Table of Revisions/Changes

Revision Number	Addition/ Revision	Issue Date	Effective Date	Measure	Description of Change	Location/Page in TRM
12-21-02	R	01/28/2022	01/01/2023	R/MF Refrigerator and Freezer Recycling	Measure Description expanded to include Compact Refrigerators and Freezers; Added default values for Compact Refrigerator and Freezers	Pg. 57
12-21-07	R	01/28/2022	01/01/2023	R/MF Steam Trap - Low Pressure Space Heating	Revised Measure Description to restrict application to failed open steam traps and to require steam trap assessment; Updated algorithm, variables and definitions to include consideration of annual hours steam traps failed; Updated condensate return factor	Pg. 286
12-21-08	R	01/28/2022	01/01/2023	R/MF Pool Pump	Measure Description expanded to allow aboveground pool pumps; Added default values associated with aboveground pool pumps; Updated Compliance Efficiency to reflect updated ENERGY STAR® standard	Pg. 336
12-21-09	R	01/28/2022	01/01/2023	R/MF Solar Pool Heater	Updated Measure Description requiring existing pump system to be retained; Removed algorithm, variable terms, and defaults associated with pump impacts; Updated algorithm to include baseline electric pool heater savings	Pg. 354
12-21-11	R	01/28/2022	01/01/2023	C/I Oven, Steamer, Fryer, and Griddle	Updated preheat hours and energy consumption default values and sources; Recalculated deemed savings values	Pg. 448
12-21-12	R	01/28/2022	01/01/2023	C/I Refrigerators and Freezers	Added baseline assumption for laboratory grade equipment; Corrected baseline consumption equation for ultra-low temperature freezers;	Pg. 459
12-21-18	R	01/28/2022	01/01/2023	C/I Steam Trap - Low Pressure Space Heating	Revised Measure Description to restrict application to failed open steam traps and to require steam trap assessment; Updated algorithm, variables and definitions to include consideration of annual hours steam traps failed; Updated condensate return factor	Pg. 803

Revision Number	Addition/ Revision	Issue Date	Effective Date	Measure	Description of Change	Location/Page in TRM
12-21-19	R	01/28/2022	01/01/2023	C/I Steam Trap Monitoring System - Low Pressure Space Heating	Revised Measure Description to clarify savings associated with repair/replacement of failed open steam traps; Updated units to reflect all connected steam traps; Updated condensate return factor	Pg. 808
12-21-23	R	01/28/2022	01/01/2023	C/I Steam Trap - Other Application	Revised Measure Description to restrict application to failed open steam traps and to require steam trap assessment; Updated algorithm, variables and definitions to include consideration of annual hours steam traps failed; Updated condensate return factor	Pg. 919
12-21-24	R	01/28/2022	01/01/2023	C/I Steam Trap Monitoring System - Other Applications	Revised Measure Description to clarify savings associated with repair/replacement of failed open steam traps; Updated units to reflect all connected steam traps; Updated condensate return factor	Pg. 925
12-21-25	R	01/28/2022	01/28/2022	Appendix P	Updated EUL entries for all measures contained in this Record of Revision	Pg. 1,271

Note: Revisions and additions to the measures listed above were undertaken by the Joint Utilities Technical Resource Manual (TRM) Management Committee between August 30, 2021 – January 28, 2022.

APPLIANCE RECYCLING

REFRIGERATOR AND FREEZER RECYCLING

Measure Description

In many cases, when a refrigerator or freezer is replaced by a homeowner, the existing unit is retained, sold or donated for use elsewhere, representing additional load on the grid. This measure covers recycling of the existing, functional equipment, thereby eliminating the consumption associated with that equipment. Refrigerator and freezer recycling programs (also called "bounty" programs) receive energy savings credit for permanently removing inefficient, functional refrigerators and freezers from the electric grid.

This measure covers the recycling of primary (i.e. installed in a kitchen) and secondary (i.e. installed elsewhere) refrigerators, refrigerator-freezers and freezers. To account for the fact that secondary equipment is occasionally installed and operating for only part of the year, a part-time use adjustment factor has been developed and embedded within the gross savings estimate for secondary units to establish average annual per unit deemed electric savings.

This measure also covers the recycling of equipment classified by the Code of Federal Regulations as "Compact refrigerator/refrigerator-freezer/freezer". This refers to any refrigerator, refrigerator-freezer or freezer with a total refrigerated volume of less than 7.75 ft^3 (220 liters), where the total refrigerated volume has been determined in accordance with the procedure prescribed in Appendix A (refrigerators and refrigerator-freezers) or B (freezers) of 10 CFR 430 Subpart B.[1]

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

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

Summer Peak Coincident Demand Savings

$$\Delta kW = units \times \left(\frac{\Delta kWh}{8{,}760}\right) \times TAF \times LSAF \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = N/A$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures recycled under the program
(ΔkWh/unit)	= Gross deemed annual electric savings per unit
TAF	= Temperature Adjustment Factor

[1] 10 CFR 430.2

LSAF	= Load Shape Adjustment Factor
CF	= Coincidence Factor
8,760	= Hours in one year

Summary of Variables and Data Sources

There are several conditions that impact the estimated savings available from a refrigerator and/or freezer-recycling program. Factors such as the average type, make, model, size, and age of units recycled significantly impact the savings. Variances in these conditions have a significant impact of the level of savings that can be achieved. In addition, the average number of hours these units are plugged in and operating impact savings. Likewise, the environmental and operational conditions also impact the energy savings. These variables make establishing a projected engineering-based calculation approach for per unit savings a complex task that is prone to error because of the effects of the compounding uncertainty associated with the potential variance within each of the key estimation variables. However, savings projections in this measure are based on impact evaluations completed in New York State conducted in compliance with the National Renewable Energy Laboratory's Uniform Methods Project (UMP) Refrigerator Recycling Evaluation Protocol.[2]

The following deemed energy impact estimates shall be used in New York for refrigerator and freezer recycling programs.

Variable	Value	Notes
(ΔkWh/unit)	Primary Refrigerator: 958 Secondary Refrigerator: 581 Freezer: 593 Compact Refrigerators, Refrigerator-Freezers and Freezers: See table below	Refrigerator and Freezer based on Appliance Recycling Program Impact Evaluation.[3]
TAF	1.22	Temperature Adjustment Factor; reflects load variance during summer peak due to increased ambient temperature conditions.[4]
LSAF	1.06	Load Shape Adjustment Factor; reflects the instantaneous differential from annual average load coincident with peak.[5]
CF	1.0	

For equipment classified by the Code of Federal Regulations as "Compact refrigerator/refrigerator-freezer/freezer", ΔkWh/unit shall be derived based on the Product Class and internal volume in cubic feet (AV) from the table below reflecting federal equipment standards for products manufactured between July 1, 2001 and September 15, 2014.

[2] NREL, The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures. January 2010-September 2016. Chapter 7: Refrigerator Recycling Evaluation Protocol
[3] Appliance Recycling Program Impact Evaluation, study prepared by DNV
[4] Blasnik, Michael, "Measurement and Verification of Residential Refrigerator Energy Use, Final Report, 2003-2004 Metering Study", July 29, 2004. It assumes 58% of New York homes have central air conditioning.
[5] Ibid.

<u>Compact Refrigerator, Refrigerator-Freezer and Freezer</u>[6]

Product Class	ΔkWh/unit
11.Compact refrigerator-freezers and refrigerators other than all-refrigerators with manual defrost	9.03AV + 252.3
11A. Compact all refrigerators---manual defrost	7.84AV + 219.1
12.Compact refrigerator-freezers--partial automatic defrost	5.91AV + 335.8
13. Compact refrigerator-freezers--automatic defrost with top-mounted freezer	11.80AV + 339.2
13I. Compact refrigerator-freezers--automatic defrost with top-mounted freezer with an automatic icemaker	11.80AV + 423.2
13A. Compact all refrigerators---automatic defrost	9.17AV + 259.3
14. Compact refrigerator-freezers--automatic defrost with side-mounted freezer	6.82AV + 456.9
14I. Compact refrigerator-freezers--automatic defrost with side-mounted freezer with an automatic icemaker	6.82AV + 540.9
15. Compact refrigerator-freezers--automatic defrost with bottom-mounted freezer	11.80AV + 339.2
15I. Compact refrigerator-freezers--automatic defrost with bottom-mounted freezer with an automatic icemaker	11.80AV + 423.2
16. Compact upright freezers with manual defrost	8.65AV + 225.7
17. Compact upright freezers with automatic defrost	10.17AV + 351.9
18. Compact chest freezers	9.25AV + 136.8

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 1.0.[7]

Baseline Efficiencies from which Energy Savings are Calculated

The savings calculations above apply to recycling of a functioning primary[8] or secondary refrigerator, refrigerator-freezer or freezer with total refrigerated volume of 7.75 ft^3 (220 liters) or more or compact refrigerator/refrigerator-freezer/freezer with total refrigerated volume of less than 7.75 ft^3 (220 liters).

Compliance Efficiency from which Incentives are Calculated

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

Operating Hours

Primary refrigerators or freezers are assumed to be connected to an electrical outlet 8,760 hours per year. Secondary units may only be connected part-time, but 8,760 hours per year is utilized in

[6] 10 CFR, 430.32 (a) Refrigerators/ refrigerator-freezer, freezers, Energy and water conservation standards and their compliance dates.
[7] *No source specified – update pending availability and review of applicable references*
[8] Savings can be claimed for recycling a primary refrigerator as long as savings for that replacement were not claimed by another energy efficiency program.

these cases as well for the sake of establishing conservative estimates of Summer Peak Coincident Demand Savings.

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

An existing residential customer recycles a primary refrigerator unit. Annual Electric Energy Savings, Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are calculated as below.

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

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

$$\Delta MMBtu = N/A$$

units = 1, from application
(ΔkWh/unit) = 958, from Summary of Variables and Data Sources table
TAF = 1.22, from Summary of Variables and Data Sources table
LSAF = 1.06, from Summary of Variables and Data Sources table
CF =1.0, from Summary of Variables and Data Sources table

$$\Delta kWh = 1 \times 958 = 958\ kWh$$

$$\Delta kW = 1 \times \left(\frac{958}{8{,}760}\right) \times 1.22 \times 1.06 \times 1.0 = 0.141\ kW$$

$$\Delta MMBtu = 0$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

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

Ancillary Electric Savings Impacts

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

References

1. 10 CFR 430.2 Definitions.
   Available from: https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=433d4d2525eac3e38a1ede79f3b5c0ed&mc=true&n=pt10.3.430&r=PART&ty=HTML#se10.3.430_12

2. NREL, The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures. January 2010-September 2016. Chapter 7: Refrigerator Recycling Evaluation Protocol.
   Available from: https://www.nrel.gov/docs/fy18osti/70472.pdf
3. Cadmus memo to Consolidated Edison, "Recommended Gross Savings Values for Refrigerator Recycling Programs", December 17, 2015
4. Con Edison EEPS Programs – Impact Evaluation of Residential Appliance Bounty Program, Energy & Resource Solutions (ERS), filed under Item Number 3788, May 4, 2015
   Available from:
   http://documents.dps.ny.gov/public/MatterManagement/MatterFilingItem.aspx?FilingSeq=148044&MatterSeq=27802
5. Blasnik, Michael, "Measurement and Verification of Residential Refrigerator Energy Use, Final Report, 2003-2004 Metering Study", July 29, 2004
   Available from: https://nascsp.org/wp-content/uploads/2018/02/blasnik_measurement-and-verification-of-residential-refrigerator.pdf
6. National Renewable Energy Laboratory, The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures, Chapter 7: Refrigerator Recycling Evaluation Protocol, April 2013.
   Available from: https://www.energy.gov/sites/prod/files/2013/05/f0/53827-7.pdf
7. Appliance Recycling Program Impact Evaluation, study prepared by DNV, June 30th, 2021.
8. 10 CFR, 430.32 (a) Refrigerators/ refrigerator-freezer, freezers, Energy and water conservation standards and their compliance dates
   Available from: https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430#430.32

Record of Revision

Record of Revision Number	**Issue Date**
2	10/15/2010
7-13-4	7/31/2013
9-13-2	9/2/2013
6-15-2	6/1/2015
12-17-2	12/31/2017
6-19-4	6/28/2019
12-21-2	1/28/2022

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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 leaking or blow-through 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 open 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 failed open only and requires the completion of a steam trap assessment to ensure the number of failed open steam traps are properly quantified. This measure does not apply to municipal steam systems. Energy savings from the installation of a stream trap monitoring system may not be claimed in conjunction with the saving presented in this measure.

