closed distribution system. They are commonly found circulating water in a hydronic heating or cooling system.

Circulator pumps used in hydronic systems are usually electrically powered centrifugal pumps. When used in homes, they are often small, sealed, and rated at a fraction of a horsepower. The sealed units used in home applications often have the motor rotor, pump impeller, and support bearings combined and sealed within the water circuit. This avoids one of the principal challenges faced by the larger, two-part pumps: maintaining a water-tight seal at the point where the pump drive shaft enters the pump body.

This measure comprises two methods for estimating energy savings associated with circulator pump replacement. The primary method relies on Hydraulic Institute listed Energy Rating (ER) and Weighted Average Input Power (WAIP) values.[1] Because Hydraulic Institute Program Guidelines are not a mandated rating standard, an alternative method dependent on manufacturer published pump curves is provided.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings, Hydraulic Institute Rated Circulators

Annual Electric Energy Savings

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

$$\Delta kWh_{cooling} = units \times \left(\frac{ER \times WAIP \times 7.46}{1{,}000}\right) \times hrs_{cooling}$$

$$\Delta kWh_{heating} = units \times \left(\frac{ER \times WAIP \times 7.46}{1{,}000}\right) \times hrs_{heating}$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \frac{\Delta kWh_{cooling}}{hrs_{cooling}} \times CF$$

[1] Hydraulic Institute ER and WAIP ratings are established in accordance with HI 41.5-2021 Program Guidelines and can be used to directly estimate ECM circulator power savings relative to a standard efficiency circulator. HI 41.5 2021 is available from: https://estore.pumps.org/mobile/Program-Guideline-for-Circulator-Pump-Energy-Rating-Program-HI-415-2021-P3334.aspx

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings, Alternative Method

Annual Electric Energy Savings

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

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

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

Summer Peak Coincident Demand Savings

$$\Delta kW = \frac{\Delta kWh_{cooling}}{hrs_{cooling}} \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

Note: Calculate the hhp to use the table of wattages:

$$hhp_{85\%} = \frac{Head_{85\%} \times Q_{85\%}}{3{,}960}$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
$\Delta kWh_{cooling}$	= Annual electric energy savings attributable to hydronic cooling system
$\Delta kWh_{heating}$	= Annual electric energy savings attributable to hydronic heating system
units	= Number of measures installed under the program
ER	= Energy Rating, from Hydraulic Institute Energy Rating label
WAIP	= Weighted Average Input Power, from Hydraulic Institute Energy Rating label
$hrs_{cooling}$	= Relevant system operating hours during the cooling season
$hrs_{heating}$	= Relevant system operating hours during the heating season
$_{baseline}$	= Characteristic of baseline condition
$_{ee}$	= Characteristic of energy efficient condition
W	= Equipment wattage

$hhp_{85\%}$ = Hydraulic horsepower at 85% of shutoff head
$Head_{85\%}$ = Pump head (ft) at 85% of shutoff head, from pump curve
$Q_{85\%}$ = Flow (gpm) at 85% of shutoff head, from pump curve
CF = Coincidence factor
1,000 = Conversion factor (W/kW), 1,000 watts equals one kW
7.46 = Conversion factor, from Hydraulic Institute
3,960 = Conversion from flow rate in gpm and pump head in ft to hhp

Summary of Variables and Data Sources

Variable	Value	Notes
ER		From application, based on Hydraulic Institute Energy Rating label for the appropriate control method.
WAIP		From application, based on Hydraulic Institute Energy Rating label for the appropriate control method.
$hrs_{cooling}$	2,208	Cooling assumes three months (92 days) of 24 hour operation
$hrs_{heating}$	5,256	Heating based on Assessment of New Energy Efficient Circulator Pump Technology. [2]
$W_{baseline}$		Lookup from table below based on EC circulator hydraulic horsepower. Interpolation based on hydraulic horsepower of the data in the table is acceptable for circulator motor hhp not provided. Application hhp shall be calculated based on pump curve at 85% of shutoff head (ft) and corresponding flowrate (GPM).
W_{ee}		Lookup from table below based on EC circulator hydraulic horsepower. Interpolation based on hydraulic horsepower of the data in the table is acceptable for circulator motor hhp not provided. Application hhp shall be calculated based on pump curve at 85% of shutoff head (ft) and corresponding flowrate (GPM).
$Head_{85\%}$		From application, based on pump curve
$Q_{85\%}$		From application, based on pump curve
CF	Heating: N/A Cooling: 0.8	

[2] Assessment of New Energy Efficient Circulator Pump Technology, pg 3-11. Assumed circulator pump is utilized 60% of the year (0.60*8,760 = 5,256).

Baseline and Efficient Circulator Wattages[3]

EC Circulator hhp	Approximate PSC Circulator Equivalent Rated hp	$W_{baseline}$	W_{ee}
0.002	1/40	60	15
0.009	1/40	77	29
0.016	1/25	96	40
0.023	1/25	124	53
0.030	1/12	132	58
0.097	1/6	269	138
0.099	1/6	282	145
0.57	1	962	555

Coincidence Factor (CF)

The prescribed value for the coincidence factor for heating is N/A.
The prescribed value for the coincidence factor for cooling is 0.8.[4]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a hydronic circulator pump operating with a standard permanent split-capacitor (PSC) motor in a residential heating and/or cooling system. Where ECM circulator is not rated by Hydraulic Institute, lookup baseline wattage from Baseline and Efficient Circulator Wattages table above.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a hydronic circulator pump operating with a high efficiency EC motor in a residential heating and/or cooling system. Where ECM circulator is not rated by Hydraulic Institute, lookup compliance case wattage from Baseline and Efficient Circulator Wattages table above. High efficiency circulators may include better impeller design that will further increase kWh savings, but these benefits are not considered in the prescribed savings estimation methodology.

Operating Hours

Annual circulator operating hours in a hydronic heating system are assumed to be 5,256, based on assumed 60% utilization of circulator pump. Savings will be less if the circulator cycles on and off with calls for heating.

Annual circulator operating hours in a hydronic cooling system are assumed to be 2,208, reflective

[3] Working Group Presentation: Circulator Pumps Appliance Standards and Rulemaking Federal Advisory Committee (ASRAC) Working Group, Ninth Meeting; Analysis Pre-meeting. Baseline and energy efficient case wattages are projected based on the engineering analysis presented by the working group. Wattage was calculated based on flow and head (Slides 56-59) and wire-to-water efficiency (67-74) of 8 representative unit groupings of motors based on hydraulic horsepower taken at four BEP loads at 100%, 75%, 50%, and 25%. The efficiencies of Single Speed Induction (EL 0) was applied as the baseline case and Single Speed ECM was applied as the energy efficient case (EL2). The four BEP wattages were averaged (Slide 4) to determine a resultant wattage.
[4] *No source specified – update pending availability and review of applicable references.*

of utilization of cooling systems for three months out of the year.

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

A PSC circulator pump motor in a hydronic heating system is replaced with an EC motor with a Hydraulic Institute Rating of 188 ER and 0.077 WAIP. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

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

$$\Delta kWh_{cooling} = N/A$$

$$\Delta kWh_{heating} = units \times \left(\frac{ER \times WAIP \times 7.46}{1{,}000}\right) \times hrs_{heating}$$

$$\Delta kW = N/A$$

units = 1, from application
ER = 188, from application
WAIP = 0.077, from application
$hrs_{heating}$ = 5,256, from Summary of Variables and Data Sources table based on application

$$\Delta kWh_{heating} = 1 \times \left(\frac{188 \times 0.077 \times 7.46}{1000}\right) \times 5{,}256 = 567.6\ kWh$$

$$\Delta kWh = 0 + 567.6 = 567.6\ kWh$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Higher efficiency circulators may lead to increased fuel consumption. Reduction in waste heat from increased efficiency in motors results in additional heating requirement. These effects are negligible and therefore not quantified in this methodology.

Ancillary Electric Savings Impacts

Higher efficiency circulators may lead to reduced electric consumption. Reduction in waste heat from increased efficiency in motors results in decreased cooling requirement. These effects are negligible and therefore not quantified in this methodology.

References

1. Hydraulic Institute Energy Rating
   Available from: https://er.pumps.org/ratings/home
2. Hydraulic Institute, Program Guideline for Circulator Pump Energy Rating Program (HI 41.5-2021)
   Available from: https://estore.pumps.org/mobile/Program-Guideline-for-Circulator-Pump-Energy-Rating-Program-HI-415-2021-P3334.aspx
3. Assessment of New Energy Efficient Circulator Pump Technology, Electric Power Research Institute, November 2010
   Available from: https://publicdownload.epri.com/PublicDownload.svc/product=000000000001020132/type=Product
4. Working Group Presentation: Circulator Pumps Appliance Standards and Rulemaking Federal Advisory Committee (ASRAC) Working Group, Ninth Meeting; Analysis Pre-meeting, Energy Efficiency and Renewable Energy Office, November 7, 2016.
   Available from: https://www.regulations.gov/document/EERE-2016-BT-STD-0004-0075

Record of Revision

Record of Revision Number	Issue Date
0	10/15/2010
6-18-4	6/26/2018
3-22-4	4/29/2022

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LIGHTING

INTERIOR AND EXTERIOR LIGHTING

Measure Description

This measure covers energy efficient lighting equipment, such as energy efficient lamps, LED lamps and improved lighting fixtures installed in interior or exterior locations. These technologies, taken separately or combined into an energy efficient lighting fixture, provide the required illumination at reduced input power.

