Table of Revisions/Changes

Revision Number	Addition/ Revision	Issue Date	Effective Date	Measure	Description of Change	Location/Page in TRM
3-21-02	R	4/14/2021	1/1/2022	R/MF Air Leakage Sealing	Added language to Measure Description detailing qualifying circumstances of application without blower door testing; Added detail specifying application of algorithm methods; Updated variable terms for consistency with other measures; Added change in infiltration rate default value when blower door test is not feasible	Pg. 57
3-21-03	R	4/14/2021	1/1/2022	R/MF Blown-In Insulation	Changed Measure Name and Measure Description to expand measure to any blown-in insulation material and application in walls, in addition to attics; Corrected heating component of Annual Electric Energy Savings equation; Corrected Equipment Type description for Steam, Oil Fired boiler efficiency	Pg. 62
3-21-10	R	4/14/2021	1/1/2022	C/I Refrigerators and Freezers	Updated Measure Description, Baseline Efficiencies, Compliance Efficiency, and sources to include ENERGY STAR® laboratory grade refrigerators and freezers	Pg. 32
3-21-18	R	4/14/2021	4/14/2021	Appendix P	Updated EUL entries for all measures contained in this Record of Revision	Pg. 996
3-21-21	R	4/14/2021	1/1/2022	R/MF Adaptive Photonic Control for HVAC Fan Motors	Modified savings algorithm, variable terms, and definitions to differentiate between savings associated with cooling, heating, and fan components; Updated Annual Fuel Energy Savings equation to consider retrofitted system space heating input fuel rating; Added detail to Operating Hours	Pg. xx
3-21-22	R	4/14/2021	1/1/2022	R/MF Steam Trap – Low Pressure Space Heating	Modified Measure Description to clarify application; Revised variable terms and definition to capture hours trap is pressurized	Pg. 237

Revision Number	Addition/ Revision	Issue Date	Effective Date	Measure	Description of Change	Location/Page in TRM
3-21-23	R	4/14/2021	1/1/2022	C/I Adaptive Photonic Control for HVAC Fan Motors	Modified savings algorithm, variable terms, and definitions to differentiate between savings associated with cooling, heating, and fan components; Updated Annual Fuel Energy Savings equation to consider retrofitted system space heating input fuel rating; Added detail to Operating Hours	Pg. xx
3-21-24	R	4/14/2021	1/1/2022	C/I Steam Trap – Low Pressure Space Heating	Modified Measure Description to clarify application; Revised variable terms, definition, default hours and source to capture hours trap is pressurized	Pg. 606
3-21-25	R	4/14/2021	1/1/2022	C/I Steam Trap Monitoring System – Low Pressure Space Heating	Modified Measure Description to clarify application; Revised variable terms, definition, default hours and source to capture hours trap is pressurized	Pg. 610

Note: Revisions and additions to the measures listed above were undertaken by the Joint Utilities Technical Resource Manual (TRM) Management Committee between January 1, 2021 – April 14, 2021.

BUILDING SHELL

AIR LEAKAGE SEALING

Measure Description

This measure covers methods of sealing air leakage paths to reduce the natural air infiltration rate of a building through the installation of products and repairs to the building envelope, including, but not limited to, caulking, gasketing, and weather stripping. Sealing the thermal envelope reduces passive convective heat transfer between conditioned and unconditioned spaces or outside air, thereby reducing heating and cooling loads and improving occupant comfort. This measure is only applicable as a retrofit in existing buildings. This measure is not applicable to gut rehab/major renovation projects, which entail whole-building envelope alterations that trigger more stringent code provisions, limiting potential incremental savings.

The exterior envelope, as well as interior walls/partitions between conditioned and unconditioned spaces should be inspected and all gaps sealed. At a minimum, the following items shall be inspected, and sealing measures may be implemented based upon inspection results:

- Caulk and weather strip doors and windows that leak air
- Repair or replace doors leading from conditioned to unconditioned space
- Seal air leaks between unconditioned (including unconditioned basement and attics) and conditioned spaces, to include, but not limited to, plumbing, ducting, electrical wiring, wall top plates, chimneys, flues, and dropped soffits.
- Use foam sealant on larger gaps around windows, baseboards, and other places where air leakage, either infiltration or exfiltration may occur.

Methods are provided below for single-family, low-rise multifamily and high-rise multifamily applications with and without blower door testing conducted before and after implementation of air sealing treatments. A blower door test is performed to measure the leakage rate by depressurizing the building to a standard pressure difference of 50 Pascals or 0.2 inches of water. The measured flowrate indicates the leakage rate, or infiltration and exfiltration rate, of the building shell. The first method below only applies to high-rise multifamily applications where blower door testing is not conducted. All other scenarios shall be addressed using the second set of algorithms below.

Blower door tests shall be performed whenever possible. The method provided below for single family/low-rise multifamily without blower door testing should only be used if blower door testing is not feasible due to health or safety concerns, e.g. the presence of a hazardous material like asbestos or mold, ongoing construction in the home or concerns regarding COVID-19.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings
(high-rise multifamily without blower door test)

Annual Electric Energy Savings

$$\Delta kWh = units \times \frac{SF}{1{,}000} \times (\Delta kWh/kSF)$$

Summer Peak Coincident Demand Savings

$$\Delta kW = units \times \frac{SF}{1{,}000} \times (\Delta kW/kSF) \times CF$$

Annual Fuel Energy Savings

$$\Delta MMBtu = units \times \frac{SF}{1{,}000} \times \frac{(\Delta therms/kSF)}{10}$$

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings
(with blower door test or single-family/low-rise multifamily without blower door test)

Annual Electric Energy Savings

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

Summer Peak Coincident Demand Savings

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

Annual Fuel Energy Savings

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

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fuel energy savings
units	= Number of measures installed under the program
SF	= Square footage of conditioned floor area affected by installation (ft^2)
(ΔkWh/kSF)	= Annual electric energy savings per thousand square feet
(ΔkW/kSF)	= Peak coincident demand electric savings per thousand square feet
(Δtherms/kSF)	= Annual fuel energy savings per thousand square feet

ΔCFM_{50}	= Change in infiltration rate (cubic foot per minute) before and after air leakage sealing as determined by blower door testing at a negative pressure differential of 50 Pa (see Summary of Variables and Data Sources for derivation for single-family and low-rise multifamily applications without blower door testing)
F_n	= Infiltration-Leakage Ratio, used to convert pressurized blower door testing results to natural infiltration rates, climate zone factor
F_h	= Infiltration-Leakage Ratio, used to convert pressurized blower door testing results to natural infiltration rates, building height factor
(ΔkWh/CFM)	= Annual electric energy savings per cubic foot per minute of reduced air leakage at 50 Pa
(ΔkW/CFM)	= Peak coincident demand electric savings per cubic foot per minute of reduced air leakage at 50 Pa
(Δtherms/CFM)	= Annual fuel energy savings per cubic foot per minute of reduced air leakage at 50 Pa
CF	= Coincidence factor
1,000	= Conversion factor from SF (ft^2) to kSF (1,000 ft^2)
10	= Conversion factor, one MMBtu equals 10 therms

Summary of Variables and Data Sources

Variable	Value	Notes
SF		From application.
(ΔkWh/kSF)		Look up from Appendix E based on city and building vintage.
(ΔkW/kSF)		Look up from Appendix E based on city and building vintage.
(Δtherms/kSF)		Look up from Appendix E based on city and building vintage.
ΔCFM_{50}		From application, results from blower door test. For single-family and low-rise multifamily homes, if conducting a blower door test is not feasible due to health and safety concerns, multiply affected area square footage by a deemed ΔCFM_{50}/SF of 0.50 (i.e., ΔCFM_{50} = 0.50 x ft^2).[1]
F_n	19	Value chosen from the range of 17-19 to reflect a conservative estimate of savings.[2]

[1] Default ΔCFM_{50}/SF of 0.50 is the median value of single-family blower door test data provided by ConEdison, conducted 2018-2020.
[2] LBL, Estimation of Infiltration from Leakage and Climate Indicators, December 1986, pg. 84

Variable	Value	Notes
F_h	1 story: 1.00 1.5 stories: 0.90 2 stories: 0.81 2.5 stories: 0.76 3+ stories: 0.70	Based on the number of conditioned stories in the building. [3] The selected value should reflect the number of stories located inside the conditioned envelope of the building. Unconditioned basements and attics should not be included. Half-story values are provided for upper levels without full height perimeter walls.
(ΔkWh/CFM)		Look up from Appendix E based on HVAC type and city.
(ΔkW/CFM)		Look up from Appendix E based on HVAC type and city.
(Δtherms/CFM)		Look up from Appendix E based on HVAC type and city.
CF	0.69	

Unit energy and demand savings were calculated from a DOE-2.2 simulation of a series of prototypical single and multifamily residential buildings. The prototype building characteristics are described in Appendix A. The unit energy and demand savings are shown in Appendix E.

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.69.[4]

Baseline Efficiencies from which Energy Savings are Calculated

Baseline natural infiltration air changes per hour of 1.0 NACH for old vintage buildings and 0.5 NACH for average vintage buildings are assumed to estimate energy and demand savings tabulated in Appendix E.

A baseline SEER value of 13 and EER value of 11.1 are used in the simulations, as detailed in Appendix A, to estimate energy and demand savings tabulated in Appendix E.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is the application of air leakage sealing treatments to an existing building envelope (excluding gut rehab/major renovations) such that the exterior envelope, as well as interior walls/partitions between conditioned and unconditioned spaces have been inspected and all gaps sealed. At a minimum, the following items shall be inspected, and sealing measures may be implemented based upon inspection results:

[3] Ibid. The value for 2.5 stories was interpolated from presented data.
[4] Based on BG&E 'Development of Residential Load Profile for Central Air Conditioners and Heat Pumps' research, the Maryland Peak Definition coincidence factor is 0.69. This study is not publicly available, but is referenced by M. M. Straub, Using Available Information for Efficient Evaluation of Demand-Side Management Programs, Electricity Journal, September 2011 and supported by research conducted by Cadmus on behalf of the RM Management Committee.