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 Fossil Fuel Energy Savings

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

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

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

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of steam traps failed open 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_{hrs} = Percentage of annual hours that steam traps are failed
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)[9]
π/4 = Orifice area development factor
$^{0.97}$ = An empirically derived constant in the Grashof equation[10]
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.
$F_{Discharge}$	0.7	Based on Massachusetts Steam Trap Evaluation[11]
F_{CR}	Condensate Return: 0.36 No Condensate Return: 1.00	Based on Massachusetts Steam Trap Evaluation [12]
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[13]

[9] Massachusetts Program Administrators and Energy Efficiency Advisory Council, "Steam Trap Evaluation Phase 2" March 8, 2017. pg 6
[10] Ibid.
[11] Ibid, pg 7
[12] Ibid, pg 17
[13] Massachusetts Program Administrators and Energy Efficiency Advisory Council, "Steam Trap Evaluation Phase 2". March 8, 2017. Table 4-7

Variable	Value	Notes
F_{hrs}	0.5	Assumes steam traps are failed open for 50% of annual operating hours
psig		From application.
P_{atm}	14.7	Atmospheric pressure (14.7 psi).

Heat of Vaporization (Btu/lb)[14]

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 that has undergone a steam trap assessment. Replaced or repaired steam traps will no longer leak or blow-through after implementation.

Operating Hours

Annual pressurized hours shall be established based on actual operation.

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

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

Four steam traps identified during a system survey as having failed open are replaced in a multifamily building with an 80% efficient gas fired steam boiler with condensate return system. Steam traps have 3/16" orifice diameter and the system has a steam gage pressure of 10 psi. The system is pressurized an estimated 2,500 hours per year. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are not applicable. Annual Fossil Fuel Energy Savings are calculated as below.

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

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

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

units = 4, from application
Dia = 0.1875, from application
psia = psig + p_{atm} = 10 + 14.7 = 24.7
psig from application
p_{atm} from Summary of Variables and Data Sources table
$F_{Discharge}$ = 0.7, from Summary of Variables and Data Sources table
F_{loss} = 0.37, from Summary of Variables and Data Sources table
ΔH_{vap} = 953, from Heat of Vaporization table based on pressure from application
Eff = 0.80, from application
hrs = 2,500, from application
F_{hrs} = 0.5, from Summary of Variables and Data Sources
F_{CR} = 0.36, from Summary of Variables and Data Sources table based on conditions from application

$$Loss_{steam} = 60 \times \frac{\pi}{4} \times 0.1875^2 \times 24.7^{0.97} \times 0.7 \times 0.37 = 9.626$$

$$\Delta MMBtu = 4 \times 9.626 \times \frac{953}{0.80} \times \frac{2{,}500}{1{,}000{,}000} \times 0.5 \times 0.36 = 20.6\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

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

Ancillary Electric Savings Impacts

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

References

1. 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 Memo to NYSEG/RG&E, "Recommendations to Update Algorithms for C&I Steam Trap Repair Energy Savings in NY TRM Introduction", October 10, 2019
3. 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	4/9/2021
12-21-7	1/28/2022

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MOTORS AND DRIVES

POOL PUMP

Measure Description

This measure covers the installation of ENERGY STAR® qualified multi-speed and variable frequency drive (VFD) residential inground and aboveground pool pumps. Pool pump speeds vary based on the pump's operation. Filtration, for example, only requires half the flow rate of running a pool cleaner. Conventional pool pumps, with only one speed, are set to run at the higher speeds required of the pool cleaner and waste energy during filtration operation by running faster than necessary. An ENERGY STAR® certified pool pump can run at different speeds and be programmed to match the pool operation with its appropriate pool pump speed. The energy saved is considerable; reducing pump speed by one-half allows the pump to use just one-eighth as much energy.[15] After January 1, 2019, all pool pumps must be rated according to Weighted Energy Factor (WEF).[16] Pool pumps that have earned this label use up to 70% less energy than non-qualified models.[17]

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

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

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

Summer Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fuel Energy Savings

$$\Delta MMBtu = N/A$$

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

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15 ENERGY STAR® Pool Pumps
16 ENERGY STAR® Pool Pumps Version 2 and Version 3 Specification Cover Letter, April 2018
17 ENERGY STAR® Pool Pump Fact Sheet, January 2018

where:

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

Summary of Variables and Data Sources

Variable	Value	Notes
V_{pool}		From application. If unknown, assume 22,000 for inground pools[18] and 10,364 for aboveground pools[19].
$N_{turnover}$		From application. If unknown, use 2 per day.[20]
WEF_{ee}		From application, or look up in Compliance Efficiency section below, based on nameplate hp (self-priming) or hydraulic hp (inground and non-self priming).
hp		From application
$EF_{baseline}$		Look up in Baseline Efficiencies section below, based on nameplate hp.
days		From application. If unknown, use 122.[21]

<u>Default Values</u>

The table below contains values for annual electric energy savings and Summer Peak Coincident Demand Savings. These values were established by using the assumed values from the Summary of Variables and Data Sources table above and the Compliance Efficiency section below. Default values additionally assume a 1.5 hp baseline pump and a 1.0 hp energy efficient pool pump.[22]

Pump Type	ΔkWh
Multi-speed or VFD, Self-Priming	1,757
Multi-speed or VFD, Non-Self Priming	1,175

Coincidence Factor (CF)

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

[18] Savings Calculator for ENERGY STAR® Certified Inground Pool Pumps (accessed 9/14/2021)
[19] Based on a circular 21' diameter pool with 4' water depth, based on market research
[20] CEE℠ High Efficiency Residential Swimming Pool Initiative, January 2013, pg 33
[21] Ibid
[22] CEE℠ High Efficiency Residential Swimming Pool Initiative, January 2013, pg 33

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a non-ENERGY STAR® qualified single-speed pool pump. The values for baseline EF are found in the table below, based on nameplate horsepower. Pump Performance Curve C is assumed for pool pumps. The pump curve compares the total head in feet of water to the flow rate of the water for a given pump at a given motor speed.

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

Compliance Efficiency from which Incentives are Calculated

The compliance condition is an ENERGY STAR® qualified multi or variable speed self-priming (inground) or non-self-priming (aboveground) pool pumps. Pumps must have a WEF (in kgal/kWh) equal to or greater than the WEF equations in the tale below based on pump sub-type and hydraulic horsepower (hhp).[23] Pump Performance Curve C is assumed for ENERGY STAR pumps. The pump curve compares the total head in feet of water to the flow rate of the water for a given pump at a given motor speed.

Pump Sub-Type	Size	Compliance WEF
Self-Priming (Inground)	Small ($hhp \leq 0.13$)	≥ 13.40
Self-Priming (Inground)	Small ($0.13 < hhp < 0.711$)	$\geq -2.45 \times \ln(hhp) + 8.40$
Self-Priming (Inground)	Standard Size ($hhp \geq 0.711$)	$\geq -2.45 \times \ln(hhp) + 8.40$
Non-Self-Priming (Aboveground)	Extra Small ($hhp \leq 0.13$)	≥ 4.92
Non-Self-Priming (Aboveground)	Standard Size ($hhp > 0.13$)	$\geq -1.00 \times \ln(hhp) + 3.85$

Typical WEF for ENERGY STAR® multi-speed and variable frequency drive pool pumps are found in the table below, based on nameplate horsepower.[24]

Pump Type	Nameplate Horsepower at High Speed					
	< 1 HP (<0.711 hhp)	1-1.4 HP (0.72 hhp)	1.65 HP (0.95 hhp)	2 HP (1.18 hhp)	2.5 HP (1.25 hhp)	3 HP (1.65 hhp)
WEF_{ee}, Self-Priming	11.1	9.30	9.00	8.30	8.35	7.51
WEF_{ee}, Non-Self-Priming	11.0	N/A	N/A	N/A	N/A	N/A

[23] ENERGY STAR® Program Requirements Product Specification for Pool Pumps, Eligibility Criteria Version 3.1, July 2021

[24] ENERGY STAR® Certified Pool Pump Product List, Accessed on 9/15/2021. WEF_{ee} were determined by taking the 25th percentile of applicable pumps to max hhps listed. The HP and hhp column header pairings are taken from the Savings Calculator for ENERGY STAR® Certified Inground Pool Pumps

Operating Hours

Based on New York's average climate, it is assumed that a pool is in use for 4 months per year.[25] While in use, the energy efficient pump cycles through pool water at a default rate of 12 hours per turnover.

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

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

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

units = 1, from application
days = 122, from application
V_{pool} = 21,000, from application
WEF_{ee} = 9.3, from application
$N_{turnover}$ = 1, from application
$EF_{baseline}$ = 2.3, from Baseline Efficiency from which Incentives are Calculated

$$\Delta kWh = 1 \times \frac{122}{1{,}000} \times 21{,}000 \times 1 \times \left[\frac{1}{2.3} - \frac{1}{9.3}\right] = 838\ kWh$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

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

Ancillary Electric Savings Impacts

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

References

1. ENERGY STAR® Program Requirements Product Specification for Pool Pumps, Eligibility Criteria Version 3.1, July 2021
   Available from:
   https://cmadmin.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%203.1%20Pool%20Pumps%20Final%20Specification.pdf

[25] It is assumed that 50% of pools are unheated and operate for 3 months per year and the other 50% of pools are heated and operate for 5 months per year, giving an average of 4 months of usage per year

2. 10 CFR Appendix B to Subpart Y of Part 431 – Uniform Test Method for the Measurement of Energy Efficiency of Dedicated-Purpose Pool Pumps
Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=1e172a51fbd7c0fa1753866066133e14&mc=true&node=pt10.3.431&rgn=div5#ap10.3.431_1466.b
3. ENERGY STAR® Pool Pumps Version 2 and Version 3 Specification Cover Letter, April 30, 2018
Available from:
https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Pool%20Pumps%20Version%202%20and%20Version%203%20Specification%20Cover%20Letter.pdf
4. ENERGY STAR® Pool Pump Fact Sheet, January 2018
Available from:
https://www.energystar.gov/sites/default/files/asset/document/PoolPumps_FactSheet_012318_0.pdf
5. Savings Calculator for ENERGY STAR® Certified Inground Pool Pumps, May 2020
Available from:
https://www.energystar.gov/productfinder/downloads/Pool_Pump_Calculator_2020.05.05_FINAL.xlsx
6. CEE℠ High Efficiency Residential Swimming Pool Initiative, Consortium for Energy Efficiency, January 2013
Available from:
https://library.cee1.org/system/files/library/9986/CEE_Res_SwimmingPoolInitiative_01Jan2013_Corrected.pdf

Record of Revision

Record of Revision Number	Issue Date
6-18-20	6/30/2018
9-18-6	9/28/2018
12-20-4	12/31/2020
12-21-8	1/28/2022

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OTHER

SOLAR POOL HEATER

Measure Description

This measure covers the installation of solar pool heating systems utilizing glazed or unglazed solar thermal collectors. Solar thermal collectors absorb sunlight, convert solar energy directly into heat and transfer heat to filtered pool water pumped through the system. Thermal collectors shall be permanently installed on a roof or raised frame.

Solar pool heaters may be installed to partially or fully offset energy consumption of traditional heaters. This measure only applies to solar pool heaters installed in place of or to supplement fossil fuel pool heaters for inground swimming pools and in installation scenarios where the existing pump system is retained. Installations requiring additional pumps or replacement of existing pumps shall be treated under a custom application. Installed thermal collector area must be 50-100% of pool surface area.[26] This methodology assumes that thermal collectors experience minimal shading between the hours of 10AM and 4PM during the summer months. Qualifying thermal collectors must be rated by Solar Rating & Certification Corporation (SRCC) and be OG-100 certified.[27]

The following algorithms corresponding to the existing system type, whether fossil fuel or electric will be used.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = \frac{CR \times SF \times days \times (1 - F_{derate})}{E_{t,baseline} \times 3{,}412} \times ElecSF$$

Summer Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = \frac{CR \times SF \times days \times (1 - F_{derate})}{E_{t,baseline} \times 1{,}000{,}000} \times FuelSF$$

where:

ΔkWh = Annual electricity energy savings

[26] US DOE “Solar Swimming Pool Heaters”.

[27] Solar Rating & Certification Corporation Directory: http://solar-rating.org/programs/og-100-program/. The Solar Rating & Certification Corporation (ICC-SRCC) is an ISO/IEC 17065-accredited third-party certification body with programs for the certification and performance rating of solar heating and cooling products. The OG-100 Solar Thermal Collector Certification Program provides certification for solar thermal collectors to the current ICC 901/SRCC 100 Solar Thermal Collector standard.

