Table of Revisions/Changes

Revision Number	Addition/ Revision	Issue Date	Effective Date	Measure	Description of Change	Location/Page in TRM
7-21-02	A	08/30/2021	08/30/2021	R/MF Dehumidifier Recycling	New Measure Added	Pg. xx
7-21-06	A	08/30/2021	08/30/2021	R/MF Window- Film	New Measure Added	Pg. xx
7-21-10	A	08/30/2021	08/30/2021	R/MF Heat Pump Pool Heater	New Measure Added	Pg. xx
7-21-14	A	08/30/2021	08/30/2021	C/I Central – Pumped GSHP	New Measure Added	Pg. xx
7-21-18	A	08/30/2021	08/30/2021	C/I Heat Pump Pool Heater	New Measure Added	Pg.
7-21-19	A	08/30/2021	08/30/2021	C/I Solar Pool Cover	New Measure Added	Pg.
7-21-21	R	08/30/2021	08/30/2021	Appendix P	Updated EUL entries for all measures in this Record of Revision	Pg. 996

Note: Revisions and additions to the measures listed above were undertaken by the Joint Utilities Technical Resource Manual (TRM) Management Committee between April 30, 2021 – August 30, 2021.

APPLIANCE RECYCLING

DEHUMIDIFIER RECYCLING

Measure Description

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

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

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

Summer Peak Coincident Demand Savings

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

Annual Fuel Energy Savings

$$\Delta MMBtu = N/A$$

where:

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

Summary of Variables and Data Sources

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

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

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.56.[2]

Baseline Efficiencies from which Energy Savings are Calculated

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

Capacity Range (pints/day)	ENERGY STAR® Labeled (L/kWh)[3]	Non- ENERGY STAR® Labeled	
		Manufacture date before Nov. 2012 (≥L/kWh)[4]	Manufacture date of Nov. 2012 or later (≥L/kWh)[5]
≤ 25	1.57	1.00	1.35
> 25 to ≤ 35	1.80	1.20	1.35
> 35 to ≤ 45	1.80	1.30	1.50
> 45 to ≤ 50	1.80	1.30	1.60
> 50 to ≤ 54	3.30	1.30	1.60
> 54 to ≤ 75	3.30	1.50	1.70
> 75 to ≤ 185	3.30	2.25	2.50

Compliance Efficiency from which Incentives are Calculated

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

Operating Hours

The dehumidifier is assumed to be operating 1,632 hours per year based on 68 days of 24 hour operation.[6]

Effective Useful Life (EUL)

See Appendix P.

[1] Savings Calculator for ENERGY STAR® Qualified Appliances (accessed 05/11/2021)
[2] A. Mendyk & D. Cautley, Dehumidifier Metering Study, Home Energy, January 2011: Summer duty cycle used as a proxy for CF.
[3] ENERGY STAR® Program Requirements for Dehumidifiers, Version 5.0, February 2019
[4] 42 U.S.C, Title 42 Chapter 77, Subchapter III, Part A, (cc)(1)
[5] Ibid, (cc)(2)
[6] Savings Calculator for ENERGY STAR® Qualified Appliances (accessed 05/11/2021)

Ancillary Fossil Fuel Savings Impacts

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

Ancillary Electric Savings Impacts

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

References

1. A. Mendyk & D. Cautley, Dehumidifier Metering Study, Home Energy, January 2011.
   Available from: http://www.homeenergy.org/show/article/id/777
2. 42 U.S.C, Title 42 Chapter 77, Subchapter III, Part A
   Available from: https://www.govinfo.gov/content/pkg/USCODE-2016-title42/html/USCODE-2016-title42-chap77-subchapIII-partA-sec6295.htm
3. Savings Calculator for ENERGY STAR® Qualified Appliances
   Available from: https://energy.mo.gov/sites/energy/files/energy-star-appliance-calculator.xlsx
4. ENERGY STAR® Program Requirements for Dehumidifiers, Version 5.0, February 2019
   Available from: https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Dehumidifiers%20Version%205.0%20Program%20Requirements.pdf

Record of Revision

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7-21-2	8/30/2021

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BUILDING SHELL

WINDOW – FILM

Measure Description

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

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

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

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

Summer Peak Coincident Demand Savings

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

Annual Fuel Energy Savings

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

where:

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

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

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

where:

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

	slope component
$(\Delta kWh/100\ SF)_b$	= Annual electric energy savings per 100 SF of window glazing area, intercept component
$(\Delta kW/100\ SF)_m$	= Peak coincident demand electric savings per 100 SF of window glazing area, slope component
$(\Delta kW/100\ SF)_b$	= Peak coincident demand electric savings per 100 SF of window glazing area, intercept component
$(\Delta therms/100\ SF)_m$	= Annual fuel energy savings per 100 SF of window glazing area, slope component
$(\Delta therms/100\ SF)_b$	= Annual fuel energy savings per 100 SF of window glazing area, intercept component
$SHGC_{ee}$	= Solar Heat Gain Coefficient of window after installation of window film
100	= Conversion from SF to 100 SF
10	= Conversion factor, one MMBtu equals 10 therms
CF	= Coincidence Factor

Summary of Variables and Data Sources

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

Unit Energy and Demand Savings

Unit energy and demand savings were derived based on linear regression analysis of results comparing energy consumption and SHGC of various window configurations modeled via LBNL's RESFEN V6.0 software. When the software was run, Solar Gain Reduction was set to typical. Typical shading is defined as: representing a statistically average solar gain reduction for a generic house, this option includes: Interior shades (Seasonal SHGC multiplier, summer value = 0.80, winter value = 0.90); 1' overhang; a 67% transmitting same-height obstruction 20' away intended to represent adjacent buildings. To account for other sources of solar heat gain reduction (insect screens, trees, dirt, building & window self-shading), the SHGC multiplier was further reduced by 0.1. This results in a final winter SHGC multiplier of 0.8 and a final summer SHGC multiplier of 0.7[7]. For additional detail on the derivation of these values, refer to the "NY TRM

[7] LBNL RESFEN6 User Manual.

Residential Window Film Supplement.xlsx" workbook.

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

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

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

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

Coincidence Factor (CF)

The recommended value for the coincidence factor is 0.69.[8]

Baseline Efficiencies from which Energy Savings are Calculated

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

The baseline condition is an existing, untreated, single pane clear glass window with an assumed solar heat gain coefficient of 0.64 and U-value of 0.879 BTU/h- ft^2- ºF. or double pane clear glass window with an assumed solar heat gain coefficient of 0.57 and U-value of 0.571 BTU/h- ft^2- ºF.[9]

Compliance Efficiency from which Incentives are Calculated

The compliance condition is an existing window with added film with a solar heat gain coefficient of 0.40 or less.[10]

Operating Hours

These operating hours assumptions are embedded in the RESFEN prototype models used to derive energy and demand savings values. See the "NY TRM Residential Window Supplement.xlsx" workbook and RESFEN V6.0 User's Manual for additional detail.[11] Operating hour assumptions for the prototypical building models are described in Appendix A. The heating EFLH for C&I buildings in NY by location, building type and vintage are tabulated in Appendix G.

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

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

Ancillary Electric Savings Impacts

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

References

1. ECCCNYS 2020, Table R402.1 Insulation and Fenestration Requirements by Components.
   Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-re-residential-energy-efficiency ccsafe.org/content/NYSECC2020P1/chapter-4-ce-commercial-energy-efficiency
2. BG&E, Development of Residential Load Profile for Central Air Conditioners and Heat Pumps

3. LBNL RESFEN6 for Calculating the Heating and Cooling Energy Use of Windows in Residential Buildings, December 2012

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

Available from: https://windows.lbl.gov/sites/default/files/Downloads/resfen60-user-manual.pdf
4. LBNL RESFEN6 User Manual.
Available from: https://windows.lbl.gov/sites/default/files/Downloads/resfen60-user-manual.pdf

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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.[12] If baseline equipment is a fossil fuel-fired pool heater, electric energy impacts result in a penalty.

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

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

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

Summer Peak Coincident Demand Savings

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

Annual 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:

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

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

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

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

where:

ΔkWh = Annual electricity energy savings
ΔkW = Peak coincident demand electric savings
ΔMMBtu = Annual fuel energy savings
$BTU_{Surface}$[13] = Annual heating energy load contributed by convection and radiation heat losses via pool surface, (BTU)
BTU_{Reheat}[14] = Annual heating energy load contributed by heating the full volume of pool water, (BTU)
BTU_{Evap}[15] = Annual heating energy load contributed by evaporation, (BTU)
$F_{elec,baseline}$ = Baseline electric pool heater flag; used to account for the presence or absence of an electric pool heater in the baseline equipment
$F_{fuel,baseline}$ = Baseline fossil fuel pool heater flag; used to account for the presence or absence of a fossil fuel-fired pool heater in the baseline equipment
$COP_{baseline}$ = 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

[13] ASHRAE Handbook: HVAC Applications, 2019, Ch 51 Service Water Heating, Swimming Pools/Health Clubs, eqn. 15
[14] Ibid, eqn. 14
[15] 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[16]; 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.[17]
T_{pool}		From application.
T_{amb}		Indoor pool ambient temperature shall come from application. For outdoor pool ambient temperature, lookup in Outdoor Pool table in the Air Temperature and Pressure section below based on nearest city.
T_{main}		Supply water temperature in water main (ºF). Lookup in Cold Water Inlet Temperature table below based on nearest city.
A_{pool}		Pool surface area, from application.[18] Assistance in determining the area of common pool shapes as follows: Elliptical: 3.14 x short radius x long radius Kidney Shaped: 0.45 x length x (width at one end x width at other end) Oval: 3.14 x radius^2 + (length of straight sides x width) Rectangular: length x width
V_{pool}		Volume of water, from application.