Beginning January 2012 and phased in through January 2014, the Energy Independence and Security Act of 2007 (EISA) regulations stipulated typical screw-based general service lamps with wattages ranging from 40W to 100W to comply with new lamp wattage standards such that the range of wattages decreased to be from 29W to 72W for rated lumen output ranging from 310 to 2,600 lumens.[5] Deemed baseline values for this measure will apply wattages based on lamp type and light output (lumens).[6]

This measure consists of two methods for estimating energy and demand savings. The primary method represented by the first set of algorithms below is suitable for both market rate and LMI applications. The alternative methodology represented by the second set of algorithms shall be used for LMI applications only. This simplified approach relies on average sampling data to establish wattage and consumption reductions and assumed hours of operation.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

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

Summer Peak Coincident Demand Savings

$$\Delta kW = units \times \frac{(W_{baseline} - W_{ee})}{1{,}000} \times (1 + HVAC_d) \times CF$$

Annual Fossil Fuel Energy Savings

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

[5] The maximum rated wattage varies for modified spectrum lamps.
[6] Energy Independence and Security Act of 2007. Pub. L. 110-140. Sec. 321. Efficient Light Bulbs H.R.6 – 86

Alternate Methods for Calculating Annual Energy Savings for LMI Projects

General Purpose LEDs

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

Candelabra LEDs

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

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

It is assumed that the ΔkWh per Candelabra lamp is 42.2 kWh. This is derived from an assumed ΔW of 33W per lamp and 3.5 hours of usage per day.

The savings associated with candelabra lamps is derived from a baseline lamp wattage that is pre-EISA 2020 adjustments. The 2007 baseline maximum for candelabra lamps in EISA states that the wattage cannot exceed 60 watts.[7]

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

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
baseline	= Characteristic of baseline condition
ee	= Characteristic of energy efficient condition
W	= Rated wattage of lamp and/or fixture (Watts)
hrs	= Lighting operating hours
$HVAC_c$	= HVAC interaction factor for annual electric energy consumption
$HVAC_d$	= HVAC interaction factor at utility summer peak hour
HVACff	= HVAC interaction factor for annual fossil fuel consumption (MMBtu/kWh)
CF	= Coincidence factor
$\Delta W_{LMI,GP}$	= Wattage reduction per general-purpose lamp (LMI only)
$\Delta kWh_{LMI,Candelabra}$	= Annual electric energy savings per candelabra lamp (LMI only)
1,000	= Conversion factor, one kW equals 1,000 Watts
365	= Days per year

[7] EISA Subtitle B Lighting Energy Efficiency Section 321 (a)(3)(C)

Summary of Variables and Data Sources

Variable	Value	Notes
$W_{baseline}$		Baseline measure Watts, from application or default values from applicable table in "Baseline Efficiencies" section below depending on program structure/delivery mechanism.
W_{ee}		Energy efficient measure Watts, from application
hrs		Look up in Operating Hours section below based on project type, installation type and location. "Interior" designation extends to any covered area not adequately lit during daylight hours by sunlight, thus requiring daytime operation of lighting. "Unknown" is not a valid selection for direct install programs. LMI projects may claim up to 16 LED lamps before requiring a lighting schedule.
$HVAC_c$	Exterior and Unconditioned Spaces: 0	HVAC interaction factor for annual electric energy consumption (dimensionless). Vintage and HVAC type weighted average by city. See Appendix D.
$HVAC_d$	Exterior and Unconditioned Space: 0	HVAC interaction factor for peak demand at utility summer peak hour (dimensionless). Vintage and HVAC type weighted average by city. See Appendix D.
$HVAC_{ff}$	Exterior and Unconditioned Space: 0	HVAC interaction factor for annual fossil fuel energy consumption (MMBtu/kWh). Vintage and HVAC type weighted average by city. See Appendix D.
CF	Interior: 0.16 Exterior: 0	"Interior" designation extends to any covered area not adequately lit during daylight hours by sunlight, thus requiring daytime operation of lighting.
$\Delta W_{LMI,GP}$	46	Wattage reduction per general-purpose lamp.[8]
$\Delta kWh_{LMI,Candelabra}$	42.2	This is derived from an assumed ΔW of 33W per lamp and 3.5 hours of usage per day.

HVAC system interaction factors are defined as the ratios of the cooling energy and demand reduction and heating energy increase per unit of lighting energy reduction. Much of the input energy for lighting systems is converted to heat that must be removed by the HVAC system. Reductions in lighting heat gains due to lighting power reduction decrease the need for space cooling and increase the need for space heating.

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

HVAC interaction factors vary by climate, HVAC system type and building type. Prescribed values for HVAC interaction factors for lighting energy and peak demand savings are shown in Appendix D. Lighting systems in unconditioned spaces or on the building exterior will have interaction factors of 0.0.

Coincidence Factor (CF)

The prescribed value for the coincidence factor for interior lighting is 0.16.[9] This value shall also be used if the installation location is unknown.

Because exterior lighting is assumed to operate during off-peak hours only, the prescribed coincidence factor for exterior lighting is 0.0.

Baseline Efficiencies from which Energy Savings are Calculated

Rated wattage baseline values should reflect the guidance noted below based on bulb type and lumens in accordance with EISA standards. [10]

General Service Lamps

Baseline wattage for general service lamps are found in the table below. Per EISA 2007 guidelines, a general service lamp is defined as a standard incandescent or halogen type lamp that:

(1) Is intended for general service applications;
(2) Has a medium screw base;
(3) Has a lumen range of not less than 310 lumens and not more than 2,600 lumens
(4) Is capable of being operated at voltage range at least partially within 110 and 130 volts.

Certain lamp types are exempt from EISA compliance, including reflector lamps (see Reflector/Flood Lamps section below), some decorative and globe shape lamps (see Specialty Lamps section below) and three-way lamps. Baseline wattage for any of these exempt lamp types shall reflect the values in column (c) of the table below, with the exception of those lamps defined in the Specialty Lamps or Reflector/Flood Lamps sections below. All other general service lamps shall use the baseline wattage values in column (b), corresponding to the applicable lumen range identified in column (a). For standard lamps that fall outside of the prescribed lumen ranges below, the manufacturer recommended baseline wattage shall be used. For a complete list and definitions of EISA-exempt lamp types, reference Sec. 321: Efficient Light Bulbs of Public Law 110-140.[11]

[9] NMR Group Inc., "Northeast Residential Lighting Hours-of-Use Study", May 5, 2014. Table 4-4: Peak Period Coincidence Factors and Confidence Intervals – Efficient Bulbs. CF referenced reflects Average Summer for NYSERDA based on ISO-NE peak period. The NYSERDA model includes UNY and DNY. The NYSERDA model does not differentiate between interior and exterior lighting. The interior lighting sample size is significantly larger than the exterior sample size. Thus, reported Coincidence Factor is appropriate for interior lighting and unknown installations.

[10] Energy Independence and Security Act of 2007. Pub. L. 110-140. Sec. 321. Efficient Light Bulbs H.R.6 – 89

[11] Energy Independence and Security Act of 2007. Pub. L. 110-140. Sec. 321. Efficient Light Bulbs H.R.6 – 82-86

Bulb Type (a)	Lumen Range (b)	EISA 2007 Incandescent Equivalent $W_{baseline}$ (c)	EISA-Exempt Incandescent Equivalent $W_{baseline}$ (d)
A-Lamp (A15, A17, A19, A21)	< 310	Use ENERGY STAR Watts Equivalent	
	310 – 749	29	40
	750 – 1,049	43	60
	1,050 – 1,489	53	75
	1,490 – 2,600	72	100
	> 2,600	Use ENERGY STAR Watts Equivalent	

Specialty Lamps

Baseline wattage for specialty lamps are found in the table below. Specialty lamps are defined as screw-base lamps that are globe, bullet, candle or decorative shaped. These can be medium base, intermediate base, or candelabra base lamps. EISA 2007 set specific limits on maximum rated wattage for incandescent intermediate and candelabra base lamps, 40W and 60W respectively. In addition, some medium screw-base specialty lamps that could be used for general service applications are specifically exempt from EISA 2007 wattage limits and include: 1) a G shape lamp with a diameter of 5 inches or more (i.e. a G40 lamp); 2) a T shape lamp that uses not more than 40 watts or has a length of more than 10 inches; (3) a B, BA, CA, F, G16–1/2, G–25, G30, S, or M–14 lamp of 40 watts or less; and 4) a silver bowl lamp.[12] Medium screw-base specialty lamps not exempt from EISA 2007 must meet the maximum wattage requirements outlined in EISA 2007. For these lamps, the baseline wattage from column (b) in the table above should be used based on the lumen output. For specialty lamps that fall outside of the prescribed lumen ranges below, the manufacturer recommended baseline wattage should be used.

[12] Ibid

Bulb Type (a)	Base Type (b)	Lumen Range (c)	$W_{baseline}$[13] (d)
Globe All G (G30, G25, G16.5)	E26 and E17	< 90	Use ENERGY STAR Watts Equivalent
		90 – 179	10
		180 – 249	20
		250 – 349	25
		350 – 749	40
		750 – 1,049	43
		1,050 – 1,489	53
		1,490 – 2,600	72
		> 2,600	Use ENERGY STAR Watts Equivalent
	E12 (Candelabra)	< 90	Use ENERGY STAR Watts Equivalent
		90 – 179	10
		180 – 249	20
		250 – 349	25
		350 – 499	40
		500 – 1,049	60
		> 1,049	Use ENERGY STAR Watts Equivalent
Globe G40	E26 (Medium), E17, and E12	< 90	Use ENERGY STAR Watts Equivalent
		90 – 179	10
		180 – 249	20
		250 – 349	25
		350 – 499	40
		500 – 1,049	60
		> 1,049	Use ENERGY STAR Watts Equivalent

[13] The baseline wattage for the specialty lamps is calculated by dividing the midpoint lumen output for the range by the mean efficacy for "General Purpose- Incandescent Omni" for Globe bulbs and "Decorative- Incandescent Omni" for Decorative bulbs found in Table C.2 (page 82) from the Energy Savings Forecast of Solid-State Lighting in General Illumination Applications Report (US DOE, 2019). The calculated baseline wattage is rounded to a standard wattage output or the maximum rated wattage for that category.