ΔkW = Peak coincident demand electric savings
$\Delta MMBtu$ = Annual fuel energy savings
$_{baseline}$ = Characteristic of baseline condition
CR = Collector Rating (Btu/ft^2-day)
SF = Square Footage of thermal collectors (ft^2)
days = Annual days pool heater is used
F_{derate} = Derating factor
$E_{t,baseline}$ = Thermal efficiency of baseline pool heater
ElecSF = Electric Savings Factor: Adjustment to electric energy savings based on fuel type
FuelSF = Fossil Fuel Savings Factor: Adjustment to fuel energy savings based on fuel type
3,412 = Conversion factor, one kilowatt-hour (kWh) equals 3,412 BTU
1,000,000 = Conversion factor, one MMBtu equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
CR		From application, as rated by Solar Rating & Certification Corporation. Value shall reflect scenario A (Pool Heating – Warm Climate) and Medium Radiation (1,500 Btu/ft^2-day).[28]
SF		From application.
days		From application. If unknown, use 122 as default, based on 4 months of operation per year.
F_{derate}	0.06	Derating factor considers approximate shading (3% deration) and operational availability (3% deration).[29]
$E_{t,baseline}$		From application. If unknown, apply 0.86 as default in partial displacement of pool heater load scenarios and 0.82 as default in complete replacement of pool heater load scenarios. [30]
ElecSF	Displacing/Replacing Electric Pool Heater: 1 Displacing/Replacing Fossil Fuel Pool Heater: 0	
FuelSF	Displacing/Replacing Electric Pool Heater: 0 Displacing/Replacing Fossil Fuel Pool Heater: 1	

[28] Solar Rating & Certification Corporation Directory; scenario selected based on review of NASA Open Data Portal, Prediction of Worldwide Energy Resources (POWER), suggesting that this is the most appropriate selection across NY cities.
[29] NREL “PVWatts Version 5 Manual” Table 6.
[30] 10 CFR 430.32 (k)(2)

Coincidence Factor (CF)

The prescribed coincidence factor for this measure is N/A.

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition for this measure is a standard efficiency electric, heat pump pool heater or fossil fuel-fired pool heater.

Compliance Efficiency from which Incentives are Calculated

The compliance condition for this measure is a thermal collector installed to offset or replace the consumption of a traditional fossil fuel-fired pool heater for an inground swimming pool. Qualifying thermal collectors must be rated by Solar Rating & Certification Corporation's OG-100 program.

Operating Hours

The annual operating days shall be taken from application. If actual operating days are unknown, 122 days may be used as a default, assuming 4 months of operation per year.

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

An existing residential customer near Syracuse replaces their gas fired inground pool heater with a solar pool heating system comprising 470 SF of glazed thermal collectors. The pool heater is in operation for 120 days per year. The Solar Pool Heater has a Collector Rating (CR) of 850 Btu/ft^2-day. Summer Peak Coincident Demand Savings are not applicable. Annual Electric Energy Savings and Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta kWh = \frac{CR \times SF \times days \ \times (1 - F_{derate})}{E_{t,baseline} \times \ 3{,}412} \times ElecSF$$

$$\Delta MMBtu = \frac{CR \times SF \times days \times (1 - F_{derate})}{E_{t,baseline} \times 1{,}000{,}000} \times FuelSF$$

Days = 120, from application
SF = 470, from application
F_{derate} = 0.06, from Summary of Variables and Data sources table
$E_{t,baseline}$ = 0.82, from Summary of Variables and Data sources table
CR = 850, from application
ElecSF = 0, from Summary of Variables and Data sources table
FuelSF = 1, from Summary of Variables and Data sources table

$$\Delta kWh = \frac{850 \times 470 \times 120 \times (1 - 0.06)}{0.82 \times 3{,}412} \times 0 = 0\ kWh$$

$$\Delta MMBtu = \frac{850 \times 470 \times 120 \times (1 - 0.06)}{0.82 \times 1{,}000{,}000} \times 1 = 54.96\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

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

Ancillary Electric Savings Impacts

Addition of a thermal collector may require a pump replacement or additional pump to meet the demands of moving pool's water to and through the collectors.[31] Scenarios with pump modifications shall be treated under a custom application, and as such are not captured in the contents of this measure.

References

1. Department of Energy, Solar Swimming Pool Heaters
   Available from: https://www.energy.gov/energysaver/solar-swimming-pool-heaters
2. Solar Rating & Certification Corporation directory
   Available from: http://solar-rating.org/directories/certified-companies/
3. National Renewable Energy Laboratory, PVWatts Version 5 Manual, September 2014
   Available from: https://www.nrel.gov/docs/fy14osti/62641.pdf
4. NOAA National Centers for Environmental Information – NCEI 1981-2010 Climate Normals
   Available from: https://www.ncdc.noaa.gov/cdo-web/datatools/normals
5. NASA's Open Data Portal, Prediction of Worldwide Energy Resources (POWER)
   Available from: https://data.nasa.gov/Earth-Science/Prediction-Of-Worldwide-Energy-Resources-POWER-/wn3p-qsan
6. Savings Calculator for ENERGY STAR® Certified Inground Pool Pumps, April 2020
   Available from: https://www.energystar.gov/productfinder/product/certified-pool-pumps/results#
7. CEE℠ High Efficiency Residential Swimming Pool Initiative, Consortium for Energy Efficiency, January 2013
   Available from:
   https://library.cee1.org/system/files/library/9986/CEE_Res_SwimmingPoolInitiative_01Jan2013_Corrected.pdf
8. 10 CFR 430.32 Energy and water conservation standards and their compliance dates
   Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=840d2f09fea283237b0f345001c03a28&mc=true&node=pt10.3.430&rgn=div5#se10.3.430_132
9. 10 CFR Appendix B to Subpart Y of Part 431 – Uniform Test Method for the Measurement of Energy Efficiency of Dedicated-Purpose Pool Pumps
   Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=1e172a51fbd7c0fa1753866066133e14&mc=true&node=pt10.3.431&rgn=div5#ap10.3.431_1466.b

[31] US DOE "Solar Swimming Pool Heaters".

Record of Revision

Record of Revision Number	Issue Date
3-20-1	3/30/2020
7-21-11	8/30/2021
12-21-9	1/28/2022

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APPLIANCE

OVEN, STEAMER, FRYER AND GRIDDLE

Measure Description

This measure covers the installation of ENERGY STAR® qualified commercial kitchen equipment that meet the descriptions below. Unless otherwise noted, presented baseline, compliance, and default values are determined from ENERGY STAR® Commercial Food Service Equipment Calculator.[32]

- Convection Ovens[33] - This measure includes gas and electric commercial convection ovens. A convection oven forces hot dry air over the surface of a food product. A full size convection oven can accommodate standard full size sheet pans measuring 18 x 26 x 1 inch. A half size convection oven can accommodate half size sheet pans measuring 18 x 13 x 1 inch. Though not eligible for ENERGY STAR® qualification, this measure includes half size gas convection ovens. Half size gas convection ovens must have an idle rate of 8,500 BTU/h or less, per assumed efficiency of qualified equipment by Pacific Gas & Electric workpaper.[34]
- Rack Ovens[35] - This measure includes gas commercial rack ovens. A rack oven is a high capacity oven in which a rack is wheeled into the oven and can be rotated during the baking process. Rack ovens range in capacity from mini rack ovens to quadruple rack ovens. Single and double rack ovens are included in this measure.
- Steamers[36] - This measure includes gas and electric commercial steamers, also known as compartment steamers. A steamer is a device that contains one or more food steaming compartments in which the energy in the steam is transferred to the food by direct contact. To calculate the savings for this measure, the number of pans must be known. Countertop, wall-mounted, and floor models mounted on a stand, pedestal, or cabinet-style base are included. Commercial steamer microwave ovens are not included in this measure.
- Fryers[37] - This measure includes gas and electric commercial deep-fat fryers. A deep-fat fryer is an appliance in which oils are placed to such a depth that the cooking food is essentially supported by displacement of the cooking fluid rather than by the bottom of the vessel. Depending on the fryer type, heat is delivered to the cooking fluid by means of an immersed electric element or band-wrapped vessel (electric fryers), or by heat transfer from gas burners through either the walls of the fryer or through tubes passing through the cooking fluid (gas fryers). Standard fryers and large vat fryers are included in this measure.
- Griddles[38] - This measure includes single-sided gas and electric commercial griddles. A single-sided commercial griddle is a commercial appliance designed for cooking food in oil or its own juices by direct contact with either a flat, smooth, hot surface or a hot

[32] ENERGY STAR® Commercial Food Service Equipment Calculator (accessed 2/26/2018)
[33] ENERGY STAR® Program Requirements Product Specification for Commercial Ovens, Eligibility Criteria, Version 2.2., March 2015
[34] PG&E Work Paper PGECOFST101 Revision 6, Table 12, pg. 18
[35] ENERGY STAR® Program Requirements Product Specification for Commercial Ovens, Eligibility Criteria, Version 2.2., March 2015
[36] ENREGY STAR® Program Requirements for Commercial Steam Cookers, Eligibility Criteria Version 1.2, August 2003
[37] ENERGY STAR® Program Requirements Product Specification for Commercial Fryers, Eligibility Criteria Final Draft Version 3.0. October 2016
[38] ENERGY STAR® Program Requirements for Commercial Griddles, Eligibility Criteria Version 1.2, January 2011

channeled cooking surface where plate temperature is thermostatically controlled. To calculate the energy savings in this measure, the griddle dimensions must be known. This measure does not include double-sided gas or electric commercial griddles.

- Gas Conveyor Ovens - Though not eligible for ENERGY STAR® qualification, this measure additionally covers the installation of energy efficient gas conveyor ovens. Conveyor ovens cook food by carrying it on a moving belt through a heated chamber. Qualifying conveyor ovens have baking efficiencies greater than or equal to 42% and idle energy rates less than or equal to 57,000 BTU/h, per assumed efficiency of qualified equipment by Pacific Gas and Electric workpaper.[39]

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings (Electric Equipment Only)

$$\Delta kWh = units \times days \times \frac{\left(\Delta BTU_{preheat} + \Delta BTU_{idle} + \Delta BTU_{cooking}\right)}{3{,}412}$$

Summer Peak Coincident Demand Savings (Electric Equipment Only)

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

Annual Fossil Fuel Energy Savings (Fossil Fuel Equipment Only)

$$\Delta MMBtu = units \times days \times \frac{\left(\Delta BTU_{preheat} + \Delta BTU_{idle} + \Delta BTU_{cooking}\right)}{1{,}000{,}000}$$

where:

$$\Delta BTU_{preheat} = N_{preheat} \times \left(BTU_{preheat,baseline} - BTU_{preheat,ee}\right)$$

$$\Delta BTU_{idle} = BTU/h_{idle,baseline} \times \left[hrs - N_{preheat} \times hrs_{preheat} - \left(\frac{lbs}{(lbs/hr)_{baseline}}\right)\right] - BTU/h_{idle,ee} \times \left[hrs - N_{preheat} \times hrs_{preheat} - \left(\frac{lbs}{(lbs/hr)_{ee}}\right)\right]$$

$$\Delta BTU_{cooking} = lbs \times Q_{food} \times \left(\frac{1}{Eff_{baseline}} - \frac{1}{Eff_{ee}}\right)$$

NOTE: $\Delta BTU_{preheat}$, ΔBTU_{idle} and $\Delta BTU_{cooking}$ terms can be calculated per the equations above using either actual qualifying equipment specs or default values as defined in the Common Variables, Baseline Efficiencies, Compliance Efficiency and Operating Hours sections below, or looked up from the Default Values table below.