[16] Simplified constant presented in ASHRAE Handbook: HVAC Application 2019 Ch 6 based on empirically derived eqn (2) constants and ASHRAE's variable assumptions
[17] 10 CFR 430.32 (k)(2)
[18] Guidance for determining surface area of common pool shapes can be found at ASHRAE Handbook: HVAC Applications, 2019, pg 51.25

Variable	Value	Notes
F_{Reheat}		From application. If pool is filled by delivery service providing preheated water, set F_{Reheat} equal to 0. Otherwise F_{Reheat} shall default to 1.[19]
U	Indoor pool: 3.75 Outdoor pool, sheltered: 5 Outdoor pool, unsheltered: 6.25	Surface heat loss coefficient (BTU/hr-ft^2-ºF).[20]
AF	0.5	Activity Factor considers activity level of the pool, allowing for splashing and a limited area of wetted deck.[21]
P_{ω}		Lookup from Saturation Vapor Pressure section below based on pool water temperature. Linear interpolation and extrapolation of the data in the table is acceptable for pool templates not provided.
P_{dp}		Lookup from indoor or outdoor pool tables in Air Temperature and Pressure section below based on ambient temperature and relative humidity (RH) or city, respectively. Linear interpolation and extrapolation of the data in the table is acceptable for pool templates not provided.
hrs		From application. Hours shall reflect the total annual hours through the swimming season (number of days between season opening and season closing x 24).
hrs_{cover}		From application. Hours shall reflect the total hours pool covered during the swimming season. Set equal to 0 if pool is left uncovered throughout swimming season.
$ESF_{cover,surface}$	0.8	Based on cost savings from DOE for gas and heat pump pool heater savings[22]
$ESF_{cover,evap}$	0.95	Effectiveness of Pool Covers to Reduce Evaporation from Swimming Pools. [23]
CF	Outdoor pool: 0 Indoor pool: 0.8	

[19] 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).

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

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

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

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

Cold Water Inlet Temperature (T_{main})
Supply water main temperatures vary according to climate, and are approximately equal to the annual average outdoor temperature plus 6°F.[24] Supply main temperatures based on the annual outdoor temperature are shown below.

City	Annual average outdoor temperature[25] (°F)	T_{main} (°F)
Albany	48.3	54.3
Binghamton	46.3	52.3
Buffalo	48.3	54.3
Massena	43.5	49.5
NYC	55.4	61.4
Poughkeepsie	49.8	55.8
Syracuse	48.3	54.3

Saturation Vapor Pressure (P_{ω})
Lookup saturation vapor pressure taken at surface water temperature for indoor and outdoor pools from the table below, based on pool temperature.[26]

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

Ambient Air Temperature and Pressure (T_{amb} and P_{dp})
Indoor pools shall apply ambient air temperature from application based on facility set point temperature. Lookup saturation vapor pressure based on facility set point temperature and relative humidity (RH) from the table below, based on psychrometric analysis. Interpolation may be performed for indoor pool ambient temperatures not listed.

Indoor Pool T_{amb} (°F)	Indoor Pool, P_{dp} (in. Hg)		
	RH 50%	RH 55%	RH 60%
72	0.40	0.44	0.47
74	0.42	0.47	0.51
76	0.45	0.50	0.54
78	0.48	0.53	0.58

[24] Burch, Jay and Christensen, Craig, "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory
[25] Average annual outdoor temperatures taken from NCDC 1981-2010 climate normals
[26] ASHRAE Handbook: Fundamentals 2017, Ch 1 Psychrometrics, Table 3 Thermodynamic Properties of Water at Saturation

Indoor Pool T_{amb} (°F)	**Indoor Pool, P_{dp} (in. Hg)**		
	RH 50%	**RH 55%**	**RH 60%**
80	0.52	0.56	0.62
82	0.55	0.61	0.66
84	0.59	0.65	0.71
86	0.63	0.69	0.75

For outdoor pools, lookup T_{amb} and P_{dp} from the table below based on location. Ambient temperature averages for outdoor pools apply a 4-month swimming season[27].

City	**Outdoor Pool T_{amb}[28] (°F)**	**Outdoor Pool P_{dp} (in. Hg)**
Albany	67.8	0.48
Binghamton	65.0	0.44
Buffalo	67.3	0.47
Massena	64.6	0.47
NYC	73.4	0.53
Poughkeepsie	68.6	0.54
Syracuse	67.5	0.48

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0 for outdoor pools and is 0.8 for indoor pools.[29]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition for this measure is an electric resistance or fossil fuel-fired pool heater.

Compliance Efficiency from which Incentives are Calculated

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

Operating Hours

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

Effective Useful Life (EUL)

See Appendix P.

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[27] It is assumed that 50% of pools are unheated and operate for 3 months per year and the other 50% of pools are heated and operate for 5 months per year, giving an average of 4 months of usage per year; June 1 through Sept 30
[28] Average ambient temperatures taken from NCDC 1981-2010 climate normals, averaged from June 1 through Sept 30
[29] *No source specified – update pending availability and review of applicable references.*

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

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HEATING, VENTILATION AND AIR CONDITIONING (HVAC)

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.[30]
- The ground loop heat exchanger is adequately sized and installed properly to allow the GSHP to meet the peak heating and peak cooling loads.
- The design loop pumping power must be less than 60 Watts per nominal installed ton[31], 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:

[30] 2017 ASHRAE Fundamentals Handbook, Chapter 18. Non-residential heating and cooling loads
[31] 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[32] 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

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

Annual Fuel Energy Savings

$$\Delta therms = \frac{BHL}{100{,}000} \times \frac{F_{FuelHeat}}{AFUE_{baseline}} \times BEFLH_{heating}$$

where:

ΔkWh = Annual electric energy savings

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

ΔkW = Peak coincident demand electric savings
Δtherms = Annual fuel energy savings
AFUE = Annual fuel utilization efficiency, seasonal efficiency for fuel heat equipment
baseline = Baseline condition or measure
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 = Energy efficient condition or measure
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 flag; used to account for the presence or absence of an electric cooling system
$F_{ElecHeat}$ = Electric heating factor flag; used to account for the presence or absence of an electric heating system
$F_{FuelHeat}$ = Fossil fuel heating flag; 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
100,000 = Conversion factor, (BTU/therm), one therm equals 100,000 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).

Variable	Value	Notes
$F_{ElecCool}$		If an electric cooling system is present, set equal to 1. Otherwise, set equal to 0.
$F_{ElecHeat}$		If an electric heating system is present, set equal to 1. Otherwise, set equal to 0.
$F_{FuelHeat}$		If a fossil fuel-fired heating system is present, set equal to 1. Otherwise, set equal to 0.
$EER_{season,baseline}$		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[33] and 0.8 in commercial and industrial applications.[34]

[33] 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.

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

Baseline Efficiencies from which Energy Savings are Calculated

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

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

Federal energy conservation standards[35] effective January 1, 2018 for small, large and very large package air conditioning and heating equipment are more stringent than NYS and NYC codes. These cases are denoted with footnotes in the table below.

Electric Cooling System Baseline Efficiencies

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

[35] 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[36]	Electric Resistance (or None)	Split System and Single Package	11.2 EER 12.9 IEER
		All Other	Split System and Single Package	11.0 EER 12.7 IEER
	≥ 135,000 BTU/h and < 240,000 BTU/h	Electric Resistance (or None)	Split System and Single Package	11.0 EER 12.4 IEER
		All Other	Split System and Single Package	10.8 EER 12.2 IEER
	≥ 240,000 BTU/h and < 760,000 BTU/h	Electric Resistance (or None)	Split System and Single Package	10.0 EER 11.6 IEER
		All Other	Split System and Single Package	9.8 EER 11.4 IEER
	≥ 760,000 BTU/h	Electric Resistance (or None)	Split System and Single Package	9.7 EER 11.2 IEER
		All Other	Split System and Single Package	9.5 EER 11.0 IEER

Electric Cooling and Heating System Baseline Efficiencies for Package Terminal Equipment

Equipment Type	**Size Category (Input)**	**Subcategory or Rating Condition**	**Minimum Efficiency ECCCNYS[37]**
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[38]	All Capacities	95°F db Outdoor Air	EER = 10.9 - (0.213 × Cap/1,000)

[36] 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)

[37] "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."

[38] 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[37]
PTHP (Cooling Mode) Standard Size	All Capacities	95°F db Outdoor Air	EER = 14.0 - (0.300 × Cap/1,000)
PTHP (Cooling Mode) Replacements/ Nonstandard Size	All Capacities	95°F db Outdoor Air	EER = 10.8 - (0.213 × Cap/1,000)
PTHP (Heating Mode) Standard Size	All Capacities	—	NYS: COP = 3.2 – (0.026 × Cap/1,000) NYC: COP = 3.7 – (0.052 × Cap/1,000)
PTHP (Heating Mode) Replacements/ Nonstandard Size	All Capacities	—	COP = 2.9 - (0.026 × Cap/1,000)

Fossil Fuel Fired Heating System Baseline Efficiencies: Systems Serving Single Units[39]

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

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

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

[39] 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[40] 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[41].
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.

[40] 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
[41] 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[42]. 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[43]. 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.

[42] 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.

