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5/28/19

Secretary Rosemary Chiavetta
Pennsylvania Public Utility Commission
Commonwealth Keystone Building, Second Floor
400 North Street
Harrisburg, Pennsylvania 17120

RE: Docket Number M-2019-3006867

Dear Ms. Chiavetta,

Please find attached comments made by Franklin Energy on the Commercial and Industrial and Residential sections of the PA TRM. Comments are made in the sidebar of the word document using the "comment" feature of Microsoft Word.

Sincerely,

Sara Aaserud

Sara Aaserud, Regional Technical Manager
Franklin Energy

TECHNICAL REFERENCE MANUAL

Volume 2: Residential Measures

State of Pennsylvania

Act 129 Energy Efficiency and Conservation Program

&

Act 213 Alternative Energy Portfolio Standards

April 2019

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2 RESIDENTIAL MEASURES

The following section of the TRM contains savings protocols for residential measures.

2.1 LIGHTING

2.1.1 ENERGY STAR LIGHTING

Target Sector	Residential Establishments
Measure Unit	Light Bulb or Fixture
Measure Life	LED: 15 years[1]
Vintage	Replace on Burnout (Upstream) Early Replacement (Direct Install)

Savings for residential energy efficient lighting products are based on a straightforward algorithm that calculates the difference between baseline and new wattage and the average daily hours of usage for the lighting unit being replaced. As of the writing of this TRM, federal standards for 2021 are uncertain. Baseline values in this measure represent the known EISA 2020 "backstop" provisions. An "in-service" rate is used to reflect the fact that not all lighting products purchased are actually installed. The algorithms include default values for estimating savings from sales to non-residential customers.

ELIGIBILITY

Definition of Efficient Equipment

In order for this measure protocol to apply, the high-efficiency equipment must be a screw-in ENERGY STAR LED bulb (general service or specialty bulb) or LED fixture.[2]

Definition of Baseline Equipment

The baseline equipment is assumed to be a bulb or fixture with an efficacy equal to 45 lumens per watt. For upstream buy-down, retail (time of sale), or efficiency kit programs, baseline wattages can be determined using the methods described below. For direct install programs where wattage of the existing bulb is known, and the existing bulb was in working condition, wattage of the existing lamp removed by the program may be used as the baseline wattage.

ALGORITHMS

The general form of the equation for the ENERGY STAR or other high-efficiency lighting energy savings algorithm is:

Total Savings $= Number\ of\ Units \times Savings\ per\ Unit$

Energy and demand savings algorithms include a term to account for cross-sector sales (i.e., lamps that end up in non-residential use). Default values for non-residential terms are based on values in Vol. 3, Sec. 3.1.7 Lighting Improvements for Midstream [WEBSITE LINK TBD]. For direct install programs or other programs where it is known that all lamps will be in residential end uses, there are no non-residential energy or demand savings.

[1] Act 129 Legislation caps measure life at 15 years. Assuming 3 hours of use a day, 15 years equals 16,425 hours. As of December 2018, average rated life hours for ENERGY STAR qualified LEDs was >22,000 hours. See https://www.energystar.gov/products/lighting_fans.

[2] The protocol also applies to products that are pending ENERGY STAR qualification.

$$\Delta kWh_{res} = \frac{Watts_{base} - Watts_{EE}}{1000\,\frac{W}{kW}} \times (1 + IE_{kWh,res}) \times ISR_{res} \times HOU_{res} \times 365\,\frac{days}{yr} \times (1 - CSS)$$

$$\Delta kWh_{non-res} = \frac{Watts_{base} - Watts_{EE}}{1000\,\frac{W}{kW}} \times (1 + IE_{kWh,non-res}) \times ISR_{non-res} \times HOU_{non-res} \times 365\,\frac{days}{yr} \times CSS$$

$$\Delta kW_{peak,res} = \frac{Watts_{base} - Watts_{EE}}{1000\,\frac{W}{kW}} \times (1 + IE_{kW,res}) \times ISR_{res} \times CF_{res} \times (1 - CSS)$$

$$\Delta kW_{peak,non-res} = \frac{Watts_{base} - Watts_{EE}}{1000\,\frac{W}{kW}} \times (1 + IE_{kW,non-res}) \times ISR_{non-res} \times CF_{non-res} \times CSS$$

Definition of Terms

Table 2-1: Terms, Values, and References for ENERGY STAR Lighting

Term	Unit	Value	Sources
$Watts_{base}$, Wattage of baseline case lamp/fixture	*Watts*	EDC Data Gathering[3] or see Baseline Wattage Values below	1
$Watts_{EE}$, Wattage of efficient case lamp/fixture	*Watts*	EDC Data Gathering	EDC Data Gathering
HOU_{res}, Average hours of use per day per unit installed for residential use	$\frac{hours}{day}$	Table 2-2	2
$HOU_{non-res}$, Average hours of use per day per unit installed for non-residential use	$\frac{hours}{day}$	EDC Data Gathering Default = 2,500	5
$IE_{kWh,res}$, HVAC Interactive Effect for LED energy for residential use	*None*	EDC Data Gathering Default = Table 2-3 Exterior Fixtures: 0%	3
$IE_{kW,res}$, HVAC Interactive Effect for LED demand for residential use	*None*	EDC Data Gathering Default =Table 2-3 Exterior Fixtures: 0%	3
$IE_{kWh,non-res}$, HVAC Interactive Effect for LED energy for non-residential use	*None*	EDC Data Gathering Default = 0%	5
$IE_{kW,non-res}$, HVAC Interactive Effect for LED demand for non-residential use	*None*	EDC Data Gathering Default = 19.2%	5
ISR_{res}, In-service rate per incented product for residential use	*%*	EDC Data Gathering[4], Default = 92%[5]	4

[3] EDCs may use the wattage of the replaced bulb for directly installed program bulbs
[4] For EDC Data Gathering, EDCs must use the method established in the DOE Uniform Methods Project, October 2017. (https://www.nrel.gov/docs/fy17osti/68562.pdf)
[5] For direct install, giveaway, and energy kit program bulbs, EDCs have the option to use an evaluated ISR when verified through PA program primary research.

Term	Unit	Value	Sources
$ISR_{non\text{-}res}$, In-service rate per incented product for non-residential use	%	EDC Data Gathering, Default = 98%	5
CF_{res}, Demand Coincidence Factor for residential use	*Proportion*	Table 2-2	2
$CF_{non\text{-}res}$, Demand Coincidence Factor for non-residential use	*Proportion*	EDC Data Gathering, Default = 0.60	5
CSS, Cross-sector sales. Share of incentivized lamps that go to non-residential uses.	%	EDC Data Gathering, Default = 7.4%	6

Variable Input Values

Baseline Wattage Values

For delivery methods where the install location is unknown, such as upstream programs, baseline wattage is dependent on lumen output. To determine the $Watts_{base}$ use the following formula:

$$Watts_{base} = Lumen\ Output \div 45\,\frac{\text{lumens}}{\text{watt}}\ ,$$

where *Lumen Output* is the rated light output of the efficient bulb in lumens.

For direct installation programs where the removed bulb is known, and the bulb is in working condition, EDCs may use the wattage of the replaced bulb in lieu of the formula.[6] For bulbs with lumens outside of the lumen bins provided, EDCs should use the manufacturer rated comparable wattage as the $Watts_{base}$.

Hours of Use and Peak Coincidence Factor Values

In the absence of more current EDC data gathering and analysis, the default values for daily hours of use (HOU_{res}) and coincidence factors (CF_{res}) are below in Table 2-2. The “all bulbs” HOU_{res} should be used for programs where it is known that the majority (> 90% or entirety) of the home’s sockets are retrofitted with efficient lighting (e.g., a direct installation program that replaces most of the bulbs in a home). All other programs, including upstream programs, should default to the efficient HOU_{res} and CF_{res}. Specific room-based HOU_{res} and CF_{res} may be used for programs where the room-type of installation is known and recorded, otherwise the whole house or unknown room value should serve as the estimate.

Table 2-2: Bulb and Fixture Hours of Use and Peak Coincidence Factor Values, by Room

Room	Efficient HOU_{res}	Efficient CF_{res}	All Bulbs HOU_{res}	All bulbs CF_{res}
Basement	1.4	0.035	1.7	0.066
Bathroom	2.8	0.105	2.3	0.096
Bedroom	2.3	0.073	1.8	0.064
Closet	1.2	0.038	0.6	0.029
Dining Room	3.2	0.118	2.7	0.108
Exterior	4.4	0.274	3.9	0.265
Hallway	2.4	0.085	1.9	0.076
Kitchen	4.4	0.150	3.9	0.142
Living Room	4.1	0.106	3.7	0.098

[6] Bulbs that are not installed during the home visit do not qualify for this exemption. This includes bulbs that are left for homeowners to install. In these instances, baseline wattages should be calculated using the provided formula.

Room	Efficient HOU_{res}	Efficient CF_{res}	All Bulbs HOU_{res}	All bulbs CF_{res}
Other	2.1	0.070	1.7	0.061
Overall Household or unknown room	3.0	0.106	2.5	0.101

Interactive Effects Values

In the absence of EDC data gathering and analysis, the default values for Energy and Demand HVAC Interactive Effects are below. Exterior Fixtures should apply a 0% IE value.

Table 2-3: Energy and Demand HVAC Interactive Effects by EDC[7]

EDC	$IE_{kWh, res}$	$IE_{kW, res}$
Duquesne	8%	13%
FE (Met-Ed)	-8%	13%
FE (Penelec)	1%	10%
FE (Penn Power)	0%	20%
FE (WPP)	-2%	30%
PPL	-6%	12%
PECO	1%	23%

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework[8] provides specific guidelines and requirements for evaluation procedures.

Sources

1) EISA standards require efficacy of 45 lumens/watt. https://www.energy.gov/sites/prod/files/2017/01/f34/gsl-irl-finalrule_2016-12-29_0.pdf

2) Statewide Evaluation Team (GDS Associates, Inc, Nexant, Research into Action, Apex Analytics LLC), "2014 Commercial & Residential Light Metering Study", January 13, 2014. Based on data derived from Tables 1-2 & 1-3 but exclusive of inefficient bulbs

3) GDS Simulation Modeling, September-November 2013. PECO values are based on an analysis of PY4 as performed by Navigant.

4) The ISR is based on an installation rate "trajectory" and includes savings for all program bulbs that are believed to be installed within three years of purchase as established in the DOE Uniform Methods Project (UMP), Chapter 6: Residential Lighting Evaluation Protocol. October 2017. This protocol estimates the three-year ISR based on a researched first year ISR. For the purposes of this TRM, a 79% first year ISR was used based on intercept surveys conducted in the PECO service territory (Navigant Consulting, Inc. "Final Annual Report to the Pennsylvania Public Utility Commission. Prepared for PECO. Program Year 5". November, 2014.)

5) See Pennsylvania TRM Vol. 3, Sec. 3.1.7 Lighting Improvements for Midstream. [WEBSITE LINK TBD]

[7] HVAC Interactive Effects modeled through REM/Rate models, using EDC specific inputs. Values were weighted to the saturation of HVAC equipment and housing types present in each EDC service territory as reported in the Pennsylvania Statewide Residential End-Use and Saturation Study, 2012. PECO values are based on an analysis of PY4 as performed by Navigant.

[8] http://www.puc.pa.gov/filing_resources/issues_laws_regulations/act_129_information/act_129_statewide_evaluator_swe_.aspx

6) Based on a savings-weighted average of EDC-reported cross-sector sales values for PY6-PY9. [WEBSITE LINK TBD]

2.1.2 Residential Occupancy Sensors

Target Sector	Residential Establishments
Measure Unit	Occupancy Sensor
Measure Life	10 years[Source 3]
Vintage	Retrofit

Savings for residential occupancy sensors inside residential homes or common areas are based on a straightforward algorithm that calculates savings based on the wattage of the fixture(s) being controlled by the occupancy sensor, the daily run hours before installation and the daily run hours after installation. This protocol provides a deemed savings value for occupancy sensors sold through an upstream buy-down or retail (time of sale) program (and therefore the controlled wattage is unknown).

Eligibility

This protocol is for the installation of occupancy sensors and/or connected (aka “smart”) lighting inside residential homes or common areas.

Algorithms

$$\Delta\, kWh = \frac{Watts_{controlled}}{1000\frac{W}{kW}} \times (RH_{old} - RH_{new}) \times 365\frac{days}{yr}$$

$$\Delta kW_{peak} = 0$$

Definition of Terms

Table 2-4: Terms, Values, and References for Residential Occupancy Sensors

Term	Unit	Value	Source
$Watts_{controlled}$, Wattage of the fixture(s) being controlled by the occupancy sensor	*W*	EDC Data Gathering Default = 105.5 W	EDC Data Gathering
RH_{old} , Daily run hours before installation	*Hours*	2.5	1
RH_{new} , Daily run hours after installation	*Hours*	1.75 (70% of RH_{old})	2

Deemed Savings

For occupancy sensors for which the controlled wattage is unknown, the deemed savings are 28.9 kWh/year per occupancy sensor. This value is based on the Phase III Market Potential Study for Pennsylvania.[Source 4]

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate

evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) Statewide Evaluation Team (GDS Associates, Inc, Nexant, Research into Action, Apex Analytics LLC), "2014 Commercial & Residential Light Metering Study", January 13, 2014.
2) Lighting control savings fractions consistent with current programs offered by National Grid, Northeast Utilities, Long Island Power Authority, NYSERDA, and Energy Efficient Vermont
3) GDS Associates, Inc. (2007). Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures. Prepared for The New England State Program Working Group.
4) Statewide Evaluation Team (GDS Associates, Inc, Nexant, Research into Action, Apex Analytics LLC), "2015 Energy Efficiency Potential Study for Pennsylvania", February 27, 2015. http://www.puc.pa.gov/pcdocs/1345079.pdf

2.1.3 LED and Electroluminescent Nightlights

Target Sector	Residential Establishments
Measure Unit	Nightlight
Measure Life	8 years[Source 1]
Vintage	Replace on Burnout

Savings from installation of plug-in LED and electroluminescent nightlights are based on a straightforward algorithm that calculates the difference between existing and new wattage and the average daily hours of usage for the lighting unit being replaced. An in-service rate is used to modify the savings based upon the outcome of participant surveys, which will inform the calculation. Demand savings is assumed to be zero for this measure.

Eligibility

This measure documents the energy savings resulting from the installation of an LED or electroluminescent nightlight instead of a standard nightlight. The target sector is primarily residential.

Algorithms

The general form of the equation for the nightlight energy savings algorithm is:

$$\Delta\, kWh = \frac{(W_{base} \times HOU_{base} - W_{ee} \times HOU_{ee})}{1000\frac{W}{kW}} \times ISR_{NL} \times 365\frac{days}{yr}$$

ΔkW_{peak} = 0 *(assumed)*

Definition of Terms

Table 2-5: Terms, Values, and References for LED and Electroluminescent Nightlights

Term	Unit	Value	Sources
W_{base}, Watts per baseline nightlight	*Watts*	EDC Data Gathering Default = 7	1
W_{ee}, Watts per efficient nightlight	*Watts*	EDC Data Gathering Default values: LED = 1 Electroluminescent = 0.03	2
HOU_{base}, Daily hours of use for baseline nightlight	$\frac{hours}{day}$	12	1
HOU_{ee}, Daily hours of use for efficient nightlight	$\frac{hours}{day}$	LED = 12 Electroluminescent = 24	3
ISR_{NL}, In-Service Rate per efficient nightlight	*None*	EDC Data Gathering Default = 0.20	4

Deemed Energy Savings

LED ΔkWh $= \frac{(7 \times 12 - 1 \times 12)}{1000\frac{W}{kW}} \times 0.2 \times 365\frac{days}{yr} = 5.3\, kWh$

$$\text{Electroluminescent } \Delta kWh = \frac{(7 \times 12 - 0.03 \times 24)}{1000\frac{W}{kW}} \times 0.2 \times 365\frac{days}{yr} = 6.1\ kWh$$

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) Southern California Edison Company, "LED, Electroluminescent & Fluorescent Night Lights", Work Paper WPSCRELG0029 Rev. 1, February 2009, pp. 2–3.

2) Limelite Equipment Specification. Personal Communication, Ralph Ruffin, EL Products, 512-357-2776/ ralph@limelite.com.

3) Electroluminescent nightlights are assumed to operate continuously.

4) Based on ISR rates reported by First Energy for nightlights in kits for PY9. See [WEBSITE LINK TBD]

2.1.4 Holiday Lights

Target Sector	Residential Applications
Measure Unit	One 25-bulb Strand of Holiday lights
Measure Life	10 years[Source 1, 2]
Vintage	Replace on Burnout

LED holiday lights reduce light strand energy consumption by up to 90%. Up to 25 strands can be connected end-to-end in terms of residential grade lights. Commercial grade lights require different power adapters and as a result, more strands can be connected end-to-end.

Eligibility

This protocol documents the energy savings attributed to the installation of LED holiday lights indoors and outdoors. LED lights must replace traditional incandescent holiday lights.

Algorithms

Algorithms yield kWh savings results per package (kWh/yr per package of LED holiday lights).

$$\Delta\,kWh_{C9} = \frac{[(INC_{C9} - LED_{C9}) \times \#Bulbs \times \#Strands \times HOU]}{1000\frac{W}{kW}}$$

$$\Delta\,kWh_{C7} = \frac{[(INC_{C7} - LED_{C7}) \times \#Bulbs \times \#Strands \times HOU]}{1000\frac{W}{kW}}$$

$$\Delta\,kWh_{mini} = \frac{[(INC_{mini} - LED_{mini}) \times \#Bulbs \times \#Strands \times HOU]}{1000\frac{W}{kW}}$$

Key assumptions

1) All estimated values reflect the use of residential (50ct. per strand) LED bulb holiday lighting.
2) Secondary impacts for heating and cooling were not evaluated.
3) It is assumed that 50% of rebated lamps are of the "mini" variety, 25% are of the C7 variety, and 25% are of the C9 variety. If the lamp type is known or fixed by program design, then the savings can be calculated as described by the algorithms above. Otherwise, the savings for the mini, C7, and C9 varieties should be weighted by 0.5, 0.25 and 0.25, respectively, as in the algorithm below.

$$\Delta\,kWh_{Default} = [\%_{C9} \times \Delta\,kWh/yr_{C9}] + [\%_{C7} \times \Delta\,kWh/yr_{C7}] + [\%_{mini} \times \Delta\,kWh/yr_{mini}]$$

Definition of Terms

Table 2-6: Terms, Values, and References for Holiday Lights

Parameter	Unit	Value	Source
LED_{mini} , Wattage of LED mini bulbs	*Watts/Bulb*	0.08	1

INC_{mini} , Wattage of incandescent mini bulbs	*Watts/Bulb*	0.48	1
LED_{C7} , Wattage of LED C7 bulbs	*Watts/Bulb*	0.48	1
INC_{C7} , Wattage of incandescent C7bulbs	*Watts/Bulb*	6.0	1
LED_{C9} , Wattage of LED C9 bulbs	*Watts/Bulb*	2.0	1
INC_{C9} , Wattage of incandescent C9 bulbs	*Watts/Bulb*	7.0	1
$\%_{Mini}$, Percentage of holiday lights that are "mini"	*%*	50%	1
$\%_{C7}$, Percentage of holiday lights that are "C7"	*%*	25%	1
$\%_{C9}$, Percentage of holiday lights that are "C9"	*%*	25%	1
$\#_{Bulbs}$, Number of bulbs per strand	*Bulbs/strand*	EDC Data Gathering Default: 50 per strand	3
$\#_{Strands}$, Number of strands of lights per package	*strands/package*	EDC Data Gathering Default: 1 strand	3
HOU , Annual hours of operation	*Hours/yr*	150	1

Deemed Savings

The deemed savings for installation of LED C9, C7, and mini lights is 37.5 kWh, 41.4 kWh, and 3 kWh, respectively. The weighted average savings are 21.2 kWh per strand. There are no demand savings as holiday lights only operate at night. Since the lights do not operate in the summer, the coincidence factor for this measure is 0.0.

Evaluation Protocol

The most appropriate evaluation protocol for this measure is verification of installation coupled with assignment of stipulated energy savings. As these lights are used on a seasonal basis, verification must occur in the winter holiday season. Given the relatively small amount of impact evaluation risk that this measure represents, and given that the savings hinge as heavily on the actual wattage of the supplanted lights than the usage of the efficient LED lights, customer interviews should be considered as an appropriate channel for verification.

Sources

1) The DSMore Michigan Database of Energy Efficiency Measures: Based on spreadsheet calculations using collected data
2) http://www.energyideas.org/documents/factsheets/HolidayLighting.pdf
3) Typical values of lights per strand and strands per package at Home Depot and other stores.

2.2 HVAC

2.2.1 High Efficiency Equipment: ASHP, CAC, GSHP, PTAC, PTHP

Target Sector	Residential Establishments
Measure Unit	Central AC, ASHP, GSHP, PTAC or PTHP Unit
Measure Life	15[Source 1]
Vintage	Early Replacement, Replace on Burnout, New Construction

The method for determining residential high-efficiency cooling and heating equipment energy impact savings is based on algorithms that determine a central air conditioner or heat pump's cooling/heating energy use and peak demand contribution. Input data is based both on fixed assumptions and data supplied from the high-efficiency equipment AEPS application form or EDC data gathering.

The algorithms applicable for this program measure the energy savings directly related to the more efficient hardware installation.

Larger commercial air conditioning and heat pump applications are dealt with in Section 3 of Volume 3: Commercial and Industrial Measures of this Manual, including GSHP systems over 65 $\frac{kBtu}{hr}$.

Eligibility

This measure requires the purchase of a high-efficiency Central Air Conditioner (CAC), Air Source Heat Pump (ASHP), Ground Source Heat Pump (GSHP), Packaged Terminal Air Conditioner (PTAC) or Packaged Terminal Heat Pump (PTHP).

Algorithms

This algorithm is used for the installation of new high efficiency air conditioners or heat pumps.

$$\Delta kWh = \Delta kWh_{cool} + \Delta kWh_{heat}$$

$$\Delta kWh_{cool} = CAPY_{cool} \times \left(\frac{OF_{cool}}{SEER_{base}} - \frac{1}{SEER_{ee}}\right) \times EFLH_{cool}$$

$$\Delta kWh_{heat} = CAPY_{heat} \times \left(\frac{OF_{heat}}{HSPF_{base}} - \frac{1}{HSPF_{ee}}\right) \times EFLH_{heat}$$

$$\Delta kW = CAPY_{cool} \times \left(\frac{OF_{cool}}{EER_{base}} - \frac{1}{EER_{ee}}\right) \times CF$$

Baseline: Room Air Conditioner(s)

EDCs may collect information about the total capacity of the (kBTU/hr) of existing RACs ($CAPY_{RAC}$) in use in the home to determine the replaced capacity. An oversizing factor is calculated from the ratio of baseline to qualifying capacity:

$$OF_{cool} = \frac{\sum CAPY_{RAC}}{CAPY_{cool}}$$

Baseline: Spaceheater(s), Electric Baseboards

EDCs may collect information about the capacity of the existing space heaters, electric furnaces, or electric baseboards. Capacity is determined using the total wattage of electric heat in use, where OF_{heat} is the ratio of the existing electric capacity to the capacity of the new equipment:

$$OF_{heat} = \frac{\sum kW_{Spaceheat} \times 3.412 \frac{\text{BTU}}{\text{W·h}}}{CAPY_{Heat}}$$

Qualifying: Ground Source Heat Pump

GSHP efficiencies are typically calculated differently than air-source units, baseline and qualifying unit efficiencies should be converted as follows, but note that the HSPF derating as outlined above ***should not be applied:***

$$SEER = EER_g \times GSHPDF \times GSER$$

$$EER = EER_g \times GSPK$$

$$HSPF = COP_g \times GSHPDF \times 3.412 \frac{\text{BTU}}{\text{W·h}}$$

Qualifying: Package Terminal Heat Pumps, Package Terminal Air Conditioners

$$SEER = EER$$

$$HSPF = COP \times 3.412 \frac{\text{BTU}}{\text{W·h}}$$

Definition of Terms

Table 2-7: Terms, Values, and References for High Efficiency Equipment: ASHP, CAC, GSHP, PTAC, PTHP

Term	Unit	Value	Sources
$CAPY_{cool}$, The cooling capacity of the equipment being installed[9]	$kBTU/hr$	EDC Data Gathering	AEPS Application; EDC Data Gathering
$CAPY_{heat}$, The heating capacity of the heat pump being installed[10]	$kBTU/hr$	EDC Data Gathering	AEPS Application; EDC Data Gathering
$CAPY_{RAC}$, The cooling capacity of the room AC for the RAC cooling baseline	$kBTU/hr$	EDC Data Gathering	EDC Data Gathering
$kW_{spaceheat}$, The heating capacity of the space heaters in kilowatts.	kW	EDC Data Gathering	EDC Data Gathering
$SEER_{base}$, Seasonal Energy Efficiency Ratio of the Baseline Unit	$\frac{BTU}{W \cdot h}$	EDC Data Gathering, Default see Table 2-8	2; EDC Data Gathering
$SEER_{ee}$, Seasonal Energy Efficiency Ratio of the qualifying unit being installed[11]	$\frac{BTU}{W \cdot h}$	EDC Data Gathering	AEPS Application; EDC Data Gathering
EER_{base} , Energy Efficiency Ratio of the Baseline Unit	$\frac{BTU}{W \cdot h}$	EDC Data Gathering, Default see Table 2-8	3; EDC Data Gathering
EER_{ee} , Energy Efficiency Ratio of the unit being installed[12]	$\frac{BTU}{W \cdot h}$	EDC Data Gathering Default: $-0.0228 \times SEER^2 + 1.1522 \times SEER$	4; EDC Data Gathering; AEPS Application

[9] This data is obtained from the AEPS Application Form or EDC's data gathering based on the model number.
[10] Ibid. This refers to the capacity of the heat pump and not any auxiliary electric resistance heat.
[11] Ibid.
[12] Ibid.

Term	Unit	Value	Sources
EER_g, Energy Efficiency Ratio of a GSHP, this is measured differently than EER of an air source heat pump and must be converted	$\frac{BTU}{W \cdot h}$	EDC Data Gathering	
$HSPF_{base}$, Heating Seasonal Performance Factor of the Baseline Unit	$\frac{BTU}{W \cdot h}$	EDC Data Gathering, Default see Table 2-8	2; EDC Data Gathering
$HSPF_{ee}$, Heating Seasonal Performance Factor of the unit being installed	$\frac{BTU}{W \cdot h}$	EDC Data Gathering	AEPS Application; EDC Data Gathering
COP_{ee}, Coefficient of Performance of the unit being installed. This is a measure of the efficiency of a heat pump	*Proportion*	EDC Data Gathering	AEPS Application; EDC Data Gathering
OF_{cool}, Oversize factor	*None*	EDC Data Gathering, Default see Table 2-9	5
OF_{heat}, Oversize factor	*None*	EDC Data Gathering, Default see Table 2-9	6
GSER, Factor used to determine the SEER of a GSHP based on its EER_g	$\frac{BTU}{W \cdot h}$	1.02	7
GSPK, Factor to convert EER_g to the equivalent EER of an air conditioner to enable comparisons to the baseline unit	*Proportion*	0.8416	7
GSHPDF, Ground Source Heat Pump De-rate Factor	*Proportion*	0.885	8
$EFLH_{cool}$, Equivalent Full Load Hours of operation during the cooling season for the average unit	$\frac{hours}{yr}$	See $EFLH_{cool}$ in Vol. 1, App. A	9
$EFLH_{heat}$, Equivalent Full Load Hours of operation during the heating season for the average unit	$\frac{hours}{yr}$	See $EFLH_{heat}$ in Vol. 1, App. A	9
CF, Demand Coincidence Factor	*Proportion*	See *CF* in Vol. 1, App. A	9

Table 2-8: Default Baseline Equipment Efficiency for High Efficiency Equipment

	Early Replacement			Replace on Burnout / New Construction		
Baseline Equip.	***SEER**base*	***EER**base*	***HSPF**base*	***SEER**base*	***EER**base*	***HSPF**base*
ASHP	13.5	11.4	8.2	14	12.0	8.2
CAC	12.1	10.6[a]	–	13	11.3	8.2
GSHP	15.0	16.6[a]	10.9	14	12.0	8.2
Elec. Baseboard	–	–	3.412	–	–	–
Elec. Furnace[13]	–	–	3.241	–	–	–
Space Heaters	–	–	3.412	–	–	–
PTAC[14,15,16]	$EER_{base} = 10.9 - (0.213 \times CAPY_{cool})$		–	$EER_{base} = 14.0 - (0.3 \times CAPY_{cool})$		–
PTHP[15,16,17]	$EER_{base} = 10.8 - (0.213 \times CAPY_{cool})$		$3.412 \frac{Btu}{W{\cdot}h} \times (2.9 - 0.026 \times CAPY_{cool})$	$EER_{base} = 14.0 - (0.3 \times CAPY_{cool})$		$3.412 \frac{Btu}{W{\cdot}h} \times (3.7 - 0.052 \times CAPY_{cool})$

a. Calculated using the equation from Source 4

Table 2-9: Default Oversize Factors for High Efficiency Equipment

Qualifying	Oversize Factor	Existing						
		ASHP	**CAC**	**Electric Baseboard**	**Electric Furnace**	**GSHP**	**RAC**	**Space Heaters**
CAC	OF_{cool}	1	1	0	0	1	1	0
HP	OF_{heat}	1	1	1	1	1	0	0.6
	OF_{cool}	1	1	0	0	1	1	0

Evaluation Protocols

The most appropriate evaluation protocol for this measure is verification of installation coupled with assignment of stipulated energy savings.

Sources

1) California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx Accessed December 2018

2) For Early Replacement ASHP, CAC: Pennsylvania Act 129 2018 Residential Baseline Study [http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-Phase3_Res_Baseline_Study_Rpt021219.pdf] For Early Replacement GSHP: the values represent the minimum efficiency values for GSHP in BEopt v2.8.0. For Replace on Burnout/New Construction ASHP, CAC, GSHP: Federal Code of Regulations 10 CFR 430. https://www.gpo.gov/fdsys/pkg/CFR-2017-title10-vol3/pdf/CFR-2017-title10-vol3-sec430-

13 Using the relation $HSPF = COP \times 3.412$ where $HSPF = 3.412$ for electric resistance heating. Electric furnace efficiency typically varies from 0.95 to 1.00, therefore a COP of 0.95 equates to an $HSPF$ of 3.241.
14 If the unit's capacity is less than 7 kBTU/hr, use 7 kBTU/hr in the calculation. If the unit's capacity is greater than 15 kBTU/h, use 15 kBTU/hr in the calculation.
15 "Early Replacement" is for nonstandard size packaged terminal air conditioners and heat pumps with existing sleeves having an external wall opening of less than 16 in. high or less than 42 in. wide and having a cross-sectional area less than 670 sq. in. Shall be factory labeled as follows: "Manufactured for nonstandard size applications only: not to be installed in new construction projects."
16 "New Construction" is intended for applications with new, standard size exterior wall openings.

32.pdf. For PTAC and PTHP: standards are based on requirements of ASHRAE 90.1-2016, Energy Standard for Buildings Except Low-Rise Residential Buildings, Table 6.8.1-4, https://www.ashrae.org/technical-resources/standards-and-guidelines/read-only-versions-of-ashrae-standards.

3) Average EER for SEER 13 units as calculated by EER = -0.02 × SEER² + 1.12 × SEER based on U.S. DOE Building America House Simulation Protocol, Revised 2010.
4) "Methodology for Calculating Cooling and Heating Energy Input-Ratio (EIR) from the Rated Seasonal Performance Eefficiency (SEER OR HSPF)" (Kim, Baltazar, Haberl). April 2013 Accessed December 2018. http://oaktrust.library.tamu.edu/bitstream/handle/1969.1/152118/ESL-TR-13-04-01.pdf
5) Based on REM/Rate modeling using models from the PA 2012 Potential Study. EFLH calculated from kWh consumption for cooling and heating. Models assume 50% over-sizing of air conditioners[17] and 40% oversizing of heat pumps.[18]
6) Assumptions used to calculate a default value for de facto heating system OF: Four (4) 1500W portable electric space heaters in use in the home with capacity of $4 \times 1.5kW \times 3412\frac{BTU}{kW{\cdot}h} = 20{,}472\ BTU$, replaced by DHP with combined heating capacity of 36kBTU. $OF = \frac{20{,}472}{36{,}000} \approx 0.6$
7) VEIC estimate. Extrapolation of manufacturer data.
8) McQuay Application Guide 31-008, Geothermal Heat Pump Design Manual, 2002. Engineering Estimate - See System Performance of Ground Source Heat Pumps
9) Based on the Phase III SWE team's analysis of regional HVAC runtime data collected from ecobee's Donate Your Data research service. https://www.ecobee.com/donateyourdata/

[17] Neme, Proctor, Nadal, "National Energy Savings Potential From Addressing Residential HVAC Installation Problems". ACEEE, February 1, 1999. https://www.proctoreng.com/dnld/NationalEnergySavingsPotentialfromAddressingResidentialHVACInstallationProblems.pdf Confirmed also by *Central Air Conditioning in Wisconsin, a compilation of recent field research.* Energy Center of Wisconsin. May 2008, emended December 15, 2010. https://www.seventhwave.org/publications/central-air-conditioning-wisconsin-compilation-recent-field-research

[18] ACCA, "Verifying ACCA Manual S Procedures," http://www.acca.org/wp-content/uploads/2014/01/Manual-S-Brochure-Final.pdf

2.2.2 HIGH EFFICIENCY EQUIPMENT: DUCTLESS HEAT PUMPS WITH MIDSTREAM DELIVERY OPTION

Target Sector	Residential Establishments
Measure Unit	Ductless Heat Pump Unit
Measure Life	15 years[Source 1]
Vintage	Early Replacement, Replace on Burnout, New Construction

ENERGY STAR Version 5.0 ductless "mini-split" heat pumps technology is typically used to convert an electric resistance heated home into an efficient single or multi-zonal ductless heat pump system.

ELIGIBILITY

This protocol documents the energy savings attributed to ductless heat pumps. Eligible equipment must meet ENERGY STAR Version 5.0 requirements. The baseline heating system could be:

1) Existing electric resistance heating
2) Electric space heaters used as the primary heating source when fossil fuel (other than natural gas) heating systems failed (referred to as de facto heating) [19]
3) A lower-efficiency ductless heat pump system
4) A ducted heat pump
5) Electric furnace
6) A non-electric fuel-based system.

The baseline cooling system can be:

1) A standard efficiency heat pump system
2) A central air conditioning system
3) A room air conditioner

For new construction or addition applications, the baseline assumption is a standard-efficiency ductless unit (Table 2-12). DHP systems may be installed as the primary heating or cooling system for the house or as a secondary heating or cooling system for a single room.

MIDSTREAM HVAC OVERVIEW

Residential ductless mini-split heat pumps midstream delivery programs will offer incentives on eligible products sold to trade allies and customers through residential sales channels such as distributors of HVAC products. This complements other delivery channels (such as downstream rebates to trade allies and customers) by providing incentives to encourage distributors to stock, promote, and sell more efficient systems.

Midstream savings calculations rely on composite baseline information formulated by blending historical participant data from PECO's downstream programs for PY8 to PY9 and PPL's programs from PY8 to PY10Q1 with the existing PA TRM deemed values for the downstream incentive program. See "Midstream Composite Baseline Calculations" below.

[19] This baseline is for participants with broken-beyond-repair oil heating systems who are heating their homes with portable electric space heaters.

Commented [SA1]: Franklin Energy

The baseline could also be no AC for installation cases other than New Construction.

ALGORITHMS

The savings depend on three main factors: baseline condition, usage (primary or secondary heating system), and the capacity of the indoor unit. This algorithm is used for the installation of new high efficiency air conditioners or heat pumps. For non-midstream delivery methods, if there are multiple zones, each zone should be calculated separately. For midstream delivery, composite values are provided.

$$\Delta kWh = \Delta kWh_{cool} + \Delta kWh_{heat}$$

$$\Delta kWh_{cool} = CAPY_{cool} \times \left(\frac{OF_{cool} \times DLF}{SEER_{base}} - \frac{1}{SEER_{ee}}\right) \times EFLH_{cool,zone} \times n_{MS\ zones}$$

Note: Be sure to use $EFLH_{cool}$ of Room ACs for secondary cooling zones, see Table 2-11.

$$\Delta kWh_{heat} = CAPY_{heat} \times \left(\frac{OF_{heat} \times DLF}{HSPF_{base}} - \frac{1}{HSPF_{ee}}\right) \times EFLH_{heat,HP,zone} \times n_{MS\ zones}$$

$$\Delta kW_{peak} = CAPY_{cool} \times \left(\frac{OF_{cool} \times DLF}{EER_{base}} - \frac{1}{EER_{ee}}\right) \times CF \times n_{MS\ zones}$$

Note: Be sure to use $EFLH_{heat}$ of Secondary HP for secondary heating zones, see Table 2-11.

Baseline: Room Air Conditioner(s)

EDCs may collect information about the capacity of existing RACs (W_{RAC}) in use in the home to determine the replaced capacity. An oversizing factor is calculated from the ratio of baseline to qualifying capacity:

$$OF_{cool} = \frac{\sum CAPY_{RAC}}{CAPY_{cool}}$$

Baseline: Spaceheater(s), Electric Baseboards

EDCs may collect information about the capacity of the existing space heaters, electric furnaces, or electric baseboards. Capacity is determined using the total wattage of wattage of electric heat in use, where OF_{heat} is the ratio of the existing electric capacity to the capacity of the new equipment:

$$OF_{heat} = \frac{\sum kW_{Spaceheat} \times 3.412 \frac{BTU}{W \cdot h}}{CAPY_{Heat}}$$

DEFINITION OF TERMS

Table 2-10: Terms, Values, and References for High Efficiency Equipment: Ductless Heat Pump

Term	Unit	Value	Sources
$CAPY_{cool}$, The cooling capacity of the central air conditioner or heat pump being installed[20]	$kBTU/hr$	EDC Data Gathering	AEPS Application; EDC Data Gathering
$CAPY_{heat}$, The heating capacity of the heat pump being installed[21]	$kBTU/hr$	EDC Data Gathering	AEPS Application; EDC Data Gathering
$CAPY_{RAC}$, The cooling capacity of the room AC. Used only for the RAC cooling baseline	$kBTU/hr$	EDC Data Gathering	EDC Data Gathering

[20] This data is obtained from the AEPS Application Form or EDC's data gathering based on the model number.
[21] Ibid.

Term	Unit	Value	Sources
$kW_{spaceheat}$, The heating capacity of the space heaters in watts.	kW	EDC Data Gathering	EDC Data Gathering
$SEER_{base}$, Seasonal Energy Efficiency Ratio of the Baseline Unit	$\frac{BTU}{W \cdot h}$	EDC Data Gathering Default: Table 2-12 or Table 2-8 in Sec. 2.2.1 Midstream: 12.1	EDC Data Gathering; 2; 10
$SEER_{ee}$, Seasonal Energy Efficiency Ratio of the qualifying unit being installed[22]	$\frac{BTU}{W \cdot h}$	EDC Data Gathering	AEPS Application; EDC Data Gathering
EER_{base} , Energy Efficiency Ratio of the Baseline Unit	$\frac{BTU}{W \cdot h}$	EDC Data Gathering Default: Table 2-12	EDC Data Gathering; 3
EER_{ee} , Energy Efficiency Ratio of the unit being installed[23]	$\frac{BTU}{W \cdot h}$	EDC Data Gathering Default: $-0.0228 \times SEER_{ee}{}^2 + 1.1522 \times SEER_{ee}$	EDC Data Gathering; AEPS Application; 4
$HSPF_{base}$, Heating Seasonal Performance Factor of the Baseline Unit	$\frac{BTU}{W \cdot h}$	EDC Data Gathering Default: Table 2-12 or Table 2-8 in 2.2.1 Midstream: 6.7	EDC Data Gathering; 2; 10
$HSPF_{ee}$, Heating Seasonal Performance Factor of the unit being installed[24]	$\frac{BTU}{W \cdot h}$	EDC Data Gathering	AEPS Application; EDC Data Gathering
OF_{cool} , Oversize factor	None	EDC Data Gathering Default: Table 2-9 Midstream: 1.1	EDC Data Gathering; 5
OF_{heat} , Oversize factor	None	EDC Data Gathering Default: Table 2-9 Midstream: 1.3	EDC Data Gathering ;6
DLF, "Duct Leakage Factor" accounts for the fact that a % of the energy is lost to duct leakage and conduction for ducted systems, but not ductless ones	None	Depends on baseline & efficient conditions: Table 2-13	7; 10

[22] Ibid.
[23] Ibid.
[24] This data is obtained from the AEPS Application Form or EDC's data gathering.

Term	Unit	Value	Sources
		Midstream, cooling: 1.02 Midstream, heating: 1.01	
zone, Primary or secondary usage level of a space, this affects $EFLH_{cool}$ and $EFLH_{heat}$. For midstream delivery, use provided composite *EFLH* values.	None	See Table 2-11	
$n_{MS\ zones}$, Average number of heating and cooling zones per site. Note: this factor applies to mid-stream delivery only.	None	1.18	10
$EFLH_{cool}$, Equivalent Full Load Hours of operation during the cooling season for the average unit	$\frac{hours}{yr}$	See $EFLH_{cool}$ in Vol. 1, App. A Use Room AC hours for secondary zones. Midstream: Table 2-18	8
$EFLH_{heat,HP}$, Equivalent Full Load Hours of operation during the heating season for the average unit	$\frac{hours}{yr}$	See $EFLH_{heat}$ in Vol. 1, App. A Use Secondary HP for secondary zones. Midstream: Table 2-18	8
CF , Demand Coincidence Factor	*Proportion*	See *CF* in Vol. 1, App. A	8

Table 2-11: Ductless Heat Pump Usage Zones

Usage Zone	Definition
Primary	Dining room Family room House hallway Living room Kitchen areas Recreation room
Secondary	Basement Bathroom Bedroom Laundry/Mudroom Office/Study Storage room Sunroom/Seasonal room

Table 2-12: Default Ductless Heat Pump Efficiencies

Baseline Equip.	Early Replacement			Replace on Burnout/New Construction		
	$SEER_{base}$	EER_{base}	$HSPF_{base}$	$SEER_{base}$	EER_{base}	$HSPF_{base}$
Ductless	13	11.3	8.2	14	12	8.2

Table 2-13: Oversize and Duct Leakage Factors for High Efficiency Equipment

	ASHP	CAC	Ductless	Electric Baseboard	Electric Furnace	New Construction	RAC	Space Heaters
DLF	1.15	1.15	1	1	1.15	1	1	1
OF_{heat}	1.4	0	1	1.4	1.4	1	0	0.6
OF_{coo}	1.4	1.5	1	0	0	1	1	0

Midstream Composite baseline Calculations

The Midstream Delivery Program estimates the baseline system using composite values calculated from historical participant data. The composite values of the baseline inputs (SEER, EER, OF, DLF, and HSPF) are based on the PA TRM values and baseline heating and cooling system splits from historical PECO PY8 to PY9 and PPL PY8 to PY10Q1 data. The composite EFLH values assume a 50/50 split between primary and secondary installations and are a weighted average of EFLH values in Appendix A: Climate Dependent Values. Table 2-14 through Table 2-18 show the inputs for the calculation of each composite baseline value.