- Caulk and weather strip doors and windows that leak air
- Repair or replace doors leading from conditioned to unconditioned space
- Seal air leaks between unconditioned (including unconditioned basement and attics) and conditioned spaces, to include, but not limited to, plumbing, ducting, electrical wiring, wall top plates, chimneys, flues, and dropped soffits.
- Use foam sealant on larger gaps around windows, baseboards, and other places where air leakage, either infiltration or exfiltration may occur.

Operating Hours

HVAC system operating hours are embedded into the deemed savings shown in Appendix E and vary by building type. See Appendix A for details on prototype building simulation parameters.

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

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

Ancillary Electric Savings Impacts

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

References

1. Lawrence Berkeley Laboratory, Estimation of Infiltration from Leakage and Climate Indicators, Sherman, M. December 1986
   Available from: http://eta-publications.lbl.gov/sites/default/files/estimation_of_inflitration_from_leakage_and_climate_indicators.pdf
2. BG&E: Development of Residential Load Profile for Central Air Conditioners and Heat Pumps
3. ECCCNYS 2020 Section C402.5.1 Air Barrier Testing
   Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-[ce]-commercial-energy-efficiency#NYSECC2020P1_CE_Ch04_SecC403
4. ECCCNYS 2020 Section R402 Building Thermal Envelope
   Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-[re]-residential-energy-efficiency#NYSECC2020P1_RE_Ch04_SecR402
5. NYSMC 2020; Section 401.2 Ventilation Required
   Available from: https://codes.iccsafe.org/content/NYSMC2020P1/chapter-4-ventilation

Record of Revision

Record of Revision Number	Issue Date
1	10/15/2010
7-13-25	7/31/2013
9-18-19	9/30/2018
12-18-2	12/28/2018
3-19-1	3/29/2019
3-21-2	4/14/2021

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BUILDING SHELL

BLOWN-IN INSULATION

Measure Description

This measure covers the installation of blown-in insulation in attics and walls. Cellulose is the most common blown-in insulation material; other materials include mineral fiber, loose-fill fiberglass, and Styrofoam pellets. Cellulose insulation is made from a cellular plant source, most commonly wood or paper, and treated with fire and pest resistant chemicals. Cellulose insulation is installed in three primary forms: loose-fill, stabilized and wall-cavity spray. Loose-fill insulation is a dry install that is blown into joist cavities in uninsulated attics or applied over existing batts. Stabilized cellulose is similar to loose-fill and applied in the same way but contains a moisture-activated adhesive that serves to increase the density of the cellulose and limit settling. Wall-cavity spray is typically applied prior to drywall installation in new construction, however insertion into existing walls is possible. This measure is restricted to blown-in loose fill insulation, stabilized cellulose, and wall-cavity spray in existing building retrofit applications.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

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

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

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

Summer Peak Coincident Demand Savings

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

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 electricity energy savings

ΔkW = Peak coincident demand electric savings
$\Delta MMBtu$ = 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
ΔR = Difference in R-value between existing insulation and total combined post-implementation insulation
A = Area of affected surfaces (attic ceiling/walls) (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
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 uninsulated, use 11 as a default value.[5]
ΔR		From application.
A		From application.

[5] Based on R-value of uninsulated/minimally insulated ceilings in both single family and multifamily homes from the DOE-2.2 simulation of a series of prototypical residential buildings. The prototype building characteristics are described in Appendix A.

Variable	Value	Notes
$F_{framing}$	Walls: 0.25 Ceilings: 0.07	ASHRAE.[6]
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.
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.[7]
HSPF		From application or use 8.2 HSPF, assuming a 3-ton central ASHP system. 8 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[9]: $EER = (1.12 \times SEER) - (0.02 \times SEER^2)$
$Eff_{FuelHeat}$		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.[10]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition for this measure is an attic or wall space without blown-in insulation.

[6] ASHRAE, 2001, "Characterization of Framing Factors for New Low-Rise Residential Building Envelopes (904-RP)," Table 7.1.
[7] ECCCNYS 2020, Table C403.3.2(1))
[8] Ibid.
[9] DOE, Building America House Simulation Protocols, October 2010
[10] Based on BG&E 'Development of Residential Load Profile for Central Air Conditioners and Heat Pumps' research, the Maryland Peak Definition coincidence factor is 0.69. This study is not publicly available, but is referenced by M. M. Straub, Using Available Information for Efficient Evaluation of Demand-Side Management Programs, Electricity Journal, September 2011 and supported by research conducted by Cadmus on behalf of the RM Management Committee.

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[11]

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[12] 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
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

[11] 10 CFR 430.32(e)
[12] 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, 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 the addition of blown-in insulation to attic or wall spaces in existing building retrofits.

Operating Hours

Effective heating and cooling hours associated with benefits of blown-in attic or wall insulation are established via the Heating and Cooling Degree Days section below.

Heating and Cooling Degree Days[13]

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

[13] HDD/CDD taken from NCEI 1981-2010 climate normal using a 65 °F balance point.

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. ASHRAE, 2001, "Characterization of Framing Factors for New Low-Rise Residential Building Envelopes (904-RP)," Table 7.1.
4. Building America House Simulation Protocols, Robert Hendron and Cheryn Engebrecht, National Renewable Energy Laboratory, October 2010
   Available from:
   https://www1.eere.energy.gov/buildings/publications/pdfs/building_america/house_simulation_revised.pdf
5. NOAA National Centers for Environmental Information – NCEI 1981-2010 Climate Normals
   Available from: https://www.ncdc.noaa.gov/cdo-web/datatools/normals

Record of Revision

Record of Revision Number	Issue Date
7-20-1	7/31/2020
3-21-3	4/14/2021

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APPLIANCE

REFRIGERATORS AND FREEZERS

Measure Description

This measure covers the installation of ENERGY STAR® compliant commercial refrigerators and freezers operating with an integral compressor and condenser. Eligible equipment includes commercial standard and hybrid refrigerators, freezers, and refrigerator-freezers. This measure is only applicable to horizontal or vertical self-contained equipment with solid or transparent doors.

This measure also covers the installation of ENERGY STAR® laboratory grade refrigerators and freezers. These products are used to store non-volatile reagents and biological specimens at stable temperatures in lab settings including hospitals, clinics, university and government research laboratories, and pharmaceuticals. Eligible equipment include general purpose and high performance laboratory grade refrigerators and freezers and ultra-low temperature freezers. A general purpose laboratory grade refrigerator is a product that cannot support a maximum peak variation in temperature equal to or less than 6 °C at set point temperatures between 0 °C and 12 °C (32 °F and 53.6 °F). A high performance laboratory grade refrigerator is a product that is designed to support a maximum peak variation in temperature no greater than 6 °C. A general purpose laboratory grade freezer is a product that cannot support a maximum peak variation in temperature equal to or less than 10 °C at set point temperatures between -40 °C and 0 °C (-40 °F and 32 °F). A high performance laboratory grade freezer product that is designed to support a maximum peak variation in temperature no greater than 10 °C. An ultra-low temperature freezer is a freezer designed for laboratory application that is capable of maintaining set point storage temperatures between -70 °C and -80 °C (-94 °F and -112 °F).[14]

Method for Calculating Annual Energy and Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times (kWh_{baseline} - kWh_{ee}) \times (1 + HVAC_c)$$

Peak Coincident Demand Savings

$$\Delta kW = units \times \left[\frac{kWh_{baseline} - kWh_{ee}}{8{,}760}\right] \times (1 + HVAC_d) \times CF$$

Annual Fuel Energy Savings

$$\Delta MMBtu = units \times (kWh_{baseline} - kWh_{ee}) \times HVAC_{ff}$$

where:

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

[14] ENERGY STAR® Refrigerators & Freezers Key Product Criteria, ENERGY STAR® Program Requirements for Laboratory Grade Refrigerators and Freezers.

ΔMMBtu	= Annual fuel energy savings
units	= Number of measures installed under the program
baseline	= Baseline condition or measure
ee	= Energy efficient condition or measure
kWh	= Annual electric energy consumption
$HVAC_c$	= 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 fuel consumption (MMBtu/kWh)
CF	= Coincidence factor
8,760	= Hours in one year

Summary of Variables and Data Sources

Variable	Value	Notes
$kWh_{baseline}$		See Baseline Efficiencies section below.
kWh_{ee}		From application.
$HVAC_c$		HVAC interaction factor for annual electric energy consumption (dimensionless), from Appendix D based on facility type, location and HVAC type.
$HVAC_d$		HVAC interaction factor for peak demand at utility summer peak hour (dimensionless), from Appendix D based on facility type, location and HVAC type.
$HVAC_{ff}$		HVAC interaction factor for annual fuel energy consumption (MMBtu/kWh), from Appendix D based on facility type, location and HVAC type.
CF	1.0	

Coincidence Factor (CF)

The recommended value for the coincidence factor is 1.0. [15]

Baseline Efficiencies from which Savings are Calculated

The baseline condition is a minimally code compliant commercial standard or hybrid refrigerator, refrigerator-freezer or freezer as defined in the Measure Description section above. Baseline annual electric consumption (kWh/yr) shall align with federally mandated maximum energy use associated with the Product Class and the chilled or frozen compartment volume (V) of the qualifying equipment.[16] Volume specification shall be taken from ENERGY STAR® qualified products listing or specification sheet of the proposed equipment. Baseline maximum daily energy consumption (kWh/day) for solid door and glass door commercial refrigerators and freezers of all volumes are calculated as shown in the table below.[17] For commercial refrigeration equipment with two or more compartments (i.e., hybrid refrigerators, hybrid freezers, hybrid refrigerator-freezers, and non-hybrid refrigerator-freezers), the maximum daily energy consumption for each

[15] *No source specified – update pending availability and review of applicable references.*
[16] 10 CFR Appendix A to Subpart C of Part 431 – Uniform Test Method for the Measurement of Energy Consumption of Commercial Refrigerators, Freezers, and Refrigerator-Freezers
[17] 10 CFR 431.66(e)(1)

model shall be the sum of the MDEC values for all of its compartments.[18] Multiply by 365 to derive annual energy consumption.