Bulb Type (a)	Base Type (b)	Lumen Range (c)	$W_{baseline}$[13] (d)
Decorative (Shapes B10, B11, B13, BA10, BA11, CA10, C7, C9, F10, F15, ST, S14)	E26 (Medium) and E17	< 70	Use ENERGY STAR Watts Equivalent
		70 – 89	10
		90 – 149	15
		150 – 299	25
		300 – 749	40
		750 – 1,049	43
		1050 – 1,489	53
		1,490 – 2,600	72
		> 2,600	Use ENERGY STAR Watts Equivalent
	Candelabra base E12	< 70	Use ENERGY STAR Watts Equivalent
		70 – 89	10
		90 – 149	15
		150 – 299	25
		300 – 449	40
		450 – 1,049	60
		> 1,049	Use ENERGY STAR Watts Equivalent

<u>Reflector/Flood Lamps</u>
Baseline wattage for reflector and flood type lamps are found in the tables below. For reflector and flood lamps that are not covered by the table below, either based on bulb type or lumen output, the manufacturer recommended baseline wattage should be used. The first part of the table lists the baseline wattage for the incandescent reflector lamp bulb types specifically exempted from federal standards and include 1) Lamps rated at 50 watts or less that are ER30, BR30, BR40, or ER40 lamps; 2) Lamps rated at 65 watts that are BR30, BR40, or ER40 lamps; or 3) R20 incandescent reflector lamps rated 45 watts or less. [14]

[14] Electronic Code of Federal Regulations, Title 10: Energy, PART 430—ENERGY CONSERVATION PROGRAM FOR CONSUMER PRODUCTS, Subpart C—Energy and Water Conservation Standards

Exempt Bulb Type (a)	Lumen Range (b)	$W_{baseline}$[15] (c)
R20	200 - 299	30
	300 – 718	45
	719 – 810	50
	811 – 1,002	55
	1,003 – 1,202	65
	1,203 – 1,516	75
	1,517 – 1,733	90
	1,734 – 2,184	100
	> 2,184	120
PAR20	200 - 299	30
	300 – 718	40
	719 – 810	50
	811 – 1,002	55
	1,003 – 1,202	65
	1,203 – 1,516	75
	1,517 – 1,733	90
	1,734 – 2,184	100
	> 2,184	120

Not Exempt Bulb Type (a)	Lumen Range (c)	$W_{baseline}$[16] (d)
BR30, BR40, ER40	200 – 299	30
	300 – 399	40
	400 – 649	50
	650 – 1,419	65
	1,420 – 1,789	75
	1,790 – 2,045	90
	2,046 – 2,578	100
	> 2,578	120

[15] The baseline wattage for the exempt reflector/flood lamps is calculated by dividing the midpoint lumen output for the range by the mean efficacy for "Downlights- Incandescent Directional" bulbs found in Table C.2 (page 82) from the Energy Savings Forecast of Solid-State Lighting in General Illumination Applications Report (US DOE, 2019). The calculated baseline wattage is rounded to a standard wattage output or the maximum rated wattage for that category.

[16] The baseline wattage is calculated based on the standards outlined in the Electronic Code of Federal Regulations, Title 10: Energy, PART 430—ENERGY CONSERVATION PROGRAM FOR CONSUMER PRODUCTS, Subpart C—Energy and Water Conservation Standards

Not Exempt Bulb Type (a)	Lumen Range (c)	$W_{baseline}$[16] (d)
ER30	200 – 299	30
	300 – 399	40
	400 – 956	50
	957 – 1183	55
	1184 – 1419	65
	1420 – 1789	75
	1790 – 2045	90
	2046 – 2578	100
	> 2578	120
PAR30, PAR38, R40	639 – 847	40
	848 – 956	50
	957 – 1,183	55
	1,184 – 1,419	65
	1,420 – 1,789	75
	1,790 – 2,045	90
	2,046 – 2,578	100
	> 2,578	120

Other Bulb Types (a)	Lumen Range (c)	$W_{baseline}$[17] (d)
R14, PAR16, R16	200 – 299	30
	300 – 399	40
	400 – 499	50
	500 – 599	60
	600 – 1,000	65
MR16	< 450	35
	450 – 600	50
	> 600	75
For any lamps/bulb types for reflector lamps not captured in the criteria above		Use ENERGY STAR Watts Equivalent

Compliance Efficiency from which Incentives are Calculated

The compliance condition is an efficient lighting product (lamp or fixture) meeting the minimum requirements of the current effective version of ENERGY STAR® Lamps specification, ENERGY STAR® Luminaires specification or the Design Lights Consortium qualified products list.

[17] The baseline wattage for the other reflector/flood bulb types is calculated by dividing the midpoint lumen output for the range by the mean efficacy for “Small Directional (MR16)- Halogen” for the MR16 bulbs or by “Downlights- Incandescent Directional” for all other bulbs found in Table C.2 (page 82) from the Energy Savings Forecast of Solid-State Lighting in General Illumination Applications Report (US DOE, 2019). The calculated baseline wattage is rounded to a standard wattage output or the maximum rated wattage for that category.

Operating Hours

Look up operating hours from the table below, based on lamp location and city. See details below for derivation of operating hours. “Interior” designation extends to any covered area not adequately lit during daylight hours by sunlight, thus requiring daytime operation of lighting. “Unknown” is not a valid selection for direct install programs.

City	Interior	Exterior	Unknown
Albany	986	2,081	1,022
Binghamton	986	2,081	1,022
Buffalo	986	2,081	1,022
Massena	986	2,081	1,022
NYC	1,752	2,117	1,752
Poughkeepsie	986	2,081	1,022
Syracuse	986	2,081	1,022

<u>NYS cities other than NYC, Interior</u>

Hours of operation for interior lighting is estimated to be 2.7 operating hours per day or 986 (2.7 x 365) hours per year. This value is derived from on-site lighting inventories of homes in New York, exclusive of New York City and Westchester County, and refined through a hierarchical model that drew upon loggers installed in Connecticut, Massachusetts, and Rhode Island.[18]

<u>NYS cities other than NYC, Exterior</u>

Hours of operation for exterior lighting is estimated to be 5.7 operating hours per day or 2,081 (5.7 x 365) hours per year. This value is derived from on-site lighting inventories of homes in New York, exclusive of New York City and Westchester County, and refined through a hierarchical model that drew upon loggers installed in Connecticut, Massachusetts, and Rhode Island. [19]

<u>NYS cities other than NYC, Unknown</u>

Hours of operation for lighting installed in an unknown location is estimated to be 2.8 operating hours per day or 1,022 (2.8 x 365) hours per year. This value is a weighted average of interior and exterior lighting hours derived from on-site lighting inventories of homes in New York, exclusive of New York City and Westchester County, and refined through a hierarchical model that drew upon loggers installed in Connecticut, Massachusetts, and Rhode Island.[20]

[18] NMR Group Inc., “Northeast Residential Lighting Hours-of-Use Study”, May 5, 2014. Table ES-5: HOU by Area Adjusted for Snapback, Table 3-2: Sample Sizes, Overall HOU Estimates by Area and Room, and hierarchical model as described in section 2.6.3 (p. 22). HOU referenced is a weighted average of interior room types for UNY and is Snapback Adjusted.

[19] NMR Group Inc., “Northeast Residential Lighting Hours-of-Use Study”, May 5, 2014. Table ES-5: HOU by Area Adjusted for Snapback and hierarchical model as described in section 2.6.3 (p. 22). HOU referenced is the value for Exterior for UNY and is Snapback Adjusted.

[20] NMR Group Inc., “Northeast Residential Lighting Hours-of-Use Study”, May 5, 2014. Table ES-5: HOU by Area Adjusted for Snapback and hierarchical model as described in section 2.6.3 (p. 22). HOU referenced is the value for Household for UNY, which is a weighted average of all room types and is Snapback Adjusted.

NYC, Interior
Hours of operation for exterior lighting is estimated to be 4.8 operating hours per day or 1,752 (4.8 x 365) hours per year. This value is derived from on-site lighting inventories of homes in New York City and Westchester County.[21]

NYC, Exterior
Hours of operation for exterior lighting is estimated to be 4.4 operating hours per day or 1,606 (4.4 x 365) hours per year. This value is derived from on-site lighting inventories of homes in New York City and Westchester County.[22]

NYC, Unknown
Hours of operation for lighting installed in an unknown location is estimated to be 4.8 operating hours per day or 1,752 (4.8 x 365) hours per year. This value is a weighted average of interior and exterior lighting hours derived from on-site lighting inventories of homes in New York City and Westchester County.[23]

LMI LED Table of Hours per Day by Unit Count

#Bulbs	Hours/day
1 - 2	3.2
3 - 5	3
6 - 7	2.5
8 - 9	1.5
10 - 16	1

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

An existing residential customer replaces twenty 60-watt incandescent lamps with 10-watt LED lamps throughout the interior of their home located near Albany. The home has a central AC and gas-furnace. Annual Electric Energy Savings, Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are calculated as below.

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

$$\Delta kW = units \times \frac{(W_{baseline} - W_{ee})}{1{,}000} \times (1 + HVAC_d) \times CF$$

[21] NMR Group Inc., "Northeast Residential Lighting Hours-of-Use Study", May 5, 2014. Table ES-6: HOU by Area Adjusted for Snapback and Table 3-2: Sample Sizes, Overall HOU Estimates by Area and Room. HOU referenced is a weighted average for interior room types for DNY and is Snapback Adjusted.
[22] NMR Group Inc., "Northeast Residential Lighting Hours-of-Use Study", May 5, 2014. Table ES-6: HOU by Area Adjusted for Snapback. HOU referenced is the value for Exterior for DNY and is Snapback Adjusted.
[23] NMR Group Inc., "Northeast Residential Lighting Hours-of-Use Study", May 5, 2014. Table ES-6: HOU by Area Adjusted for Snapback. HOU referenced is the value for Household for DNY, which is a weighted average of all room types and is Snapback Adjusted. The study's sample size included far more interior to exterior lights, thus a weighted distribution heavily favors the interior lighting hours.