Table 2-14: Midstream DHP – SEER and EER Baseline Splits

Cooling Type	$SEER_{base}$	EER_{base}	Split[25]
Central AC	13.0	11.3	4%
DHP or ASHP	14.0	12.0	8%
No existing cooling for primary space	13.0	11.3	29%
No existing cooling for secondary space	11.3	9.8	30%
Room AC	11.3	9.8	30%
Composite[26]	12.1	10.5	100%

Table 2-15: Midstream DHP – HSPF Baseline Splits

Heating Type	$HSPF_{base}$	Split
ASHP	8.2	3%
Electric furnace	3.2	1%
Electric resistance or de facto space heaters	3.4	32%
No existing or non-electric heating	8.2	57%
Standard DHP	8.2	8%
Composite	6.7	100%

[25] The split represents the approximate percentage of projects in the PECO and PPL territory that have the indicated Cooling Type. The split is calculated by dividing the number of projects with the indicated Cooling Type by the total number of projects in PECO PY8 to PY9 and PPL PY8 to PY10Q1 historical data set. The split is rounded to the nearest percent.

[26] The composite value represents the weighted average of the system type based on the relative system splits. The computed average is rounded to the nearest tenth.

Table 2-16: Midstream DHP – DLF_{cool} and OF_{cool} Baseline Splits

Cooling Type	DLF_{cool}	OF_{cool}	Split
Central AC	1.15	1.5	8%
Central ASHP	1.15	1.4	5%
Ductless Heat Pump	1.00	1.0	19%
Room AC	1.00	1.0	69%
Composite	1.02	1.1	100%

Table 2-17: Midstream DHP – DLF_{heat} and OF_{heat} Baseline Splits

Heating Type	DLF_{heat}	OF_{heat}	Split
Central ASHP	1.15	1.4	6%
De facto Space Heaters	1.00	0.6	5%
Ductless Heat Pump	1.00	1.0	26%
Electric Baseboard	1.00	1.4	62%
Electric Furnace	1.15	1.4	1%
Composite	1.01	1.3	100%

Table 2-18: Midstream DHP – Composite EFLH Values

Reference City	Zone	Composite $EFLH_{cool}$	Composite $EFLH_{heat}$
Allentown	C	377	1040
Binghamton, NY	A	218	1277
Bradford	G	135	1445
Erie	I	307	1213
Harrisburg	E	479	1129
Philadelphia	D	512	906
Pittsburgh	H	356	1073
Scranton	B	310	1143
Williamsport	F	366	1085

Evaluation Protocols

The most appropriate evaluation protocol for this measure is verification of installation coupled with assignment of stipulated energy savings. A sample of pre- and post-metering is recommended to verify heating and cooling savings but billing analysis will be accepted as a proper form of savings verification and evaluation.

The composite baseline values will be updated as needed from the downstream program participation data set.

Sources

1) California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020,

http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx. Accessed December 2018.

2) Federal Code of Regulations 10 CFR 430. https://www.gpo.gov/fdsys/pkg/CFR-2017-title10-vol3/pdf/CFR-2017-title10-vol3-sec430-32.pdf

3) Average EER for SEER 13 units as calculated by EER = -0.02 × SEER² + 1.12 × SEER based on U.S. DOE Building America House Simulation Protocol, Revised 2010.

4) "Methodology for Calculating Cooling and Heating Energy Input-Ratio (EIR) from the Rated Seasonal Performance Eefficiency (SEER OR HSPF)" (Kim, Baltazar, Haberl). April 2013 Accessed December 2018. http://oaktrust.library.tamu.edu/bitstream/handle/1969.1/152118/ESL-TR-13-04-01.pdf

5) Based on REM/Rate modeling using models from the PA 2012 Potential Study. Models assume 50% over-sizing of air conditioners[27] and 40% oversizing of heat pumps.[28]

6) Assumptions used to calculate a default value for de facto heating system OF: Four (4) 1500W portable electric space heaters in use in the home with capacity of $4 \times 1.5kW \times 3412 \frac{BTU}{kW{\cdot}h} = 20{,}472\ BTU$, replaced by DHP with combined heating capacity of 36kBTU. $OF = \frac{20{,}472}{36{,}000} \approx 0.6$

7) Assumption used in Illinois 2014 TRM, Ductless Heat Pumps Measure, p. 531, footnote 877. Reasonable assumption when compared to http://www.energystar.gov/index.cfm?c=home_improvement.hm_improvement_ducts and Residential HVAC and Distribution Research Implementation,. Berkeley Labs. May, 2002, p. 6. http://epb.lbl.gov/publications/pdf/lbnl-47214.pdf

8) Based on the Phase III SWE team's analysis of regional HVAC runtime data collected from ecobee's Donate Your Data research service. https://www.ecobee.com/donateyourdata/

9) Assumptions used to calculate a default value for de facto heating system OF: Four (4) 1500 W portable electric space heaters in use in the home with capacity of 1500 × 3.412 × 4 = 20,472 BTU, replaced by DHP with combined heating capacity of 36,000 BTU. OF = 20,472 / 36,000 = 0.6.

10) PECO PY8 to PY9 Program Participation Data and PPL PY8 to PY10Q1 Program Participation Data

[27] Neme, Proctor, Nadal, "National Energy Savings Potential From Addressing Residential HVAC Installation Problems. ACEEE, February 1, 1999. Confirmed also by *Central Air Conditioning in Wisconsin, a compilation of recent field research.* Energy Center of Wisconsin. May 2008, emended December 15, 2010, http://ecw.org/sites/default/files/241-1_0.pdf

[28] ACCA, "Verifying ACCA Manual S Procedures," http://www.acca.org/wp-content/uploads/2014/01/Manual-S-Brochure-Final.pdf

2.2.3 Properly Sized Cooling

Target Sector	Residential Establishments
Measure Unit	CAC, ASHP, Ductless Mini-split, GSHP, PTAC or PTHP Unit
Measure Life	15[Source 1]
Vintage	Replace on Burnout, New Construction

This algorithm is specifically intended for the quality installation of new units.

Eligibility

Proper sizing requires Manual J calculations, following of ENERGY STAR HVAC Quality Installation procedures, or similar calculations. This measure may be combined with Section 2.2.1 or 2.2.2.

Algorithms

$$\Delta kWh = \frac{CAPY_{cool}}{SEER_{ee}} \times PSF \times EFLH_{cool}$$

$$\Delta kW = \frac{CAPY_{cool}}{EER_{ee}} \times PSF \times CF$$

Definition of Terms

Table 2-19: Terms, Values, and References for Properly Sized Cooling

Term	Unit	Value	Sources
$CAPY_{cool}$, The cooling capacity of the air conditioner or heat pump being installed[29]	$kBTU/hr$	EDC Data Gathering	AEPS Application; EDC Data Gathering
$SEER_{ee}$, Seasonal Energy Efficiency Ratio of the qualifying unit being installed[30]	$\frac{BTU}{W \cdot h}$	EDC Data Gathering	AEPS Application; EDC Data Gathering
EER_{ee} , Energy Efficiency Ratio of the unit being installed[31]	$\frac{BTU}{W \cdot h}$	EDC Data Gathering Default: $-0.0228 \times SEER^2 + 1.1522 \times SEER$	2; EDC Data Gathering
PSF , Proper Sizing Factor or the assumed savings due to proper sizing and proper installation	Proportion	0.05	3
$EFLH_{cool}$, Equivalent Full Load Hours of operation during the cooling season for the average unit	$\frac{hours}{yr}$	See $EFLH_{cool}$ in Vol. 1, App. A	4
CF , Demand Coincidence Factor	Proportion	See CF in Vol. 1, App. A	4

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate

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29 This data is obtained from the AEPS Application Form or EDC's data gathering based on the model number.
30 Ibid.
31 Ibid.

evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx. Accessed December 2018.
2) "Methodology for Calculating Cooling and Heating Energy Input-Ratio (EIR) from the Rated Seasonal Performance Eefficiency (SEER OR HSPF)" (Kim, Baltazar, Haberl). April 2013 Accessed December 2018. http://oaktrust.library.tamu.edu/bitstream/handle/1969.1/152118/ESL-TR-13-04-01.pdf
3) Northeast Energy Efficiency Partnerships, Inc., "Strategies to Increase Residential HVAC Efficiency in the Northeast", (February 2006): Appendix C Benefits of HVAC Contractor Training: Field Research Results 03-STAC-01, p. 46.
4) Based on the Phase III SWE team's analysis of regional HVAC runtime data collected from ecobee's Donate Your Data research service, https://www.ecobee.com/donateyourdata/.

2.2.4 ECM Circulation Fans

Target Sector	Residential Establishments
Measure Unit	ECM Circulation Fan
Measure Life	15 years[Source 1]
Measure Vintage	Early Replacement, Replace on Burnout

This protocol covers energy and demand savings associated with retrofit of permanent-split capacitor (PSC) evaporator fan motors in an air handling unit with an electronically commutated motor (ECM).

Eligibility

This measure is targeted to residential customers whose air handling equipment currently uses a standard low-efficiency permanent split capacitor (PSC) fan motor rather than an ECM.

The targeted fan can supply heating or cooling only, or both heating and cooling. A default savings option is offered if motor input wattage is not known. However, these parameters should be collected by EDCs for greatest accuracy.

Acceptable baseline conditions are an existing circulating fan with a PSC fan motor.

Efficient conditions are a circulating fan with an ECM.

Algorithms

This algorithm is used for the installation of new high efficiency circulating fans, or air handler replacement that includes a high efficiency fan.

Commented [SA2]: Franklin Energy

https://appliance-standards.org/standards-projected-savings/furnace-fan-standards-published-2014

New baseline in 2019 where brushless permanent magnet motors is the baseline

$$\Delta kWh_{heat} = ECM_{kW} \times EFLH_{heat}$$

$$\Delta kWh_{cool} = ECM_{kW} \times EFLH_{cool}$$

$$\Delta kW = ECM_{kW} \times CF$$

Definition of Terms

Table 2-20: Terms, Values, and References for ECM Furnace Fan

Term	Unit	Value	Sources
ECM_{kW}, Reduced energy demand of the efficient ECM vs. baseline PSC motor.	*kW*	EDC Data Gathering, Default: 0.116	2, EDC Data Gathering
$EFLH_{cool}$, Equivalent Full Load Hours of operation during the cooling season for the average unit	$\frac{hours}{yr}$	See *$EFLH_{cool}$* in Vol. 1, App. A	3
$EFLH_{heat}$, Equivalent Full Load Hours of operation during the heating season for the average unit	$\frac{hours}{yr}$	See *$EFLH_{heat}$* in Vol. 1, App. A	3
CF, Demand Coincidence Factor	*Proportion*	See *CF* in Vol. 1, App. A	3

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) "Energy Savings from Efficient Furnace Fan Air Handlers in Massachusetts," ACEEE, Sachs and Smith, 2003. For the purpose of calculating the total Resource Cost Test for Act 129, measure cannot claim savings for more than fifteen years.
2) Cadmus (Public Service Commission of Wisconsin), "Focus on Energy Evaluated Deemed Savings Changes", November 2014, Table 3 Description of Variables for Furnaces with ECM. https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf
3) Based on the Phase III SWE team's analysis of regional HVAC runtime data collected from ecobee's Donate Your Data research service, https://www.ecobee.com/donateyourdata/.

2.2.5 GSHP Desuperheaters

Target Sector	Residential Establishments
Measure Unit	GSHP Desuperheater
Measure Life	15 years
Vintage	Retrofit

Eligibility

Installation of a desuperheater on an new or existing Ground Source Heat Pump to replace an electric water heater.

Commented [SA3]: Franklin Energy

There are several types of electric water heaters. Does this include all of them? Maybe it is better to list the applicable options: electric storage, instantaneous, or heat pump water heater.

Algorithms

This algorithm is used for the installation of a desuperheater for a GSHP unit.

$$\Delta kWh = \frac{\frac{EF_{SH}}{UEF_{Base}} \times HW \times 365\frac{days}{yr} \times 8.3\frac{BTU}{gal \cdot °F} \times (T_{hot} - T_{cold})}{3{,}412\ \frac{BTU}{kWh}}$$

$$\Delta kW = \Delta kWh \times ETDF$$

Definition of Terms

Table 2-21: Terms, Values, and References for GSHP Desuperheater

Term	Unit	Value	Sources
EF_{SH} , Energy Factor per desuperheater	*None*	0.17	1, 2
HW, Daily hot water use	*Gallons/Day*	45.5	7
T_{hot}, Hot Water Temperature	*°F*	119	3
T_{cold}, Cold Water Temperature	*°F*	52	4
UEF_{base} , Energy Factor of Electric Water Heater	*None*	EDC Data Gathering, Default: 1.02	EDC Data Gathering, 5
$ETDF$, Energy to Demand Factor	*None*	0.00008047	6

Commented [SA4]: Franklin Energy

We recommend providing a table for different baseline electric water heaters, such as storage, instantaneous, heat pump and an unknown value.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Default Savings

Default savings are 451.1 kWh and 0.036 kW demand savings.

Sources

1) "Residential Ground Source Heat Pumps with Integrated Domestic Hot Water Generation: Performance Results from Long-Term Monitoring", U.S. Department of Energy, November 2012.

2) Desuperheater Study, New England Electric System, 1998 42 U.S.C.A 6295(i) (West Supp. 2011) and 10 C.F.R. 430.32 (x) (2011).

3) Pennsylvania Statewide Residential End-Use and Saturation Study, 2014, http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-2014_PA_Statewide_Act129_Residential_Baseline_Study.pdf.

4) Using Rock Spring, PA (Site 2036) as a proxy, the mean of soil temperature at 40 inch depth is 51.861. Calculated using Daily SCAN Standard - Period of Record data from April 1999 to December 2018 from the Natural Resource Conservation Service Database. https://wcc.sc.egov.usda.gov/nwcc/rgrpt?report=daily_scan_por&state=PA. Methodology follows Missouri TRM 2017 Volume 2: Commercial and Industrial Measures. p. 78. https://energy.mo.gov/sites/energy/files/MOTRM2017Volume2.pdf

5) Pennsylvania Act 129 2018 Residential Baseline Study, http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-Phase3_Res_Baseline_Study_Rpt021219.pdf.

6) Straub, Mary and Switzer, Sheldon. "Using Available Information for Efficient Evaluation of Demand Side Management Programs". Study by BG&E. The Electricity Journal, Aug/Sept. 2011. p. 95. http://www.sciencedirect.com/science/article/pii/S1040619011001941

7) "Residential End Uses of Water, Version 2." *Water Research Foundation.* (Apr 2016), p. 5. https://www.circleofblue.org/wp-content/uploads/2016/04/WRF_REU2016.pdf

2.2.6 AIR CONDITIONER & HEAT PUMP MAINTENANCE

Target Sector	Residential Establishments
Measure Unit	Central A/C, ASHP, Ductless Mini-Split HP, GSHP, PTAC or PTHP Unit
Measure Life	3 years[Source 1]
Vintage	Retrofit

This algorithm is used for measures providing services to maintain, service or tune-up refrigerant-driven Central A/C and heat pump units. The tune-up must include the following at a minimum:

- Check refrigerant charge level and correct as necessary
- Clean filters as needed
- Inspect and lubricate bearings
- Inspect and clean condenser and, if accessible, evaporator coil

ELIGIBILITY

An existing central A/C, air source heat pump, ground source heat pump, ductless mini-split heat pump, PTAC, or PTHP unit.

ALGORITHMS

$$\Delta kWh = \Delta kWh_{cool} + \Delta kWh_{heat}$$

$$\Delta kWh_{cool} = \frac{CAPY_{cool}}{SEER_{base}} \times MF \times EFLH_{cool}$$

$$\Delta kWh_{heat}{}^{32} = \frac{CAPY_{heat}}{HSPF_{base}} \times MF \times EFLH_{heat,HP}$$

$$\Delta kW = \frac{CAPY_{cool}}{EER_{base}} \times MF \times CF$$

Ground Source Heat Pumps (GSHP)

GSHP efficiencies are typically calculated differently than air-source units and baseline efficiencies should be converted as follows:

$$SEER_{base} = EER_g \times GSHPDF \times GSER$$

$$EER_{base} = EER_g \times GSPK$$

$$HSPF_{base} = COP_g \times GSHPDF \times 3.412 \frac{\text{BTU}}{\text{W·h}}$$

PTAC and PTHP

$$SEER_{base} = EER_{base}$$

[32] Does not apply for CAC or PTAC.

Definition of Terms

Table 2-22: Terms, Values, and References for Air Conditioner & Heat Pump Maintenance

Term	Unit	Value	Sources
$CAPY_{cool}$, The cooling capacity of the central air conditioner or heat pump being installed[33]	$kBTU/hr$	EDC Data Gathering	AEPS Application; EDC Data Gathering
$CAPY_{heat}$, The heating capacity of the heat pump being installed[34]	$kBTU/hr$	EDC Data Gathering	AEPS Application; EDC Data Gathering
MF , Maintenance Factor or assumed savings due to completing recommended maintenance on installed cooling equipment	*Proportion*	0.05	2
$EFLH_{cool}$, Equivalent Full Load Hours of operation during the cooling season for the average unit	$\frac{hours}{yr}$	See $EFLH_{cool}$ in Vol. 1, App. A	3
$EFLH_{heat,HP}$, Equivalent Full Load Hours of operation during the heating season for the average unit	$\frac{hours}{yr}$	See $EFLH_{heat}$ in Vol. 1, App. A	3
$SEER_{base}$, Seasonal Energy Efficiency Ratio of the Baseline Unit	$\frac{BTU}{W \cdot h}$	EDC Data Gathering, Default: Table 2-23	EDC Data Gathering 4
$HSPF_{base}$, Heating Seasonal Performance Factor of the Baseline Unit	$\frac{BTU}{W \cdot h}$	EDC Data Gathering, Default: Table 2-23	EDC Data Gathering 4
EER_g , Energy Efficiency Ratio of a GSHP, this is measured differently than EER of an air source heat pump and must be converted	$\frac{BTU}{W \cdot h}$	EDC Data Gathering Default: 16.6	4
EER_{base} , Energy Efficiency Ratio of the Baseline Unit	$\frac{BTU}{W \cdot h}$	EDC Data Gathering	
COP_g , Coefficient of Performance. This is a measure of the efficiency of a ground source heat pump	*None*	EDC Data Gathering Default: 3.6	AEPS Application; EDC Data Gathering
GSER , Factor used to determine the SEER of a GSHP based on its EER_g	$\frac{BTU}{W \cdot h}$	1.02	5
GSPK , Factor to convert EER_g to the equivalent EER of an air conditioner to enable comparisons to the baseline unit	*Proportion*	0.8416	5
GSHPDF , Ground Source Heat Pump De-rate Factor	*Proportion*	0.885	6
CF , Demand Coincidence Factor	*Proportion*	See *CF* in Vol. 1, App. A	3

[33] This data is obtained from the AEPS Application Form or EDC's data gathering based on the model number.
[34] Ibid.

Commented [SA5]: Franklin Energy

Recommend adding a separate set of hours if some of these HVAC units are secondary units. Please see the "Ductless Mini-Split Heat Pump Measure"

Table 2-23: Default Equipment Efficiency

Type	$SEER_{base}$	$HSPF_{base}$
Central Air Conditioner	12.1	N/A
Room Air Conditioner	11.4	N/A
Air-Source Heat Pump	13.5	8.2
Ground-Source Heat Pump	15.0	10.9
Ductless Mini-Split	14.9	2.6
Electric Resistance	N/A	3.412
PTAC (EER_{base})[35]	$EER_{base} = 10.9 - (0.213 \times CAPY_{cool})$	N/A
PTHP (EER_{base})[34]	$EER_{base} = 10.8 - (0.213 \times CAPY_{cool})$	$HSPF_{base} = 3.412 \frac{BTU}{W \cdot h} \times (2.9 - (0.026 \times CAPY_{cool}))$

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx. Accessed December 2018.
2) Energy Center of Wisconsin, “Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research”, May 2008.
3) Based on the Phase III SWE team’s analysis of regional HVAC runtime data collected from ecobee’s Donate Your Data research service. https://www.ecobee.com/donateyourdata/
4) Pennsylvania Act 129 2018 Residential Baseline Study, http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-Phase3_Res_Baseline_Study_Rpt021219.pdf. Due to small sample size for GSHP in Pennsylvania Act 129 2018 Residential Baseline Study this value is lowest efficiency value from BEopt v2.8.0. PTAC and PTHP standards are based on requirements of ASHRAE 90.1-2016, Energy Standard for Buildings Except Low-Rise Residential Buildings, Table 6.8.1-4, https://www.ashrae.org/technical-resources/standards-and-guidelines/read-only-versions-of-ashrae-standards.
5) VEIC estimate. Extrapolation of manufacturer data.
6) McQuay Application Guide 31-008, Geothermal Heat Pump Design Manual, 2002. Engineering Estimate - See System Performance of Ground Source Heat Pumps

[35] If the unit’s capacity is less than 7 kBTU/hr, use 7 kBTU/hr in the calculation. If the unit’s capacity is greater than 15 kBTU/h, use 15 kBTU/hr in the calculation.

2.2.7 Fuel Switching: Electric Heat to Gas/Propane/Oil Heat

Target Sector	Residential Establishments
Measure Unit	Gas, Propane, or Oil Heater
Measure Life	15 years
Vintage	Replace on Burnout

This protocol documents the energy savings attributed to converting from an existing electric heating system to a new natural gas, propane, or oil furnace or boiler in a residential home.

The baseline for this measure is an existing residential home with an electric primary heating source. The heating source can be electric baseboards, electric furnace, or electric air source heat pump.

Eligibility

The target sector primarily consists of single-family residences.

EDCs may provide incentives for equipment with efficiencies greater than or equal to the applicable ENERGY STAR requirement per the following table.

Equipment	Energy Star Requirements
Gas Furnace Source 1	AFUE rating of 95% or greater Furnace fan must have electronically commutated fan motor (ECM) Less than or equal to 2.0% air leakage
Oil Furnace Source 1	AFUE rating of 85% or greater Furnace fan must have electronically commutated fan motor (ECM) Less than or equal to 2.0% air leakage
Gas Boiler Source 2	AFUE rating of 90% or greater
Oil Boiler Source 2	AFUE rating of 87% or greater

Algorithms

The energy savings are the full energy consumption of the electric heating source minus the energy consumption of the fossil fuel furnace blower motor. EDCs may use billing analysis using program participant data to claim measure savings, in lieu of the defaults provided in this measure protocol. The energy savings are obtained through the following formulas:

Heating savings with electric furnace (assumes 95% efficiency):[36]

$$\Delta kWh \quad = EFLH_{heat,non-HP} \times \frac{CAPY_{elec}}{3.241\frac{\text{BTU}}{\text{Wh}}}$$

Heating savings with electric baseboards (assumes 100% efficiency):

[36] Using the relation $HSPF = COP \times 3.412$ where $HSPF = 3.412$ for electric resistance heating. Electric furnace efficiency typically varies from 0.95 to 1.00, therefore a COP of 0.95 equates to an $HSPF$ of 3.241.

$$\Delta\, kWh \quad = EFLH_{heat,non-HP} \times \left(\frac{CAPY_{elec}}{3.412 \frac{\text{BTU}}{\text{Wh}}} - \frac{HP_{motor} \times 0.746 \frac{\text{kW}}{\text{hp}}}{\eta_{motor}} \right)$$

Heating savings with electric air source heat pump:

$$\Delta kWh \quad = \frac{EFLH_{heat,HP} \times CAPY_{HP\,heat}}{HSPF} - \frac{EFLH_{heat,non-HP} \times HP_{motor} \times 0.746 \frac{kW}{hp}}{\eta_{motor}}$$

For boilers, the annual pump energy consumption is negligible (<50 kWh per year) and not included in this calculation.[37]

There are no peak demand savings as it is a heating-only measure.

Although there is a significant electric savings, there is also an associated increase in natural gas energy consumption:

$$\Delta MMBTU \quad = -\Delta kWh \times 0.003412 \frac{\text{MMBTU}}{\text{kWh}}$$

DEFINITION OF TERMS

The default values for each term are shown in the table below.

Table 2-24: Terms, Values, and References for Fuel Switching: Electric Heat to Gas Heat

Term	Units	Value	Source
$CAPY_{elec}$, Total heating capacity of existing electric baseboards or electric furnace	$\frac{kBTU}{hr}$	EDC Data Gathering	EDC Data Gathering
$CAPY_{HP\,heat}$, Total heating capacity of existing electric ASHP	$\frac{kBTU}{hr}$	EDC Data Gathering	EDC Data Gathering
$EFLH_{heat,HP}$, Equivalent Full Load Heating hours for Air Source Heat Pumps	$\frac{hours}{yr}$	See $EFLH_{heat,HP}$ values in Vol. 1, App. A	3
$EFLH_{heat,non-HP}$, Equivalent Full Load Heating hours for furnaces, boilers, and electric baseboards	$\frac{hours}{yr}$	See $EFLH_{heat,non-HP}$ values in Vol. 1, App. A	3
HSPF , Heating Seasonal Performance Factor for existing heat pump	$\frac{BTU}{W \cdot hr}$	EDC Data Gathering or Default = 8.2	EDC Data Gathering 4
$AFUE_{fuel\,heat}$, Annual Fuel Utilization Efficiency for the new gas or oil furnace or boiler	*%*	EDC Data Gathering or Defaults: NG/LPG furnace = 95% NG/LPG boiler = 90% Oil furnace = 85% Oil boiler = 87%	EDC Data Gathering 1,2
HP_{motor} , Furnace blower motor horsepower	*hp*	EDC Data Gathering or Default = ½	EDC Data Gathering 5

[37] Pump motors are typically 1/25 HP. With 1,000 hour runtime and 80% assumed efficiency, this translates to 37 kWh.

Term	Units	Value	Source
η_{motor} , Efficiency of furnace blower motor	%	EDC Data Gathering or Default = 50%	EDC Data Gathering Typical efficiency of ½ HP blower motor

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) ENERGY STAR Program Requirements: Product Specification for Boilers, v3.0. https://www.energystar.gov/sites/default/files/specs//private/Boilers%20Program%20Requirements%20Version%203%200.pdf
2) ENERGY STAR Program Requirements: Product Specification for Furnaces, v4.1. https://www.energystar.gov/sites/default/files/Furnaces%20Version%204.1_Program%20Requirements_0.pdf
3) Based on the Phase III SWE team's analysis of regional HVAC runtime data collected from ecobee's Donate Your Data research service. https://www.ecobee.com/donateyourdata/
4) Pennsylvania Act 129 2018 Residential Baseline Study, http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-Phase3_Res_Baseline_Study_Rpt021219.pdf.
5) Average blower motor capacity for gas furnace, typical range = ¼ to ¾ HP.

2.2.8 ENERGY STAR Room Air Conditioners

Target Sector	Residential Establishments
Measure Unit	Room Air Conditioner
Measure Life	9 years[Source 1]
Vintage	Replace on Burnout

Eligibility

This measure relates to the purchase and installation of a room air conditioner meeting ENERGY STAR Version 4.1 criteria.

Algorithms

To determine resource savings, the per-unit estimates in the algorithms will be multiplied by the number of room air conditioners. The number of room air conditioners will be determined using market assessments and market tracking.

As of June 1, 2014 RAC units have a CEER rating as well as an EER. CEER is the Combined Energy Efficiency Ratio, which incorporates standby power into the calculation. This will be the value used in the savings algorithm.

$$\Delta\, kWh = CAPY \times \left(\frac{1}{CEER_{base}} - \frac{1}{CEER_{ee}}\right) \times EFLH_{RAC}$$

$$\Delta kW_{peak} = CAPY \times \left(\frac{1}{CEER_{base}} - \frac{1}{CEER_{ee}}\right) \times CF$$

Definition of Terms

Table 2-25: Terms, Values, and References for ENERGY STAR Room AC

Term	Unit	Value	Sources
CAPY, The cooling capacity of the room air conditioner (RAC) being installed	$\frac{kBTU}{hr}$	EDC Data Gathering Default = 7,500	5
$CEER_{base}$, Combined Energy Efficiency ratio of the baseline unit	$\frac{BTU}{W \cdot h}$	Federal Standard Values in Table 2-26, Table 2-27, or Table 2-28 Default = 11.0	2
$CEER_{ee}$, Combined Energy efficiency ratio of the RAC being installed	$\frac{BTU}{W \cdot h}$	EDC Data Gathering Default = ENERGY STAR values in in Table 2-26, Table 2-27, or Table 2-28	3
$EFLH_{RAC}$, Equivalent full load hours of the RAC being installed	$\frac{hours}{year}$	See $EFLH_{RAC}$ in Vol. 1, App. A	4
CF, Demand coincidence factor	*Proportion*	See *CF* in Vol. 1, App. A	4

Table 2-26 lists the minimum federal efficiency standards as of October 2018 and minimum ENERGY STAR efficiency standards for RAC units of various capacity ranges and with and without louvered sides. Units without louvered sides are also referred to as "through the wall" units or "built-in" units. Note that the new federal standards are based on the Combined Energy Efficiency Ratio metric (CEER), which is a metric that incorporates energy use in all modes, including standby and off modes.

Table 2-26: RAC (without reverse cycle) Federal Minimum Efficiency and ENERGY STAR Version 4.1 Standards

Capacity (BTU/h)	Federal Standard CEER, with louvered sides	ENERGY STAR CEER, with louvered sides	Federal Standard CEER, without louvered sides	ENERGY STAR CEER, without louvered sides
<6,000	11.0	12.1	10.0	11.0
6,000–7,999				
8,000–10,999	10.9	12.0	9.6	10.6
11,000–13,999			9.5	10.5
14,000–19,999	10.7	11.8	9.3	10.2
20,000–24,999	9.4	10.3	9.4	10.3
25,000–27,999	9.0			10.3
≥28,000	9.0	9.9	9.4	10.3

Table 2-27 lists the minimum federal efficiency standards and minimum ENERGY STAR efficiency standards for casement-only and casement-slider RAC units. Casement-only refers to a RAC designed for mounting in a casement window with an encased assembly with a width of 14.8 inches or less and a height of 11.2 inches or less. Casement-slider refers to a RAC with an encased assembly designed for mounting in a sliding or casement window with a width of 15.5 inches or less.

Table 2-27: Casement-Only and Casement-Slider RAC Federal Minimum Efficiency and ENERGY STAR Version 4.1 Standards

Casement	Federal Standard CEER	ENERGY STAR CEER
Casement-only	9.5	10.5
Casement-slider	10.4	11.4

Table 2-28 lists the minimum federal efficiency standards and minimum ENERGY STAR efficiency standards for reverse-cycle RAC units.

Table 2-28: Reverse-Cycle RAC Federal Minimum Efficiency Standards and ENERGY STAR Version 4.1 Standards

Capacity (BTU/h)	Federal Standard CEER, with louvered sides	ENERGY STAR CEER, with louvered sides	Federal Standard CEER, without louvered sides	ENERGY STAR CEER, without louvered sides
< 14,000	n/a	n/a	9.3	10.2
≥ 14,000			8.7	9.6
< 20,000	9.8	10.8	n/a	n/a
≥ 20,000	9.3	10.2		

DEFAULT SAVINGS

Default energy savings values assume a CAPY=7,500 BTU/hr[Source 7], louvered sides, no reverse cycle unit ($CEER_{base}$ = 11.0, $CEER_{ee}$ = 12.1).

Table 2-29: Deemed EFLH and Default Energy Savings

Climate Region	Reference City	ΔkWh/yr	ΔkW_{peak}
C	Allentown	11.0	0.022
A	Binghamton, NY	6.4	0.016
G	Bradford	4.0	0.014
I	Erie	9.0	0.016
E	Harrisburg	14.1	0.028
D	Philadelphia	15.0	0.026
H	Pittsburgh	10.5	0.023
B	Scranton	9.1	0.020
F	Williamsport	10.7	0.024

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx . Accessed December 2018.
2) Federal standards: U.S. Department of Energy. Code of Federal Regulations. 10 CFR, part 430.32(b). Effective June 1, 2014. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/41
3) ENERGY STAR Program Requirements Product Specification for Room Air Conditioners, Eligibility Criteria Version 4.1. October 26, 2015. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%204.1%20Room%20Air%20Conditioners%20Specification_0.pdf
4) Based on the Phase III SWE team's analysis of regional HVAC runtime data collected from ecobee's Donate Your Data research service, https://www.ecobee.com/donateyourdata/.
5) Statewide average for all housing types from Pennsylvania Act 129 2018 Residential Baseline Study, http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-Phase3_Res_Baseline_Study_Rpt021219.pdf.

2.2.9 Room AC (RAC) Retirement

Target Sector	Residential Establishments
Measure Unit	Room A/C
Measure Life	3 years[Source 1]
Vintage	Early Retirement, Early Replacement

This measure is defined as retirement and recycling without replacement of an *operable* but older and inefficient room AC (RAC) unit that would not have otherwise been recycled. The assumption is that these units will be permanently removed from the grid rather than handed down or sold for use in another location by another EDC customer, and furthermore that they would not have been recycled without this program. This measure is quite different from other energy-efficiency measures in that the energy/demand savings is not the difference between a pre- and post-configuration, but is instead the result of complete elimination of the existing RAC.

Eligibility

The savings are *not* attributable to the customer that owned the RAC, but instead are attributed to a *hypothetical user of the equipment had it not been recycled*. Energy and demand savings is the estimated energy consumption of the retired unit over its remaining useful life (RUL).

Algorithms

Although this is a fully deemed approach, any of these values can and should be evaluated and used to improve the savings estimates for this measure in subsequent TRM revisions.

Retirement-Only

All EDC programs are currently operated under this scenario. For this approach, impacts are based only on the existing unit, and savings apply *only for the remaining useful life (RUL) of the unit*.

$$\Delta\, kWh \quad = \left(\frac{CAPY}{EER_{RetRAC}}\right) \times EFLH_{RAC}$$

$$\Delta kW_{peak} \quad = \left(\frac{CAPY}{EER_{RetRAC}}\right) \times CF$$

Replacement and Recycling

For this approach, the ENERGY STAR upgrade measure would have to be combined with recycling via a turn-in event at a retail appliance store, where the old RAC is turned in at the same time that a new one is purchased. Unlike the retirement-only measure, the savings here are attributed to the customer that owns the retired RAC, and are based on the old unit and original unit being of the same size and configuration. In this case, two savings calculations would be needed. One would be applied over the remaining life of the recycled unit, and another would be used for the rest of the effective useful life, as explained below.

For the remaining useful life (RUL) of the existing RAC: The baseline value is the EER of the retired unit.

$$\Delta\, kWh \quad = CAPY \times \left(\frac{1}{EE_{RetRAC}} - \frac{1}{EER_{ee}}\right) \times EFLH_{RAC}$$

$$\Delta kW_{peak} = CAPY \times \left(\frac{1}{EER_{RetRAC}} - \frac{1}{EER_{ee}}\right) \times CF$$

After the RUL for (EUL-RUL) years: The baseline EER would revert to the minimum Federal appliance standard CEER. RAC units have a “CEER” rating in addition to an “EER”. CEER is the “Combined Energy Efficiency Ratio”, which incorporates standby power into the calculation. This will be the value used in the $\Delta\ kWh$ calculation.

$$\Delta\ kWh = CAPY \times \left(\frac{1}{CEER_{base}} - \frac{1}{CEER_{ee}}\right) \times EFLH_{RAC}$$

$$\Delta kW_{peak} = CAPY \times \left(\frac{1}{CEER_{base}} - \frac{1}{CEER_{ee}}\right) \times CF$$

Definition of Terms

Table 2-30: Terms, Values, and References for Room AC Retirement

Term	Unit	Value	Sources
$EFLH_{RAC}$, Equivalent Full Load Hours of operation for the installed measure. In actuality, the number of hours and time of operation can vary drastically depending on the RAC location (living room, bedroom, home office, etc.).	$\frac{hours}{yr}$	See $EFLH_{RAC}$ in Vol. 1, App. A	1
CAPY , Rated cooling capacity (size) of the RAC unit.	$\frac{kBTU}{hr}$	EDC Data Gathering Default: 7,500	3
EER_{RetRAC} , The Energy Efficiency Ratio of the unit being retired-recycled.[38]	$\frac{BTU}{W \cdot h}$	EDC Data Gathering Default: 9.8	4
EER_{ee} , The Energy Efficiency Ratio for an ENERGY STAR RAC	$\frac{BTU}{W \cdot h}$	12.1	6
$CEER_{base}$, (for a 8,000 BTU/h unit), The Combined Energy Efficiency Ratio of a RAC that meets the minimum federal appliance standard efficiency.	$\frac{BTU}{W \cdot h}$	11.0	5
$CEER_{ee}$, (for a 8,000 BTU/h unit), The Combined Energy Efficiency Ratio for an ENERGY STAR RAC.	$\frac{BTU}{W \cdot h}$	EDC Data Gathering Default=12.1	5
CF , Demand Coincidence Factor	*Proportion*	See *CF* in Vol. 1, App. A	2

[38] Note that this value is the EER value, as CEER were introduced later.

Table 2-31: RAC Retirement-Only EFLH and Energy Savings by City

Climate Region	Reference City	Energy Impact (kWh)	Demand Impact (kW)
C	Allentown	136.2	0.271
A	Binghamton, NY	78.8	0.203
G	Bradford	49.0	0.167
I	Erie	111.0	0.203
E	Harrisburg	173.7	0.345
D	Philadelphia	185.2	0.324
H	Pittsburgh	129.3	0.282
B	Scranton	112.5	0.249
F	Williamsport	132.4	0.299

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx . Accessed December 2018.

2) Based on the Phase III SWE team's analysis of regional HVAC runtime data collected from ecobee's Donate Your Data research service, https://www.ecobee.com/donateyourdata/.

3) Mid Atlantic TRM Version 7.0. May, 2017. Prepared by Vermont Energy Investment Corporation. An adjustment to the ES RAC EFLHs of 31% was used for the "Window A/C" measure. The average ratio of EFLH for Room AC provided in RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008 (http://www.puc.nh.gov/Electric/Monitoring%20and%20Evaluation%20Reports/National%20Grid/117_RLW_CF %20Res%20RAC.pdf) to FLH for Central Cooling for the same location (provided by AHRI: http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls is 31%. This factor was applied to the EFLH for Central Cooling provided for PA cities and averaged to come up with the assumption for EFLH for Room AC." https://neep.org/sites/default/files/resources/Mid_Atlantic_TRM_V7_FINAL.pdf

4) Statewide average capacity of RAC units, Pennsylvania Act 129 2018 Residential Baseline Study, http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-Phase3_Res_Baseline_Study_Rpt021219.pdf.

5) Minimum Federal Standard for most common room AC type (8000-14,999 capacity range with louvered sides) per federal standards from 10/1/2000 to 5/31/2014. Note that this value is the EER value, as CEER were introduced later.

6) ENERGY STAR Program Requirements Product Specification for Room Air Conditioners, Eligibility Criteria Version 4.1. October 26, 2015.

https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%204.1%20Room%20Air%20Conditioners%20Specification_0.pdf

2.2.10 Duct Sealing & Duct Insulation

Target Sector	Residential Establishments
Measure Unit	Duct Sealing and/or Insulation Project
Measure Life	15 years[Source 1]
Vintage	Retrofit

This measure describes evaluating the savings associated with performing duct sealing using mastic sealant or metal tape to the distribution system of homes with either central air conditioning or a ducted heating system. The measure also applies to insulating ductwork in unconditioned and semi-conditioned spaces of residential buildings.

If duct insulation is involved with the improvement, the first method, "Evaluation of Distribution Efficiency," must be used to estimate energy savings.

1) **Evaluation of Distribution Efficiency** – this methodology requires the evaluation of three duct characteristics below, and use of the Building Performance Institute's "Guidance on Estimating Distribution Efficiency",[Source 2] which are summarized in Table 2-34 and Table 2-35 for convenience.
    a. Duct location, including percentage of duct work found within the conditioned space
    b. Duct leakage evaluation
    c. Duct insulation evaluation
2) **RESNET Test 380 4.4.2** – this method involves the pressurization of the house to 25 Pascals with reference to outside and a simultaneous pressurization of the duct system to reach equilibrium with the envelope or inside pressure of zero Pascals. A blower door is used to pressurize the building to 25 Pascals with reference to outside, when that is achieved the duct blaster is used to equalize the pressure difference between the duct system and the house. The amount of air required to bring the duct system to zero Pascals with reference to the building is the amount of air leaking through the ductwork to the outside. This technique is described in detail in section 4.4.2 of the ANSI/RESNET/ICC 380 - 2016 Standards: http://www.resnet.us/professional/standards

Eligibility

The efficient condition is sealed duct work throughout the unconditioned space in the home. The existing baseline condition is leaky duct work within the unconditioned space in the home.

