Table of Revisions/Changes

Revision Number	Addition/ Revision	Issue Date	Effective Date	Measure	Description of Change	Location/Page in TRM
12-20-01	R	12/31/2020	1/1/2022	R/MF Insulation – Hot Water and Steam Pipe	Expanded default tables to include 0.5 inch diameter pipe; Updated language regarding other pipe materials from "under evaluation" to "ineligible due to limited savings"	Pg. 68
12-20-02	R	12/31/2020	1/1/2022	R/MF Insulation – Opaque Shell	Added language to Measure Description regarding wall and ceiling insulation; Revised savings estimation methodology, variable terms, definitions and default tables to rely on from application insulation upgrades, weather data, and HVAC efficiency, removing dependency on Appendix E	Pg. 74
12-20-04	R	12/31/2020	1/1/2022	R/MF Pool Pump	Reworded Measure Description for clarity; Revised savings estimation methodology, variable terms, definitions, deemed savings values, and default tables to reflect updated ENERGY STAR savings calculator; Updated Summer Peak Coincident Demand Savings to N/A	Pg. 277
12-20-06	R	12/31/2020	1/1/2022	C/I Insulation – Hot Water and Steam Pipe	Corrected Equipment Type description for Steam, Oil Fired boiler efficiency; Expanded default tables to include 0.5 inch diameter pipe; Updated language regarding other pipe materials from under evaluation to ineligible due to limited savings	Pg. 392
12-20-10	R	12/31/2020	12/31/2020	C/I Notched and Synchronous Belt	Updated algorithm to include HVAC interactive effects; Added algorithm to estimate fuel savings; Modified Ancillary Fossil Fuel/Electric Savings Impacts to reflect included HVAC impacts	Pg. 651
12-20-12	R	12/31/2020	12/31/2020	Appendix P	Updated EUL entries for all measures contained in this Record of Revision; Added Common References section	Pg. 996

Revision Number	Addition/ Revision	Issue Date	Effective Date	Measure	Description of Change	Location/Page in TRM
12-20-13	R	12/31/2020	1/1/2022	R/MF Interior and Exterior Lighting	Updated Measure Description regarding EISA 2007 regulations; Updated Coincidence Factor; Updated baseline wattage default lookup tables; Modified Operating Hours to include location dependency	Pg. 266

Note: Revisions and additions to the measures listed above were undertaken by the Joint Utilities Technical Resource Manual (TRM) Management Committee between August 12, 2020 – December 31, 2020.

BUILDING SHELL

INSULATION - HOT WATER AND STEAM PIPE

Measure Description

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

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

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

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

Summer Peak Coincident Demand Savings

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

Annual Fuel Energy Savings

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

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fuel energy savings
baseline	= Baseline condition or measure
ee	= Energy efficient measure
(UA/L)	= Overall heat transfer coefficient per unit length (BTU/h-°F-ft)
E_t	= Thermal efficiency of hot water source
l	= Length of installed insulation (ft)
ΔT	= Temperature difference between hot water in pipe and surrounding ambient air temperature (°F)
hrs	= Annual operating hours

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

Summary of Variables and Data Sources

Variable	Value	Notes
$(UA/L)_{baseline}$		Lookup from Baseline Efficiencies section below, based on pipe diameter, pipe material and application.
$(UA/L)_{ee}$		Lookup from Compliance Efficiency section below, based on pipe diameter and insulation type and thickness.
$E_{t,elec}$	DHW: 0.98	Recovery efficiency of typical electric storage type water heater.[1]
$E_{t,fuel}$	DHW: 0.75 Gas-Fired HW Boiler: 0.84 AFUE Gas-Fired Steam Boiler: 0.82 AFUE Oil-Fired HW Boiler: 0.86 AFUE Oil-Fired Steam Boiler: 0.85 AFUE	Recovery efficiency of typical gas and oil storage type water heater and baseline efficiency of residential-size space heating boilers. [2,3]
l		From application
ΔT	$T_{pipe} - T_{amb}$	
T_{pipe}	DHW: 125 HW Boiler: 160 Steam Boiler: 212	Average temperature of hot water in distribution system piping (°F). [4]
T_{amb}	DHW: 70 Space Heat: 50	Surrounding average ambient air temperature (°F). [5,6]

[1] Per 10 CFR 430 Subpart B Appendix E – Uniform Test Method for Measuring the Energy Consumption of Water Heaters: *6.3.2 Recovery Efficiency*
[2] Per 10 CFR 430, typical recovery efficiency of a gas water heater, which is used for the purposes of this measure as a proxy for thermal efficiency, is 0.75. See for example, 10 CFR 430 Subpart B Appendix C1, 5.6.1.1.
[3] 10 CFR 430.32(e)(iii)(A)
[4] 10 CFR 430 Appendix E to Subpart B of Part 430 Uniform Test Method for Measuring the Energy Consumption of Water Heaters, Section 2. Test Conditions, 2.5 Set Point Temperature.
[5] Average annual ambient temperature in unconditioned spaces
[6] Average ambient temperature based on typical heating season conditions of unconditioned basements

Variable	Value	Notes
ElecSF	Electric WH: 1.00 Fuel WH: 0 Unknown WH: 0.31 Space Heat: 0	Based on EIA Residential Energy Consumption Survey (RECS) 2015 for Middle Atlantic States.[7] "Unknown" shall only be applied when the collection of information on water heating fuel is not feasible due to program configuration or delivery mechanism.
FuelSF	Electric WH: 0 Fuel WH: 1.00 Unknown WH: 0.56 Space Heat: 1.00	Based on EIA Residential Energy Consumption Survey (RECS) 2015 for Middle Atlantic States.[8] "Unknown" shall only be applied when the collection of information on water heating fuel is not feasible due to program configuration or delivery mechanism.
hrs	DHW: 8,760 Space Heat: $EFLH_{heating}$ (Appendix G)	See Operating Hours section below.
CF	DHW: 1.0 Space Heat: N/A	

Coincidence Factor (CF)

The prescribed value for the coincidence factor for domestic water heating is 1.0.[9]
The prescribed value for the coincidence factor for space heating is N/A.

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a length of uninsulated copper or steel domestic hot water or space heating piping located in an unconditioned space. Prescribed $(UA/L)_{baseline}$ values are provided in the table below based on the diameter of pipe, pipe material, and application. Pipe wall resistance and exterior film resistance were not considered in the derivation of the values below. Values were developed using NAIMA's 3E Plus software program .[10] Insulation of CPVC, PEX and HDPE piping is not eligible for savings under this measure.[11]

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

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

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a length of copper or steel service hot water or space heating hot water/steam distribution piping insulated in accordance with ECCCNYS[12] which require hot water piping with 0.50" nominal diameter and larger to be insulated with a minimum thermal resistance of R-3. The R-value is the thermal resistance of the insulating material, which is derived by dividing the thickness of the material by the material's thermal conductivity, or k-value. Thermal transmittance, or the material's U-factor, is the inverse of the R-value.

The $(UA/L)_{ee}$ values associated with fiberglass, rigid foam and cellular glass insulation of various thicknesses provided in the table below shall be used to establish the compliance condition heat transfer coefficient. Pipe diameter and insulation type and thickness shall be taken from the application. The values below were calculated using a k-value of 0.25 BTU-in/h-°F-ft^2 for fiberglass and 0.35 BTU-in/ h-°F-ft^2 for rigid foam and cellular glass insulation at 100°F. Pipe wall resistance and exterior film resistance were ignored in the derivation of the values below. Values were developed using NAIMA's 3E Plus software program.[13]

Pipe Diam. (in)	$(UA/L)_{ee}$											
	Fiberglass						Rigid Foam/Cellular Glass					
	0.5 in	1 in	1.5 in	2 in	2.5 in	3 in	0.5 in	1 in	1.5 in	2 in	2.5 in	3 in
0.50	0.13	0.09	0.08	0.07	0.06	0.06	0.15	0.12	0.10	0.09	0.09	0.08
0.75	0.14	0.11	0.09	0.08	0.07	0.07	0.17	0.13	0.11	0.10	0.10	0.09
1.00	0.17	0.12	0.10	0.09	0.08	0.07	0.19	0.15	0.13	0.12	0.11	0.10
1.25	0.20	0.14	0.11	0.10	0.09	0.08	0.23	0.17	0.15	0.13	0.12	0.11
1.50	0.22	0.15	0.12	0.11	0.10	0.09	0.25	0.19	0.16	0.14	0.13	0.12
2.00	0.26	0.18	0.14	0.12	0.11	0.10	0.29	0.22	0.18	0.16	0.14	0.13
2.50	0.30	0.20	0.16	0.14	0.12	0.11	0.34	0.25	0.20	0.18	0.16	0.15
3.00	0.35	0.24	0.18	0.16	0.14	0.12	0.39	0.29	0.23	0.20	0.18	0.16
3.50	0.40	0.26	0.20	0.17	0.15	0.13	0.44	0.32	0.26	0.22	0.20	0.18