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

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

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

Compliance Efficiency from which Incentives are Calculated

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

$EWT_{avg,h} = EWT_{min} + 10°F$

$EWT_{avg,c} = EWT_{max} - 10°F$

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

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

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

where:

$COP_{GLHP,full}$ = Rated COP of the unit at GLHP full load heating conditions
$COP_{GLHP,part}$ = Rated COP of the unit at GLHP part load heating conditions
$EER_{GLHP,full}$ = Rated EER of the unit at GLHP full load cooling conditions
$EER_{GLHP,part}$ = Rated EER of the unit at GLHP part load cooling conditions
$EWT_{avg,h}$ = The average entering loop temperature in the heating season
$EWT_{avg,c}$ = The average entering loop temperature in the cooling season
$F_{dist,c}$ = Factor to adjust the cooling efficiency to account for additional fan power
$F_{dist,h}$ = Factor to adjust the heating efficiency to account for additional fan power
F_{full} = Seasonal weighting factor for full load efficiency
F_{part} = Seasonal weighting factor for part load efficiency
$F_{pump, part}$ = Factor to adjust part load efficiency to account for additional pumping power
$F_{pump,full}$ = Factor to adjust full load efficiency to account for additional pumping power
0.01 = Correction for fractional change in EER or COP per each 1°F in entering loop temperature[44]

[44] 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.[45] 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.[46] For single stage use 0.

[45] 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.

[46] 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**	**Clg**	**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.[47]

The purpose of the distribution (i.e., fan or pump) correction factor, $F_{dist,h}$ and $F_{dist,c}$ is to determine the equivalent amount of distribution power for the baseline system, such as a fuel fired furnace or boiler. The correction factor considers the differential distribution power between the GSHP

[47] Ibid.

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
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

Facility Type	CZ*	BEFLH Heating			BEFLH Cooling		
		Pre-1980	Post-1980	NC	Pre-1980	Post-1980	NC
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

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.

$$\Delta therms_{DHW-WWHP} = \frac{Q_{DHW-WWHP}}{100{,}000} \times \frac{F_{FFDHW}}{UEF_{baseline}}$$

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

$$Q_{DHW-WWHP} = 1.1 \times GPD \times 365 \times 8.33 \times \Delta T_{main}$$

$$COP_{DHW-WWHP} = COP_{AHRI,GLHP} \times 0.95$$

where:

$\Delta therms_{DHW-WWHP}$ = Fossil fuel energy displaced by dedicated DHW-WWHP

$\Delta kWh_{DHW-WWHP}$	= Electricity savings from dedicated DHW-WWHP operation
$COP_{AHRI,GLHP}$	= Rated COP for a per ISO13256-2 at GLHP conditions (32°F source-side, 104°F load-side)
$COP_{DHW-WWHP}$	= Overall annual COP of dedicated DHW-WWHP
F_{EDHW}	= Flag indicating that baseline DHW system is electric
F_{FFDHW}	= Flag indicating that baseline DHW system is fossil fuel fired
GPD	= Gallons per day consumption, for DHW system
$Q_{DHW-WWHP}$	= Annual DHW load served by dedicated DHW-WWHP, BTU
$UEF_{baseline}$	= Uniform energy factor of baseline DHW appliance (gas or electric). For commercial systems use AFUE or Et in place of UEF, as appropriate.
ΔT_{main}	= Average temperature difference between water heater set point temperature and the supply water temperature in water main (°F)
0.95	= Correction factor from AHRI rated conditions to 50-60°F source-side, 120-130°F load-side.
1.1	= Factor to increase DHW load served by DHW-WWHP to account for 10% tank losses (that are embedded in UEF).
8.33	= Energy required (BTU) to heat one gallon of water by one-degree Fahrenheit
365	= Days in one year
3,412	= Conversion factor, one kWh equals 3,412 BTU
100,000	= Conversion factor (BTU/therm), one therm equals 100,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
F_{EDHW}	1 for electric DHW	Flag indicating baseline DHW is electric
F_{FFDHW}	1 for gas-fired DHW	Flag indicating baseline DHW is fossil fuel-fired
GPD	17.2 × # of people	Calculated based on number of people served by the system. For small commercial buildings consult the table below for proper GPD values.
T_{main}		Supply water temperature in water main (°F). Lookup in Cold Water Inlet Temperature table below based on nearest city.
T_{set}	130	Tank storage temperature (°F).
$UEF_{baseline}$		Uniform Energy Factor of the baseline condition. See Baseline Efficiencies section for details regarding derivation of this input.
ΔT_{main}	T_{set} - T_{main}	Average temperature difference between water heater set point temperature and the supply water temperature in water main (°F).

Hot Water Consumption for Commercial and Multifamily Building Applications

Building Type	GPD	Rate	Notes/Assumptions	Source

Assembly	239	7.02 GPD per 1,000 SF	Assumes 10% hot water, 34,000 SF	EIA[48]: 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[49]: School with Showers
Dormitory	8,600	17.2 GPD per resident	Assumes 500 residents	Water Research Foundation[50]
Elementary School	250	0.5 GPD per student	Assumes 500 students	NREL: School
Fast Food Restaurant	500	500 GPD per restaurant		FSTC[51]: Quick Service
Full-Service Restaurant	2,500	2,500 GPD per restaurant		FSTC: Full Service
Grocery	172	3.43 GPD per 1,000 SF	Assumes 10% hot water, 50,000 SF	EIA: Mercantile
High School	1,520	1.9 GPD per person	Assumes 800 students	NREL: School with Showers
Hospital	16,938	54.42 GPD per 1,000 SF	Assumes 40% hot water, 250,000 SF	EIA: Health Care, Inpatient
Hotel	9,104	45.52 GPD per 1,000 SF	Assumes 40% hot water, 200,000 SF	EIA: Lodging
Large Office	550	1.1 GPD per person	Assumes 500 people	NREL: Office
Large Retail	446	3.43 GPD per 1,000 SF	Assumes 10% hot water, 130,000 SF	EIA: Mercantile
Light Industrial	489	4.89 GPD per 1,000 SF	Assumes 10% hot water, 100,000 SF	EIA: Other
Motel	1,366	45.52 GPD per 1,000 SF	Assumes 40% hot water, 30,000 SF	EIA: Lodging
Multifamily High-Rise	4,600	46 GPD per unit	Assumes 100 units	Water Research Foundation
Multifamily Low-Rise	552	46 GPD per unit	Assumes 12 units	Water Research Foundation
Refrigerated Warehouse	86	0.93 GPD per 1,000 SF	Assumes 10% hot water, 92,000 SF	EIA: Warehouse and Storage
Religious	77	7.02 GPD per 1,000 SF	Assumes 10% hot water, 11,000 SF	EIA: Public Assembly
Small Office	110	1.1 GPD per person	Assumes 100 people	NREL: Office
Small Retail	27	3.43 GPD per 1,000 SF	Assumes 10% hot water, 8,000 SF	EIA: Mercantile
University	1,000	0.5 GPD per student	Assumes 2,000 students	NREL: School
Warehouse	465	0.93 GPD per 1,000 SF	Assumes 10% hot water, 500,000 SF	EIA: Warehouse and Storage
Other	Calculate	4.89 GPD per 1,000 SF	Assumes 10% hot water	EIA: Other

Cold Water Inlet Temperature (T_{main})

Supply water main temperatures vary according to climate and are approximately equal to the annual average outdoor temperature plus 6°F.[52] Supply main temperatures based on the annual outdoor temperature are shown below.

City	Annual average outdoor temperature[53] (°F)	T_{main} (°F)
Albany	48.3	54.3
Binghamton	46.3	52.3
Buffalo	48.3	54.3
Massena	43.5	49.5
NYC	55.4	61.4
Poughkeepsie	49.8	55.8
Syracuse	48.3	54.3

Baseline Efficiencies from which Energy Savings are Calculated

[48] 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

[49] National Renewable Energy Laboratory, Saving Energy in Commercial Buildings: Domestic Hot Water Assessment Guidelines, Table 1. Hot Water Use By Building Type, June 2011

[50] Water Research Foundation: Residential End Uses of Water, Version 2, April 2016

[51] Improving Commercial Kitchen Hot Water System Perofmrance, Design Guide – Energy Efficient Heating, Delivery and Use, Table 1. Typical hot water system cost for restaurants, March 2010

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

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

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.[54]

Residential Water Heaters[55]

Product Class	Rated Storage Volume and Input Rating	Draw Pattern	Uniform Energy Factor
Gas-Fired Storage Water Heater	≥ 20 gal and ≤ 55 gal	Very Small	0.3456 - (0.0020 x vt*)
		Low	0.5982 - (0.0019 x vt)
		Medium	0.6483 - (0.0017 x vt)
		High	0.6920 - (0.0013 x vt)
	> 55 gal and ≤ 100 gal	Very Small	0.6470 - (0.0006 x vt)
		Low	0.7689 - (0.0005 x vt)
		Medium	0.7897 - (0.0004 x vt)
		High	0.8072 - (0.0003 x vt)
Oil-fired Storage Water Heater	≤50 gal	Very Small	0.2509 − (0.0012 × vt)
		Low	0.5330 − (0.0016 × vt)
		Medium	0.6078 − (0.0016 × vt)
		High	0.6815 − (0.0014 × vt)
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

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

[55] 10 CFR 430.32(d)

First Hour Rating vs. Draw Pattern (Storage Type Only)[56]

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

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

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

Ancillary Electric Savings Impacts

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

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[56] 10 CFR 429.17

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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. [57] If baseline equipment is a fossil fuel-fired pool heater, electric energy impacts result in a penalty.