Type (Closed)	Maximum Daily Energy Consumption (kWh/day)			
	Refrigerator		Freezer	
	Solid Door	Glass Door	Solid Door	Glass Door
Vertical	≤ 0.05×V + 1.36	≤ 0.10×V + 0.86	≤ 0.22×V + 1.38	≤ 0.29×V + 2.95
Horizontal	≤ 0.05×V + 0.91	≤ 0.06×V + 0.37	≤ 0.06×V + 1.12	≤ 0.08×V + 1.23

Ultra-Low Temperature (ULT) Freezers @ -75 °C Energy Consumption[19]

Maximum Daily Energy Consumption (kWh/day)
ULT Freezer
2.51-0.06×V+0.10×1 (assumed frequency of door opening, moderate)

Compliance Efficiency from which Incentives are Calculated

The compliance condition is an ENERGY STAR® qualified commercial refrigerator, refrigerator-freezer or freezer, general purpose or high performance laboratory grade refrigerator or freezer or ultra low-temperature laboratory grade freezer as defined in the Measure Description section above. ENERGY STAR® rated refrigerators must meet the specifications in the tables below for maximum daily energy consumption (kWh/day).[20] Annual electric energy consumption of the qualifying equipment shall come from application. If unknown, use maximum energy consumption based on qualifying equipment volume from the tables below. Volume specification shall be taken from ENERGY STAR® qualified products listing or specification sheet of the proposed equipment. Multiply by 365 to derive annual energy consumption (kWh/year).

Vertical Closed Energy Consumption

Volume (ft^3)	Maximum Daily Energy Consumption (kWh/day)			
	Refrigerator		Freezer	
	Solid Door	Glass Door	Solid Door	Glass Door
0 < V < 15	≤ 0.022×V+0.97	≤ 0.095×V+0.445	≤ 0.210×V+0.900	≤ 0.232×V+2.36
15 ≤ V < 30	≤ 0.066×V+0.31	≤ 0.050×V+1.120	≤ 0.120×V+2.248	≤ 0.232×V+2.36
30 ≤ V < 50	≤ 0.040×V+1.09	≤ 0.076×V+0.340	≤ 0.285×V-2.703	≤ 0.232×V+2.36
50 ≤ V	≤ 0.024×V+1.89	≤ 0.105×V-1.111	≤ 0.142×V+4.445	≤ 0.232×V+2.36

Horizontal Closed Energy Consumption

Volume (ft^3)	Maximum Daily Energy Consumption (kWh/day)			
	Refrigerator		Freezer	
	Solid Door	Glass Door	Solid Door	Glass Door
All volumes	≤ 0.05×V+0.28	≤ 0.05×V+0.28	≤ 0.057×V+0.55	≤ 0.057×V+0.55

18 10 CFR 431.66(e)(2)
19 ULT Freezers Base Case Investigation, Eversource Energy
20 ENERGY STAR® Program Requirements Product Specification for Commercial Refrigerators and Freezers, Eligibility Criteria Version 4.0

Laboratory Grade Refrigerators Energy Consumption[21]

Applications	Volume	Maximum Daily Energy Consumption (kWh/day)
General Purpose	0 ≤ V < 25	≤ 0.124×V+2.0
	25 ≤ V	≤ 0.121×V+2.07
High performance	0 ≤ V < 25	≤ 0.184×V+3.5
	25 ≤ V < 44	≤ 0.153×V+4.28
	44 ≤ V	≤ 0.125×V+5.5

Laboratory Grade Freezers Energy Consumption[22]

Applications	Volume	Maximum Daily Energy Consumption (kWh/day)
General Purpose	0 ≤ V < 15	≤ 0.033×V+2.0
	15 ≤ V < 30	≤ 0.05×V+1.75
	30 ≤ V	≤ 0.188×V-2.375
High performance	0 ≤ V < 22	≤ 0.09×V+10
	22 ≤ V	≤ 0.426×V+2.63

Laboratory Grade Ultra-Low Temperature (ULT) Freezers @ -75 °C Energy Consumption

Maximum Daily Energy Consumption (kWh/day)
0.55×V

Operating Hours

Refrigeration products are assumed to be plugged into an electrical outlet 8,760 hours per year. Compressor cycling is inherent in the specified annual energy consumption of baseline and qualifying equipment.

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

High-efficiency refrigeration products reject less heat into the conditioned space than standard equipment, increasing space heating requirements while decreasing cooling load. The HVAC interaction factors calculated from the prototypical building DOE-2 models as a function of facility type, location and HVAC system type are shown in Appendix D.

Ancillary Electric Savings Impacts

High-efficiency refrigeration products reject less heat into the conditioned space than standard equipment, increasing space heating requirements while decreasing cooling load. The HVAC interaction factors calculated from the prototypical building DOE-2 models as a function of facility

[21] ENERGY STAR® Program Requirements for Laboratory Grade Refrigerators and Freezers
[22] Ibid.

type, location and HVAC system type are shown in Appendix D.

References

1. ENERGY STAR® Refrigerators & Freezers Key Product Criteria, March 27, 2017
   Available from:
   https://www.energystar.gov/products/commercial_food_service_equipment/commercial_refrigerators_freezers/key_product_criteria
2. 10 CFR Appendix A to Subpart C of Part 431 – Uniform Test Method for the Measurement of Energy Consumption of Commercial Refrigerators, Freezers, and Refrigerator-Freezers
   Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=fa8761ce7ff31d0c22aaf4e1c4992575&mc=true&node=pt10.3.431&rgn=div5#ap10.3.431_166.a
3. 10 CFR 431.66 Energy conservation standards and their effective dates.
   Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=4892a800dfd3976a79848bb42372bfda&mc=true&node=pt10.3.431&rgn=div5#se10.3.431_166
4. ENERGY STAR® Program Requirements Product Specification for Commercial Refrigerators and Freezers, Eligibility Criteria Version 4.0
   Available from:
   https://www.energystar.gov/sites/default/files/asset/document/Commercial%20Refrigerators%20and%20Freezers%20V4%20Spec%20Final%20Version_0.pdf
5. ENERGY STAR® Program Requirements for Laboratory Grade Refrigerators and Freezers.
   Available from:
   https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20V1.1%20Lab%20Grade%20Refrigerator%20and%20Freezer%20Program%20Requirements.pdf
6. Ultra-low Freezer base case investigations, Eversouce Energy, October 2, 2017

Record of Revision

Record of Revision Number	Issue Date
1	10/15/2010
9-18-7	9/30/2018
3-21-10	4/14/2021

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APPENDIX P

EFFECTIVE USEFUL LIFE (EUL)

SINGLE AND MULTI-FAMILY RESIDENTIAL MEASURES

Category	Single and Multi-family Residential Measures	Sector	EUL (years)	Source
Appliance	Air Purifier	Residential	9	ENERGY STAR® Calc[23]
	Clothes Dryer	Residential	14	ENERGY STAR® M&I Scoping Report[24]
	Clothes Washer	Residential	11	DEER 2014 EUL ID: Appl-EffCW
	Dehumidifier	Residential	12	ENERGY STAR® Calc[25]
	Dishwasher	Residential	11	DEER 2014 EUL ID: Appl-EffDW
	Fireplace	Residential	15	DOE[26]
	Refrigerator and Freezer	Residential	14	DEER 2014 EUL ID: Appl-ESRefg
	Soundbar	Residential	7	RPP Product Analysis[27]
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

[23] 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
[24] ENERGY STAR® Market & Industry Scoping Report: Residential Clothes Dryer, November 2011.
[25] ENERGY STAR® Dehumidifier Calculator https://www.energystar.gov/ia/partners/promotions/cool_change/downloads/CalculatorConsumerDehumidifier.xls
[26] 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
[27] 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[28]
	Air Leakage Sealing	Residential	15	GDS[29]
	Insulation – Hot Water and Steam Pipe	Residential	15	GDS[30]
	Insulation – Opaque Shell	Residential	25	GDS[31]
	Storm Window	Residential	20	DOE[32]
	Window	Residential	20	DEER 2014 EUL ID: BS-Win
Domestic Hot Water (DHW)	Heat Pump Water Heater (HPWH)	Residential	10	DEER 2014 EUL ID: WtrHt-HtPmp
	Indirect Water Heater	Residential	11	DEER 2014 EUL ID: WtrHt-Res-Gas
	Storage Water Heater - Gas	Residential	15	PA Consulting Group[33]
	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[34]
DHW - Control	Drain Water Heat Recovery (DWHR)	Residential	30	2019 Title 24[35]
	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[36]

[28] At least one manufacturer's warranty period. www.gss-ee.com/products.html

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

[30] Ibid.

[31] Ibid.

[32] https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-22864rev2.pdf

[33] 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

[34] https://www.energy.gov/energysaver/solar-swimming-pool-heaters

[35] 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

[36] 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[37]
	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[38]
	Boiler and Furnace - Combination (“Combi”) Furnace	Residential	20	DEER 2014[39] 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[40]

[37] GDS Associates, Inc., Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures, June 2007, Table 1 – Residential Measures
[38] 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
[39] Based on DEER value for high efficiency boiler and instantaneous water heater
[40] 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[41,42]
	Heat Pump - Air Source (ASHP)	Residential	15	DEER 2014 EUL ID: HV-Res HP
	Heat Pump – Ground Source (GSHP)	Residential	25	ASHRAE[43]
	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[44]
	Thermostat – All Types	Residential	11	DEER 2014 EUL ID: HVAC-ProgTStats

[41] 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
[42] 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
[43] ASHRAE: Owning and Operating Cost Database, Equipment Life/Maintenance Cost Survey: https://xp20.ashrae.org/publicdatabase/system_service_life.asp?selected_system_type=1
[44] 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[45]
	Smart Thermostatic Radiator Enclosure	Residential	15	DEER 2014 EUL ID: Motors-fan[46]
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[47]
			50,000 hours	DLC[48]

[45] U.S. DOE, "Thermostatic Radiator Valve Evaluation", January 2015, Table 4. pg. 16
[46] Based on assumed EUL of integrated fan, which is expected to be the first component to fail
[47] 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
[48] 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[49]
		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[50]

[49] 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
[50] 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[51]