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

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

Operating Hours

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

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

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

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

Ancillary Electric Savings Impacts

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

References

1. 10 CFR 430 Subpart B – Test Procedures, Appendix E – Uniform Test Method for Measuring the Energy Consumption of Water Heaters
   Available from: https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=9624a8ba0987aaae248454c49194a661&mc=true&n=pt10.3.430&r=PART&ty=HTML#ap10.3.430_127.e
2. 10 CFR 430 Subpart B – Test Procedures, Appendix C1 - Uniform Test Method for Measuring the Energy Consumption of Dishwashers
   Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=9acb5e05dd1d96230c64079cf0c03102&mc=true&node=pt10.3.430&rgn=div5#ap10.3.430_127.c1
3. 10 CFR 430.32 Energy and water conservation standards and their compliance dates.
   Available from: http://www.ecfr.gov/cgi-bin/text-idx?SID=a9921a66f2b4f66a32ec851916b7b9d9&mc=true&node=se10.3.430_132&rgn=div8

4. 10 CFR 430 Appendix E to Subpart B of Part 430 Uniform Test Method for Measuring the Energy Consumption of Water Heaters, Section 2. Test Conditions, 2.5 Set Point Temperature
   Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=80dfa785ea350ebeee184bb0ae03e7f0&mc=true&node=ap10.3.430_127.e&rgn=div9
5. EIA Residential Energy Consumption Survey (RECS) 2015 Survey Data for Middle Atlantic States, February 2015
   Available from:
   https://www.eia.gov/consumption/residential/data/2015/hc/php/hc8.7.php
6. 3E Plus, NAIMA, Insulation Institute, Version 4.1
   Available from: https://insulationinstitute.org/tools-resources/free-3e-plus/
7. ECCCNYS 2020 R403.5.3 Hot water pipe insulation (Prescriptive) Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-[re]-residential-energy-efficiency#NYSECC2020P1_RE_Ch04_SecR402

Record of Revision

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

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BUILDING SHELL

INSULATION - OPAQUE SHELL

Measure Description

This measure covers the installation of wall and ceiling insulation to reduce the thermal conductance of the building envelope. Energy and demand savings are realized through reductions in the building's heating and cooling loads. Existing (baseline) and installed (qualifying) shell R-values must be captured in order to estimate energy savings.. This measure is only applicable as a retrofit in existing single and multi-family buildings, excluding gut rehab/major renovation projects. These projects entail whole-building envelope alterations that trigger more stringent code provisions, limiting potential incremental savings.

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

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

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

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

$$\Delta kWh_{heating} = \frac{\left(\frac{1}{R_{baseline}} - \frac{1}{R_{baseline} + \Delta R}\right) \times A \times \left(1 - F_{framing}\right) \times HDD \times 24 \times F_{ElecHeat}}{3{,}412 \times HSPF}$$

Summer Peak Coincident Demand Savings

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

Annual Fuel Energy Savings

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

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fuel energy savings
$\Delta kWh_{cooling}$	= Annual electric cooling energy savings
$\Delta kWh_{heating}$	= Annual electric heating energy savings
$R_{baseline}$	= R-value of existing insulation (ft^2-F°-h/BTU)

ΔR = Difference in R-value between installed insulation and existing insulation (ft^2-F^o-h/BTU)
A = Area of insulated surfaces (ft^2)
$F_{framing}$ = Framing factor
F_{CEC} = Central electric cooling factor; used to account for the presence or absence of a central electric cooling system
CDD = Cooling Degree Days - The number of degrees that a day's average temperature is above some baseline temperature, which represents the temperature above which buildings need to be cooled. The baseline temperature is typically 65°F, but may vary based on application.
HDD = Heating Degree Days - The number of degrees that a day's average temperature is below some baseline temperature, which represents the temperature below which buildings need to be heated. The baseline temperature is typically 65°F, but may vary based on application.
$F_{ElecHeat}$ = Electric heating factor, used to account for the presence or absence of an electric heating system
$F_{FuelHeat}$ = Fuel heating factor, used to account for the presence or absence of a fuel heating system
SEER = Seasonal average energy efficiency ratio over the cooling season, BTU/watt-hour, used for average U.S. location/region
HSPF = Heating seasonal performance factor, BTU/watt-hour, total heating output (supply heat) in BTU (including supplemental heaters) during the heating season / total electric energy heat pump consumed (in watt-hour)
EER = Energy efficiency ratio under peak conditions (BTU/watt-hour)
$Eff_{FuelHeat}$ = Efficiency of fuel heating equipment (AFUE, Et, or Ec)
CF = Coincidence factor
24 = Hours in one day
1,000 = Conversion factor, one kW equals 1,000 watts
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
$R_{baseline}$		From application. If unknown, lookup in Baseline Efficiency section below, based on building vintage and building envelope component.
ΔR		From application.
A		From application.
$F_{framing}$	Walls: 0.25 Ceilings: 0.07	ASHRAE.[14]
F_{CEC}		If a central electric cooling system is present, set equal to 1. Otherwise, set equal to 0.
CDD		Lookup based on location in Heating and Cooling Degree Days table below.

[14] ASHRAE, 2001, "Characterization of Framing Factors for New Low-Rise Residential Building Envelopes (904-RP)," Table 7.1.

Variable	Value	Notes
HDD		Lookup based on location in Heating and Cooling Degree Days table below.
$F_{ElecHeat}$		Use a value of 1.0 if the building is electrically heated. Otherwise, use 0.0.
$F_{FuelHeat}$		Use a value of 1.0 if the building is fuel heated. Otherwise, use 0.0.
SEER		From application or use 13 SEER, assuming a minimally code compliant, 3-ton, split system AC.[15]
HSPF		From application or use 8.2 HSPF, assuming a 3-ton central ASHP system. 16 For electric resistance heating and electric furnaces, use 3.4 HSPF. If taken from application, COP must be converted to HSPF using the equivalency HSPF = COP x 3.412.
EER		From application. If unknown, baseline EER is established as follows[17]: $EER = (1.12 \times SEER) - (0.02 \times SEER^2)$
$Eff_{FuelHeat}$		From application. If unknown, lookup based on system size and type in Baseline Efficiencies from which Energy Savings are Calculated section below.
CF	0.69	

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.69.[18]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a building envelope with insufficient insulation (i.e., not compliant with all applicable construction code requirements). R-value of existing insulation shall come from application. If unknown, lookup in the Existing Building Envelope R-value table below based on building vintage and building envelope component. Alternatively, R-3.1 per inch of existing insulation may be applied.[19]

[15] ECCCNYS 2020, Table C403.3.2(1))
[16] Ibid.
[17] DOE, Building America House Simulation Protocols, October 2010
[18] 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.
[19] DOE, Energy Saver, Insulation Materials. Assumes "low-density" fiberglass batts for 2 by 4 inch stud-framed wall (R-11/3.5 inch = R-3.1 per inch of insulation).

Existing Building Envelope R-value

Vintage	Wall	Ceiling
Pre-war uninsulated brick[20]	4	2
Prior to 1979[21]	7	11
From 1979 through 2006[22]	11	19
From 2007 through the present[23]	19	38 (Climate Zones 4 & 5) 49 (Climate Zone 6)

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

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

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

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

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 or 0.80 E_t
	≥ 225 kBTU/h	0.80 Et
Warm Air Furnace, Oil Fired	< 225 kBTU/h	0.83 AFUE or 0.80 E_t
	≥ 225 kBTU/h	0.80 Et
Warm Air Unit Heaters, Gas Fired	All Capacities	0.80 Ec
Warm Air Unit Heaters, Oil Fired	All Capacities	0.80 Ec

[20] Wall insulation assumes three 4'' brick layers; no insulation; 2'' air gap resistance only, Ceiling assumes no ceiling insulation, as captured in Appendix A of this TRM for Multi-Family Low-Rise
[21] Wall insulation assumes wood frame with siding; no insulation in 2 by 4 wall; 3.5 inch air gap resistance only, Ceiling assumes Minimal ceiling insulation, as captured in Appendix A of this TRM for Multi-Family Low-Rise
[22] Wall insulation assumes wood frame with siding; Fiberglass insulation in 2 by 4 wall per MEC 1980, Ceiling insulation assumes Fiberglass insulation per MEC 1980, as captured in Appendix A of this TRM for Multi-Family Low-Rise
[23] ECCCNYS 2007 as captured in Appendix A of this TRM for Multi-Family Low-Rise
[24] 10 CFR 430.32(e)
[25] ECCCNYS 2020, Table C403.3.2(4) & Table C403.3.2(5)

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

Compliance Efficiency from which Incentives are Calculated

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

Opaque shell insulation improvements performed under this measure shall be installed such that that all altered envelope components comply with all federal, state, local and municipal codes and standards applicable to alterations to existing buildings, including but not limited to Section R503.1 of ECCCNYS 2020[26] requiring all existing ceiling, wall, and floor cavities exposed during construction to be filled with insulation. Thermal envelope components not altered as part of this measure (e.g. continuous insulation in wood-framed buildings) are not required to meet code for compliance.