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

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

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

Summer Peak Coincident Demand Savings

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

Annual 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:

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

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

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

[57] 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 fuel energy savings
$BTU_{Surface}$[58] = Annual heating energy load contributed by convection and radiation heat losses via pool surface, (BTU)
BTU_{Reheat}[59] = Annual heating energy load contributed by heating the full volume of pool water, (BTU)
BTU_{Evap}[60] = Annual heating energy load contributed by evaporation, (BTU)
$F_{elec,baseline}$ = Baseline electric pool heater flag; used to account for the presence or absence of an electric pool heater in the baseline equipment
$F_{fuel,baseline}$ = Baseline fossil fuel pool heater flag; used to account for the presence or absence of a fossil fuel-fired pool heater in the baseline equipment
$COP_{baseline}$ = 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, ($BTU/hr\text{-}ft^2\text{-}^{o}F$)
AF = Activity Factor, consideration of activity within pool
P_{ω} = Saturation vapor pressure taken at surface water temperature, (in. Hg)
P_{dp} = Saturation pressure at dew point, (in. Hg)
hrs = Total annual swimming season hours
hrs_{cover} = Total annual hours pool covered during the swimming season
$ESF_{cover,surface}$ = Energy Savings Factor of pool cover to insulate from convective and radiation heat losses
$ESF_{cover,evap}$ = Energy Savings Factor of pool cover to insulate from evaporative heat loss
CF = Coincidence factor
0.1 = Simplified empirically derived evaporation factor considering latent heat and air flow[61]; 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, ($lb/hr\text{-}ft^2\text{-}in.\ hg$)

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[58] ASHRAE Handbook: HVAC Applications, 2019, Ch 51 Service Water Heating, Swimming Pools/Health Clubs, eqn. 15
[59] Ibid, eqn. 14
[60] ASHRAE Handbook: HVAC Applications, 2019, Ch 6 Indoor Swimming Pools, eqn. 3, multiplied by required heating temperature difference
[61] Simplified constant presented in ASHRAE Handbook: HVAC Application 2019 Ch 6 based on empirically derived eqn (2) constants and ASHRAE's variable assumptions

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.[62]
T_{pool}		From application.
T_{amb}		Indoor pool ambient temperature shall come from application. For outdoor pool ambient temperature, lookup in Outdoor Pool table in the Air Temperature and Pressure section below based on nearest city.
T_{main}		Supply water temperature in water main (ºF). Lookup in Cold Water Inlet Temperature table below based on nearest city.
A_{pool}		Pool surface area, from application.[63] Assistance in determining the area of common pool shapes as follows: Elliptical: 3.14 x short radius x long radius Kidney Shaped: 0.45 x length x (width at one end x width at other end) Oval: 3.14 x radius^2 + (length of straight sides x width) Rectangular: length x width
V_{pool}		Volume of water, from application.
F_{Reheat}		From application. If pool is filled by delivery service providing preheated water, set F_{Reheat} equal to 0. Otherwise F_{Reheat} shall default to 1.[64]

[62] 10 CFR 430.32 (k)(2)
[63] Guidance for determining surface area of common pool shapes can be found at ASHRAE Handbook: HVAC Applications, 2019, pg 51.25
[64] The water temperature of an undrained pool between swim seasons is assumed to have reached the water main temperature by the beginning of the next swim season. If the pool remains open throughout the year, it is assumed the pool undergoes one effective full pool volume reheat from water main temperature for cleaning and other maintenance (CDC, Healthy Swimming, Operating Public Swimming Pools).

Variable	Value	Notes
U	Indoor pool: 3.9 Outdoor pool, sheltered: 5.3 Outdoor pool, unsheltered: 6.6	Surface heat loss coefficient (BTU/hr-ft^2-ºF).[65]
AF		Lookup from table in Activity Factor section below based on pool function.
P_ω		Lookup from Saturation Vapor Pressure section below based on pool water temperature. Linear interpolation and extrapolation of the data in the table is acceptable for pool templates not provided.
P_{dp}		Lookup from indoor or outdoor pool tables in Air Temperature and Pressure section below based on ambient temperature and relative humidity (RH) or city, respectively. Linear interpolation and extrapolation of the data in the table is acceptable for pool templates not provided.
hrs		From application. Hours shall reflect the total annual hours through the swimming season (number of days between season opening and season closing x 24).
hrs_{cover}		From application. Hours shall reflect the total hours pool covered during the swimming season. Set equal to 0 if pool is left uncovered throughout swimming season. If installing a heat pump pool heater in conjunction with a newly added pool cover, calculate savings from this measure without pool cover consideration and calculate savings from pool cover with efficiency of heat pump pool heater.
$ESF_{cover,surface}$	0.8	Based on cost savings from DOE for gas and heat pump pool heater savings[66]
$ESF_{cover,evap}$	0.95	Effectiveness of Pool Covers to Reduce Evaporation from Swimming Pools. [67]
CF	Outdoor pool: 0 Indoor pool: 0.8	

<u>Cold Water Inlet Temperature (T_{main})</u>

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

[65] ASHRAE Handbook: HVAC Applications, 2019, Ch 51, eqn. 15. Surface heat loss coefficient adjusted from ASHRAE Handbook rolled up surface heat transfer conservations by discounting contribution of evaporation (50-60%) and applying the following assumption for wind velocity: Indoor pools experience wind speeds less than 3.5 mph (10.5x0.5x0.75), outdoor sheltered pools experience wind speeds between 3.5 and 5 mph (10.5x0.5), and outdoor unsheltered pools experience wind speeds above 5 mph (10.5x0.5x1.25).

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

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

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

outdoor temperature are shown below.

City	Annual average outdoor temperature[69] (°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.[70]

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

Ambient Air Temperature and Pressure (T_{amb} and P_{dp})
Indoor pools shall apply ambient air temperature from application based on facility set point temperature. Lookup saturation vapor pressure based on facility set point temperature and relative humidity (RH) from the table below, based on psychrometric analysis. Interpolation may be performed for indoor pool ambient temperatures not listed.

Indoor Pool T_{amb} (°F)	Indoor Pool, P_{dp} (in. Hg)		
	RH 50%	RH 55%	RH 60%
72	0.40	0.44	0.47
74	0.42	0.47	0.51
76	0.45	0.50	0.54
78	0.48	0.53	0.58
80	0.52	0.56	0.62
82	0.55	0.61	0.66
84	0.59	0.65	0.71
86	0.63	0.69	0.75

[69] Average annual outdoor temperatures taken from NCDC 1981-2010 climate normals
[70] ASHRAE Handbook: Fundamentals 2017, Ch 1 Psychrometrics, Table 3 Thermodynamic Properties of Water at Saturation

For outdoor pools, lookup T_{amb} and $\underline{P_{dp}}$ from the table below based on location. Ambient temperature averages for outdoor pools apply a 4-month swimming season[71].

City	Outdoor Pool T_{amb}[72] (°F)	Outdoor Pool P_{dp} (in. Hg)
Albany	67.8	0.48
Binghamton	65.0	0.44
Buffalo	67.3	0.47
Massena	64.6	0.47
NYC	73.4	0.53
Poughkeepsie	68.6	0.54
Syracuse	67.5	0.48

Activity Factor

Activity Factor considers activity level of the pool, allowing for splashing and a limited area of wetted deck.[73] Look up Activity Factor from the table below based on pool application.

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

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0 for outdoor pools and is 0.8 for indoor pools.[74]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition for this measure is an electric resistance or fossil fuel-fired pool heater.

Compliance Efficiency from which Incentives are Calculated

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

[71] It is assumed that 50% of pools are unheated and operate for 3 months per year and the other 50% of pools are heated and operate for 5 months per year, giving an average of 4 months of usage per year; June 1 through Sept 30
[72] Average ambient temperatures taken from NCDC 1981-2010 climate normals, averaged from June 1 through Sept 30
[73] ASHRAE Handbook, Applications, 2019, Ch 6, Table 1
[74] *No source specified – update pending availability and review of applicable references.*

Operating Hours

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

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

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SOLAR POOL COVER

Measure Description

This measure is applicable to solar pool covers, which are partially transparent plastic covers that allow solar heat to transfer to the pool water without allowing heat out of the pool. Solar pool covers are typically made of several sheets of plastic with an inner layer of air bubbles. This design ensures the cover can float on the pool surface. Solar pool covers are assumed to be removed when the pool is open and in place when the pool is closed.

The solar pool cover measure is intended to reflect the installation of new solar pool covers on heated pools. Solar pool covers are meant to be used during the pool's off-hours to insulate and heat the pool water, while also preventing evaporation of the pool water.