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

units = 20, from application
$W_{baseline}$ = 60, from application
W_{ee} = 10, from application
hrs = 986, from Operating Hours section table based on lamp location and city from application
$HVAC_c$ = 0.043, from Appendix D based on building type, HVAC type, and location from application
$HVAC_d$ = 0.073, from Appendix D based on building type, HVAC type, and location from application
CF = 0.16, from Summary of Variables and Data Sources table based on lamp location from application
$HVAC_{ff}$ = -0.003, from Appendix D based on building type, HVAC type, and location from application

$$\Delta kWh = 20 \times \frac{(60 - 10)}{1{,}000} \times 986 \times (1 + 0.043) = 1{,}028\ kWh$$

$$\Delta kW = 20 \times \frac{(60 - 10)}{1{,}000} \times (1 + 0.073) \times 0.16 = 0.17\ kW$$

$$\Delta MMBtu = 20 \times \frac{(60 - 10)}{1{,}000} \times 986 \times (-0.003) = -2.96\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Reduction in lighting power increases space heating requirements in conditioned spaces. Interactive HVAC impacts are addressed in prescribed energy savings calculation methodology.

Ancillary Electric Savings Impacts

Reduction in lighting power decreases cooling requirements in conditioned spaces. Interactive HVAC impacts are addressed in prescribed energy savings calculation methodology.

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Record of Revision

Record of Revision Number	Issue Date
1	10/15/2010
7-13-2	7/31/2013
6-15-3	6/1/2015
1-16-3	12/31/2015
1-17-4	12/31/2016
9-17-2	9/30/2017
12-19-6	12/23/2019
12-19-7	12/23/2019
12-20-13	12/31/2020
7-21-9	8/30/2021
3-22-5	4/29/2022

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Heating, Ventilation and Air Conditioning (HVAC)

Electronically Commutated (EC) Motor – Hydronic Circulator Pumps

Measure Description

This measure covers the replacement of standard efficiency permanent split capacitor (PSC) motor circulator pumps with electronically commutated (EC) motor circulator pumps in HVAC hydronic and DHW systems, excluding Ground Source Heat Pump ground loops. This measure is not applicable to systems used in industrial processes. A circulator pump is a specific type of pump used to circulate liquids in a closed distribution system. They are commonly found circulating water in a hydronic heating or cooling system.

Circulator pumps used in hydronic and DHW systems are typically electrically powered centrifugal pumps. For residential-rated equipment installed in commercial applications, use the residential measure entitled "Electronically Commutated (EC) Motor – Hydronic Circulator Pumps".

This measure comprises two methods for estimating energy savings associated with circulator pump replacement. The primary method relies on Hydraulic Institute listed Energy Rating (ER) and Weighted Average Input Power (WAIP) values.[24] Because Hydraulic Institute Program Guidelines are not a mandated rating standard, an alternative method dependent on manufacturer published pump curves is provided.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings, Hydraulic Institute Rated Circulators

Annual Electric Energy Savings

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

$$\Delta kWh_{cooling} = units \times \left(\frac{ER \times WAIP \times 7.46}{1{,}000}\right) \times hrs_{cooling}$$

$$\Delta kWh_{heating} = units \times \left(\frac{ER \times WAIP \times 7.46}{1{,}000}\right) \times hrs_{heating}$$

$$\Delta kWh_{DHW} = units \times \left(\frac{ER \times WAIP \times 7.46}{1{,}000}\right) \times hrs_{DHW}$$

[24] Hydraulic Institute ER and WAIP ratings are established in accordance with HI 41.5-2021 Program Guidelines and can be used to directly estimate ECM circulator power savings relative to a standard efficiency circulator. HI 41.5 2021 is available from: https://estore.pumps.org/mobile/Program-Guideline-for-Circulator-Pump-Energy-Rating-Program-HI-415-2021-P3334.aspx

Summer Peak Coincident Demand Savings

$$\Delta kW = \frac{\Delta kWh_{cooling}}{hrs_{cooling}} \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings, Alternative Method

Annual Electric Energy Savings

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

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

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

$$\Delta kWh_{DHW} = units \times \left(\frac{W_{baseline} - W_{ee}}{1{,}000}\right) \times hrs_{DHW}$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \frac{\Delta kWh_{cooling}}{hrs_{cooling}} \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

Note: Calculate the hhp to use the table of wattages:

$$hhp_{85\%} = \frac{Head_{85\%} \times Q_{85\%}}{3{,}960}$$

where:

ΔkWh = Annual electric energy savings
ΔkW = Peak coincident demand electric savings
$\Delta MMBtu$ = Annual fossil fuel energy savings
$\Delta kWh_{cooling}$ = Annual electric energy savings attributable to hydronic cooling system
$\Delta kWh_{heating}$ = Annual electric energy savings attributable to hydronic heating system
ΔkWh_{DHW} = Annual electric energy savings attributable to DHW system

units	= Number of measures installed under the program
ER	= Energy Rating, from Hydraulic Institute Energy Rating label
WAIP	= Weighted Average Input Power, from Hydraulic Institute Energy Rating label
$hrs_{cooling}$	= Relevant system operating hours during the cooling season
$hrs_{heating}$	= Relevant system operating hours during the heating season
hrs_{DHW}	= Relevant DHW system operating hours
$_{baseline}$	= Characteristic of baseline condition
$_{ee}$	= Characteristic of energy efficient condition
W	= Equipment wattage
$hhp_{85\%}$	= Hydraulic horsepower at 85% of shutoff head
$Head_{85\%}$	= Pump head (ft) at 85% of shutoff head, from pump curve
$Q_{85\%}$	= Flow (gpm) at 85% of shutoff head, from pump curve
CF	= Coincidence factor
1,000	= Conversion factor (W/kW), 1,000 watts equals one kW
7.46	= Conversion factor, from Hydraulic Institute
3,960	= Conversion from flow rate in gpm and pump head in ft to hhp

Summary of Variables and Data Sources

Variable	Value	Notes
ER		From application, based on Hydraulic Institute Energy Rating label for the appropriate control method.
WAIP		From application, based on Hydraulic Institute Energy Rating label for the appropriate control method.
hrs	Continuous Heating: 5,256 Continuous Cooling: 2,208 On/Off Control Heating: From Application On/Off Control Cooling: From Application DHW: From application	From application; Continuous heating based on Assessment of New Energy Efficient Circulator Pump Technology.[25] Continuous cooling assumes three months (92 days) of 24-hour operation. On/Off control heating and cooling from application. If unknown, lookup based on location and facility type in Operating Hours section below. DHW from application. If unknown, lookup based on facility type in Operating Hours section below.

[25] Assessment of New Energy Efficient Circulator Pump Technology, pg 3-11. Assumed circulator pump is utilized 60% of the year (0.60*8,760 = 5,256)

Variable	Value	Notes
$W_{baseline}$		Lookup from table below based on EC circulator hydraulic horsepower. Interpolation based on hydraulic horsepower of the data in the table is acceptable for circulator motor hhp not provided. Application hhp shall be calculated based on pump curve at 85% of shutoff head (ft) and corresponding flowrate (GPM).
W_{ee}		Lookup from table below based on EC circulator hydraulic horsepower. Interpolation based on hydraulic horsepower of the data in the table is acceptable for circulator motor hhp not provided. Application hhp shall be calculated based on pump curve at 85% of shutoff head (ft) and corresponding flowrate (GPM).
$Head_{85\%}$		From application, based on pump curve
$Q_{85\%}$		From application, based on pump curve
CF	Heating: N/A Continuous Cooling: 1.0 On/Off Control Cooling: 0.8 DHW: N/A	

Baseline and Efficient Circulator Wattages[26]

EC Circulator hhp	Approximate PSC Circulator Equivalent Rated hp	$W_{baseline}$	W_{ee}
0.002	1/40	60	15
0.009	1/40	77	29
0.016	1/25	96	40
0.023	1/25	124	53
0.030	1/12	132	58
0.097	1/6	269	138
0.099	1/6	282	145
0.57	1	962	555

[26] Working Group Presentation: Circulator Pumps Appliance Standards and Rulemaking Federal Advisory Committee (ASRAC) Working Group, Ninth Meeting; Analysis Pre-meeting. Baseline and energy efficient case wattages are projected based on the engineering analysis presented by the working group. Wattage was calculated based on flow and head (Slides 56-59) and wire-to-water efficiency (67-74) of 8 representative unit groupings of motors based on hydraulic horsepower taken at four BEP loads at 100%, 75%, 50%, and 25%. The efficiencies of Single Speed Induction (EL 0) was applied as the baseline case and Single Speed ECM was applied as the energy efficient case (EL2). The four BEP wattages were averaged (Slide 4) to determine a resultant wattage.

Coincidence Factor (CF)

The prescribed coincidence factor for continuous or on/off control heating is N/A.
The prescribed coincidence factor for continuous cooling is 1.0 and on/off control cooling is 0.8.[27]
The prescribed coincidence factor for DHW is N/A.[28]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a circulator pump operating with a standard permanent split-capacitor (PSC) motor in a commercial or industrial heating, cooling and/or DHW system. Where ECM circulator is not rated by Hydraulic Institute, lookup baseline wattage from Baseline and Efficient Circulator Wattages table above.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a hydronic circulator pump operating with a high efficiency EC motor in a commercial or industrial heating, cooling and/or DHW system. Where ECM circulator is not rated by Hydraulic Institute, lookup compliance case wattage from Baseline and Efficient Circulator Wattages table above. High efficiency circulators may include better impeller design that will increase kWh savings, but these benefits are not considered in the prescribed savings estimation methodology.

Operating Hours

Annual circulator operating hours in a continuous operation hydronic heating system are assumed to be 5,256, based on assumed 60% utilization of circulator pump.

Annual circulator operating hours in a continuous operation hydronic cooling system are assumed to be 2,208, based on assumed 25% utilization of circulator pump.