Algorithms

Methodology 1: Evaluation of Distribution Efficiency

Determine Distribution Efficiency by evaluating duct system before and after duct sealing using Building Performance Institute "Guidance on Estimating Distribution Efficiency" or the values reproduced from that document in Table 2-34 that match the duct system, and if the majority of the duct sytem is in conditioned space add the matching value from Table 2-35, not to exceed 100%.

$$\Delta kWh_{cooling} = \frac{\frac{\left(DE_{post(cool)} - DE_{pre(cool)}\right)}{DE_{post(cool)}} \times EFLH_{cool} \times CAPY_{cool}}{SEER}$$

$$\Delta kWh_{heating} = \frac{\frac{(DE_{post(heat)} - DE_{pre(heat)})}{DE_{post(heat)}} \times EFLH_{heat} \times CAPY_{heat}}{COP \times 3.412 \frac{\mathrm{BTU}}{\mathrm{Wh}}}$$

Methodology 2: RESNET Test 803.7

a) Determine Duct Leakage rate before and after performing duct sealing

$$\Delta CFM_{25DB} = CFM_{25BASE} - CFM_{25EE}$$

b) Calculate Energy Savings

$$\Delta\, kWh/yr_{cooling} = \frac{\left(\frac{\Delta CFM25_{25DB}}{\frac{CAPY_{cool}}{12\frac{kBTUh}{ton}} \times TCFM} \times EFLH_{cool} \times CAPY_{cool}\right)}{SEER}$$

$$\Delta\, kWh/yr_{heating} = \frac{\left(\frac{\Delta CFM25_{25DB}}{\frac{CAPY_{heat}}{12\frac{kBTUh}{ton}} \times TCFM} \times EFLH_{heat} \times CAPY_{heat}\right)}{COP \times 3.412\frac{Btu}{Wh}}$$

Summer Coincident Peak Demand Savings

$$\Delta kW_{peak} = \frac{\Delta kWh_{cooling}}{EFLH_{cool}} \times CF$$

Definition of Terms

Table 2-32: Terms, Values, and References for Duct Sealing

Term	Unit	Value	Source
CF , Demand Coincidence Factor	*Proportion*	See *CF* in Vol. 1, App. A	4
CFM_{25BASE} , Standard Duct Leakage test result at 25 Pascal pressure differential of the duct system prior to sealing, calculated from the duct blaster fan flow chart	$\frac{ft^3}{min}$	EDC Data Gathering	3
CFM_{25DB} , Cubic feet per minute of air leaving the duct system at 25 Pascals	$\frac{ft^3}{min}$	EDC Data Gathering	3
CFM_{25EE} , Standard Duct Leakage test result at 25 Pascal pressure differential of the duct system after sealing, calculated from the duct blaster fan flow chart	$\frac{ft^3}{min}$	EDC Data Gathering	3
$CAPY_{cool}$, Capacity of Air Cooling System	*kBTU/hr*	EDC Data Gathering	EDC Data Gathering
$CAPY_{heat}$, Capacity of Air Heating System	*kBTU/hr*	EDC Data Gathering	EDC Data Gathering
TCFM , Conversion from tons of cooling to CFM	$\frac{CFM}{ton}$	400	5

Term	Unit	Value	Source
SEER , Efficiency of cooling equipment	$\frac{BTU}{W \cdot h}$	EDC Data Gathering Default = Table 2-33	6
COP , Efficiency of Heating Equipment	*None*	EDC Data Gathering Default = Table 2-33	6
$EFLH_{cool}$, Cooling equivalent full load hours	$\frac{hours}{year}$	See $EFLH_{cool}$ in Vol. 1, App. A	4
$EFLH_{heat}$, Heating equivalent full load hours	$\frac{hours}{year}$	See $EFLH_{heat}$ in Vol. 1, App. A	4
DE_{post} , Distribution efficiency after duct sealing and insulation	*None*	Table 2-34, Table 2-35 Not to exceed 100%	2
DE_{pre} , Distribution efficiency before duct sealing and insulation	*None*	Table 2-34, Table 2-35 Not to exceed 100%	2

Table 2-33: Default Equipment Efficiencies

Type	$SEER_{base}$	$HSPF_{base}$
Central Air Conditioner	12.1	N/A
Room Air Conditioner	11.4	N/A
Air-Source Heat Pump	13.5	8.2
Ground-Source Heat Pump	15.0	10.9
Ductless Mini-Split	14.9	2.6
PTAC	13.0	N/A
PTHP	13.0	7.7

Table 2-34: Distribution Efficiency by Climate Zone; Conditioned Air Type; Duct Location, Leakage & Insulation

Insulation	Location	Attic				Basement				Vented Crawl			
	HVAC Type	Heat		Cool		Heat		Cool		Heat		Cool	
	Leakage \ CZ*	4&5	6	4&5	6	4&5	6	4&5	6	4&5	6	4&5	6
R-0	Leaky	69%	64%	61%	61%	93%	92%	81%	92%	74%	71%	76%	90%
	Average	73%	68%	64%	66%	94%	94%	87%	95%	78%	74%	83%	93%
	Tight	77%	73%	73%	74%	95%	95%	94%	98%	82%	78%	91%	97%
R-2	Leaky	76%	73%	65%	67%	94%	94%	83%	92%	80%	78%	78%	91%
	Average	82%	79%	74%	75%	96%	95%	88%	95%	85%	83%	85%	94%
	Tight	87%	85%	84%	85%	97%	97%	95%	98%	90%	88%	93%	97%
R-4+	Leaky	79%	76%	67%	70%	95%	95%	83%	93%	82%	80%	79%	91%
	Average	84%	82%	77%	78%	96%	96%	89%	95%	87%	85%	86%	94%
	Tight	90%	89%	87%	88%	98%	98%	95%	98%	92%	91%	94%	97%
R-8+	Leaky	80%	78%	69%	71%	95%	95%	83%	93%	84%	82%	79%	91%
	Average	86%	84%	79%	80%	97%	97%	89%	95%	89%	87%	87%	94%
	Tight	92%	91%	90%	90%	98%	98%	95%	98%	94%	93%	94%	98%

* Climate Regions A and G correspond to IECC Climate Zone 6, the rest of the state is IECC Climate Zone 4 or 5.

Table 2-35: Distribution Efficiency Adders for Cond. Space (%) by Conditioned Air; Duct Location, Leakage & Insulation

Location	Attic				Basement				Vented Crawl			
HVAC Type	Heat		Cool		Heat		Cool		Heat		Cool*	
Insulation \ Conditioned	50%	80%	50%	80%	50%	80%	50%	80%	50%	80%	50%	80%
R-0	6%	4%	11%	9%	2%	3%	2%	3%	6%	3%	11%	5%
R-2	4%	5%	6%	7%	1%	1%	1%	2%	3%	2%	5%	3%
R-4+	3%	3%	4%	5%	1%	1%	1%	1%	2%	1%	4%	3%
R-8+	3%	2%	3%	3%	1%	1%	1%	1%	2%	1%	2%	2%

* In Climate Zone 6 (Climate Regions A & G), the cooling adder is fixed at 1% for ductwork in 80% conditioned space.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx . Accessed December 2018. Limited to Act 129 maximum of 15 years.

2) Building Performance Institute, Distribution Efficiency Table, http://www.bpi.org/sites/default/files/Guidance%20on%20Estimating%20Distribution%20Efficiency.pdf. Reproduced by permission.

3) Resnet Energy Services Network, Standards for Performance Testing. http://www.resnet.us/blog/wp-content/uploads/2016/01/ANSI-RESNET-ICC_380-2016-posted-on-website-6-15-16.pdf

4) Based on the Phase III SWE team's analysis of regional HVAC runtime data collected from ecobee's Donate Your Data research service. https://www.ecobee.com/donateyourdata/

5) Heating, Air conditioning & Refrigeration Distributors International https://energy.mo.gov/sites/energy/files/61-why-400-cfm-per-ton.pdf

6) Pennsylvania Act 129 2018 Residential Basline Study , http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-Phase3_Res_Baseline_Study_Rpt021219.pdf. Due to small sample sizes, GSHP is lowest efficiency value from BEopt v2.8.0, and PTAC and PTHP are minimum federal standard efficiencies.

2.2.11 Air Handler Filter Whistles

Target Sector	Residential Establishments
Measure Unit	Filter whistle (to promote regular filter change-out)
Measure Life	5 years[Source 6]
Vintage	Retrofit

Dirty air handler filters increase electricity consumption for the circulating fan. Filter whistles attach to the filter in the air handler, and make a sound when it is time to replace the filter.[Source 7]

Eligibility

Savings estimates are based on reduced blower fan motor power requirements for winter and summer use of the blower fan motor. This air handler filter whistle measure applies to central forced-air furnaces, central AC and heat pump systems. Where homes do not have A/C or heat pump systems for cooling, only the annual heating savings will apply.

Algorithms

$\Delta kWh \quad = \Delta kWh_{heat} + \Delta kWh_{cool}$

$\Delta kWh_{heat} \quad = kW_{motor} \times EFLH_{heat} \times EI \times ISR$

$\Delta kWh_{cool} \quad = kW_{motor} \times EFLH_{cool} \times EI \times ISR$

$\Delta kW \quad = \Delta kWh_{cool} \div EFLH_{cool} \times CF$

Definition of Terms

Table 2-36: Terms, Values, and References for Air Handler Filter Whistle

Term	Unit	Value	Sources
kW_{motor} , Average motor full load electric demand	kW	0.377	1
$EFLH_{heat}$, Estimated Full Load Hours (Heating)	$\frac{hours}{yr}$	See $EFLH_{heat}$ in Vol. 1, App. A	5
$EFLH_{cool}$, Estimated Full Load Hours (Cooling)	$\frac{hours}{yr}$	See $EFLH_{cool}$ in Vol. 1, App. A	5
EI , Efficiency Improvement	%	15%	2, 4
ISR , In-service Rate	%	EDC Data Gathering Default = 15%	3
CF , Coincidence Factor	*Proportion*	See *CF* in Vol. 1., App. A	5

Default Savings

The following table presents the assumptions and the results of the deemed savings for each reference location.

Table 2-37: Default Air Handler Filter Whistle Savings

Climate Region	Reference City	Heating		Cooling	
		Furnace kWh	ASHP kWh	kWh	kW
C	Allentown	7.7	10.5	4.9	0.003
A	Binghamton, NY	9.8	12.7	2.8	0.002
G	Bradford	11.4	14.2	1.7	0.002
I	Erie	8.9	12.1	4.0	0.002
E	Harrisburg	8.5	11.2	6.2	0.004
D	Philadelphia	6.5	9.2	6.6	0.004
H	Pittsburgh	8.0	10.8	4.6	0.003
B	Scranton	8.5	11.4	4.0	0.003
F	Williamsport	7.9	10.9	4.7	0.003

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) Typical blower motor capacity for gas furnace is ¼ to ¾ HP, $\frac{1}{2}\,\text{HP} \times 0.746\frac{\text{kW}}{\text{hp}} = 0.377\text{kW}$.

2) US DOE Office of Energy Efficiency and Renewable Energy - "Energy Savers" publication - "Clogged air filters will reduce system efficiency by 30% or more." Savings estimates assume the 30% quoted is the worst case and typical households will be at the median or 15% that is assumed to be the efficiency improvement when furnace filters are kept clean.

3) The In Service Rate is the average of values reported by First Energy EDCs for kits including an air handler furnace whistle for PY9. See [WEBSITE LINK TBD]

4) Energy.gov. "Maintaining Your Air Conditioner". Accessed 7/16/2014. Says that replacing a dirty air filter with a clean one can lower total air conditioner energy consumption by 5-15%. Since the algorithms in this measure only take into account the blower fan energy use, a 15% savings seems reasonable.

5) Based on the Phase III SWE team's analysis of regional HVAC runtime data collected from ecobee's Donate Your Data research service, https://www.ecobee.com/donateyourdata/.

6) California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx . Accessed December 2018.

7) Your Filter Connection, "What is a Furnace Filter Whistle?". https://yourfilterconnection.com/blogs/help/what-is-a-furnace-filter-whistle. Accessed December, 2018.

2.2.12 ENERGY STAR® Certified Connected Thermostats

Target Sector	Residential Homes, including single or multifamily in-unit spaces
Measure Unit	Residential Thermostat
Measure Life	11 years[Source 5]
Vintage	Retrofit, Replace on Burnout, or new construction

ENERGY STAR®-certified connected thermostats (CT) save heating and cooling energy by operating residential HVAC systems more efficiently. CTs that meet the ENERGY STAR® specification[8] will have functions that are located in the home and on the Internet (the cloud). Homes must have Wi-Fi to enable full operating capabilities.

ENERGY STAR®-certified connected thermostats may replace either a manual thermostat or a conventional programmable thermostat. The energy savings assume an existing ducted HVAC system with either an air source heat pump, fossil fuel heating with central AC, or an electric furnace with central AC. Electric resistance baseboard heating as the primary heating system is not eligible for savings to be claimed through this measure protocol because CTs are low voltage thermostats, which use 24 volts. Electric baseboard heating requires line-voltage thermostats, which can be either 120 or 240 volts.

Eligibility

This measure documents the energy savings resulting from the following product installations:

- ENERGY STAR®-certified connected thermostat (CT)

Savings are assessed in this protocol for three different installation scenarios:

1. **Customer self-installation of CT (no education).**
   Under this scenario, customers purchase and install the CT on their own without any education on installing and operationg the thermostat (aside from any manufacturer instructions included in the CT box at the time of purchase). This scenario applies to upstream programs where EDCs discount the device cost at the point of purchase.
2. **Customer self-installation with education on installation and operation of CT.**
   Under this scenario, customers purchase the program-qualified CT and, in order to receive the incentive, certify in the incentive application that they have completed the specified education on how to install and operate the thermostat. The education may consist of viewing of videos and/or completion of a short online training module on the installation and operational details of the thermostat.
3. **Professional installation with instructions on operating the CT**.
   For professional installation with operational instructions, the thermostat must be installed by a utility representative, ICSP, or program affiliated trade ally, at the time of the installation, the installer must explain the operational details of the thermostat to the customer. It is important to note that professional installation by contractors unaffiliated with the program may not focus on the energy savings capabilities of the device and would not produce higher savings. For example, an electrician might only focus on the wiring needs and provide little or no direction to the homeowner on how to leverage device capabilities for energy savings.

Table 2-38: Installation Classification

Installation Scenario	Installation Cost Paid By	Installation Type	Capacity Term(s)
Thermostat installed by EDC contractor during audit or other visit	EDC	Professional	EDC Data Gathering
Thermostat installed by contractor affiliated with EDC program (ICSP or trade ally)	EDC or Participant	Professional	EDC Data Gathering
Thermostat installed by licensed electrical or HVAC contractor - invoice, work order, etc. provided	Participant	Professional	EDC Data Gathering
Thermostat installed by homeowner or friend/family who certifies receiving education on operating the thermostat at the time of applying for the rebate.	Participant	Self-Installation + Education	Default
Thermostat installed by licensed electrical or HVAC contractor - no invoice, work order or other documentation supplied	Participant	Self-Installation + Education	Default
Thermostat installed by homeowner or friend/family	Participant	Self-Installation	Default

Commented [SA6]: Franklin Energy

Can this be better quantified?

Finally, energy saving factor (ESF) values are specified based on whether the thermostat is installed by the customer (self-installation), the customer with education (self-installation + education), or by a professional contractor/utility representative (professional installation).

ALGORITHMS

Energy Savings
Total savings are calculated as a combination of heating and cooling season savings. The heating savings calculation varies depending on whether heat is provided by a heat pump, electric furnace, or gas furnace. There are no heating savings for boilers.

$$\Delta kWh = \Delta kWh_{cool} + \Delta kWh_{heat}$$

$$\Delta kWh_{cool} = CAPY_{cool} \times \frac{EFLH_{cool}}{SEER \times Eff_{duct}} \times ESF_{cool}$$

$$\Delta kWh_{heat,HP} = CAPY_{HP} \times \frac{EFLH_{heat,HP}}{HSPF \times Eff_{duct}} \times ESF_{heat}$$

$$\Delta kWh_{heat,elecfurrn} = CAPY_{elecfurn} \times \frac{EFLH_{heat,non-HP}}{3.412\frac{\text{BTU}}{\text{W}\cdot\text{h}} \times Eff_{duct}} \times ESF_{heat} \times DF$$

$$\Delta kWh_{heat,fuelfurn} = \frac{HP_{motor} \times 0.746\frac{\text{kW}}{\text{HP}}}{\eta_{motor}} \times EFLH_{heat,non-HP} \times ESF_{heat}$$

Derate Factor
Heating ESF estimates are largely based on results from studies looking at connected thermostats applied to natural gas furnaces. However, it is likely that customers with electric furnaces are already more conscious of managing their energy consumption than those with gas furnaces due to the higher cost of electric resistance heat, thus savings from a gas furnace study may be overstated if not adjusted.

Blended Baseline
The ESF value applied in the equations above is determined based on the type of thermostat being replaced (manual, programmable, or unknown baseline), the existing heating and/or cooling HVAC equipment in the home, and the program design type. When a known blended baseline of manual

and programmable thermostats is present, the following equation may be used to find the appropriate ESF value for the blended baseline.

$$ESF_{connected\ over\ mixed} = (ESF_{connected\ over\ manual} \times \%_{Manual}) + (ESF_{connected\ over\ prog.} \times \%_{Programmable})$$

Demand Savings
Connected thermostats are expected to primarily save energy during off-peak hours. No peak demand savings are assigned to this measure.

DEFINITION OF TERMS

Table 2-39: Residential Electric HVAC Calculation Assumptions

Term	Unit	Value	Sources
$CAPY_{cool}$, Capacity of air conditioning unit	$\frac{kBTU}{hr}$	EDC Data Gathering of Nameplate data	EDC Data Gathering
		Default = 30,000 / unit	1
$CAPY_{HP}$, Normal heat capacity of Heat Pump System.	$\frac{kBTU}{hr}$	EDC Data Gathering of Nameplate Data	EDC Data Gathering
		Default = 32,000 / unit	1
$CAPY_{elecfurn}$, Normal heat capacity of Electric Furnace systems	$\frac{kBTU}{hr}$	EDC Data Gathering of Nameplate data	EDC Data Gathering
		Default = 60,249 / unit	1
SEER, Seasonal Energy Efficiency Ratio	$\frac{BTU}{W \cdot h}$	EDC Data Gathering of Nameplate data	EDC Data Gathering
		Default: CAC = 12.1 Heat Pump = 13.5	1
$HSPF_{heat\ pump}$, Heating Seasonal Performance Factor of Heat Pump	$\frac{BTU}{W \cdot h}$	EDC Data Gathering of Nameplate data	EDC Data Gathering
		Heat Pump Default = 8.2	1
Eff_{duct}, Duct System Efficiency	*None*	0.8	3
$EFLH_{cool}$, Equivalent Full Load Hours for Cooling	$\frac{hours}{yr}$	See $EFLH_{cool}$ in Vol. 1, App. A	4
$EFLH_{heat,HP}$, Equivalent Full Load Hours for ASHP Systems	$\frac{hours}{yr}$	See $EFLH_{heat,HP}$ in Vol. 1, App. A	4
$EFLH_{heat,non-HP}$ Equivalent Full Load Hours for Electric or Gas Furnaces	$\frac{hours}{yr}$	See $EFLH_{heat,non-HP}$ in Vol. 1, App. A	4
HP_{motor}, Gas furnace blower motor horsepower	*Hp*	EDC Data Gathering Default = ½	Average blower motor capacity for gas furnace (typical range = ¼ hp to ¾ hp)
		Nameplate	EDC Data Gathering

Term	Unit	Value	Sources
η_{motor}, Efficiency of furnace blower motor	%	EDC Data Gathering Default = 50%	Typical efficiency of ½ hp blower motor
$\%_{Programmable}$, % central AC systems with a programmable thermostat	*None*	EDC Data Gathering	EDC Data Gathering
		Forced Air Default = 58%	1
$\%_{Manual}$, % central AC systems with a manual thermostat	*None*	EDC Data Gathering	EDC Data Gathering
		Forced Air Default = 42%	1
ESF_{cool}, cooling energy saving factor	*None*	See Table 2-40	Composite of multiple sources
ESF_{heat}, heating energy saving factor	*None*	See Table 2-41	Composite of multiple sources
DF, Derate Factor for Electric Resistance Heating Systems	*None*	0.85	Professional Judgement

Table 2-40 and Table 2-41 show ESF values for cooling and heating (percentage of heating or cooling consumption saved by thermostat type, installation type, and HVAC system type). Each value taken from a secondary literature study has a footnote with its corresponding reference. All other ESF values (without footnotes) were calculated from the referenced value to find ESF values for different baselines.

Table 2-40: Cooling Energy Savings Factors (ESF_{cool})

Installation Type	Baseline	ASHP Cooling	CAC Cooling
Upstream buy-down (Customer Self-Installation)	Unknown Mix Default	4.8%[a]	4.8%[a]
Customer Self-Installation with Education	Unknown Mix Default	7.5%[b]	7.5%[b]
Professional Installation	Manual	11.3%[c]	11.3%[c]
	Conventional Programmable	9.3%[d]	9.3%[d]

[a] *Source 6*

[b] *Cooling savings are based on average of savings from unknown mix default with customer self-installation and average of professional installation savings from manual and programmable thermostats. In this case, 7.5%=((11.3%×0.42 + 9.3%×0.58) + 4.8%) / 2*

[c] *Average of cooling savings estimates from multiple studies. Sources: 2, 7, 9, 12,*

[d] *The ESF value is applied here subtracts the assumed savings value from programmable thermostats in the 2016 Pennsylvania TRM (2.0%) from the manual thermostat baseline ESF.*

Table 2-41: Heating Energy Savings Factors (ESF_{heat})

Program Type	Baseline	Air Source Heat Pump	Furnace/Boiler Heating (Electric or Fossil)
Upstream buy-down (Customer Self-Installation)	Unknown Mix Default	6.4%[a]	6.4%[a]
Customer Self-Installation with Education	Unknown Mix Default	7.9%[b]	7.9%[b]
Professional Installation	Manual	11.5%[c]	11.5%[c]
	Conventional programmable	7.9%[d]	7.9%[d]

[a] Average of heating estimates from two studies. Sources: 9, 11

[b] Heating savings are based on average of savings from unknown mix default with customer self-installation and average of professional installation savings from manual and programmable thermostats. In this case, 7.9%=((11.5%×0.42 + 7.9%×0.58) + 6.4%) / 2

[c] Average of four heating savings estimates from four studies. Sources: 7, 10, 12

[d] The ESF value for a is applied here as an estimate until information becomes available showing different savings incented through a direct install program.

DEFAULT SAVINGS

Table 2-42 through Table 2-44 provide deemed energy savings values by program type, HVAC system type, and baseline thermostat style using statewide average EFLH values

Table 2-42: Default Statewide Cooling Savings (kWh/yr)

Program Type	Baseline	ASHP Cooling	CAC Cooling
Upstream buy-down (Customer Self-Installation)	Unknown Mix Default	69	77
Customer Self-Installation with Education	Unknown Mix Default	108	120
Professional Installation	Manual	163	182
	Conventional programmable	134	150

Table 2-43: Default Statewide Heating Savings (kWh/yr)

Program Type	Baseline	ASHP with Electric Auxiliary Heating	Electric Furnace	Fossil Fuel Furnace (Fan Only)
Upstream buy-down (Customer Self-Installation)	Unknown Mix Default	420	1,213	48
Customer Self-Installation with Education	Unknown Mix Default	519	1,499	60
Professional Installation	Manual	756	2,180	87
	Conventional programmable	519	1,498	60

Table 2-44: Default Statewide Total Heating and Cooling Savings (kWh/yr)

Program Type	Baseline	ASHP with Electric Aux	CAC w/ Electric Furnace	CAC w/ Gas (Fan)
Upstream buy-down (Customer Self-Installation)	Unknown Mix Default	490	1,290	125
Customer Self-Installation with Education	Unknown Mix Default	627	1,619	180
Professional Installation	Manual	918	2,362	268
	Conventional programmable	653	1,647	209

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. Evaluation contractors may chose to propose independent assessments of the ESF factors to the SWE in their EM&V plans. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) Pennsylvania Act 129 2018 Residential Baseline Study, http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-Phase3_Res_Baseline_Study_Rpt021219.pdf.

2) EnerNOC, Xcel Energy: In-Home Smart Device Pilot. Public Service Company of Colorado," March, 2014, https://www.xcelenergy.com/staticfiles/xe/Regulatory/Regulatory%20PDFs/CO-DSM/CO-2014-IHSD-Pilot-Evaluation.pdf

3) New York Standard Approach for Estimating Energy Savings from Energy Efficiency Measures in Commercial and Industrial Programs, September 1, 2009. http://www3.dps.ny.gov/W/PSCWeb.nsf/96f0fec0b45a3c6485257688006a701a/766a83dce56eca35852576da006d79a7/$FILE/90_day_CI_manual_final_9-1-09.pdf

4) Based on the Phase III SWE team's analysis of regional HVAC runtime data collected from ecobee's Donate Your Data research service, https://www.ecobee.com/donateyourdata/.

5) California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx . Accessed December 2018.

6) Navigant Consulting, Inc., "Illinois Smart Thermostat – Annual and Seasonal kWh Savings – Impact Findings," February 26, 2016. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_5/Illinois_Smart_Thermostat_Electric_Impact_Findings_2016-02-26.pdf

7) The Cadmus Group, Inc., "Vectren: Evaluation of 2013–2014 Programmable and Smart Thermostat Program," January 2014, http://www.cadmusgroup.com/wp-content/uploads/2015/06/Cadmus_Vectren_Nest_Report_Jan2015.pdf?submissionGuid=664af99c-7ff7-4afe-a8e6-b6c7acc4d9cb

8) Energy Star Program Requirements for Connected Thermostat Products https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Program%20Requirements%20for%20Connected%20Thermostats%20Version%201.0.pdf V1.0 12/23/2016

9) Apex Analytics LLC, "Energy Trust of Oregon Nest Thermostat Smart Thermostat Pilot Evaluation," March 1, 2016, https://www.energytrust.org/wp-content/uploads/2016/12/Smart_Thermostat_Pilot_Evaluation-Final_wSR.pdf

10) Apex Analytics LLC, "Energy Trust of Oregon Nest Thermostat Heat Pump Control Pilot Evaluation," October 10, 2014, https://nest.com/-downloads/press/documents/energy-trust-of-oregon-pilot-evaluation-whitepaper.pdf

11) Navigant Consulting, Inc., "Residential Smart Thermostats: Impact Analysis – Gas Preliminary Findings," December 16, 2015, http://ilsagfiles.org/SAG_files/Meeting_Materials/2015/December_2015_Meetings/Presentations/Smart_Tstat_Preliminary_Gas_Impact_Findings_2015-12-08_to_IL_SAG.pdf

12) The Cadmus Group, Inc., "Wi-Fi Programmable Controllable Thermostat Pilot Program Evaluation,:September 2012, http://ma-eeac.org/wordpress/wp-content/uploads/Wi-Fi-Programmable-Controllable-Thermostat-Pilot-Program-Evaluation_Part-of-the-Massachusetts-2011-Residential-Retrofit-Low-Income-Program-Area-Study.pdf

2.2.13 Furnace Maintenance

Target Sector	Residential Establishments
Measure Unit	Per Furnace
Measure Life	2 years[Source 1]
Vintage	Retrofit

Regular preventative maintenance of residential furnaces provides numerous potential benefits including increased efficiency, increased comfort, reduced repairs and increased safety. This protocol covers the calculation of energy savings associated with preventative maintenance of a residential furnace.

Eligibility

The measure requires that an approved technician inspect, clean and adjust the furnace. This service must include the following:

- Measure combustion efficiency and temperature rise with flue analyzer
- Check and replace filter if necessary
- Clean burners, pilot and pilot tube, flame baffle, heat exchanger and blower
- Check and adjust gas pressure to manufacturer's recommendation
- Inspect the condition of the heat exchanger(s)
- Check that flue and venting are operating properly
- Check fan belt and replace if necessary
- Inspect wiring for loose connections
- Check for correct line and load voltage and amperage
- Check safety locks for proper operation
-

The algorithms and savings are valid for servicing once every two years. If serviced more frequently, the energy savings factor (ESF) will need to be re-evaluated.

Algorithms

The annual energy savings are obtained through the following formula. There are no demand savings for this measure.

$$\Delta kWh = kW_{motor} \times EFLH_{heat,non-HP} \times ESF$$

Definition of Terms

Table 2-45: Terms, Values, and References for Furnace Maintenance

Term	Unit	Values	Source
kW_{motor} , Average motor full load electric demand	*kW*	0.377	2
$EFLH_{heat,non-HP}$, Equivalent full load heating hours	Hours/year	See *EFLH* $EFLH_{heat,non-HP}$ in Vol. 1, App. A	3
ESF, Energy savings factor	None	2%	4

Default Savings

Table 2-46: Default Savings per Input kBTU/h for Furnace Maintenance

Climate Region	Reference City	Energy Savings (kWh)
C	Allentown	6.8
A	Binghamton, NY	8.7
G	Bradford	10.2
I	Erie	7.9
E	Harrisburg	7.5
D	Philadelphia	5.7
H	Pittsburgh	7.1
B	Scranton	7.5
F	Williamsport	7.0

Commented [SA7]: Franklin Energy

The savings presented in this table do not appear to be on an "input kBtu/h" basis, and do not align with the equations provided above.

Scranton for example using the equation above of: kW x EFLH x ESF = 0.377 x 1000 x 0.02 = 7.54 kWh

Using this table, the implied savings for a 60 MBH furnace is 45 kWh.

The 0.377 kW demand savings appears to be correct as this translates to ½ hp furnace fan.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1. Act on Energy Commercial Technical Reference Manual No. 2010-4, 9.2.3 Gas Forced-Air Furnace Tune-up.
2. Average blower motor capacity for gas furnace (typical range = ¼ hp to ¾ hp). Converted to kW with 1 HP = 0.7547 kW.
3. Based on the Phase III SWE team's analysis of regional HVAC runtime data collected from ecobee's Donate Your Data research service, https://www.ecobee.com/donateyourdata/.
4. State of Minnesota, Technical Reference Manual for Energy Conservation Improvement Programs, Version 2.0. http://mn.gov/commerce-stat/pdfs/mn-trm-v2.0-041616.pdf

2.3 DOMESTIC HOT WATER

2.3.1 HEAT PUMP WATER HEATERS

Target Sector	Residential Establishments
Measure Unit	Water Heater
Measure Life	10 years[Source 1]
Vintage	Replace on Burnout

Heat Pump Water Heaters take heat from the surrounding air and transfer it to the water in the tank, unlike conventional water heaters, which use either gas (or sometimes other fuel) burners or electric resistance heating coils to heat the water.

ELIGIBILITY

This protocol documents the energy savings attributed to heat pump water heaters with Uniform Energy Factors meeting Energy Star Criteria Version 3.2.[Source 2] The target sector primarily consists of single-family residences.

ALGORITHMS

The energy savings calculation utilizes average performance data for available residential heat pump and standard electric resistance water heaters and typical water usage for residential homes. The algorithms take into account interactive effects between the water heater and HVAC system when installed inside conditioned space. The energy savings are obtained through the following formula:

$$\Delta kWh = \frac{\left(\frac{1}{UEF_{base}} - \frac{1}{UEF_{ee} \times F_{derate}}\right) \times HW \times 365\frac{\text{days}}{\text{yr}} \times 8.3\frac{\text{BTU}}{\text{gal}\cdot{}^\circ\text{F}} \times (T_{out} - T_{in})}{3412\frac{\text{BTU}}{\text{kWh}}} + \Delta kWh_{ie,cool} - \Delta kWh_{ie,heat}$$

Include below interactive effects calculations only when water heater is installed inside conditioned space with electric heating and cooling.

- If either electric heating or electric cooling is absent, then the respective interactive effect will equal zero.
- When installed outside of conditioned space, both interactive effects will equal zero, and the appropriate F_{derate} in Table 2-50 will account for reduced performance due to cooler annual temperatures.
- If installation location is unknown (such as with midstream delivery programs), use the 'Default' value for F_{derate} in Table 2-50 and both interactive effects will equal zero.

$$\Delta kWh_{ie,cool} = \frac{HW \times \frac{8.3\ \text{Btu}}{\text{Gal} \times {}^\circ\text{F}} \times (T_{out} - T_{in}) \times EFLH_{cool}}{24\frac{\text{hrs}}{\text{day}} \times SEER \times 1000\frac{\text{W}}{\text{kW}}}$$

$$\Delta kWh_{ie,heat} = \frac{HW \times \frac{8.3\ \text{Btu}}{\text{Gal} \times {}^\circ\text{F}} \times (T_{out} - T_{in}) \times EFLH_{heat}}{24\frac{\text{hrs}}{\text{day}} \times HSPF \times 1000\frac{\text{W}}{\text{kW}}}$$

For heat pump water heaters, demand savings result primarily from a reduced connected load. However, since the interactive effects during the heating season have no effect on the peak demand, the heating season interactive effects are subtracted from the total kWh savings before the ETDF is applied. The demand reduction is taken as the annual energy savings multiplied by the ratio of the average demand between 2 PM and 6 PM on summer weekdays to the total annual energy usage.

$$\Delta kW_{peak} = ETDF \times \left(\Delta kWh - \Delta kWh_{ie,heat}\right)$$

ETDF (Energy to Demand Factor) is defined below:

$$ETDF = \frac{Average\ Demand_{Summer\ WD\ 2\text{-}6\ PM}}{Annual\ Energy\ Usage}$$

The ratio of the average demand between 2 PM and 6 PM on summer weekdays to the total annual energy usage is taken from an electric water heater metering study performed by BG&E.[Source 10]

Definition of Terms

Table 2-47: Terms, Values, and References for Heat Pump Water Heater

Term	Unit	Values	Source
UEF_{base}, Uniform Energy Factor of baseline water heater	*None*	See Table 2-49 Default: 0.9207 (50 gal., unknown draw)	3
UEF_{ee}, Uniform Energy Factor of proposed efficient water heater	*gallons*	EDC Data Gathering Default ≤55 Gals: 2.0 Default >55 Gal: 2.2	2
HW, Hot water used per day in gallons	$\frac{gallons}{day}$	45.5	4
T_{out}, Temperature of hot water	*°F*	119	5
T_{in}, Temperature of cold water supply	*°F*	52	6
F_{derate}, COP De-rating factor	*Proportion*	Table 2-50	7, and discussion below
$EFLH_{cool}$, Equivalent Full Load Hours for cooling	$\frac{hours}{yr}$	See $EFLH_{cool}$ in Vol. 1, App. A	8
$EFLH_{heat}$, Equivalent Full Load Hours for heating	$\frac{hours}{yr}$	See $EFLH_{heat}$ in Vol. 1, App. A	8
$HSPF$, Heating Seasonal Performance Factor of heating equipment	$\frac{BTU}{W \cdot h}$	EDC Data Gathering Default see Table 2-48	9
$SEER$, Seasonal Energy Efficiency Ratio of cooling equipment	$\frac{BTU}{W \cdot h}$	EDC Data Gathering Default see Table 2-48	9
$ETDF$, Energy to Demand Factor (defined above)	$\frac{kW}{kWh/_{yr}}$	0.00008047	10

Table 2-48: Default Cooling and Heating System Efficiencies

Type	SEER	HSPF
Central Air Conditioner	12.1	N/A
Room Air Conditioner	11.4	N/A
Air-Source Heat Pump	13.5	8.2
Ground-Source Heat Pump	15.0	10.9
Ductless Mini-Split	14.9	8.9
Electric Resistance	N/A	3.412

Uniform Energy Factors Based on Tank Size

The current Federal Standards for electric water heater Uniform Energy Factors (UEF) vary based on draw pattern. This standard, which went into effect at the end of 2016, replaces the old federal standard equal to 0.96-(0.0003×Rated Storage in Gallons) for tanks equal to or smaller than 55 gallons and 2.057 – (0.00113×Rated Storage) for tanks larger than 55 gallons. The following table shows the UEF for various tanks sizes using both the new standard with draw patters, and the pre-draw pattern standard, which will likely be more common in replacements through 2021.

Table 2-49: Minimum Baseline Uniform Energy Factors Based on Tank Size

Tank Size (gallons)	Draw Pattern	UEF Calculation	Minimum UEF
40	Pre-2017	0.9600-(0.0003×V_r)	0.948
	Very Small	0.8808-(0.0008×V_r)	0.8488
	Low	0.9254-(0.0003×V_r)	0.9134
	Medium	0.9307-(0.0002×V_r)	0.9227
	Large	0.9349-(0.0001×V_r)	0.9309
50	Pre-2017	0.9600-(0.0003×V_r)	0.945
	Very Small	0.8808-(0.0008×V_r)	0.8408
	Low	0.9254-(0.0003×V_r)	0.9104
	Medium	0.9307-(0.0002×V_r)	0.9207
	Large	0.9349-(0.0001×V_r)	0.9299
65	Pre-2017	2.057-(0.00113×V_r)	1.984
	Very Small	1.9236-(0.0011×V_r)	1.8521
	Low	2.0440-(0.0011×V_r)	1.9725
	Medium	2.1171-(0.0011×V_r)	2.0456
	Large	2.2418-(0.0011×V_r)	2.1703
80	Pre-2017	2.057-(0.00113×V_r)	1.967
	Very Small	1.9236-(0.0011×V_r)	1.8356
	Low	2.0440-(0.0011×V_r)	1.956
	Medium	2.1171-(0.0011×V_r)	2.0291
	Large	2.2418-(0.0011×V_r)	2.1538
120	Pre-2017	2.057-(0.00113×V_r)	1.921

Tank Size (gallons)	Draw Pattern	UEF Calculation	Minimum UEF
	Very Small	1.9236-(0.0011×V_r)	1.7916
	Low	2.0440-(0.0011×V_r)	1.912
	Medium	2.1171-(0.0011×V_r)	1.9851
	Large	2.2418-(0.0011×V_r)	2.1098

Heat Pump Water Heater Uniform Energy Factor

The Uniform Energy Factors (UEF) are determined from a DOE testing procedure that is carried out at 67.5°F dry bulb and 56°F wet bulb temperatures. However, the average dry and wet bulb temperatures in PA are in the range of 50-56˚F DB and 45-50 °F WB[39]. The heat pump performance is temperature and humidity dependent, therefor the location and type of installation is significant. To account for this, a UEF de-rating factor (F_{derate}) has been adapted from a 2013 NEEA HPWH field study.[Source 7] The results used are for "Heating Zone 1", which is comprised of Olympia, WA and Portland, OR and have average dry and wet bulb temperatures (51˚F DB, 47˚F WB and 55˚F DB, 49˚F WB, respectively)[40] comparable to Pennsylvania.

Table 2-50: UEF De-rating Factor for Various Installation Locations

Installation Location	F_{derate}[41]
Inside Conditioned Space	0.98
Unconditioned Garage	0.85
Unconditioned Basement	0.72
Default[42]	0.87

Default Savings

Default savings for the installation of heat pump water heaters *not located inside conditioned space* are calculated using the formulas below.

$$\Delta \mathrm{kWh} = \left(\frac{1}{UEF_{base}} - \frac{1}{UEF_{ee} \times F_{derate}}\right) \times 2841.27\frac{kWh}{yr}$$

$$\Delta kW_{peak} = \frac{\Delta kWh}{12426.83\frac{kWh}{kW}}$$

Evaluation Protocols

The most appropriate evaluation protocol for this measure is verification of installation coupled with calculation of energy and demand savings using above algorithms.

39 Based on average weather data from weatherbase.com for the climate reference cities referenced elsewhere in this TRM

40 Ibid

41 Calculated by dividing the COP in each location from Figure 15 by the rated Energy Factor (2.35) of the unit tested in the study (AirGenerate ATI66).

42 Weighted average of values for water heater locations for all space heating fuel types in Table 107 of Northwest Energy Efficiency Alliance 2011 Residential Building Stock Assessment: Single-Family Characteristics and Energy Use. Published September 18, 2012. Online at https://neea.org/resources/2011-rbsa-single-family-characteristics-and-energy-use

Sources

1) California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx. Accessed December 2018.
2) ENERGY STAR Program Requirements for Residential Water Heaters. https://www.energystar.gov/sites/default/files/Water%20Heaters%20Final%20Version%203.2_Program%20Requirements.pdf
3) U.S. Federal Standards for Residential Water Heaters. Effective April 16, 2015. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/27
4) "Residential End Uses of Water, Version 2." *Water Research Foundation.* (Apr 2016), p. 5. https://www.circleofblue.org/wp-content/uploads/2016/04/WRF_REU2016.pdf
5) Pennsylvania Act 129 2018 Residential Baseline Study, http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-Phase3_Res_Baseline_Study_Rpt021219.pdf.
6) Using Rock Spring, PA (Site 2036) as a proxy, the mean of soil temperature at 40 inch depth is 51.861. Calculated using Daily SCAN Standard - Period of Record data from April 1999 to December 2018 from the Natural Resource Conservation Service Database. https://wcc.sc.egov.usda.gov/nwcc/rgrpt?report=daily_scan_por&state=PA. Methodology follows Missouri TRM 2017 Volume 2: Commercial and Industrial Measures. p. 78. https://energy.mo.gov/sites/energy/files/MOTRM2017Volume2.pdf
7) NEEA Heat Pump Water Heater Field Study Report. Prepared by Fluid Market Strategies, 2013. https://rpsc.energy.gov/tech-solutions/sites/default/files/attachments/NEEA_HPWH_Field-Study-Report_October-2013.pdf (Note: when this source discusses "ducted" vs "non-ducted" systems it refers to the water heater's heat pump exhaust, not to the HVAC ducts.)
8) Based on the Phase III SWE team's analysis of regional HVAC runtime data collected from ecobee's Donate Your Data research service. https://www.ecobee.com/donateyourdata/
9) Pennsylvania Act 129 2018 Residential Baseline Study, http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-Phase3_Res_Baseline_Study_Rpt021219.pdf. Due to small sample size for GSHP in Pennsylvania Act 129 2018 Residential Baseline Study this value is lowest efficiency value from BEopt v2.8.0.
10) Straub, Mary and Switzer, Sheldon. "Using Available Information for Efficient Evaluation of Demand Side Management Programs". Study by BG&E. The Electricity Journal, Aug/Sept. 2011. p. 95. http://www.sciencedirect.com/science/article/pii/S1040619011001941
11) ENERGY STAR Product Specifications for Residential Water Heaters Version 3.0. Effective April 15, 2016. http://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Water%20Heaters%20Version%203%200%20Program%20Requirements_0.pdf

2.3.2 SOLAR WATER HEATERS

Target Sector	Residential Establishments
Measure Unit	Water Heater
Measure Life	15 years[Source 1]
Vintage	Retrofit

Solar water heaters utilize solar energy to heat water, which reduces electricity required to heat water.

ELIGIBILITY

This protocol documents the energy savings attributed to solar water in PA. The target sector is single-family residences with an existing eletric water heater.

ALGORITHMS

The energy savings calculation utilizes average performance data for available residential solar and standard water heaters and typical water usage for residential homes. The energy savings are obtained through the following formula:

$$\Delta kWh = \frac{\left(\frac{1}{UEF_{base}} - \frac{1}{UEF_{ee}}\right) \times HW \times 365\frac{\text{days}}{\text{yr}} \times 8.3\frac{\text{BTU}}{\text{gal}\cdot{}^{\circ}\text{F}} \times (T_{out} - T_{in})}{3412\frac{\text{BTU}}{\text{kWh}}}$$

The demand reduction is taken as the annual energy usage of the *baseline* water heater multiplied by the ratio of the average demand between 2PM and 6PM on summer weekdays to the total annual energy usage. Note that this is a different formulation than the demand savings calculations for other water heaters. This modification of the formula reflects the fact that a solar water heater's capacity is subject to seasonal variation, and that during the peak summer season, the water heater is expected to fully supply all domestic hot water needs.

$$\Delta kW_{peak} = ETDF \times kWh_{base}$$

Where:

$$kWh_{base} = \frac{\frac{1}{UEF_{base}} \times HW \times 365\frac{days}{yr} \times 8.3\frac{BTU}{gal\cdot{}^{\circ}F} \times (T_{out} - T_{in})}{3412\frac{BTU}{kWh}}$$

ETDF (Energy to Demand Factor) is defined below:

$$ETDF = \frac{Average\ Demand_{Summer\ WD\ 2\ PM\text{-}\ 6\ PM}}{Annual\ Energy\ Usage}$$

The ratio of the average demand between 2 PM and 6 PM on summer weekdays to the total annual energy usage is taken from an electric water heater metering study performed by BG&E.[Source 2]

Definition of Terms

Table 2-51: Terms, Values, and References for Solar Water Heater

Term	Unit	Values	Source
UEF_{base}, Energy Factor of baseline electric water heater	*Proportion*	EDC Data Gathering	EDC Data Gathering
		Default = 0.90	4
UEF_{ee}, Year-round average Energy Factor of proposed solar water heater	*Proportion*	EDC Data Gathering	EDC Data Gathering
		Default = 2.62	2
HW, Hot water used per day in gallons	$\frac{gallons}{day}$	45.5	5
T_{out}, Temperature of hot water	$°F$	119	6
T_{in}, Temperature of cold water supply	$°F$	52	7
ETDF, Energy to Demand Factor (defined above)	$\frac{kW}{\frac{kWh}{yr}}$	0.00008047	3

Default Savings

Default energy and demand savings are as follows:

ΔkWh = 1,974.4 kWh

ΔkW = 0.2420 kW

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) ENERGY STAR Solar Water Heater Benefits and Savings. Accessed 8/8/2014. http://www.energystar.gov/index.cfm?c=solar_wheat.pr_savings_benefits
2) The average energy factor for all solar water heaters with collector areas of 50 ft^2 or smaller is from https://secure.solar-rating.org/Certification/Ratings/RatingsSummaryPage.aspx
3) Straub, Mary and Switzer, Sheldon. "Using Available Information for Efficient Evaluation of Demand Side Management Programs". Study by BG&E. The Electricity Journal, Aug/Sept. 2011. p. 95. http://www.sciencedirect.com/science/article/pii/S1040619011001941
4) Value is mean UEF for standard electric standalone water heaters from Pennsylvania Act 129 2018 Residential Baseline Study, http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-Phase3_Res_Baseline_Study_Rpt021219.pdf.
5) Residential Energy Consumption Survey, EIA, 2009.