Pools must have an existing or newly installed pool heater to be eligible for savings. Seasonal pool covers are not eligible. This measure is restricted to outdoor pools only.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = F_{elec} \times \left(\frac{\Delta kBTU_{cover}}{Eff_{poolheater}}\right) \times \frac{1}{3.412}$$

Summer Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fuel Energy Savings

$$\Delta MMBtu = F_{ff} \times \left(\frac{\Delta kBTU_{cover}}{Eff_{poolheater}}\right) \times \frac{1}{1{,}000}$$

where:

$$\Delta kBTU_{cover} = \frac{\left[\left(BTU_{surface} \times ESF_{cover,surface}\right) + \left(BTU_{evap} \times ESF_{cover,evap}\right)\right]}{1{,}000} \times \frac{hrs_{cover}}{hrs}$$

$$BTU_{surface} = \left(T_{pool} - T_{amb}\right) \times A_{pool} \times U \times hrs$$

$$BTU_{evap} = 0.1 \times AF \times A_{pool} \times \left(P_{\omega} - P_{dp}\right) \times \left(T_{pool} - T_{main}\right) \times hrs$$

where:

ΔkWh = Annual electricity energy savings
ΔkW = Peak coincident demand electric savings
$\Delta MMBtu$ = Annual fuel energy savings
F_{elec} = Electric pool heating flag; use to account for the presence or absence of an electric pool heater
F_{ff} = Fossil fuel pool heating flag; use to account for the presence or absence of a fossil fuel pool heater
$\Delta kBTU_{cover}$ = Annual reduction of heat loss due to installation of cover
$Eff_{poolheater}$ = Efficiency of pool heater
$BTU_{surface}$ = Convective loss from the surface of the pool to the surrounding air
BTU_{evap} = Water evaporated from the surface of the pool to the surrounding area
hrs_{cover} = Total annual hours pool covered during the swimming season
$ESF_{cover,surface}$ = Energy Savings Factor of pool cover to insulate from convective and radiation heat losses
$ESF_{cover,evap}$ = Energy Savings Factor of pool cover to insulate from evaporative heat loss
T_{pool} = Pool temperature set point, (ºF)
T_{amb} = Average temperature of surrounding ambient air, (ºF)
T_{main} = Supply water temperature in water main, (ºF)
A_{pool} = Surface area of pool, (ft^2)
U = Surface heat loss coefficient, ($BTU/hr\text{-}ft^2\text{-}ºF$)
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
0.1 = Simplified empirically derived evaporation factor considering latent heat and air flow[75]; 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, ($lb/hr\text{-}ft^2\text{-}in.\ hg$)
3.412 = Conversion factor, one watt-hour equals 3.412 BTU
1,000 = Conversion factor, one MMBtu equals 1,000 kBTU

Summary of Variables and Data Sources

Variable	Value	Notes
F_{elec}		If pool heater is electric, set equal to 1. Otherwise, set equal to 0.
F_{ff}		If pool heater is fossil-fuel fired, set equal to 1. Otherwise, set equal to 0.
$Eff_{poolheater}$		From application. If unknown, see table below.
$ESF_{cover,surface}$	0.80	Based on cost savings from DOE for gas and heat pump pool heater savings[76]

[75] Simplified constant presented in ASHRAE Handbook: HVAC Application 2019 Ch 6 based on empirically derived eqn (2) constants and ASHRAE's variable assumptions
[76] U.S. D.O.E., Swimming Pool Covers

Variable	Value	Notes
$ESF_{cover,evap}$	0.95	Effectiveness of Pool Covers to Reduce Evaporation from Swimming Pools. [77]
hrs_{cover}		From application. If unknown, assume 12 hours multiplied by the total number of days that of the pool season .
T_{pool}		From application. If pool temperature is not known, liner interpolation and extrapolation is acceptable to establish values.
T_{amb}		For outdoor pool ambient temperature, lookup in Outdoor Pool table in the Air Temperature and Pressure section below based on nearest city.
T_{main}		Supply water temperature in water main (ºF). Lookup in Cold Water Inlet Temperature table below based on nearest city.
A_{pool}		Pool surface area, from application.[78] Assistance in determining the area of common pool shapes as follows: Elliptical: 3.14 x short radius x long radius Kidney Shaped: 0.45 x length x (width at one end x width at other end) Oval: 3.14 x radius^2 + (length of straight sides x width) Rectangular: length x width
U	Outdoor pool, sheltered: 5.3 Outdoor pool, unsheltered: 6.6	Surface heat loss coefficient (BTU/hr-ft^2-ºF).[79]
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.

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

[78] Guidance for determining surface area of common pool shapes can be found at ASHRAE Handbook: HVAC Applications, 2019, pg 51.25

[79] ASHRAE Handbook: HVAC Applications, 2019, Ch 51, eqn. 15. Surface heat loss coefficient adjusted from ASHRAE Handbook rolled up surface heat transfer conservations by discounting contribution of evaporation (50-60%) and applying the following assumption for wind velocity: Indoor pools experience wind speeds less than 3.5 mph (10.5x0.5x0.75), outdoor sheltered pools experience wind speeds between 3.5 and 5 mph (10.5x0.5), and outdoor unsheltered pools experience wind speeds above 5 mph (10.5x0.5x1.25).

Variable	Value	Notes
P_{dp}		Lookup from indoor or outdoor pool tables in Air Temperature and Pressure section below based on ambient temperature and relative humidity (RH) or city, respectively.
hrs		From application. Hours shall reflect the total annual hours through the swimming season (number of days between season opening and season closing x 24).

Efficiency of Pool Heater by Heater Type

Pool Heater Type	$Eff_{poolheater}$	Source
Electric Heat Pump Pool Heater	5.0 COP	Heat pump pool heater COP's range from 3.0 to 7.0.
Electric Resistance Pool Heater	1.0 COP	Standard for electric resistance heating
Gas Pool Heater	0.82	10 CFR 430.32 (k)(2)

Cold Water Inlet Temperature (T_{main})

Supply water main temperatures vary according to climate, and are approximately equal to the annual average outdoor temperature plus 6°F.[80] Supply main temperatures based on the annual outdoor temperature are shown below.

City	T_{amb}[81] (°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.[82]

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

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

[81] Average annual outdoor temperatures taken from NCDC 1981-2010 climate normals

[82] ASHRAE Handbook: Fundamentals 2017, Ch 1 Psychrometrics, Table 3 Thermodynamic Properties of Water at Saturation

Pool Temperature, T_{pool} (°F)	P_{ω} (in Hg)
82	1.10
84	1.18

Ambient Air Temperature and Pressure (T_{amb} and P_{dp})

For outdoor pools, lookup T_{amb} and P_{dp} from the table below based on location. Ambient temperature averages for outdoor pools apply a 4-month swimming season[83].

City	Outdoor Pool T_{amb}[84] (°F)	Outdoor Pool P_{dp} (in. Hg)
Albany	67.8	0.48
Binghamton	65.0	0.44
Buffalo	67.3	0.47
Massena	64.6	0.47
NYC	73.4	0.53
Poughkeepsie	68.6	0.54
Syracuse	67.5	0.48

Activity Factor

Activity Factor considers activity level of the pool, allowing for splashing and a limited area of wetted deck.[85] Look up Activity Factor from the table below based on pool application.

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

Coincidence Factor (CF)

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

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition assumes no existing solar or nighttime cover. Existing seasonal covers used during the off season are not considered baseline.

[83] It is assumed that 50% of pools are unheated and operate for 3 months per year and the other 50% of pools are heated and operate for 5 months per year, giving an average of 4 months of usage per year; June 1 through Sept 30

[84] Average ambient temperatures taken from NCDC 1981-2010 climate normals, averaged from June 1 through Sept 30

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

Compliance Efficiency from which Incentives are Calculated

The compliance condition is an outdoor pool with a solar pool cover.

Operating Hours

Operating hours shall reflect the total annual hours of the swimming season. Covered hours are reflective of the times the pool cover is in use and should not reflect the times the pool is in use. Covered hours will correlate to the hours the pool is unoccupied during the seasons that the pool is filled for use.

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

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

Ancillary Electric Savings Impacts

While indoor pools may achieve some additional savings from the reduced ventilation required to remove the evaporated pool water, no relevant studies have been performed to date that would allow quantification of these impacts. Until additional information is available, these impacts are excluded from the prescribed formulation of savings.

References

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

8. National Plasterers Council, Effectiveness of Pool Covers to Reduce Evaporation from Swimming Pools, prepared by California Polytechnic State University, January 2016 Available from: https://cdn.ymaws.com/www.npconline.org/resource/resmgr/Docs/Evaporation_Study_Report.pdf

Record of Revision

Record of Revision Number	Issue Date
7-21-19	8/30/2021

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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[86]
	Clothes Dryer	Residential	14	ENERGY STAR® M&I Scoping Report[87]
	Clothes Washer	Residential	11	DEER 2014 EUL ID: Appl-EffCW
	Dehumidifier	Residential	12	ENERGY STAR® Calc[88]
	Dishwasher	Residential	11	DEER 2014 EUL ID: Appl-EffDW
	Fireplace	Residential	15	DOE[89]
	Refrigerator and Freezer	Residential	14	DEER 2014 EUL ID: Appl-ESRefg
	Soundbar	Residential	7	RPP Product Analysis[90]
	Advanced Power Strip (APS)	Residential	8	DEER 2014 EUL ID: Plug-OccSens
Appliance Control	Air Conditioner - Room (RAC) Recycling	Residential	3	DEER 2014 EUL ID: HV-RAC-RUL

[86] Savings Calculator for ENERGY STAR® Qualified Appliances (last updated October 2016) Available from: https://www.energystar.gov/buildings/facility-owners-and-managers/existing-buildings/save-energy/purchase-energy-saving-products
[87] ENERGY STAR® Market & Industry Scoping Report: Residential Clothes Dryer, November 2011.
[88] ENERGY STAR® Dehumidifier Calculator https://www.energystar.gov/ia/partners/promotions/cool_change/downloads/CalculatorConsumerDehumidifier.xls
[89] 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
[90] Retail Products Platform Product Analysis, Last Updated May 25, 2016. Available from: https://drive.google.com/file/d/0B9Fd3ckbKJp5OEpWSHg1eksyZ1U/view