[51] 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[52]
	Milk Pre-Cooler Heat Exchanger	C&I	15	PA Consulting Group[53]
	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[54]
	Variable Speed Drive Milk Pump Plate Cooler	C&I	15	PA Consulting Group[55]
	Variable Speed Drive Vacuum Pump	C&I	15	PA Consulting Group[56]
Appliance	Clothes Dryer	C&I	14	ENERGY STAR®M&I Report[57]
	Clothes Washer	C&I	11	DEER 2014 EUL ID: Appl-EffCW
	Cooking Equipment[58]	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[59]
	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

52 PG&E Work Paper PGE3PAGR117, October 12, 2017
53 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
54 Based on EUL's for Advanced Power Strips
55 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
56 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
57 ENERGY STAR® Market & Industry Scoping Report: Residential Clothes Dryer, November 2011.
58 Applicable to all kitchen cooking equipment not otherwise listed
59 ENERGY STAR® Savings Calculator for ENERGY STAR® Certified Commercial Kitchen Equipment www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx?5da4-3d90&5da4-3d90

Category	Commercial & Industrial Measures	Sector	EUL (years)	Source
Appliance Recycling	Air Conditioner – Room (RAC)	C&I	9	DEER 2014 EUL ID: HV-RAC-ES
Building Shell	Air Leakage Sealing	C&I	15	GDS[60]
	Cool Roof	C&I	15	DEER 2014 EUL ID: BldgEnv-CoolRoof
	Insulation - Hot Water and Steam Pipe	C&I	15	GDS[61]
	Insulation - Opaque Shell	C&I	30	ET & CEC[62]
	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[63]
	Engineered Air Nozzle	C&I	15	Wisconsin PSC[64]
	No Air Loss Water Drain	C&I	13	MA Measure Life Study[65]
	Refrigerated Air Dryer	C&I	13	Other State TRMs [66]
	Compressed Air Heat Recovery	C&I	13	Other State TRMs [67]
	Flow Controller	C&I	13	Other State TRMs [68]
	Low Pressure Drop Filter	C&I	5	Other State TRMs [69]
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

[60] GDS Associates, Inc., Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures, June 2007, Table 1 – Residential Measures
[61] GDS Associates, Inc., Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures, June 2007, Table 1 – Residential Measures
[62] Energy Trust uses 30 years for commercial applications. CEC uses 30 years for insulation in Title 24 analysis.
[63] 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.
[64] PA Consulting Group (2009). *Business Programs: Measure Life Study*. Prepared for State of Wisconsin Public Service Commission
[65] 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
[66] 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.
[67] Ibid.
[68] Ibid.
[69] Ibid.

Category	Commercial & Industrial Measures	Sector	EUL (years)	Source
DHW - Control	Drain Water Heat Recovery (DWHR)	C&I	30	2019 Title 24[70]
	Low-Flow – Faucet Aerator	C&I	10	DEER 2014 EUL ID: WtrHt-WH-Aertr
	Low-Flow – Pre-Rinse Spray Valve (PRSV)	C&I	5	GDS
	Low-Flow – Salon Valve	C&I	10	DEER 2014 EUL ID: WtrHt-WH-Shrhd
	Low-Flow – Showerhead	C&I	10	DEER 2014 EUL ID: WtrHt-WH-Shrhd
	Central DHW Control	C&I	15	NREL[71]
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[72]
	Boiler and Furnace - Combination ("Combi") Furnace	C&I	20	DEER 2014[73] 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[74]
	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

[70] 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
[71] https://www.nrel.gov/docs/fy16osti/64541.pdf
[72] 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
[73] Based on DEER value for high efficiency boiler and instantaneous water heater
[74] Ecotope Natural Gas Efficiency and Conservation Measure Resource Assessment (2003)

Category	Commercial & Industrial Measures	Sector	EUL (years)	Source
Heating, Ventilation and Air Conditioning (HVAC)	Electronically Commutated (EC) Motor – Hydronic Circulator Pump	C&I	15	DEER 2014 EUL ID: Motors-pump
	Economizer –Dual Enthalpy Air Side	C&I	10	DEER 2014 EUL ID: HVAC-addEcono
	Furnace, Gas Fired	C&I	23	DOE[75,76]
	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[77]
	High Volume Low Speed Fan	C&I	15	PA Consulting Group[78]
	Infrared Heater	C&I	17	GDS[79]
	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[80]
	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

[75] 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

[76] 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

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

[78] 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

[79] 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

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

Category	Commercial & Industrial Measures	Sector	EUL (years)	Source
HVAC – Control	Adaptive Photonic Control	C&I	EUL = Retrofitted motor RUL = Retrofitted motor EUL – (Current Year – Mfr. Year) **Default = 5**	DEER 2014 EUL ID: Motors-fan
	Direct Digital Control (DDC) System	C&I	15	DEER 2014 EUL ID: HVAC-EMS
	Demand Control Ventilation (DCV)	C&I	15	DEER 2014 EUL ID: HVAC-VSD-DCV
	Energy Management System	C&I	15	DEER 2014 EUL ID: HVAC-EMS
	Energy Management System – Guest Room	C&I	15	DEER 2014 EUL ID: HVAC-EMS
	Boiler Economizer	C&I	EUL = Boiler RUL = Boiler EUL – (Current Year – Mfr. Year) **Default = 5**	GDS[81]
	Kitchen Demand Ventilation Control	C&I	15	PG&E[82]
	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[83]
	Advanced Rooftop Control	C&I	EUL = RUL of Existing RTU = RTU EUL – (Current Year – Year of Mfr.) **Default = 5**	N/A

[81] 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
[82] PG&E Work Paper WPSDGENRCC0019, June 15, 2012
[83] 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[84]
Lighting	Light Fixture	LED Fixture (Interior)	C&I	Rated Life listed by ENERGY STAR or default to 25,000 hrs/annual lighting operating hrs or 15 yrs if rated lifetime or annual operating hrs are not known	ENERGY STAR®[85]
		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®[86]
		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®[87]
		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

[84] 50,000 hours per L_{70} requirements prescribed by the DLC's Product Qualification Criteria, Technical Requirement Table version 4.4

[85] 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

[86] 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

[87] 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[88]
			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[89]
Lighting - Control	Bi-Level Lighting	C&I	15	ComEd[90]
	Integrated Interior Lighting Control	C&I	15	ComEd[91]
	Non-Integrated Interior Lighting Control	C&I	10	GDS[92]
	Plug-Load Occupancy Sensor	C&I	8	DEER[93]
Motors and Drives	Motor (incl. PEI Pumps)	C&I	15	DEER 2014 EUL ID: Motors-HiEff
	Notched & Synchronous Belt	C&I	5	DEER 2014 EUL ID: HV-CoggedBelt
	Pool Pump	C&I	10	DEER 2014 EUL ID: OutD-PoolPump
	Variable Frequency Drive (VFD) – Fan and Pump	C&I	15	DEER 2014 EUL ID: HVAC-VSDSupFan
	Elevator Modernization	C&I	15	DEER 2014[94]

88 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

89 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

90 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

91 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

92 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

93 DEER value for lighting occupancy sensors

94 Assumes same EUL as VFD measure.

Category	Commercial & Industrial Measures	Sector	EUL (years)	Source
Other	High Efficiency Transformer	C&I	32	DOE[95]
	High Frequency Battery Charger	C&I	15	PG&E[96]
	Pool Heater	C&I	8	DOE[97]
Process Equipment	Steam Trap – Other Applications	C&I	6	DEER 2014 EUL ID: HVAC-StmTrp
	Ozone Laundry	C&I	10	PG&E[98]
	Process Exhaust Filtration	C&I	15	CIBSE[99]
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

[95] https://www.federalregister.gov/documents/2019/06/18/2019-12761/energy-conservation-program-energy-conservation-standards-for-distribution-transformers

[96] https://www.kannahconsulting.com/wp-content/uploads/2016/08/2010-10-11_Battery_Charger_Title_20_CASE_Report_v2-2-2.pdf, pg 43

[97] 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

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

[99] Chartered Institution of Building Services Engineers. "Probabilistic Estimation of Service Life." An industrial ventilation system consists of a fan and a set of filters; Fan and Filter EUL are 15 to 20 years depending on type. http://www.cibse.org/knowledge/cibse-technical-symposium-2011/probabilistic-estimation-of-service-life.

Category	Commercial & Industrial Measures	Sector	EUL (years)	Source
Refrigeration - Control	Anti-Condensation Heater Control	C&I	12	DEER 2014 EUL ID: GrocDisp-ASH
	Condenser Pressure and Temperature Control	C&I	15	DEER 2014 EUL ID: GrocSys-Cndsr
	Evaporator Fan Control	C&I	16	DEER 2014 EUL ID: Groc-WlkIn-WEvapFMtrCtrl
	Floating Head Pressure Control	C&I	10	PA Consulting Group [100]

Common References

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

Record of Revision

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

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

Record of Revision Number	Issue Date
12-19-17	12/23/2019
3-20-17	3/30/2020
7-20-20	7/31/2020
12-20-12	12/31/2020
3-21-18	4/14/2021

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Heating, Ventilation and Air Conditioning (HVAC) – Control

Adaptive Photonic Control for HVAC Fan Motors

Measure Description

This measure covers the installation of adaptive photonic control systems applied to HVAC fan motors. Adaptive photonic control involves integration with an HVAC system's motors including PTACs, PTHPs, mini-splits, central air units and furnace distribution system supply fans. It enables adaptive speed control for single-speed AC fan motors using sensors by continuously adapting to end-user requirements. The controller uses photonic (opto-electronic) transducers and graphical apertures that are integrated into intelligent, signal and vector processors enabling their use as analog power controllers[101,102]. It provides an adaptive airflow solution by tracking air temperature and optimizing operation based on climate conditions. Savings accrue not only from the reduction of fan speed to match thermal delivery rates, but also through better air mixing in the space and more effective heat transfer on the coils when the system is in operation. By adjusting airflow to improve heat transfer, the controller improves whole system operating efficiency and significantly reduces compressor run times.

This measure is only applicable to adaptive photonic control integrated into single-speed AC induction fan motors rated up to 5 horsepower (HP) that do not have speed variability restriction (e.g., via centrifugal speed switch).[103,104] Savings estimated per this methodology may be claimed in retrofit applications as well as in new construction applications where electronically commutated (EC) motors are not otherwise required by federal, state, local or municipal codes or standards.