Operating Hours

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

Heating and Cooling Degree Days[27]

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

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

City	HDD	CDD
Poughkeepsie	6,210	671
Syracuse	6,651	570

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

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

Ancillary Electric Savings Impacts

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

References

1. BG&E: Development of Residential Load Profile for Central Air Conditioners and Heat Pumps
2. ECCCNYS 2020 Section R402 Building Thermal Envelope
   Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-[ce]-commercial-energy-efficiency#NYSECC2020P1_CE_Ch04_SecC402
3. ECCCNYS 2020 Section R403 Systems
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Record of Revision

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1	10/15/2010
7-13-25	7/31/2013
7-13-38	7/31/2013
9-18-2	9/28/2018
3-19-2	3/29/2019
12-19-2	12/23/2019
12-20-2	12/31/2020

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MOTORS AND DRIVES

POOL PUMP

Measure Description

This measure covers the installation of ENERGY STAR® qualified multi-speed and variable frequency drive (VFD) residential inground pool pumps. Pool pump speeds vary based on the pump's operation. Filtration, for example, only requires half the flow rate of running a pool cleaner. Conventional pool pumps, with only one speed, are set to run at the higher speeds required of the pool cleaner and waste energy during filtration operation by running faster than necessary. An ENERGY STAR® certified pool pump can run at different speeds and be programmed to match the pool operation with its appropriate pool pump speed. The energy saved is considerable; reducing pump speed by one-half allows the pump to use just one-eighth as much energy.[28] After January 1, 2019, all pool pumps must be rated according to Weighted Energy Factor (WEF).[29] Pool pumps that have earned this label use up to 70% less energy than non-qualified models.[30]

This measure is applicable to multi-speed and VFD inground or self-priming pool pumps with a total horsepower rating between 1 and 3 HP. While single-speed pumps, non-self-priming pumps, and pressure cleanser booster pumps are eligible under ENERGY STAR® qualified product criteria, there was a critical lack of information regarding ENERGY STAR® calculations and assumptions pertaining to this equipment available at the time of publication of this measure. The measure scope will be expanded as more information becomes available. This measure is not applicable to community pools in multifamily housing complexes.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

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

Summer Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fuel Energy Savings

$$\Delta MMBtu = N/A$$

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

where:

ΔkWh = Annual electric energy savings

[28] ENERGY STAR® Pool Pumps
[29] ENERGY STAR® Pool Pumps Version 2 and Version 3 Specification Cover Letter, April 2018
[30] ENERGY STAR® Pool Pump Fact Sheet, January 2018

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

Summary of Variables and Data Sources

Variable	Value	Notes
V_{pool}		From application. If unknown, assume 22,000.[31]
$N_{turnover}$		From application. If unknown, use 2 per day.[32]
WEF_{ee}		From application, or look up in Compliance Efficiency section below, based on nameplate hp.
hp		From application
$EF_{baseline}$		Look up in Baseline Efficiencies section below, based on nameplate hp.
days		From application. If unknown, use 122. [33]

Default Values

The table below contains values for annual electric energy savings and Summer Peak Coincident Demand Savings. These values were established by using the assumed values from the Summary of Variables and Data Sources table above. Default values additionally assume a 22,000-gallon pool, a 1.5 hp baseline pump performing 2 turnovers per day lasting 9.4 hours, and a 1.0 hp qualifying pump performing 2 turnover per day lasting 12 hours each. [34]

Pump Type	Rated in WEF	
	ΔkWh	ΔkW
Multi-speed or VFD	1,744	0.216

Coincidence Factor (CF)

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

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a non-ENERGY STAR® qualified single-speed pool pump. The values for baseline EF are found in the table below, based on nameplate horsepower. Pump Performance

[31] Savings Calculator for ENERGY STAR® Certified Inground Pool Pumps (accessed 7/14/2020)
[32] CEE[SM] High Efficiency Residential Swimming Pool Initiative, January 2013, pg 33
[33] Ibid
[34] CEE[SM] High Efficiency Residential Swimming Pool Initiative, January 2013, pg 33

Curve C is assumed for pool pumps. The pump curve compares the total head in feet of water to the flow rate of the water for a given pump at a given motor speed.

Pump Type and Variable	Nameplate Horsepower						
	0.5	0.75	1	1.5	2	2.5	3
$EF_{baseline}$	3.4	3.3	2.5	2.3	2.3	2.2	2.0

Compliance Efficiency from which Incentives are Calculated

The compliance condition is an ENERGY STAR® qualified multi or variable speed self-priming, inground pool pump. Self-priming pool pumps must have a WEF (in kgal/kWh) equal to or greater than the equation below for pumps on curve C.[35]

$$WEF \geq -230 \times ln(hhp) + 6.59$$

where:
hhp = hydraulic horsepower, equal to or greater than 0.711

Multi-Speed and Variable Frequency Drive Pool Pumps[36]
Typical WEF for ENERGY STAR® multi-speed and variable frequency drive pool pumps are found in the table below, based on nameplate horsepower. Pump Performance Curve C is assumed for ENERGY STAR pumps. The pump curve compares the total head in feet of water to the flow rate of the water for a given pump at a given motor speed.

Pump Type and Variable	Nameplate Horsepower at High Speed				
	1-1.4 HP (0.72 hhp)	1.65 HP (0.95 hhp)	2 HP (1.18 hhp)	2.5 HP (1.25 hhp)	3 HP (1.65 hhp)
WEF_{ee}	8.7	8.9	9.3	7.4	7.1

Operating Hours

Based on New York's average climate, it is assumed that a pool is in use for 4 months per year.[37] While in use, the energy efficient pump cycles through pool water at a default rate of 12 hours per turnover.

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.

[35] ENERGY STAR® Program Requirements Product Specification for Pool Pumps, Eligibility Criteria Version 2.0, January 2019
[36] Ibid
[37] 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

Ancillary Electric Savings Impacts

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

References

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6-18-20	6/30/2018
9-18-6	9/28/2018
12-20-4	12/31/2020

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BUILDING SHELL

INSULATION - HOT WATER AND STEAM PIPE

Measure Description

This measure covers the installation of fiberglass or rigid foam/cellular glass pipe insulation in space heating hot water/steam and domestic hot water (DHW) distribution systems on piping with a nominal diameter between 0.50″ and 8.00″. Estimation of energy savings depend on the type and size of the pipe, type and thickness of the insulation, supply temperature of the heating medium and ambient temperature.

This measure is applicable in retrofit applications and must be installed by a qualified contractor complying with all relevant construction and safety codes and standards. All insulation materials installed under this measure are to be tested in accordance with all pertinent federal testing standards (ASTM) and must be rated for the temperature range of the heating medium conveyed by the affected system. Service hot water pipe insulation for non-recirculating systems is limited to insulation of hot water distribution pipe in unconditioned spaces only. Space heating pipe insulation is limited to insulation installed in unheated spaces only.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

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

Summer Peak Coincident Demand Savings

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

Annual Fuel Energy Savings

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

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fuel energy savings
baseline	= Baseline condition or measure
ee	= Energy efficient measure
(UA/L)	= Overall heat transfer coefficient per unit length (BTU/h-°F-ft)
E_t	= Thermal efficiency of hot water or steam system
l	= Length of installed insulation (ft) in unconditioned spaces
ΔT_{amb}	= Temperature difference between hot water or steam in pipe and surrounding ambient air temperature (°F)

hrs = Annual operating hours
ElecSF = Electric Savings Factor for water heaters: Adjustment to electric water heating energy savings based on water heating fuel
FuelSF = Fuel Savings Factor for water heaters: Adjustment to fuel water heating energy savings based on water heating fuel
CF = Coincidence factor
3,412 = Conversion factor, one kWh equals 3,412 BTU
1,000,000 = Conversion factor, one MMBtu equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
$(UA/L)_{baseline}$		Lookup from Baseline Efficiencies section below, based on pipe diameter.
$(UA/L)_{ee}$		Lookup from Compliance Efficiency section below, based on pipe diameter and insulation type and thickness.
$E_{t,elec}$	DHW: 0.98	From application. If unknown, use default thermal efficiency of typical electric storage type water heater provided.[38]
$E_{t,fuel}$	DHW: 0.80 HW and Steam Boilers: See Boiler Efficiencies section below	From application. If unknown, use default efficiency of typical gas storage type water heater and boiler efficiencies provided. 39
l		From application.
ΔT_{amb}	$T_{pipe} - T_{amb}$	
T_{pipe}	DHW: 125 HW Boiler: 160 Steam Boiler: 212	Average temperature of hot water in distribution system piping (°F). 40
T_{amb}	DHW: 70 Space Heat: 50	Surrounding average ambient air temperature (°F). 41,[42]
ElecSF	Electric WH: 1.0 Fuel WH: 0 Unknown WH: 0.45 Space Heat: 0	Based on EIA Commercial Buildings Energy Consumption Survey (CBECS) 2012 for Middle Atlantic States.[43]