Category	Single and Multi-family Residential Measures	Sector	EUL (years)	Source
Appliance Recycling	Dehumidifier Recycling	Residential	3	Assumes same RUL as RAC
	Refrigerator Recycling	Residential	5	DEER 2014 EUL ID: Appl-RecRef
	Freezer Recycling	Residential	4	DEER 2014 EUL ID: Appl-RecFrzr
	Air Conditioner – Room (RAC) Cover and Gap Sealer	Residential	3	See note below[91]
Building Shell	Air Leakage Sealing	Residential	15	GDS[92]
	Insulation – Hot Water and Steam Pipe	Residential	15	GDS[93]
	Insulation – Opaque Shell	Residential	25	GDS[94]
	Storm Window	Residential	20	DOE[95]
	Window	Residential	20	DEER 2014 EUL ID: BS-Win
	Window - Film	Residential	10	DEER 2014 EUL ID: GlazDaylt-WinFilm
	Heat Pump Water Heater (HPWH)	Residential	10	DEER 2014 EUL ID: WtrHt-HtPmp
Domestic Hot Water (DHW)	Indirect Water Heater	Residential	11	DEER 2014 EUL ID: WtrHt-Res-Gas
	Storage Water Heater - Gas	Residential	15	PA Consulting Group[96]
	Storage Water Heater - Electric	Residential	13	DEER 2014 EUL ID: WtrHt-Res-Elec
	Instantaneous Water Heater	Residential	20	DEER 2014 EUL ID: WtrHt-Instant-Res
	Solar Pool Heater	Residential	15	DOE[97]

[91] Average/typical manufacturer warranty period for AC covers
[92] GDS Associates, Inc., Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures, June 2007, Table 1 – Residential Measures
[93] Ibid.
[94] Ibid.
[95] https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-22864rev2.pdf
[96] PA Consulting Group Inc., Focus on Energy Evaluation Business Programs: Measure Life Study, final report dated August 25, 2009. Available from: https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
[97] https://www.energy.gov/energysaver/solar-swimming-pool-heaters

Category	Single and Multi-family Residential Measures	Sector	EUL (years)	Source
DHW - Control	Low-Flow – Faucet Aerator	Residential	10	DEER 2014 EUL ID: WtrHt-WH-Aertr
	Low-Flow – Showerhead	Residential	10	DEER 2014 EUL ID: WtrHt-WH-Shrhd
	Thermostatic Shower Restriction Valve	Residential	10	UPC[98]
	Air Conditioner – Central (CAC)	Residential	15	DEER 2014 EUL ID: HV-ResAC
Heating, Ventilation and Air Conditioning (HVAC)	Air Conditioner – Room (RAC)	Residential	12	GDS[99]
	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[100]
	Boiler and Furnace - Combination (“Combi”) Furnace	Residential	20	DEER 2014[101] 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

[98] 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.
[99] GDS Associates, Inc., Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures, June 2007, Table 1 – Residential Measures
[100] Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Furnaces, February 10, 2015, Table 8.2.17. Product definition of furnaces includes electric boilers with firing rates of less than 300,000 BTU/h
Available from: https://energy.mo.gov/sites/energy/files/technical-support-document---residential-furances_doe.pdf
[101] 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[102]
	Furnace, Gas Fired	Residential	22	DOE[103,104]
	Gas Heat Pump	Residential	15	DEER 2014 EUL ID: HV-Res HP
	Heat Pump - Air Source (ASHP)	Residential	15	DEER 2014 EUL ID: HV-Res HP
	Heat Pump – Ground Source (GSHP)	Residential	25	ASHRAE[105]
	Heat Pump – PTHP	Residential	15	DEER 2014 EUL ID: HVAC-PTHP
	Refrigerant Charge Correction & Tune-Up – Air Conditioner and Heat Pump	Residential	10	DEER 2014 EUL ID: HV-RefChrg
	Tune-Up - Boiler	Residential	5	DEER 2014 EUL ID: BlrTuneup
	Tune-Up - Furnace	Residential	5	DEER 2014 EUL ID: BlrTuneup
	Unit Heater, Gas Fired	Residential	13	ASHRAE Handbook, 2015
	Adaptive Photonic Control	Residential	EUL = Retrofitted motor RUL = Retrofitted motor EUL – (Current Year – Mfr. Year) **Default = 5**	DEER 2014 EUL ID: Motors-fan
HVAC - Control	Outdoor Temperature Setback Control for Hydronic Boiler	Residential	EUL = Boiler RUL = Boiler EUL – (Current Year – Mfr. Year) **Default = 5**	N/A

[102] PA Consulting Group Inc., Focus on Energy Evaluation Business Programs: Measure Life Study, final report dated August 25, 2009. Available from: https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
[103] U.S. DOE. "Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Furnaces" and "Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Commercial Warm Air Furnaces." August 30, 2016. Available from: https://www.regulations.gov/document?D=EERE-2014-BT-STD-0031-0217
[104] U.S. DOE. "Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Commercial Warm Air Furnaces." December 30, 2015. Available from: https://www.regulations.gov/document?D=EERE-2013-BT-STD-0021-0050
[105] ASHRAE: Owning and Operating Cost Database, Equipment Life/Maintenance Cost Survey: https://xp20.ashrae.org/publicdatabase/system_service_life.asp?selected_system_type=1

Category	Single and Multi-family Residential Measures	Sector	EUL (years)	Source
HVAC - Control	Steam Trap – Low Pressure Space Heating	Residential	6	DEER 2014 EUL ID: HVAC-StmTrp
	Submetering	Multifamily	10	NYSERDA[106]
	Thermostat – All Types	Residential	11	DEER 2014 EUL ID: HVAC-ProgTStats
	Thermostatic Radiator Valve – One Pipe Steam Radiator	Multifamily	15	DOE[107]
	Smart Thermostatic Radiator Enclosure	Residential	15	DEER 2014 EUL ID: Motors-fan[108]
	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[109]
Lighting	LED Lamp Light Fixture	Residential LED (Interior)	50,000 hours	DLC[110]
			Residential	Rated Life listed by ENERGY STAR or default to 25,000 hrs/ annual lighting operating hrs or 15 yrs if rated lifetime or annual operating hours are not known

106 NYSERDA Residential Electric Submetering Manual
107 U.S. DOE, "Thermostatic Radiator Valve Evaluation", January 2015, Table 4. pg. 16
108 Based on assumed EUL of integrated fan, which is expected to be the first component to fail
109 ENERGY STAR® Program Requirements Product Specification for Lamps (Light Bulbs) V2.1, June 2017, p. 19 (Capped at 20 years). https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V2.1%20Final%20Specification.pdf
110 Placed on the Qualified Products List by the Design Light Consortium (DLC) 50,000 hours, according to the appropriate Application Category as specified in the DLC's Product Qualification Criteria, Technical Requirement Table version 4.4 or higher

Category	Single and Multi-family Residential Measures		Sector	EUL (years)	Source
Lighting	Light Fixture Bi-Level Lighting	LED (Exterior)	Residential	Rated Life listed by ENERGY STAR or default to 35,000 hrs/ annual lighting operating hrs or 15 yrs if rated lifetime or annual operating hours are not known	ENERGY STAR® Fixtures[111]
		LED (Inseparable)	Residential	Rated Life listed by ENERGY STAR or default to 50,000 hrs/ annual lighting operating hrs or 15 yrs if rated lifetime or annual operating hours are not known	ENERGY STAR® Fixtures
		Multifamily Common Area	15	ComEd[112]	ENERGY STAR® Fixtures
Lighting Control	Pool Pump		Residential	10	DEER 2014 EUL ID: OutD-PoolPump
Motors and Drives	Pool Circulator Timer		Residential	10	DEER 2014 EUL ID: OutD-PoolPump
	Heat Pump Pool Heater		Residential	15	DEER 2014 EUL ID: HV-Res HP
Other	Pool Heater		Residential	8	DOE[113]
	Solar Pool Heater		Residential	15	DOE[114]

[111] ENERGY STAR® Program Requirements Product Specification for Luminaires (Light Fixtures) V2.2, August 2019, p. 18 (Capped at 20 years). https://www.energystar.gov/sites/default/files/Luminaires%20V2.2%20Final%20Specification.pdf

[112] ComEd Luminaire Level Lighting Control IPA Program Impact Evaluation Report prepared by Navigant Available from: http://ilsagfiles.org/SAG_files/Evaluation_Documents/ComEd/ComEd_EPY9_Evaluation_Reports_Final/ComEd_PY9_LLLC_IPA_Program_Impact_Evaluation_Report_2018-06-05_Final.pdf

[113] DOE, Chapter 8, Life-Cycle Cost and Payback Period Analyses, Table 8.75 Available from: https://www.regulations.gov/document?D=EERE-2006-STD-0129-0170

[114] 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[115]
	Milk Pre-Cooler Heat Exchanger	C&I	15	PA Consulting Group[116]
	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[117]
	Variable Speed Drive Milk Pump Plate Cooler	C&I	15	PA Consulting Group[118]
	Variable Speed Drive Vacuum Pump	C&I	15	PA Consulting Group[119]
Appliance	Clothes Dryer	C&I	14	ENERGY STAR®M&I Report[120]
	Clothes Washer	C&I	11	DEER 2014 EUL ID: Appl-EffCW
	Cooking Equipment[121]	C&I	12	DEER 2014 EUL IDs: Various
	Dishwasher	C&I	10 – Under Counter 15 – Single Door 20 – Conveyor Type 10 – Pots, Pans & Utensils	ENERGY STAR®Calc[122]
	Ice Maker	C&I	10	DEER 2014 EUL ID: Cook-IceMach
	Refrigerator and Freezer	C&I	12	DEER 2014 EUL ID: Cook-SDRef
Appliance - Control	Advanced Power Strip (APS)	C&I	8	DEER 2014 EUL ID: Plug-OccSens
	Vending Machine and Novelty Cooler Control	C&I	5	DEER 2014 EUL ID: Plug-VendCtrler