Method for Calculating Annual Energy and Peak Coincident Demand Savings

Annual Electric Energy Savings

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

$$\Delta kWh_{cooling} = units \times \frac{(W_{cooling} \times ESF)}{1{,}000} \times LF \times hrs_{cooling}$$

$$\Delta kWh_{heating} = units \times \frac{(W_{heating} \times ESF)}{1{,}000} \times LF \times hrs_{heating}$$

$$\Delta kWh_{fan} = units \times \frac{(W_{blowerfan} \times ESF)}{1{,}000} \times LF \times hrs_{fan}$$

101 IEEE Transactions on Industrial Electronics, 'A novel switched reluctance motor drive with optical graphical programming technology', 2000.
102 ACHR News, Fan Coil Units Get VSD, 2005
103 San Diego Gas & Electric, Work Paper WPSDGENRHC1051, Revision 1, Sept 2016
104 Comfort-Plus Drive™, Variable Speed Drive for Fan Coil Units, 2005

Note: ΔkWh_{fan} is only applicable if fan is set to on position during occupancy

Summer Peak Coincident Demand Savings

$$\Delta kW = units \times \frac{(W_{cooling} \times ESF)}{1{,}000} \times LF \times CF$$

Annual Fuel Energy Savings

$$\Delta MMBtu = units \times \frac{(kBtu/h_{in} \times ESF)}{1{,}000} \times LF \times hrs_{heating}$$

where:

$$W_{cooling} = W_{evaporator} + W_{compressor} + W_{condenser}$$

$$W_{heating} = W_{evaporator} + W_{ElecHeat}$$

$$W_{fanonly} = W_{blowerfan}$$

$$W_{evaporator} = V_{evaporator} \times A_{evaporator} \times PF$$

$$W_{compressor} = V_{compressor} \times A_{compressor} \times PF$$

$$W_{condenser} = V_{condenser} \times A_{condenser} \times PF$$

$$hrs_{fan} = hrs - (hrs_{cooling} + hrs_{heating})$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fuel energy savings
$\Delta kWh_{cooling}$	= Annual electric energy savings in cooling mode
$\Delta kWh_{heating}$	= Annual electric energy savings in heating mode
ΔkWh_{fan}	= Annual electric energy savings in fan only mode
units	= Number of measures installed under the program
$W_{cooling}$	= Retrofitted system peak wattage in cooling mode
$W_{heating}$	= Retrofitted system peak wattage in heating mode
$W_{evaporator}$	= Retrofitted system evaporator wattage, based on nameplate specifications
$W_{compressor}$	= Retrofitted system compressor wattage, based on nameplate specifications
$W_{condenser}$	= Retrofitted system condenser wattage, based on nameplate specifications
$W_{blowerfan}$	= Retrofitted system blower fan wattage, based on nameplate specifications
$W_{ElecHeat}$	= Retrofitted system electric resistance heating element wattage, based on nameplate specifications, where applicable
$V_{evaporator}$	= Retrofitted system evaporator voltage

$V_{compressor}$ = Retrofitted system compressor voltage
$V_{condenser}$ = Retrofitted system condenser voltage
$A_{evaporator}$ = Retrofitted system evaporator amps
$A_{compressor}$ = Retrofitted system compressor amps
$A_{condenser}$ = Retrofitted system condenser amps
PF = Power factor
$kBtu/h_{in}$ = Retrofitted system space heating input fuel rating (kBtu/h)
ESF = Energy savings factor
LF = Motor load factor
$hrs_{cooling}$ = Retrofitted system annual operating hours in cooling mode
$hrs_{heating}$ = Retrofitted system annual operating hours in heating mode
hrs_{fan} = Retrofitted system annual operating hours in fan only mode
hrs = Retrofitted system annual operating hours
CF = Coincidence factor
1,000 = Conversion factor, one kW equals 1,000 watts

Summary of Variables and Data Sources

Variable	Value	Notes
$W_{ElecHeat}$		From application.
$V_{evaporator}$		From application.
$V_{compressor}$		From application.
$V_{condenser}$		From application.
$A_{evaporator}$		From application.
$A_{compressor}$		From application.
$A_{condenser}$		From application.
PF	0.85	From Standard Handbook of Electrical Engineers[105] and the Engineering Toolbox.[106]
$kBtu/h_{in}$		From application.
ESF	0.30	Average of multiple validation tests.[107]
LF	0.9	Assumed value to reflect that motors do not typically run at 100% of rated power.
$hrs_{cooling}$		From application. If unknown, see Operating Hours section below.
$hrs_{heating}$		From application. If unknown, see Operating Hours section below.
hrs		From application.
CF	0.69	

[105] Standard Handbook for Electrical Engineers (McGraw-Hill Handbooks), Donald G. Fink, ISBN 10: 0070220050 / ISBN 13: 9780070220058, Published by McGraw-Hill Publishing Co., 1999
[106] Engineering Tool Box, Power Factors for Inductive Loads, https://www.engineeringtoolbox.com/power-factor-electrical-motor-d_654.html
[107] Aclectic, Adaptive Control Technologies, Validation Tests

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.69.[108]

Baseline Efficiencies from which Savings are Calculated

The baseline condition is a standard efficiency, single-speed AC induction motor in a direct-drive HVAC circulation (blower) fan application. Baseline wattage shall be derived from the nameplate rating of existing system components.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a single-speed AC induction motor with adaptive photonic control as described in the Measure Description section above in a direct-drive HVAC circulation (blower) fan application.

Operating Hours

Annual cooling mode, heating mode and total system operating hours shall be taken from application. If cooling and heating mode operating hours are unknown, look up from Appendix G (i.e., cooling and heating equivalent load full hours shall be used as proxy values for annual cooling mode and annual heating mode hours, respectively). Total system operating hours must be taken from application in all cases.

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

HVAC circulation fans with adaptive photonic controlled AC motors generate less heat during operation, resulting in decreased cooling loads and increased heating loads. These effects are captured in the prescribed methodology detailed above. The HVAC interaction factors calculated from the prototypical building DOE-2 models as a function of the building and HVAC system type are shown in Appendix D.

Ancillary Electric Savings Impacts

HVAC circulation fan with adaptive photonic controlled AC motors generate less heat during operation, resulting in decreased cooling loads and increased heating loads. These effects are captured in the prescribed methodology detailed above. The HVAC interaction factors calculated from the prototypical building DOE-2 models as a function of the building and HVAC system type are shown in Appendix D.

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

References

1. A novel switched reluctance motor drive with optical graphical programming technology, Clarkson University, P. Pillay; Yaguang Liu; O.G. Durham, IEEE Transactions on Industrial Electronics (Volume: 47, Issue: 4, Aug 2000).
   Available from: https://ieeexplore.ieee.org/document/857972
2. Fan Coil Units Get VSD, The Air Conditioning, Heating, Refrigeration News, 2005
   Available from: https://www.achrnews.com/articles/95898-fan-coil-units-get-vsd#:~:text=They%20are%20small%20air%2Dhandling,stacked%2C%20or%20installed%20horizontally%20overhead.
3. Guest Room PTAC/PTHP Adaptive Climate Controller, San Diego Gas & Electric, Energy Efficiency Engineering, Work Paper WPSDGENRHC1051, Revision 1, Sept 2016.
   Available from: http://www.deeresources.net/workpapers
4. Comfort-Plus Drive™, Variable Speed Drive for Fan Coil Units, Carrier Corporation, 2005
   Available from: https://dms.hvacpartners.com/docs/1003/Public/08/05-02-0501-01.pdf
5. Standard Handbook for Electrical Engineers (McGraw-Hill Handbooks), Donald G. Fink, ISBN 10: 0070220050 / ISBN 13: 9780070220058, Published by McGraw-Hill Publishing Co., 1999
6. Engineering Tool Box, Power Factors for Inductive Loads
   Available from: https://www.engineeringtoolbox.com/power-factor-electrical-motor-d_654.html
7. Multiple Validation Tests of Adaptive Photonic Technology Controller at (1) ConEdison, (2) Environmental Test Laboratory, (3) EME Consulting Engineers (NYSERDA), (4) SUNY Oneonta, (5) Tim Garrison (Third Party), (6) McQuay Cooling Tests, (7) Purdue University Tests and (8) ConEdison Tests by ERS.
   Available from: https://efbb029c-a900-4301-9ab1-40fc00b9e54e.filesusr.com/ugd/9cd7aa_186d85d0a69b4da4b69f07ea0d03eeff.pdf?index=true
8. BG&E: Development of Residential Load Profile for Central Air Conditioners and Heat Pumps

Record of Revision

Record of Revision Number	Issue Date
12-20-3	12/31/2020
3-21-21	4/14/2021

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HEATING, VENTILATION AND AIR CONDITIONING (HVAC) – CONTROL

STEAM TRAP – LOW PRESSURE SPACE HEATING

Measure Description

This measure covers the repair or replacement of steam traps in low-pressure (≤15 psig) steam space heating applications on existing residential steam systems served by fossil fuel-fired boilers. Steam systems distribute heat from boilers to satisfy space heating requirements. Steam distribution systems contain steam traps. Steam traps that fail may allow excess steam to escape, thus increasing the amount of steam that must be generated to meet end-use requirements. This measure is intended for the repair or replacement of steam traps only. This measure does not apply to municipal steam systems.

All traps are susceptible to wear and dirt contamination and require periodic inspection and maintenance to ensure correct operation. Faulty steam traps (leaking or blow-through) can be diagnosed with ultrasonic, temperature, or conductivity monitoring techniques. Regular steam trap maintenance and faulty steam trap replacement are steps that minimize steam production. There are three major types of steam traps that are applicable: 1) thermostatic (including float and thermostatic), 2) mechanical and 3) thermodynamic.