6) Pennsylvania Statewide Residential End-Use and Saturation Study, 2014, http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-2014_PA_Statewide_Act129_Residential_Baseline_Study.pdf.

7) Using Rock Spring, PA (Site 2036) as a proxy, the mean of soil temperature at 40 inch depth is 51.861. Calculated using Daily SCAN Standard - Period of Record data from April 1999 to December 2018 from the Natural Resource Conservation Service Database. https://wcc.sc.egov.usda.gov/nwcc/rgrpt?report=daily_scan_por&state=PA . Methodology follows Missouri TRM 2017 Volume 2: Commercial and Industrial Measures. p. 78. https://energy.mo.gov/sites/energy/files/MOTRM2017Volume2.pdf

2.3.3 Fuel Switching: Electric Resistance to Fossil Fuel Water Heater

Target Sector	Residential
Measure Unit	Water Heater
Measure Life	Gas:11 years Source 1 Propane: 11 years Source 1
Vintage	Replace on Burnout

Eligibility

This protocol documents the energy savings attributed to converting from a standard electric resistance water heater to an ENERGY STAR Version 3.2 natural gas or propane water heater. If a customer submits a rebate for a product that has applied for ENERGY STAR Certification but has not yet been certified, the savings will be counted for that product contingent upon its eventual certification as an ENERGY STAR measure. If at any point the product is rejected by ENERGY STAR, the product is then ineligible for the program and savings will not be counted.

The target sector primarily consists of single-family residences.

Algorithms

The energy savings calculation utilizes average performance data for available residential standard electric and fossil fuel-fired water heaters and typical water usage for residential homes. Because there is little electric energy associated with a fossil fuel-fired water heater, the energy savings are the full energy utilization of the electric water heater. The energy savings are obtained through the following formula:

$$\Delta\text{kWh} = \frac{\frac{1}{UEF_{base,elec}} \times HW \times 365\ \frac{\text{days}}{\text{yr}} \times 8.3 \frac{BTU}{gal\cdot°F} \times (T_{out} - T_{in})}{3412\ \frac{\text{BTU}}{\text{kWh}}}$$

Although there is a significant electric savings, there is an associated increase in fossil fuel energy consumption. While this fossil fuel consumption does not count against PA Act 129 energy savings, it is expected to be used in the program TRC test. The increased fossil fuel usage is obtained through the following formula:

$$\Delta MMBTU = \frac{\frac{1}{UEF_{installed}} \times HW \times 365\ \frac{\text{days}}{\text{yr}} \times 8.3 \frac{Btu}{gal\cdot°F} \times (T_{out} - T_{in})}{1{,}000{,}000\ \frac{\text{BTU}}{\text{MMBTU}}}$$

Demand savings result from the removal of the connected load of the electric water heater. The demand reduction is taken as the annual energy savings multiplied by the ratio of the average energy usage between 2 PM and 6 PM on summer weekdays to the total annual energy usage.

$$\Delta kW_{peak} = ETDF \times \Delta kWh$$

ETDF (Energy to Demand Factor) is defined below:

$$ETDF = \frac{Average\ Demand_{Summer\ WD\ 2PM\text{-}6\ PM}}{Annual\ Energy\ Usage}$$

The ratio of the average energy usage between 2 PM and 6 PM on summer weekdays to the total annual energy usage is taken from an electric water heater metering study performed by BG&E.[Source 8]

Definition of Terms

Table 2-52: Terms, Values, and References for Fuel Switching: Electric Resistance to Fossil Fuel Water Heater

Term	Unit	Values	Source
$UEF_{base,elec}$, Energy Factor of baseline water heater	*Proportion*	EDC Data Gathering Default: Table 2-49 in in Section 2.3.1	2
$UEF_{installed,\ NG}$, Energy Factor of installed natural gas water heater	*Proportion*	EDC Data Gathering Default: ≤55 Gallons= 0.67 >55 Gallons= 0.77	3
$UEF_{installed,Propane}$, Energy Factor of installed propane water heater	*Proportion*	EDC Data Gathering Default: ≤55 Gallons= 0.67 >55 Gallons= 0.77	3
$UEF_{installed,Tankless\ Water\ Heater}$, Energy Factor of installed tankless water heater	*Proportion*	EDC Data Gathering Default: ≥0.90	3
HW , Hot water used per day in gallons	$\frac{gallons}{day}$	45.5	5
T_{out} , Temperature of hot water	*°F*	119	6
T_{in} , Temperature of cold water supply	*°F*	52	7
ETDF , Energy to Demand Factor (defined above)	$\frac{kW}{\frac{kWh}{yr}}$	0.00008047	8

Energy Factors based on Tank Size

The current Federal Standards for electric water heater Energy Factors vary based on draw pattern. This standard, which went into effect at the end of 2016, replaces the old federal standard equal to 0.96-(0.0003×Rated Storage in Gallons) for tanks equal to or smaller than 55 gallons and 2.057 – (0.00113×Rated Storage) for tanks larger than 55 gallons. The baseline Energy Factors for various tank sizes are listed in Table 2-49 in Section 2.3.1.

Default Savings

The electric savings for the installation of a fossil fuel water heater should be calculated using the partially deemed algorithm below.

$$\Delta kWh = \frac{\frac{1}{UEF_{base,elec}} \times HW \times 365\,\frac{\text{days}}{\text{yr}} \times 8.3\,\frac{\text{Btu}}{\text{gal}\cdot°\text{F}} \times (T_{out} - T_{in})}{3412\,\frac{\text{BTU}}{\text{kWh}}}$$

$$\Delta kW_{peak} = \text{ETDF} \times \Delta\text{kWh}$$

The default savings for the installation of a 50 gallon natural gas/ propane/oil water heater in place of a standard electric water heater are listed in Table 2-53 below.

Table 2-53: Energy Savings & Demand Reductions for Fuel Switching, Domestic Hot Water Electric to Fossil Fuel

Electric unit Energy Factor	Energy Savings (kWh/yr)	Demand Reduction (kW)
0.9207	2,938.9	0.2365

The default fossil fuel consumption for the installation of a standard efficiency natural gas/ propane/oil water heater in place of a standard electric water heater is listed in Table 2-54 below.

Table 2-54: Fuel Consumption for Fuel Switching, Domestic Hot Water Electric to Fossil Fuel

Fuel Type	Energy Factor	Fossil Fuel Consumption (MMBTU/yr)
Gas	0.67	13.78
Propane	0.67	13.78

Note: 10.87 gallons of propane provide 1 MMBTU of heat.

Evaluation Protocols

The most appropriate evaluation protocol for this measure is verification of installation coupled with assignment of stipulated energy savings.

Sources

1) DEER Effective Useful Life values, accessed Oct. 2018. http://www.deeresources.com/

2) U.S. Federal Standards for Residential Water Heaters. Effective April 16, 2015. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/27

3) Commission Order requires fuel switching to ENERGY STAR measures, not standard efficiency measures. The Energy Factor has therefore been updated to reflect the Energy Star 3.2 standard for Gas Storage Water Heaters From Residential Water Heaters Key Product Criteria. https://www.energystar.gov/sites/default/files/Water%20Heaters%20Final%20Version%203.2_Program%20Requirements_1.pdf Accessed Oct. 2018. For the Commission Order see p. 42 of the TRC Final Test Order.

4) Federal Standards are 0.68 -0.0019 x Rated Storage in Gallons for oil-fired storage water heater. For a 50-gallon tank this 0.585. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/27

5) "Residential End Uses of Water, Version 2." *Water Research Foundation.* (Apr 2016), p. 5. https://www.circleofblue.org/wp-content/uploads/2016/04/WRF_REU2016.pdf

6) Pennsylvania Statewide Residential End-Use and Saturation Study, 2014, http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-2014_PA_Statewide_Act129_Residential_Baseline_Study.pdf.

7) Using Rock Spring, PA (Site 2036) as a proxy, the mean of soil temperature at 40 inch depth is 51.861. Calculated using Daily SCAN Standard - Period of Record data from April 1999 to December 2018 from the Natural Resource Conservation Service Database. https://wcc.sc.egov.usda.gov/nwcc/rgrpt?report=daily_scan_por&state=PA. Methodology

follows Missouri TRM 2017 Volume 2: Commercial and Industrial Measures. p. 78. https://energy.mo.gov/sites/energy/files/MOTRM2017Volume2.pdf

8) Straub, Mary and Switzer, Sheldon. "Using Available Information for Efficient Evaluation of Demand Side Management Programs". Study by BG&E. The Electricity Journal. Aug/Sept, 2011. p. 95. http://www.sciencedirect.com/science/article/pii/S1040619011001941

2.3.4 Water Heater Tank Wrap

Target Sector	Residential
Measure Unit	Tank
Measure Life	7 years Source 5
Vintage	Retrofit

This measure applies to the installation of an insulated tank wrap or "blanket" to existing residential electric hot water heaters.

The base case for this measure is a standard residential, tank-style, electric water heater with no external insulation wrap.

Eligibility

This measure documents the energy savings attributed to installing an insulating tank wrap on an existing electric resistance water heater. The target sector is residential.

The U.S. Department of Energy recommends adding a water heater wrap of at least R-8 to any water heater with an existing R-value less than R-24.[43]

Algorithms

The annual energy savings for this measure are assumed to be dependent upon decreases in the overall heat transfer coefficient that are achieved by increasing the total R-value of the tank insulation.

$$\Delta kWh = \frac{HOU}{3412\frac{BTU}{kWh} \times \eta_{Elec}} \times \left(\frac{A_{base}}{R_{base}} - \frac{A_{insul}}{R_{insul}}\right) \times \left(T_{setpoint} - T_{ambient}\right)$$

$$\Delta kW_{peak} = \frac{\Delta kWh}{HOU} \times CF$$

Definition of Terms

Table 2-55: Terms, Values, and References for Water Heater Tank Wrap

Term	Unit	Value	Source
R_{base}, R-value is a measure of resistance to heat flow prior to adding tank wrap	$\frac{Hr \cdot F \cdot ft^2}{Btu}$	Default: 12 or EDC Data Gathering	1
R_{insul}, R-value is a measure of resistance to heat flow after addition of tank wrap	$\frac{Hr \cdot °F \cdot ft^2}{Btu}$	Default: 20 or EDC Data Gathering	2
A_{base}, Surface area of storage tank prior to adding tank wrap	ft^2	See Table 2-56	
A_{insul}, Surface area of storage tank after addition of tank wrap	ft^2	See Table 2-56	
η_{Elec}, Thermal efficiency of electric heater element	*Proportion*	0.98	3

[43] "Energy Savers", U.S. Department of Energy, accessed June, 2018 https://www.energy.gov/energysaver/services/do-it-yourself-energy-savings-projects/savings-project-insulate-your-water

Term	Unit	Value	Source
$T_{setpoint}$, Temperature of hot water in tank	˚F	119	4
$T_{ambient}$, Temperature of ambient air	˚F	70	4
HOU , Annual hours of use for water heater tank	*Hours/yr*	8,760	
CF , Demand Coincidence Factor	*Proportion*	1.0	

Table 2-56: Deemed savings by water heater capacity

Capacity (gal)	R_{base}	R_{insul}	A_{base} (ft^2)[44]	A_{insul} (ft^2)[45]	ΔkWh	ΔkW
30	8	16	19.16	20.94	139.4	0.0159
30	10	18	19.16	20.94	96.6	0.0110
30	12	20	19.16	20.94	70.6	0.0081
30	8	18	19.16	20.94	158.1	0.0180
30	10	20	19.16	20.94	111.6	0.0127
30	12	22	19.16	20.94	82.8	0.0094
40	8	16	23.18	25.31	168.9	0.0193
40	10	18	23.18	25.31	117.1	0.0134
40	12	20	23.18	25.31	85.5	0.0098
40	8	18	23.18	25.31	191.5	0.0219
40	10	20	23.18	25.31	135.1	0.0154
40	12	22	23.18	25.31	100.3	0.0114
50	8	16	24.99	27.06	183.9	0.0210
50	10	18	24.99	27.06	127.8	0.0146
50	12	20	24.99	27.06	93.6	0.0107
50	8	18	24.99	27.06	208.0	0.0237
50	10	20	24.99	27.06	147.1	0.0168
50	12	22	24.99	27.06	109.4	0.0125
80	8	16	31.84	34.14	237.0	0.0271
80	10	18	31.84	34.14	165.3	0.0189
80	12	20	31.84	34.14	121.5	0.0139
80	8	18	31.84	34.14	267.4	0.0305
80	10	20	31.84	34.14	189.6	0.0216
80	12	22	31.84	34.14	141.4	0.0161

[44] Area values were calculated from average dimensions of several commercially available units, with radius values measured to the center of the insulation. Area includes tank sides and top to account for typical wrap coverage.
[45] A_{insul} was calculated by assuming that the water heater wrap is a 2" thick fiberglass material.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) Conservative estimate of R-12.
2) The water heater wrap is assumed to be a fiberglass blanket with R-8, increasing the total to R-20.
3) AHRI Directory. All electric storage water heaters have a recovery efficiency of 0.98. https://nextgen.ahridirectory.org/Search/QuickSearch?category=8&searchTypeId=3&producttype=15
4) Pennsylvania Statewide Residential End-Use and Saturation Study, 2014, http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-2014_PA_Statewide_Act129_Residential_Baseline_Study.pdf.
5) California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx. Accessed December 2018.

2.3.5 WATER HEATER TEMPERATURE SETBACK

Target Sector	Residential Establishments
Measure Unit	Water Heater Temperature
Measure Life	2 years[Source 10]
Vintage	Retrofit

In homes where the water heater setpoint temperature is set high, savings can be achieved by lowering the setpoint temperature. The recommended lower setpoint is 120˚F, but EDCs may substitute another if needed. Savings occur only when the lower temperature of the hot water does not require the use of more hot water. Savings do not occur in applications such as a shower or faucet where the user adjusts the hot water flow to make up for the lower temperature. Clothes washer hot water use and water heater tank losses are included in the savings calculation, but shower, faucet, and dishwasher use are not included due to expected behavioral and automatic (dishwasher) adjustments in response to lower water temperature. It is expected that the net energy use for the dish washer hot water will remain the same after a temperature reduction because dishwashers will adjust hot water temperature to necessary levels using internal heating elements.

ELIGIBILITY

This protocol documents the energy savings attributed to reducing the electric or heat pump water heater temperature setpoint. The primary target sector is single-family residences.

ALGORITHMS

The annual energy savings calculation utilizes average performance data for available residential water heaters and typical water usage for residential homes. The energy savings are obtained through the following formula, where the first term in the parentheses corresponds to tank loss savings and the second to clothes washer savings:

$$\Delta kWh = \frac{(T_{hot\,i} - T_{hot\,f})}{3412\frac{\text{BTU}}{\text{kWh}}} \times \left(\frac{A_{tank} \times 8760\frac{\text{hrs}}{\text{yr}}}{R_{tank} \times \eta_{elec}} + \frac{Cycles_{wash} \times V_{HW} \times 8.3\frac{\text{BTU}}{\text{gal}\cdot{}^{\circ}\text{F}}}{UEF_{WH}}\right)$$

Demand savings result from reduced hours of operation of the heating element, rather than a reduced connected load. The demand reduction is taken as the annual energy savings multiplied by the ratio of the average demand between 2 PM and 6 PM on summer weekdays to the total annual energy usage.

$$\Delta kW_{peak} = ETDF \times \Delta\, kWh$$

ETDF (Energy to Demand Factor) is defined below:

$$ETDF = \frac{Average\ Demand_{Summer\ WD\ 2PM\text{-}6\ PM}}{Annual\ Energy\ Usage}$$

The ratio of the average demand between 2 PM and 6 PM on summer weekdays to the total annual energy usage is taken from an electric water heater metering study performed by BG&E.[Source 8]

DEFINITION OF TERMS

Table 2-57: Terms, Values, and References for Water Heater Temperature Setback

Term	Unit	Values	Source
UEF_{WH} , Energy Factor of water heater	*Proportion*	EDC data collection Default: Electric Storage= 0.904 HPWH= 2.0	1
R_{tank} , R value of water heater tank	$\frac{hr \cdot °F \cdot ft^2}{BTU}$	EDC Data Gathering Default: 12	9
A_{tank} , Surface Area of water heater tank	ft^2	EDC Data Gathering Default: 24.99	50 gal. value in Table 2-58
η_{elec} , Thermal efficiency of electric heater element (equiv. to COP for HPWH)	*Proportion*	Electric Storage: 0.98 HPWH: 2.1	2, 3
V_{HW} , Volume of hot water used per cycle by clothes washer	*gallons/day*	7	4
$Cycles_{wash}$, Number of clothes washer cycles per year	$\frac{cycles}{yr}$	Clothes washer present: 251 No clothes washer: 0	5
T_{hot_i} , Temperature setpoint of water heater initially	*°F*	EDC Data Gathering Default: 130	6
T_{hot_f}, Temperature setpoint of water heater after setback	*°F*	EDC data collection Default: 119	7
$ETDF$, Energy To Demand Factor (defined above)	$\frac{kW}{\frac{kWh}{yr}}$	0.00008047	8

DEFAULT SAVINGS

The energy savings and demand reductions are prescriptive according to the above formulae. However, some values for common configurations are provided in Table 2-58 below.

Table 2-58: Default Energy Savings and Demand Reductions

Type	$Cycles_{wash}$	η_{elec}	UEF_{WH}	Energy Savings (ΔkWh)	Demand Reduction (ΔkW_{peak})
Electric Storage	0	0.98	0.904	60.0	0.0048
Electric Storage	260	0.98	0.904	113.9	0.0092
HPWH	0	2.1	2.0	28.0	0.0023
HPWH	260	2.1	2.0	52.4	0.0042

EVALUATION PROTOCOLS

The most appropriate evaluation protocol for this measure is verification of water heater temperature setpoint coupled with assignment of stipulated energy savings.

SOURCES

1) Previous Federal Standards from 2004-2015 are 0.97 -0.00132 x Rated Storage in Gallons. For a 50-gallon tank this is 0.904. “Energy Conservation Program: Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters” US Dept of Energy Docket Number: EE–2006–BT-STD–0129, p. 30. The previous, long-standing requirements are used since this is a Retrofit measure applied to existing equipment, not new equipment.
2) AHRI Directory. All electric storage water heaters have a recovery efficiency of .98. https://www.ahridirectory.org/Search/QuickSearch?category=8&searchTypeId=3&producttype=15
3) NEEA Heat Pump Water Heater Field Study Report. Prepared by Fluid Market Strategies. October 22, 2013. http://neea.org/docs/default-source/reports/heat-pump-water-heater-field-study-report.pdf?sfvrsn=5
4) Federal Energy Management Program Energy Cost Calculator, March 2010 (visited October 23, 2018) https://www.energy.gov/node/789966
5) Calculated using “Frequency of clothes washer use” and “Frequency of dryer use” data for the Mid-Atlantic region from U.S. Department of Energy. 2015 Residential Energy Consumption Survey (2015). https://www.eia.gov/consumption/residential/data/2015/index.php?view=microdata
6) Engineering assumption
7) Pennsylvania Statewide Residential End-Use and Saturation Study, 2014, http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-2014_PA_Statewide_Act129_Residential_Baseline_Study.pdf.
8) Straub, Mary and Switzer, Sheldon. "Using Available Information for Efficient Evaluation of Demand Side Management Programs". Study by BG&E. The Electricity Journal. Aug/Sept, 2011. p. 95. http://www.sciencedirect.com/science/article/pii/S1040619011001941
9) Conservative estimate of R-12
10) Illinois Statewide Technical reference Manual for Energy Efficiency Version 7.0. Effective January 1, 2019. http://www.ilsag.info/technical-reference-manual.html

2.3.6 Water Heater Pipe Insulation

Target Sector	Residential Establishments
Measure Unit	Water Heater
Measure Life	13 years Source 3
Vintage	Retrofit

This measure relates to the installation of ¾" thick foam insulation on exposed pipe in unconditioned space. The baseline for this measure is a standard efficiency 50 gallon electric water heater (UEF=0.9207) with an annual energy usage of 2,939 kWh. [46]

Commented [SA8]: Franklin Energy

This source provides a good definition of "unconditioned" space: BSR/RESNET 301-2013 Standard for the Calculation and Labeling of the Energy Performance of Low-Rise Residential Buildings using the HERS Index

HERS definition: Unconditioned Space – The outdoor environment or an area or room within a building that is not Conditioned Space but which may contain heat sources or sinks that influence the temperature of the area or room. Where conditioned space is defined as An area or room within a building serviced by a space heating or cooling system designed to maintain human comfort in accordance with ASHRAE Standard 55-2010.

The Energy Code definition does not apply.

Eligibility

This protocol documents the energy savings for an electric water heater attributable to insulating exposed pipe in unconditioned space, ¾" thick. The target sector primarily consists of residential establishments.

Algorithms

The annual energy savings are assumed to be 3% of the annual energy use of an electric water heater (2,939 kWh), or 88.2 kWh based on 10 feet of insulation. This estimate is based on a recent report prepared by the ACEEE for the State of Pennsylvania (Source 1). On a per foot basis, this is equivalent to 8.82 kWh.

ΔkWh = *8.82 kWh/yr per foot of installed insulation*

The summer coincident peak kW savings are calculated as follows:

$\Delta kW_{peak} = \Delta kWh \times ETDF$

Definition of Terms

Table 2-59: Terms, Values, and References for Water Heater Pipe Insulation

Term	Unit	Value	Source
ΔkWh, annual energy savings per foot of installed pipe insulation	$\frac{\frac{kWh}{yr}}{ft}$	8.82	1
ETDF, Energy to Demand Factor	$\frac{kW}{\frac{kWh}{yr}}$	0.00008047	2
ΔkW_{peak} , Summer peak kW savings per foot of installed pipe insulation	$\frac{kW}{ft}$	0.00071	-

[46] See 2.3.1 Heat Pump Water Heaters section for baseline water heater consumption formula and assumptions.

The demand reduction is taken as the annual energy savings multiplied by the ratio of the average energy usage during 2 PM to 6 PM on summer weekdays to the total annual energy usage. The Energy to Demand Factor is defined as:

$$ETDF = \frac{Average\ Demand_{Summer\ WD\ 2PM\text{-}6PM}}{Annual\ Energy\ Usage}$$

The ratio of the average energy usage between 2 PM to 6 PM on summer weekdays to the total annual energy usage is taken from an electric water heater metering study performed by BG&E.[Source 2]

Evaluation Protocols

The most appropriate evaluation protocol for this measure is verification of installation coupled with assignment of stipulated energy savings.

Sources

1) American Council for an Energy-Efficient Economy, Summit Blue Consulting, Vermont Energy Investment Corporation, ICF International, and Synapse Energy Economics, Potential for Energy Efficiency, Demand Response, and Onsite Solar Energy in Pennsylvania, Report Number E093, April 2009, p. 117.
2) Straub, Mary and Switzer, Sheldon. "Using Available Information for Efficient Evaluation of Demand Side Management Programs". Study by BG&E. The Electricity Journal. Aug/Sept, 2011. p. 95. http://www.sciencedirect.com/science/article/pii/S1040619011001941
3) California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx. Accessed November 13, 2018

2.3.7 Low Flow Faucet Aerators

Target Sector	Residential Establishments
Measure Unit	Aerator
Measure Life	10 years[Source 1]
Vintage	Retrofit

Installation of low-flow faucet aerators is an inexpensive and lasting approach for water conservation. These efficient aerators reduce water consumption and consequently reduce hot water usage and save energy associated with heating the water. This protocol presents the assumptions, analysis and savings from replacing standard flow aerators with low-flow aerators in kitchens and bathrooms.

The low-flow kitchen and bathroom aerators will save on the electric energy usage due to the reduced demand of hot water. The maximum flow rate of qualifying kitchen and bathroom aerators is 1.5 gallons per minute.

Commented [SA9]: Franklin Energy

This measure can also be applicable to laminar flow restrictors.

Eligibility

This protocol documents the energy savings attributable to efficient low flow aerators in residential applications. The savings claimed for this measure are attainable in homes with standard resistive water heaters. Homes with non-electric water heaters do not qualify for this measure.

Commented [SA10]: Franklin Energy

Table 2-60 notes that HPWH are also applicable.

We recommend making these clarifications in the introduction of the measure:

The savings noted in this measure are attainable in homes with standard resistive storage or instantaneous water heaters. They are also applicable to homes with HPWH.

Homes with non-electric water heaters do not qualify for this measure.

Algorithms

The energy savings and demand reduction are obtained through the following calculations:

$$\Delta kWh = \frac{(GPM_{base} - GPM_{low}) \times 8.3\frac{BTU}{gal \cdot {}^{\circ}F} \times (T_{out} - T_{in})}{3412\frac{BTU}{kWh} \times RE} \times \frac{DF \times T_{person-day} \times N_{persons} \times 365\frac{days}{yr}}{N_{faucets-home}} \times ISR \times ELEC$$

$$\Delta kW_{peak} = \Delta kWh \times ETDF$$

Where:

$$ETDF = \frac{CF}{HOU} = \frac{\%_{faucet\ use,peak} \times 60\frac{\text{minutes}}{\text{hour}}}{365\frac{\text{days}}{\text{yr}} \times 240\frac{\text{minutes}}{\text{daily peak}}}$$

Given:

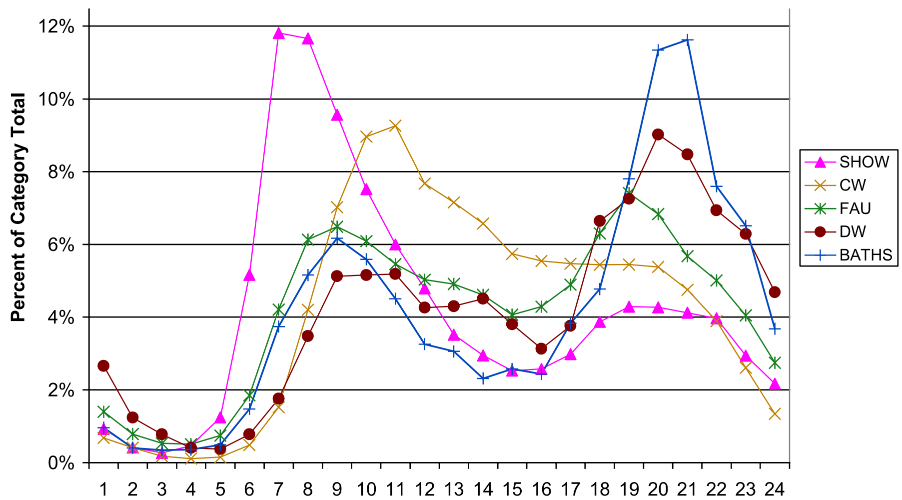
$$CF = \frac{\%_{faucet\ use,peak} \times T_{person-day} \times N_{persons}}{N_{faucets-home} \times 240\frac{\text{minutes}}{\text{daily peak}}}$$

$$HOU = \frac{T_{person-day} \times N_{persons} \times 365\frac{\text{days}}{\text{yr}}}{N_{faucets-home} \times 60\frac{\text{minutes}}{\text{hour}}}$$

The ratio of the average energy usage during 2 PM and 6 PM on summer weekdays to the total annual energy usage is taken from average daily load shape data collected for faucets from an

Aquacraft, Inc study.[Source 2] The average daily load shapes (percentages of daily energy usage that occur within each hour) are plotted in Figure 2-1 below (symbol FAU represents faucets).

Figure 2-1: Daily Load Shapes for Hot Water Measures[Source 2]



DEFINITION OF TERMS

Table 2-60: Low Flow Faucet Aerator Calculation Assumptions

Term	Unit	Value	Source
GPM_{base}, Average baseline flow rate of aerator (GPM)	$\frac{gallons}{minute}$	Default =2.2 Or EDC Data Gathering	3
GPM_{low}, Average post measure flow rate of aerator (GPM)	$\frac{gallons}{minute}$	Default = 1.5 Or EDC Data Gathering	3
$T_{person\text{-}day}$, Average time of hot water usage per person per day (minutes)	$\frac{minutes}{day}$	Kitchen=4.5 Bathroom=1.6 Unknown=6.1	4
$N_{persons}$, Average number of persons per household	$\frac{persons}{house}$	Default SF=2.5 Default MF=1.7 Default Unknown=2.5 Or EDC Data Gathering	11
T_{out}, Average mixed water temperature flowing from the faucet (ºF)	˚F	Kitchen=93 Bathroom=86 Unknown= 87.8	6
T_{in}, Average temperature of water entering the house (ºF)	˚F	52	7
RE, Recovery efficiency of electric water heater	*Proportion*	Default: 0.98 HPWH: 2.1	8, 10

Commented [SA11]: Franklin Energy

We recommend expanding the legend text to clearly notate what the load shapes are for.

Commented [SA12]: Franklin Energy

Are there any cases when the proposed GPM of the new unit would not be known?

Commented [SA13]: Franklin Energy

Recommend noting that 0.98 is for resistance type DHW heaters.

Term	Unit	Value	Source
ETDF, Energy To Demand Factor	$\frac{kW}{kWh/yr}$	0.000134	2
$N_{faucets-home}$, Average number of faucets in the home	$\frac{faucets}{house}$	EDC Data Gathering, Default see Table 2-61	5
DF , Percentage of water flowing down drain	%	Kitchen=75% Bathroom=90% Unknown=79.5%	9
ISR , In Service Rate	%	EDC Data Gathering, Kit Delivery Default: 28% Direct Install Default: 100%	EDC Data Gathering, 12
$ELEC$, Percentage of homes with electric water heat	%	Default: Unknown=35% Or EDC Data Gathering: Electric = 100% Fossil Fuel = 0.0%	5
$\%_{faucet\ use,peak}$, percentage of daily faucet use during PJM peak period	%	19.5%	2

Table 2-61: Average Number of Faucets per Home

Faucet Type	Single Family	Multifamily	Unknown
Kitchen	1.1	1.0	1.0
Bathroom	2.2	1.2	2.0
Unknown	3.3	2.2	3.0

Default Savings

Table 2-62: Default Savings for Low Flow Faucet Aerators

Housing Type	Faucet Location	Water Heater Fuel (% electric)	Kit Delivery: Unit Energy Savings (kWh)	Kit Delivery: Unit Demand Savings (kW)	Direct Install: Unit Energy Savings (kWh)	Direct Install: Unit Demand Savings (kW)
Single Family	Kitchen	Unknown (35%)	19.5	0.0026	69.8	0.0094
	Bathroom	Unknown (35%)	3.5	0.0005	12.3	0.0017
	Unknown	Unknown (35%)	8.2	0.0011	29.2	0.0039
Multifamily	Kitchen	Unknown (35%)	14.6	0.0020	52.2	0.0070
	Bathroom	Unknown (35%)	4.3	0.0006	15.4	0.0021
	Unknown	Unknown (35%)	8.3	0.0011	29.8	0.0040
Statewide (Unknown Housing Type)	Kitchen	Unknown (35%)	21.5	0.0029	76.8	0.0103
	Bathroom	Unknown (35%)	3.8	0.0005	13.6	0.0018
	Unknown	Unknown (35%)	9.0	0.0012	32.1	0.0043
Single Family	Kitchen	Electric (100%)	55.8	0.0075	199.5	0.0267
	Bathroom	Electric (100%)	9.9	0.0013	35.3	0.0047
	Unknown	Electric (100%)	23.4	0.0031	83.4	0.0112

Multifamily	Kitchen	Electric (100%)	41.8	0.0056	149.2	0.0200
	Bathroom	Electric (100%)	12.3	0.0017	44.0	0.0059
	Unknown	Electric (100%)	23.8	0.0032	85.1	0.0114
Statewide (Unknown Housing Type)	Kitchen	Electric (100%)	61.4	0.0082	219.4	0.0294
	Bathroom	Electric (100%)	10.9	0.0015	38.8	0.0052
	Unknown	Electric (100%)	25.7	0.0034	91.8	0.0123

Evaluation Protocols

The most appropriate evaluation protocol for this measure is verification of installation coupled with EDC Data Gathering.

Sources

1) California's Database of Energy Efficiency Resources (DEER), updated 2/5/2014. http://www.deeresources.com/files/DEER2013codeUpdate/download/DEER2014-EUL-table-update_2014-02-05.xlsx

2) Aquacraft, Inc., Water Engineering and Management. The end use of hot water in single family homes from flow trace analysis. 2001. http://s3.amazonaws.com/zanran_storage/www.aquacraft.com/ContentPages/47768067.pdf. The statewide values were used for inputs in the ETDF. algorithm components. The CF for faucets is found to be 0.00413: $[\%\ \text{faucet use during peak} \times (T_{Person\text{-}Day} \times N_{Person}) / (N_{faucets\text{-}home})] / 240\ (\text{minutes in peak period}) = [19.5\% \times (6.1 \text{ x } 2.5 / 3.0)] / 240 = 0.00413$. The Hours for faucets is found to be 30.9: $(T_{Person\text{-}Day} \times N_{Persons} \times 365) / (N_{faucets\text{-}home}) / 60 = (6.1 \text{ x } 2.5 \text{ x } 365) / 3.0 / 60 = 30.9$. The resulting F_{ED} is calculated to be 0.000134: $\text{CF} / \text{Hours} = 0.00413 / 30.9 = 0.000134$.

3) Cadmus and Opinion Dynamics Evaluation Team. Showerhead and Faucet Aerator Meter Study. For Michigan Evaluation Working Group. June 2013. Baseline GPM of replaced aerators is set to the federal minimum GPM of 2.2. The GPM of new aerators is set to the typical rated GPM value of 1.5 GPM. Discounted GPM flow rates were not applied because the "throttle factor" adjustment was found to have been already accounted for in the mixed water temperature variable. Additionally, the GPM_{Base} was set to a default value of 2.2 due to the inability to verify what the GPM flow rate was of the replaced faucet.

4) Cadmus and Opinion Dynamics Evaluation Team. Showerhead and Faucet Aerator Meter Study. For Michigan Evaluation Working Group. June 2013. If aerator location is known, use the corresponding kitchen/bathroom value. If unknown, use 6.1 min/person/day as the average length of use value, which is the total for the household: kitchen $(4.5\ \text{min/person/day}) + \text{bathroom}\ (1.6\ \text{min/person/day}) = 6.1\ \text{min/person/day}$.

5) Pennsylvania Act 129 2018 Residential Baseline Study, http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-Phase3_Res_Baseline_Study_Rpt021219.pdf.

6) Table 7. Cadmus and Opinion Dynamics Evaluation Team. Showerhead and Faucet Aerator Meter Study. For Michigan Evaluation Working Group. June 2013. The study finds that the average mixed water temperature flowing from the kitchen and bathroom faucets is 93ºF and 86ºF, respectively. If the faucet location is unknown, 87.8ºF is the corresponding value to be used, which was calculated by taking a weighted average of faucet type (using the statewide values): $(1 \times 93 + 3 \times 86)/(1+3) = 87.8$.

7) Using Rock Spring, PA (Site 2036) as a proxy, the mean of soil temperature at 40 inch depth is 51.861. Calculated using Daily SCAN Standard - Period of Record data from April 1999 to December 2018 from the Natural Resource Conservation Service Database.

https://wcc.sc.egov.usda.gov/nwcc/rgrpt?report=daily_scan_por&state=PA. Methodology follows Missouri TRM 2017 Volume 2: Commercial and Industrial Measures. p. 78. https://energy.mo.gov/sites/energy/files/MOTRM2017Volume2.pdf

8) AHRI Directory. All electric storage water heaters have a recovery efficiency of .98. https://www.ahridirectory.org/Search/SearchForm?programId=24&searchTypeId=2

9) Illinois TRM Effective June 1, 2013. Faucet usages are at times dictated by volume, only “directly down the drain” usage will provide savings. Due to the lack of a metering study that has determined this specific factor, the Illinois Technical Advisory Group has deemed these values to be 75% for the kitchen and 90% for the bathroom. If the aerator location is unknown an average of 79.5% should be used which is based on the assumption that 70% of household water runs through the kitchen faucet and 30% through the bathroom $0.7 \times 0.75 + 0.3 \times 0.) = 0.795$.

10) NEEA Heat Pump Water Heater Field Study Report. Prepared by Fluid Market Strategies. October 22, 2013. https://neea.org/img/uploads/heat-pump-water-heater-field-study-report.pdf.

11) American Community Survey 5-Year (2013-2017) Estimates for 2017. http://factfinder.census.gov.

12) Average of PY9 values for kit delivery for First Energy EDCs. [WEBSITE LINK TBD]

2.3.8 Low Flow Showerheads

Target Sector	Residential Establishments
Measure Unit	Water Heater
Measure Life	9 years[Source 1]
Vintage	Retrofit

This measure relates to the installation of a low flow (generally 1.5 GPM) showerhead in bathrooms in homes with electric water heater. The baseline is a standard showerhead using 2.5 GPM.

Eligibility

This protocol documents the energy savings attributable to replacing a standard showerhead with an energy efficient low flow showerhead for electric water heaters. The target sector primarily consists of residential establishments.

Commented [SA14]: Franklin Energy

The savings noted in this measure are attainable in homes with standard resistive storage or instantaneous water heaters. They are also applicable to homes with HPWH.

Homes with non-electric water heaters do not qualify for this measure.

We recommend making these clarifications in the introduction of the measure.

Algorithms

The annual energy savings are obtained through the following formula:

$$\Delta kWh = \frac{(GPM_{base} - GPM_{low}) \times 8.3\frac{BTU}{gal \cdot {}^{\circ}F} \times (T_{out} - T_{in})}{3412\frac{BTU}{kWh} \times RE} \times \frac{T_{person-day} \times N_{persons} \times N_{showers-day} \times 365\frac{days}{yr}}{N_{showerheads-home}} \times ISR \times ELEC$$

$$\Delta kW_{peak} = \Delta kWh \times ETDF$$

Where:

$$ETDF = \frac{CF}{HOU} = \frac{\%_{shower\ use,peak} \times 60\frac{\text{minutes}}{\text{hour}}}{365\frac{\text{days}}{\text{yr}} \times 240\frac{\text{minutes}}{\text{daily peak}}}$$

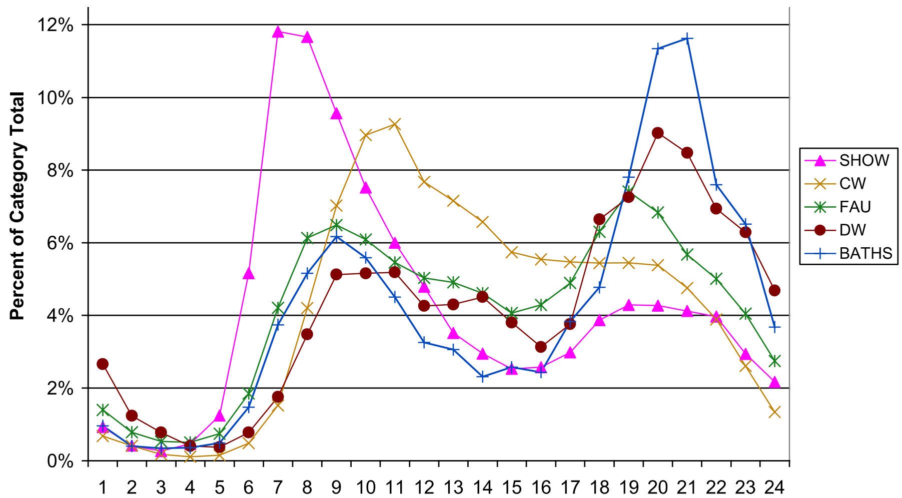
Given:

$$CF = \frac{\%_{shower\ use,peak} \times T_{person-day} \times N_{persons} \times N_{showers-day}}{N_{showerheads-home} \times 240\frac{\text{minutes}}{\text{daily peak}}}$$

$$HOU = \frac{T_{person-day} \times N_{persons} \times N_{showers-day} \times 365\frac{\text{days}}{\text{yr}}}{N_{showerheads-home} \times 60\frac{\text{minutes}}{\text{hour}}}$$

The ratio of the average energy usage during 2 PM and 6 PM on summer weekdays to the total annual energy usage is taken from average daily load shape data collected for showerheads from an Aquacraft, Inc study.[Source 2] The average daily load shapes (percentages of daily energy usage that occur within each hour) during are plotted in Figure 2-2 below (symbol SHOW represents showerheads).

Figure 2-2: Daily Load Shapes for Hot Water Measures Source 2



Commented [SA15]: Franklin Energy

We recommend expanding the text in the legend so that the load shapes are clearly defined.

Definition of Terms

Table 2-63: Terms, Values, and References for Low Flow Showerhead

Term	Unit	Value	Source
GPM_{base} , Gallons per minute of baseline showerhead	$\frac{gallons}{minute}$	Default value = 2.5	3
GPM_{low} , Gallons per minute of low flow showerhead	$\frac{gallons}{minute}$	EDC Data Gathering	
$T_{person-day}$, Average time of shower usage per person (minutes)	$\frac{minutes}{day}$	7.8	5
$N_{persons}$, Average number of persons per household	$\frac{persons}{house}$	EDC Data Gathering or Default SF=2.5 Default MF=1.7 Default unknown=2.5	6
$N_{showers-day}$, Average number of showers per person per day	$\frac{showers/person}{day}$	0.6	7
$N_{showerheads-home}$, Average number of showers in the home	$\frac{showers}{house}$	EDC Data Gathering or Default SF=1.6 Default MF=1.1 Default unknown = 1.5	8
T_{out} , Assumed temperature of water used by showerhead	$°F$	101	9
T_{in} , Assumed temperature of water entering house	$°F$	52	10
RE , Recovery efficiency of electric water heater	*Proportion*	Default: 0.98 HPWH: 2.1	11, 13

Commented [SA16]: Franklin Energy

Add the option of obtaining the "EDC Data Gathering"

Commented [SA17]: Franklin Energy

Recommend noting that 0.98 is for resistance type DHW heaters.