[38] Per 10 CFR 431 Subpart G, Appendix B 5.7.1
[39] Per 10 CFR 431.110 (a)
[40] 10 CFR Appendix E to Subpart B of Part 430—Uniform Test Method for Measuring the Energy Consumption of Water Heaters, Section 2. Test Conditions, 2.5 Set Point Temperature.
[41] Average annual ambient temperature in unconditioned spaces
[42] Average ambient temperature based on typical heating season conditions of unconditioned basements
[43] EIA Commercial Building Energy Consumption Survey (CBECS) 2012 for Middle Atlantic States, Table B4, Water-heating energy sources ("Unknown" calculated as the number of buildings with electric water heating divided by the total number of buildings with electric or gas water heating)

Variable	Value	Notes
FuelSF	Electric WH: 0 Fuel WH: 1.0 Unknown WH: 0.55 Space Heat: 1.0	Based on EIA Commercial Buildings Energy Consumption Survey (CBECS) 2012 for Middle Atlantic States.[44]
hrs	DHW: 8,760 Space Heat: $EFLH_{heating}$ (Appendix G)	See Operating Hours section below.
CF	Electric DHW: 1.0 Hot Water: N/A	

Boiler Efficiency

Efficiency for commercial boilers is defined by the Code of Federal Regulations (CFR) and subsequently adopted by the Energy Conservation Construction Code of New York State[45] as shown below.

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

Coincidence Factor (CF)

The prescribed value for the coincidence factor for domestic water heating is 1.0.[46]
The prescribed value for the coincidence factor for hot water heating is N/A.

[44] EIA Commercial Building Energy Consumption Survey (CBECS) 2012 for Middle Atlantic States, Table B4, Water-heating energy sources ("Unknown" calculated as the number of buildings with gas water heating divided by the total number of buildings with electric or gas water heating)
[45] ECCCNYS 2020, Table C403.3.2(5)
[46] *No source specified – update pending availability and review of applicable references.*

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is bare copper or steel domestic hot water or space heating piping. Prescribed $(UA/L)_{baseline}$ values are provided in the table below based on the diameter of pipe, pipe material, and application. CPVC, PEX and HDPE piping were not considered.[47] Pipe wall resistance and exterior film resistance were not considered in the derivation of the values below. Calculations were developed with NAIMA's 3E Plus software program.[48]

Pipe Diam. (in)	$(UA/L)_{baseline}$				
	Bare Copper Piping			Bare Steel Piping	
	Domestic Hot Water	Hot Water Heat	Steam Heat	Hot Water Heat	Steam Heat
0.50	0.44	0.48	0.53	0.53	0.59
0.75	0.54	0.58	0.64	0.65	0.72
1.00	0.65	0.70	0.78	0.79	0.88
1.25	0.80	0.86	0.96	0.97	1.09
1.50	0.90	0.97	1.09	1.10	1.23
2.00	1.10	1.19	1.33	1.34	1.51
2.50	1.31	1.42	1.58	1.60	1.80
3.00	1.57	1.70	1.90	1.92	2.16
3.50	1.77	1.92	2.15	2.18	2.45
4.00	1.98	2.14	2.40	2.43	2.73
5.00	2.41	2.61	2.92	2.97	3.34
6.00	2.84	3.07	3.45	3.50	3.94
8.00	3.64	3.94	4.42	4.50	5.06

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a length of service hot water or space heating hot water/steam distribution piping insulated in accordance with ECCCNYS[49]. Minimum required insulation thicknesses per material conductivity are outlined in the table below based on fluid operating temperature and pipe diameter ranges.

Fluid Operating Temperature Range and Usage (°F)	Conductivity BTU-in/h-ft^2-F	Mean Rating Temperature	Nominal Pipe or Tube Size (in)				
			< 1	≥ 1 and < 1.5	≥ 1.5 and < 4	≥ 4 and < 8	8
201-250	0.27-0.30	150	2.5	2.5	2.5	3.0	3.0
141-200	0.25-0.29	125	1.5	1.5	2.0	2.0	2.0
105-140	0.21-0.28	100	1.0	1.0	1.5	1.5	1.5
40-60	0.21-0.27	75	0.5	0.5	1.0	1.0	1.0
< 40	0.20-0.26	50	0.5	1.0	1.0	1.0	1.5

[47] These piping materials were found to have limited savings potential through preliminarily modeling in 3E Plus® Version 4.1

[48] Insulation Institute, 3E Plus® Version 4.1

[49] ECCCNYS 2020, Table C403.11.3 Minimum Pipe Insulation Thickness

For piping smaller than 1.5 inches and located in partitions within conditioned spaces, reduction of these thicknesses by 1 inch shall be permitted, before thickness adjustment if necessary, but not to a thickness less than 1 inch. For insulation outside the stated conductivity range, use the following equation to adjust the minimum required thickness from the table above:

$$T = r \times [(1 + t/r) \times K/k \ - 1]$$

where:

T = minimum insulation thickness
r = actual outside radius of pipe
t = insulation thickness listed in the table for applicable fluid temperature
K = conductivity of alternate material at mean rating temperature indicated for the applicable fluid temperature
k = the upper value of the conductivity range listed in the table for the applicable fluid temperature

The R-value is the thermal resistance of the insulating material, which is derived by dividing the thickness of the material by the material's thermal conductivity, or k-value. Thermal transmittance, or the material's U-factor, is the inverse of the R-value.

The $(UA/L)_{ee}$ values associated with fiberglass and rigid foam/cellular glass insulation of various thicknesses provided in the table below shall be used to establish the compliance condition heat transfer coefficient. Pipe diameter and insulation type and thickness shall be taken from the application. The values below were calculated assuming a k-value of 0.25 BTU-in/hr-°F-ft^2 for fiberglass and 0.35 BTU-in/ hr-°F-ft^2 for rigid foam/cellular glass insulation at 100°F. Pipe wall resistance and exterior film resistance were not considered in the derivation of the values below. Calculations were developed with NAIMA's 3E Plus software program.[50]

Pipe Diam. (in)	$(UA/L)_{ee}$											
	Fiberglass						Rigid Foam/Cellular Glass					
	0.5 in	1 in	1.5 in	2 in	2.5 in	3 in	0.5 in	1 in	1.5 in	2 in	2.5 in	3 in
0.50	0.13	0.09	0.08	0.07	0.06	0.06	0.15	0.12	0.10	0.09	0.09	0.08
0.75	0.14	0.11	0.09	0.08	0.07	0.07	0.17	0.13	0.11	0.10	0.10	0.09
1.00	0.17	0.12	0.10	0.09	0.08	0.07	0.19	0.15	0.13	0.12	0.11	0.10
1.25	0.20	0.14	0.11	0.10	0.09	0.08	0.23	0.17	0.15	0.13	0.12	0.11
1.50	0.22	0.15	0.12	0.11	0.10	0.09	0.25	0.19	0.16	0.14	0.13	0.12
2.00	0.26	0.18	0.14	0.12	0.11	0.10	0.29	0.22	0.18	0.16	0.14	0.13
2.50	0.30	0.20	0.16	0.14	0.12	0.11	0.34	0.25	0.20	0.18	0.16	0.15
3.00	0.35	0.24	0.18	0.16	0.14	0.12	0.39	0.29	0.23	0.20	0.18	0.16
3.50	0.40	0.26	0.20	0.17	0.15	0.13	0.44	0.32	0.26	0.22	0.20	0.18
4.00	0.44	0.29	0.22	0.18	0.16	0.14	0.48	0.35	0.28	0.24	0.21	0.19
5.00	0.52	0.34	0.26	0.22	0.19	0.17	0.58	0.41	0.33	0.28	0.25	0.22
6.00	0.61	0.39	0.30	0.25	0.21	0.19	0.67	0.47	0.37	0.32	0.28	0.25
8.00	0.77	0.49	0.37	0.30	0.26	0.23	0.84	0.59	0.46	0.39	0.34	0.30

Service hot water pipe insulation for non-recirculating systems is limited to insulation of hot water distribution pipe in unconditioned spaces. Space heating pipe insulation is limited to insulation installed in unheated spaces only.

[50] Insulation Institute, 3E Plus® Version 4.1

Operating Hours

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

Operating hours for water and steam boiler space heating systems are prescribed by equivalent full-load hours. Equipment heating EFLH shall be taken from the application. If unknown, default EFLH by facility type, system type and location can be found in Appendix G.