On/Off control heating or cooling system operating hours shall come from application. If unknown, lookup in the table below based on location and facility type. Default HVAC system load hours were developed from NOAA hourly normals by assuming a 65ºF balance point temperature and summing dry bulb hours above the balance point for HVAC cooling and below the balance point for HVAC heating during building operating hours.[29] Operating hour assumptions for facility types are described in Appendix A.

Facility/System Type	Albany	Binghamton	Buffalo	Massena*	NYC	Poughkeepsie**	Syracuse
Assembly Cooling Hours	1,473	1,204	1,380	1,337	1,748	1,579	1,441
Assembly Heating Hours	3,181	3,445	3,284	3,331	2,908	3,092	3,227
Auto Repair Cooling Hours	1,405	1,170	1,309	1,273	1,639	1,475	1,369

[27] *No source specified – update pending availability and review of applicable references.*
[28] *No source specified – update pending availability and review of applicable references.*
[29] NOAA National Centers for Environmental Information – NCEI 2010 Hourly Normals

Facility/System Type	Albany	Binghamton	Buffalo	Massena*	NYC	Poughkeepsie**	Syracuse
Auto Repair Heating Hours	2,891	3,128	3,001	3,037	2,658	2,837	2,940
Big Box Retail Cooling Hours	1,317	1,105	1,218	1,190	1,520	1,360	1,274
Big Box Retail Heating Hours	2,622	2,837	2,733	2,761	2,417	2,594	2,675
Community College Cooling Hours	1,041	855	972	950	1,224	1,131	1,030
Community College Heating Hours	2,177	2,370	2,257	2,288	1,999	2,106	2,204
Dormitory Cooling Hours	1,761	1,309	1,722	1,515	2,863	2,327	1,672
Dormitory Heating Hours	6,784	7,292	6,801	7,070	5,735	6,257	6,872
Elementary School Cooling Hours	959	785	895	873	1,129	1,051	947
Elementary School Heating Hours	2,008	2,182	2,077	2,116	1,838	1,929	2,027
Fast Food Restaurant Cooling Hours	1,657	1,290	1,569	1,483	2,171	1,894	1,603
Fast Food Restaurant Heating Hours	4,412	4,789	4,504	4,610	3,918	4,204	4,475
Full-Service Restaurant Cooling Hours	1,594	1,275	1,511	1,418	1,982	1,720	1,526
Full-Service Restaurant Heating Hours	3,764	4,071	3,862	3,951	3,394	3,663	3,840
Grocery Cooling Hours	1,593	1,254	1,502	1,435	2,057	1,812	1,552
Grocery Heating Hours	4,119	4,474	4,219	4,306	3,673	3,929	4,176
High School Cooling Hours	1,041	855	972	950	1,224	1,131	1,030
High School Heating Hours	2,177	2,370	2,257	2,288	1,999	2,106	2,204
Hospital Cooling Hours	1,761	1,309	1,722	1,515	2,863	2,327	1,672
Hospital Heating Hours	6,784	7,292	6,801	7,070	5,735	6,257	6,872
Hotel Cooling Hours	1,761	1,309	1,722	1,515	2,863	2,327	1,672
Hotel Heating Hours	6,784	7,292	6,801	7,070	5,735	6,257	6,872
Large Office Cooling Hours	938	787	870	853	1,077	997	923

Facility/System Type	Albany	Binghamton	Buffalo	Massena*	NYC	Poughkeepsie**	Syracuse
Large Office Heating Hours	1,820	1,980	1,902	1,920	1,685	1,777	1,847
Large Retail Cooling Hours	1,441	1,192	1,352	1,305	1,705	1,521	1,402
Large Retail Heating Hours	3,056	3,304	3,164	3,211	2,798	2,995	3,112
Light Industrial Cooling Hours	1,034	817	967	936	1,334	1,211	1,022
Light Industrial Heating Hours	2,634	2,878	2,708	2,758	2,349	2,482	2,659
Motel Cooling Hours	1,761	1,309	1,722	1,515	2,863	2,327	1,672
Motel Heating Hours	6,784	7,292	6,801	7,070	5,735	6,257	6,872
Religious Cooling Hours	849	720	771	768	951	864	819
Religious Heating Hours	1,506	1,639	1,590	1,596	1,395	1,499	1,540
Small Office Cooling Hours	829	694	771	754	956	891	818
Small Office Heating Hours	1,622	1,765	1,692	1,711	1,498	1,574	1,642
Small Retail Cooling Hours	1,368	1,139	1,275	1,235	1,604	1,421	1,321
Small Retail Heating Hours	2,823	3,052	2,933	2,973	2,590	2,788	2,884
University Cooling Hours	1,287	1,048	1,214	1,168	1,547	1,387	1,260
University Heating Hours	2,850	3,089	2,940	2,990	2,600	2,772	2,897
Warehouse Cooling Hours	861	681	803	778	1,045	965	849
Warehouse Heating Hours	1,947	2,141	2,015	2,051	1,769	1,861	1,966

*Massena hourly normals are approximated from Burlington, VT data due to limited available data
** Poughkeepsie hourly normals are approximated from Long Island ISLIP airport data due to limited available data

DHW circulator operating hours shall come from application. If unknown, lookup in the table below based on facility type. Operating hour assumptions for the prototypical building models are described in Appendix A.

Facility Type	Hours (hrs/yr)
Auto Repair	4,368
Big Box Retail	4,004
Community College	3,276
Dormitory	8,760
Elementary School	3,016
Fast Food Restaurant	6,188

Facility Type	Hours (hrs/yr)
Full-Service Restaurant	5,460
Grocery	5,824
High School	3,276
Hospital	8,760
Hotel	8,760
Large Office	2,808
Large Retail	4,576
Light Industrial	3,120
Motel	8,760
Religious	2,392
Small Office	2,808
Small Retail	4,264
University	4,212
Warehouse	2,860

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

A PSC circulator pump motor in a hydronic heating system is replaced with an EC motor with a Hydraulic institute Rating of 155 ER and 0.070 WAIP. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

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

$$\Delta kWh_{cooling} = N/A$$

$$\Delta kWh_{heating} = units \times \left(\frac{ER \times WAIP \times 7.46}{1{,}000}\right) \times hrs_{heating}$$

$$\Delta kWh_{DHW} = N/A$$

$$\Delta kW = N/A$$

units = 1, from application
ER = 155, from application
WAIP = 0.070, from application
hrs = 5,256, from Summary of Variables and Data Sources table based on application
CF = 0.8, from Summary of Variables and Data Sources table

$$\Delta kWh_{heating} = 1 \times \left(\frac{155 \times 0.070 \times 7.46}{1000}\right) \times 5{,}256 = 425\ kWh$$

$$\Delta kWh = 0 + 425 + 0 = 425\ kWh$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Higher efficiency circulators may lead to increased fossil fuel consumption in fossil fuel heated buildings. Reduction in waste heat from increased efficiency in motors results in additional heating requirement. Reduction in waste heat from increased efficiency in motors also results in a reduced cooling requirement. These effects are not quantified in this methodology.

Ancillary Electric Savings Impacts

Higher efficiency circulators may lead to increased electric consumption in electrically heated buildings. Reduction in waste heat from increased efficiency in motors results in additional heating requirement. Reduction in waste heat from increased efficiency in motors also results in a reduced cooling requirement. These effects are not quantified in this methodology.

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Record of Revision

Record of Revision Number	Issue Date
12-19-13	12/23/2019
3-22-8	4/29/2022

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OTHER

HEAT PUMP POOL HEATER

Measure Description

This measure is applicable to electric heat pump pool heaters in residential applications. Heat pumps capture heat and move it from one place to another. The saving equations presented herein comprise three aspects of pool heating: convective heat loss via pool surface area due to water and air temperature differential, initial heat of full pool volume for seasonal pool use and reheat of pool refill on year-round pools, and the heating of added pool water to offset water loss through evaporation.[30] If baseline equipment is a fossil fuel-fired pool heater, electric energy impacts result in a penalty.

This measure is only applicable to inground outdoor pools and is not applicable to spas. This measure is not applicable to community pools in multifamily housing complexes. For community pools, refer to the Commercial Heat Pump Pool Heater measure in this TRM.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = \frac{\left(BTU_{Surface} + BTU_{Reheat} + BTU_{Evap}\right)}{3{,}412} \times \left(\frac{F_{elec,baseline}}{COP_{baseline}} - \frac{1}{COP_{ee}}\right)$$

Summer Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = \frac{\left(BTU_{Surface} + BTU_{Reheat} + BTU_{Evap}\right)}{1{,}000{,}000} \times \frac{F_{fuel,baseline}}{E_{t,baseline}}$$

where:

$$BTU_{Surface} = \left(T_{pool} - T_{amb}\right) \times A_{pool} \times U \times \left[hrs - \left(hrs_{cover} \times ESF_{cover,surface}\right)\right]$$

$$BTU_{Reheat} = V_{pool} \times 8.33 \times \left(T_{pool} - T_{main}\right) \times F_{Reheat}$$

$$BTU_{Evap} = 0.1 \times AF \times A_{pool} \times \left(P_{\omega} - P_{dp}\right) \times \left(T_{pool} - T_{main}\right) \times \left[hrs - \left(hrs_{cover} \times ESF_{cover,evap}\right)\right]$$

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[30] ASHRAE Handbook: HVAC Applications, 2019, pg 51.25. ASHRAE states that except in aboveground pools and rare cases where cold groundwater flows past the pool walls, conductive losses through pool walls are small and can be ignored. ASRHAE additionally indicates that radiation losses that occur due to sky temperature differentials at night may be offset by solar heat gains of an unshaded pool during the day.

where:

ΔkWh	= Annual electricity energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
$BTU_{Surface}$[31]	= Annual heating energy load contributed by convection and radiation heat losses via pool surface, (BTU)
BTU_{Reheat}[32]	= Annual heating energy load contributed by heating the full volume of pool water, (BTU)
BTU_{Evap}[33]	= Annual heating energy load contributed by evaporation, (BTU)
$F_{elec,baseline}$	= Baseline electric pool heater factor; used to account for the presence or absence of an electric pool heater
$F_{fuel,baseline}$	= Baseline fossil fuel pool heater factor; used to account for the presence or absence of a fossil fuel pool heater
$COP_{baseline}$	= Coefficient of performance, ratio of output energy/input energy of baseline electric resistance pool heater, if present
COP_{ee}	= Coefficient of performance, ratio of output energy/input energy of heat pump pool heater
$E_{t,baseline}$	= Thermal efficiency of baseline fossil fuel-fired pool heater, if present
T_{pool}	= Pool temperature set point, (ºF)
T_{amb}	= Average temperature of surrounding ambient air, (ºF)
T_{main}	= Supply water temperature in water main, (ºF)
A_{pool}	= Surface area of pool, (ft^2)
V_{pool}	= Volume of pool water, (gallons)
F_{Reheat}	= Factor capturing annual number of times full pool volume is heated to the desired temperature, whether as the result of refill or heating of pool water from ground water temperature at start of season
U	= Surface heat loss coefficient, (BTU/hr-ft^2-ºF)
AF	= Activity Factor, consideration of activity within pool
P_{ω}	= Saturation vapor pressure taken at surface water temperature, (in. Hg)
P_{dp}	= Saturation pressure at dew point, (in. Hg)
hrs	= Total annual swimming season hours
hrs_{cover}	= Total annual hours pool covered during the swimming season
$ESF_{cover,surface}$	= Energy Savings Factor of pool cover to insulate from convective and radiation heat losses
$ESF_{cover,evap}$	= Energy Savings Factor of pool cover to insulate from evaporative heat loss
CF	= Coincidence factor

[31] ASHRAE Handbook: HVAC Applications, 2019, Ch 51 Service Water Heating, Swimming Pools/Health Clubs, eqn. 15

[32] Ibid, eqn. 14

[33] ASHRAE Handbook: HVAC Applications, 2019, Ch 6 Indoor Swimming Pools, eqn. 3, multiplied by required heating temperature difference

0.1 = Simplified empirically derived evaporation factor considering latent heat and air flow[34]; assumes 1,000 BTU/lb of latent heat required to change water to vapor at surface water temperature and air velocity over water surface ranging from 10 to 30 fpm, (lb/hr-ft^2-in. hg)
8.33 = Energy required (BTU) to heat one gallon of water by one degree Fahrenheit
3,412 = Conversion factor, one kWh equals 3,412 BTU
1,000,000 = Conversion factor, one MMBtu equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
$F_{elec,baseline}$		If baseline system is an electric resistance pool heater, set equal to 1. Otherwise, set equal to 0.
$F_{fuel,baseline}$		If baseline system is a fossil fuel-fired pool heater, set equal to 1. Otherwise, set equal to 0.
$COP_{baseline}$		If baseline pool heater is electric, assume 1.0.
COP_{ee}		From application.
$E_{t,baseline}$		From application. If unknown, use 0.82 as default.[35]
T_{pool}		From application.
T_{amb}		Ambient temperature, lookup in Outdoor Pool table in the Air Temperature and Pressure section below based on nearest city.
T_{main}		Supply water temperature in water main (ºF). Lookup in Cold Water Inlet Temperature table below based on nearest city.
A_{pool}		Pool surface area, from application.[36] Assistance in determining the area of common pool shapes as follows: Elliptical: 3.14 x short radius x long radius Kidney Shaped: 0.45 x length x (width at one end x width at other end) Oval: 3.14 x radius^2 + (length of straight sides x width) Rectangular: length x width
V_{pool}		Volume of water in gallons, from application.
F_{Reheat}		From application. If pool is filled by delivery service providing preheated water, set F_{Reheat} equal to 0. Otherwise F_{Reheat} shall default to 1.[37]

[34] Simplified constant presented in ASHRAE Handbook: HVAC Application 2019 Ch 6 based on empirically derived eqn (2) constants and ASHRAE's variable assumptions
[35] 10 CFR 430.32 (k)(2)
[36] Guidance for determining surface area of common pool shapes can be found at ASHRAE Handbook: HVAC Applications, 2019, pg 51.25
[37] The water temperature of an undrained pool between swim seasons is assumed to have reached the water main temperature by the beginning of the next swim season. If the pool remains open throughout the year, it is assumed

Variable	Value	Notes
U	Outdoor pool, sheltered: 5.3 Outdoor pool, unsheltered: 6.6	Surface heat loss coefficient (BTU/hr-ft²-ºF).[38]
AF	0.5	Activity Factor considers activity level of the pool, allowing for splashing and a limited area of wetted deck.[39]
P_{ω}		Lookup from Saturation Vapor Pressure section below based on pool water temperature. Linear interpolation and extrapolation of the data in the table is acceptable for pool templates not provided.
P_{dp}		Lookup from outdoor pool tables in Air Temperature and Pressure section below based on ambient temperature and relative humidity (RH) or city, respectively. Linear interpolation and extrapolation of the data in the table is acceptable for pool templates not provided.
hrs		From application. Hours shall reflect the total annual hours through the swimming season (number of days between season opening and season closing x 24).
hrs_{cover}		From application. Hours shall reflect the total hours pool covered during the swimming season. Set equal to 0 if pool is left uncovered throughout swimming season.
$ESF_{cover,surface}$	0.8	Based on cost savings from DOE for gas and heat pump pool heater savings[40]
$ESF_{cover,evap}$	0.95	Effectiveness of Pool Covers to Reduce Evaporation from Swimming Pools.[41]

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.[42] Supply main temperatures based on the annual outdoor temperature are shown below.

the pool undergoes one effective full pool volume reheat from water main temperature for cleaning and other maintenance (CDC, Healthy Swimming, Operating Public Swimming Pools).

[38] ASHRAE Handbook: HVAC Applications, 2019, Ch 51, eqn. 15. Surface heat loss coefficient adjusted from ASHRAE Handbook rolled up surface heat transfer conservations by discounting contribution of evaporation (50-60%) and applying the following assumption for wind velocity: Outdoor sheltered pools experience wind speeds between 3.5 and 5 mph (10.5x0.5) and outdoor unsheltered pools experience wind speeds above 5 mph (10.5x0.5x1.25).

[39] ASHRAE Handbook, Applications, 2019, Ch 6, Table 1

[40] U.S. D.O.E., Swimming Pool Covers

[41] National Plasterers Council, Effectiveness of Pool Covers to Reduce Evaporation from Swimming Pools, prepared by California Polytechnic State University, January 2016

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

City	Annual average outdoor temperature[43] (°F)	T_{main} (°F)
Albany	48.3	54.3
Binghamton	46.3	52.3
Buffalo	48.3	54.3
Massena	43.5	49.5
NYC	55.4	61.4
Poughkeepsie	49.8	55.8
Syracuse	48.3	54.3

Saturation Vapor Pressure (P_{ω})
Lookup saturation vapor pressure taken at surface water temperature for outdoor pools from the table below, based on pool temperature.[44]

Pool Temperature, T_{pool} (°F)	P_{ω} (in. Hg)
72	0.79
74	0.85
76	0.91
78	0.97
80	1.03
82	1.10
84	1.18

Ambient Air Temperature and Pressure (T_{amb} and P_{dp})
Lookup T_{amb} and P_{dp} from the table below based on location. Ambient temperature averages for outdoor pools apply a 5-month swimming season[45].

City	Outdoor Pool T_{amb}[46] (°F)	Outdoor Pool P_{dp} (in. Hg)
Albany	67.8	0.44
Binghamton	65.0	0.41
Buffalo	67.3	0.43
Massena	64.6	0.43
NYC	73.4	0.48
Poughkeepsie	68.6	0.49
Syracuse	67.5	0.44

Coincidence Factor (CF)

[43] Average annual outdoor temperatures taken from NCDC 1981-2010 climate normals
[44] ASHRAE Handbook: Fundamentals 2017, Ch 1 Psychrometrics, Table 3 Thermodynamic Properties of Water at Saturation
[45] It is assumed that heated pools operate for 5 months per year; May 1 through Sept 30
[46] Average ambient temperatures taken from NCDC 1981-2010 climate normals, averaged from June 1 through Sept 30

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

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition for this measure is an electric resistance or fossil fuel-fired pool heater. For New Construction, use gas baseline values if there is existing gas service to the property – otherwise, use electric baseline values.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is an AHRI-certified heat pump pool heater.

Operating Hours

The annual operating hours shall be taken from application based on the number of total hours of residence's swimming season and total hours pool is covered during the swimming season.

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

A gas pool heater is replaced with a heat pump pool heater at a single family home located near Albany. The swimming season spans 3 months (2,208 hours) per year and the pool is left uncovered at night. The pool is 15 ft by 30 ft and has a volume of 17,600 gallons, and is sheltered from winds by the house and backyard trees. The pool temperature is maintained at 80ºF. The replaced gas pool heater has an efficiency of 0.84 and the heat pump pool heater has an efficiency of 5.0 COP. Annual Electric Energy Savings, Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta kWh = \frac{\left(BTU_{Surface} + BTU_{Reheat} + BTU_{Evap}\right)}{3{,}412} \times \left(\frac{F_{elec,baseline}}{COP_{baseline}} - \frac{1}{COP_{ee}}\right)$$

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

$$\Delta MMBtu = \frac{\left(BTU_{Surface} + BTU_{Reheat} + BTU_{Evap}\right)}{1{,}000{,}000} \times \frac{F_{fuel,baseline}}{E_{t,baseline}}$$

where:

$$BTU_{Surface} = \left(T_{pool} - T_{amb}\right) \times A_{pool} \times U \times \left[hrs - \left(hrs_{cover} \times ESF_{cover,surface}\right)\right]$$

$$BTU_{Reheat} = V_{pool} \times 8.33 \times \left(T_{pool} - T_{main}\right) \times F_{Reheat}$$

$$BTU_{Evap} = 0.1 \times AF \times A_{pool} \times \left(P_{\omega} - P_{dp}\right) \times \left(T_{pool} - T_{main}\right) \times \left[hrs - \left(hrs_{cover} \times ESF_{cover,evap}\right)\right]$$