Term	Unit	Value	Source
$ETDF$, Energy To Demand Factor	$\frac{kW}{kWh/yr}$	0.00008014	12
ISR, In Service Rate	%	EDC Data Gathering, Kit Default = 35% Direct Install Default = 100%	EDC Data Gathering, 14
$ELEC$, Percentage of homes with electric water heat	%	EDC Data Gathering or Default: Unknown=35% Electric = 100% Fossil Fuel = 0.0%	8
$\%_{shower\ use,peak}$, percentage of daily shower use during PJM peak period	%	11.7%	12

Default Savings

Table 2-64: Default Savings for Low Flow Showerheads

Housing Type	Low Flow Rate (gpm)	Water Heater Fuel (% electric)	Energy Savings per Unit (kWh)		Demand Savings per Unit (kW)	
			Kit Delivery	Direct Install	Kit Delivery	Direct Install
Single Family	2.0	Unknown (35%)	19.9	56.8	0.0016	0.0046
	1.75	Unknown (35%)	29.8	85.2	0.0024	0.0068
	1.5	Unknown (35%)	39.8	113.6	0.0032	0.0091
Multifamily	2.0	Unknown (35%)	19.7	56.2	0.0016	0.0045
	1.75	Unknown (35%)	29.5	84.3	0.0024	0.0068
	1.5	Unknown (35%)	39.3	112.4	0.0032	0.0090
Statewide (Unknown Housing Type)	2.0	Unknown (35%)	21.2	60.6	0.0017	0.0049
	1.75	Unknown (35%)	31.8	90.9	0.0025	0.0073
	1.5	Unknown (35%)	42.4	121.2	0.0034	0.0097
Single Family	2.0	Electric (100%)	56.8	162.3	0.0046	0.0130
	1.75	Electric (100%)	85.2	243.5	0.0068	0.0195
	1.5	Electric (100%)	113.6	324.6	0.0091	0.0260
Multifamily	2.0	Electric (100%)	56.2	160.5	0.0045	0.0129
	1.75	Electric (100%)	84.3	240.8	0.0068	0.0193
	1.5	Electric (100%)	112.4	321.1	0.0090	0.0257
Statewide (Unknown Housing Type)	2.0	Electric (100%)	60.6	173.1	0.0049	0.0139
	1.75	Electric (100%)	90.9	259.7	0.0073	0.0208
	1.5	Electric (100%)	121.2	346.3	0.0097	0.0278

Evaluation Protocols

The most appropriate evaluation protocol for this measure is verification of installation coupled with EDC Data Gathering.

SOURCES

1) Efficiency Vermont, Technical Reference User Manual: Measure Savings Algorithms and Cost Assumptions, TRM User Manual No. 2008-53, 07/18/08, http://www.veic.org/docs/ResourceLibrary/TRM-User-Manual-Excerpts.pdf

2) Aquacraft, Inc., Water Engineering and Management. The end use of hot water in single family homes from flow trace analysis. 2001. http://s3.amazonaws.com/zanran_storage/www.aquacraft.com/ContentPages/47768067.pdf

3) Cadmus and Opinion Dynamics Evaluation Team. Showerhead and Faucet Aerator Meter Study. For Michigan Evaluation Working Group. June 2013. Uses the federal minimum GPM allowed as the baseline for the replaced showerheads, corresponding to 2.5 GPM.

4) Illinois TRM Effective June 1, 2013. Allows for varying flow rate of the low-flow showerhead, most notably values of 2.0 GPM, 1.75 GPM and 1.5 GPM. Custom or actual values are also allowed for.

5) Table 6. Cadmus and Opinion Dynamics Evaluation Team. Showerhead and Faucet Aerator Meter Study. For Michigan Evaluation Working Group. June 2013. The study compared shower length by single-family and multifamily populations, finding no statistical difference in showering times. For the energy-saving analysis, the study used the combined single-family and multifamily average shower length of 7.8 minutes.

6) American Community Survey 5-Year (2013-2017) Estimates for 2017. http://factfinder.census.gov.

7) Table 8. Cadmus and Opinion Dynamics Evaluation Team. Showerhead and Faucet Aerator Meter Study. For Michigan Evaluation Working Group. June 2013. For each shower fixture metered, the evaluation team knew the total number of showers taken, duration of time meters remained in each home, and total occupants reported to live in the home. From these values average showers taken per day, per person was calculated. The study compared showers per day, per person by single-family and multifamily populations, finding no statistical difference in the values. For the energy-saving analysis, the study used the combined single-family and multifamily average showers per day, per person of 0.6.

8) Pennsylvania Act 129 2018 Residential Baseline Study, http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-Phase3_Res_Baseline_Study_Rpt021219.pdf.

9) Cadmus and Opinion Dynamics Evaluation Team. Showerhead and Faucet Aerator Meter Study. For Michigan Evaluation Working Group. June 2013. Temperature sensors provided the mixed water temperature readings resulting in an average of 101ºF.

10) Using Rock Spring, PA (Site 2036) as a proxy, the mean of soil temperature at 40 inch depth is 51.861. Calculated using Daily SCAN Standard - Period of Record data from April 1999 to December 2018 from the Natural Resource Conservation Service Database. https://wcc.sc.egov.usda.gov/nwcc/rgrpt?report=daily_scan_por&state=PA. Methodology follows Missouri TRM 2017 Volume 2: Commercial and Industrial Measures. p. 78. https://energy.mo.gov/sites/energy/files/MOTRM2017Volume2.pdf

11) AHRI Directory. All electric storage water heaters have a recovery efficiency of .98. https://www.ahridirectory.org/Search/SearchForm?programId=24&searchTypeId=2

12) Aquacraft, Inc., Water Engineering and Management. The end use of hot water in single family homes from flow trace analysis. 2001. http://s3.amazonaws.com/zanran_storage/www.aquacraft.com/ContentPages/47768067.pdf. The statewide values were used for inputs in the ETDF algorithm components. The CF for showerheads is found to be 0.00380: $[\%\ \text{showerhead use during peak} \times (T_{Person\text{-}Day} \times N_{Person} \times N_{showers\text{-}day}) / (N_{showerheads\text{-}home})] / 240\ (\text{minutes in peak period}) = [11.7\% \times (7.8 \times 2.5 \times 0.6 / 1.5)]$

$/\ 240 = 0.00371$. The Hours for showerheads is found to be 47.5: $(T_{Person\text{-}Day} \times N_{Persons} \times 365)\ /(N_{showerheads\text{-}home})\ /\ 60 = (7.8 \text{ x } 2.5 \text{ x } 0.6 \text{ x } 365)\ /\ 1.5\ /\ 60 = 47.5$. The resulting ETDF is calculated to be 0.00008014: $\text{CF}\ /\ \text{Hours} = 0.00380\ /\ 47.5 = 0.00008014$.

13) NEEA Heat Pump Water Heater Field Study Report. Prepared by Fluid Market Strategies. October 22, 2013. https://neea.org/img/uploads/heat-pump-water-heater-field-study-report.pdf

14) Average of PY9 values for kit delivery for First Energy EDCs. [WEBSITE LINK TBD]

2.3.9 Thermostatic Shower Restriction Valves

Target Sector	Residential Establishments
Measure Unit	Water Heater
Measure Life	15 years Source 1
Vintage	Retrofit

This measure relates to the installation of a device that reduces hot water usage during shower warm-up by way of a thermostatic shower restriction valve, reducing hot water waste during shower warm-up.

Eligibility

This protocol documents the energy savings attributable to installing a thermostatic restriction valve, device, or equivalent product on an existing showerhead. Only homes with electric water heaters are eligible, and the savings associated with this measure may be combined with a low flow showerhead as the sum of the savings of the two measures. The target sector primarily consists of residences.

Commented [SA18]: Franklin Energy

We recommend making these clarifications in the introduction of the measure:

The savings noted in this measure are attainable in homes with standard resistive storage or instantaneous water heaters. They are also applicable to homes with HPWH.

Homes with non-electric water heaters do not qualify for this measure.

Algorithms

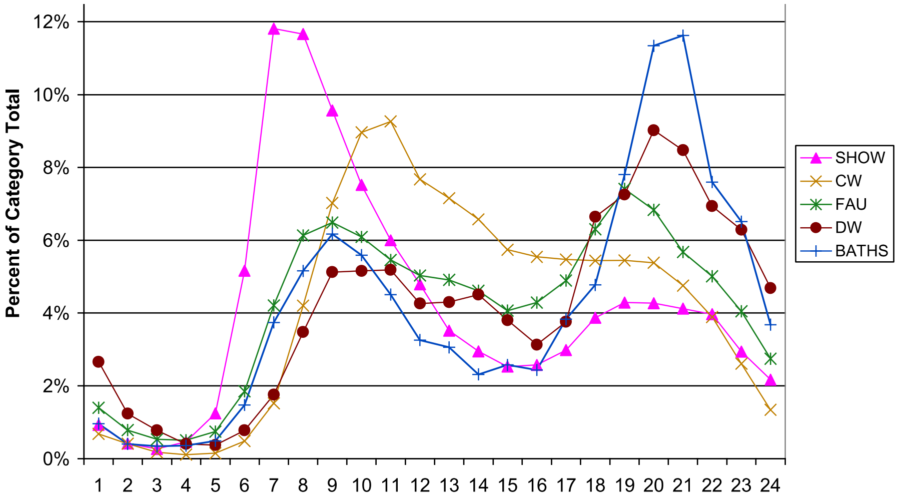
The annual energy savings are obtained through the following formula:

$$\Delta kWh = ISR \times ELEC \times \frac{GPM_{base} \times 8.3\frac{BTU}{gal\cdot°F} \times (T_{out} - T_{in})}{3412\frac{BTU}{kWh} \times RE} \times \frac{BehavioralWasteSeconds \times \left(N_{persons} \times N_{showers-day}\right) \times 365\frac{days}{yr}}{60\ \frac{sec}{min} \times N_{showerheads-home}}$$

$$\Delta kW_{peak} = \Delta kWh \times ETDF$$

The ratio of the average energy usage during 2 PM and 6 PM on summer weekdays to the total annual energy usage is taken from average daily load shape data collected for showerheads from an Aquacraft, Inc study. Source 2 The average daily load shapes (percentages of daily energy usage that occur within each hour) during are plotted in Figure 2-3: Daily Load Shapes for Hot Water Measures below (symbol SHOW represents showerheads).

Figure 2-3: Daily Load Shapes for Hot Water Measures Source 2



Commented [SA19]: Franklin Energy

We recommend expanding the legend text to clearly notate what the load shapes are for.

Definition of Terms

Table 2-65: Terms, Values, and References for Thermostatic Shower Restriction Valve

Parameter	Unit	Value	Source
GPM_{Base}, Gallons per minute of baseline showerhead	$\frac{gallons}{min}$	EDC Data Gathering or Default: Standard shower head=2.5 Low Flow Shower Head=1.5	3
$N_{persons}$, Average number of persons per household	$\frac{persons}{household}$	EDC Data Gathering or Default: SF=2.5 MF=1.7 Unknown=2.5	4
$N_{Showers\text{-}Day}$, Average number of showers per person per day	$\frac{showers}{day}$	0.6	5
$N_{showerheads-home}$, Average number of showerhead fixtures in the home	*None*	EDC Data Gathering or Default: SF=1.6 MF=1.1 Unknown = 1.5	6
T_{out}, Assumed temperature of water used by showerhead	$^{\circ}F$	EDC Data Gathering or Default: 104	7
T_{in}, Assumed temperature of water entering house	$^{\circ}F$	52	8
RE, Recovery efficiency of electric water heater	*Proportion*	Default: 0.98 HPWH: 2.1	9, 11
ETDF, Energy To Demand Factor	$\frac{kW}{kWh/yr}$	0.00008014	10
ISR, In Service Rate	*%*	EDC Data Gathering Default: 100%	EDC Data Gathering

Commented [SA20]: Franklin Energy

Recommend noting that 0.98 is for resistance type DHW heaters.

Parameter	Unit	Value	Source
ELEC, Percentage of homes with electric water heat	%	EDC Data Gathering or Default: Electric = 100% Fossil Fuel = 0.0% Unknown=35%	6
BehavioralWasteSeconds, Time	sec	EDC Data Gathering or Default = 59	7

Default Savings

Default savings values should only be used for direct install delivery.

Table 2-66: Default Savings for Thermostatic Restriction Valve

Application	Baseline Flowrate (GPM)	Water Heater Fuel (% electric)	Energy Savings (kWh/yr)	Peak Demand Reduction (kW)
Single Family	2.5	Unknown (35%)	38.0	0.0030
	2	Unknown (35%)	30.4	0.0024
	1.5	Unknown (35%)	22.8	0.0018
Multifamily	2.5	Unknown (35%)	37.6	0.0030
	2	Unknown (35%)	30.1	0.0024
	1.5	Unknown (35%)	22.6	0.0018
Unknown / Default Housing Type	2.5	Unknown (35%)	40.5	0.0032
	2	Unknown (35%)	32.4	0.0026
	1.5	Unknown (35%)	24.3	0.0019
Single Family	2.5	Electric (100%)	108.6	0.0087
	2	Electric (100%)	86.9	0.0070
	1.5	Electric (100%)	65.1	0.0052
Multifamily	2.5	Electric (100%)	107.4	0.0086
	2	Electric (100%)	85.9	0.0069
	1.5	Electric (100%)	64.4	0.0052
Unknown / Default Housing Type	2.5	Electric (100%)	115.8	0.0093
	2	Electric (100%)	92.7	0.0074
	1.5	Electric (100%)	69.5	0.0056

Evaluation Protocols

The most appropriate evaluation protocol for this measure is verification of installation coupled with EDC Data Gathering.

Sources

1) Uniform Plumbing Code (UPC) certification under the International Association of Plumbing and Mechanical Officials standard IGC 244-2007a stipulates device must meet 10,000 cycles without failure. Measure life: $[10{,}000 \text{ cycles} / (N_{persons} \text{ x } N_{showers\text{-}day} \text{ x } 365)] = [10{,}000 / (2.5 \text{ x } 0.6$

x 365)] = 18 years. Note that measure life is calculated to be 18 years; however, PA Act 129 savings can be claimed for no more than 15 years.

2) Aquacraft, Inc., Water Engineering and Management. The end use of hot water in single family homes from flow trace analysis. 2001. http://s3.amazonaws.com/zanran_storage/www.aquacraft.com/ContentPages/47768067.pdf.

3) Cadmus and Opinion Dynamics Evaluation Team. Showerhead and Faucet Aerator Meter Study. For Michigan Evaluation Working Group. June 2013. Uses the federal minimum GPM allowed as the baseline for the replaced showerheads, corresponding to 2.5 GPM.

4) American Community Survey 5-Year (2013-2017) Estimates for 2017. http://factfinder.census.gov.

5) Table 8. Cadmus and Opinion Dynamics Evaluation Team. Showerhead and Faucet Aerator Meter Study. For Michigan Evaluation Working Group. June 2013. For each shower fixture metered, the evaluation team knew the total number of showers taken, duration of time meters remained in each home, and total occupants reported to live in the home. From these values average showers taken per day, per person was calculated. The study compared showers per day, per person by single-family and multifamily populations, finding no statistical difference in the values. For the energy-saving analysis, the study used the combined single-family and multifamily average showers per day, per person of 0.6.

6) Pennsylvania Act 129 2018 Residential Baseline Study, http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-Phase3_Res_Baseline_Study_Rpt021219.pdf.

7) PPL Electric 2014 ShowerStart Pilot Study. Cadmus memo to PPL Electric in November 2014. The previous T_{out} value was based on the average water temperature of the entire shower, whereas this pilot study T_{out} value is based on the average water temperature of the period after the user resumed the water flow by pulling the ShowerStart cord. This pilot study T_{out} value is more accurate than the previous value because it excludes the warmup phase of the shower and thus reflects the temperature of the water saved by the ShowerStart device during the behavioral waste period more accurately. The BehavioralWasteSeconds value represents the average time the ShowerStart device is engaged during a shower. The BehavioralWasteSeconds value includes instances when the user did not engage the ShowerStart device (instances when BehavioralWasteSeconds = 0s).

8) Using Rock Spring, PA (Site 2036) as a proxy, the mean of soil temperature at 40 inch depth is 51.861. Calculated using Daily SCAN Standard - Period of Record data from April 1999 to December 2018 from the Natural Resource Conservation Service Database. https://wcc.sc.egov.usda.gov/nwcc/rgrpt?report=daily_scan_por&state=PA. Methodology follows Missouri TRM 2017 Volume 2: Commercial and Industrial Measures. p. 78. https://energy.mo.gov/sites/energy/files/MOTRM2017Volume2.pdf

9) AHRI Directory. All electric storage water heaters have a recovery efficiency of .98. https://www.ahridirectory.org/Search/SearchForm?programId=24&searchTypeId=2

10) Aquacraft, Inc., Water Engineering and Management. The end use of hot water in single family homes from flow trace analysis. 2001. http://s3.amazonaws.com/zanran_storage/www.aquacraft.com/ContentPages/47768067.pdf. The statewide values were used for inputs in the ETDF algorithm components. The CF for showerheads is found to be 0.00380: [% showerhead use during peak × ($T_{Person\text{-}Day}$ × N_{Person} × $N_{showers\text{-}day}$) /($N_{showerheads\text{-}home}$)] / 240 (minutes in peak period) = [11.7% × (7.8 x 2.5 x 0.6 / 1.5)] / 240 = 0.00371. The Hours for showerheads is found to be 47.5: ($T_{Person\text{-}Day}$× $N_{Persons}$× 365) /($N_{showerheads\text{-}home}$) / 60 = (7.8 x 2.5 x 0.6 x 365) / 1.5 / 60 = 47.5. The resulting ETDF is calculated to be 0.00008014: CF / Hours = 0.00380 / 47.5 = 0.00008014.

11) NEEA Heat Pump Water Heater Field Study Report. Prepared by Fluid Market Strategies. October 22, 2013. https://neea.org/img/uploads/heat-pump-water-heater-field-study-report.pdf

2.4 APPLIANCES

2.4.1 ENERGY STAR REFRIGERATORS

Target Sector	Residential Establishments
Measure Unit	Refrigerator
Measure Life	14 years[Source 1]
Vintage	Replace on Burnout

ELIGIBILITY

This measure is for the purchase and installation of a new refrigerator meeting ENERGY STAR or ENERGY STAR Most Efficient criteria. An ENERGY STAR refrigerator is about 10 percent more efficient than the minimum federal government standard. The ENERGY STAR Most Efficient is a new certification that identifies the most efficient products among those that qualify for ENERGY STAR. ENERGY STAR Most Efficient refrigerators must be at least 15 percent more efficient than the minimum federal standard.

ALGORITHMS

To determine resource savings, the per-unit estimates in the algorithms will be multiplied by the number of refrigerators. The number of refrigerators will be determined using market assessments and market tracking.

If the volume and configuration of the refrigerator is known, the baseline model's annual energy consumption (kWh_{base}) may be determined using Table 2-68.

The efficient model's annual energy consumption (kWh_{ee} or kWh_{me}) may be determined using manufacturers' test data for the given model. Where test data is not available the algorithms in Table 2-68 and Table 2-70 for "ENERGY STAR and ENERGY STAR Most Efficient maximum energy usage in kWh/year" may be used to determine the efficient energy consumption for a conservative savings estimate.

ENERGY STAR Refrigerator

$$\Delta kWh = kWh_{base} - kWh_{ee}$$

$$\Delta kW_{peak} = (kWh_{base} - kWh_{ee}) \times ETDF$$

ENERGY STAR Most Efficient Refrigerator

$$\Delta kWh = kWh_{base} - kWh_{me}$$

$$\Delta kW_{peak} = (kWh_{base} - kWh_{me}) \times ETDF$$

Definition of Terms

Table 2-67: Terms, Values, and References for ENERGY STAR Refrigerators

Term	Unit	Value	Source
kWh_{base} , Annual energy consumption of baseline unit	*kWh/yr*	EDC Data Gathering Default = Table 2-68	2
kWh_{ee} , Annual energy consumption of ENERGY STAR qualified unit	*kWh/yr*	EDC Data Gathering Default = Table 2-68	3
kWh_{me} , Annual energy consumption of ENERGY STAR Most Efficient qualified unit	*kWh/yr*	EDC Data Gathering Default = Table 2-69	4
ETDF , Energy to Demand Factor	$\frac{kW}{\frac{kWh}{yr}}$	0.0001614	5

Refrigerator energy use is characterized by configuration (top freezer, bottom freezer, etc.), volume, whether defrost is manual or automatic and whether there is through-the-door ice. If this information is known, annual energy consumption (kWh_{base}) of the federal standard model may be determined using Table 2-68. The efficient model's annual energy consumption (kWh_{ee} or kWh_{me}) may be determined using manufacturer's test data for the given model. Where test data is not available, the algorithms in Table 2-68 and Table 2-69 for "ENERGY STAR and ENERGY STAR Most Efficient maximum energy usage in kWh/year" may be used to determine efficient energy consumption for a conservative savings estimate.

The term "AV" in the equations refers to "Adjusted Volume" in ft^3. For Category 1 and 1A "All-refrigerators":

$$AV = Fresh\ Volume + Freezer\ Volume$$

For all other categories:

$$AV = Fresh\ Volume + 1.76 \times Freezer\ Volume$$

Table 2-68: Federal Standard and ENERGY STAR Refrigerators Maximum Annual Energy Consumption if Configuration and Volume Known[47]

Refrigerator Category	Federal Standard Maximum Usage in kWh/yr	ENERGY STAR Maximum Energy Usage in kWh/yr
Standard Size Models: 7.75 cubic feet or greater		
1. Refrigerator-freezers and refrigerators other than all-refrigerators with manual defrost.	7.99 × AV + 225.0	7.19 × AV + 202.5
1A. All-refrigerators—manual defrost.	6.79 × AV + 193.6	6.11 × AV + 174.2
2. Refrigerator-freezers—partial automatic defrost	7.99 × AV + 225.0	7.19 × AV + 202.5
3. Refrigerator-freezers—automatic defrost with top-mounted freezer without an automatic icemaker.	8.07 × AV + 233.7	7.26 × AV + 210.3

[47] Lettering convention (1, 1A, etc) of Federal standard and ENERGY STAR specifications included for clear reference to the standards as well as for correspondence to entries in the default savings table.

Refrigerator Category	Federal Standard Maximum Usage in kWh/yr	ENERGY STAR Maximum Energy Usage in kWh/yr
3-BI. Built-in refrigerator-freezer—automatic defrost with top-mounted freezer without an automatic icemaker.	9.15 × AV + 264.9	8.24 × AV + 238.4
3I. Refrigerator-freezers—automatic defrost with top-mounted freezer with an automatic icemaker without through-the-door ice service.	8.07 × AV + 317.7	7.26 × AV + 294.3
3I-BI. Built-in refrigerator-freezers—automatic defrost with top-mounted freezer with an automatic icemaker without through-the-door ice service.	9.15 × AV + 348.9	8.24 × AV + 322.4
3A. All-refrigerators—automatic defrost.	7.07 × AV + 201.6	6.36 × AV + 181.4
3A-BI. Built-in All-refrigerators—automatic defrost.	8.02 × AV + 228.5	7.22 × AV + 205.7
4. Refrigerator-freezers—automatic defrost with side-mounted freezer without an automatic icemaker.	8.51 × AV + 297.8	7.66 × AV + 268.0
4-BI. Built-In Refrigerator-freezers—automatic defrost with side-mounted freezer without an automatic icemaker.	10.22 × AV + 357.4	9.20 × AV + 321.7
4I. Refrigerator-freezers—automatic defrost with side-mounted freezer with an automatic icemaker without through-the-door ice service.	8.51 × AV + 381.8	7.66 × AV + 352.0
4I-BI. Built-In Refrigerator-freezers—automatic defrost with side-mounted freezer with an automatic icemaker without through-the-door ice service.	10.22 × AV + 441.4	9.20 × AV + 405.7
5. Refrigerator-freezers—automatic defrost with bottom-mounted freezer without an automatic icemaker.	8.85 × AV + 317.0	7.97 × AV + 285.3
5-BI. Built-In Refrigerator-freezers—automatic defrost with bottom-mounted freezer without an automatic icemaker.	9.40 × AV + 336.9	8.46 × AV + 303.2
5I. Refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker without through-the-door ice service.	8.85 × AV + 401.0	7.97 × AV + 369.3
5I-BI. Built-In Refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker without through-the-door ice service.	9.40 × AV + 420.9	8.46 × AV + 387.2
5A. Refrigerator-freezer—automatic defrost with bottom-mounted freezer with through-the-door ice service.	9.25 × AV + 475.4	8.33 × AV + 436.3
5A-BI. Built-in refrigerator-freezer—automatic defrost with bottom-mounted freezer with through-the-door ice service.	9.83 × AV + 499.9	8.85 × AV + 458.3
6. Refrigerator-freezers—automatic defrost with top-mounted freezer with through-the-door ice service.	8.40 × AV + 385.4	7.56 × AV + 355.3
7. Refrigerator-freezers—automatic defrost with side-mounted freezer with through-the-door ice service.	8.54 × AV + 432.8	7.69 × AV + 397.9

Refrigerator Category	Federal Standard Maximum Usage in kWh/yr	ENERGY STAR Maximum Energy Usage in kWh/yr
7-BI. Built-In Refrigerator-freezers—automatic defrost with side-mounted freezer with through-the-door ice service.	10.25 × AV + 502.6	9.23 × AV + 460.7
Compact Size Models: Less than 7.75 cubic feet and 36 inches or less in height		
11. Compact refrigerator-freezers and refrigerators other than all-refrigerators with manual defrost.	9.03 × AV + 252.3	8.13 × AV + 227.1
11A.Compact all-refrigerators—manual defrost.	7.84 × AV + 219.1	7.06 × AV + 197.2
12. Compact refrigerator-freezers—partial automatic defrost	5.91 × AV + 335.8	5.32 × AV + 302.2
13. Compact refrigerator-freezers—automatic defrost with top-mounted freezer.	11.80 × AV + 339.2	10.62 × AV + 305.3
13I. Compact refrigerator-freezers—automatic defrost with top-mounted freezer with an automatic icemaker.	11.80 × AV + 423.2	10.62 × AV + 389.3
13A. Compact all-refrigerators—automatic defrost.	9.17 × AV + 259.3	8.25 × AV + 233.4
14. Compact refrigerator-freezers—automatic defrost with side-mounted freezer.	6.82 × AV + 456.9	6.14 × AV + 411.2
14I. Compact refrigerator-freezers—automatic defrost with side-mounted freezer with an automatic icemaker.	6.82 × AV + 540.9	6.14 × AV + 495.2
15. Compact refrigerator-freezers—automatic defrost with bottom-mounted freezer.	11.80 × AV + 339.2	10.62 × AV + 305.3
15I. Compact refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker.	11.80 × AV + 423.2	10.62 × AV + 389.3

Table 2-69: Default Savings Values for ENERGY STAR Refrigerators[48]

Refrigerator Category	Assumed Volume of Unit (cubic feet) Source 6	Conventional Unit Energy Usage in kWh/yr	ENERGY STAR Energy Usage in kWh/yr	ΔkWh/yr	ΔkW_{peak}
1A. All-refrigerators—manual defrost.	12.2	276	249	28	0.0045
2. Refrigerator-freezers—partial automatic defrost	12.2	322	290	32	0.0052
3I. Refrigerator-freezers—automatic defrost with top-mounted freezer with an automatic icemaker without through-the-door ice service.	17.9	462	424	38	0.0061

[48] Lettering convention (1A, 2, etc) of Federal standard and ENERGY STAR specifications included for clear reference to the standards as well as for correspondence to entries in the default savings table.

Refrigerator Category	Assumed Volume of Unit (cubic feet) Source 6	Conventional Unit Energy Usage in kWh/yr	ENERGY STAR Energy Usage in kWh/yr	ΔkWh/yr	ΔkW_{peak}
4I. Refrigerator-freezers—automatic defrost with side-mounted freezer with an automatic icemaker without through-the-door ice service.	22.7	575	526	49	0.0079
5I. Refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker without through-the-door ice service.	20.0	578	529	49	0.0079
7. Refrigerator-freezers—automatic defrost with side-mounted freezer with through-the-door ice service.	24.6	643	587	56	0.0090
5A. Refrigerator-freezer—automatic defrost with bottom-mounted freezer with through-the-door ice service.	25.4	710	648	62	0.0100
3A. All-refrigerators—automatic defrost.	12.2	288	259	29	0.0047
Compact Size Models: Less than 7.75 cubic feet and 36 inches or less in height					
11A.Compact all-refrigerators—manual defrost.	3.3	245	220	24	0.0038
12. Compact refrigerator-freezers—partial automatic defrost	3.3	355	320	36	0.0058
13. Compact refrigerator-freezers—automatic defrost with top-mounted freezer.	4.5	392	353	39	0.0063
15. Compact refrigerator-freezers—automatic defrost with bottom-mounted freezer.	5.1	399	359	40	0.0065

ENERGY STAR Most Efficient annual energy consumption (kWh_{me}) may be determined using manufacturer's test data for the given model. Where test data is not available, the algorithms in Table 2-70 for "ENERGY STAR Most Efficient maximum energy usage in kWh/year" may be used to determine efficient energy consumption for a conservative savings estimate. Baseline annual energy usage consumption (kWh_{base}) of the federal standard model may be determined using Table 2-68. E_{ann} stands for Maximum Annual Energy Usage.

Table 2-70: ENERGY STAR Most Efficient Annual Energy Usage if Configuration and Volume Known Source 4

Refrigerator Category	ENERGY STAR Most Efficient Maximum Annual Energy Usage in kWh/yr
1. Refrigerator-freezers and refrigerators other than all-refrigerators with manual defrost.	$AV \leq 65.6$, $E_{ann} \leq 6.79 \times AV + 191.3$

Refrigerator Category	ENERGY STAR Most Efficient Maximum Annual Energy Usage in kWh/yr
	AV > 65.6, E_{ann} ≤ 637
2. Refrigerator-freezers—partial automatic defrost	AV ≤ 65.6, E_{ann} ≤ 6.79 × AV + 191.3 AV > 65.6, E_{ann} ≤ 637
3. Refrigerator-freezers—automatic defrost with top-mounted freezer without an automatic icemaker.	≤637 kWh/yr
3-BI. Built-in refrigerator-freezer—automatic defrost with top-mounted freezer without an automatic icemaker.	≤637 kWh/yr
3I. Refrigerator-freezers—automatic defrost with top-mounted freezer with an automatic icemaker without through-the-door ice service.	≤637 kWh/yr
3I-BI. Built-in refrigerator-freezers—automatic defrost with top-mounted freezer with an automatic icemaker without through-the-door ice service.	AV ≤ 51.6, E_{ann} ≤ 6.86 × AV + 282.6 AV > 51.6, E_{ann} ≤ 637
4. Refrigerator-freezers—automatic defrost with side-mounted freezer without an automatic icemaker.	AV ≤ 53.0, E_{ann} ≤ 7.23 × AV + 253.1 AV > 53.0, E_{ann} ≤ 637
4-BI. Built-In Refrigerator-freezers—automatic defrost with side-mounted freezer without an automatic icemaker.	AV ≤ 53.0, E_{ann} ≤ 7.23 × AV + 253.1 AV > 53.0, E_{ann} ≤ 637
4I. Refrigerator-freezers—automatic defrost with side-mounted freezer with an automatic icemaker without through-the-door ice service.	AV ≤ 41.4, E_{ann} ≤ 7.23 × AV + 337.1 AV > 41.4, E_{ann} ≤ 637
4I-BI. Built-In Refrigerator-freezers—automatic defrost with side-mounted freezer with an automatic icemaker without through-the-door ice service.	AV ≤ 41.4, E_{ann} ≤ 7.23 × AV + 337.1 AV > 41.4, E_{ann} ≤ 637
5. Refrigerator-freezers—automatic defrost with bottom-mounted freezer without an automatic icemaker.	AV ≤ 48.8, E_{ann} ≤ 7.52 × AV + 269.5 AV > 48.8, E_{ann} ≤ 637
5-BI. Built-In Refrigerator-freezers—automatic defrost with bottom-mounted freezer without an automatic icemaker.	AV ≤ 48.8, E_{ann} ≤ 7.52 × AV + 269.5 AV > 48.8, E_{ann} ≤ 637
5I. Refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker without through-the-door ice service.	AV ≤ 37.7, E_{ann} ≤ 7.52 × AV + 353.5 AV > 37.7, E_{ann} ≤ 637
5I-BI. Built-In Refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker without through-the-door ice service.	AV ≤ 37.7, E_{ann} ≤ 7.52 × AV + 353.5 AV > 37.7, E_{ann} ≤ 637
5A. Refrigerator-freezer—automatic defrost with bottom-mounted freezer with through-the-door ice service.	AV ≤ 28.0, E_{ann} ≤ 7.86 × AV + 416.7 AV > 28.0, E_{ann} ≤ 637

Refrigerator Category	ENERGY STAR Most Efficient Maximum Annual Energy Usage in kWh/yr
5A-BI. Built-in refrigerator-freezer—automatic defrost with bottom-mounted freezer with through-the-door ice service.	$AV \le 28.0$, $E_{ann} \le 7.86 \times AV + 416.7$ $AV > 28.0$, $E_{ann} \le 637$
956. Refrigerator-freezers—automatic defrost with top-mounted freezer with through-the-door ice service.	$AV < 41.5$, $E_{ann} \le 7.14 \times AV + 340.2$ $AV > 41.5$, $E_{ann} \le 637$
7. Refrigerator-freezers—automatic defrost with side-mounted freezer with through-the-door ice service.	$AV \le 35.3$, $E_{ann} \le 7.26 \times AV + 380.5$ $AV > 35.3$, $E_{ann} \le 637$
7-BI. Built-In Refrigerator-freezers—automatic defrost with side-mounted freezer with through-the-door ice service.	$AV \le 35.3$, $E_{ann} \le 7.26 \times AV + 380.5$ $AV > 35.3$, $E_{ann} \le 637$

DEFAULT SAVINGS

Table 2-71: Default Savings Values for ENERGY STAR Most Efficient Refrigerators Source 4

Refrigerator Category	Assumed Volume of Unit (ft^3) Source 7	Conventional Unit Energy Usage in kWh/yr[49]	ENERGY STAR Most Efficient Consumption in kWh/yr Source 4	ΔkWh	ΔkW_{peak}
3. Refrigerator-freezers—automatic defrost with top-mounted freezer without an automatic icemaker.	17.1	372	333	39	0.0063
3I. Refrigerator-freezers—automatic defrost with top-mounted freezer with an automatic icemaker without through-the-door ice service.	21.4	490	448	42	0.0068
5-BI. Built-In Refrigerator-freezers—automatic defrost with bottom-mounted freezer without an automatic icemaker.	10.9	439	336	103	0.0167
5. Refrigerator-freezers—automatic defrost with bottom-mounted freezer without an automatic icemaker.	14.9	449	367	82	0.0132
5I. Refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker without through-the-door ice service.	22.1	597	511	86	0.0138
5A. Refrigerator-freezer—automatic defrost with bottom-mounted freezer with through-the-door ice service.	30.2	755	621	134	0.0216
5I-BI. Built-In Refrigerator-freezers—automatic defrost with bottom-	25.50	631	519	112	0.0181

[49] Baseline consumption of unit based on category and assumed volume.

Refrigerator Category	Assumed Volume of Unit (ft^3) Source 7	Conventional Unit Energy Usage in kWh/yr[49]	ENERGY STAR Most Efficient Consumption in kWh/yr Source 4	ΔkWh	ΔkW_{peak}
mounted freezer without an automatic icemaker.					
7. Refrigerator-freezers—automatic defrost with side-mounted freezer with through-the-door ice service.	27.5	668	525	143	0.0231

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx. Accessed December 2018.
2) Federal Standards for Residential Refrigerators and Freezers, Effective 9/14/2014. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/43
3) ENERGY STAR Program Requirements Product Specifications for Residential Refrigerators and Freezers Version 5.0. Effective 9/15/2014. https://www.energystar.gov/ia/partners/product_specs/program_reqs/Refrigerators_and_Freezers_Program_Requirements_V5.0.pdf
4) ENERGY STAR Recognition Criteria for Most Efficient Refrigerator-Freezers. Table 2. https://www.energystar.gov/sites/default/files/Refrigerator-Freezers%20ENERGY%20STAR%20Most%20Efficient%202018%20Final%20Criteria.pdf
5) Consistent with the conversion factors in the Mid-Atlantic, Illinois, and Wisconsin TRMs. Derived from: (Temperature Adjustment Factor × Load Shape Adjustment Factor)/8760 hours. The temperature adjustment factor is 1.23 and is based on Blasnik, Michael, "Measurement and Verification of Residential Refrigerator Energy Use, Final Report, 2003-2004 Metering Study", July 29, 2004 (p. 47) and assuming 78% of refrigerators are in cooled space (based on BGE Energy Use Survey, Report of Findings, December 2005; Mathew Greenwald & Associates) and 22% in un-cooled space. The load shape adjustment factor is 1.15, based on the same report.
6) ENERGY STAR Appliances Calculator. Accessed July 2018. https://www.energystar.gov/sites/default/files/asset/document/appliance_calculator.xlsx
7) ENERGY STAR Most Efficient volumes taken from average sizes of qualified units. Energy Star Qualified Models. Accessed July 25, 2018. https://www.energystar.gov/productfinder/product/certified-residential-refrigerators/results

2.4.2 ENERGY STAR Freezers

Target Sector	Residential Establishments
Measure Unit	Freezer
Measure Life	11 years Source 4
Vintage	Replace on Burnout

Eligibility

This measure is for the purchase and installation of a new freezer meeting ENERGY STAR criteria. An ENERGY STAR freezer must be at least 10 percent more efficient than the minimum federal government standard.

Algorithms

To determine resource savings, the per-unit estimates in the algorithms will be multiplied by the number of freezers. The number of freezers will be determined using market assessments and market tracking.

If the volume and configuration of the freezer is known, the baseline model's annual energy consumption (kWh_{base}) may be are determined using Table 2-72. The efficient model's annual energy consumption (kWh_{ee}) may be determined using manufacturer's test data for the given model. Where test data is not available the algorithms in Table 2-73 for "ENERGY STAR Maximum Energy Usage in kWh/year" may be used to determine the efficient energy consumption for a conservative savings estimate

ENERGY STAR Freezer

$$\Delta kWh = kWh_{base} - kWh_{ee}$$

$$\Delta kW_{peak} = (kWh_{base} - kWh_{ee}) \times ETDF$$

Definition of Terms

Table 2-72: Terms, Values, and References for ENERGY STAR Freezers

Term	Unit	Value	Source
kWh_{base} , Annual energy consumption of baseline unit	kWh/yr	EDC Data Gathering Default = Table 2-73	1
kWh_{ee} , Annual energy consumption of ENERGY STAR qualified unit	kWh/yr	EDC Data Gathering Default = Table 2-73	2
ETDF , Energy to Demand Factor	$\frac{kW}{\frac{kWh}{yr}}$	0.0001614	3

Freezer energy use is characterized by configuration (upright, chest or compact), volume and whether defrost is manual or automatic. If this information is known, annual energy consumption of the federal minimum efficiency standard model may be determined using Table 2-72. The efficient model's annual energy consumption (kWh_{ee}) may be determined using manufacturers' test data for the given model. Where test data is not available, the algorithms in Table 2-73 for "ENERGY STAR maximum energy usage in kWh/year" may be used to determine efficient energy consumption for a conservative savings estimate. The term "AV" in the equations refers to "Adjusted Volume," which is $\mathrm{AV} = 1.76 \times \mathrm{Freezer\ Volume}$.

Table 2-73: Federal Standard and ENERGY STAR Freezers Maximum Annual Energy Consumption if Configuration and Volume Known[50]

Freezer Category	Federal Standard Maximum Usage (kWh/yr)	ENERGY STAR Maximum Energy Usage (kWh/yr)
8. Upright freezers with manual defrost.	5.57 × AV + 193.7	5.01 × AV + 174.3
9. Upright freezers with automatic defrost without an automatic icemaker.	8.62 × AV + 228.3	7.76 × AV + 205.5
9I. Upright freezers with automatic defrost with an automatic icemaker.	8.62 × AV + 312.3	7.76 × AV + 289.5
9-BI. Built-In Upright freezers with automatic defrost without an automatic icemaker.	9.86 × AV + 260.9	8.87 × AV + 234.8
9I-BI. Built-in upright freezers with automatic defrost with an automatic icemaker.	9.86 × AV + 344.9	8.87 × AV + 318.8
10. Chest freezers and all other freezers except compact freezers.	7.29 × AV + 107.8	6.56 × AV + 97.0
10A. Chest freezers with automatic defrost.	10.24 × AV + 148.1	9.22 × AV + 133.3
16. Compact upright freezers with manual defrost.	8.65 × AV + 225.7	7.79 × AV + 203.1
17. Compact upright freezers with automatic defrost.	10.17 × AV + 351.9	9.15 × AV + 316.7
18. Compact chest freezers.	9.25 × AV + 136.8	8.33 × AV + 123.1

The default values for each configuration are given in Table 2-74. Note that a compact freezer is defined as a freezer that has a volume less than 7.75 cubic feet and is 36 inches or less in height.

[50] Lettering convention (8, 9, 9I, etc) of Federal standard and ENERGY STAR specifications included for clear reference to the standards as well as for correspondence to entries in the default savings table.

Default Savings

Table 2-74: Default Savings Values for ENERGY STAR Freezers

Freezer Category	Average Unit Adj. Volume (ft^3)	Conventional Usage Source 5 (kWh/yr)	ENERGY STAR Usage Source 5 (kWh/yr)	ΔkWh	ΔkW_{peak}
8. Upright freezers with manual defrost.	12.6	264	237	27	0.0043
9. Upright freezers with automatic defrost without an automatic icemaker.	24.7	441	397	44	0.0071
10. Chest freezers and all other freezers except compact freezers.	18.5	243	218	25	0.0039
16. Compact upright freezers with manual defrost.	3.7	257	231	26	0.0042
17. Compact upright freezers with automatic defrost.	7.7	430	387	43	0.0070
18. Compact chest freezers.	8.9	219	197	22	0.0035

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) Federal Standards for Residential Refrigerators and Freezers, Effective 9/14/2014. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/43

2) ENERGY STAR Program Requirements Product Specifications for Residential Refrigerators and Freezers Version 5.0. Effective 9/15/2014. http://www.energystar.gov/products/specs/system/files/ENERGY%20STAR%20Final%20Version%205.0%20Residential%20Refrigerators%20and%20Freezers%20Program%20Requirements.pdf

3) Consistent with the conversion factors in the Mid-Atlantic, Illinois, and Wisconsin TRMs. Derived from: (Temperature Adjustment Factor × Load Shape Adjustment Factor)/8760 hours. The temperature adjustment factor is 1.23 and is based on Blasnik, Michael, "Measurement and Verification of Residential Refrigerator Energy Use, Final Report, 2003-2004 Metering Study", July 29, 2004 (p. 47) and assuming 78% of refrigerators are in cooled space (based on BGE Energy Use Survey, Report of Findings, December 2005; Mathew

Greenwald & Associates) and 22% in un-cooled space. The load shape adjustment factor is 1.15, based on the same report.

4) California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx. Accessed December 2018.