[115] PG&E Work Paper PGE3PAGR117, October 12, 2017
[116] PA Consulting Group Inc., Focus on Energy Evaluation Business Programs: Measure Life Study, final report dated August 25, 2009. Available from: https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
[117] Based on EUL's for Advanced Power Strips
[118] PA Consulting Group Inc., Focus on Energy Evaluation Business Programs: Measure Life Study, final report dated August 25, 2009. Available from: https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
[119] PA Consulting Group Inc., Focus on Energy Evaluation Business Programs: Measure Life Study, final report dated August 25, 2009. Available from: https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
[120] ENERGY STAR® Market & Industry Scoping Report: Residential Clothes Dryer, November 2011.
[121] Applicable to all kitchen cooking equipment not otherwise listed
[122] ENERGY STAR® Savings Calculator for ENERGY STAR® Certified Commercial Kitchen Equipment www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx?5da4-3d90&5da4-3d90

Category	Commercial & Industrial Measures	Sector	EUL (years)	Source
Appliance Recycling	Air Conditioner – Room (RAC)	C&I	9	DEER 2014 EUL ID: HV-RAC-ES
Building Shell	Air Leakage Sealing	C&I	15	GDS[123]
	Cool Roof	C&I	15	DEER 2014 EUL ID: BldgEnv-CoolRoof
	Insulation - Hot Water and Steam Pipe	C&I	15	GDS[124]
	Insulation - Opaque Shell	C&I	30	ET & CEC[125]
	Window - Film	C&I	10	DEER 2014 EUL ID: GlazDaylt-WinFilm
	Window - Glazing	C&I	20	DEER 2014 EUL ID: BS-Win
	Air Curtains	C&I	15	DEER 2014 EUL ID: Motors-fan
Compressed Air	Air Compressor	C&I	13	Other State TRMs[126]
	Engineered Air Nozzle	C&I	15	Wisconsin PSC[127]
	No Air Loss Water Drain	C&I	13	MA Measure Life Study[128]
	Refrigerated Air Dryer	C&I	13	Other State TRMs [129]
	Compressed Air Heat Recovery	C&I	13	Other State TRMs [130]
	Flow Controller	C&I	13	Other State TRMs [131]
	Low Pressure Drop Filter	C&I	5	Other State TRMs [132]
Domestic Hot Water (DHW)	Heat Pump Water Heater (HPWH)	C&I	10	DEER EUL ID: WtrHt-HtPmp
	Indirect Water Heater	C&I	15	DEER 2014 EUL ID: WtrHt-Com
	Instantaneous Water Heater	C&I	20	DEER 2014 EUL ID: WtrHt-Instant-Com
	Storage Tank Water Heater	C&I	15	DEER 2014 EUL ID: WtrHt-Com

[123] GDS Associates, Inc., Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures, June 2007, Table 1 – Residential Measures
[124] GDS Associates, Inc., Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures, June 2007, Table 1 – Residential Measures
[125] Energy Trust uses 30 years for commercial applications. CEC uses 30 years for insulation in Title 24 analysis.
[126] 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.
[127] PA Consulting Group (2009). *Business Programs: Measure Life Study*. Prepared for State of Wisconsin Public Service Commission
[128] 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
[129] 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.
[130] Ibid.
[131] Ibid.
[132] Ibid.

Category	Commercial & Industrial Measures	Sector	EUL (years)	Source
DHW - Control	Drain Water Heat Recovery (DWHR)	C&I	30	2019 Title 24[133]
	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[134]
Heating, Ventilation and Air Conditioning (HVAC)	Air Conditioner – PTAC	C&I	15	DEER 2014 EUL ID: HVAC-PTAC
	Air Conditioner – Unitary	C&I	15	DEER 2014 EUL ID: HVAC-airAC
	Boiler and Furnace - Combination ("Combi") Boiler	C&I	22	DOE[135]
	Boiler and Furnace - Combination ("Combi") Furnace	C&I	20	DEER 2014[136] EUL ID: HVAC-Frnc
	Boiler, Hot Water – Steel Water Tube	C&I	24	ASHRAE Handbook, 2015
	Boiler, Hot Water – Steel Fire Tube	C&I	25	ASHRAE Handbook, 2015
	Boiler, Hot Water – Cast Iron	C&I	35	ASHRAE Handbook, 2015
	Boiler, Steam – Steel Water Tube	C&I	30	ASHRAE Handbook, 2015
	Boiler, Steam – Steel Fire Tube	C&I	25	ASHRAE Handbook, 2015
	Boiler, Steam – Cast Iron	C&I	30	ASHRAE Handbook, 2015
	Chiller – Air & Water Cooled	C&I	20	DEER 2014 EUL ID: HVAC-Chlr
	Chiller – Cooling Tower	C&I	15	DEER 2014 EUL ID: HVAC-ClTwrPkgSys
	Condensing Unit Heater	C&I	18	Ecotope[137]
	Duct Sealing and Insulation	C&I	18	DEER 2014 EUL ID: HVAC-DuctSeal
	Electronically Commutated (EC) Motor - HVAC Blower Fan	C&I	15	DEER 2014 EUL ID: Motors-Fan

133 2019 Title 24, Part 6 CASE Report. "Drain Water Heat Recovery – Final Report." Available from: http://title24stakeholders.com/wp-content/uploads/2017/09/2019-T24-CASE-Report_DWHR_Final_September-2017.pdf

134 https://www.nrel.gov/docs/fy16osti/64541.pdf

135 Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Furnaces, February 10, 2015, Table 8.2.17
Available from: https://energy.mo.gov/sites/energy/files/technical-support-document---residential-furances_doe.pdf

136 Based on DEER value for high efficiency boiler and instantaneous water heater

137 Ecotope Natural Gas Efficiency and Conservation Measure Resource Assessment (2003)

Category	Commercial & Industrial Measures	Sector	EUL (years)	Source
Heating, Ventilation and Air Conditioning (HVAC)	Electronically Commutated (EC) Motor – Hydronic Circulator Pump	C&I	15	DEER 2014 EUL ID: Motors-pump
	Economizer –Dual Enthalpy Air Side	C&I	10	DEER 2014 EUL ID: HVAC-addEcono
	Furnace, Gas Fired	C&I	23	DOE[138,139]
	Gas Heat Pump	C&I	15	DEER 2014 EUL ID: HV-Res HP
	Heat Pump – Unitary & Applied	C&I	15	DEER 2014 EUL ID: HVAC-airHP
	Heat Pump – PTHP	C&I	15	DEER 2014 EUL ID: HVAC-PTHP
	Heat Pump – Water Source (WSHP)	C&I	25	ASHRAE[140]
	High Volume Low Speed Fan	C&I	15	PA Consulting Group[141]
	Infrared Heater	C&I	17	GDS[142]
	Refrigerant Charge Correction & Tune Up – Air Conditioner and Heat Pump	C&I	10	DEER 2014 EUL ID: HVAC-RefChg
	Tune-Up – Boiler	C&I	5	DEER 2014 EUL ID: BlrTuneup
	Tune-Up – Chiller System	C&I	5	WI EUL DB[143]
	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

138 U.S. DOE. "Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Furnaces" and "Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Commercial Warm Air Furnaces." August 30, 2016. Available from: https://www.regulations.gov/document?D=EERE-2014-BT-STD-0031-0217

139 U.S. DOE. "Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Commercial Warm Air Furnaces." December 30, 2015. Available from: https://www.regulations.gov/document?D=EERE-2013-BT-STD-0021-0050

140 ASHRAE Owning and Operating Cost Database
Available from: https://xp20.ashrae.org/publicdatabase/system_service_life.asp?selected_system_type=1

141 PA Consulting Group Inc., Focus on Energy Evaluation Business Programs: Measure Life Study, final report dated August 25, 2009. Available from: https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf

142 GDS Associates, Inc. "Natural Gas Efficiency Potential Study." DTE Energy. July 29, 2016. Available from: https://www.michigan.gov/documents/mpsc/DTE_2016_NG_ee_potential_study_w_appendices_vFINAL_554360_7.pdf

143 Wisconsin Public Service Commission: Equipment Useful Life Database, 2013
Excerpt available from: https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf

Category	Commercial & Industrial Measures	Sector	EUL (years)	Source
HVAC – Control	Adaptive Photonic Control	C&I	EUL = Retrofitted motor RUL = Retrofitted motor EUL – (Current Year – Mfr. Year) **Default = 5**	DEER 2014 EUL ID: Motors-fan
	Direct Digital Control (DDC) System	C&I	15	DEER 2014 EUL ID: HVAC-EMS
	Demand Control Ventilation (DCV)	C&I	15	DEER 2014 EUL ID: HVAC-VSD-DCV
	Energy Management System	C&I	15	DEER 2014 EUL ID: HVAC-EMS
	Energy Management System – Guest Room	C&I	15	DEER 2014 EUL ID: HVAC-EMS
	Boiler Economizer	C&I	EUL = Boiler RUL = Boiler EUL – (Current Year – Mfr. Year) **Default = 5**	GDS[144]
	Kitchen Demand Ventilation Control	C&I	15	PG&E[145]
	Outdoor Temperature Setback Control for Hydronic Boiler	C&I	EUL = Boiler RUL = Boiler EUL – (Current Year – Mfr. Year) **Default = 5**	N/A
	Steam Trap – Low-Pressure Space Heating	C&I	6	DEER 2014 EUL ID: HVAC-StmTrp
	Thermostat – Programmable Thermostat – Wi-Fi (Communicating)	C&I	11	DEER 2014 EUL ID: HVAC-ProgTStats
	Thermostatic Radiator Valve	C&I	15	DOE[146]
	Advanced Rooftop Control	C&I	EUL = RUL of Existing RTU = RTU EUL – (Current Year – Year of Mfr.) **Default = 5**	N/A