[39] PG&E Work Paper PGECOFST117 Revision 5, Table 9, pg. 11-12, where 1 pizza equals 0.76 lbs

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
$\Delta MMBtu$	= Annual fossil fuel energy savings
$\Delta BTU_{preheat}$	= Daily preheat energy savings
ΔBTU_{idle}	= Daily idle energy savings
$\Delta BTU_{cooking}$	= Daily cooking energy savings
units	= Number of measures installed under the program
days	= Operating days per year
hrs	= Daily operating hours
$_{baseline}$	= Characteristic of baseline condition
$_{ee}$	= Characteristic of energy efficient condition
$BTU_{preheat}$	= Equipment preheat energy (BTU)
$N_{preheat}$	= Number of preheats per day
$hrs_{preheat}$	= Preheat duration (hours)
BTU/h_{idle}	= Equipment idle energy rate (BTU/h)
(lbs/hr)	= Equipment production capacity (lbs/hr)
lbs	= Total daily food production
Q_{food}	= Heat to food (BTU/lb)
Eff	= Equipment convection/steam mode cooking efficiency
CF	= Coincidence factor
3,412	= Conversion factor, one kW equals 3,412 BTU/h
1,000,000	= Conversion factor, one MMBtu equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
$\Delta BTU_{preheat}$		Calculate based on calculations above or look up in Default Values table below.
ΔBTU_{idle}		Calculate based on calculations above or look up in Default Values table below.
$\Delta BTU_{cooking}$		Calculate based on calculations above or look up in Default Values table below.
days		From application or look up based on facility type in Operating Hours section below.
hrs		From application or look up based on facility type in Operating Hours section below.
$N_{preheat}$	1	Pacific Gas and Electric. [40]
$BTU_{preheat,baseline}$		Look up based on qualifying equipment type in Baseline Efficiencies section below.
$BTU_{preheat,ee}$		From application or look up based on qualifying equipment type in Compliance Efficiency section below.
$BTU/h_{idle,baseline}$		Look up based on qualifying equipment type in Baseline Efficiencies section below.
$BTU/h_{idle,ee}$		From application or look up based on qualifying equipment type in Compliance Efficiency section below.

[40] Shared assumption from all PG&E Work Papers referenced in this measure

Variable	Value	Notes
$hrs_{preheat}$		Look up based on qualifying equipment type in Common Variables table below.
$(lbs/hr)_{baseline}$		Look up based on qualifying equipment type in Baseline Efficiencies section below.
$(lbs/hr)_{ee}$		From application or look up based on qualifying equipment type in Compliance Efficiency section below
Lbs		From application or look up based on qualifying equipment type in Common Variables table below.
Q_{food}		Look up based on qualifying equipment type in Common Variables table below.
$Eff_{baseline}$		Look up based on qualifying equipment type in Baseline Efficiencies section below.
Eff_{ee}		From application or look up based on qualifying equipment type in Compliance Efficiency section below.
CF	0.9	

Default Values

The table below contains values and simplified calculations for $\Delta BTU_{preheat}$, ΔBTU_{idle} and $\Delta BTU_{cooking}$ terms that may be used in the formulation of estimated savings in lieu of utilizing the calculations prescribed above for these terms. These values were established by performing those calculations using assumed values from the Common Variables, Baseline Efficiencies and Compliance Efficiency sections below.

Equipment	$\Delta BTU_{preheat}$	ΔBTU_{idle}	$\Delta BTU_{cooking}$
Convection Oven, Electric, Full Size	580	1,365 x hrs -1,708	3,250
Convection Oven, Electric, Half Size	648	102 x hrs -1,000	1,553
Convection Oven, Gas, Full Size	9,551	3,100 x hrs -4,673	2,470
Convection Oven, Gas, Half Size	9,625	3,500 x hrs -11,842	27,778
Conveyor Oven, Gas	-5,000	13,000 x hrs -55,144	124,405
Rack Oven, Gas, Double Rack	34,242	35,000 x hrs -179,550	397,692
Rack Oven, Gas, Single Rack	7,416	18,000 x hrs -89,017	176,250
Steamer, Electric	4,129	14,581 x hrs -10,792	19,385
Steamer, Gas	9,706	27,378 x hrs -23,156	42,368
Fryer, Electric, Standard	648	1,365 x hrs -3,791	10,988
Fryer, Electric, Large Vat	1,194	853 x hrs -1,911	15,268
Fryer, Gas	6,331	5,000 x hrs -15,381	73,286
Fryer, Gas, Large Vat	5,000	4,000 x hrs -8,556	73,286
Griddle, Electric	6,828	1,638 x hrs -7,451	5,220
Griddle, Gas	6,000	5,100 x hrs -49,875	23,438

Common Variables[41]

Equipment	Value		
	$hrs_{preheat}$	lbs	Q_{food} (BTU/lb)
Convection Oven, Electric, Full Size	0.14[42]	100	250
Convection Oven, Electric, Half Size	0.14[43]	100	250
Convection Oven, Gas, Full Size	0.14[44]	100	250
Convection Oven, Gas, Half Size	0.18[45]	100	250
Conveyor Oven, Gas	0.25[46]	190	250
Rack Oven, Gas, Double Rack	0.33[47]	1,200[48]	235
Rack Oven, Gas, Single Rack	0.33[49]	600	235
Steamer, Electric	0.22[50]	100	105
Steamer, Gas	0.22[51]	100	105
Fryer, Electric, Standard	0.14[52]	150	570
Fryer, Electric, Large Vat	0.14[53]	150	570
Fryer, Gas, Standard	0.23[54]	150	570
Fryer, Gas, Large Vat	0.23[55]	150	570
Griddle, Electric	0.25[56]	100	475
Griddle, Gas	0.25[57]	100	475

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.9.[58]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is food service equipment as defined in the Measure Description above with operating characteristics per the table below. Values are as reported from referenced ENERGY STAR® Commercial Food Service Equipment Calculator unless otherwise noted.[59]

[41] ENERGY STAR® Commercial Food Service Equipment Calculator (accessed 2/26/2018), unless otherwise noted
[42] California TF, Work Paper SWFS001-02, pg. 7
[43] California TF, Work Paper SWFS001-02, pg. 7
[44] California TF, Work Paper SWFS001-02, pg. 11
[45] California TF, Work Paper SWFS001-02, pg. 18
[46] California TF, Work Paper SWFS008-01, pg. 7, where 1 pizza equals 0.76 lbs
[47] California TF, Work Paper SWFS014-02, pg. 7
[48] Ibid
[49] Ibid, pg. 8
[50] California TF, Work Paper SWFS005-02, pg. 9
[51] California TF, Work Paper SWFS005-02, pg. 13
[52] California TF, Work Paper SWFS011-03, pg, 8
[53] Ibid
[54] California TF, Work Paper SWFS011-03, pg, 12
[55] Ibid
[56] California TF Work Paper SWFS004 Revision 1,pg. 7
[57] California TF Work Paper SWFS004 Revision 1,pg. 10
[58] Shared assumption from all PG&E Work Papers referenced in this measure
[59] ENERGY STAR® Commercial Food Service Equipment Calculator (accessed 2/26/2018)

Equipment	$BTU_{preheat,baseline}$ (BTU)	$BTUh_{idle,baseline}$ (BTU/h)	$(lbs/hr)_{baseline}$	$Eff_{baseline}$
Convection Oven, Electric, Full Size	5,323[60]	6,824	90	0.65
Convection Oven, Electric, Half Size	3,037[61]	3,514	45	0.68
Convection Oven, Gas, Full Size	13,096[62]	15,100	83	0.44
Convection Oven, Gas, Half Size[63]	6,000	12,000	45	0.30
Conveyor Oven, Gas[64]	48,662	70,000	114	0.20
Rack Oven, Gas, Double Rack	90,009[65]	65,000	250	0.30
Rack Oven, Gas, Single Rack	54,817[66]	43,000	130	0.30
Steamer, Electric	5,186[67]	2,047 + 3,767 x no. pans[68]	23.3 x no. pans	0.26
Steamer, Gas	18,833[69]	9,000 + 6,524 x no. pans[70]	23.3 x no. pans	0.15
Fryer, Electric, Standard	5,971[71]	4,094	65	0.75
Fryer, Electric, Large Vat	10,577[72]	4,606	100	0.70
Fryer, Gas, Standard	16,609[73]	14,000	60	0.35
Fryer, Gas, Large Vat	27,000[74]	16,000	100	0.35

[60] California TF, Work Paper SWFS001-02, pg. 7
[61] California TF, Work Paper SWFS001-02, pg. 7
[62] Ibid, pg. 11
[63] Ibid
[64] California TF, Work Paper SWFS008-02, pg. 7, where 1 pizza equals 0.76 lbs
[65] California TF, Work Paper SWFS014-02, pg. 8
[66] California TF, Work Paper SWFS014-02, pg. 7
[67] California TF, Work Paper SWFS005-02, pg. 9
[68] Represents energy rate when steamers are in idle mode and in constant steam mode: $(1 – Ts)*BTU/h_{idle,baseline}+ Ts*(lb/hr)_{baseline}*Q_{food}/Eff_{baseline}$, where Ts (time in constant steam mode) = 40% of non-cook time and $BTU/h_{idle,baseline}$ = 3,412 BTU/h for baseline electric steamers
[69] California TF, Work Paper SWFS005-02, pg. 13
[70] Represents energy rate when steams are in idle mode and in constant steam mode: $(1 – Ts)*BTU/h_{idle,baseline}+ Ts*(lb/hr)_{baseline}*Q_{food}/Eff_{baseline}$, where Ts (time in constant steam mode) = 40% of non-cook time and $BTU/h_{idle,baseline}$ = 15,000 BTU/h for baseline gas steamers
[71] California TF, Work Paper SWFS011-02, pg. 8
[72] California TF, Work Paper SWFS011-02, pg. 8
[73] California TF, Work Paper SWFS011-02, pg. 11
[74] California TF, Work Paper SWFS011-02, pg. 11

Equipment	$BTU_{preheat,baseline}$ (BTU)	$BTUhi_{dle,baseline}$ (BTU/h)	$(lbs/hr)_{baseline}$	$Eff_{baseline}$
Griddle, Electric	2,275 x griddle area[75]	1,365 x griddle area	5.83 x griddle area	0.65
Griddle, Gas	3,500 x griddle area[76]	3,500 x griddle area	4.17 x griddle area	0.32

Compliance Efficiency from which Incentives are Calculated

The compliance condition is ENERGY STAR® food service equipment meeting the minimum performance specifications listed in the table below. Operating characteristics shall be taken from application. When unavailable, default characteristics shall be taken from the table below. Preheat energy and all values are reported from referenced California TF workpaper sources.

Equipment	$BTU_{preheat,ee}$ (BTU)	$BTU/h_{idle,ee}$ (BTU/h)	$(lbs/hr)_{ee}$	Eff_{ee}
Convection Oven, Electric, Full Size	4,743[77]	5,459	90	0.71
Convection Oven, Electric, Half Size	2,388[78]	3,412	49	0.71
Convection Oven, Gas, Full Size	9,449[79]	12,000	86	0.46
Convection Oven, Gas, Half Size[80]	3,375	8,500	55	0.45
Conveyor Oven, Gas[81]	40,000	57,000	167	0.42
Rack Oven, Gas, Double Rack	65,758[82]	30,000	250	0.52
Rack Oven, Gas, Single Rack	42,584[83]	25,000	130	0.48
Steamer, Electric	989[84]	1,678 x no. pans*[85]	16.7 x no. pans	0.50

[75] California TF, Work Paper SWFS004-01, pg. 7
[76] California TF, Work Paper SWFS004-01, pg. 7
[77] California TF, Work Paper SWFS001-02, pg. 7
[78] California TF, Work Paper SWFS001-02, pg. 7
[79] Ibid, pg. 11
[80] Ibid
[81] California TF, Work Paper SWFS008-02, pg. 7, where 1 pizza equals 0.76 lbs
[82] California TF, Work Paper SWFS014-02, pg. 8
[83] California TF, Work Paper SWFS014-02, pg. 8
[84] California TF, Work Paper SWFS005-02, pg. 9
[85] Represents energy rate when steamer are in idle mode and in constant steam mode: $(1 – Ts)*BTU/h_{idle,ee} + Ts*(lb/hr/pan)*Q_{food}/Eff_{ee}$, where Ts (time in constant steam mode) = 40% of non-cook time and $BTU/h_{idle,ee}$ = 455 BTU/h x no. of pans for compliance electric steamers

Equipment	$BTU_{preheat,ee}$ (BTU)	$BTU/h_{idle,ee}$ (BTU/h)	$(lbs/hr)_{ee}$	Eff_{ee}
Steamer, Gas	10,294[86]	3,463 x no. pans*[87]	20.0 x no. pans	0.38
Fryer, Electric, Standard	5,323[88]	2,730	70	0.83
Fryer, Electric, Large Vat	9,383[89]	3,753	110	0.80
Fryer, Gas, Standard	10,278[90]	9,000	65	0.50
Fryer, Gas, Large Vat	22,000[91]	12,000	110	0.50
Griddle, Electric	1,137 x griddle area[92]	1,092 x griddle area	6.67 x griddle area	0.70
Griddle, Gas	2,500 x griddle area[93]	2,650 x griddle area	7.5 x griddle area	0.38

* For steamers with greater than 6 pans, assume no. pans equals 6 for steamer idle energy rate