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

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

Ancillary Electric Savings Impacts

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

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Record of Revision

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12-18-9	12/28/2018
12-20-6	12/31/2020

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MOTORS AND DRIVES

NOTCHED AND SYNCHRONOUS BELT

Measure Description

This measure covers the replacement of smooth V-belts in electric HVAC fan or pump motors with notched or synchronous belts. V-belts between the motor and the supply air fan and/or return air fan are typical in larger packaged and split HVAC systems. A notched belt has grooves or notches that run perpendicular to the belt's length, which reduces the bending resistance of the belt. Notched belts can use the same pulleys as cross-section standard V-belts. They run cooler, last longer, and are about 2% more efficient than standard V-belts. Synchronous belts (also called cogged, timing, positive-drive, or high-torque drive belts) are toothed and require the installation of mating grooved sprockets. These belts operate with a consistent efficiency of 98% and maintain their efficiency over a wide load range.

Estimated savings are based upon the improved transfer of the motor shaft energy to the fan by replacing a smooth V-belt with a notched belt or synchronous belt in a belt drive system. The savings assume that the fan speed remains the same while the motor operates at a lower torque and speed. For notched belts, adjustable pulleys provide easy reductions in fan speed.[51] For synchronous belts, belt sockets must be selected that correct for the improved transmission of motor energy or the actual operating costs can increase.[52]

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times \frac{hp \times 0.746}{Eff_{motor}} \times RLF \times \left(\frac{1}{Eff_{baseline}} - \frac{1}{Eff_{ee}}\right) \times FLH \times (1 + HVAC_c)$$

Summer Peak Coincident Demand Savings

$$\Delta kW = units \times \frac{hp \times 0.746}{Eff_{motor}} \times RLF \times \left(\frac{1}{Eff_{baseline}} - \frac{1}{Eff_{ee}}\right) \times (1 + HVAC_d) \times CF$$

Annual Fuel Energy Savings

$$\Delta MMBtu = units \times \frac{hp \times 0.746}{Eff_{motor}} \times RLF \times \left(\frac{1}{Eff_{baseline}} - \frac{1}{Eff_{ee}}\right) \times FLH \times HVAC_{ff}$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fuel energy savings
units	= Number of motors converted to notched or synchronous belts
hp	= Horsepower per retrofitted motor

[51] Changing Fan Speed with an Adjustable Pulley, Rob "Doc" Falke, Contracting Business Magazine, April 18,2012
[52] Replace V-Belts with Cogged or Synchronous Belt Drives, The News, November 3, 2008.

RLF = Rated load factor
$Eff_{baseline}$ = Efficiency of V-belts
Eff_{ee} = Efficiency of notched or synchronous belts
Eff_{motor} = Efficiency of retrofitted motor (existing motor is assumed to remain in place)
FLH = Full-load hours
$HVAC_c$ = HVAC interaction factor for annual electric energy consumption
$HVAC_d$ = HVAC interaction factor at utility summer peak hour
$HVAC_{ff}$ = HVAC interaction factor for annual fossil fuel consumption
CF = Coincidence factor
0.746 = Conversion factor (kW/hp), 746 watts equals one horsepower

Summary of Variables and Data Sources

Variable	Value	Notes
hp		Rated horsepower of the retrofitted motor, from application.
Eff_{motor}		Full-load efficiency of the baseline motor, from application. Or look up from Appendix L based on efficient motor type (open or enclosed), number of poles (2, 4 or 6) and horsepower. If unknown assume 0.93.[53]
RLF		Percent of rated motor load at normal operation. (RLF = hp_{peak}/hp_{max}), from application. If unknown, assume 0.75.[54]
FLH		Full-load hours in the energy efficient case, from application. If unknown, look up based on facility type and motor application in the Operating Hours section below.
$Eff_{baseline}$	0.93	US DOE[55]
Eff_{ee}	Notched: 0.95 Synchronous: 0.98	Use default value based upon efficient belt type from application for notched[56] and synchronous[57] belt drives.
$HVAC_c$		HVAC interaction factor for annual electric energy consumption (dimensionless). For motors in unconditioned spaces, set to 0. Otherwise, this value shall come from Appendix D in based on vintage and HVAC type weighted average by city.
$HVAC_d$		HVAC interaction factor for peak demand at utility summer peak hour (dimensionless). For motors in unconditioned spaces, set to 0. Otherwise, this value shall come from Appendix D in based on vintage and HVAC type weighted average by city.
$HVAC_{ff}$		HVAC interaction factor for annual fuel energy consumption (MMBtu/kWh). For motors in unconditioned spaces, set to 0. Otherwise, this value shall come from Appendix D in based on vintage and HVAC type weighted average by city.

[53] Premium-Efficiency Motors, Energy Innovators Initiative Technical Fact Sheet, Office of Energy Efficiency of Natural Resources Canada. Average efficiency of 75% load premium motors 5-50 hp.
[54] U.S. DOE, Determining Electric Motor Load and Efficiency, p. 1; assumes system is designed to maximize efficiency.
[55] U.S. DOE, Motor Tip Sheet #3, Replace V-Belts with Cogged or Synchronous Belt Drives, Motor Tip Sheet #3, DOE/GO-102000-0972, January 2000. Nominal efficiency of unmaintained belt.
[56] Ibid. 2% better than standard V-belt
[57] Ibid.

Variable	Value	Notes
CF	0.8	

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.8.[58]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is an electric HVAC fan or pump motor driven by a smooth V-belt system.

Compliance Efficiency from which Incentives are Calculated

The energy efficient condition is an electric HVAC fan or pump motor driven by a notched or synchronous belt system.

Operating Hours

Motor full-load hours are defined as the total annual energy consumption divided by the peak hourly demand.

$FLH = kWh/kW_{max}$

For loads that do not vary with time (i.e., a motor driving a constant load), full-load hours are equal to the operating hours.

If full-load hours are unknown, use default values based on the application and building type from the table below.[59]

Annual Operating Hours

Facility Type	Distribution Fan Motor (hours)	Cooling Tower Fans (hours)
Auto Related	4,056	1,878
Bakery	2,854	1,445
Banks, Financial Centers	3,748	1,767
Church	1,955	1,121
College - Cafeteria	6,376	2,713
College - Classes/Administrative	2,586	1,348
College - Dormitory	3,066	1,521
Commercial Condos	4,055	1,877
Convenience Stores	6,376	2,713
Convention Center	1,954	1,121
Court House	3,748	1,767
Dining: Bar Lounge/Leisure	4,182	1,923

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

[59] Connecticut Program Savings Document, 12th Edition for 2017 Program Year, UIL Holdings Corporation and Eversource Energy, October 2016. Appendix 5, Hours of Use

Facility Type	Distribution Fan Motor (hours)	Cooling Tower Fans (hours)
Dining: Cafeteria / Fast Food	6,456	2,742
Dining: Family	4,182	1,923
Entertainment	1,952	1,120
Exercise Center	5,836	2,518
Fast Food Restaurants	6,376	2,713
Fire Station (Unmanned)	1,953	1,121
Food Stores	4,055	1,877
Gymnasium	2,586	1,348
Hospitals	7,674	3,180
Hospitals / Health Care	7,666	3,177
Industrial - 1 Shift	2,857	1,446
Industrial - 2 Shift	4,730	2,120
Industrial - 3 Shift	6,631	2,805
Laundromats	4,056	1,878
Library	3,748	1,767
Light Manufacturers	2,857	1,446
Lodging (Hotels/Motels)	3,064	1,521
Mall Concourse	4,833	2,157
Manufacturing Facility	2,857	1,446
Medical Offices	3,748	1,767
Motion Picture Theatre	1,954	1,121
Multi-Family (Common Areas)	7,665	3,177
Museum	3,748	1,767
Nursing Homes	5,840	2,520
Office (General Office Types)	3,748	1,767
Office/Retail	3,748	1,767
Parking Garages & Lots	4,368	1,990
Penitentiary	5,477	2,389
Performing Arts Theatre	2,586	1,348
Police / Fire Stations (24 Hr)	7,665	3,177
Post Office	3,748	1,767
Pump Stations	1,949	1,119
Refrigerated Warehouse	2,602	1,354
Religious Building	1,955	1,121
Residential (Except Nursing Homes)	3,066	1,521
Restaurants	4,182	1,923
Retail	4,057	1,878
School / University	2,187	1,205
Small Services	3,750	1,768
Sports Arena	1,954	1,121
Town Hall	3,748	1,767
Transportation	6,456	2,742

Facility Type	Distribution Fan Motor (hours)	Cooling Tower Fans (hours)
Warehouse (Not Refrigerated)	2,602	1,354
Waste Water Treatment Plant	6,631	2,805
Workshop	3,750	1,768

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

High efficiency belt drive systems reject less heat into the conditioned space increasing space heating requirements. The HVAC interaction factors calculated from the prototypical building DOE-2 models as a function of the building and HVAC system type are shown in Appendix D.