5) ENERGY STAR Qualified Refrigerators and Freezers. Accessed October 2018. https://data.energystar.gov/Active-Specifications/ENERGY-STAR-Certified-Residential-Freezers/8t9c-g3tn/data

2.4.3 REFRIGERATOR / FREEZER RECYCLING WITH AND WITHOUT REPLACEMENT

Target Sector	Residential Establishments
Measure Life	**Without Replacement:** Source 1 Refrigerator: 5 years Freezer: 4 years **With Replacement (see Measure Life below):** Refrigerator: 6 years Freezer: 5 years
Vintage	Early Retirement, Early Replacement

ELIGIBILITY

Refrigerator recycling programs are designed to save energy through the removal of old-but operable refrigerators from service. By offering free pickup, providing incentives, and disseminating information about the operating cost of old refrigerators, these programs are designed to encourage consumers to:

- Discontinue the use of secondary refrigerators
- Relinquish refrigerators previously used as primary units when they are replaced (rather than keeping the old refrigerator as a secondary unit)
- Prevent the continued use of old refrigerators in another household through a direct transfer (giving it away or selling it) or indirect transfer (resale on the used appliance market).

Commonly implemented by third-party contractors (who collect and decommission participating appliances), these programs generate energy savings through the retirement of inefficient appliances. The decommissioning process captures environmentally harmful refrigerants and foam and enables the recycling of the plastic, metal, and wiring components.

This protocol applies to both residential and non-residential sectors, as refrigerator and freezer usage and energy usage are assumed to be independent of customer rate class.[51] The savings algorithms are based on regression analysis of metered data on kWh consumption from other States. The savings algorithms for this measure can be applied to refrigerator and freezer retirements or early replacements meeting the following criteria:

1) Existing, working refrigerator or freezer 10-30 cubic feet in size (savings do not apply if unit is not working)
2) Unit is a primary or secondary unit

EDCs can use data gathering to calculate program savings using the savings algorithms, the Existing Unit Energy Consumption (UEC) regression equation coefficients, and actual program year recycled refrigerator/freezer data.

[51] For example, non-residential rate class usage cases include residential dwellings that are master-metered, usage in offices or any other applications that involve typical refrigerator usage.

ALGORITHMS

The total annual energy savings (kWh/yr) achieved from recycling old-but-operable refrigerators are calculated using the following general algorithms:

Energy Savings

$\Delta kWh \quad = N \times (UEC - kWh_{ee}) \times PART_{USE}$

Note that lifetime savings will be calculated with this same general algorithm but with an adjusted measure life.

Unit Energy Consumption Source 2

To calculate the UEC of the existing refrigerator or freezer an EDC can calculate program savings using the savings algorithms, the Existing UEC regression equation coefficients, and actual program year recycled refrigerator/freezer data. An EDC's use of actual program year data can provide a more accurate annual ex ante savings estimate than default values would due to the changing mix of recycled appliance models from year-to-year.

The kWh_{ee} of the efficient refrigerator may be determined using manufacturers' test data for the given model. If test data are not available, the algorithms in Table 2-68 or Table 2-70 may be used to determine the efficient energy consumption for ENERGY STAR and ENERGY STAR Most Efficient models, respectively.

The kWh_{ee} of the efficient freezers may be determined using manufacturers' test data for the given model. If test data are not available, the algorithms in Table 2-73 may be used to determine the efficient unit's energy consumption.

Note that if the unit is being recycled without replacement, the $REPLACEMENT_{UEC}$ variable takes on the value of zero.

$$UEC_{Refrigerator} = 365.25\ days \times \Big(0.582 + 0.027 \times AGE + 1.055 \times +0.067 \times AV - 1.977 \times CONFIG_{single-door} + 1.071 \times CONFIG_{side-by-side} + 0.605 \times PRIMARY + 0.02 \times \left(UNCONDITIONED \times CDD \div 365.25 \frac{days}{year}\right) - 0.045 \times \left(UNCONDITIONED \times HDD \div 365.25 \frac{days}{year}\right)\Big)$$

$$UEC_{Freezer} = 365.25\ days \times \Big(-0.955 + 0.0454 \times AGE + 0.543 \times PRE1990 + 0.120 \times AV + 0.298 \times CONFIG_{chest} + 0.082 \times \left(UNCONDITIONED \times CDD \div 365.25 \frac{days}{year}\right) - 0.031 \times \left(UNCONDITIONED \times HDD \div 365.25 \frac{days}{year}\right)\Big)$$

Adjusted Volume (AV)

The adjusted volume equations below account for the greater load of freezer compartments compared to compartments for fresh food. For Category 1 and 1A "All-refrigerators":

$AV \quad = Fresh\ Volume + Freezer\ Volume$

For all other categories:

$AV \quad = Fresh\ Volume + 1.76 \times Freezer\ Volume$

Part-Use Factor

When calculating default per unit kWh savings for a removed refrigerator or freezer, it is necessary to calculate and apply a "Part-Use" factor. "Part-use" is an appliance recycling-specific adjustment factor used to convert the UEC (determined through the methods detailed above) into an average per-unit deemed savings value. The UEC itself is not equal to the default savings value, because: (1) the UEC model yields an estimate of annual consumption, and (2) not all recycled refrigerators and freezers would have operated year-round had they not been decommissioned through the program.

In Program Year 3, the Commission determined that the average removed refrigerator was plugged in and used 72.8% of the year and the average freezer was plugged in and used 84.5% of the year.[Source 4] These are the default values for the part-use factor. EDCs may elect to calculate an EDC-specific part-use factor for a specific program year. In the event an EDC desires to calculate an EDC-specific part-use factor, EDCs should use the methodology described in section 4.3 of the DOE, Uniform Methods Project protocol.[Source 3]

Peak Demand Savings

Use the below algorithm to calculate the peak demand savings. Multiply the annual kWh savings by an Energy to Demand Factor (ETDF), which is supplied below.

$$\Delta kW_{peak} = \Delta kWh \times ETDF$$

DEFINITION OF TERMS

Table 2-75: Terms, Values, and References for Refrigerator and Freezer Recycling

Term	Unit	Values	Source
N , The number of refrigerators recycled through the program	*None*	EDC Data Gathering	
PART_USE , The portion of the year the average refrigerator or freezer would likely have operated if not recycled through the program	%	EDC Data Gathering According to Section 4.4 of UMP Protocol Default: Refrigerator= 72.8% Freezer= 84.5%	4
ETDF , Energy to Demand Factor	$\frac{kW}{\frac{kWh}{yr}}$	0.0001119	5
AGE, age of appliance	*years*	EDC Data Gathering	
PRE1990, Fraction of appliances manufactured before 1990	%	EDC Data Gathering	
AV, Adjusted Volume/calculated as described above	ft^3	EDC Data Gathering	
$CONFIG_{single\text{-}door}$, Fraction of refrigerators with single-door configuration	%	EDC Data Gathering	
$CONFIG_{side\text{-}by\text{-}side}$, Fraction of refrigeraors with side-by-side configuration	%	EDC Data Gathering	
$CONFIG_{chest}$, Fraction of freezers with chest configuration	%	EDC Data Gathering	
PRIMARY, Fraction of appliances in primary use (in absence of program)	%	EDC Data Gathering	
UNCONDITIONED, Fraction of appliances located in Unconditioned space	%	EDC Data Gathering Default: Refrigerator=8% Freezer=45%	9
CDD, Cooling degree days	°F-day/year	See CDD in Vol. 1, App. A	10

HDD, Heating degree days	°F-day/year	See HDD in Vol. 1, App. A	10
kWh_{ee} , Annual energy consumption of ENERGY STAR qualified unit	*kWh/yr*	EDC Data Gathering Refrigerator Default: See Table 2-68 or Table 2-70 in Sec. 2.4.1 ENERGY STAR Refrigerators Freezer Default: See Table 2-73 in Sec. 2.4.2 ENERGY STAR Freezers	7, 8

Refrigerator energy use is characterized by configuration (top freezer, bottom freezer, etc.), volume, whether defrost is manual or automatic and whether there is through-the-door ice. The efficient model's annual energy consumption may be determined using manufacturer's test data for the given model. If test data are not available, the algorithms Table 2-68 or Table 2-70 in Sec. 2.4.1 ENERGY STAR Refrigerators in may be used to determine the efficient energy consumption for ENERGY STAR and ENERGY STAR Most Efficient models, respectively. The default values for each configuration are reported in Table 2-69 (ENERGY STAR) or Table 2-71 (ENERGY STAR Most Efficient) in Sec. 2.4.1, ENERGY STAR Refrigerators.

Freezer energy use is characterized by configuration (upright, chest or compact), volume and whether defrost is manual or automatic. The efficient model's annual energy consumption may be determined using manufacturers' test data for the given model. If test data are not available, the algorithms in Table 2-73 in Sec. 2.4.2, ENERGY STAR Freezers may be used to determine the efficient unit's energy consumption. The default values for each configuration are reported in Table 2-74 in Section 2.4.2 ENERGY STAR Freezers. Note that a compact freezer is defined as a freezer that has a volume less than 7.75 cubic feet and is 36 inches or less in height.

MEASURE LIFE

The measure lives for refrigerators and freezers recycled without replacement are 5 years and 4 years, respectively, from the California DEER EUA table. These values represent 1/3 of the EUL of a new refrigerator or freezer.

For refrigerators and freezers recycled with replacement, the adjusted measure life is 6 years for refrigerators and 5 years for freezers.

Adjusted Measure Life Rationale:
Refrigerator/freezer recycling with replacement programs commonly calculate savings over two periods, the RUL of the existing unit, and the remainder of the EUL of the efficient unit beyond the RUL of the existing unit. For the first period of savings (the RUL of the existing unit), the energy savings are equal to the savings difference between the existing baseline unit and the ENERGY STAR unit; the RUL can be assumed to be 1/3 of the measure EUL of the ENERGY STAR unit. For the second period of savings (the remaining EUL of the efficient unit), the energy savings are equal to the difference between a Federal Standard unit and the ENERGY STAR unit.

The EUL of a new ENERGY STAR refrigerator is 12 years (see section 2.4.1, ENERGY STAR Refrigerators). However, a study of a low-income refrigerator replacement program for SDG&E (2006) found that among the program's target population, refrigerators are likely to be replaced less frequently than among average customers. As a result, the report updating the California DEER database recommended an EUL of 18 years for such programs.[Source 6]

To simplify the calculation of savings and remove the need to calculate two different savings, an adjusted value for measure life of 6 years for both low-income specific and non-low-income specific programs can be used with the savings difference between the existing baseline unit and the

ENERGY STAR unit over the adjusted measure life. The 6-year adjusted measure life is derived by averaging the lifetime savings of a non-low-income replacement with a 12-year measure life and a low-income replacement with an 18-year measure life.

The derivation of the 6-year adjusted measure life can be demonstrated with an example of a typical refrigerator replacement with an ENERGY STAR unit. Assuming a refrigerator of type 5I in section 2.4.1, ENERGY STAR Refrigerators with an adjusted volume of 20 ft^3, annual savings would be 578 kWh for the RUL of the existing baseline unit and annual savings of 49 kWh for the remaining EUL.[52]

In the case of a non-low-income program there is an RUL of 4 years for the existing unit (1/3 * 12 = 4) and a remaining EUL of the efficient unit of 8 years (2/3 * 12 = 8). The lifetime savings are equal to 2,706 kWh (578 kWh/yr * 4 yrs + 49 kWh / yr * 8 yrs), resulting in an adjusted measure life of 5 years: 2,706 kWh / 578 kWh/yr = 5 years.

In the case of a low-income program there is an RUL of 6 years for the existing unit (1/3 * 18 = 6) and a remaining EUL of the efficient unit of 12 years (2/3 * 18 = 12). The lifetime savings are equal to 4,059 kWh (578 kWh/yr * 6 yrs + 49 kWh / yr * 12 yrs), resulting in an adjusted measure life of 7 years: 4,059 kWh / 578 kWh/yr = 7 years.

Averaging the two lifetime savings values results in an adjusted measure life of 6 years (3,383 kWh / 578 kWh/yr = 6 years) that can be used for both low-income specific and non-low-income specific programs.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx Accessed December 2018.
2) US DOE Uniform Method Project, Savings Protocol for Refrigerator Retirement, April 2017. https://www.nrel.gov/docs/fy17osti/68563.pdf
3) U.S. Department of Energy, Uniform Methods Project protocol titled “Refrigerator Recycling Evaluation Protocol”, prepared by Doug Bruchs and Josh Keeling of the Cadmus Group, September 2013. https://www.nrel.gov/docs/fy17osti/68563.pdf
4) Based on a Cadmus survey of 510 PPL participants in PY8.
5) Assessment of Energy and Capacity Savings Potential In Iowa. Quantec in collaboration with Summit Blue Consulting, Nexant, Inc., A-TEC Energy Corporation, and Britt/Makela Group, prepared for the Iowa utility Association, February 2008. http://plainsjustice.org/files/EEP-08-1/Quantec/QuantecReportVol1.pdf
6) 2004–2005 Final Report: A Measurement and Evaluation Study of the 2004-2005 Limited Income Refrigerator Replacement & Lighting Program, Prepared for: San Diego Gas & Electric, July 31, 2006

[52] A refrigerator with automatic defrost with bottom-mounted freezer with an automatic icemaker without through-the-door ice service.

7) Federal Standards for Residential Refrigerators and Freezers, Effective 9/14/2014. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/43

8) ENERGY STAR Program Requirements Product Specifications for Residential Refrigerators and Freezers Version 5.0. Effective 9/15/2014. https://www.energystar.gov/ia/partners/product_specs/program_reqs/Refrigerators_and_Freezers_Program_Requirements_V5.0.pdf.

9) Statewide average for all housing types from Pennsylvania Act 129 2018 Residential Baseline Study, http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-Phase3_Res_Baseline_Study_Rpt021219.pdf.

10) PA SWE Team Calculations with data from the National Solar Radiation Database. 1991–2005 Update: Typical Meteorological Year 3. NREL. http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html.

2.4.4 ENERGY STAR CLOTHES WASHERS

Target Sector	Residential Establishments
Measure Unit	Clothes Washer
Measure Life	11 years[Source 1]
Vintage	Replace on Burnout

This measure is for the purchase and installation of a clothes washer meeting ENERGY STAR eligibility criteria. ENERGY STAR clothes washers use less energy and hot water than non-qualified models.

ELIGIBILITY

This protocol documents the energy savings attributed to purchasing an ENERGY STAR clothes washer instead of a standard one. If a customer submits a rebate for a product that has applied for ENERGY STAR Certification but has not yet been certified, the savings will be counted for that product contingent upon its eventual certification as an ENERGY STAR measure. If at any point the product is rejected by ENERGY STAR, the product is then ineligible for the program and savings will not be counted. The target sector is residential.

ALGORITHMS

The general form of the equation for the ENERGY STAR Clothes Washer measure savings algorithm is:

Total Savings $= Number\ of\ Clothes\ Washers \times Savings\ per\ Clothes\ Washer$

To determine resource savings, the per-unit estimates in the algorithms will be multiplied by the number of clothes washers.

Per unit energy and demand savings are given by the following algorithms:

$$\Delta\, kWh = Cycles \times \left(\frac{CAPY_{base}}{IMEF_{base}} \times \left(CW_{base} + DHW_{base} \times \%_{ElecDWH} + Dryer_{base} \times \%_{ElecDryer} \times \%_{\frac{dry}{wash}} \right) - \frac{CAPY_{ee}}{IMEF_{ee}} \times \left(CW_{ee} + DHW_{ee} \times \%_{ElecDWH} + Dryer_{ee} \times \%_{ElecDryer} \times \%_{\frac{dry}{wash}} \right) \right)$$

$$\Delta kW_{peak} = \frac{\Delta kWh}{Cycles \times Time_{cycle}} \times CF$$

Where IMEF is the Integrated Modified Energy Factor, which is the energy performance metric for clothes washers. IMEF is defined as:

> *IMEF is the quotient of the cubic foot capacity of the clothes container, C, divided by the total clothes washer energy consumption per cycle, with such energy consumption expressed as the sum of the machine electrical energy consumption (M), the hot water energy consumption (E), the energy required for removal of the remaining moisture in the wash load (D), and the combined low-power mode energy consumption (L). The higher the value, the more efficient the clothes washer is.*[Source 2]

$$IMEF = \frac{C}{(M + E + D + L)}$$

Definition of Terms

Table 2-76: Terms, Values, and References for ENERGY STAR Clothes Washers

Term	Unit	Value	Source
$CAPY_{base}$, Capacity of baseline clothes washer	ft^3	EDC Data Gathering Default: 3.5	EDC Data Gathering 1
$CAPY_{EE}$, Capacity of ENERGY STAR clothes washer	ft^3	EDC Data Gathering Default: 3.5	EDC Data Gathering 1
$IMEF_{base}$, Integrated Modified Energy Factor of baseline clothes washer	$\frac{ft^3}{(kWh/cycle)}$	Table 2-77	8
$IMEF_{EE}$, Integrated Modified Energy Factor of ENERGY STAR clothes washer	$\frac{ft^3}{(kWh/cycle)}$	EDC Data Gathering Default: Table 2-77	EDC Data Gathering 2
Cycles , Number of clothes washer cycles per year	$\frac{cycles}{yr}$	251	5
CW_{base} , % of total energy consumption for baseline clothes washer mechanical operation	%	8.1%	4
CW_{EE} , % of total energy consumption for ENERGY STAR clothes washer mechanical operation	%	5.8%	4
DHW_{base} , % of total energy consumption attributed to baseline clothes washer water heating	%	26.5%	4
DHW_{EE} , % of total energy consumption attributed to ENERGY STAR clothes washer water heating	%	31.2%	4
$\%_{ElecDWH}$, % of water heaters that are electric	%	EDC Data Gathering Default: 35%	EDC Data Gathering 3
$Dryer_{base}$, % of total energy consumption for baseline clothes washerdryer operation	%	65.4%	4

Term	Unit	Value	Source
$Dryer_{EE}$, % of total energy consumption for ENERGY STAR clothes washer dryer operation	*%*	63.0%	4
$\%_{ElecDryer}$, Percentage of dryers that are electric	*%*	EDC Data Gathering Default: 74%	EDC Data Gathering 3
$\%_{\frac{dry}{wash}}$, Percentage of homes with a dryer that use the dryer every time clothes are washed	*%*	Default= 96% Or EDC data gathering	5
$Time_{cycle}$, average duration of a clothes washer cycle	*hours*	1.04	6
CF , Demand Coincidence Factor. The coincidence of average clothes washer demand to summer system peak	*Proportion*	0.029	7

The current federal standard for clothes washers went into effect on January 1, 2018, and is not scheduled to change until 2024. The efficiency standards are detailed in Table 2-77.

Note that the current standards are based on the Integrated Modified Energy Factor (IMEF) and Integrated Water Factor (IWF). The IMEF incorporates energy use in standby and off modes and includes updates to the provisions of per-cycle measurements. The IWF more accurately represents consumer usage patterns as compared to the current metric. Previous standards were based on MEF and WF.

Table 2-77: Federal Standards and ENERGY STAR Specifications for Clothes Washers[Source 2, 8]

Configuration	Minimum IMEF	ENERGY STAR Minimum IMEF
Top-loading, Standard	1.57	2.06
Front-loading, Standard	1.84	2.76

DEFAULT SAVINGS

Table 2-78: Default Clothes Washer Savings

Fuel Mix	Washer Type	ΔkWh	ΔkW_{peak}
Electric DHW/Electric Dryer	Top-Loading	129.2	0.0144
	Front-Loading	154.7	0.0172
Electric DHW/Gas Dryer	Top-Loading	35.8	0.0040
	Front-Loading	47.4	0.0053
Gas DHW/Electric Dryer	Top-Loading	114.0	0.0127
	Front-Loading	127.5	0.0142
Gas DHW/Gas Dryer	Top-Loading	20.6	0.0023
	Front-Loading	20.2	0.0022

Default (35% Electric DHW, 75% Electric Dryer)	Top-Loading	95.0	0.0106
	Front-Loading	109.1	0.0121

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) Energy Star Calculator, EPA research on available models. Accessed August 2018. https://www.energystar.gov/sites/default/files/asset/document/appliance_calculator.xlsx
2) ENERGY STAR Clothes Washers Product Specification Version 7.0. https://www.energystar.gov/products/appliances/clothes_washers/key_product_criteria
3) Statewide average for all housing types from Pennsylvania Act 129 2018 Residential Baseline Study, 2018, http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-Phase3_Res_Baseline_Study_Rpt021219.pdf.
4) The percentage of total consumption that is used for the machine, water heating and dryer varies with efficiency. Percentages were developed using the above parameters and using the U.S. Department of Energy's Life-Cycle Cost and Payback Period tool, available at: http://www1.eere.energy.gov/buildings/appliance_standards/residential/clothes_washers_support_stakeholder_negotiations.html
5) Calculated using "Frequency of clothes washer use" and "Frequency of dryer use" data for the Mid-Atlantic region from U.S. Department of Energy. 2015 Residential Energy Consumption Survey (2015). https://www.eia.gov/consumption/residential/data/2015/index.php?view=microdata
6) Metered data from Navigant Consulting "EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (June 1, 2012–May 31, 2013) Appliance Rebate Program." March 21, 2014, p. 36. Same value as used in and 2018 Mid Atlantic TRM V 8.0. 1.04 hours/cycle derived from 254 cycles/yr and 265 hours/yr run time.
7) Value from Clothes Washer Measure, Mid Atlantic TRM 2014. Metered data from Navigant Consulting "EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (June 1, 2012 – May 31, 2013) Appliance Rebate Program." March 21, 2014, p. 36.
8) U.S. Department of Energy. 10 CFR Parts 429 and 430. Energy Conservation Program: Energy Conservation Standards for Residential Clothes Washers. Direct Final Rule. https://www.ecfr.gov/cgi-bin/text-idx?SID=86e70cbc87e5af18caca2e5c205bd107&mc=true&node=se10.3.430_132&rgn=div8

2.4.5 ENERGY STAR Clothes Dryers

Target Sector	Residential
Measure Unit	Clothes Dryer
Measure Life	12 years[Source 4]
Vintage	Replace on Burnout

ENERGY STAR Clothes Dryers have a higher CEF (Combined Energy Factor) that standard dryers, and may incorporate a moisture sensor to reduce excessive drying of clothes and prolonged drying cycles.

Eligibility

This protocol documents the energy savings attributed to purchasing an electric ENERGY STAR Dryer that meets or exceeds the CEF_{ee} requirement in Table 2-80 instead of a standard dryer. If a customer submits a rebate for a product that has applied for ENERGY STAR Certification but has not yet been certified, the savings will be counted for that product contingent upon its eventual certification as an ENERGY STAR measure. If at any point the product is rejected by ENERGY STAR, the product is then ineligible for the program and savings will not be counted.[53] The target sector is residential.

Algorithms

The energy savings are obtained through the following formulas:

$$\Delta kWh/yr = \left(\frac{1}{CEF_{base}} - \frac{1}{CEF_{ee}}\right) \times Load_{avg} \times Cycles_{wash} \times \%_{\frac{dry}{wash}}$$

$$\Delta kW_{peak} = \left(\frac{\frac{1}{CEF_{base}}}{Time_{base}} - \frac{\frac{1}{CEF_{ee}}}{Time_{ee}}\right) \times Load_{avg} \times CF$$

Definition of Terms

Table 2-79: Terms, Values, and References for ENERGY STAR Clothes Dryers

Term	Unit	Values	Source
$Cycles_{wash}$, Number of washing machine cycles per year	*cycles/yr*	251 cycles/year	1
$Load_{avg}$, Weight of average dryer load, in pounds per load	*lbs/load*	Standard: 8.45 lbs/load Compact: 3.00 lbs/load	2
$\%_{\frac{dry}{wash}}$, Percentage of homes with a dryer that use the dryer for every load	*%*	96% Or EDC data gathering	1
CEF_{base} , Combined Energy Factor of baseline dryer, in lbs/kWh	*lbs/kWh*	Table 2-80 or EDC Data Gathering	3

[53] The Pennsylvania SWE and PUC TUS staff added this condition relating to certification that has been applied for but not yet received at the request of several of the Pennsylvania EDCs. EDCs will be responsible for tracking whether certification is granted.

CEF_{ee} , Combined Energy Factor of ENERGY STAR dryer, in lbs/kWh	*lbs/kWh*	Table 2-80 or EDC Data Gathering	2
$Time_{base}$, Duration of baseline dryer drying cycle	Hours/ cycle	EDC Data Gathering Default = 1.0	Assumption
$Time_{ee}$, Duration of efficient dryer drying cycle	Hours/ cycle	EDC Data Gathering Default = 1.0	Assumption
CF , Coincidence Factor	*Proportion*	0.029	Based on CF assumption for Clothes Washers

Table 2-80: Combined Energy Factor for Federal Minimum Standard and ENERGY STAR Dryers

Product Type	CEF_{base} (lbs/kWh)	CEF_{ee} (lbs/kWh)
Vented Electric, Standard (4.4 ft³ or greater capacity)	3.73	3.93
Vented Electric, Compact (120V) (less than 4.4 ft³ capacity)	3.61	3.80
Vented Electric, Compact (240V) (less than 4.4 ft³ capacity)	3.27	3.45

Default Savings

Table 2-81: Default Energy Savings and Demand Reductions for ENERGY STAR Clothes Dryers

Product Type	Energy Savings (kWh/yr)	Demand Reduction (kW)
Vented Electric, Standard (4.4 ft³ or greater capacity)	27.8	0.0033
Vented Electric, Compact (120V) (less than 4.4 ft³ capacity)	10.0	0.0012
Vented Electric, Compact (240V) (less than 4.4 ft³ capacity)	11.5	0.0014

Evaluation Protocols

The most appropriate evaluation protocol for this measure is verification of installation coupled with calculation of energy and demand savings using above algorithms.

Sources

1) Calculated using “Frequency of clothes washer use” and “Frequency of dryer use” data for the Mid-Atlantic region from U.S. Department of Energy. 2015 Residential Energy Consumption Survey (2015). https://www.eia.gov/consumption/residential/data/2015/index.php?view=microdata

2) Energy Star. “Clothes Dryers Key Product Criteria. “ ENERGY STAR Specification for Clothes Dryers Version 1.0, Effective January 1, 2015. https://www.energystar.gov/products/appliances/clothes_dryers/key_product_criteria

3) Federal Code of Regulations 10 CFR 430. https://www.gpo.gov/fdsys/pkg/CFR-2017-title10-vol3/pdf/CFR-2017-title10-vol3-sec430-32.pdf

4) California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx. Accessed December 2018.

2.4.6 Heat Pump Clothes Dryers

Target Sector	Residential Establishments
Measure Unit	Per Clothes Dryer
Measure Life	13 years Source 1
Vintage	Replace on Burnout, New Construction

Heat pump clothes dryers are more energy-efficient than standard dryers. A conventional dryer heats air, passes it through the clothing drum, and exhausts the hot air. A heat pump dryer works by circulating hot air through the clothing drum, extracting moisture from the clothing that becomes condensation after passing over an evaporator coil, then reheating the air before it passes through the drum again. The heat pump dryer saves energy by recirculating the warm air, requiring less heat to reach the desired temperature, and because the process requires a lower air temperature overall to dry clothes.

Eligibility

This protocol documents the energy savings attributed to installing a heat pump clothes dryer that meets or exceeds the default CEF_{ee} requirements in Table 2-82. The target sector is residential.

Algorithms

The following algorithms shall be used to calculate the annual energy savings and coincident peak demand savings for this measure:

$$\Delta kWh = \left(\frac{1}{CEF_{base}} - \frac{1}{CEF_{ee}}\right) \times Load_{avg} \times Cycles_{wash} \times \%_{\frac{dry}{wash}}$$

$$\Delta kW_{peak} = \left(\frac{\frac{1}{CEF_{base}}}{Time_{base}} - \frac{\frac{1}{CEF_{ee}}}{Time_{ee}}\right) \times Load_{avg} \times CF$$

Definition of Terms

Table 2-82: Terms, Values, and References for Heat Pump Clothes Dryers

Term	Unit	Values	Source
ΔkWh , Annual Energy Savings	kWh/yr	Table 2-83	-
ΔkW_{peak} , Peak Demand Savings	kW	Table 2-83	-
$Cycles_{wash}$, Number of washing machine cycles per year	cycles/yr	EDC Data Gathering Default = 251	2
$Load_{avg}$, Weight of average dryer load	lbs/cycle	Standard = 8.45 Compact = 3.00	3
$\%_{\frac{dry}{wash}}$, Percentage of washed loads that get dried	%	Default = 96%	2
CEF_{base} , Combined Energy Factor of baseline dryer, in lbs/kWh	lbs/kWh	EDC Data Gathering See CEF_{base} of Table 2-80 in Sec. 0	4
CEF_{ee} , Combined Energy Factor of heat pump dryer, in lbs/kWh	lbs/kWh	EDC Data Gathering Default:	5

		≥4.4 ft^3 (std) = 4.50 <4.4 ft^3 (cmpct) = 4.71	
$Time_{base}$, Duration of baseline dryer drying cycle	*Hours/ cycle*	EDC Data Gathering Default = 1.0	Assumption
$Time_{ee}$, Duration of efficient dryer drying cycle	*Hours/ cycle*	EDC Data Gathering Heat Pump = 1.2	6
CF , Coincidence Factor	*None*	EDC Data Gathering Default = 0.029	Based on CF assumption for Clothes Washers

Default Savings

Table 2-83: Default Savings for Heat Pump Clothes Dryers

Heat Pump Type	Energy Savings (kWh/yr)	Peak Demand Reduction (kW)
4.4 ft^3 or greater capacity	93.4	0.0203
Less than 4.4 ft^3 capacity, 120 V	46.8	0.0087
Less than 4.4 ft^3 capacity, 240 V	67.6	0.0112

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvanial Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) ENERGY STAR, ENERGY STAR Market & Industry Scoping Report - Residential Clothes Dryers, November 2011. https://www.energystar.gov/sites/default/files/asset/document/ENERGY_STAR_Scoping_Report_Residential_Clothes_Dryers.pdf

2) Calculated using “Frequency of clothes washer use” and “Frequency of dryer use” data for the Mid-Atlantic region from U.S. Department of Energy. 2015 Residential Energy Consumption Survey (2015). https://www.eia.gov/consumption/residential/data/2015/index.php?view=microdata

3) Energy Star. “Clothes Dryers Key Product Criteria. “ ENERGY STAR Specification for Clothes Dryers Version 1.0, Effective January 1, 2015. https://www.energystar.gov/products/appliances/clothes_dryers/key_product_criteria

4) U.S. Code of Federal Regulations, Part 430, Subpart C, *Energy and Water Conservation Standards*. http://www.ecfr.gov/cgi-bin/text-idx?rgn=div8&node=10:3.0.1.4.18.3.9.2

5) ENERGY STAR, *Certified Clothes Dryers*. https://www.energystar.gov/productfinder/product/certified-clothes-dryers/results (Examined the “ventless” dryers and removed dryers that were condensing and not heat pump. Then took the average CEF of the two different capacity bins.)

6) CLASP, SEDI and Ecova, Analysis of Potential Energy Savings from Heat Pump Clothes Dryers in North America, March 2013. http://www.ecosresearch.com/wp-content/uploads/2015/12/2013_Analysis-of-Potential-Energy-Savings-from-Heat-Pump-Clothes-Dryers-in-North-America.pdf

2.4.7 Fuel Switching: Electric Clothes Dryer to Gas Clothes Dryer

Target Sector	Residential Establishments
Measure Unit	Fuel Switch: Electric Clothes Dryer to Gas Clothes Dryer
Measure Life	12 years[Source 1]
Vintage	Replace on Burnout

This protocol outlines the savings associated to purchasing an ENERGY STAR gas clothes dryers to replace an electric dryer. The measure characterization and savings estimates are based on average usage per person and average number of people per household. Therefore, this is a deemed measure with identical savings applied to all installation instances, applicable across all housing types.

Eligibility

This measure is targeted to residential customers that purchase an ENERGY STAR gas clothes dryer rather than an electric dryer.

Algorithms

$$\Delta kWh = kWh_{base} - kWh_{gas} = 577 - 30 = 547$$

$$\Delta MMBtu = -1.99$$

$$\Delta kW_{peak} = \frac{\Delta\, kWh}{Cycles_{wash} \times \%_{\frac{wash}{dry}} \times Time_{cycle}} \times CF = 0.066$$

Definition of Terms

Table 2-84: Terms, Values, and References for Fuel Switching: Electric Clothes Dryer to Gas Clothes Dryer

Term	Unit	Values	Source
kWh_{base}, Baseline annual electricity consumption of electric dryer, deemed	$\frac{kWh}{yr}$	577	2, 3
kWh_{gas} , Annual electricity consumption of gas dryer, deemed	$\frac{kWh}{yr}$	30	4
$\Delta MMBtu$, Weighted average gas fuel savings (negative indicates increase in consumption)	*MMBTU*	-1.99	5
$Cycles_{wash}$, Number of washing machine cycles per year	cycles/yr	251	6
$\%_{\frac{dry}{wash}}$, Percentage of homes with a dryer that use the dryer every time clothes are washed	%	96%	6
$Time_{cycle}$, Duration of average drying cycle in hours	hours	1	Assumption
CF, Coincidence Factor	*Proportion*	0.029	Based on CF assumption for Clothes Washers

Default Savings

Savings estimates for this measure are fully deemed and may be claimed using the algorithms above and the deemed variable inputs.

ΔkWh = 547 kWh
ΔkW = 0.066

Evaluation Protocols

The appropriate evaluation protocol is to verify installation and proper selection of deemed values.

Sources

1) California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx. Accessed December 2018.

2) Statewide average for all housing types from Pennsylvania Act 129 2018 Residential Baseline Study, 2018,[54] http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-Phase3_Res_Baseline_Study_Rpt021219.pdf.

3) 2011-04 Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment. Residential Clothes Dryers and Room Air Conditioners, Chapter 7. Table 7.3.4: Electric Standard and Gas Clothes Dryer: Average Annual Energy Consumption Levels by Efficiency https://www.regulations.gov/document?D=EERE-2007-BT-STD-0010-0053 [55]

4) *Ibid.* Median annual electricity consumption of gas dryers

5) Negative gas fuel savings indicate increase in fuel consumption. Average annual consumption for ENERGY STAR qualified gas units as of 6/22/2015: 685.3kWh/yr. Scaling from 283 cycles/yr (national 2005 RECS) to 251×96%=241 cycles/yr (Mid-Atlantic 2015 RECS): 583.5 kWh/yr. Converting to MMBTU: 583.5×0.003412 = 1.99 MMBTU/yr.

6) Calculated using "Frequency of clothes washer use" and "Frequency of dryer use" data for the Mid-Atlantic region from U.S. Department of Energy. 2015 Residential Energy Consumption Survey (2015). https://www.eia.gov/consumption/residential/data/2015/index.php?view=microdata

[54] Statewide average of 3.12 EF for electric dryers, comparable to 3.77 CEF; q.v. the federal standard of 3.73 CEF at Table 2-78 in Sec. 2.4.5

[55] Average annual electricity consumption of 3.73 and 3.81 CEF dryers scaled from 283 cycles/yr (national 2005 RECS) to 251×96%=241 cycles/yr (Mid-Atlantic 2015 RECS).

2.4.8 ENERGY STAR DISHWASHERS

Target Sector	Residential Establishments
Measure Unit	Dishwasher
Measure Life	10 years[Source 1]
Vintage	Replace on Burnout

ELIGIBILITY

This measure is for the purchase and installation of a dishwasher meeting ENERGY STAR eligibility criteria. ENERGY STAR dishwashers use less energy and hot water than non-qualified models.

ALGORITHMS

The general form of the measure savings equation for ENERGY STAR Dishwashers is:

Total Savings $= Number\ of\ Dishwashers \times Savings\ per\ Dishwasher$

To determine resource savings, the per-unit estimates in the algorithms will be multiplied by the number of dishwashers. The number of dishwashers will be determined using market assessments and market tracking.

Per unit energy and demand savings algorithms for dishwashers utilizing electrically heated hot water:

$$\Delta \quad = (kWh_{base} - kWh_{ee}) \times (\%kWh_{OP} + \%kWh_{heat} \times \%Electric_{DHW})$$

$$\Delta kW_{peak} = \frac{\Delta\, kWh/yr}{HOU} \times CF$$

DEFINITION OF TERMS

Table 2-85: Terms, Values, and References for ENERGY STAR Dishwashers

Term	Unit	Value	Source
kWh_{base}, *Annual energy consumption of baseline dishwasher*	*kWh/yr*	307	1, 6
kWh_{ee}, *Annual energy consumption of ENERGY STAR qualified unit*	*kWh/yr*	270	1, 7
$\%kWh_{op}$, *Percentage of unit dishwasher energy consumption used for operation*	*%*	44%	1
$\%kWh_{heat}$, *Percentage of dishwasher unit energy consumption used for water heating*	*%*	56%	1
$\%Electric_{DW}$, *Percentage of dishwashers assumed to utilize electrically heated hot water*	*%*	EDC Data Gathering Default = 31.7%	2
HOU , Hours of use per year	*hours/yr*	234	3
CF, Demand Coincidence Factor. The coincidence of average dishwasher demand to summer system peak	*Proportion*	0.026	4, 5

ENERGY STAR qualified dishwashers must use less than or equal to the water and energy consumption values given in Table 2-86. Note, as of May 30, 2013, ENERGY STAR compact dishwashers have the same maximum water and energy consumption requirements as the federal standard and therefore are not included in the TRM since there is not energy savings to be calculated for installation of an ENERGY STAR compact dishwasher. A standard sized dishwasher is defined as any dishwasher that can hold 8 or more place settings and at least six serving pieces.[Source 6]

Table 2-86: Federal Standard and ENERGY STAR v 6.0 Residential Dishwasher Standard

Product Type	Federal Standard[Source 6]		ENERGY STAR v 6.0[Source 7]	
	Water (gallons per cycle)	Energy (kWh per year)	Water (gallons per cycle)	Energy (kWh per year)
Standard	≤ 5.0	≤ 307	≤ 3.5	≤ 270

The default savings values for electric and non-electric water heating and the default fuel mix from Table 2-87.

Table 2-87: Default Dishwasher Energy Savings

Water Heating	$\Delta kWh/yr$	ΔkW_{peak}
Electric (%Electric$_{DHW}$ = 100%)	37.0	0.00411
Non-Electric (%Electric$_{DHW}$ = 0%)	16.3	0.00181
Default Fuel Mix (%Electric$_{DHW}$ = 43%)	22.8	0.00254

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) ENERGY STAR Appliances Calculator. Accessed July 2018. Energy Star Calculator, EPA research on available models. Accessed August 2018. https://www.energystar.gov/sites/default/files/asset/document/appliance_calculator.xlsx

2) Statewide average for all housing types from Pennsylvania Statewide Residential Baseline Study, 2018.

3) 2014 Pennsylvania Residential Baseline Study, http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-2014_PA_Statewide_Act129_Residential_Baseline_Study.pdf. HOU=(3 loads/week)×(52 weeks/yr)×(1.5 hours/load). 3 load/week comes from 2014 Baseline study. 1.5 hours/load is assumption used by Efficiency Vermont and Illinois Statewide TRMs

4) Calculated from Itron eShapes, 8760 hourly data by end use for Missouri, as provided by Ameren. This is the CF value for ENERGY STAR Dishwashers from Illinois Statewide TRM Version 7.0, June 2018.

5) Illinois Statewide Technical reference Manual for Energy Efficiency Version 7.0. Effective January 1, 2019. http://www.ilsag.info/technical-reference-manual.html

6) US Department of ENERGY Website. Appliance and Equipment Standards. Accessed Aug. 2018. https://www.ecfr.gov/cgi-bin/text-idx?SID=86e70cbc87e5af18caca2e5c205bd107&mc=true&node=se10.3.430_132&rgn=div8

7) Dishwashers Key product Criteria. Accessed Aug. 2018. https://www.energystar.gov/products/appliances/dishwashers/key_product_criteria

2.4.9 ENERGY STAR Dehumidifiers

Target Sector	Residential Establishments
Measure Unit	Dehumidifier
Measure Life	12 years[Source 1]
Vintage	Replace on Burnout

ENERGY STAR qualified dehumidifiers are 15 percent more efficient than non-qualified models due to more efficient refrigeration coils, compressors and fans. ENERGY STAR Most Efficient dehumidifiers are 23 percent more efficient than standard products.[Source 6]

Eligibility

This protocol documents the energy and demand savings attributed to purchasing an ENERGY STAR or ENERGY STAR Most Efficient dehumidifier instead of a standard one. Dehumidifiers must meet ENERGY STAR Version 4.0 Product Specifications to qualify. The target sector is residential.

Algorithms

The general form of the equation for the ENERGY STAR Dehumidifier savings algorithm is:

Total Savings $= Number\ of\ Dehumidifiers \times Savings\ per\ Dehumidifier$

To determine resource savings, the per-unit estimates in the algorithms will be multiplied by the number of dehumidifiers. The number of dehumidifiers will be determined using market assessments and market tracking.

Per unit energy and demand savings algorithms:

$$\Delta \quad = \left(\frac{CAPY \times 0.473\frac{\text{liters}}{\text{pint}}}{24\frac{\text{hours}}{\text{day}}}\right) \times HOU \times \left(\frac{1}{L/kWh_{base}} - \frac{1}{L/kWh_{ee}}\right)$$

$$\Delta kW_{peak} = \frac{\Delta\, kWh/yr}{HOU} \times CF$$

Definition of Terms

Table 2-88: Terms, Values, and References for ENERGY STAR Dehumidifier

Term	Unit	Value	Sources
CAPY , Average capacity of the unit	$\frac{pints}{day}$	EDC Data Gathering	EDC Data Gathering
HOU , Annual hours of operation	$\frac{hours}{yr}$	1,632	1
L/kWh_{base} *, Baseline unit liters of water per kWh consumed*	$\frac{liters}{kWh}$	Table 2-89	2
L/kWh_{ee} *, ENERGY STAR qualified unit liters of water per kWh consumed*	$\frac{liters}{kWh}$	EDC Data Gathering Default: Table 2-90 or Table 2-91	3, 5
CF , Demand Coincidence Factor	*Proportion*	0.405	4

Table 2-89 shows the federal standard minimum efficiency standards. Federal standards are effective as of June 13, 2019. Table 2-90 shows ENERGY STAR 4.0 standards effective as of October 25, 2016. Table 2-91 shows ENERGY STAR Most Efficient 2018 criteria, effective January 2018. Federal standards and ENERGY STAR Most Effiecient criteria distinguish between portable dehumidifiers (designed to dehumidify a confined living space and plugged into an electrical outlet) and whole-home dehumidifiers (incorporated into the home's HVAC system and designed to dehumidify all conditioned spaces).

Table 2-89: Dehumidifier Minimum Federal Efficiency Standards

Type	Capacity (pints/day)	Federal Standard (L/kWh_{base})
Portable dehumidifier	≤ 25	≥ 1.30
	> 25 to ≤ 50	≥ 1.60
	> 50	≥ 2.80
Whole-home dehumidifier	**Product Case Volume (ft³)**	**Federal Standard (L/kWh_{base})**
	≤ 8	≥ 1.77
	> 8	≥ 2.41

Table 2-90: Dehumidifier ENERGY STAR Standards

Capacity (pints/day)	ENERGY STAR (L/kWh_{ee})
< 75	≥ 2.00
75 to ≤ 185	≥ 2.80

Table 2-91: Dehumidifier ENERGY STAR Most Efficient Criteria

Type	Capacity (pints/day)	ENERGY STAR (L/kWh_{e})
Portable	< 75	≥ 2.20
Whole House	< 75	≥ 2.30

DEFAULT SAVINGS

The annual energy usage and savings of an ENERGY STAR unit over the federal minimum standard are presented in Table 2-92 for each capacity range.