Operating Hours

Equipment operating hours per day and days per year shall be taken from the application if known. Default operating hours per day and days per year are provided below, established based on a weighted average of values associated with similar facility types, as reported by the California Energy Commission.[94]

Facility Type	hours/day	days/year
Community College	11	283
Fast Food Restaurant	14	363
Full Service Restaurant	12	321
Grocery	12	365
Hospital	11	365
Hotel	20	365
Miscellaneous	9	325
Motel	20	365
Primary School	5	180
Secondary School	8	180
Office	12	250
University	11	283

[86] California TF, Work Paper SWFS005-02, pg. 13
[87] Represents energy rate when steamers are in idle mode and in constant steam mode: (1 – Ts)*$BTU/h_{idle,ee}$+ Ts*(lb/hr/pan)*Q_{food}/Eff_{ee}, where Ts (time in constant steam mode) = 40% of non-cook time and $BTU/h_{idle,ee}$ = 2,088 BTU/h x no. of pans for compliance gas steamers
[88] California TF, Work Paper SWFS011-02, pg. 8
[89] California TF, Work Paper SWFS011-02, pg. 8
[90] California TF, Work Paper SWFS011-02, pg. 11
[91] California TF, Work Paper SWFS011-02, pg. 11
[92] California TF Work Paper SWFS004-01, pg. 7
[93] California TF Work Paper SWFS004 -01, pg. 10
[94] California Energy Commission, Characterizing the Energy Efficiency Potential of Gas-Fired Commercial Foodservice Equipment, Appendix E

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

A full-size electric convection oven with 90 lb/hr capacity, 3,470 $BTU_{preheat}$, 5,500 BTU/h_{idle} and 72% efficiency is installed in a restaurant in NYC, which operates for 12 hours a day for 320 days per year. Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

$$\Delta kWh = units \times days \times \frac{\left(\Delta BTU_{preheat} + \Delta BTU_{idle} + \Delta BTU_{cooking}\right)}{3{,}412}$$

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

where:

$$\Delta BTU_{preheat} = N_{preheat} \times \left(BTU_{preheat,baseline} - BTU_{preheat,ee}\right)$$

$$\Delta BTU_{idle} = BTU/h_{idle,baseline} \times \left[hrs - N_{preheat} \times hrs_{preheat} - \left(\frac{lbs}{(lbs/hr)_{baseline}}\right)\right] - BTU/h_{idle,ee} \times \left[hrs - N_{preheat} \times hrs_{preheat} - \left(\frac{lbs}{(lbs/hr)_{ee}}\right)\right]$$

$$\Delta BTU_{cooking} = lbs \times Q_{food} \times \left(\frac{1}{Eff_{baseline}} - \frac{1}{Eff_{ee}}\right)$$

units = 1, from application
days = 320 days/year, from application
$N_{preheat}$ = 1, from Summary of Variables and Data Sources
$BTU_{preheat,baseline}$ = 5,323 BTU, from Baseline Efficiencies from which Energy Savings are calculated
$BTU_{preheat,ee}$ = 3,470 BTU, from application
$BTU/h_{idle,baseline}$ = 6,824 BTU, from Baseline Efficiencies from which Energy Savings are calculated
$BTU/h_{idle,ee}$ = 5,500 BTU, from application
$Hrs_{preheat}$ = 0.14, from Common Variables
Hrs = 12 hours/day, from application
Lbs = 100 lbs, from Common Variables
$(Lbs/hr)_{baseline}$ =90 lbs/hr, from Baseline Efficiencies from which Energy Savings are calculated
(lbs/hr)ee = 90, from application
Q_{food} = 250 BTU/lb, from Common Variables
$Eff_{baseline}$ = 65%, from Baseline Efficiencies from which Energy Savings are calculated
Eff_{ee} = 0.72, from application
CF = 0.9, from Summary of Variables and Data Sources

$$\Delta BTU_{preheat} = 1 \times (5{,}323 - 3{,}470) = 1{,}853$$

$$\Delta BTU_{idle} = 6{,}824 \times \left[12 - 1 \times 0.14 - \left(\frac{100}{90}\right)\right] - 5{,}500 \times \left[12 - 1 \times 0.14 - \left(\frac{100}{90}\right)\right] = 14{,}231$$

$$\Delta BTU_{cooking} = 100 \times 250 \times \left(\frac{1}{0.65} - \frac{1}{0.72}\right) = 3{,}739$$

$$\Delta kWh = 1 \times 320 \times \frac{(1{,}853 + 14{,}231 + 3{,}739)}{3{,}412} = 1{,}859\ kWh$$

$$\Delta kW = \frac{1{,}859}{(320 \times 12)} \times 0.9 = 0.44\ kW$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

More efficient food service equipment rejects less heat into the condition space than standard equipment, increasing space heating requirements while decreasing cooling load. However, no relevant studies have been performed to date that would allow quantification of these impacts. Until additional information is available, these impacts are excluded from the prescribed formulation of savings.

Ancillary Electric Savings Impacts

More efficient food service equipment rejects less heat into the condition space than standard equipment, increasing space heating requirements while decreasing cooling load. However, no relevant studies have been performed to date that would allow quantification of these impacts. Until additional information is available, these impacts are excluded from the prescribed formulation of savings.

References

1. ENERGY STAR® Program Requirements Product Specification for Commercial Ovens, Eligibility Criteria Version 2.2, October 2015
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2. ENERGY STAR® Program Requirements Product Specification for Commercial Steam Cookers, Eligibility Criteria Version 1.2, August 2003
   Available from:
   https://www.energystar.gov/sites/default/files/specs/private/Commercial_Steam_Cookers_Program_Requirements%20v1_2.pdf

3. ENERGY STAR® Program Requirements Product Specification for Commercial Fryers Eligibility Criteria Final Draft Version 3.0, October 2016
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4. ENERGY STAR® Program Requirements Product Specification for Commercial Griddles, Eligibility Criteria Version 1.2, January 2011
Available from:
https://www.energystar.gov/ia/partners/product_specs/program_reqs/Commercial_Griddles_Program_Requirements.pdf
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Available from: https://www.energystar.gov/buildings/facility-owners-and-managers/existing-buildings/save-energy/purchase-energy-saving-products
6. California Technical Forum workpaper, Commercial Convection Oven- Electric and Gas, SWFS001-02, January 2020.
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10. California Technical Forum workpaper, Commercial Fryer, SWFS011-03, June 2021.
11. California Technical Forum workpaper, Commercial Griddle, SWFS004-1, October 2018.
12. California Energy Commission, Energy Research and Development Division, Characterizing the Energy Efficiency Potential of Gas-Fired Commercial Foodservice Equipment, October 2014
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Record of Revision

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3-18-18	3/29/2018
3-20-4	3/30/2020
12-21-11	1/28/2022

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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).[95]

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 Fossil 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
ΔMMBtu = Annual fossil fuel energy savings

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

units	= Number of measures installed under the program
baseline	= Characteristic of baseline condition
ee	= Characteristic of energy efficient condition
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 fossil 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 to establish baseline for commercial refrigerators and freezers and ultra-low temperature laboratory grade freezers. For other laboratory grade equipment, $kWh_{baseline} = 1.3 \times kWh_{ee}$.[96]
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 fossil 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. [97]

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. For other laboratory grade equipment, $kWh_{baseline} = 1.3 \times kWh_{ee}$.[98]

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.[99] Volume specification shall be taken from ENERGY STAR® qualified products listing or specification sheet of the proposed equipment. Baseline maximum

[96] Benefits of ENERGY STAR ® Certified Commercial Food Service Equipment, EPA.
[97] *No source specified – update pending availability and review of applicable references.*
[98] Benefits of ENERGY STAR ® Certified Commercial Food Service Equipment, EPA.
[99] 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

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.[100] 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 model shall be the sum of the MDEC values for all of its compartments.[101] Results of the equations below shall be multiplied by 365 to derive annual baseline 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[102]

Maximum Daily Energy Consumption (kWh/day)
ULT Freezer
V × (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).[103] 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

[100] 10 CFR 431.66(e)(1)
[101] 10 CFR 431.66(e)(2)
[102] ULT Freezers Base Case Investigation, Eversource Energy
[103] ENERGY STAR® Program Requirements Product Specification for Commercial Refrigerators and Freezers, Eligibility Criteria Version 4.0

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

Laboratory Grade Refrigerators Energy Consumption[104]

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[105]

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.

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

An ENERGY STAR® qualified commercial glass door vertical refrigerator with 25 ft^3 internal volume and rated daily energy consumption of 2.05 kWh is installed in a grocery store in Albany. The building has central air conditioning and gas heat. Annual Electric Energy Savings, Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are calculated as below.

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

[104] ENERGY STAR® Program Requirements for Laboratory Grade Refrigerators and Freezers
[105] Ibid.

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

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

units = 1, from application
$kWh_{baseline}$ = (0.10 x V + 0.86) x 365 = (0.10 x 25 + 0.86) x 365 = 1,226 kWh
$kWh_{baseline}$ equation from Baseline Efficiency section based on equipment type and volume
V = 25, from application
kWh_{ee} = 2.05 x 365 = 748 kWh, from application
HVACc = 0.120, from Appendix D based on location, HVAC configuration, and facility type
HVACd = 0.200, from Appendix D based on location, HVAC configuration, and facility type
HVACff = -0.002, from Appendix D based on location, HVAC configuration, and facility type
CF = 1.0, from Summary of Variables and Data Sources

$$\Delta kWh = 1 \times (1{,}226 - 748) \times (1 + 0.120) = 535\ kWh$$

$$\Delta kW = 1 \times \left[\frac{1{,}226 - 748}{8{,}760}\right] \times (1 + 0.200) \times 1.0 = 0.066\ kW$$

$$\Delta MMBtu = 1 \times (1{,}226 - 748) \times (-0.002) = -0.96\ MMBtu$$

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 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.
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6. Ultra-Low Freezer Base Case Investigations, Eversouce Energy, October 2, 2017
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Record of Revision Number	Issue Date
1	10/15/2010
9-18-7	9/30/2018
3-21-10	4/9/2021
12-21-12	1/28/2022

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HEATING, VENTILATION AND AIR CONDITIONING CONTROL

STEAM TRAP – LOW PRESSURE SPACE HEATING

Measure Description

This measure covers the repair or replacement of leaking or blow-through 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 open 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 failed open only and requires the completion of a steam trap assessment to ensure the number of failed open steam traps are properly quantified. This measure does not apply to municipal steam systems. Energy savings from the installation of a stream trap monitoring system may not be claimed in conjunction with the saving presented in this measure.

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 Fossil Fuel Energy Savings

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

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

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

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of steam traps failed open 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_{hrs} = Percentage of annual hours that steam traps are failed
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)[106]
$\pi/4$ = Orifice area development factor
$^{0.97}$ = An empirically derived constant in the Grashof equation[107]
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.[108]
$F_{Discharge}$	0.7	Based on Massachusetts Steam Trap Evaluation[109]
F_{CR}	Condensate Return: 0.36 No Condensate Return: 1.00	Based on Massachusetts Steam Trap Evaluation [110]
Dia		From application.
psia		Calculated per the equation above, dependent upon system operating pressure (psia).

[106] Massachusetts Program Administrators and Energy Efficiency Advisory Council, "Steam Trap Evaluation Phase 2" March 8, 2017. pg 6
[107] Ibid.
[108] ERS, "Two-Tier Steam Trap Savings Study", April 26, 2018. pg 5 . Applying a default of operating hours results in conservative energy savings for circumstances when pressurized hours are unknown.
[109] Ibid, pg 7
[110] Ibid, pg 17

Variable	Value	Notes
F_{Loss}	0.37	Based on Massachusetts Steam Trap Evaluation[111]
F_{hrs}	0.5	Assumes steam traps are failed open for 50% of annual operating hours
psig		From application.
P_{atm}	14.7	Atmospheric pressure (14.7 psi).

Heat of Vaporization (Btu/lb)[112]

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 that has undergone a steam trap assessment. Replaced or repaired traps will no longer leak or blow-through after installation.

[111] Massachusetts Program Administrators and Energy Efficiency Advisory Council, “Steam Trap Evaluation Phase 2” Table 4-7, March 8, 2017.
[112] Thermodynamic Properties of Steam Including Data for the Liquid and Solid Phases (1936)

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.[113]

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

Four steam traps identified during a system survey as having failed open are replaced in a commercial building with an 80% gas fired steam boiler with condensate return system. Steam traps have 3/16" orifice diameter and the system has a steam gage pressure of 10 psi. The system is pressurized an estimated 2,500 hours per year. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are not applicable. Annual Fossil Fuel Energy Savings are calculated as below.