Ancillary Electric Savings Impacts

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

References

1. Changing Fan Speed with an Adjustable Pulley, Rob "Doc" Falke, Contracting Business Magazine, April 18,2012
   Available from: https://www.contractingbusiness.com/archive/changing-fan-speed-adjustable-pulley
2. Replace V-Belts with Cogged or Synchronous Belt Drives, The News, November 3, 2008
   Available from: https://www.achrnews.com/articles/107928-replace-v-belts-with-cogged-or-synchronous-belt-drives
3. Office of Energy Efficiency of Natural Resources Canada, Energy Innovators Initiative Technical Fact Sheet, Premium-Efficiency Motors
   Available from: https://www.prismengineering.com/sites/default/files/upload/fact-sheets/Prism-Fact-sheet-Premium-efficiency-motors.pdf
4. U.S. DOE, Determining Electric Motor Load and Efficiency
   Available from: https://energy.gov/sites/prod/files/2014/04/f15/10097517.pdf
5. U.S. DOE, Motor Tip Sheet #3, Replace V-Belts with Cogged or Synchronous Belt Drives
   Available from: https://www.nrel.gov/docs/fy00osti/27833.pdf
6. Connecticut Program Savings Document, 12th Edition for 2017 Program Year, UIL Holdings Corporation and Eversource Energy, October 2016. Appendix 5, Hours of Use.
   Available from: https://www.puc.nh.gov/EESE%20Board/EERS_WG/ct_trm.pdf

Record of Revisions

Record of Revision Number	Issue Date
7-20-17	7/31/2020
12-20-10	12/31/2020

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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[60]
	Clothes Dryer	Residential	14	ENERGY STAR® M&I Scoping Report[61]
	Clothes Washer	Residential	11	DEER 2014 EUL ID: Appl-EffCW
	Dehumidifier	Residential	12	ENERGY STAR® Calc[62]
	Dishwasher	Residential	11	DEER 2014 EUL ID: Appl-EffDW
	Fireplace	Residential	15	DOE[63]
	Refrigerator and Freezer	Residential	14	DEER 2014 EUL ID: Appl-ESRefg
	Soundbar	Residential	7	RPP Product Analysis[64]
Appliance Control	Advanced Power Strip (APS)	Residential	8	DEER 2014 EUL ID: Plug-OccSens
Appliance Recycling	Air Conditioner - Room (RAC) Recycling	Residential	3	DEER 2014 EUL ID: HV-RAC-RUL
	Refrigerator Recycling	Residential	5	DEER 2014 EUL ID: Appl-RecRef
	Freezer Recycling	Residential	4	DEER 2014 EUL ID: Appl-RecFrzr

[60] 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

[61] ENERGY STAR® Market & Industry Scoping Report: Residential Clothes Dryer, November 2011.

[62] ENERGY STAR® Dehumidifier Calculator https://www.energystar.gov/ia/partners/promotions/cool_change/downloads/CalculatorConsumerDehumidifier.xls

[63] 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

[64] 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
Building Shell	Air Conditioner – Room (RAC) Cover and Gap Sealer	Residential	5	See note below[65]
	Air Leakage Sealing	Residential	15	GDS[66]
	Insulation – Hot Water and Steam Pipe	Residential	15	GDS[67]
	Insulation – Opaque Shell	Residential	25	GDS[68]
	Storm Window	Residential	20	DOE[69]
	Window	Residential	20	DEER 2014 EUL ID: BS-Win
Domestic Hot Water	Heat Pump Water Heater (HPWH)	Residential	10	DEER 2014 EUL ID: WtrHt-HtPmp
	Indirect Water Heater	Residential	11	DEER 2014 EUL ID: WtrHt-Res-Gas
	Storage Water Heater - Gas	Residential	15	PA Consulting Group[70]
	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[71]
Domestic Hot Water - Control	Drain Water Heat Recovery	Residential	30	2019 Title 24[72]
	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[73]

[65] At least one manufacturer's warranty period. www.gss-ee.com/products.html
[66] GDS Associates, Inc., Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures, June 2007, Table 1 – Residential Measures
[67] Ibid.
[68] Ibid.
[69] https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-22864rev2.pdf
[70] 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
[71] https://www.energy.gov/energysaver/solar-swimming-pool-heaters
[72] 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
[73] UPC certification under the International Association of Plumbing and Mechanical Officials standard IGC 244-2007a. A standard that includes a lifecycle test consisting of 10,000 cycles without fail. 10,000 cycles is the equivalent of three users showering daily for more than nine years.

Category	Single and Multi-family Residential Measures	Sector	EUL (years)	Source
Heating, Ventilation and Air Conditioning (HVAC)	Air Conditioner – Central (CAC)	Residential	15	DEER 2014 EUL ID: HV-ResAC
	Air Conditioner – Room (RAC)	Residential	12	GDS[74]
	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[75]
	Boiler and Furnace - Combination ("Combi") Furnace	Residential	20	DEER 2014[76] 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
	Energy and Heat Recovery Ventilator	Residential	14	PA Consulting Group[77]

[74] GDS Associates, Inc., Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures, June 2007, Table 1 – Residential Measures

[75] 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

[76] Based on DEER value for high efficiency boiler and instantaneous water heater

[77] 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

Category	Single and Multi-family Residential Measures	Sector	EUL (years)	Source
Heating, Ventilation and Air Conditioning (HVAC)	Furnace, Gas Fired	Residential	22	DOE[78],79
	Heat Pump - Air Source (ASHP)	Residential	15	DEER 2014 EUL ID: HV-Res HP
	Heat Pump – Ground Source (GSHP)	Residential	25	ASHRAE[80]
	Heat Pump – PTHP	Residential	15	DEER 2014 EUL ID: HVAC-PTHP
	Refrigerant Charge Correction & Tune-Up – Air Conditioner and Heat Pump	Residential	10	DEER 2014 EUL ID: HV-RefChrg
	Tune-Up - Boiler	Residential	5	DEER 2014 EUL ID: BlrTuneup
	Tune-Up - Furnace	Residential	5	DEER 2014 EUL ID: BlrTuneup
	Unit Heater, Gas Fired	Residential	13	ASHRAE Handbook, 2015
HVAC - Control	Adaptive Photonic Control	Residential	EUL = Retrofitted motor RUL = Retrofitted motor EUL – (Current Year – Mfr. Year) **Default = 5**	DEER 2014 EUL ID: Motors-fan
	Outdoor Temperature Setback Control for Hydronic Boiler	Residential	EUL = Boiler RUL = Boiler EUL – (Current Year – Mfr. Year) **Default = 5**	N/A
	Steam Trap – Low Pressure Space Heating	Residential	6	DEER 2014 EUL ID: HVAC-StmTrp
	Submetering	Multifamily	10	NYSERDA[81]
	Thermostat – All Types	Residential	11	DEER 2014 EUL ID: HVAC-ProgTStats

[78] 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

[79] 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

[80] ASHRAE: Owning and Operating Cost Database, Equipment Life/Maintenance Cost Survey: https://xp20.ashrae.org/publicdatabase/system_service_life.asp?selected_system_type=1

[81] NYSERDA Residential Electric Submetering Manual

Category	Single and Multi-family Residential Measures	Sector	EUL (years)	Source
HVAC - Control	Thermostatic Radiator Valve – One Pipe Steam Radiator	Multifamily	15	DOE[82]
	Smart Thermostatic Radiator Enclosure	Residential	15	DEER 2014 EUL ID: Motors-fan[83]
Lighting	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[84]
			50,000 hours	DLC[85]

[82] U.S. DOE, "Thermostatic Radiator Valve Evaluation", January 2015, Table 4. pg. 16
[83] Based on assumed EUL of integrated fan, which is expected to be the first component to fail
[84] 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
[85] 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	LED (Interior)	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	ENERGY STAR® Fixtures[86]
		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
		LED (Inseparable)	Residential	Rated Life listed by ENERGY STAR or default to 50,000 hrs/ annual lighting operating hrs or 15 yrs if rated lifetime or annual operating hours are not known	ENERGY STAR® Fixtures
Lighting Control	Bi-Level Lighting		Multifamily Common Area	15	ComEd[87]

[86] 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

[87] 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

Category	Single and Multi-family Residential Measures	Sector	EUL (years)	Source
Motors and Drives	Pool Pump	Residential	10	DEER 2014 EUL ID: OutD-PoolPump
	Pool Circulator Timer	Residential	10	DEER 2014 EUL ID: OutD-PoolPump
Other	Pool Heater	Residential	8	DOE[88]