Table 2-92: Dehumidifier Default Energy Savings

Efficient Product[56]	Capacity Range (pints/day)	Default Capacity (pints/day)	Federal Standard (kWh/yr)	Efficient Standard (kWh/yr)	ΔkWh/yr	ΔkW_{peak}
ENERGY STAR	≤ 25	25	1.3	2.0	216	0.05372
	> 25 to ≤ 50	50	1.6	2.0	201	0.04989
ENERGY STAR Most Efficient - Portable	≤ 25	25	1.3	2.2	253	0.06279
	> 25 to ≤ 50	50	1.6	2.2	274	0.06803
ENERGY STAR Most Efficient – Whole House with product case volume ≤ 8 ft³	< 75	63[57]	1.77	2.3	264	0.06547

tandards for portable dehumidiers with capacity of >50 pints/day and for whole home dehumidifiers with product case volume > 8 ft³.

[57] Average of products listed on ENERGY STAR Most Efficient 2018 – Dehumidifiers. https://www.energystar.gov/most-efficient/me-certified-dehumidifiers/ Accessed November 16, 2018.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) ENERGY STAR Appliance Savings Calculator. Accessedd August, 2018. https://www.energystar.gov/sites/default/files/asset/document/appliance_calculator.xlsx
2) US Department of ENERGY Website. Appliance and Equipment Standards. Accessed June 2014. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/55
3) ENERGY STAR Program Requirements Product Specification for Dehumidifiers, Eligibility Criteria Version 4.0. Accessed November 2, 2018. https://www.energystar.gov/products/appliances/dehumidifiers/key_efficiency_criteria
4) Dehumidifier Metering in PA and Ohio by ADM from 7/17/2013 to 9/22/2013. 31 Units metered. Assumes all non-coincident peaks occur within window and that the average load during this window is representative of the June PJM days as well.
5) ENERGY STAR Most Efficient 2018 Recognition Criteria: Dehumidifiers. Accessed November 2, 2018. https://www.energystar.gov/ia/partners/downloads/most_efficient/2018/Dehumidifiers%20ENERGY%20STAR%20Most%20Efficient%202018%20Final%20Criteria.pdf?cddb-3642
6) ENERGY STAR Most Efficient 2019 memo. Accessed November 2, 2018. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Most%20Efficient%202019%20Memo_0.pdf

2.4.10 Dehumidifier Retirement

Target Sector	Residential Establishments
Measure Unit	Dehumidifier
Measure Life	4 years[58]
Vintage	Early Retirement

This measure is defined as retirement and recycling without direct EDC replacement of an *operable* but older and inefficient room dehumidifier unit that would not have otherwise been recycled. The assumption is that these units will be permanently removed from the grid rather than handed down or sold for use in another location by another EDC customer, and furthermore that they would not have been recycled without this program. This measure is quite different from other energy-efficiency measures in that the energy/demand savings is not the difference between a pre- and post- configuration, but is instead the result of complete elimination of the existing dehumidifier.

Eligibility

The savings are not attributable to the customer that owned the dehumidifier, but instead are attributed to a *hypothetical user* of the equipment had it not been recycled. Energy and demand savings is the estimated energy consumption of the retired unit over its remaining useful life (RUL).

Algorithms

Impacts are based only on the existing unit, and savings apply *only for the remaining useful life (RUL) of the unit*.

The energy savings and demand reduction of this measure were established using actual metered residential dehumidifier usage data.

The metered data was best fit with a polynomial which is second order in temperature humidity index and first order in capacity:[Source 1]

$$kWh = -8.36 \cdot 10^{-3} \times THI_{PJM}{}^{2} + 1.19 \times THI_{PJM} + 4.07 \cdot 10^{-2} \times CAPY + -38.37$$

where:

THI_{PJM} $= DB - 0.55 \times (1 - RH) \times (DB - 58)$ for DB ≥ 58°F
$= DB$ for DB < 58°F

Similarly, demand was modeled with the following capacity-dependent linear regression:[Source 2]

$$kW = 1.3 \cdot 10^{-3} \times CAPY + 1.07 \cdot 10^{-1}$$

[58] CA DEER gives the following rule-of-thumb for remaining useful life: RUL = (1/3) X EUL. As the Energy Star Dehumidifier [replacement] uses an EUL of 12 years, we have a suggested RUL of (1/3) X 12 years = 4 years.

DEFINITION OF TERMS

Table 2-93: Terms, Values, and References for Dehumidifier Retirement

Term	Unit	Value	Sources
CAPY , Average capacity of the unit	$\frac{pints}{day}$	EDC Data Gathering Default: 51 pt/day	EDC Data Gathering 3
THI , Temperature Humidity Index	-	Calculated	4
DB , Dry bulb temperature	*℉*	See Source	5
RH , Relative humidity	*%*	See Source	5

The results of the kWh calculation for typical dehumidifier capacities in each of the Climate Regions are presented in the following table:

Table 2-94: Dehumidifier Retirement Annual Energy Savings (kWh)

Annual kWh Savings by Climate Region											
Climate Region	Reference City	Capacity (pints per day)									
		25	30	35	40	45	50	60	65	70	110
C	**Allentown**	628	656	684	712	740	768	824	852	881	1105
A	**Bradford**	386	404	422	440	458	476	512	530	547	691
G	**Binghamton**	470	492	513	534	556	577	620	641	663	834
I	**Erie**	557	582	607	632	656	681	731	756	781	979
E	**Harrisburg**	656	686	715	745	774	804	863	892	922	1158
D	**Philadelphia**	726	758	791	823	856	888	954	986	1019	1280
H	**Pittsburgh**	605	632	659	686	713	740	795	822	849	1066
B	**Scranton**	577	603	628	654	680	706	758	784	810	1016
F	**Williamsport**	651	680	709	738	767	797	855	884	913	1146

The peak kW reduction for recycling a dehumidifier was taken to be equal to the peak demand of the existing unit. These results are presented in the following table:

Table 2-95: Dehumidifier Retirement Peak Demand Reduction (kW)

Capacity	25	30	35	40	45	50	60	65	70	110
kW	0.1393	0.1458	0.1523	0.1588	0.1653	0.1718	0.1848	0.1913	0.1979	0.2499

DEFAULT SAVINGS

For programs that do not track capacity, an “unknown” category has been provided based on the weighted average capacity of dehumidifier sales data:

Table 2-96: Default Dehumidifier Retirement Annual Energy Savings (kWh)

Annual kWh Savings by Climate Region		
Region	**Reference City**	**Default**
C	Allentown	774
A	Bradford	479
G	Binghamton, NY	581
I	Erie	686
E	Harrisburg	810
D	Philadelphia	895
H	Pittsburgh	746
B	Scranton	711
F	Williamsport	802

Table 2-97: Default Dehumidifier Retirement Peak Demand Reduction (kW)

Capacity	Default
kW	0.1731

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify retirement and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify retirement and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) Dehumidifier Metering in PA and Ohio by ADM from 7/17/2013 to 9/22/2013. 31 Units metered; five-minute interval power data was recorded. 58% of the units were Energy Star rated.
2) Ibid., by Act 129 Peak Demand window
3) Statewide average for all housing types from Pennsylvania Act 129 2018 Residential Baseline Study, 2018, http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-Phase3_Res_Baseline_Study_Rpt021219.pdf.
4) "PJM Manual 19: Load Forecasting and Analysis Revision: 32". p. 14. https://www.pjm.com/~/media/documents/manuals/m19.ashx . Accessed January 2019.
5) National Solar Radiation Database. 1991–2005 Update: Typical Meteorological Year 3. NREL. http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html.

2.4.11 ENERGY STAR Ceiling Fans

Target Sector	Residential Establishments
Measure Unit	Ceiling Fan Unit
Measure Life	15 years for fan,Source 1 See 2.1.1 for lighting
Vintage	Replace on Burnout

ENERGY STAR ceiling fans require a more efficient CFM/Watt rating than standard ceiling fans as well as ENERGY STAR qualified lighting for those with light kits included. Both of these features save energy compared to standard ceiling fans.

Eligibility

This protocol documents the energy savings attributed to installing an ENERGY STAR Version 4.0 ceiling fan (with or without a lighting kit) in lieu of a standard efficiency ceiling fan meeting the January 21, 2020 federal efficiency requirements.Source 2 If a customer submits a rebate for a product that has applied for ENERGY STAR Certification but has not yet been certified, the savings will be counted for that product contingent upon its eventual certification as an ENERGY STAR measure. If at any point the product is rejected by ENERGY STAR, the product is then ineligible for the program and savings will not be counted.[59] The target sector primarily consists of single-family residences.

Algorithms

The total energy savings is equal to the savings contribution of the fan plus the savings contribution of the lighting, if applicable. If the ENERGY STAR fan does not include a lighting kit, then $\Delta kWh_{\text{lighting}} = 0$. These algorithms do not seek to estimate the behavioral change attributable to the use of a ceiling fan vs. a lower AC setting.

The energy savings are obtained through the following formula:

$$\Delta kWh = \Delta kWh_{fan} + \Delta kWh_{lighting}$$

$$\Delta kWh_{fan} = \Delta W_{fan} \times \frac{1\ kW}{1000\ W} \times HOU_{fan} \times 365\frac{days}{yr}$$

$\Delta kWh_{lighting}$ = ΔkWh from Section 2.1.1: ENERGY STAR Lighting

Demand savings result from the lower connected load of the ENERGY STAR fan and ENERGY STAR lighting. Peak demand savings are estimated using a Coincidence Factor (CF).

$$\Delta kW_{peak,total} = \Delta kW_{peak,fan} + \Delta kW_{peak,lighting}$$

$$\Delta kW_{peak,fan} = \Delta W_{fan} \times \frac{1\ kW}{1000\ W} \times CF_{fan}$$

$\Delta kW_{peak,lighting}$ = ΔkW_{peak} from Section 2.1.1: ENERGY STAR Lighting

[59] The Pennsylvania SWE and PUC TUS staff added this condition relating to certification that has been applied for but not yet received at the request of several of the Pennsylvania EDCs. EDCs will be responsible for tracking whether certification is granted.

Definition of Terms

Table 2-98: Terms, Values, and References for ENERGY STAR Ceiling Fans

Component	Unit	Values	Source
ΔW_{fan}, Weighted average wattage reduction from ENERGY STAR ceiling fan	*Watts*	Default: See Table 2-99	2, 3, 5, 6
HOU_{fan} , fan daily hours of use	$\frac{hours}{day}$	EDC Data Gathering Default: 3.0 hours/day[60]	4
CF_{fan} , Demand Coincidence Factor	*Proportion*	EDC Data Gathering Default: 0.091[61]	7
$CF_{lighting}$, Demand Coincidence Factor	*Proportion*	See Section 2.1	7

Table 2-99: Assumed Wattage of ENERGY STAR Ceiling Fans on High Setting

Ceiling Fan Type	Diameter, D (inches)	ΔW_{fan} (Watts)
Standard and Low-Mount High Speed Small Diameter (HSSD) Ceiling Fans	D ≤ 36	0
	36 < D < 78	23
	D ≥ 78"	31
Hugger Ceiling Fan[62]	36 < D < 78	33

Default Savings

Table 2-100: Energy Savings and Demand Reductions for ENERGY STAR Ceiling Fans

Product Type (Fan Only)	Diameter, D (inches)	Energy Savings (kWh)	Demand Reduction (kW)
Standard and Low-Mount High Speed Small Diameter (HSSD) Ceiling Fans	D ≤ 36	0	0.000
	36 < D < 78	25	0.002
	D ≥ 78	34	0.002
Hugger Ceiling Fan	36 < D < 78	36	0.003

Evaluation Protocols

The most appropriate evaluation protocol for this measure is verification of installation coupled with calculation of energy and demand savings using above algorithms.

Sources

1) Residential and C&I Lighting and HVAC Report Prepared for SPWG, 2007. p. C-2.

2) Energy and water conservation standards and their compliance dates.10 C.F.R. § 430.32.

[60] The 3 hour/day for a ceiling fan is assumed here to be the same hours of use as a typical residential lightbulb, in absence of better data.. EDCs are allowed to do research on hours of use for ceiling fans in lieu of using the 3 hours/day figure. It is likely that the hours of use for ceiling fans is different than that of residential lighting.

[61] Assumed same usage characteristics as lighting. EDCs are allowed to do research on Coincidence Factor for ceiling fans in lieu of using the 3 hours/day figure. It is likely that the hours of use for ceiling fans is different than that of residential lighting.

[62] The ENERGY STAR 4.0 specifications allow for hugger ceiling fans with blade spans of ≤ 36" and ≥ 78", however, as of December 2018, there are no ENERGY STAR qualified products meeting those criteria. They were therefore omitted from this characterization.

3) See ENERGY STAR Ceiling Fans Work Paper 2018.12.5.xlsx for calculations and description of methodology.

4) ENERGY STAR Lighting Fixture and Ceiling Fan Calculator. Updated September 2013.

5) ENERGY STAR® Program Requirements Product Specification for Residential Ceiling Fans and Ceiling Fan Light Kits Eligibility Criteria Version 4.0

6) ENERGY STAR Certified Ceiling Fans | EPA ENERGY STAR. https://www.energystar.gov/productfinder/product/certified-ceiling-fans/results. Accessed 12/5/2018.

7) EmPOWER Maryland 2012 Final Evaluation Report: Residential Lighting Program, Prepared by Navigant Consulting and the Cadmus Group, Inc., March 2013, Table 50.

2.4.12 ENERGY STAR Air Purifiers

Target Sector	Residential Establishments
Measure Unit	Number of Air Purifiers installed
Measure Life	9 years[Source 1]
Vintage	Replace on Burnout, Early Replacement, Retrofit, New Construction

An air purifier (cleaner) is a portable electric appliance that removes dust and fine particles from indoor air. This measure characterizes the purchase and installation of a unit meeting the efficiency specifications of ENERGY STAR in place of or instead of a baseline model.

Eligibility

This measure targets residential customers who purchase and install an air purifier that meets ENERGY STAR specifications rather than installing a non-ENERGY STAR unit. In order to qualify, installed air purifiers must meet the following efficiency specifications of ENERGY STAR:

- Must produce a minimum 50 Clean Air Delivery Rate (CADR) for Dust to be considered under this specification.
- Minimum Performance Requirement: = 2.0 CADR/Watt (Dust)
- Standby Power Requirement: = 2.0 Watts or less. Qualifying models that perform secondary consumer functions (e.g. clock, remote control) must meet the standby power requirement.
- UL Safety Requirement: Models that emit ozone as a byproduct of air cleaning must meet UL Standard 867 (ozone production must not exceed 50ppb)

Algorithms

The following algorithms shall be used to calculate the annual energy savings and coincident peak demand savings for this measure:

$$\Delta kWh = kWh_{Base} - kWh_{EStar}$$

$$\Delta kW_{peak} = CF \times \frac{\Delta kWh}{HOURS}$$

Definition of Terms

Table 2-101: Terms, Values, and References for ENERGY STAR Air Purifier

Term	Unit	Values	Source
kWh_{Base}, Baseline kWh consumption per year	kWh/year	EDC Data Gathering Default = See Table 2-102	1
kWh_{EStar}, ENERGY STAR kWh consumption per year	kWh/year	EDC Data Gathering Default = See Table 2-102	1

HOURS, Average hours of use per year	Hours/year	EDC Data Gathering Default = 5,840	1
CF, Summer Peak Coincidence Factor	None	EDC Data Gathering Default = 0.67	1, 2

Default Savings

Table 2-102: Energy Savings Calculation Default Values

Clean Air Delivery Rate (CADR)	CADR Used in Calculation	Baseline Unit Energy Consumption (kWh/yr)	ENERGY STAR Unit Energy Consumption (kWh/yr)	∆kWh
CADR 51-100	75	441	148	293
CADR 101-150	125	733	245	488
CADR 151-200	175	1,025	342	683
CADR 201-250	225	1,317	440	877
CADR Over 250	275	1,609	537	1,072

Table 2-103: Demand Savings Calculation Default Values

Clean Air Delivery Rate (CADR)	CADR Used in Calculation	ΔkW_{peak}
CADR 51-100	75	0.0336
CADR 101-150	125	0.0560
CADR 151-200	175	0.0784
CADR 201-250	225	0.1006
CADR Over 250	275	0.1230

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1. ENERGY STAR, ENERGY STAR Appliance Calculator, last updated October 2016. https://www.energystar.gov/sites/default/files/asset/document/appliance_calculator.xlsx
2. Assumes appliance use is equally likely at any hour of the day or night.

2.5 CONSUMER ELECTRONICS

2.5.1 ENERGY STAR OFFICE EQUIPMENT

Target Sector	Residential Establishments
Measure Unit	Office Equipment Device
Measure Life Source 1	Computer: 4 years Monitor: 4 years Fax: 4 years Printer: 5 years Copier: 6 years Multifunction Device: 6 years
Vintage	Replace on Burnout

ELIGIBILITY

This protocol estimates savings for installing ENERGY STAR office equipment compared to standard efficiency equipment in residential applications. The measurement of energy and demand savings is based on a deemed savings value multiplied by the quantity of the measure. The target sector is primarily residential.

ALGORITHMS

The general form of the equation for the ENERGY STAR Office Equipment measure annual savings is:

Total Savings $= Number\ of\ Units \times\ Savings\ per\ Unit$

To determine resource savings, the per-unit estimates in the algorithms will be multiplied by the number of units. Per unit savings are primarily derived from the ENERGY STAR calculator for office equipment.

ENERGY STAR Computer

$\Delta kWh = ESav_{COM}$
$\Delta kW_{peak} = DSav_{COM}$

ENERGY STAR Fax Machine

$\Delta kWh = ESav_{FAX}$
$\Delta kW_{peak} = DSav_{FAX}$

ENERGY STAR Copier

$\Delta kWh = ESav_{COP}$
$\Delta kW_{peak} = DSav_{COP}$

ENERGY STAR Printer

$\Delta kWh = ESav_{PRI}$
$\Delta kW_{peak} = DSav_{PRI}$

ENERGY STAR Multifunction Device

$\Delta kWh = ESav_{MUL}$

$\Delta kW_{peak} = DSav_{MUL}$

ENERGY STAR Monitor

$\Delta kWh = ESav_{MON}$

$\Delta kW_{peak} = DSav_{MON}$

Definition of Terms

Table 2-104: Terms, Values, and References for ENERGY STAR Office Equipment

Term	Unit	Value	Sources
$ESav_{COM}$, Electricity savings per purchased ENERGY STAR computer. $ESav_{FAX}$, Electricity savings per purchased ENERGY STAR Fax Machine $ESav_{COP}$, Electricity savings per purchased ENERGY STAR Copier $ESav_{PRI}$, Electricity savings per purchased ENERGY STAR Printer $ESav_{MUL}$, Electricity savings per purchased ENERGY STAR Multifunction Device $ESav_{MON}$, Electricity savings per purchased ENERGY STAR Monitor	*kWh/yr*	See Table 2-105	1
$DSav_{COM}$, Summer demand savings per purchased ENERGY STAR computer. $DSav_{FAX}$, Summer demand savings per purchased ENERGY STAR Fax Machine $DSav_{COP}$, Summer demand savings per purchased ENERGY STAR Copier $DSav_{PRI}$, Summer demand savings per purchased ENERGY STAR Printer $DSav_{MUL}$, Summer demand savings per purchased ENERGY STAR Multifunction Device $DSav_{MON}$, Monitor	*kW/yr*	See Table 2-105	1

DEFAULT SAVINGS

Table 2-105: ENERGY STAR Office Equipment Energy and Demand Savings Values

Measure		Energy Savings (ESav, kWh)	Demand Savings (DSav, kW)	Source
Computer (Desktop)		119	0.0161	1
Computer (Laptop)		22	0.0030	1
Fax Machine (laser)		16	0.0022	1
Copier (monochrome)	≤ 5images/min	37	0.0050	1
	5 < images/min ≤ 15	26	0.0035	
	15 < images/min ≤ 20	10	0.0011	
	20 < images/min ≤ 30	42	0.0057	
	30 < images/min ≤ 40	50	0.0068	
	40 < images/min ≤ 65	181	0.0244	
	65 < images/min ≤ 82	372	0.0502	
	82 < images/min ≤ 90	469	0.0633	
	> 90 images/min	686	0.0926	
Printer (laser, monochrome)	≤ 5 images/min	37	0.0050	1
	5 < images/min ≤ 15	26	0.0035	
	15 < images/min ≤ 20	24	0.0031	
	20 < images/min ≤ 30	42	0.0057	
	30 < images/min ≤ 40	50	0.0068	
	40 < images/min ≤ 65	181	0.0244	
	65 < images/min ≤ 82	372	0.0502	
	82 < images/min ≤ 90	542	0.0732	
	> 90 images/min	686	0.0926	
Printer (Ink Jet)		6	0.0008	1
Multifunction Device (laser, monochrome)	≤ 5 images/min	57	0.0077	1
	5 < images/min ≤ 10	48	0.0065	
	10 < images/min ≤ 26	52	0.0070	
	26 < images/min ≤ 30	93	0.0126	
	30 < images/min ≤ 50	248	0.0335	
	50 < images/min ≤ 68	420	0.0567	
	68 < images/min ≤ 80	597	0.0806	
	> 80 images/min	764	0.1031	
Multifunction Device (Ink Jet)		6	0.0008	1
Monitor		24	0.0032	1

EVALUATION PROTOCOLS

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) **ENERGY STAR Office Equipment Calculator** http://www.energystar.gov/sites/default/files/asset/document/Office%20Equipment%20Calculator.xlsx (Referenced latest version released in October 2016). Default values were used. Using a commercial office equipment load shape, the percentage of total savings that occur during the PJM peak demand period was calculated and multiplied by the energy savings. As of December 1, 2018, the published ENERGY STAR Office Equipment Calculator does not reflect the current specification for computers (ENERGY STAR® Program Requirements Product Specification for Computers Eligibility Criteria Version 7.1). V7.1 introduced modest improvements to both desktop and laptop computer efficiency. As a result, the savings values for computers presented in this measure entry reflect savings for V6-compliant models. This characterization should be updated when an updated ENERGY STAR Office Equipment Calculator becomes available.

2.5.2 Advanced Power Strips

Target Sector	Residential Establishments
Measure Unit	Per Advanced Power Strip
Measure Life	5 years[Source 4]
Vintage	Retrofit

Commented [SA21]: Franklin Energy

This is 7 years for C&I, but only 5 years for Residential. IS there a reason for this?

Advanced Power Strips (APS) are power strips that contain a number of power-saver sockets. There are two types of APS: Tier 1 and Tier 2.

Tier 1 APS have a master control socket arrangement and will shut off the items plugged into the controlled power-saver sockets when they sense that the appliance plugged into the master socket has been turned off. Conversely, the appliance plugged into the master control socket has to be turned on and left on for the devices plugged into the power-saver sockets to function.

Tier 2 APS deliver additional functionality beyond that of a Tier 1 unit, as Tier 2 units manage both standby and active power consumption. The Tier 2 APS manage standby power consumption by turning off devices from a control event; this could be a TV or other item powering off, which then powers off the controlled outlets to save energy. Active power consumption is managed by the Tier 2 unit by monitoring a user's engagement or presence in a room by either or both infrared remote signals sensing or motion sensing. If after a period of user absence or inactivity, The Tier 2 unit will shut off all items plugged into the controlled outlets, thus saving energy. There are two types of Tier 2 APS available on the market. Tier 2 Infrared (IR) detect signals sent by remote controls to identify activity, while Tier 2 Infrared-Occupancy Sensing (IR-OS) use infrared signals as well as an occupancy sensing component to detect activity and sense for times to shut down. Due to uncertainty surrounding the differences in savings for each technology, the Tier 2 savings are blended into a single number.

Eligibility

This protocol documents the energy savings attributed to the installation of smart strip plugs. The most likely area of application is in residential spaces, i.e. single-family and multifamily homes. However, commercial applications are also appropriate for smart strips (see Volume 3, Section 3.9.3 Advanced Power Strip Plug Outlets [WEBSITE LINK TBD]). The protocol considers usage of smart strips with home office systems and home entertainment systems.

Algorithms

The energy savings and demand reduction for Tier 1 and Tier 2 APS outlets are obtained from several recently conducted field studies, with the savings estimates applied to measured in-service rates (ISR) and realization rates (RR) to determine final savings.

The energy savings and demand reduction are calculated for both home office and home entertainment use for Tier 1 strips, and only for home entertainment use for Tier 2 strips.[63] For Tier 1 strips, if the intended use of the power strip is not specified, or if multiple power strips are purchased, the algorithm for "unspecified use" should be applied. If it is known that the power strip is intended to be used for an entertainment center, the "entertainment center" algorithm should be applied, while the "home office" algorithm should be applied if it is being used in a home office setting. For Tier 2 strips, the end use is assumed to be a home entertainment center and the savings vary based on the type of Tier 2 strip, IR, IR-OS, or unspecified.

Tier 1 Smart Strip:

[63] Tier 2 strips are typically installed only in home entertainment center applications.

$$\Delta kWh_{t1\_unspecified} = Annual\_Usage_{unspecified} \times ERP_{t1\_unspecified} \times ISR \times RR$$

$$\Delta kWh_{t1\_entertainment} = Annual\_Usage_{entertainment} \times ERP_{t1\_entertainment} \times ISR \times RR$$

$$\Delta kWh_{t1\_office} = Annual\_Usage_{office} \times ERP_{t1\_office} \times ISR \times RR$$

$$\Delta kW_{peak,\ t1\_unspecified} = Load_{unspecified} \times ERP_{peak,\ t1\_unspecified} \times ISR$$

$$\Delta kW_{peak,\ t1\_entertainment} = Load_{entertainment} \times ERP_{peak,\ t1\_entertainment} \times ISR$$

$$\Delta kW_{peak,\ t1\_home\ office} = Load_{office} \times ERP_{peak,\ t1\_office} \times ISR$$

Tier 2 Smart Strip:

$$\Delta kWh_{t2} = Annual\_Usage_{entertainment} \times ERP_{t2} \times ISR \times RR$$

$$\Delta kW_{peak,\ t2} = Load_{entertainment} \times ERP_{peak,\ t2} \times ISR$$

DEFINITION OF TERMS

Table 2-106: Terms, Values, and References for Advanced Power Strips

Parameter	Unit	Value	Source
$Annual\_Usage_{entertainment}$, Annual usage of home entertainment system	*kWh*	471	1
$Annual\_Usage_{office}$, Annual usage of home office system	*kWh*	399	1
$Annual\_Usage_{unspecified}$, Annual usage of unspecified end-use[64]	*kWh*	449	1, 2
$Load_{entertainment}$, Demand of home enertainment system	*kW*	0.058	3
$Load_{office}$, Demand of home office system	*kW*	0.044	3
$Load_{unspecified}$, Demand of unspecified end-use	*kW*	0.052	3
ERP, energy reduction percentage	*%*	See Table 2-107	1
ERP_{peak}, energy reduction percentage during peak period	*%*	See Table 2-107	1
ISR, In-service Rate	*%*	EDC Data Collection or see Table 2-107	2
RR, Realization Rate	*kWh*	0.92	2

The following table shows the Energy Reduction Percentage (ERP) and In-Service Rate (ISR) for each strip type and end use.

[64] Note that this was based on the MA RPLNC 17-4/5 APS Survey that determined Tier 1 APS to be used in home entertainment settings 60% of the time, and 40% in home office environments.

Table 2-107: Impact Factors for APS Strip Types

Strip Type	End-Use	ERP	ERP_{peak}	ISR
Tier 1	Home Entertainment Center	27%	20%	86%
Tier 1	Home Office	21%	18%	86%
Tier 1	Unspecified	25%	19%	86%
Tier 2	Home Entertainment Center	44%	41%	74%

Default Savings

Table 2-108: Default Savings for Advanced Power Strips

APS Type	End Use	Energy Savings (kWh)	Peak Demand Reduction (kW)
Tier 1	Home Entertainment Center	100.6	0.010
Tier 1	Home Office	66.3	0.007
Tier 1	Unspecified use or multiple purchased	88.8	0.009
Tier 2	Home Entertainment Center	141.1	0.018

Commented [SA22]: Franklin Energy

Averaging Home entertainment center and Home Office is likely overclaiming savings for multiple purchase/unknown end use. Often these are not plugged in correctly or only the master/uncontrolled sockets are used therefore achieving no savings

Evaluation Protocols

The most appropriate evaluation protocol for this measure is verification of installation coupled with assignment of stipulated energy savings.

Sources

1. "RLPNC 17-3: Advanced Power Strip Metering Study," *Massachusetts Programs Administrators and EEAC,* (Oct. 2018), http://ma-eeac.org/wordpress/wp-content/uploads/RLPNC_173_APSMeteringReport_5OCT2018_Finalv2.pdf
2. "RLPNC 17-4 and 17-5: Products Impact Evaluation of In-service and Short-Term Retention Rates Study," *Massachusetts Programs Administrators and EEAC,* (Oct. 2018), http://ma-eeac.org/wordpress/wp-content/uploads/RLPNC_1745_APSProductsSurveys_5Oct2018_Final.pdf
3. As reported in correspondence with authors of Source 1 and Source 2.
4. California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx. Accessed December 2018.

2.6 BUILDING SHELL

2.6.1 RESIDENTIAL AIR SEALING

Target Sector	Residential Establishments, limited to single family detached houses
Measure Unit	Residential Air Sealing
Measure Life	15 years Source 5
Vintage	Retrofit

Thermal shell air leaks are sealed through strategic use and installation of air-tight materials. Leaks are detected and leakage rates measured with the assistance of a blower-door test. This measure applies to the sealing of thermal shell air leaks in existing residential homes with a primary electric heating and/or cooling source.

ELIGIBILITY

The baseline for this measure is the existing air leakage as determined through approved and appropriate test methods using a blower door. The baseline condition of a building upon first inspection significantly impacts the opportunity for cost-effective energy savings through air-sealing.

Air sealing materials and diagnostic testing should meet all qualification criteria for program eligibility. The initial and final tested leakage rates should be performed in such a manner that the identified reductions can be properly discerned, particularly in situations where multiple building envelope measures may be implemented simultaneously.

For example, if air sealing, duct sealing and insulation are all installed as a whole home retrofit, efforts should be made to isolate the CFM reductions from each measure individually. This may require performance of a blower door test between each measure installation. Alternatively, the baseline blower door test may be performed after the duct sealing is completed, then air sealing measures installed and the retrofit blower door test completed prior to installation of the new insulation.

This measure is applicable to single family detached houses only.

ALGORITHMS

To calculate ΔkWh add together the cooling and heating savings calculated using the appropriate coefficients from

Table 2-111 and Table 2-112 for the matching equipment type and climate region in the algorithm below. For example, if a residence has gas heat with Central AC, there is no heating component to the savings calculations. If a residence has Electric Resistance heating and no AC, calculate the savings for “Baseboard” heating. Ductless installations such as baseboards and mini-split heat pumps should substitute 100% for $\frac{Duct_{proto}}{Duct_{base}}$.

$$\Delta kWh_{cool} = \frac{\eta_{proto}}{\eta_{base}} \times \frac{Duct_{proto}}{Duct_{base}} \times \left(\frac{a_{cool}}{100{,}000} \times \left(CFM50_{base}{}^2 - CFM50_{ee}{}^2\right) + b_{cool} \times \left(CFM50_{base} - CFM50_{ee}\right)\right)$$

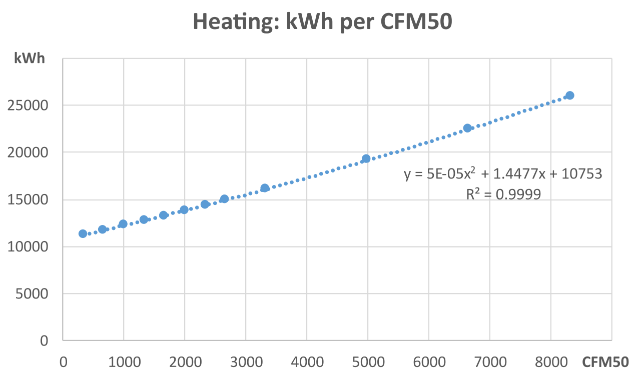
$$\Delta kWh_{heat} = \frac{\eta_{proto}}{\eta_{base}} \times \frac{Duct_{proto}}{Duct_{base}} \times \left(\frac{a_{heat}}{100{,}000} \times \left(CFM50_{base}{}^{2} - CFM50_{ee}{}^{2}\right) + b_{heat} \times \left(CFM50_{base} - CFM50_{ee}\right) \right)$$

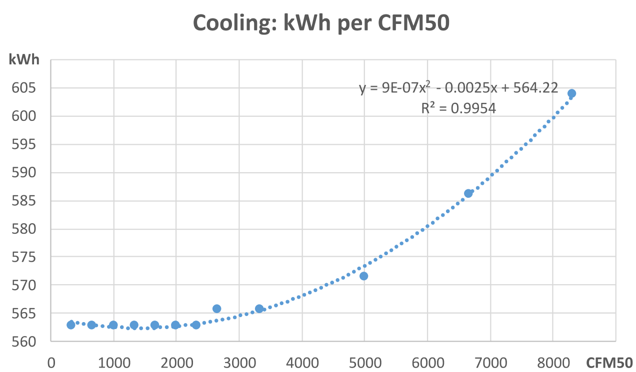
$$\Delta kWh = \Delta kWh_{cool} + \Delta kWh_{heat}$$

$$\Delta kW_{peak} = \Delta kWh_{cool} \div EFLH_{cool} \times CF$$

Note: The savings equations above are based on *quadratic* regressions because cooling savings fall off quickly with changes in infiltration in heating dominated climates, whereas some heating technologies exhibit escalating savings as in the example plot below. This results in small coefficients for the squared term, which are therefore multiplied by 10^5 to simplify Table 2-111 and Table 2-112.

Figure 2-4: Example Regressions for Ductless Mini-splits in Climate Region A





Definition of Terms

Table 2-109: Terms, Values, and References for Residential Air Sealing

Term	Unit	Values	Source
$CFM50_{base}$, Baseline infiltration at 50 Pa	CFM_{50}	Measured, EDC Data Gathering	EDC Data Gathering
$CFM50_{ee}$, Infiltration at 50 Pa post air sealing	CFM_{50}	Measured, EDC Data Gathering	EDC Data Gathering
$Duct_{base}$, Baseline duct efficiency	None	Measured, EDC Data Gathering	EDC Data Gathering
$Duct_{proto}$, Prototype duct efficiency	None	Default: See Table 2-34 in Sec. 2.2.10 for "R-2 Average Basement + 50% Conditioned"	1
η_{base} , Baseline equipment efficiency	varies	Measured, EDC Data Gathering Default: η_{proto}	EDC Data Gathering
η_{proto} , Prototype equipment efficiency	varies	See Table 2-110	2
a_{system} , Unit Energy Savings per CFM50[2] of air leakage reduction	$\frac{kWh/yr}{CFM_{50}{}^2}$	See Table 2-111	3
b_{system} , Unit Energy Savings per CFM50 of air leakage reduction	$\frac{kWh/yr}{CFM_{50}}$	See Table 2-112	3
$EFLH_{cool}$, Equivalent Full Load Cooling hours	$\frac{hours}{year}$	See $EFLH_{cool}$ in Vol.1, App. A	4
CF, Demand Coincidence Factor	Proportion	See *CF* in Vol.1, App. A	4

Default Unit Energy Savings Coefficient & Equipment Efficiency Tables

Savings may be claimed using the algorithms above and the algorithm's input default values below, in conjunction with customer-specific blower door test data. Site specific data from blower door testing is required to be used in conjunction with these default energy savings values, as outlined in the algorithms.

Table 2-110: Default Residential Equipment Efficiency

	Cooling				Heating				
	ASHP	Central AC	Mini-split	GSHP	ASHP	Base-board	Electric Furnace	Mini-split	GSHP
Efficiency	15	12.1	14.9	16.6	8.5	1	1	8.9	3.6
Units	SEER	SEER	SEER	EER	HSPF	COP	COP	HSPF	COP

Table 2-111: Default Unit Energy Savings per Reduced CFM50[2] for Air Sealing

Climate Region	Reference City	a_{cool}				a_{heat}				
		ASHP	Central AC	Mini-split	GSHP	ASHP	Base-board	Electric Furnace	Mini-split	GSHP
C	Allentown	-0.042	-0.076	0.09	0.023	5.064	1.166	3.485	0.944	0.413
A	Binghamton	0.028	0.018	0.087	0.046	3.335	1.271	4.653	0.986	0.293
G	Bradford	0.043	0.02	0.067	0.06	0.112	1.515	4.545	1.173	0.283
I	Erie	0.022	0.004	0.058	0.027	5.67	1.318	4.309	1.066	0.367
E	Harrisburg	-0.079	-0.125	0.126	-0.066	4.488	1.242	3.488	0.886	0.112
D	Philadelphia	-0.08	-0.121	0.096	0.002	3.078	1.004	2.208	0.792	0.286
H	Pittsburgh	-0.014	-0.053	0.075	0.079	4.657	1.185	2.778	0.93	0.497
B	Scranton	0.004	-0.029	0.086	0.058	4.845	1.21	4.073	0.958	0.411
F	Williamsport	-0.037	-0.032	0.104	0.052	5.175	1.181	3.477	0.925	0.392

Table 2-112: Default Unit Energy Savings per Reduced CFM50 for Air Sealing

Climate Region	Reference City	b_{cool}				b_{heat}				
		ASHP	Central AC	Mini-split	GSHP	ASHP	Base-board	Mini-split	Electric Furnace	GSHP
C	Allentown	0.025	0.033	0.004	0.007	0.951	1.966	0.864	2.138	0.616
A	Binghamton	-0.001	0.001	-0.002	-0.007	1.948	2.393	1.448	2.599	0.788
G	Bradford	-0.007	-0.005	-0.007	-0.011	2.703	2.803	2.001	3.032	0.951
I	Erie	0.004	0.001	-0.003	-0.004	1.279	2.238	1.098	2.423	0.726
E	Harrisburg	0.055	0.066	0.025	0.033	1.092	2.194	1.032	2.378	0.709
D	Philadelphia	0.05	0.061	0.017	0.023	0.589	1.604	0.573	1.752	0.498
H	Pittsburgh	0.019	0.026	0.005	-0.002	1.051	1.958	0.99	2.125	0.612
B	Scranton	0.009	0.013	-0.002	-0.004	1.25	2.056	1.004	2.24	0.659
F	Williamsport	0.02	0.023	0.001	-0.001	1.048	1.981	0.932	2.158	0.627

EVALUATION PROTOCOLS

The appropriate evaluation protocol for this measure is desk audit verification that the pre and post blower door tests were performed in accordance with industry standards. Verification through desk audits require confirmation of the proper application of the TRM protocol using default unit energy and demand savings values in coordination with blower door test results. Field verification of each test or re-test is not required.

Sources

1) Pennsylvania Act 129 2018 Residential Baseline, http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-Phase3_Res_Baseline_Study_Rpt021219.pdf.
2) Equipment efficiencies were chosen based on weighted single-family detached results from the 2017 Pennsylvania Residental Baseline, standardized equipment library entries (ASHP), and expertise (GSHP).
3) Based on modelling using BEopt v2.8.0 performed by NMR Group, Inc. Unit energy savings were calculated by modeling a prototypical Pennsylvania single family detached house with statewide average characteristics determined through the Pennsylvania Act 129 2018 Residential Baseline. Simulations for each equipment-climate region combination were performed at multiple levels of air leakage (1, 2, 3, 4, 5, 6, 7, 8, 10, 15, 20, and 25 ACH50). The heating or cooling loads for each system combination were then fitted with separate quadratic regressions, the coefficients of which are the UES values. Supporing files can be found at [WEBSITE LINK TBD].
4) Based on the Phase III SWE team's analysis of regional HVAC runtime data collected from ecobee's Donate Your Data research service, https://www.ecobee.com/donateyourdata/.
5) Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, 2007

2.6.2 Weather Stripping, Caulking, and Outlet Gaskets

Target Sector	Residential Establishments
Measure Unit	Per Project
Measure Life	15 years
Vintage	Retrofit

Residential structures can lose significant amounts of heat through the infiltration of unconditioned outside air into the conditioned space. Infiltration enters conditioned spaces in a variety of ways: building joints, gaps in door and window frames, basement and attic penetrations (electrical and plumbing) and recessed light fixtures. Air sealing measures like adding weather stripping, caulking and installing outlet gaskets can reduce the amount of infiltration and the related heating and cooling for a building.

Eligibility

To be eligible:

- Weather stripping must be installed on doors, windows, or attic hatches/doors.
- Caulking and/or spray foam sealant must be applied to window frames, door frames or plumbing/electrical penetrations.
- Gaskets must be installed on electrical outlets.

In addition, **this measure is limited to projects with less than than 400 kWh of savings**. Projects with 400 kWh or more of savings should follow Section 2.6.1 – Residential Air Sealing.

Algorithms

There are two approaches that can be utilized to estimate savings due to air sealing, one using algorithms requiring EDC data gathering, and a default savings method when data are unavailable. The annual energy and peak demand savings are obtained through the following formulas:

$$\Delta kWh_{cool} = \frac{1.08 \times \Delta CFM_{50} \times CDD \times 24\frac{hr}{day} \times ISR}{N \times SEER \times 1{,}000\frac{W}{kW}} \times LM \times DUA$$

$$\Delta kWh_{heat} = \frac{1.08 \times \Delta CFM_{50} \times HDD \times 24\frac{hr}{day} \times ISR}{N \times HSPF \times 1{,}000\frac{W}{kW}}$$

$$\Delta kWh = (\Delta kWh_{cool} + \Delta kWh_{heat}) < 400\ kWh$$ If > 400 kWh use Sec. 2.6.1

$$\Delta kW_{peak} = \Delta kWh_{cool} \times PCF$$

Commented [SA23]: Franklin Energy

Delete repeated word "than"

Commented [SA24]: FranklinEnergy

Consider adding an additional kWh_{heat} for savings that are achieved through a reduction in fan run time for systems with a gas furnace (such as is done with the IL TRM)

Consider adding fuel-based energy savings for propane/natural gas etc.