[144] Natural Gas Energy Efficiency Potential in Massachusetts, GDS Associates, 2009. Available from: http://ma-eeac.org/wordpress/wp-content/uploads/5_Natural-Gas-EE-Potenial-in-MA.pdf
[145] PG&E Work Paper WPSDGENRCC0019, June 15, 2012
[146] U.S. DOE. "Thermostatic Radiator Valve Evaluation." January 2015. Available from: https://www.nrel.gov/docs/fy15osti/63388.pdf

Category	Commercial & Industrial Measures		Sector	EUL (years)	Source
Lighting	Light Fixture	LED Fixture (DLC)	C&I	50,000 hrs /annual lighting operating hrs or 15 yrs if annual operating hrs are not known	DLC[147]
	Light Fixture	LED Fixture (Interior)	C&I	Rated Life listed by ENERGY STAR or default to 25,000 hrs/annual lighting operating hrs or 15 yrs if rated lifetime or annual operating hrs are not known	ENERGY STAR®[148]
		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®[149]
		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®[150]
		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

[147] 50,000 hours per L_{70} requirements prescribed by the DLC's Product Qualification Criteria, Technical Requirement Table version 4.4

[148] Placed on the Qualified Fixture List by ENERGY STAR®, according to the appropriate luminaire classification as specified in the ENERGY STAR® Program requirements for Luminaires, version 2.1. Divided by estimated annual use, but capped at 20 years regardless (consistent with C&I redecoration and business type change patterns

[149] Placed on the Qualified Fixture List by ENERGY STAR®, according to the appropriate luminaire classification as specified in the ENERGY STAR® Program requirements for Luminaires, version 2.1. Divided by estimated annual use, but capped at 20 years regardless (consistent with C&I redecoration and business type change patterns

[150] Placed on the Qualified Fixture List by ENERGY STAR®, according to the appropriate luminaire classification as specified in the ENERGY STAR® Program requirements for Luminaires, version 2.1. Divided by estimated annual use, but capped at 20 years regardless (consistent with C&I redecoration and business type change patterns

Category	Commercial & Industrial Measures	Sector	EUL (years)	Source
Lighting	LED Lamp	C&I	50,000 hours	DLC[151]
			Rated Life listed by ENERGY STAR or default to 15,000 hrs /annual lighting operating hrs or 15 yrs if rated lifetime or annual operating hrs are not known	ENERGY STAR®
	Refrigerated Case LED	C&I	16	DEER 2014 EUL ID: GrocDisp-FixtLtg-LED
	Lighting Power Density (LPD)	C&I	15	GDS[152]
Lighting - Control	Bi-Level Lighting	C&I	15	ComEd[153]
	Integrated Interior Lighting Control	C&I	15	ComEd[154]
	Non-Integrated Interior Lighting Control	C&I	10	GDS[155]
	Plug-Load Occupancy Sensor	C&I	8	DEER[156]
Motors and Drives	Motor (incl. PEI Pumps)	C&I	15	DEER 2014 EUL ID: Motors-HiEff
	Notched & Synchronous Belt	C&I	5	DEER 2014 EUL ID: HV-CoggedBelt
	Pool Pump	C&I	10	DEER 2014 EUL ID: OutD-PoolPump
	Variable Frequency Drive (VFD) – Fan and Pump	C&I	15	DEER 2014 EUL ID: HVAC-VSDSupFan
	Elevator Modernization	C&I	15	DEER 2014[157]

151 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

152 Measure Life Report, Residential and Commercial/Industrial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007. As directed in the Interior and Exterior Lighting measure, new construction projects may be evaluated based on LPD. This value is provided for use with new construction LPD projects only.
Available from: https://energy.mo.gov/sites/energy/files/measure-life-report-2007.pdf

153 ComEd Luminaire Level Lighting Control IPA Program Impact Evaluation Report prepared by Navigant
Available from:
http://ilsagfiles.org/SAG_files/Evaluation_Documents/ComEd/ComEd_EPY9_Evaluation_Reports_Final/ComEd_PY9_LLLC_IPA_Program_Impact_Evaluation_Report_2018-06-05_Final.pdf

154 ComEd Luminaire Level Lighting Control IPA Program Impact Evaluation Report prepared by Navigant
Available from:
http://ilsagfiles.org/SAG_files/Evaluation_Documents/ComEd/ComEd_EPY9_Evaluation_Reports_Final/ComEd_PY9_LLLC_IPA_Program_Impact_Evaluation_Report_2018-06-05_Final.pdf

155 Measure Life Report, Residential and Commercial/Industrial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.
Available from: https://energy.mo.gov/sites/energy/files/measure-life-report-2007.pdf

156 DEER value for lighting occupancy sensors

157 Assumes same EUL as VFD measure.

Category	Commercial & Industrial Measures	Sector	EUL (years)	Source
Other	Heat Pump Pool Heater	C&I	15	DEER 2014 EUL ID: HV-Res HP
	High Efficiency Transformer	C&I	32	DOE[158]
	High Frequency Battery Charger	C&I	15	PG&E[159]
	High Viscosity Industrial Lubricant	C&I	10	ExxonMobil
	Pool Heater	C&I	8	DOE[160]
	Solar Pool Cover	C&I	5	CALMAC[161]
Process Equipment	Steam Trap – Other Applications	C&I	6	DEER 2014 EUL ID: HVAC-StmTrp
	Ozone Laundry	C&I	10	PG&E[162]
	Process Exhaust Filtration	C&I	15	CIBSE[163]
Refrigeration	Air-Cooled Refrigeration Condenser	C&I	15	DEER 2014 EUL ID: GrocSys-Cndsr
	Automatic Door Closer for Walk-In Cooler/Freezer	C&I	8	DEER 2014 EUL ID: GrocWlkIn-DrClsr
	Cooler and Freezer Door Gasket	C&I	4	DEER 2014 EUL ID: GrocWlkIn-StripCrtn, GrocWlkIn-WDrGask
	Cooler and Freezer Door Strip	C&I	4	DEER 2014 EUL ID: GrocWlkIn-StripCrtn, GrocWlkIn-WDrGask
	EC Motor – Refrigerated Case or Walk-In Cooler/Freezer Evaporator Fan	C&I	15	DEER 2014 EUL ID: GrocDisp-FEvapFanMtr
	Equipment (Condenser, Compressor, and Sub-cooling)	C&I	15	DEER 2014 EUL ID: GrocSys-MechSubcl
	Evaporator Fan Motor – with Permanent Magnet Synchronous Motor (PMSM)	C&I	15	DEER 2014 EUL ID: GrocDisp-FEvapFanMtr
	Refrigerated Case Door	C&I	12	DEER 2014 EUL ID: GrocDisp-FixtDoors
	Refrigerated Case Night Cover	C&I	5	DEER 2014 EUL ID: GrocDisp-DispCvrs

[158] https://www.federalregister.gov/documents/2019/06/18/2019-12761/energy-conservation-program-energy-conservation-standards-for-distribution-transformers
[159] https://www.kannahconsulting.com/wp-content/uploads/2016/08/2010-10-11_Battery_Charger_Title_20_CASE_Report_v2-2-2.pdf, pg 43
[160] DOE, Chapter 8, Life-Cycle Cost and Payback Period Analyses, Table 8.75 Available from: https://www.regulations.gov/document?D=EERE-2006-STD-0129-0170
[161] http://www.calmac.org/publications/PoolCoverReport_2015_Final_Report_Appendices.pdf
[162] PG&E Work Paper PGECOAPP123, August 22, 2017
[163] Chartered Institution of Building Services Engineers. "Probabilistic Estimation of Service Life." An industrial ventilation system consists of a fan and a set of filters; Fan and Filter EUL are 15 to 20 years depending on type. http://www.cibse.org/knowledge/cibse-technical-symposium-2011/probabilistic-estimation-of-service-life.

Category	Commercial & Industrial Measures	Sector	EUL (years)	Source
Refrigeration - Control	Anti-Condensation Heater Control	C&I	12	DEER 2014 EUL ID: GrocDisp-ASH
	Condenser Pressure and Temperature Control	C&I	15	DEER 2014 EUL ID: GrocSys-Cndsr
	Evaporator Fan Control	C&I	16	DEER 2014 EUL ID: Groc-WlkIn-WEvapFMtrCtrl
	Floating Head Pressure Control	C&I	10	PA Consulting Group [164]

Common References

1. DEER 2014 EUL
   Available from:
   http://www.deeresources.com/files/DEER2013codeUpdate/download/DEER2014-EUL-table-update_2014-02-05.xlsx
2. GDS Associates, Inc., Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures, June 2007
   Available from:
   https://library.cee1.org/system/files/library/8842/CEE_Eval_MeasureLifeStudyLights%2526HVACGDS_1Jun2007.pdf

Record of Revision

Record of Revision Number	Issue Date
EUL's originally listed in July 18, 2011 Order	7/18/2011
Additional EUL's posted on web site	Subsequent to 7/18/2011 Order
7-13-28	7/31/2013
6-14-1	6/19/2014
6-14-2	6/19/2014
6-15-4	6/1/2015
6-16-2	6/30/2016
1-17-8	12/31/2016
6-17-16	6/30/2017
9-17-11	9/30/2017
12-17-17	12/31/2017
3-18-21	3/31/2018
6-18-23	6/30/2018
9-18-21	9/30/2018
12-18-17	12/28/2018
3-19-16	3/29/2019
6-19-14	6/30/2019
9-19-10	9/30/2019

[164] PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study. Final Report." August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf

Record of Revision Number	Issue Date
12-19-17	12/23/2019
3-20-17	3/30/2020
7-20-20	7/31/2020
12-20-12	12/31/2020
3-21-18	3/31/2021
7-21-21	8/30/2021

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