[88] 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

COMMERCIAL AND INDUSTRIAL MEASURES

Category	Commercial & Industrial Measures	Sector	EUL (years)	Source
Agricultural Equipment	High Speed Fans	C&I	10	PG&E[89]
	Milk Pre-Cooler Heat Exchanger	C&I	15	PA Consulting Group[90]
	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[91]
	Variable Speed Drive Milk Pump Plate Cooler	C&I	15	PA Consulting Group[92]
	Variable Speed Drive Vacuum Pump	C&I	15	PA Consulting Group[93]
Appliance	Clothes Dryer	C&I	14	ENERGY STAR®M&I Report[94]
	Cooking Equipment[95]	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[96]
	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
Appliance Recycling	Air Conditioner – Room (RAC)	C&I	9	DEER 2014 EUL ID: HV-RAC-ES

[89] PG&E Work Paper PGE3PAGR117, October 12, 2017
[90] 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
[91] Based on EUL's for Advanced Power Strips
[92] 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
[93] 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
[94] ENERGY STAR® Market & Industry Scoping Report: Residential Clothes Dryer, November 2011.
[95] Applicable to all kitchen cooking equipment not otherwise listed
[96] 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
Building Shell	Cool Roof	C&I	15	DEER 2014 EUL ID: BldgEnv-CoolRoof
	Insulation - Hot Water and Steam Pipe	C&I	15	GDS[97]
	Insulation - Opaque Shell	C&I	30	ET & CEC[98]
	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[99]
	Engineered Air Nozzle	C&I	15	Wisconsin PSC[100]
	No Air Loss Water Drain	C&I	13	MA Measure Life Study[101]
	Refrigerated Air Dryer	C&I	13	Other State TRMs [102]
	Compressed Air Heat Recovery	C&I	13	Other State TRMs [103]
	Flow Controller	C&I	13	Other State TRMs [104]
	Low Pressure Drop Filter	C&I	5	Other State TRMs [105]
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
DHW - Control	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

[97] GDS Associates, Inc., Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures, June 2007, Table 1 – Residential Measures
[98] Energy Trust uses 30 years for commercial applications. CEC uses 30 years for insulation in Title 24 analysis.
[99] 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.
[100] PA Consulting Group (2009). *Business Programs: Measure Life Study*. Prepared for State of Wisconsin Public Service Commission
[101] 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
[102] 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.
[103] Ibid.
[104] Ibid.
[105] Ibid.

Category	Commercial & Industrial Measures	Sector	EUL (years)	Source
DHW - Control	Low-Flow – Showerhead	C&I	10	DEER 2014 EUL ID: WtrHt-WH-Shrhd
	Central DHW Control	C&I	15	NREL[106]
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[107]
	Boiler and Furnace - Combination ("Combi") Furnace	C&I	20	DEER 2014[108] 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[109]
	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
	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

[106] https://www.nrel.gov/docs/fy16osti/64541.pdf
[107] 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
[108] Based on DEER value for high efficiency boiler and instantaneous water heater
[109] Ecotope Natural Gas Efficiency and Conservation Measure Resource Assessment (2003)

Category	Commercial & Industrial Measures	Sector	EUL (years)	Source
Heating, Ventilation and Air Conditioning (HVAC)	Furnace, Gas Fired	C&I	23	DOE[110],111
	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[112]
	High Volume Low Speed Fan	C&I	15	PA Consulting Group[113]
	Infrared Heater	C&I	17	GDS[114]
	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[115]
	Tune-Up – Furnace	C&I	5	DEER 2014 EUL ID: BlrTuneup
	Variable Refrigerant Flow (VRF) System	C&I	15	DEER 2014 EUL ID: HVAC-VSD-pump
	Unit Heater, Gas Fired	C&I	13	ASHRAE Handbook, 2015
HVAC – Control	Adaptive Photonic Control	C&I	EUL = Retrofitted motor RUL = Retrofitted motor EUL – (Current Year – Mfr. Year) **Default = 5**	DEER 2014 EUL ID: Motors-fan
	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

[110] 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

[111] 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

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

[113] 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

[114] 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

[115] 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	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[116]
	Kitchen Demand Ventilation Control	C&I	15	PG&E[117]
	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[118]
	Advanced Rooftop Control	C&I	EUL = RUL of Existing RTU = RTU EUL – (Current Year – Year of Mfr.) **Default = 5**	N/A

[116] 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
[117] PG&E Work Paper WPSDGENRCC0019, June 15, 2012
[118] 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[119]
		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®120
		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®121
		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®122
		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

[119] 50,000 hours per L_{70} requirements prescribed by the DLC's Product Qualification Criteria, Technical Requirement Table version 4.4

[120] 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

[121] 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

[122] 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[123]
			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[124]
Lighting - Control	Bi-Level Lighting	C&I	15	ComEd[125]
	Integrated Interior Lighting Control	C&I	15	ComEd[126]
	Non-Integrated Interior Lighting Control	C&I	10	GDS[127]
	Plug-Load Occupancy Sensor	C&I	8	DEER[128]
Motors and Drives	Motor	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[129]

[123] 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

[124] 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

[125] 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

[126] 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

[127] 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

[128] DEER value for lighting occupancy sensors

[129] Assumes same EUL as VFD measure.

Category	Commercial & Industrial Measures	Sector	EUL (years)	Source
Other	Pool Heater	C&I	8	DOE[130]
Process Equipment	Steam Trap – Other Applications	C&I	6	DEER 2014 EUL ID: HVAC-StmTrp
	Ozone Laundry	C&I	10	PG&E[131]
	Process Exhaust Filtration	C&I	15	CIBSE[132]
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
	Electronically Commutated (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
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 [133]

[130] 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

[131] PG&E Work Paper PGECOAPP123, August 22, 2017

[132] 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.

[133] 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

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, Table 1 – Residential Measures 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
12-19-17	12/23/2019
3-20-17	3/30/2020
7-20-20	7/31/2020
12-20-12	12/31/2020

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LIGHTING

INTERIOR AND EXTERIOR LIGHTING

Measure Description

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

Beginning January 2012 and phased in through January 2014, the Energy Independence and Security Act of 2007 (EISA) regulations stipulated typical screw-based general service lamps with wattages ranging from 40W to 100W to comply with new lamp wattage standards such that the range of wattages decreased to be from 29W to 72W for rated lumen output ranging from 310 to 2,600 lumens.[134] Deemed baseline values for this measure will apply wattages based on lamp type and light output (lumens).[135]

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

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

Summer Peak Coincident Demand Savings

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

Annual Fuel Energy Savings

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

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fuel energy savings
units	= Number of measures installed under the program
W	= Rated wattage of lamp and/or fixture (Watts)
baseline	= Baseline condition or measure
ee	= Energy efficient condition or measure
hrs	= Lighting operating hours
$HVAC_c$	= HVAC interaction factor for annual electric energy consumption

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

$HVAC_d$ = HVAC interaction factor at utility summer peak hour
$HVAC_{ff}$ = HVAC interaction factor for annual fuel consumption (MMBtu/kWh)
CF = Coincidence factor
1,000 = Conversion factor, one kW equals 1,000 Watts

Summary of Variables and Data Sources

Variable	Value	Notes
W_{ee}		Energy efficient measure Watts, from application
$W_{baseline}$		Baseline measure Watts, from application or default values from applicable table in "Baseline Efficiencies…" section below depending on program structure/delivery mechanism.
hrs		Look up in Operating Hours section below based on installation type and location. "Interior" designation extends to any covered area not adequately lit during daylight hours by sunlight, thus requiring daytime operation of lighting. "Unknown" is not a valid selection for direct install programs.
$HVAC_c$	Exterior and Unconditioned Spaces: 0	HVAC interaction factor for annual electric energy consumption (dimensionless). Vintage and HVAC type weighted average by city. See Appendix D.
$HVAC_d$	Exterior and Unconditioned Space: 0	HVAC interaction factor for peak demand at utility summer peak hour (dimensionless). Vintage and HVAC type weighted average by city. See Appendix D.
$HVAC_{ff}$	Exterior and Unconditioned Space: 0	HVAC interaction factor for annual fuel energy consumption (MMBtu/kWh). Vintage and HVAC type weighted average by city. See Appendix D.
CF	Interior: 0.16 Exterior: 0	"Interior" designation extends to any covered area not adequately lit during daylight hours by sunlight, thus requiring daytime operation of lighting.

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

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

Coincidence Factor (CF)

The prescribed value for the coincidence factor for interior lighting is 0.16.[136] This value shall also be used if the installation location is unknown.