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

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

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

units = 4, from application
Dia = 0.1875, from application
psia = psig + p_{atm} = 10 + 14.7 = 24.7
psig from application
p_{atm} from Summary of Variables and Data Sources table
$F_{Discharge}$ = 0.7, from Summary of Variables and Data Sources table
F_{loss} = 0.37, from Summary of Variables and Data Sources table
ΔH_{vap} = 953, from Heat of Vaporization table based on pressure from application
Eff = 0.80, from application
hrs = 2,500, from application
F_{hrs} = 0.5, from Summary of Variables and Data Sources table
F_{CR} = 0.36, from Summary of Variables and Data Sources table based on conditions from application

$$Loss_{steam} = 60 \times \frac{\pi}{4} \times 0.1875^2 \times 24.7^{0.97} \times 0.7 \times 0.37 = 9.626$$

$$\Delta MMBtu = 4 \times 9.626 \times \frac{953}{0.80} \times \frac{2{,}500}{1{,}000{,}000} \times 0.5 \times 0.36 = 20.6\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P

[113] ERS, "Two-Tier Steam Trap Savings Study", April 26, 2018. pg 5

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)

Record of Revision

Record of Revision Number	Issue Date
6-17-14	6/30/2017
3-20-10	3/30/2020
3-21-24	4/9//2021
12-21-18	1/28/2022

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HEATING, VENTILATION AND AIR CONDITIONING 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 open 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 blow-through 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. This steam trap monitoring system measure considers the energy savings resulting from the repair/replacement of steam traps throughout the lifetime of the monitoring system, and additional energy savings from other methodologies may not be claimed.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = N/A$$

Summer Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings

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

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

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

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Total number of steam traps connected to the monitoring system
$Loss_{steam}$	= 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 ($lb_m / in^{0.06}\text{-}lb^{0.97}\text{-}hr$)[114]
π/4 = Orifice area development factor
$^{0.97}$ = An empirically derived constant in the Grashof equation[115]
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.[116]
$F_{Discharge}$	0.7	Based on Massachusetts Steam Trap Evaluation[117]
F_{Failed}		From application, based upon historical data for facility, if unknown assume 0.15.[118,119,120]
F_{hrs}	0.5	Assumes steam traps would fail for 50% of annual operating hours without monitoring system
F_{CR}	Condensate Return: 0.36 No Condensate Return: 1.00	Based on Massachusetts Steam Trap Evaluation [121]

[114] Massachusetts Program Administrators and Energy Efficiency Advisory Council, "Steam Trap Evaluation Phase 2" March 8, 2017. pg 6
[115] Ibid.
[116] ERS, "Two-Tier Steam Trap Savings Study", April 26, 2018. pg 5. Applying a default of operating hours results in conservative energy savings for circumstances when pressurized hours are unknown.
[117] Ibid, pg 7
[118] Average annual failure rate based upon steam trap EUL of 6 years
[119] Emerson whitepaper 00840-0200-4708, "Impact of failed steam traps on process plants", Rev AA, April 2013. p 4.
[120] U.S. DOE, Energy Tips: Steam, Inspect and Repair Steam Traps, Steam Tip Sheet #1, DOE/GO-102012-3401, January 2012
[121] Ibid, pg 17

Variable	Value	Notes
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[122]
psig		From application.
P_{atm}	14.7	Atmospheric pressure (14.7 psi).

Heat of Vaporization (Btu/lb)[123]

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.

Compliance Efficiency from which Incentives are Calculated

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

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

A steam trap monitoring system is installed on a commercial gas low-pressure steam space heating system. The system comprises 30 steam traps and has nameplate efficiency of 82% with

[122] Massachusetts Program Administrators and Energy Efficiency Advisory Council, "Steam Trap Evaluation Phase 2" Table 4-7, March 8, 2017.
[123] Thermodynamic Properties of Steam Including Data for the Liquid and Solid Phases (1936)

an installed condensate return system. Steam traps have 3/16" orifice diameter and the system has a steam gage pressure of 10 psi. Traps are pressurized an estimated 2,500 hours per year. Previous steam trap inspections at the site captured an annual failure rate of 20%. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are not applicable. Annual Fossil Fuel Energy Savings are calculated as below.

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

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

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

units = 30, from application
Dia = 0.1875, from application
Psia = psig + p_{atm} = 10 + 14.7 = 24.7
psig from application
p_{atm} from Summary of Variables and Data Sources table
$F_{Discharge}$ 0.7, from Summary of Variables and Data Sources table
F_{loss} = 0.37, from Summary of Variables and Data Sources table
F_{hrs} = 0.5, from Summary of Variables and Data Sources table
F_{failed} = 0.2, from Summary of Variables and Data Sources table
ΔH_{vap} = 953, from Heat of Vaporization table based on pressure from application
Eff = 0.82, from application
hrs = 2,500, from application
F_{CR} = 0.36, from Summary of Variables and Data Sources table based on conditions from application

$$Loss_{steam} = 60 \times \frac{\pi}{4} \times 0.1875^2 \times 24.7^{0.97} \times 0.7 \times 0.37 = 9.626$$

$$\Delta MMBtu = 30 \times 9.626 \times \frac{953}{0.82} \times \frac{2{,}500}{1{,}000{,}000} \times 0.5 \times 0.2 \times 0.36 = 30.2\ MMBtu$$

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.[124]

Effective Useful Life (EUL)

See Appendix P.

[124] ERS, “Two-Tier Steam Trap Savings Study”, April 26, 2018. pg 5

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)
5. Emmerson, White Paper 00840-0200-4708, Rev AA, "Impact of failed steam traps on process plants", April 2013
   Available from: https://www.emerson.com/documents/automation/white-paper-impact-of-failed-steam-traps-on-process-plants-rosemount-en-77018.pdf
6. US Department of Energy, Energy Tips: Steam, Inspect and Repair Steam Trap", Steam Tip Sheet #1, January 2012
   Available from: https://www.energy.gov/sites/prod/files/2014/05/f16/steam1_traps.pdf

Record of Revisions

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7-20-15	7/31/2020
3-21-25	4/9/2021
12-21-19	1/28/2022

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PROCESS EQUIPMENT

STEAM TRAP - OTHER APPLICATION

Measure Description

Steam systems distribute heat from boilers to satisfy space heating, process, and commercial end-use requirements. Steam distribution systems contain steam traps, which are automatic valves that remove condensate, air, and other non-condensable gases, while preventing or minimizing steam loss. Steam traps that fail open allow excess steam to escape, thus increasing the amount of steam that must be generated to meet end-use requirements. This measure and calculations are applicable to steam traps served by fossil fuel-fired boilers, for low, medium, and high pressure (0-3,000 psig) non-space heating steam applications, where flash steam on the condensate side of steam traps is not utilized for other heating processes. These steam applications include but are not limited to: steam humidifiers, high pressure PRV stations, medium pressure PRV stations, and steam to hot water heat exchangers. This measure does not apply to municipal steam systems. Energy savings from the installation of a stream trap monitoring system may not be claimed in conjunction with the saving presented in this measure.

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 traps. A system-wide assessment of steam trap operation and functionality is required for this measure and estimated energy savings is restricted to the repair or replacement of failed open traps only.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = N/A$$

Summer Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings

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

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

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

where:

ΔkWh = Annual electric energy savings
ΔkW = Peak coincident demand electric savings
$\Delta MMBtu$ = Annual fossil fuel energy savings
units = Number of steam traps failed open 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 of steam trap operation
F_{hrs} = Percentage of annual hours that steam traps are failed
$F_{Discharge}$ = 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
Dia = Internal Diameter (I.D.) of steam trap orifice (inches)
psia = Absolute steam pressure (psia)
F_{Loss} = Steam loss adjustment factor
psig = Steam gauge pressure (psi)
p_{atm} = Atmospheric pressure (psi) where system is vented and not a pressurized or vacuum condensate return system; otherwise, psia should be established such that P_a reflects the pressure differential between the inlet and outlet of the steam trap
60 = An empirically derived constant in the Grashof's equation (lb_m/ $in^{0.06}$-$lb^{0.97}$-hr).[125]
$\pi/4$ = Orifice area development factor
$^{0.97}$ = An empirically derived constant in the Grashof equation
1,000,000 = Conversion factor, 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 a default of 8,424 for industrial applications[126] and 2,425 for dry cleaners.[127]
$F_{Discharge}$	0.7	Based on Massachusetts Steam Trap Evaluation[128]

[125] Massachusetts Program Administrators and Energy Efficiency Advisory Council, "Steam Trap Evaluation Phase 2" March 8, 2017. pg 6
[126] Assumes constant operation except for 2 weeks out of the year when boilers are often shutoff for maintenance
[127] CLEAResult "Work Paper Steam Traps Revision #2" Revision 3 dated March 2, 2012. The CLEAResults Work Paper is not publicly available, but is referenced by the Illinois TRM Version 6, pg 214
[128] Ibid, pg 7

Variable	Value	Notes
F_{CR}	Condensate Return: 0.36 No Condensate Return: 1.00	Based on Massachusetts Steam Trap Evaluation [129]
Dia		From application. If unknown, defaults are provided for certain system pressure ranges in the Orifice Diameter table below.
psia		Calculated per the equation above, dependent upon system operating pressure (psia).
F_{Loss}	0.37	Based on Massachusetts Steam Trap Evaluation[130]
F_{hrs}	0.5	Assumes steam traps would fail for 50% of annual operating hours without monitoring system
psig		From application.
P_{atm}		Atmospheric pressure (14.7 psi) where system is vented and not a pressurized or vacuum condensate return system; otherwise, P_{atm} should be established such that psia reflects the pressure differential across the steam trap.

Heat of Vaporization (BTU/lb)[131]

Pressure (psig)	Heat of Vaporization (BTU/lb)	Pressure (psig)	Heat of Vaporization (BTU/lb)	Pressure (psig)	Heat of Vaporization (BTU/lb)
0	970	**70**	898	**500**	752
1	968	**75**	895	**550**	740
2	966	**80**	892	**600**	729
3	964	**85**	889	**700**	707
4	962	**90**	886	**800**	686
5	961	**95**	884	**900**	667
6	959	**100**	881	**1,000**	647
7	957	**110**	876	**1,100**	628
8	956	**120**	871	**1,200**	612
9	954	**130**	866	**1,300**	591
10	953	**140**	862	**1,400**	573
15	946	**150**	857	**1,500**	555
20	940	**160**	853	**1,600**	536
25	934	**170**	849	**1,700**	518
30	929	**180**	845	**1,800**	500
35	924	**190**	842	**1,900**	481
40	920	**200**	838	**2,000**	462
45	916	**250**	821	**2,250**	412
50	912	**300**	805	**2,500**	357

[129] Ibid, pg 17

[130] Massachusetts Program Administrators and Energy Efficiency Advisory Council, "Steam Trap Evaluation Phase 2" Table 4-7, March 8, 2017.

[131] Calculated from NIST Standard Reference Database 10, "NIST/ASME Steam Properties," Ver. 2.11, National Institute of Standards and Technology, U.S. Department of Commerce, Gaithersburg, MD, 1997

Pressure (psig)	Heat of Vaporization (BTU/lb)	Pressure (psig)	Heat of Vaporization (BTU/lb)	Pressure (psig)	Heat of Vaporization (BTU/lb)
55	908	**350**	791	**2,750**	293
60	905	**400**	777	**3,000**	209
65	901	**450**	764		

Orifice Diameter[132]

System Pressure	Diameter of Orifice (in)
< 15 psig	No Default
≥ 15 psig and < 30 psig	0.1875
≥ 30 psig and < 300 psig	0.2500
≥ 300 psig	No Default

Coincidence Factor (CF)

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

Baseline Efficiencies from which Energy Savings are Calculated

The baseline is assumed to be a leaking or blow-through steam trap failed open on a non-space heating steam system.

Compliance Efficiency from which Incentives are Calculated

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

Operating Hours

Operating hours of steam trap system are assumed to be 8,424[133] for industrial and process applications and 2,425[134] for steam traps used in dry cleaners.

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

Four steam traps identified during a system survey as having failed open are replaced in an industrial process facility with an 80% gas fired steam boiler with condensate return system. Steam traps have 1/4" orifice diameter and the system has a steam gage pressure of 200 psi. The system is pressurized an estimated 8,250 hours per year. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are not applicable. Annual Fossil Fuel Energy Savings are calculated as below.