T_{pool} = 80, from application

T_{amb} = 67.8, from Ambient Air Temperature and Pressure section based on location from application
A_{pool} = width x length = 15' x 30' = 450'
Width and length from application
U = 5.3, from Summary of Variables and Data Sources table based on conditions from application
hrs = 2,208, from application
hrs_{cover} = 0, from application
$ESF_{cover,surface}$ = 0.8, from Summary of Variables and Data Sources table
V_{pool} = 17,600, from application
T_{main} = 54.3, from Cold Water Inlet Temperature table based on location from application
F_{Reheat} = 1, from Summary of Variables and Data Sources table
AF = 0.5, from Summary of Variables and Data Sources table
P_{ω} = 1.03, from Saturation Vapor Pressure section based on pool temperature from application
P_{dp} = 0.44, from Ambient Air Temperature and Pressure section based on location from application
$ESF_{cover,evap}$ = 0.95, from Summary of Variables and Data Sources table
$F_{elec,baseline}$ = 0, from Summary of Variables and Data Sources table based on application
COP_{ee} = 5.0, from application
CF = 0, from Summary of Variables and Data Sources table based on application
$F_{fuel,baseline}$ = 1, from Summary of Variables and Data Sources table based on application
$E_{t,baseline}$ = 0.84, from application

$$BTU_{Surface} = (80 - 67.8) \times 450 \times 5.3 \times [2{,}208 - (0)] = 64{,}246{,}176\ Btu$$

$$BTU_{Reheat} = 17{,}600 \times 8.33 \times (80 - 54.3) \times 1 = 3{,}767{,}826\ Btu$$

$$BTU_{Evap} = 0.1 \times 0.5 \times 450 \times (1.03 - 0.44) \times (80 - 54.3) \times [2{,}208 - (0)] = 753{,}297\ Btu$$

$$\Delta kWh = \frac{(64{,}246{,}176 + 3{,}767{,}826 + 753{,}297)}{3{,}412} \times \left(0 - \frac{1}{5}\right) = -4{,}031\ kWh$$

$$\Delta kW = \frac{-4{,}031}{2{,}208} \times 0 = 0\ kW$$

$$\Delta MMBtu = \frac{(64{,}246{,}176 + 3{,}767{,}826 + 702{,}227)}{1{,}000{,}000} \times \frac{1}{0.84} = 81.8\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

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

Ancillary Electric Savings Impacts

Higher efficiency heat pump pool heaters may require fewer pool water circulations through the pool pump, alleviating some of the pool pump energy load. This energy impact is not considered in the methodology for this measure.

References

1. 2019 ASHRAE Handbook – HVAC Applications, Chapter 6: Indoor Swimming Pools
2. 2019 ASHRAE Handbook – HVAC Applications, Chapter 51: Service Water Heating
3. 2017 ASHRAE Handbook – Fundamentals, Chapter 1, Psychrometrics
4. 10 CFR 430.32 Energy and water conservation standards and their compliance dates
   Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=840d2f09fea283237b0f345001c03a28&mc=true&node=pt10.3.430&rgn=div5#se10.3.430_132
5. U.S. D.O.E., Swimming Pool Covers.
   Available from: https://www.energy.gov/energysaver/swimming-pool-covers
6. Burch, Jay and Craig Christensen; "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory
   Available from:
   http://citeseerx.ist.psu.edu/viewdoc/download;jsessionid=05D73BA6EF5ECCF71969D083FB317991?doi=10.1.1.515.6885&rep=rep1&type=pdf
7. NOAA National Center for Environmental Information – NCEI 1981 – 2010 Annual/Seasonal Climate Normals
   Available from: https://www.ncdc.noaa.gov/cdo-web/datatools/normals
8. National Plasterers Council, Effectiveness of Pool Covers to Reduce Evaporation from Swimming Pools, prepared by California Polytechnic State University, January 2016
   Available from:
   https://cdn.ymaws.com/www.npconline.org/resource/resmgr/Docs/Evaporation_Study_Report.pdf

Record of Revision

Record of Revision Number	Issue Date
7-21-10	8/30/2021
3-22-9	4/29/2022

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Other

Heat Pump Pool Heater

Measure Description

This measure is applicable to electric heat pump pool heaters in commercial and multifamily community pool applications. Heat pumps capture heat and move it from one place to another. The saving equations presented herein comprise three aspects of pool heating: convective heat loss via pool surface area due to water and air temperature differential, initial heat of full pool volume for seasonal pool use and reheat of pool refill on year round pools, and the heating of added pool water to offset water loss through evaporation. [47] If baseline equipment is a fossil fuel-fired pool heater, electric energy impacts result in a penalty.

This measure is restricted to inground outdoor pools and is not applicable to spas.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = \frac{\left(BTU_{Surface} + BTU_{Reheat} + BTU_{Evap}\right)}{3{,}412} \times \left(\frac{F_{elec,baseline}}{COP_{baseline}} - \frac{1}{COP_{ee}}\right)$$

Summer Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = \frac{\left(BTU_{Surface} + BTU_{Reheat} + BTU_{Evap}\right)}{1{,}000{,}000} \times \frac{F_{fuel,baseline}}{E_{t,baseline}}$$

where:

$$BTU_{Surface} = \left(T_{pool} - T_{amb}\right) \times A_{pool} \times U \times \left[hrs - \left(hrs_{cover} \times ESF_{cover,surface}\right)\right]$$

$$BTU_{Reheat} = V_{pool} \times 8.33 \times \left(T_{pool} - T_{main}\right) \times F_{Reheat}$$

$$BTU_{Evap} = 0.1 \times AF \times A_{pool} \times \left(P_{\omega} - P_{dp}\right) \times \left(T_{pool} - T_{main}\right) \times \left[hrs - \left(hrs_{cover} \times ESF_{cover,evap}\right)\right]$$

[47] ASHRAE Handbook: HVAC Applications, 2019, pg 51.25. ASHRAE states that except in aboveground pools and rare cases where cold groundwater flows past the pool walls, conductive losses through pool walls are small and can be ignored. ASRHAE additionally indicates that radiation losses that occur due to sky temperature differentials at night may be offset by solar heat gains of an unshaded pool during the day.

where:

ΔkWh	= Annual electricity energy savings
ΔkW	= Peak coincident demand electric savings
$\Delta MMBtu$	= Annual fossil fuel energy savings
$BTU_{Surface}$[48]	= Annual heating energy load contributed by convection and radiation heat losses via pool surface, (BTU)
BTU_{Reheat}[49]	= Annual heating energy load contributed by heating the full volume of pool water, (BTU)
BTU_{Evap}[50]	= Annual heating energy load contributed by evaporation, (BTU)
$F_{elec,baseline}$	= Baseline electric pool heater factor; used to account for the presence or absence of an electric pool heater
$F_{fuel,baseline}$	= Baseline fossil fuel pool heater factor; used to account for the presence or absence of a fossil fuel pool heater
$COP_{baseline}$	= Coefficient of performance, ratio of output energy/input energy of baseline electric resistance pool heater, if present
COP_{ee}	= Coefficient of performance, ratio of output energy/input energy of heat pump pool heater
$E_{t,baseline}$	= Thermal efficiency of baseline fossil fuel-fired pool heater, if present
T_{pool}	= Pool temperature set point, (ºF)
T_{amb}	= Average temperature of surrounding ambient air, (ºF)
T_{main}	= Supply water temperature in water main, (ºF)
A_{pool}	= Surface area of pool, (ft^2)
V_{pool}	= Volume of pool water, (gallons)
F_{Reheat}	= Factor capturing annual number of times full pool volume is heated to the desired temperature, whether as the result of refill or heating of pool water from ground water temperature at start of season
U	= Surface heat loss coefficient, ($BTU/hr\text{-}ft^2\text{-}ºF$)
AF	= Activity Factor, consideration of activity within pool
P_{ω}	= Saturation vapor pressure taken at surface water temperature, (in. Hg)
P_{dp}	= Saturation pressure at dew point, (in. Hg)
hrs	= Total annual swimming season hours
hrs_{cover}	= Total annual hours pool covered during the swimming season
$ESF_{cover,surface}$	= Energy Savings Factor of pool cover to insulate from convective and radiation heat losses
$ESF_{cover,evap}$	= Energy Savings Factor of pool cover to insulate from evaporative heat loss
0.1	= Simplified empirically derived evaporation factor considering latent heat and air flow[51]; assumes 1,000 BTU/lb of latent heat required to change water to vapor at surface water temperature and air velocity over water surface ranging from 10 to 30 fpm, ($lb/hr\text{-}ft^2\text{-}in.\ hg$)
8.33	= Energy required (BTU) to heat one gallon of water by one degree Fahrenheit

[48] ASHRAE Handbook: HVAC Applications, 2019, Ch 51 Service Water Heating, Swimming Pools/Health Clubs, eqn. 15

[49] Ibid, eqn. 14

[50] ASHRAE Handbook: HVAC Applications, 2019, Ch 6 Indoor Swimming Pools, eqn. 3, multiplied by required heating temperature difference

[51] Simplified constant presented in ASHRAE Handbook: HVAC Application 2019 Ch 6 based on empirically derived eqn (2) constants and ASHRAE's variable assumptions

3,412	= Conversion factor, one kWh equals 3,412 BTU
1,000,000	= Conversion factor, one MMBtu equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
$F_{elec,baseline}$		If baseline system is an electric resistance pool heater, set equal to 1. Otherwise, set equal to 0.
$F_{fuel,baseline}$		If baseline system is a fossil fuel-fired pool heater, set equal to 1. Otherwise, set equal to 0.
$COP_{baseline}$		If baseline pool heater is electric, assume 1.0.
COP_{ee}		From application.
$E_{t,baseline}$		From application. If unknown, use 0.82 as default.[52]
T_{pool}		From application.
T_{amb}		Ambient temperature, lookup in Outdoor Pool table in the Air Temperature and Pressure section below based on nearest city.
T_{main}		Supply water temperature in water main (ºF). Lookup in Cold Water Inlet Temperature table below based on nearest city.
A_{pool}		Pool surface area, from application.[53] Assistance in determining the area of common pool shapes as follows: Elliptical: 3.14 x short radius x long radius Kidney Shaped: 0.45 x length x (width at one end x width at other end) Oval: 3.14 x radius^2 + (length of straight sides x width) Rectangular: length x width
V_{pool}		Volume of water in gallons, from application.
F_{Reheat}		From application. If pool is filled by delivery service providing preheated water, set F_{Reheat} equal to 0. Otherwise F_{Reheat} shall default to 1.[54]

[52] 10 CFR 430.32 (k)(2)
[53] Guidance for determining surface area of common pool shapes can be found at ASHRAE Handbook: HVAC Applications, 2019, pg 51.25
[54] The water temperature of an undrained pool between swim seasons is assumed to have reached the water main temperature by the beginning of the next swim season. If the pool remains open throughout the year, it is assumed the pool undergoes one effective full pool volume reheat from water main temperature for cleaning and other maintenance (CDC, Healthy Swimming, Operating Public Swimming Pools).