Method for Calculating Annual Energy and Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = N/A$$

Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fuel Energy Savings

$$\Delta MMBtu = units \times Loss_{steam} \times \frac{\Delta H_{vap}}{Eff} \times \frac{hrs}{1{,}000{,}000} \times F_{CR}$$

$$Loss_{steam} = 60 \times \frac{\pi}{4} \times Dia^2 \times psia^{0.97} \times F_{Discharge} \times F_{Loss}$$

$$psia = psig + p_{atm}$$

where:

ΔkWh = Annual electric energy savings
ΔkW = Peak coincident demand electric savings
ΔMMBtu = Annual fuel energy savings
units = Number of steam traps repaired/replaced under the program
$Loss_{steam}$ = Hourly steam loss per failed trap (lb/hr)

ΔH_{vap} = Heat of vaporization (latent heat), in BTU/lb, at system operating pressure (psig)
Eff = Efficiency of boiler
hrs = Annual hours trap pressurized
F_{CR} = Condensate Return Factor, used to account for the proportion of energy lost that is returned to the system via condensate line
Dia = Internal Diameter (I.D.) of steam trap orifice (inches)
psia = Absolute steam pressure (psi)
$F_{Discharge}$ = Discharge coefficient
F_{Loss} = Steam loss adjustment factor
psig = Steam gage pressure (psi)
p_{atm} = Atmospheric pressure (psi)
60 = An empirically derived constant in the Grashof's equation (lb_m/ $in^{0.06}$-$lb^{0.97}$-hr)[109]
$\pi/4$ = Orifice area development factor
0.97 = An empirically derived constant in the Grashof equation[110]
1,000,000 = Conversion from Btu to MMBtu (100,000 Btu/MMBtu)

Summary of Variables and Data Sources

Variable	Value	Notes
$Loss_{steam}$		Calculated per the equation above, dependent upon system operating pressure (psig), steam trap orifice diameter (Dia) and steam loss adjustment factor (F_{Loss}).
ΔH_{vap}		Look up from table below based on system operating pressure (psig).
Eff		Boiler efficiency, from application. Either E_t or AFUE shall be used, based on nameplate rating metric of existing equipment or actual system efficiency as provided on the application and documented by the customer.
hrs		From application.
$F_{Discharge}$	0.7	Based on Massachusetts Steam Trap Evaluation[111]
F_{CR}	Condensate Return: 0.45 No Condensate Return: 1.00	Based on ERS memo to NYSEG/RG&E[112]
Dia		From application.
psia		Calculated per the equation above, dependent upon system operating pressure (psia).
F_{Loss}	0.37	Based on Massachusetts Steam Trap Evaluation[113]

[109] Massachusetts Program Administrators and Energy Efficiency Advisory Council, "Steam Trap Evaluation Phase 2" March 8, 2017. pg 6
[110] Ibid.
[111] Ibid, pg 7
[112] ERS Memo to NYSEG/RG&E, "Recommendations to Update Algorithms for C&I Steam Trap Repair Energy Savings in NY TRM Introduction", October 10, 2019
[113] Massachusetts Program Administrators and Energy Efficiency Advisory Council, "Steam Trap Evaluation Phase 2". March 8, 2017. Table 4-7

Variable	Value	Notes
psig		From application.
P_{atm}	14.7	Atmospheric pressure (14.7 psi).

Heat of Vaporization (Btu/lb)[114]

Pressure (psig)	Heat of Vaporization (Btu/lb)
0	970
1	968
2	966
3	964
4	962
5	961
6	959
7	957
8	956
9	954
10	953
11	951
12	950
13	948
14	947
15	946

Coincidence Factor (CF)

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

Baseline Efficiencies from which Savings are Calculated

The baseline condition is a leaking or blow-through steam trap on a low-pressure steam space heating system.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is an intact (replaced or repaired) steam trap on a low-pressure steam space heating system. Replaced or repaired steam traps will no longer leak or blow-through after installation.

Operating Hours

Annual pressurized hours shall be established based on actual operation.

[114] Thermodynamic Properties of Steam Including Data for the Liquid and Solid Phases (1936)

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. ERS Memo to NYSEG/RG&E, "Recommendations to Update Algorithms for C&I Steam Trap Repair Energy Savings in NY TRM Introduction", October 10, 2019
2. Joseph Henry Keenan and Frederick G. Keyes, Thermodynamic Properties of Steam Including Data for the Liquid and Solid Phases, John Wiley and Sons, New York (1936)

Record of Revision

Record of Revision Number	Issue Date
6-18-19	6/30/2018
3-20-2	3/30/2020
3-21-22	4/14/2021

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HEATING, VENTILATION AND AIR CONDITIONING (HVAC) – CONTROL

ADAPTIVE PHOTONIC CONTROL FOR HVAC FAN MOTORS

Measure Description

This measure covers the installation of adaptive photonic control systems applied to HVAC fan motors. Adaptive photonic control involves integration with an HVAC system's motors including PTACs, PTHPs, mini-splits, central air units and furnace distribution system supply fans. It enables adaptive speed control for single-speed AC fan motors using sensors by continuously adapting to end-user requirements. The controller uses photonic (opto-electronic) transducers and graphical apertures that are integrated into intelligent, signal and vector processors enabling their use as analog power controllers[115,116]. It provides an adaptive airflow solution by tracking air temperature and optimizing operation based on climate conditions. Savings accrue not only from the reduction of fan speed to match thermal delivery rates, but also through better air mixing in the space and more effective heat transfer on the coils when the system is in operation. By adjusting airflow to improve heat transfer, the controller improves whole system operating efficiency and significantly reduces compressor run times.

This measure is only applicable to adaptive photonic control integrated into single-speed AC induction fan motors rated up to 5 horsepower (HP) that do not have speed variability restriction (e.g., via centrifugal speed switch).[117,118] Savings estimated per this methodology may be claimed in retrofit applications as well as in new construction applications where electronically commutated (EC) motors are not otherwise required by federal, state, local or municipal codes or standards.

Method for Calculating Annual Energy and Peak Coincident Demand Savings

Annual Electric Energy Savings

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

$$\Delta kWh_{cooling} = units \times \frac{(W_{cooling} \times ESF)}{1{,}000} \times LF \times hrs_{cooling}$$

$$\Delta kWh_{heating} = units \times \frac{(W_{heating} \times ESF)}{1{,}000} \times LF \times hrs_{heating}$$

$$\Delta kWh_{fan} = units \times \frac{(W_{blowerfan} \times ESF)}{1{,}000} \times LF \times hrs_{fan}$$

Note: ΔkWh_{fan} is only applicable if fan is set to on position during occupancy

[115] IEEE Transactions on Industrial Electronics, 'A novel switched reluctance motor drive with optical graphical programming technology', 2000.
[116] ACHR News, Fan Coil Units Get VSD, 2005
[117] San Diego Gas & Electric, Work Paper WPSDGENRHC1051, Revision 1, Sept 2016
[118] Comfort-Plus Drive™, Variable Speed Drive for Fan Coil Units, 2005

Summer Peak Coincident Demand Savings

$$\Delta kW = units \times \frac{(W_{cooling} \times ESF)}{1{,}000} \times LF \times CF$$

Annual Fuel Energy Savings

$$\Delta MMBtu = units \times \frac{(kBtu/h_{in} \times ESF)}{1{,}000} \times LF \times hrs_{heating}$$

where:

$$W_{cooling} = W_{evaporator} + W_{compressor} + W_{condenser}$$

$$W_{heating} = W_{evaporator} + W_{ElecHeat}$$

$$W_{fanonly} = W_{blowerfan}$$

$$W_{evaporator} = V_{evaporator} \times A_{evaporator} \times PF$$

$$W_{compressor} = V_{compressor} \times A_{compressor} \times PF$$

$$W_{condenser} = V_{condenser} \times A_{condenser} \times PF$$

$$hrs_{fan} = hrs - (hrs_{cooling} + hrs_{heating})$$

where:

ΔkWh = Annual electric energy savings
ΔkW = Peak coincident demand electric savings
ΔMMBtu = Annual fuel energy savings
$\Delta kWh_{cooling}$ = Annual electric energy savings in cooling mode
$\Delta kWh_{heating}$ = Annual electric energy savings in heating mode
ΔkWh_{fan} = Annual electric energy savings in fan only mode
units = Number of measures installed under the program
$W_{cooling}$ = Retrofitted system peak wattage in cooling mode
$W_{heating}$ = Retrofitted system peak wattage in heating mode
$W_{evaporator}$ = Retrofitted system evaporator wattage, based on nameplate specifications
$W_{compressor}$ = Retrofitted system compressor wattage, based on nameplate specifications
$W_{condenser}$ = Retrofitted system condenser wattage, based on nameplate specifications
$W_{blowerfan}$ = Retrofitted system blower fan wattage, based on nameplate specifications
$W_{ElecHeat}$ = Retrofitted system electric resistance heating element wattage, based on nameplate specifications, where applicable
$V_{evaporator}$ = Retrofitted system evaporator voltage
$V_{compressor}$ = Retrofitted system compressor voltage
$V_{condenser}$ = Retrofitted system condenser voltage

$A_{evaporator}$ = Retrofitted system evaporator amps
$A_{compressor}$ = Retrofitted system compressor amps
$A_{condenser}$ = Retrofitted system condenser amps
PF = Power factor
$kBtu/h_{in}$ = Retrofitted system space heating input fuel rating (kBtu/h)
ESF = Energy savings factor
LF = Motor load factor
$hrs_{cooling}$ = Retrofitted system annual operating hours in cooling mode
$hrs_{heating}$ = Retrofitted system annual operating hours in heating mode
hrs_{fan} = Retrofitted system annual operating hours in fan only mode
hrs = Retrofitted system annual operating hours
CF = Coincidence factor
1,000 = Conversion factor, one kW equals 1,000 watts

Summary of Variables and Data Sources

Variable	Value	Notes
$W_{ElecHeat}$		From application.
$V_{evaporator}$		From application.
$V_{compressor}$		From application.
$V_{condenser}$		From application.
$A_{evaporator}$		From application.
$A_{compressor}$		From application.
$A_{condenser}$		From application.
PF	0.85	From Standard Handbook of Electrical Engineers[119] and the Engineering Toolbox.[120]
$kBtu/h_{in}$		From application.
ESF	0.30	Average of multiple validation tests.[121]
LF	0.9	Assumed value to reflect that motors do not typically run at 100% of rated power.
$hrs_{cooling}$		From application. If unknown, see Operating Hours section below.
$hrs_{heating}$		From application. If unknown, see Operating Hours section below.
hrs		From application. If unknown, see Operating Hours section below.
CF	0.8	

[119] Standard Handbook for Electrical Engineers (McGraw-Hill Handbooks), Donald G. Fink, ISBN 10: 0070220050 / ISBN 13: 9780070220058, Published by McGraw-Hill Publishing Co., 1999
[120] Engineering Tool Box, Power Factors for Inductive Loads, https://www.engineeringtoolbox.com/power-factor-electrical-motor-d_654.html
[121] Aclectic, Adaptive Control Technologies, Validation Tests

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.8.[122]

Baseline Efficiencies from which Savings are Calculated

The baseline condition is a standard efficiency, single-speed AC induction motor in a direct-drive HVAC circulation (blower) fan application. Baseline wattage shall be derived from the nameplate rating of existing system components.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a single-speed AC induction motor with adaptive photonic control as described in the Measure Description section above in a direct-drive HVAC circulation (blower) fan application.