[132] Illinois TRM via ConEd Large C&I Program Impact and Process Evaluation, prepared by Navigant, August 2019, slide 74

[133] Assumes constant operation except for 2 weeks out of the year when boilers are often shutoff for maintenance

[134] CLEAResult "Work Paper Steam Traps Revision #2" Revision 3 dated March 2, 2012, Work Paper not publicly available, but reported in Illinois TRM Version 6, pg 214

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

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

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

units = 4, from application
Dia = 0.25, from application
psia = psig + p_{atm} = 200 + 14.7 = 214.7
psig from application
p_{atm} from Summary of Variables and Data Sources table
$F_{Discharge}$ = 0.7, from Summary of Variables and Data Sources table
F_{loss} = 0.37, from Summary of Variables and Data Sources table
ΔH_{vap} = 838, from Heat of Vaporization table based on pressure from application
Eff = 0.80, from application
hrs = 8,250, from application
F_{hrs} = 0.5, from Summary of Variables and Data Sources table
F_{CR} = 0.36, from Summary of Variables and Data Sources table based on conditions from application

$$Loss_{steam} = 60 \times \frac{\pi}{4} \times 0.25^2 \times 214.7^{0.97} \times 0.7 \times 0.37 = 139.411$$

$$\Delta MMBtu = 4 \times 139.411 \times \frac{838}{0.80} \times \frac{8{,}250}{1{,}000{,}000} \times 0.5 \times 0.36 = 867.44\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

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

Ancillary Electric Savings Impacts

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

References

1. Massachusetts Program Administrators and Energy Efficiency Advisory Council, “Steam Trap Evaluation Phase 2”, March 8, 2017.
Available from: http://ma-eeac.org/wordpress/wp-content/uploads/Steam-Trap-Evaluation-Phase-II.pdf

2. Illinois Technical Reference Manual, Version 8, October 17, 2019
Available from: https://www.ilsag.info/technical-reference-manual/il_trm_version_8/
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. "NIST/ASME Steam Properties," Ver. 2.11, National Institute of Standards and Technology, U.S. Department of Commerce, Gaithersburg, MD, 1997
5. Large Commercial & Industrial (Large C&I) Program Impact and Process Evaluation, Presented to Con Edison, Prepared by Navigant, August 2019
Available from:
http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7B614F67CD-8511-4E76-A963-38B3079505B5%7D

Record of Revision

Record of Revision Number	Issue Date
9-18-17	9/28/2018
3-19-11	3/29/2019
3-20-12	3/30/2020
12-21-23	1/28/2022

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PROCESS EQUIPMENT

STEAM TRAP MONITORING SYSTEM – OTHER APPLICATIONS

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 open 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 blow-through steam traps. Savings are calculated similarly to regular steam trap replacement, but due to the presence of the monitoring software, this measure has longer lifetime savings. This steam trap monitoring system measure considers the energy savings resulting from the repair/replacement of steam traps throughout the lifetime of the monitoring system, and additional energy savings from other methodologies may not be claimed.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = N/A$$

Summer Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings

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

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

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

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Total number of steam traps connected to the monitoring system
$Loss_{steam}$	= 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 of steam trap operation
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)
F_{CR} = Condensate Return Factor, used to account for the proportion of energy lost that is returned to the system via condensate line
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)[135]
π/4 = Orifice area development factor
$^{0.97}$ = An empirically derived constant in the Grashof equation[136]
1,000,000 = Conversion factor, 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		Look up in Operating Hours Section below.
$F_{Discharge}$	0.7	Based on Massachusetts Steam Trap Evaluation[137]
F_{Failed}		From application, based upon historical data for facility, if unknown assume 0.15.[138]
F_{CR}	Condensate Return: 0.36 No Condensate Return: 1.00	Based on ERS memo to NYSEG/RG&E[139]
Dia		From application. If unknown, defaults are provided for certain system pressure ranges in the Orifice Diameter table below.
psia		Calculated per the equation above, dependent upon system operating pressure (psia).

[135] Massachusetts Program Administrators and Energy Efficiency Advisory Council, "Steam Trap Evaluation Phase 2" March 8, 2017. pg 6
[136] Ibid.
[137] Ibid, pg 7
[138] Average annual failure rate based upon steam trap EUL of 6 years
[139] 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.

Variable	Value	Notes
F_{Loss}	0.37	Based on Massachusetts Steam Trap Evaluation[140]
F_{hrs}	0.5	Assumes steam traps would fail for 50% of annual operating hours without monitoring system
psig		From application.
P_{atm}	14.7	Atmospheric pressure (14.7 psi) where system is vented and not a pressurized or vacuum condensate return system; otherwise, psia should be established such that P_a reflects the pressure differential across the steam trap.

Heat of Vaporization (BTU/lb)[141]

Pressure (psig)	Heat of Vaporization (BTU/lb)	Pressure (psig)	Heat of Vaporization (BTU/lb)	Pressure (psig)	Heat of Vaporization (BTU/lb)
0	970	**70**	898	**500**	752
1	968	**75**	895	**550**	740
2	966	**80**	892	**600**	729
3	964	**85**	889	**700**	707
4	962	**90**	886	**800**	686
5	961	**95**	884	**900**	667
6	959	**100**	881	**1,000**	647
7	957	**110**	876	**1,100**	584
8	956	**120**	871	**1,200**	354
9	954	**130**	866	**1,300**	591
10	953	**140**	862	**1,400**	573
15	946	**150**	857	**1,500**	555
20	940	**160**	853	**1,600**	536
25	934	**170**	849	**1,700**	518
30	929	**180**	845	**1,800**	500
35	924	**190**	842	**1,900**	481
40	920	**200**	838	**2,000**	462
45	916	**250**	821	**2,250**	412
50	912	**300**	805	**2,500**	357
55	908	**350**	791	**2,750**	293
60	905	**400**	777	**3,000**	209
65	901	**450**	764		

[140] Massachusetts Program Administrators and Energy Efficiency Advisory Council, "Steam Trap Evaluation Phase 2" Table 4-7, March 8, 2017.
[141] Values in this table were calculated from NIST Standard Reference Database 10, "NIST/ASME Steam Properties," Ver. 2.11, National Institute of Standards and Technology, U.S. Department of Commerce, Gaithersburg, MD, 1997

Orifice Diameter[142]

System Pressure	Diameter of Orifice (in)
< 15 psig	No Default
≥ 15 psig and < 30 psig	0.1875
≥ 30 psig and < 300 psig	0.2500
≥ 300 psig	No Default

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.

Compliance Efficiency from which Incentives are Calculated

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

Operating Hours

Operating hours of steam trap system are assumed to be 8,424 for industrial and process applications and 2,425 for steam traps used in dry cleaners.

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

A steam trap monitoring system is installed on an industrial process steam system. The system comprises 30 steam traps and has nameplate efficiency of 82% with an installed condensate return system. Steam traps have 1/4" orifice diameter and the system has a steam gage pressure of 200 psi. Traps are pressurized an estimated 8,250 hours per year. Previous steam trap inspections at the site captured an annual failure rate of 20%. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are not applicable. Annual Fossil Fuel Energy Savings are calculated as below.

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

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

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

units = 30, from application
Dia = 0.25, from application
Psia = psig + p_{atm} = 200 + 14.7 = 214.7
psig from application

[142] Illinois TRM via ConEd Large C&I Program Impact and Process Evaluation, prepared by Navigant, August 2019, slide 74

p_{atm} from Summary of Variables and Data Sources table
$F_{Discharge}$ = 0.7, from Summary of Variables and Data Sources table
F_{loss} = 0.37, from Summary of Variables and Data Sources table
F_{hrs} = 0.5, from Summary of Variables and Data Sources table
F_{failed} = 0.2, from Summary of Variables and Data Sources table
ΔH_{vap} = 838, from Heat of Vaporization table based on pressure from application
Eff = 0.82, from application
hrs = 8,250, from application
F_{CR} = 0.36, from Summary of Variables and Data Sources table based on conditions from application

$$Loss_{steam} = 60 \times \frac{\pi}{4} \times 0.25^2 \times 214.7^{0.97} \times 0.7 \times 0.37 = 139.411$$

$$\Delta MMBtu = 30 \times 139.411 \times \frac{838}{0.82} \times \frac{8{,}250}{1{,}000{,}000} \times 0.5 \times 0.2 \times 0.36 = 1{,}269.42\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

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

Ancillary Electric Savings Impacts

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

References

1. Massachusetts Program Administrators and Energy Efficiency Advisory Council, "Steam Trap Evaluation Phase 2", March 8, 2017.
   Available from: http://ma-eeac.org/wordpress/wp-content/uploads/Steam-Trap-Evaluation-Phase-II.pdf
2. 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
3. "NIST/ASME Steam Properties," Ver. 2.11, National Institute of Standards and Technology, U.S. Department of Commerce, Gaithersburg, MD, 1997
4. Large Commercial & Industrial (Large C&I) Program Impact and Process Evaluation, Presented to Con Edison, Prepared by Navigant, August 2019
   Available from:
   http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7B614F67CD-8511-4E76-A963-38B3079505B5%7D

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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[143]
	Clothes Dryer	Residential	14	ENERGY STAR® M&I Scoping Report[144]
	Clothes Washer	Residential	11	DEER 2014 EUL ID: Appl-EffCW
	Dehumidifier	Residential	12	ENERGY STAR® Calc[145]
	Dishwasher	Residential	11	DEER 2014 EUL ID: Appl-EffDW
	Fireplace	Residential	15	DOE[146]
	Induction Cooktop	Residential	16	DEER 2014 EUL ID: Appl-Elec_Cooking
	Refrigerator and Freezer	Residential	14	DEER 2014 EUL ID: Appl-ESRefg
	Soundbar	Residential	7	RPP Product Analysis[147]
Appliance Control	Advanced Power Strip (APS)	Residential	8	DEER 2014 EUL ID: Plug-OccSens
Appliance Recycling	Air Conditioner - Room (RAC) Recycling	Residential	3	DEER 2014 EUL ID: HV-RAC-RUL
	Dehumidifier Recycling	Residential	3	Assumes same RUL as RAC
	Refrigerator Recycling	Residential	5	DEER 2014 EUL ID: Appl-RecRef

[143] 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
[144] ENERGY STAR® Market & Industry Scoping Report: Residential Clothes Dryer, November 2011.
[145] ENERGY STAR® Dehumidifier Calculator https://www.energystar.gov/ia/partners/promotions/cool_change/downloads/CalculatorConsumerDehumidifier.xls
[146] 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
[147] Retail Products Platform Product Analysis, Last Updated May 25, 2016. Available from: https://drive.google.com/file/d/0B9Fd3ckbKJp5OEpWSHg1eksyZ1U/view

Category	Single and Multi-family Residential Measures	Sector	EUL (years)	Source
Appliance Recycling	Freezer Recycling	Residential	4	DEER 2014 EUL ID: Appl-RecFrzr
Building Shell	Air Conditioner – Room (RAC) Cover and Gap Sealer	Residential	3	See note below[148]
	Air Leakage Sealing	Residential	15	GDS[149]
	Insulation – Hot Water and Steam Pipe	Residential	15	GDS[150]
	Insulation – Opaque Shell	Residential	25	GDS[151]
	Storm Window	Residential	20	DOE[152]
	Window	Residential	20	DEER 2014 EUL ID: BS-Win
	Window - Film	Residential	10	DEER 2014 EUL ID: GlazDaylt-WinFilm
Domestic Hot Water (DHW)	Heat Pump Water Heater (HPWH)	Residential	10	DEER 2014 EUL ID: WtrHt-HtPmp
	Indirect Water Heater	Residential	11	DEER 2014 EUL ID: WtrHt-Res-Gas
	Storage Water Heater - Gas	Residential	15	PA Consulting Group[153]
	Storage Water Heater - Electric	Residential	13	DEER 2014 EUL ID: WtrHt-Res-Elec
	Instantaneous Water Heater	Residential	20	DEER 2014 EUL ID: WtrHt-Instant-Res
DHW - Control	DHW Thermostat Setback	Residential	RUL of DHW System **Default = 5**	N/A
	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
DHW - Control	Thermostatic Shower Restriction Valve	Residential	10	UPC[154]

148 Average/typical manufacturer warranty period for AC covers
149 GDS Associates, Inc., Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures, June 2007, Table 1 – Residential Measures
150 Ibid.
151 Ibid.
152 https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-22864rev2.pdf
153 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
154 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[155]
	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[156]
	Boiler and Furnace - Combination (“Combi”) Furnace	Residential	20	DEER 2014[157] 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

[155] GDS Associates, Inc., Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures, June 2007, Table 1 – Residential Measures
[156] 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
[157] Based on DEER value for high efficiency boiler and instantaneous water heater