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

Baseline Efficiencies from which Energy Savings are Calculated

Rated wattage baseline values should reflect the guidance noted below based on bulb type and lumens in accordance with EISA standards. [137]

General Service Lamps

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

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

Certain lamp types are exempt from EISA compliance, including reflector lamps (see Reflector/Flood Lamps section below), some decorative and globe shape lamps (see Specialty Lamps section below) and three-way lamps. Baseline wattage for any of these exempt lamp types shall reflect the values in column (c) of the table below, with the exception of those lamps defined in the Specialty Lamps or Reflector/Flood Lamps sections below. All other general service lamps shall use the baseline wattage values in column (b), corresponding to the applicable lumen range identified in column (a). For standard lamps that fall outside of the prescribed lumen ranges below, the manufacturer recommended baseline wattage shall be used. For a complete list and definitions of EISA-exempt lamp types, reference Sec. 321: Efficient Light Bulbs of Public Law 110-140.[138]

Lumen Range **(a)**	**EISA 2007 Incandescent Equivalent** **$W_{baseline}$** **(b)**	**EISA-Exempt Incandescent Equivalent** **$W_{baseline}$** **(c)**
310 – 749	29	40
750 – 1,049	43	60
1,050 – 1,489	53	75
1,490 – 2,600	72	100

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

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

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

Specialty Lamps

Baseline wattage for specialty lamps are found in the table below. Specialty lamps are defined as screw-base lamps that are globe, bullet, candle or decorative shaped. These can be medium base, intermediate base, or candelabra base lamps. EISA 2007 set specific limits on maximum rated wattage for incandescent intermediate and candelabra base lamps, 40W and 60W respectively. In addition, some medium screw-base specialty lamps that could be used for general service applications are specifically exempt from EISA 2007 wattage limits and include: 1) a G shape lamp with a diameter of 5 inches or more (i.e. a G40 lamp); 2) a T shape lamp that uses not more than 40 watts or has a length of more than 10 inches; (3) a B, BA, CA, F, G16–1/2, G–25, G30, S, or M–14 lamp of 40 watts or less; and 4) a silver bowl lamp.[139] Medium screw-base specialty lamps not exempt from EISA 2007 must meet the maximum wattage requirements outlined in EISA 2007. For these lamps, the baseline wattage from column (b) in the table above should be used based on the lumen output. For specialty lamps that fall outside of the prescribed lumen ranges below, the manufacturer recommended baseline wattage should be used.

Bulb Type (a)	**Base Type (b)**	**Lumen Range (c)**	**$W_{baseline}$[140] (d)**
Globe	Medium and intermediate base	90 – 179	10
		180 – 249	20
		250 – 349	25
		350 – 749	40
	Candelabra base	90 – 179	10
		180 – 249	20
		250 – 349	25
		350 – 499	40
		500 – 1,049	60
Decorative (Shapes B, BA, C, CA, DC, F, G)	Medium and intermediate base	70 – 89	10
		90 – 149	15
		150 – 299	25
		300 – 749	40
	Candelabra base	70 – 89	10
		90 – 149	15
		150 – 299	25
		300 – 449	40
		450 – 1,049	60

Reflector/Flood Lamps

Baseline wattage for reflector and flood type lamps are found in the tables below. For reflector and flood lamps that are not covered by the table below, either based on bulb type or lumen output, the manufacturer recommended baseline wattage should be used. The first part of the table lists the baseline wattage for the incandescent reflector lamp bulb types specifically

[139] Ibid

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

exempted from federal standards and include 1) Lamps rated at 50 watts or less that are ER30, BR30, BR40, or ER40 lamps; 2) Lamps rated at 65 watts that are BR30, BR40, or ER40 lamps; or 3) R20 incandescent reflector lamps rated 45 watts or less. [141]

Exempt Bulb Type (a)	Lumen Range (b)	$W_{baseline}$ [142] (c)
ER30, BR30, BR40, or ER40	300 – 399	40
	400 – 449	50
BR30, BR40, or ER40	650 – 1,183	65
R20	< 300	30
	300 – 450	45

Not Exempt Bulb Type (a)	Diameter (b)	Lumen Range (c)	$W_{baseline}$ [143] (d)
All other R, PAR, ER, BR, BPAR, or similar bulb shapes, with diameter >2.25", other than those listed above	> 2.25" and ≤ 2.5"	541 – 718	40
		719 – 810	50
		811 - 1,002	55
		1,003 – 1,202	65
		1,203 – 1,516	75
		1,517 – 1,733	90
		1,734 – 2,184	100
		> 2,184	120
	> 2.5"	639 – 847	40
		848 – 956	50
		957 – 1,183	55
		1,184 – 1,419	65
		1,420 – 1,789	75
		1,790 – 2,045	90
		2,046 – 2,578	100
		> 2,578	120

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

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

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

Other Bulb Types (a)	Diameter (b)	Lumen Range (c)	$W_{baseline}$ [144] (d)
All ER, BR, BPAR, or similar bulb shapes	≤ 2.25"	300 – 399	40
		400 – 499	50
		500 – 599	60
		600 – 1,000	65
MR16	2"	< 450	35
		450 – 600	50
		> 600	75
All other reflector lamps not included above	All	200 – 299	30
		300 – 399	40

Compliance Efficiency from which Incentives are Calculated

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

Operating Hours

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

City	Interior	Exterior	Unknown
Albany	986	2,081	1,022
Binghamton	986	2,081	1,022
Buffalo	986	2,081	1,022
Massena	986	2,081	1,022
NYC	1,752	1,606	1,752
Poughkeepsie	986	2,081	1,022
Syracuse	986	2,081	1,022

NYS cities other than NYC, Interior

Hours of operation for interior lighting is estimated to be 2.7 operating hours per day or 986 (2.7 x 365) hours per year. This value is derived from on-site lighting inventories of homes in New York, exclusive of New York City and Westchester County, and refined through a hierarchical model that drew upon loggers installed in Connecticut, Massachusetts, and Rhode Island.[145]

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

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

NYS cities other than NYC, Exterior
Hours of operation for exterior lighting is estimated to be 5.7 operating hours per day or 2,081 (5.7 x 365) hours per year. This value is derived from on-site lighting inventories of homes in New York, exclusive of New York City and Westchester County, and refined through a hierarchical model that drew upon loggers installed in Connecticut, Massachusetts, and Rhode Island. [146]

NYS cities other than NYC, Unknown
Hours of operation for lighting installed in an unknown location is estimated to be 2.8 operating hours per day or 1,022 (2.8 x 365) hours per year. This value is a weighted average of interior and exterior lighting hours derived from on-site lighting inventories of homes in New York, exclusive of New York City and Westchester County, and refined through a hierarchical model that drew upon loggers installed in Connecticut, Massachusetts, and Rhode Island.[147]

NYC, Interior
Hours of operation for interior lighting is estimated to be 4.8 operating hours per day or 1,752 (4.8 x 365) hours per year. This value is derived from on-site lighting inventories of homes in New York City and Westchester County.[148]

NYC, Exterior
Hours of operation for exterior lighting is estimated to be 4.4 operating hours per day or 1,606 (4.4 x 365) hours per year. This value is derived from on-site lighting inventories of homes in New York City and Westchester County.[149]

NYC, Unknown
Hours of operation for lighting installed in an unknown location is estimated to be 4.8 operating hours per day or 1,752 (4.8 x 365) hours per year. This value is a weighted average of interior and exterior lighting hours derived from on-site lighting inventories of homes in New York City and Westchester County.[150]

Effective Useful Life (EUL)

See Appendix P.

[146] NMR Group Inc., "Northeast Residential Lighting Hours-of-Use Study", May 5, 2014. Table ES-5: HOU by Area Adjusted for Snapback and hierarchical model as described in section 2.6.3 (p. 22). HOU referenced is the value for Exterior for UNY and is Snapback Adjusted.
[147] NMR Group Inc., "Northeast Residential Lighting Hours-of-Use Study", May 5, 2014. Table ES-5: HOU by Area Adjusted for Snapback and hierarchical model as described in section 2.6.3 (p. 22). HOU referenced is the value for Household for UNY, which is a weighted average of all room types and is Snapback Adjusted.
[148] NMR Group Inc., "Northeast Residential Lighting Hours-of-Use Study", May 5, 2014. Table ES-6: HOU by Area Adjusted for Snapback and Table 3-2: Sample Sizes, Overall HOU Estimates by Area and Room. HOU referenced is a weighted average for interior room types for DNY and is Snapback Adjusted.
[149] NMR Group Inc., "Northeast Residential Lighting Hours-of-Use Study", May 5, 2014. Table ES-6: HOU by Area Adjusted for Snapback. HOU referenced is the value for Exterior for DNY and is Snapback Adjusted.
[150] NMR Group Inc., "Northeast Residential Lighting Hours-of-Use Study", May 5, 2014. Table ES-6: HOU by Area Adjusted for Snapback. HOU referenced is the value for Household for DNY, which is a weighted average of all room types and is Snapback Adjusted. The study's sample size included far more interior to exterior lights, thus a weighted distribution heavily favors the interior lighting hours.

Ancillary Fossil Fuel Savings Impacts

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

Ancillary Electric Savings Impacts

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

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