Variable	Value	Notes
U	Outdoor pool, sheltered: 5.3 Outdoor pool, unsheltered: 6.6	Surface heat loss coefficient (BTU/hr-ft^2-ºF).[55]
AF		Lookup from table in Activity Factor section below based on pool function.
P_{ω}		Lookup from Saturation Vapor Pressure section below based on pool water temperature. Linear interpolation and extrapolation of the data in the table is acceptable for pool templates not provided.
P_{dp}		Lookup from pool table in Air Temperature and Pressure section below based on ambient temperature and relative humidity (RH) or city, respectively. Linear interpolation and extrapolation of the data in the table is acceptable for pool templates not provided.
hrs		From application. Hours shall reflect the total annual hours through the swimming season (number of days between season opening and season closing x 24).
hrs_{cover}		From application. Hours shall reflect the total hours pool covered during the swimming season. Set equal to 0 if pool is left uncovered throughout swimming season. If installing a heat pump pool heater in conjunction with a newly added pool cover, calculate savings from this measure without pool cover consideration and calculate savings from pool cover with efficiency of heat pump pool heater.
$ESF_{cover,surface}$	0.8	Based on cost savings from DOE for gas and heat pump pool heater savings[56]
$ESF_{cover,evap}$	0.95	Effectiveness of Pool Covers to Reduce Evaporation from Swimming Pools. [57]

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.[58] Supply main temperatures based on the annual outdoor temperature are shown below.

[55] ASHRAE Handbook: HVAC Applications, 2019, Ch 51, eqn. 15. Surface heat loss coefficient adjusted from ASHRAE Handbook rolled up surface heat transfer conservations by discounting contribution of evaporation (50-60%) and applying the following assumption for wind velocity: Outdoor sheltered pools experience wind speeds between 3.5 and 5 mph (10.5x0.5) and outdoor unsheltered pools experience wind speeds above 5 mph (10.5x0.5x1.25).

[56] U.S. D.O.E., Swimming Pool Covers

[57] National Plasterers Council, Effectiveness of Pool Covers to Reduce Evaporation from Swimming Pools, prepared by California Polytechnic State University, January 2016

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

City	Annual average outdoor temperature[59] (°F)	T_{main} (°F)
Albany	48.3	54.3
Binghamton	46.3	52.3
Buffalo	48.3	54.3
Massena	43.5	49.5
NYC	55.4	61.4
Poughkeepsie	49.8	55.8
Syracuse	48.3	54.3

Saturation Vapor Pressure (P_ω)
Lookup saturation vapor pressure taken at surface water temperature from the table below, based on pool temperature.[60]

Pool Temperature, T_{pool} (°F)	P_ω (in Hg)
72	0.79
74	0.85
76	0.91
78	0.97
80	1.03
82	1.10
84	1.18

Ambient Air Temperature and Pressure (T_{amb} and P_{dp})
Lookup T_{amb} and P_{dp} from the table below based on location. Ambient temperature averages for outdoor pools apply a 5-month swimming season[61].

City	Outdoor Pool T_{amb}[62] (°F)	Outdoor Pool P_{dp} (in. Hg)
Albany	67.8	0.44
Binghamton	65.0	0.41
Buffalo	67.3	0.43
Massena	64.6	0.43
NYC	73.4	0.48
Poughkeepsie	68.6	0.49
Syracuse	67.5	0.44

[59] Average annual outdoor temperatures taken from NCDC 1981-2010 climate normals
[60] ASHRAE Handbook: Fundamentals 2017, Ch 1 Psychrometrics, Table 3 Thermodynamic Properties of Water at Saturation
[61] It is assumed that heated pools operate for 5 months per year; May 1 through Sept 30
[62] Average ambient temperatures taken from NCDC 1981-2010 climate normals, averaged from June 1 through Sept 30

Activity Factor

Activity Factor considers activity level of the pool, allowing for splashing and a limited area of wetted deck.[63] Look up Activity Factor from the table below based on pool application.

Type of Pool	Activity Factor (AF)
Condominium	0.65
Therapy	0.65
Hotel	0.80
Public, School	1.00
Whirlpool	1.00
Wavepool, Water Slide	1.50

Coincidence Factor (CF)

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

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition for this measure is an electric resistance or fossil fuel-fired pool heater. For New Construction, use gas baseline values if there is existing gas service to the property – otherwise, use electric baseline values.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is an AHRI-certified heat pump pool heater.

Operating Hours

The annual operating hours shall be taken from application based on the number of total hours of facility's swimming season and total hours pool is covered during the swimming season.

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

A gas pool heater is replaced with a heat pump pool heater at an outdoor pool at a public school with some wind sheltering located near Albany. The pool is open 3 months (2,208 hours) per year. The pool is covered every night, for 12 hours/day (1,104 hours/year). The pool is 75 ft by 35 ft and has 80,000 gallons of water. The pool temperature is maintained at 78ºF. The pool is drained once annually on average for cleaning and maintenance. The replaced gas pool heater has an efficiency of 86% and the heat pump pool heater has an efficiency of 5.0 COP. Annual Electric Energy Savings, Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta kWh = \frac{\left(BTU_{Surface} + BTU_{Reheat} + BTU_{Evap}\right)}{3{,}412} \times \left(\frac{F_{elec,baseline}}{COP_{baseline}} - \frac{1}{COP_{ee}}\right)$$

$$\Delta kW = N/A$$

[63] ASHRAE Handbook, Applications, 2019, Ch 6, Table 1

$$\Delta MMBtu = \frac{(BTU_{Surface} + BTU_{Reheat} + BTU_{Evap})}{1{,}000{,}000} \times \frac{F_{fuel,baseline}}{E_{t,baseline}}$$

where:

$$BTU_{Surface} = (T_{pool} - T_{amb}) \times A_{pool} \times U \times [hrs - (hrs_{cover} \times ESF_{cover,surface})]$$

$$BTU_{Reheat} = V_{pool} \times 8.33 \times (T_{pool} - T_{main}) \times F_{Reheat}$$

$$BTU_{Evap} = 0.1 \times AF \times A_{pool} \times (P_{\omega} - P_{dp}) \times (T_{pool} - T_{main}) \times [hrs - (hrs_{cover} \times ESF_{cover,evap})]$$

T_{pool} = 78, from application
T_{amb} = 67.8, from application
A_{pool} = width x length = 75' x 35' = 2,625'
Width and length from application
U = 5.3, from Summary of Variables and Data Sources table based on conditions from application
hrs = 2,208, from application
hrs_{cover} = 1,104, from application
$ESF_{cover,surface}$ = 0.8, from Summary of Variables and Data Sources table
V_{pool} = 80,000, from application
T_{main} = 54.3, from Cold Water Inlet Temperature table based on location from application
F_{Reheat} = 1, from Summary of Variables and Data Sources table
AF = 1.0, from Summary of Variables and Data Sources table
P_{ω} = 0.97, from Saturation Vapor Pressure section based on pool temperature from application
P_{dp} = 0.44, from Ambient Air Temperature and Pressure section based on location from application
$ESF_{cover,evap}$ = 0.95, from Summary of Variables and Data Sources table
$F_{elec,baseline}$ = 0, from Summary of Variables and Data Sources table based on application
COP_{ee} = 5.0, from application
$F_{fuel,baseline}$ = 1, from Summary of Variables and Data Sources table based on application
$E_{t,baseline}$ = 0.86, from application

$$BTU_{Surface} = (78 - 67.8) \times 2{,}625 \times 5.3 \times [2{,}208 - (1{,}104 \times 0.8)] = 187{,}999{,}056 Btu$$

$$BTU_{Reheat} = 80{,}000 \times 8.33 \times (78 - 54.3) \times 1 = 15{,}793{,}680\ Btu$$

$$BTU_{Evap} = 0.1 \times 1.0 \times 2{,}625 \times (0.97 - 0.44) \times (78 - 54.3) \times [2{,}208 - (1{,}104 \times 0.95)] = 3{,}822{,}187\ Btu$$

$$\Delta kWh = \frac{(187{,}999{,}056 + 15{,}793{,}680 + 3{,}822{,}187)}{3{,}412} \times \left(0 - \frac{1}{5.0}\right) = -12170\ kWh$$

$$\Delta MMBtu = \frac{(187{,}999{,}056 + 15{,}793{,}680 + 3{,}822{,}187)}{1{,}000{,}000} \times \frac{1}{0.86} = 241\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

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

Ancillary Electric Savings Impacts

Higher efficiency heat pump pool heaters may require fewer pool water circulations through the pool pump, alleviating some of the pool pump energy load. This energy impact is not considered in the methodology for this measure.

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Record of Revision

Record of Revision Number	Issue Date
7-21-18	8/30/2021
3-22-10	4/29/2022

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