Category	Single and Multi-family Residential Measures	Sector	EUL (years)	Source
Heating, Ventilation and Air Conditioning (HVAC)	Energy and Heat Recovery Ventilator	Residential	14	PA Consulting Group[158]
	Furnace, Gas Fired	Residential	22	DOE[159,160]
	Gas Heat Pump	Residential	15	DEER 2014 EUL ID: HV-Res HP
	Heat Pump - Air Source (ASHP)	Residential	15	DEER 2014 EUL ID: HV-Res HP
	Heat Pump – Ground Source (GSHP)	Residential	25	ASHRAE[161]
	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

[158] 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

[159] 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

[160] 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

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

Category	Single and Multi-family Residential Measures	Sector	EUL (years)	Source
HVAC - Control	Steam Trap – Low Pressure Space Heating	Residential	6	DEER 2014 EUL ID: HVAC-StmTrp
	Submetering	Multifamily	10	NYSERDA[162]
	Thermostat – All Types	Residential	11	DEER 2014 EUL ID: HVAC-ProgTStats
	Thermostatic Radiator Valve – One Pipe Steam Radiator	Multifamily	15	DOE[163]
	Smart Thermostatic Radiator Enclosure	Residential	15	DEER 2014 EUL ID: Motors-fan[164]
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[165]
	Light Fixture	Residential LED (Interior)	50,000 hours	DLC[166]
			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

[162] NYSERDA Residential Electric Submetering Manual
[163] U.S. DOE, "Thermostatic Radiator Valve Evaluation", January 2015, Table 4. pg. 16
[164] Based on assumed EUL of integrated fan, which is expected to be the first component to fail
[165] 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
[166] 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 (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[167]
		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[168]
Motors and Drives	Pool Pump		Residential	10	DEER 2014 EUL ID: OutD-PoolPump
	Pool Circulator Timer		Residential	10	DEER 2014 EUL ID: OutD-PoolPump
	Heat Pump Pool Heater		Residential	15	DEER 2014 EUL ID: HV-Res HP
Other	Pool Heater		Residential	8	DOE[169]
	Solar Pool Heater		Residential	15	DOE[170]

[167] 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
[168] 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
[169] 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
[170] https://www.energy.gov/energysaver/solar-swimming-pool-heaters

COMMERCIAL AND INDUSTRIAL MEASURES

Category	Commercial & Industrial Measures	Sector	EUL (years)	Source
Agricultural Equipment	High Speed Fans	C&I	10	PG&E[171]
	Livestock Waterer	C&I	10	PA Consulting Group[172]
	Milk Pre-Cooler Heat Exchanger	C&I	15	Ibid
	Refrigeration Heat Recovery	C&I	14	DEER 2014 EUL ID: HVAC-ChlrComp-Ag
	Scroll Compressor	C&I	12	DEER 2014 EUL ID: RefgWrhs-ScrollComp
Agricultural Equipment - Control	Engine Block Heater Timer	C&I	8	See note below[173]
	Variable Speed Drive Milk Pump Plate Cooler	C&I	15	PA Consulting Group[174]
	Variable Speed Drive Vacuum Pump	C&I	15	PA Consulting Group[175]
Appliance	Clothes Dryer	C&I	14	ENERGY STAR®M&I Report[176]
	Clothes Washer	C&I	11	DEER 2014 EUL ID: Appl-EffCW
	Cooking Equipment[177]	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[178]
	Ice Maker	C&I	10	DEER 2014 EUL ID: Cook-IceMach
	Refrigerator and Freezer	C&I	12	DEER 2014 EUL ID: Cook-SDRef
Appliance - Control	Advanced Power Strip (APS)	C&I	8	DEER 2014 EUL ID: Plug-OccSens
	Vending Machine and Novelty Cooler Control	C&I	5	DEER 2014 EUL ID: Plug-VendCtrler
Appliance Recycling	Air Conditioner – Room (RAC)	C&I	9	DEER 2014 EUL ID: HV-RAC-ES

[171] PG&E Work Paper PGE3PAGR117, October 12, 2017
[172] 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
[173] Based on EUL's for Advanced Power Strips
[174] 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
[175] 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
[176] ENERGY STAR® Market & Industry Scoping Report: Residential Clothes Dryer, November 2011.
[177] Applicable to all kitchen cooking equipment not otherwise listed
[178] ENERGY STAR® Savings Calculator for ENERGY STAR® Certified Commercial Kitchen Equipment www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx?5da4-3d90&5da4-3d90

Category	Commercial & Industrial Measures	Sector	EUL (years)	Source
Building Shell	Air Leakage Sealing	C&I	15	GDS[179]
	Cool Roof	C&I	15	DEER 2014 EUL ID: BldgEnv-CoolRoof
	Insulation - Hot Water and Steam Pipe	C&I	15	GDS[180]
	Insulation - Opaque Shell	C&I	30	ET & CEC[181]
	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[182]
	Engineered Air Nozzle	C&I	15	Wisconsin PSC[183]
	No Air Loss Water Drain	C&I	13	MA Measure Life Study[184]
	Refrigerated Air Dryer	C&I	13	Other State TRMs [185]
	Compressed Air Heat Recovery	C&I	13	Other State TRMs [186]
	Flow Controller	C&I	13	Other State TRMs [187]
	Low Pressure Drop Filter	C&I	5	Other State TRMs [188]
Domestic Hot Water (DHW)	Heat Pump Water Heater (HPWH)	C&I	10	DEER EUL ID: WtrHt-HtPmp
	Indirect Water Heater	C&I	15	DEER 2014 EUL ID: WtrHt-Com
	Instantaneous Water Heater	C&I	20	DEER 2014 EUL ID: WtrHt-Instant-Com
	Storage Tank Water Heater	C&I	15	DEER 2014 EUL ID: WtrHt-Com
DHW - Control	DHW Thermostat Setback	C&I	RUL of DHW System **Default = 5**	N/A

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

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

[181] Energy Trust uses 30 years for commercial applications. CEC uses 30 years for insulation in Title 24 analysis.

[182] 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.

[183] PA Consulting Group (2009). *Business Programs: Measure Life Study*. Prepared for State of Wisconsin Public Service Commission

[184] 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

[185] 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.

[186] Ibid.

[187] Ibid.

[188] Ibid.

Category	Commercial & Industrial Measures	Sector	EUL (years)	Source
DHW – Control	Drain Water Heat Recovery (DWHR)	C&I	30	2019 Title 24[189]
	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[190]
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[191]
	Boiler and Furnace - Combination (“Combi”) Furnace	C&I	20	DEER 2014[192] 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[193]
	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

[189] 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
[190] https://www.nrel.gov/docs/fy16osti/64541.pdf
[191] 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
[192] Based on DEER value for high efficiency boiler and instantaneous water heater
[193] 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[194,195]
	Gas Heat Pump	C&I	15	DEER 2014 EUL ID: HV-Res HP
	Heat Pump – Unitary & Applied	C&I	15	DEER 2014 EUL ID: HVAC-airHP
	Heat Pump – PTHP	C&I	15	DEER 2014 EUL ID: HVAC-PTHP
	Heat Pump – Water Source (WSHP)	C&I	25	ASHRAE[196]
	High Volume Low Speed Fan	C&I	15	PA Consulting Group[197]
	Infrared Heater	C&I	17	GDS[198]
	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[199]
	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

[194] 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

[195] 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

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

[197] 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

[198] 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

[199] 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[200]
	Kitchen Demand Ventilation Control	C&I	15	PG&E[201]
	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
	Steam Trap Monitoring System – Low-Pressure Space Heating	C&I	15	DEER 2014 EUL ID: HVAC-EMS
	Thermostat – Programmable Thermostat – Wi-Fi (Communicating)	C&I	11	DEER 2014 EUL ID: HVAC-ProgTStats
	Thermostatic Radiator Valve	C&I	15	DOE[202]
	Advanced Rooftop Control	C&I	EUL = RUL of Existing RTU = RTU EUL – (Current Year – Year of Mfr.) **Default = 5**	N/A

[200] 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
[201] PG&E Work Paper WPSDGENRCC0019, June 15, 2012
[202] 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[203]
	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®[204]
		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®[205]
		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®[206]
		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

[203] 50,000 hours per L_{70} requirements prescribed by the DLC's Product Qualification Criteria, Technical Requirement Table version 4.4

[204] 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

[205] 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

[206] 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[207]
			Rated Life listed by ENERGY STAR or default to 15,000 hrs /annual lighting operating hrs or 15 yrs if rated lifetime or annual operating hrs are not known	ENERGY STAR®
	LED Open Sign	C&I	16	DEER 2014 EUL ID: LED-sign
	Refrigerated Case LED	C&I	16	DEER 2014 EUL ID: GrocDisp-FixtLtg-LED
	Lighting Power Density (LPD)	C&I	15	GDS[208]
Lighting - Control	Bi-Level Lighting	C&I	15	ComEd[209]
	Integrated Interior Control	C&I	15	ComEd[210]
	Non-Integrated Interior Control	C&I	10	GDS[211]
	Plug-Load Occupancy Sensor	C&I	8	DEER[212]
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[213]

[207] 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

[208] 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

[209] 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

[210] 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

[211] 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

[212] DEER value for lighting occupancy sensors

[213] Assumes same EUL as VFD measure.

Category	Commercial & Industrial Measures	Sector	EUL (years)	Source
Other	Heat Pump Pool Heater	C&I	15	DEER 2014 EUL ID: HV-Res HP
	High Efficiency Transformer	C&I	32	DOE[214]
	High Frequency Battery Charger	C&I	15	PG&E[215]
	High Viscosity Industrial Lubricant	C&I	10	ExxonMobil
	Pool Heater	C&I	8	DOE[216]
	Solar Pool Cover	C&I	5	CALMAC[217]
Process Equipment	Steam Trap – Other Applications	C&I	6	DEER 2014 EUL ID: HVAC-StmTrp
	Steam Trap Monitoring System – Other Applications	C&I	15	DEER 2014 EUL ID: HVAC-EMS
	Ozone Laundry	C&I	10	PG&E[218]
	Process Exhaust Filtration	C&I	15	CIBSE[219]
Refrigeration	Air-Cooled Refrigeration Condenser	C&I	15	DEER 2014 EUL ID: GrocSys-Cndsr
	Automatic Door Closer for Walk-In Cooler/Freezer	C&I	8	DEER 2014 EUL ID: GrocWlkIn-DrClsr
	Cooler and Freezer Door Gasket	C&I	4	DEER 2014 EUL ID: GrocWlkIn-StripCrtn, GrocWlkIn-WDrGask
	Cooler and Freezer Door Strip	C&I	4	DEER 2014 EUL ID: GrocWlkIn-StripCrtn, GrocWlkIn-WDrGask
	EC Motor – Refrigerated Case or Walk-In Cooler/Freezer Evaporator Fan	C&I	15	DEER 2014 EUL ID: GrocDisp-FEvapFanMtr
	Equipment (Condenser, Compressor, and Sub-cooling)	C&I	15	DEER 2014 EUL ID: GrocSys-MechSubcl
	Evaporator Fan Motor – with Permanent Magnet Synchronous Motor (PMSM)	C&I	15	DEER 2014 EUL ID: GrocDisp-FEvapFanMtr
	Refrigerated Case Door	C&I	12	DEER 2014 EUL ID: GrocDisp-FixtDoors

[214] https://www.federalregister.gov/documents/2019/06/18/2019-12761/energy-conservation-program-energy-conservation-standards-for-distribution-transformers
[215] https://www.kannahconsulting.com/wp-content/uploads/2016/08/2010-10-11_Battery_Charger_Title_20_CASE_Report_v2-2-2.pdf, pg 43
[216] 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
[217] http://www.calmac.org/publications/PoolCoverReport_2015_Final_Report_Appendices.pdf
[218] PG&E Work Paper PGECOAPP123, August 22, 2017
[219] 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	Refrigerated Case Night Cover	C&I	5	DEER 2014 EUL ID: GrocDisp-DispCvrs
Refrigeration - Control	Anti-Condensation Heater Control	C&I	12	DEER 2014 EUL ID: GrocDisp-ASH
	Condenser Pressure and Temperature Control	C&I	15	DEER 2014 EUL ID: GrocSys-Cndsr
	Evaporator Fan Control	C&I	16	DEER 2014 EUL ID: Groc-WlkIn-WEvapFMtrCtrl
	Floating Head Pressure Control	C&I	10	PA Consulting Group [220]

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

[220] 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
9-19-10	9/30/2019
12-19-17	12/23/2019
3-20-17	3/30/2020
7-20-20	7/31/2020
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3-21-18	3/31/2021
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