Operating Hours

Annual cooling mode, heating mode and total system operating hours shall be taken from application. If the operating hours are unknown, look up cooling and heating mode operating hours from Appendix G (i.e., cooling and heating equivalent load full hours shall be used as proxy values for annual cooling mode and annual heating mode hours, respectively). If the circulation fan is set to on during facility operation, look up total system operating hours by building type from the table below.

Facility Type	Hours (hrs/yr)	HVAC Int	Facility Type	Hours (hrs/yr)	HVAC Int
Auto Related*	2,810	AR	Manufacturing Facility	2,857	Ind
Automotive / Transportation Service or Repair Facility (24/7)	8,760	AR	Medical Offices	3,748	SOfc
Bakery	2,854	FS	Motion Picture Theatre	1,954	Asy
Banks	3,748	SOfc	Multi-Family (Common Areas)	7,665	MFL
Church	1,955	Rel	Museum	3,748	Asy
College – Cafeteria**	2,713	FS	Nursing Homes	5,840	MFL
College – Classes	2,586	CC	Office (General Office Types)**	3,013	SOfc/ LOfc
College - Dormitory	3,066	Dorm	Parking Garages	4,368	None
Commercial Condos***	3,100	SOfc	Parking Garages (24/7)	7,717	None
Convenience Stores	6,376	SRet	Parking Lots	4,100	None
Convention Center	1,954	Asy	Penitentiary	5,477	MFL
Court House	3,748	LOfc	Performing Arts Theatre	2,586	Asy
Dining: Bar Lounge/Leisure	4,182	FS	Police / Fire Stations (24 Hr)	7,665	Asy
Dining: Cafeteria / Fast Food	6,456	FF	Post Office	3,748	SRet

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

Facility Type	Hours (hrs/yr)	HVAC Int	Facility Type	Hours (hrs/yr)	HVAC Int
Dining: Family	4,182	FS	Pump Stations	1,949	Ind
Entertainment	1,952	Asy	Refrigerated Warehouse	2,602	RWH
Exercise Center	5,836	SRet	Religious Building	1,955	Rel
Fast Food Restaurants	6,376	FF	Restaurants	4,182	FS
Fire Station (Unmanned)	1,953	Asy	Retail	3,463	SRet/ LRet
Food Stores	4,055	Gro	School / University	2,187	Univ
Gymnasium	2,586	Asy	Schools (Jr./Sr. High)	2,187	HS
Hospitals	7,674	Hosp	Schools (Preschool/Elementary)	2,187	Sch
Hospitals / Health Care	7,666	Hosp	Schools (Technical/Vocational)	2,187	CC
Industrial - 1 Shift	2,857	Ind	Small Services	3,750	SOfc
Industrial - 2 Shift	4,730	Ind	Sports Arena	1,954	Asy
Industrial - 3 Shift	6,631	Ind	Town Hall	3,748	Asy
Laundromats	4,056	SRet	Transportation	6,456	Asy
Library	3,748	LOfc	Warehouse (Not Refrigerated)	2,602	WH
Light Manufacturers**	2,613	Ind	Waste Water Treatment Plant	6,631	Ind
Lodging (Hotels/Motels)	3,064	Hotel/ Motel	Workshop	3,750	Ind
Mall Concourse	4,833	LRet			

* New car showrooms and Big Box retail stores with evening and/or weekend hours should use the Facility Type "Retail" for lighting operating hours.
** Lighting operating hours data from the 2008 California DEER Update study
*** Lighting operating hours data for offices used

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

HVAC circulation fans with adaptive photonic controlled AC motors generate less heat during operation, resulting in decreased cooling loads and increased heating loads. These effects are captured in the prescribed methodology detailed above. The HVAC interaction factors calculated from the prototypical building DOE-2 models as a function of the building and HVAC system type are shown in Appendix D.

Ancillary Electric Savings Impacts

HVAC circulation fan with adaptive photonic controlled AC motors generate less heat during operation, resulting in decreased cooling loads and increased heating loads. These effects are captured in the prescribed methodology detailed above. The HVAC interaction factors calculated from the prototypical building DOE-2 models as a function of the building and HVAC system type are shown in Appendix D.

References

1. A novel switched reluctance motor drive with optical graphical programming technology, Clarkson University, P. Pillay; Yaguang Liu; O.G. Durham, IEEE Transactions on Industrial Electronics (Volume: 47, Issue: 4, Aug 2000).
   Available from: https://ieeexplore.ieee.org/document/857972
2. Fan Coil Units Get VSD, The Air Conditioning, Heating, Refrigeration News, 2005
   Available from: https://www.achrnews.com/articles/95898-fan-coil-units-get-vsd#:~:text=They%20are%20small%20air%2Dhandling,stacked%2C%20or%20installed%20horizontally%20overhead.
3. Guest Room PTAC/PTHP Adaptive Climate Controller, San Diego Gas & Electric, Energy Efficiency Engineering, Work Paper WPSDGENRHC1051, Revision 1, Sept 2016.
   Available from: http://www.deeresources.net/workpapers
4. Comfort-Plus Drive™, Variable Speed Drive for Fan Coil Units, Carrier Corporation, 2005
   Available from: https://dms.hvacpartners.com/docs/1003/Public/08/05-02-0501-01.pdf
5. Standard Handbook for Electrical Engineers (McGraw-Hill Handbooks), Donald G. Fink, ISBN 10: 0070220050 / ISBN 13: 9780070220058, Published by McGraw-Hill Publishing Co., 1999
6. Engineering Tool Box, Power Factors for Inductive Loads
   Available from: https://www.engineeringtoolbox.com/power-factor-electrical-motor-d_654.html
7. Multiple Validation Tests of Adaptive Photonic Technology Controller at (1) ConEdison, (2) Environmental Test Laboratory, (3) EME Consulting Engineers (NYSERDA), (4) SUNY Oneonta, (5) Tim Garrison (Third Party), (6) McQuay Cooling Tests, (7) Purdue University Tests and (8) ConEdison Tests by ERS.
   Available from: https://efbb029c-a900-4301-9ab1-40fc00b9e54e.filesusr.com/ugd/9cd7aa_186d85d0a69b4da4b69f07ea0d03eeff.pdf?index=true

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12-20-7	12/31/2020
3-21-23	4/14/2021

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HEATING, VENTILATION AND AIR CONDITIONING (HVAC) – CONTROL

STEAM TRAP – LOW PRESSURE SPACE HEATING

Measure Description

This measure covers the repair or replacement of steam traps in low-pressure (≤15 psig) steam space heating applications on existing commercial steam systems served by fossil fuel-fired boilers. Steam systems distribute heat from boilers to satisfy space heating requirements. Steam distribution systems contain steam traps. Steam traps that fail may allow excess steam to escape, thus increasing the amount of steam that must be generated to meet end-use requirements. This measure is intended for the repair or replacement of steam traps only. This measure does not apply to municipal steam systems.

All traps are susceptible to wear and dirt contamination and require periodic inspection and maintenance to ensure correct operation. Faulty steam traps (leaking or blow-through) can be diagnosed with ultrasonic, temperature, or conductivity monitoring techniques. Regular steam trap maintenance and faulty steam trap replacement are steps that minimize steam production. There are three major types of steam traps that are applicable: 1) thermostatic (including float and thermostatic), 2) mechanical and 3) thermodynamic.

Method for Calculating Annual Energy and Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = N/A$$

Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fuel Energy Savings

$$\Delta MMBtu = units \times Loss_{steam} \times \frac{\Delta H_{vap}}{Eff} \times \frac{hrs}{1{,}000{,}000} \times F_{CR}$$

$$Loss_{steam} = 60 \times \frac{\pi}{4} \times Dia^2 \times psia^{0.97} \times F_{Discharge} \times F_{Loss}$$

$$psia = psig + p_{atm}$$

where:

ΔkWh = Annual electric energy savings
ΔkW = Peak coincident demand electric savings
ΔMMBtu = Annual fuel energy savings
units = Number of steam traps repaired/replaced under the program
$Loss_{steam}$ = Hourly steam loss per failed trap (lb/hr)

ΔH_{vap}	= Heat of vaporization (latent heat), in BTU/lb, at system operating pressure (psig)
Eff	= Efficiency of boiler
hrs	= Annual hours trap pressurized
F_{CR}	= Condensate Return Factor, used to account for the proportion of energy lost that is returned to the system via condensate line
Dia	= Internal Diameter (I.D.) of steam trap orifice (inches)
psia	= Absolute steam pressure (psi)
$F_{Discharge}$	= Discharge coefficient
F_{Loss}	= Steam loss adjustment factor
psig	= Steam gage pressure (psi)
p_{atm}	= Atmospheric pressure (psi)
60	= An empirically derived constant in the Grashof's equation (lb_m/ $in^{0.06}$-$lb^{0.97}$-hr)[123]
π/4	= Orifice area development factor
0.97	= An empirically derived constant in the Grashof equation[124]
1,000,000	= Conversion from Btu to MMBtu (1,000,000 Btu/MMBtu)

Summary of Variables and Data Sources

Variable	Value	Notes
$Loss_{steam}$		Calculated per the equation above, dependent upon system operating pressure (psig), steam trap orifice diameter (Dia) and steam loss adjustment factor (F_{Loss}).
ΔH_{vap}		Look up from table below based on system operating pressure (psig).
Eff		Boiler efficiency, from application. Either E_t or AFUE shall be used, based on nameplate rating metric of existing equipment or actual system efficiency as provided on the application and documented by the customer.
hrs		From application. If unknown, use 2,525 as a default.[125]
$F_{Discharge}$	0.7	Based on Massachusetts Steam Trap Evaluation[126]
F_{CR}	Condensate Return: 0.45 No Condensate Return: 1.00	Based on ERS memo to NYSEG/RG&E[127]
Dia		From application.
psia		Calculated per the equation above, dependent upon system operating pressure (psia).
F_{Loss}	0.37	Based on Massachusetts Steam Trap Evaluation[128]

[123] Massachusetts Program Administrators and Energy Efficiency Advisory Council, "Steam Trap Evaluation Phase 2" March 8, 2017. pg 6
[124] Ibid.
[125] ERS, "Two-Tier Steam Trap Savings Study", April 26, 2018. pg 5
[126] Ibid, pg 7
[127] ERS Memo to NYSEG/RG&E, "Recommendations to Update Algorithms for C&I Steam Trap Repair Energy Savings in NY TRM Introduction", October 10, 2019
[128] Massachusetts Program Administrators and Energy Efficiency Advisory Council, "Steam Trap Evaluation Phase 2" Table 4-7, March 8, 2017.

Variable	Value	Notes
psig		From application.
P_{atm}	14.7	Atmospheric pressure (14.7 psi).

Heat of Vaporization (Btu/lb)[129]

Pressure (psig)	Heat of Vaporization (Btu/lb)
0	970
1	968
2	966
3	964
4	962
5	961
6	959
7	957
8	956
9	954
10	953
11	951
12	950
13	948
14	947
15	946

Coincidence Factor (CF)

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

Baseline Efficiencies from which Savings are Calculated

The baseline condition is a leaking or blow-through steam trap on a low-pressure steam space heating system.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is an intact (replaced or repaired) steam trap on a low-pressure steam space heating system. Replaced or repaired traps will no longer leak or blow-through after installation.

Operating Hours

Annual pressurized hours shall be established based on actual operation when feasible. When unknown, the default of 2,525 hours identified for low pressure steam trap operating conditions of sample sites described in MA's steam trap evaluation shall be used.[130]

[129] Thermodynamic Properties of Steam Including Data for the Liquid and Solid Phases (1936)
[130] ERS, "Two-Tier Steam Trap Savings Study", April 26, 2018. pg 5

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. Massachusetts Program Administrators and Energy Efficiency Advisory Council, "Steam Trap Evaluation Phase 2", March 8, 2017.
   Available from: http://www.ripuc.ri.gov/eventsactions/docket/4755-TRM-MA%20CIEC%20P59%20Steam%20Trap%20Evaluation%20Report%20FINAL%2020170308.pdf
2. ERS, "Two-Tier Steam Trap Savings Study", April 26, 2018
   Available from: https://api-plus.anbetrack.com/etrm-gateway/etrm/api/v1/etrm/documents/5ee4886f6996f22b867df794/view?authToken=bb7e8bd0f9ae7708c589a0742f8f62fdb14916a2ddcb02e3ca0cfffb741c830196cae58cbc266586c734602d97f8efed3e8f602559fd43c6cb8b8e08597356f32fefb1d3bdea07
3. ERS Memo to NYSEG/RG&E, "Recommendations to Update Algorithms for C&I Steam Trap Repair Energy Savings in NY TRM Introduction", October 10, 2019
4. Joseph Henry Keenan and Frederick G. Keyes, Thermodynamic Properties of Steam Including Data for the Liquid and Solid Phases, John Wiley and Sons, New York (1936)

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6-17-14	6/30/2017
3-20-10	3/30/2020
3-21-24	4/14/2021

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HEATING, VENTILATION AND AIR CONDITIONING (HVAC) - CONTROL

STEAM TRAP MONITORING SYSTEM – LOW PRESSURE SPACE HEATING

Measure Description

Many facilities that contain steam systems only perform steam trap surveys once a year. This can result in significant steam loss if a steam trap actively fails sometime between annual audits. This measure covers the installation of automatic steam trap monitoring systems, which alert maintenance personnel to failed steam traps, enabling rapid repair or replacement. Individual sensors on steam traps can feed data to a hub that displays the status of each monitored steam trap. Energy savings are based on elimination of steam trap losses occurring before the annual maintenance inspection for leaking or failed steam traps. Annual maintenance audits are expected to continue as usual post-implementation. Savings are calculated similarly to regular steam trap replacement, but due to the presence of the monitoring software, this measure has longer lifetime savings.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = N/A$$

Summer Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fuel Energy Savings

$$\Delta MMBtu = units \times Loss_{steam} \times \frac{\Delta H_{vap}}{Eff} \times \frac{hrs}{1{,}000{,}000} \times F_{hrs} \times F_{Failed} \times F_{CR}$$

$$Loss_{steam} = 60 \times \frac{\pi}{4} \times Dia^2 \times psia^{0.97} \times F_{Discharge} \times F_{Loss}$$

$$psia = psig + p_{atm}$$

where:

ΔkWh = Annual electric energy savings
ΔkW = Peak coincident demand electric savings
ΔMMBtu = Annual fuel energy savings
units = Number of steam traps repaired/replaced under the program
$Loss_{steam}$ = Hourly steam loss per failed trap (lb/hr)
ΔH_{vap} = Heat of vaporization (latent heat), in BTU/lb, at system operating pressure (psig)
Eff = Efficiency of boiler
hrs = Annual hours trap pressurized
F_{failed} = The percentage of steam traps that fail annually

F_{hrs} = Percentage of annual hours that steam traps are failed
Dia = Internal Diameter (I.D.) of steam trap orifice (inches)
psia = Absolute steam pressure (psi)
$F_{Discharge}$ = Discharge coefficient
F_{CR} = Condensate return factor, used to account for the proportion of energy lost that is returned to the system via condensate line
F_{Loss} = Steam loss adjustment factor
psig = Steam gage pressure (psi)
p_{atm} = Atmospheric pressure (psi)
60 = An empirically derived constant in the Grashof's equation ($lb_m / in^{0.06}$-$lb^{0.97}$-hr)[131]
π/4 = Orifice area development factor
0.97 = An empirically derived constant in the Grashof equation[132]
1,000,000 = Conversion factor (BTU/MMBtu), one MMBtu equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
$Loss_{steam}$		Calculated per the equation above, dependent upon system operating pressure (psig), steam trap orifice diameter (Dia) and steam loss adjustment factor (F_{Loss}).
ΔH_{vap}		Look up from table below based on system operating pressure (psig).
Eff		Boiler efficiency, from application. Either E_t or AFUE shall be used, based on nameplate rating metric of existing equipment or actual system efficiency as provided on the application and documented by the customer.
hrs		From application. If unknown, use 2,525 as a default.[133]
$F_{Discharge}$	0.7	Based on Massachusetts Steam Trap Evaluation[134]
F_{Failed}		From application, based upon historical data for facility, if unknown assume 0.15.[135,136,137]
F_{hrs}	0.5	Assumes steam traps would fail for 50% of annual operating hours without monitoring system

[131] Massachusetts Program Administrators and Energy Efficiency Advisory Council, "Steam Trap Evaluation Phase 2" March 8, 2017. pg 6
[132] Ibid.
[133] ERS, "Two-Tier Steam Trap Savings Study", April 26, 2018. pg 5
[134] Ibid, pg 7
[135] Average annual failure rate based upon EUL of 6 years
[136] Emerson whitepaper 00840-0200-4708, "Impact of failed steam traps on process plants", Rev AA, April 2013. p 4.
[137] U.S. DOE, Energy Tips: Steam, Inspect and Repair Steam Traps, Steam Tip Sheet #1, DOE/GO-102012-3401, January 2012

Variable	Value	Notes
F_{CR}	Condensate Return: 0.45 No Condensate Return: 1.00	Based on ERS memo to NYSEG/RG&E[138]
Dia		From application.
psia		Calculated per the equation above, dependent upon system operating pressure (psia).
F_{Loss}	0.37	Based on Massachusetts Steam Trap Evaluation[139]
psig		From application.
P_{atm}	14.7	Atmospheric pressure (14.7 psi).

Heat of Vaporization (Btu/lb)[140]

Pressure (psig)	Heat of Vaporization (Btu/lb)
0	970
1	968
2	966
3	964
4	962
5	961
6	959
7	957
8	956
9	954
10	953
11	951
12	950
13	948
14	947
15	946

Coincidence Factor (CF)

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

Baseline Efficiencies from which Savings are Calculated

The baseline condition is a steam distribution system without a steam trap monitoring system.

[138] ERS Memo to NYSEG/RG&E, "Recommendations to Update Algorithms for C&I Steam Trap Repair Energy Savings in NY TRM Introduction", October 10, 2019. The CR factor is used to account for some of the steam energy being returned to the system rather than being vented into the atmosphere.
[139] Massachusetts Program Administrators and Energy Efficiency Advisory Council, "Steam Trap Evaluation Phase 2" Table 4-7, March 8, 2017.
[140] Thermodynamic Properties of Steam Including Data for the Liquid and Solid Phases (1936)

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a steam distribution system with a steam trap monitoring system.

Operating Hours

Annual pressurized hours shall be established based on actual operation when feasible. When unknown, the default of 2,525 hours identified for low pressure steam trap operating conditions of sample sites described in MA's steam trap evaluation shall be used.[141]

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

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

Ancillary Electric Savings Impacts

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

References

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2. ERS, "Two-Tier Steam Trap Savings Study", April 26, 2018
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3. ERS Memo to NYSEG/RG&E, "Recommendations to Update Algorithms for C&I Steam Trap Repair Energy Savings in NY TRM Introduction", October 10, 2019
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6. US Department of Energy, Energy Tips: Steam, Inspect and Repair Steam Trap", Steam Tip Sheet #1, January 2012
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[141] ERS, "Two-Tier Steam Trap Savings Study", April 26, 2018. pg 5

Record of Revisions

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3-21-25	4/14/2021

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