Ground Source Heat Pumps (GSHP)

GSHP efficiencies are typically calculated differently than air-source units, baseline and qualifying unit efficiencies should be converted as follows should be converted as follows:

$$SEER = EER_g \times GSHPDF \times GSER$$

$$HSPF = COP_g \times GSHPDF \times 3.412 \frac{BTU}{W \cdot h}$$

PTAC and PTHP

$$SEER = EER$$

Definition of Terms

Table 2-113: Terms, Values, and References for Weather Stripping

Term	Unit	Values	Source
1.08, Conversion factor that converts CFM air (at 70°F) to BTU/hr-°F	$\frac{BTU \times min}{hr \times °F \times ft^3}$	1.08	-
ΔCFM_{50}, Reduction in air leakage at a test pressure of 50 Pascals	*CFM*	See Table 2-117	1, 4
CDD, Cooling degree-days	*°F-day/year*	See CDD values in Vol. 1, App. A	10
HDD, Heating degree-days	*°F-day/year*	See HDD values in Vol. 1, App. A	10
ISR, In-service rate	None	Kit delivery: EDC Data Gathering Direct install = 1	EDC Data Gathering
LM, Latent multiplier to convert the calculated sensible load to the total (sensible and latent) load	None	See Table 2-115	5
DUA, Discretionary use adjustment to account for uncertainty in predicting cooling system usage patterns of occupants	None	0.75	3
N, Correlation factor. This factor accounts for four environmental characteristics that may influence infiltration, which include climate, building height, wind shielding and building leakiness	None	See Table 2-114 Default = 16.7	2
$SEER$, Cooling system seasonal efficiency	$\frac{Btu}{W \cdot h}$	EDC Data Gathering Default: See Table 2-116	7
$HSPF$, Heating system seasonal efficiency	$\frac{Btu}{W \cdot h}$	EDC Data Gathering Default: See Table 2-116	7
EER, Energy Efficiency Ratio of a GSHP, this is measured differently than EER of an air source heat pump and must be converted	$\frac{BTU}{W \cdot h}$	EDC Data Gathering	-

Commented [SA25]: Franklin Energy

It is worth noting that the IL TRM uses an alternate approach where prescriptive savings for gaskets (kWh/gasket), sweeps (kWh/sweep), caulking (kWh/foot), and weatherstripping (kWh/ft.) installation is based upon this source: "Evaluation of the Weatherization Residential Assistance Partnership and Helps Programs (WRAP/Helps)." Middletown, CT: KEMA, 2010. Accessed July 30, 2015, and adjusted for relative HDD of Bridgeport/Hartford CT with the IL climate zones.

Commented [SA26]: Franklin Energy

It worth nothing that the IL TRM applies an additional 85% distribution efficiency to account for duct losses for heat pump systems (ASHP and GSHP).

COP, Coefficient of Performance. This is a measure of the efficiency of a heat pump	*None*	EDC Data Gathering	-
$GSER$, Factor used to determine the SEER of a GSHP based on its EERg	$\frac{BTU}{W \cdot h}$	1.02	8
$GSPK$, Factor to convert EERg to the equivalent EER of an air conditioner to enable comparisons to the baseline unit	*Proportion*	0.8416	8
$GSHPDF$, Ground Source Heat Pump De-rate Factor	*Proportion*	0.885	9
PCF, Peak demand savings conversion factor	*kW/kWh*	0.000017 (1.7×10^{-5})	6

Table 2-114: Correlation Factor Source 2

Commented [SA27]: Franklin Energy

The IL TRM has separate N factors/separate tables depending on heating or cooling. The N factors are larger during the cooling season than the heating season.

Shielding/Stories	1	1.5	2	3
Well-shielded	22.2	20.0	17.8	15.5
Normal	18.5	16.7	14.8	13.0
Exposed	16.7	15.0	13.3	11.7

Table 2-115: Latent Multiplier Values by Climate Reference City

Climate Region	Reference City	LM
C	Allentown	9.0
A	Binghamton, NY	6.75
G	Bradford	16.0
I	Erie	13.0
E	Harrisburg	5.6
D	Philadelphia	7.8
H	Pittsburgh	7.3
B	Scranton	9.3
F	Williamsport	9.5

Table 2-116: Default Cooling and Heating System Efficiencies

Type	SEER	HSPF
Central Air Conditioner	12.1	N/A
Room Air Conditioner	11.4	N/A
Air-Source Heat Pump	13.5	8.2
Ground-Source Heat Pump	15.0	10.9
Ductless Mini-Split	14.9	8.9
Electric Resistance	N/A	3.412

Table 2-117: Typical Reductions in Leakage Source 1

Technology	Application	ΔCFM50 Source 4
Weather Stripping	Single Door	25.5 CFM/door
	Double Door	0.73 CFM/ft^2
	Casement Window	0.036 CFM/lf of crack
	Double Horizontal Slider, Wood	0.473 CFM/lf of crack
	Double-Hung	1.618 CFM/lf of crack
	Double-Hung, with Storm Window	0.164 CFM/lf of crack
	Average Weatherstripping	0.639 CFM/lf of crack
Caulking	Piping/Plumbing/Wiring Penetrations	10.9 CFM each
	Window Framing, Masonry	1.364 CFM/ft^2
	Window Framing, Wood	0.382 CFM/ft^2
	Door Frame, Masonry	1.018 CFM/ft^2
	Door Frame, Wood	0.364 CFM/ft^2
	Average Window/Door Caulking	0.689 CFM/lf of crack
Average Window/Door Caulking and Weather Stripping		*0.664 CFM/lf of crack*
Gasket	Electrical Outlets	6.491 CFM each

DEFAULT SAVINGS

If the information needed to utilize the algorithms is unavailable, the default savings listed below may be used. The default savings are based on a home with a 12.1 SEER CAC and electric resistance heat (COP=1). The default savings assume direct install of measures. To use default savings for kit delivery measures, EDCs must determine an ISR multiplier through independent research.

Table 2-118: Default Annual Energy Savings

Climate Region	Reference City	Cooling Savings (kWh)			Heating Savings (kWh)		
		Caulked Penetrations (per pen.)	Weather Stripping, Caulking and Sealing (per 10 lf)	Outlet Gaskets (per gasket)	Caulked Penetrations (per pen.)	Weather Stripping, Caulking and Sealing (per 10 lf)	Outlet Gaskets (per outlet)
C	Allentown	7.317	4.457	4.357	28.178	17.165	16.780
A	Binghamton, NY	2.875	1.752	1.712	34.997	21.319	20.841
G	Bradford	3.433	2.091	2.044	40.930	24.933	24.374
I	Erie	7.917	4.823	4.714	32.207	19.619	19.179
E	Harrisburg	6.603	4.022	3.932	30.466	18.559	18.143
D	Philadelphia	9.426	5.742	5.613	23.971	14.602	14.275
H	Pittsburgh	5.666	3.452	3.374	29.014	17.674	17.278
B	Scranton	5.928	3.611	3.530	30.556	18.614	18.196
F	Williamsport	7.284	4.437	4.338	28.581	17.411	17.020

Table 2-119: Default Summer Peak Demand Savings

Climate Region	Reference City	Caulked Penetrations (ΔkW/ pen.)	Weather Stripping, Caulking and Sealing (ΔkW/10 lf)	Outlet Gaskets (ΔkW/gasket)
C	Allentown	0.0001244	0.0000758	0.0000741
A	Binghamton, NY	0.0000489	0.0000298	0.0000291
G	Bradford	0.0000584	0.0000356	0.0000348
I	Erie	0.0001346	0.0000820	0.0000801
E	Harrisburg	0.0001122	0.0000684	0.0000668
D	Philadelphia	0.0001602	0.0000976	0.0000954
H	Pittsburgh	0.0000963	0.0000587	0.0000574
B	Scranton	0.0001008	0.0000614	0.0000600
F	Williamsport	0.0001238	0.0000754	0.0000737

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures. For kit delivery, EDCs should estimate in-service rate through customer surveys.

Sources

1) ASHRAE, 2001 AHSRAE Handbook – Fundamentals, Table 1.
2) ENERGY STAR Home Sealing Specification, Version 1.0. October 2001. https://www.energystar.gov/ia/home_improvement/home_sealing/ES_HS_Spec_v1_0b.pdf
3) Energy Center of Wisconsin, "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research," May 2008. https://focusonenergy.com/sites/default/files/centralairconditioning_report.pdf
4) ΔCFM50 is estimated by dividing the ELA by 0.055. See p. 83, The Energy Conservatory, Minneapolis Blower Door Operation Manual, http://energyconservatory.com/wp-content/uploads/2014/07/Blower-Door-model-3-and-4.pdf
5) LM values calculated as total load (sensible + latent) divided by sensible load, from sensible and latent values in Harriman et al. "Dehumidification and Cooling Loads from Ventilation Air." ASHRAE Journal. November 1997. https://energy.mo.gov/sites/energy/files/harriman-dehumidification-and-cooling-loads-from-ventilation-air.pdf
6) KEMA, Evaluation of the Weatherization Residential Assistance Partnership (WRAP) and Helps Programs, September 2010. http://www.energizect.com/sites/default/files/Final%20WRAP%20%20Helps%20Report.pdf
7) For all systems excluding ground source heat pumps: Pennsylvania Act 129 2018 Residential Baseline Study, http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-Phase3_Res_Baseline_Study_Rpt021219.pdf. Due to small sample size in residential

baseline, the lowest efficiency options available in BEopt were chosen as defaults for ground source heat pumps.

8) VEIC estimate. Extrapolation of manufacturer data.
9) McQuay Application Guide 31-008, Geothermal Heat Pump Design Manual, 2002. Engineering Estimate - See System Performance of Ground Source Heat Pumps
10) PA SWE Team Calculations with data from the National Solar Radiation Database. 1991–2005 Update: Typical Meteorological Year 3. NREL. http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html

2.6.3 CEILING/ATTIC, WALL, FLOOR AND RIM JOIST INSULATION

Target Sector	Residential Establishments
Measure Unit	Per Project
Measure Life	15 years Sources 1, 2
Vintage	Retrofit

This protocol covers the calculation of energy and demand savings associated with insulating ceilings/attics, walls, floors above vented crawlspaces, and rim joists in residential buildings.

ELIGIBILITY

Ceiling/Attic or Wall Insulation
This measure applies to installation/retrofit of new or additional insulation in a ceiling/attic, or walls of existing residential homes or apartment units in multifamily complexes with a primary electric heating and/or cooling source. The installation must achieve a finished ceiling/attic insulation rating of R-49 or higher, and/or must add wall insulation of at least an R-6 or greater rating.Source 12

Floor Insulation
This measure requires the installation of new insulation to the floors of existing residential buildings with vented (unconditioned) crawlspaces and a primary electric heating and/or cooling source. The installation must achieve a finished floor insulation R-value of R-30 or higher, except for homes in IECC Climate Zone 4, where R-19 is permissable.Source 12

Rim Joist Insulation
This measure protocol applies to the installation of insulation in the rim joists of residential homes. This includes the rim joists of unvented crawlspaces and the rim joists between the first and second floor of a residence. The insulation should have either a minimum R-10 continuous insulated sheathing on the interior or exterior of the home, or R-13 cavity insulation at the interior of the rim joist. Because of the difficulty of a proper air-sealed installation, using fiberglass batts between the joists is not usually recommended. The insulation should be sprayed foam or rigid foam.Source 3

ALGORITHMS

The annual energy and peak demand savings are obtained through the following formulas. Note that these equations are applied separately for each ceiling / attic, wall, floor, and rim joist component upgraded.

$$\Delta kWh_{cool,component} = \left(\frac{1}{R_{base}} - \frac{1}{R_{ee}}\right) \times A_{component} \times (1 - FF) \times \frac{24\frac{hr}{day} \times CDD \times DUA}{SEER \times 1{,}000\frac{W}{kW}} \times F_{RAC} \times AHF$$

$$\Delta kWh_{heat,component} = \left(\frac{1}{R_{base}} - \frac{1}{R_{ee}}\right) \times A_{component} \times (1 - FF) \times \frac{24\frac{hr}{day} \times HDD}{HSPF \times 1{,}000\frac{W}{kW}}$$

$$\Delta kWh = \sum\nolimits_{components} \Delta kWh_{cool} + \Delta kWh_{heat}$$

$$\Delta kW_{peak} = \frac{\Delta kWh_{cool}}{EFLH_{cool}} \times CF$$

Ground Source Heat Pumps (GSHP)

GSHP efficiencies are typically calculated differently than air-source units, baseline and qualifying unit efficiencies should be converted as follows should be converted as follows:

$$SEER = EER_g \times GSHPDF \times GSER$$

$$HSPF = COP_g \times GSHPDF \times 3.412 \frac{\text{BTU}}{\text{W·h}}$$

PTAC and PTHP

$$SEER = EER$$

DEFINITION OF TERMS

Table 2-120: Terms, Values, and References for Basement Wall Insulation

Term	Unit	Values	Source
ΔkWh_{cool}, Annual cooling energy savings	*kWh/year*	Calculated	-
ΔkWh_{heat}, Annual heating energy savings	*kWh/year*	Calculated	-
R_{base}, R-value of existing insulation	*°F.ft²‧hr/BTU*	EDC Data Gathering Default: Table 2-122	9, 10
R_{ee}, R-value of insulation added	*°F.ft²‧hr/BTU*	EDC Data Gathering Default: Table 2-122	9, 10
A, Area of component being insulated	*Ft²*	EDC Data Gathering	-
FF, Framing factor, designed to account for space that is occupied by framing	None	If externally applied or non-floor component = 0% If studs and cavity = 12%	4
CDD, Annual cooling degree-days, base 65°F	*°F-day/year*	See *CDD* in Vol 1., App. A	15
HDD, Annual heating degree-days, base 65°F	*°F-day/year*	See *HDD* in Vol 1., App. A	15
$EFLH_{cool}$, Equivalent full load cooling hours	*Hours/year*	See $EFLH_{cool}$ in Vol 1., App. A	14
DUA, Discretionary use adjustment to account for uncertainty in predicting cooling system usage patterns of occupants	None	0.75	5
$SEER$, Cooling system seasonal efficiency	$\frac{Btu}{W \cdot h}$	EDC Data Gathering Default: See Table 2-121	6

$HSPF$, Heating system seasonal efficiency	$\frac{BTU}{W \cdot h}$	EDC Data Gathering Default: See Table 2-121	6
F_{RAC}, Adjustment factor to relate insulated area to area served by room air conditioners	None	If Room AC = 0.38 If non-Room AC = 1.0	7
COP, Coefficient of Performance. This is a measure of the efficiency of a heat pump	*None*	EDC Data Gathering	-
EER_g, Energy Efficiency Ratio of a GSHP, this is measured differently than EER of an air source heat pump and must be converted	$\frac{BTU}{W \cdot h}$	EDC Data Gathering Default = 16.6	-
$GSER$, Factor used to determine the SEER of a GSHP based on its EERg	$\frac{BTU}{W \cdot h}$	1.02	12
$GSPK$, Factor to convert EERg to the equivalent EER of an air conditioner to enable comparisons to the baseline unit	*Proportion*	0.8416	12
$GSHPDF$, Ground Source Heat Pump De-rate Factor	*Proportion*	0.885	13
CF, Coincidence factor	None	See *CF* in Vol. 1, App. A	14
AHF, Adjustment for cooling savings to account for inaccuracies in engineering algorithms.	*None*	1.21 if adding attic ins., 1.0 if not	8

Table 2-121: Default Cooling and Heating System Efficiencies

Type	SEER	HSPF
Central Air Conditioner	12.1	N/A
Room Air Conditioner	11.4	N/A
Air-Source Heat Pump	13.5	8.2
Ground-Source Heat Pump	15.0	10.9
Ductless Mini-Split	14.9	8.9
Electric Resistance	N/A	3.412

Table 2-122: Default Base and Energy Efficient (Insulated) R Values

Component	Existing Condition	Value ($\frac{°F \cdot ft^2 \cdot hr}{Btu}$)
$R_{ceil,base,}$ Assembly R-value of ceiling/attic before retrofit	Un-insulated attic	5
	4.5" (R-13) of existing attic insulation	16
	6" (R-19) of existing attic insulation	22
	10" (R-30) of existing attic insulation	30
$R_{ceil,ee,}$ Assembly R-value of ceiling/attic after retrofit	Retrofit to R-49 total attic insulation	49
$R_{wall,base}$, Assembly R-value of wall before retrofit	Assumes existing, un-insulated wall with 2x4 studs @ 16" o.c., w/ wood/vinyl siding	5
$R_{wall,ee}$, Assembly R-value of wall after retrofit	Assumes adding R-6 per DOE recommendations	11
$R_{floor,base}$, R-value of floor before retrofit	Thermal resistance of existing floor insulation above crawlspace	3.96
$R_{floor,ee}$, R-value of floor after retrofit	Thermal resistance of insulation added to floor above crawlspace	EDC Data Gathering
$R_{rim_{joist_{base}}}$, R-value of rim joist before retrofit	Baseline R-value of rim joist	2.5
$R_{rim_{joist_{ee}}}$, R-value of rim joist after retrofit	R-value of installed spray foam or rigid foam insulation applied to rim joist	EDC Data Gathering

DEFAULT SAVINGS

There are no default savings for this measure.

EVALUATION PROTOCOLS

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

SOURCES

1) GDS Associates, Inc., Measure Life Report, *Residential and Commercial/Industrial Lighting and HVAC Measures*, 2007. https://library.cee1.org/system/files/library/8842/CEE_Eval_MeasureLifeStudyLights%2526HVACGDS_1Jun2007.pdf

2) State of Ohio Energy Efficiency Technical Reference Manual, prepared for the Public Utilities Commission of Ohio by Vermont Energy Investment Corporation. August 6, 2010.

3) Minnesota Department of Commerce, Home Envelope, An Energy Guide to Help You Keep the Outside Out and the Inside In.

http://mn.gov/commerce/energy/topics/resources/Consumer-Guides/home-envelope/basement.jsp

4) CEC 2001A. "Characterization of Framing Factors for Low-Rise Residential Building Envelopes in California" - Public Interest Energy Research Program: Final Report, Publication Number: 500-02-002, Dec 2001. http://www.energy.ca.gov/reports/2002-09-06_500-02-002.PDF .

5) Energy Center of Wisconsin, "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research," https://focusonenergy.com/sites/default/files/centralairconditioning_report.pdf

6) For all systems excluding ground source heat pumps: Pennsylvania Act 129 2018 Residential Baseline Study, http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-Phase3_Res_Baseline_Study_Rpt021219.pdf. Due to small sample size in residential baseline, the lowest efficiency options available in BEopt were chosen as defaults for ground source heat pumps.

7) From PECO baseline study, average home size = 2,323 ft^2, average number of room AC units per home = 2.1. Average Room AC capacity = 10,000 BTU/hr per ENERGY STAR Room AC Calculator, which serves 425 ft^2 (average between 400 and 450 ft^2 for 10,000 BTU/hr unit per ENERGY STAR Room AC sizing chart). F_{RAC} = (425 ft^2 × 2.1)/(2,323 ft^2) = 0.38.

8) Illinois Statewide Technical Reference Manual, Version 7.0. September 28, 2018. http://www.ilsag.info/technical-reference-manual.html .

9) Used eQuest 3.64 to derive roof assembly R-values. When insulation is added between the joists as in most insulation up to R-30 (10"), the assembly R-value is based on a parallel heat transfer calculation of the insulation and joists, rather than a series heat transfer.

10) 2009 ASHRAE Fundamentals, Chapter 25 and 26. Method from "Total Thermal Resistance of a Flat Building Assembly" in Chapter 25. Values from Chapter 26: interior air film = 0.68, 1.5" wooden rim joist = 1.65, exterior air film = 0.17. Total= 2.50 *°F-ft²-h/BTU*

11) 2015 International Energy Conservation Code, Table R402.1.2: Insulation and Fenestration Requirements by Component. https://codes.iccsafe.org/content/IECC2015/chapter-4-re-residential-energy-efficiency

12) VEIC estimate. Extrapolation of manufacturer data.

13) McQuay Application Guide 31-008, Geothermal Heat Pump Design Manual, 2002. Engineering Estimate - See System Performance of Ground Source Heat Pumps

14) Based on the Phase III SWE team's analysis of regional HVAC runtime data collected from ecobee's Donate Your Data research service. https://www.ecobee.com/donateyourdata/

15) PA SWE Team Calculations with data from the National Solar Radiation Database. 1991–2005 Update: Typical Meteorological Year 3. NREL. http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html

2.6.4 Basement Wall Insulation

Target Sector	Residential Establishments
Measure Unit	Per Project
Measure Life	15 years Source 1
Vintage	Retrofit

This protocol covers the calculation of energy and demand savings associated with insulating walls in conditioned and semi-conditioned (i.e. unfinished) basements. Cooling savings are only produced from insulation improvements to above-grade portions of the wall, since the below-grade portions are expected to be cooler than the temperature set point of the building. Heating savings will be produced from the entire insulation improvement, though in varying quantities depending on whether above or below grade.

Eligibility

This measure requires the installation of new insulation to the basement walls of existing residential buildings. The installation must achieve a finished wall insulation value of R-10 (if continuous insulation) or R-13 (if cavity insulation such as batts between studs) in IECC Climate Zone 4 or R-15 (if continuous insulation) or R-19 (if cavity insulation such as batts between studs) in IECC Climate Zones 5 and 6.Source 9

Algorithms

The annual energy and peak demand savings are obtained through the following formulas:

$$\Delta kWh_{cool} = \left(\frac{1}{R_{Exist}} - \frac{1}{R_{Exist}+R_{ins}}\right) \times H_{AG} \times L_{BP} \times (1-FF) \times \frac{24\frac{hr}{day} \times CDD \times DUA}{SEER \times 1{,}000\frac{W}{kW}} \times F_{RAC}$$

$$\Delta kWh_{heat} = \left(\left(\frac{1}{R_{Exist}} - \frac{1}{R_{Exist}+R_{ins}}\right) \times H_{AG} + \left(\frac{1}{R_{Exist}-R_{BG}} - \frac{1}{R_{Exist}+R_{BG}+R_{ins}}\right) \times H_{BG}\right) \times L_{BP} \times (1-F_f) \times \frac{24\frac{hr}{day} \times HDD}{HSPF \times 1{,}000\frac{W}{kW}}$$

$$\Delta kWh = \Delta kWh_{cool} + \Delta kWh_{heat}$$

$$\Delta kW_{peak} = \frac{\Delta kWh_{cool}}{EFLH_{cool}} \times CF$$

Ground Source Heat Pumps (GSHP)

GSHP efficiencies are typically calculated differently than air-source units, baseline and qualifying unit efficiencies should be converted as follows should be converted as follows:

$$SEER = EER_g \times GSHPDF \times GSER$$

$$HSPF = COP_g \times GSHPDF \times 3.412\frac{BTU}{W\cdot h}$$

PTAC and PTHP

$$SEER = EER$$

Commented [SA28]: Franklin Energy

The IL TRM has an additional factor, ADJBasementCool, which is 80% and added "to account for prescriptive engineering algorithms overclaiming savings" but does not include the F_{RAC} factor.

Commented [SA29]: Franklin Energy

This should actually be $R_{Exist} + R_{BG}$. This represents the thermal resistance of the existing wall plus the thermal resistance of the earth below grade.

Actually, since R_{BG} already includes an R-1 for existing concrete wall, then R_{Exist} value is not needed. Or, is R_{Exist} representing the wall framing adjacent to the concrete wall/foundation (if there is wall framing)? This may need to be clarified.

The IL TRM does not include an R_{Exist} value in the below grade portion of the savings calculation since the R_{BG} value already includes an R-1 for existing concrete wall. Either way these R values should be added not subtracted.

Commented [SA30]: Franklin Energy

The IL TRM has an additional factor, ADJBasementHeat, which is 60% and added "to account for prescriptive engineering algorithms overclaiming savings".

Definition of Terms

Table 2-123: Terms, Values, and References for Basement Wall Insulation

Term	Unit	Values	Source
ΔkWh_{cool}, Annual cooling energy savings	*kWh/year*	Calculated	-
ΔkWh_{heat}, Annual heating energy savings	*kWh/year*	Calculated	-
R_{Exist}, Thermal resistance of existing wall insulation.	*°F.ft².hr/BTU*	EDC Data Gathering Default = existing nominal R-value + 1; Minimum = 1. (An uninsulated wall is assumed to be R-1.)	2
R_{BG}, Thermal resistance of existing wall below grade. Assumes R-1 for concrete wall.	*°F.ft².hr/BTU*	EDC Data Gathering See Table 2-124	3
R_{ins}, Thermal resistance of insulation added to wall	*°F.ft².hr/BTU*	EDC Data Gathering	-
H_{AG}, Height of insulated basement wall above ground	*Feet*	EDC Data Gathering	-
H_{BG}, Height of insulated basement wall below ground	*Feet*	EDC Data Gathering	–
L_{BP}, Length of basement wall around insulated perimeter	*Feet*	EDC Data Gathering	-
FF, Frame factor, designed to account for space that is occupied framing	None	If externally applied = 0% If studs and cavity = 25%	4
CDD, Annual cooling degree-days	*°F-day/year*	See CDD in Vol 1., App. A	12
HDD, Annual heating degree-days	*°F-day/year*	See HDD in Vol 1., App. A	12
DUA, Discretionary use adjustment to account for uncertainty in predicting cooling system usage patterns of occupants	None	0.75	5
$SEER$, Cooling system seasonal efficiency	$\frac{BTU}{W \cdot h}$	EDC Data Gathering Default: See Table 2-125	6
$HSPF$, Heating system seasonal efficiency	$\frac{BTU}{W \cdot h}$	EDC Data Gathering Default: See Table 2-125	6
F_{RAC}, Adjustment factor to relate insulated area to area served by room air conditioners	None	If Room AC = 0.38 If non-Room AC = 1.0	7
COP, Coefficient of Performance. This is a measure of the efficiency of a heat pump	None	EDC Data Gathering	-

Term	Unit	Values	Source
EER_g , Energy Efficiency Ratio of a GSHP, this is measured differently than EER of an air source heat pump and must be converted	$\frac{BTU}{W \cdot h}$	EDC Data Gathering Default = 16.6	-
$GSER$, Factor used to determine the SEER of a GSHP based on its EERg	$\frac{BTU}{W \cdot h}$	1.02	9
$GSPK$, Factor to convert EERg to the equivalent EER of an air conditioner to enable comparisons to the baseline unit	*Proportion*	0.8416	9
$GSHPDF$, Ground Source Heat Pump De-rate Factor	*Proportion*	0.885	10
$EFLH_{cool}$, Equivalent full load cooling hours	*Hours/year*	See $EFLH_{cool}$ in Vol 1., App. A	11
CF , Coincidence factor	None	See *CF* in Vol 1., App. A	11

Table 2-124: Below Grade Thermal Resistance Values

Thermal Resistance (°F-ft²-h/BTU)									
Depth Below Grade (ft)	0	1	2	3	4	5	6	7	8
Total below grade, average (including R-1 for concrete wall)	3.44	4.47	5.41	6.41	7.42	8.46	9.46	10.53	11.69

Table 2-125: Default Cooling and Heating System Efficiencies

Type	SEER	HSPF
Central Air Conditioner	12.1	N/A
Room Air Conditioner	11.4	N/A
Air-Source Heat Pump	13.5	8.2
Ground-Source Heat Pump	15.0	10.9
Ductless Mini-Split	14.9	8.9
Electric Resistance	N/A	3.412

Commented [SA31]: Franklin Energy

IL TRM applies an additional 85% distribution efficiency to account for duct losses for heat pumps.

Default Savings

There are no default savings for this measure.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) GDS Associates, Inc., Measure Life Report, *Residential and Commercial/Industrial Lighting and HVAC Measures*, 2007. Reduced to 15 years maximum as required by Act 129. https://library.cee1.org/system/files/library/8842/CEE_Eval_MeasureLifeStudyLights%2526HVACGDS_1Jun2007.pdf
2) ORNL Builders Foundation Handbook, crawl space data from Table 5-5: Initial Effective R-values for Uninsulated Foundation System and Adjacent Soil, 1991, http://smartenergy.illinois.edu/pdf/Archive/FoundationHandbookforBuilders.pdf
3) Illinois Statewide Technical Reference Manual, Version 7.0. September 28, 2018. http://www.ilsag.info/technical-reference-manual.html
4) CEC 2001A. "Characterization of Framing Factors for Low Rise Residential Building Envelopes in California" - Public Interest Energy Research Program: Final Report, Publication Number: 500-02-002, Dec 2001. http://www.energy.ca.gov/reports/2002-09-06_500-02-002.PDF
5) Energy Center of Wisconsin, "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research," https://focusonenergy.com/sites/default/files/centralairconditioning_report.pdf
6) For all systems excluding ground source heat pumps: Pennsylvania Act 129 2018 Residential Baseline Study, http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-Phase3_Res_Baseline_Study_Rpt021219.pdf. Due to small sample size in residential baseline, the lowest efficiency options available in BEopt were chosen as defaults for ground source heat pumps.
7) From PECO baseline study, average home size = 2,323 ft^2, average number of room AC units per home = 2.1. Average Room AC capacity = 10,000 BTU/hr per ENERGY STAR Room AC Calculator, which serves 425 ft^2 (average between 400 and 450 ft^2 for 10,000 BTU/hr unit per ENERGY STAR Room AC sizing chart). $F_{RAC} = (425\ \text{ft}^2 \times 2.1)/(2{,}323\ \text{ft}^2) = 0.38$.
8) 2015 International Energy Conservation Code, Table R402.1.2: Insulation and Fenestration Requirements by Component. https://codes.iccsafe.org/content/IECC2015/chapter-4-re-residential-energy-efficiency
9) VEIC estimate. Extrapolation of manufacturer data.
10) McQuay Application Guide 31-008, Geothermal Heat Pump Design Manual, 2002. Engineering Estimate - See System Performance of Ground Source Heat Pumps
11) Based on the Phase III SWE team's analysis of regional HVAC runtime data collected from ecobee's Donate Your Data research service. https://www.ecobee.com/donateyourdata/
12) PA SWE Team Calculations with data from the National Solar Radiation Database. 1991–2005 Update: Typical Meteorological Year 3. NREL. http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html

2.6.5 Crawl Space Wall Insulation

Target Sector	Residential Establishments
Measure Unit	Insulation Addition
Measure Life	15 years Source 1
Vintage	Retrofit

A residential crawl space is a structural foundation that is tall enough for a person to crawl within the space to perform any necessary maintenance. This measure protocol applies to the installation of insulation in the crawl space walls of residential homes. The baseline is a crawl space that has no insulation.

Eligibility

This measure protocol applies to the installation of insulation in the unvented crawl space walls of residential homes with ductwork. Research has shown that vented crawlspaces that are sealed and insulated operate similarly to basements in providing benefits such as energy savings, comfort, moisture control, long-term durability, and healthier air quality.[Source 2] Sealing the crawl space must follow the required PA building codes, including covering the earth with a Class I vapor retarder and providing ventilation of at least 1cfm per 50 ft^2 of crawlspace. In addition, sealing of the crawlspace must not block access to the space. The insulation should have either a minimum R-10 continuous insulated sheathing on the interior or exterior of the home, or R-13 cavity insulation at the interior of the crawl space wall in IECC Climate Zone 4, and R-15 continuous or R-19 cavity insulation in zones 5 or 6.[Source 3]

Algorithms

Savings are due to a reduction in cooling and heating requirements due to insulation.

$$\Delta kWh = \Delta kWh_{cool} + \Delta kWh_{heat}$$

$$\Delta kWh_{cool} = \left(\frac{1}{R_{base}} - \frac{1}{R_{base} + R_{ee}}\right) \times \frac{L \times H_{ag} \times (1 - FF) \times CDD \times 24\frac{\text{hr}}{\text{day}}}{\text{SEER} \times 1{,}000\frac{\text{W}}{\text{kW}}} \times DUA$$

$$\Delta kWh_{heat} = \left\{\left(\frac{1}{R_{base}} - \frac{1}{R_{base} + R_{ee}}\right) \times H_{ag} + \left(\frac{1}{R_{base} + R_{Earth}} - \frac{1}{R_{base} + R_{Earth} + R_{ee}}\right) \times H_{bg}\right\} \times \frac{L \times (1 - FF) \times HDD \times 24\frac{\text{hr}}{\text{day}}}{\text{HSPF} \times 1{,}000\frac{\text{W}}{\text{kW}}} \times AF$$

$$\Delta kW_{peak} = \frac{\Delta kWh_{cool}}{EFLH_{cool}} \times CF$$

Ground Source Heat Pumps (GSHP)

GSHP efficiencies are typically calculated differently than air-source units, baseline and qualifying unit efficiencies should be converted as follows should be converted as follows:

$$SEER = EER_g \times GSHPDF \times GSER$$

$$HSPF = COP_g \times GSHPDF \times 3.412\frac{\text{BTU}}{\text{W}\cdot\text{h}}$$

PTAC and PTHP

$$SEER = EER$$

Definition of Terms

Table 2-126: Terms, Values, and References for Residential Crawl Space Insulation

Term	Unit	Values	Source
R_{base}, baseline R-value of foundation wall	*°F-ft²-h/BTU*	EDC Data Gathering Default = 1.73	4
R_{Earth}, average R-value for the thermal resistance of the Earth at the height of insulated crawlspace wall below grade (H_{bg})	*°F-ft²-h/BTU*	Table 2-127	5
R_{ee}, R-value of installed spray foam, rigid foam, or cavity insulation applied to crawlspace wall	*°F-ft²-h/BTU*	EDC Data Gathering	EDC Data Gathering
L, length of crawlspace wall around the entire insulated perimeter	*ft*	EDC Data Gathering	EDC Data Gathering
H_{ag}, height of insulated crawlspace wall above grade	*ft*	EDC Data Gathering	EDC Data Gathering
H_{bg}, height of insulated crawlspace wall below grade	*ft*	EDC Data Gathering	EDC Data Gathering
FF, framing factor, adjustment to account for area of framing when cavity insulation is used	*Proportion*	External foam: 0.0 Spray foam : 0.0 Other cavity ins.: 0.25	6
CDD, cooling degree days matched to crawlspace condition. Insulation in unconditioned spaces (standard crawlspace) is modeled by reducing the degree days to reflect the smaller but non-zero contribution to heating and cooling load.	*°F-day*	See CDD in Vol. 1 App. A	13
HDD, heating degree days matched to crawlspace condition	*°F-day*	See HDD in Vol. 1 App. A	13
DUA, Discretionary Use Adjustment, adjustment for times when AC is not operating even though conditions may call for it	*Proportion*	0.75	7
SEER, Cooling system seasonal efficiency	$\frac{BTU}{W \cdot h}$	EDC Data Gathering Default: Table 2-128	8
HSPF, Heating system seasonal efficiency	*Proportion*	EDC Data Gathering Default: Table 2-128	8
AF, adjustment factor, accounts for prescriptive engineering algorithms overestimating savings	*Proportion*	0.88	9
COP, Coefficient of Performance. This is a measure of the efficiency of a heat pump	None	EDC Data Gathering	-
EER, Energy Efficiency Ratio of a GSHP, this is measured differently than EER of an air source heat pump and must be converted	$\frac{BTU}{W \cdot h}$	EDC Data Gathering	-

Term	Unit	Values	Source
$GSER$, Factor used to determine the SEER of a GSHP based on its EERg	$\frac{BTU}{W \cdot h}$	1.02	11
$GSPK$, Factor to convert EERg to the equivalent EER of an air conditioner to enable comparisons to the baseline unit	*Proportion*	0.8416	11
$GSHPDF$, Ground Source Heat Pump De-rate Factor	*Proportion*	0.885	12
$EFLH_{cool}$, equivalent full-load hours of air conditioning	*hours*	EDC Data Gathering or See $EFLH_{cool}$ in Vol. 1 App. A	EDC Data Gathering 10
CF, coincidence factor	*Proportion*	See *CF* in Vol. 1 App. A	10

Table 2-127 should be used to determine the average thermal resistance of the Earth (R_{Earth}) at the height of crawlspace wall below grade (H_{bg}). Use a crawlspace wall that is 5ft in height as an example of proper use of the table. If the crawlspace wall is 5 ft in height and 1ft is above grade (H_{ag} = 1ft), then the remaining 4ft are below grade (H_{bg} = 4ft). To determine the R_{Earth} for that below-grade wall height, look for the column for H_{bg} = 4ft in Table 2-127. R_{Earth} in this example is therefore 6.42 °F-ft^2-h/BTU.

Table 2-127: Below-grade R-values

H_{bg} (ft)	0	1	2	3	4	5	6	7	8
R_{Earth} (°F-ft^2-h/BTU)	2.44	3.47	4.41	5.41	6.42	7.46	8.46	9.53	10.69

Table 2-128: Default Cooling and Heating System Efficiencies

Type	SEER	HSPF
Central Air Conditioner	12.1	N/A
Room Air Conditioner	11.4	N/A
Air-Source Heat Pump	13.5	8.2
Ground-Source Heat Pump	15.0	10.9
Ductless Mini-Split	14.9	8.9
Electric Resistance	N/A	3.412

Default Savings

There are no default savings for this measure.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with

verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures Prepared for The New England State Program Working Group, http://library.cee1.org/content/measure-life-report-residential-and-commercialindustrial-lighting-and-hvac-measures . Measure life for insulation is 25 years. Note that PA Act 129 savings can be claimed for no more than 15 years, thus the 15 year measure life.
2) USDOE, Guide to Closing and Conditioning Ventilated Crawlspaces, http://www.nrel.gov/docs/fy13osti/54859.pdf
3) 2015 International Energy Conservation Code, Table R402.1.2: Insulation and Fenestration Requirements by Component. https://codes.iccsafe.org/content/IECC2015/chapter-4-re-residential-energy-efficiency
4) 2009 ASHRAE Fundamentals, Chapter 25 and 26. Method from "Total Thermal Resistance of a Flat Building Assembly" in Chapter 25. Values from Chapter 26: interior air film = 0.68, 7" concrete or CMU wall = 0.88, exterior air film = 0.17. Total= 1.73 *°F-ft^2-h/BTU*
5) ASHRAE Fundamentals Handbook, 1977. Adapted from Table 1, p. 24.4
6) ASHRAE Fundamentals Handbook, 2009. Adapted from Chapter 27, p. 27.4
7) Energy Center of Wisconsin, May 2008 metering study; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research", p31. http://cleanefficientenergy.org/resource/central-air-conditioning-wisconsin-compilation-recent-field-research
8) For all systems excluding ground source heat pumps: Pennsylvania Act 129 2018 Residential Baseline Study, http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-Phase3_Res_Baseline_Study_Rpt021219.pdf. Due to small sample size in residential baseline, the lowest efficiency options available in BEopt were chosen as defaults for ground source heat pumps.
9) "Home Energy Services Impact Evaluation", August 2012. Based on comparing algorithm derived savings estimate and evaluated bill analysis estimate. http://ma-eeac.org/wordpress/wp-content/uploads/Home-Energy-Services-Impact-Evaluation-Report_Part-of-the-Massachusetts-2011-Residential-Retrofit-and-Low-Income-Program-Area-Evaluation.pdf
10) Based on the Phase III SWE team's analysis of regional HVAC runtime data collected from ecobee's Donate Your Data research service. https://www.ecobee.com/donateyourdata/
11) VEIC estimate. Extrapolation of manufacturer data.
12) McQuay Application Guide 31-008, Geothermal Heat Pump Design Manual, 2002. Engineering Estimate - See System Performance of Ground Source Heat Pumps
13) PA SWE Team Calculations with data from the National Solar Radiation Database. 1991–2005 Update: Typical Meteorological Year 3. NREL. http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html

2.6.6 ENERGY STAR WINDOWS

Target Sector	Residential Establishments
Measure Unit	Window Area
Measure Life	(15 max, but 20 for TRC) years Source 1
Vintage	Retrofit

ELIGIBILITY

This protocol documents the energy savings for replacing existing windows in a residence with ENERGY STAR certified windows.

ALGORITHMS

$$\Delta kWh = \Delta kWh_{cool} + \Delta kWh_{heat}$$

$$\Delta kWh_{cool} = Area\ of\ Window\ ft^2 \times \frac{\eta_{proto}}{\eta_{base}} \times UES_{region,system}$$

$$\Delta kWh_{heat} = Area\ of\ Window\ ft^2 \times \frac{\eta_{proto}}{\eta_{base}} \times UES_{region,system}$$

$$\Delta kW = \frac{\Delta kWh_{cool}}{EFLH_{cool}} \times CF$$

DEFINITION OF TERMS

Table 2-129: Terms, Values, and References for ENERGY STAR Windows

Term	Unit	Value	Sources
$UES_{region,system}$, Climate region dependent electricity savings for efficient glazing	$\frac{kWh}{ft^2}$	See Table 2-130	2
η_{base} , Baseline equipment efficiency	varies	Measured, EDC Data Gathering Default: η_{proto}	
η_{proto} , Prototype equipment efficiency	varies	See Table 2-8 in Sec. 2.2	3
$EFLH_{cool}$, Equivalent Full Load Cooling hours	$\frac{hours}{year}$	See $EFLH_{cool}$ in Vol. 1, App. A	4
CF, Demand Coincidence Factor	*Proportion*	See *CF* in Vol. 1, App. A	4

Table 2-130: Default $UES_{region,system}$, kWh per Square Foot of Replaced Window

Reference City	Cooling				Heating				
	ASHP	Central AC	Mini-split	GSHP	ASHP	Electric Furnace	Base-board	Mini-split	GSHP
Allentown	0.66	1.50	0.59	0.57	2.86	3.40	3.12	2.10	0.95
Binghamton	0.46	0.65	0.47	0.36	4.50	4.60	4.28	3.56	1.27
Bradford	0.35	1.10	0.34	0.25	5.57	5.51	7.86	4.63	1.58
Erie	0.51	0.51	0.46	0.41	4.07	4.81	4.07	3.12	1.35
Harrisburg	0.75	0.82	0.73	0.66	2.84	3.91	3.17	2.40	1.06
Philadelphia	0.86	0.83	0.76	0.86	1.68	2.53	5.85	1.31	0.68
Pittsburgh	0.66	0.66	0.64	0.60	3.06	3.82	3.06	2.28	1.07
Scranton	0.59	0.68	0.57	0.50	3.36	3.83	3.55	2.58	1.06
Williamsport	0.65	0.46	0.61	0.58	2.99	3.47	5.08	2.19	0.96

Evaluation Protocols

The appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx. Accessed December 2018.

2) Based on modelling using BEopt v2.8.0 performed by NMR Group, Inc. Unit energy savings were calculated by modeling a prototypical Pennsylvania single family detached house with statewide average characteristics determined through the Pennsylvania Act 129 2018 Residential Baseline Study. Simulations for each equipment-climate region combination were performed for plain double-plane (0.49 U, 0.56 SHGC) and triple-pane ENERGY STAR (0.27 U, 0.26 SHGC) windows. The difference in heating and cooling loads were then apportioned evenly among the 322 square feet of windows in the prototype home yielding the UES values.

3) Pennsylvania Act 129 2018 Residential Baseline, http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-Phase3_Res_Baseline_Study_Rpt021219.pdf.

4) Based on the Phase III SWE team's analysis of regional HVAC runtime data collected from ecobee's Donate Your Data research service. https://www.ecobee.com/donateyourdata/

2.6.7 Residential Window Repair

Target Sector	Residential Establishments
Measure Unit	Per window repaired
Measure Life	15 years Source 1
Vintage	Retrofit

Most residential windows lose some heat to air leakage, which is typically measured in infiltration per window area (CFM/ft^2). In 2004, the National Fenestration Rating Council (NFRC) listed a range of typical air leakage rates from 0.06 CFM/ft^2 to 1.0 CFM/ft^2, though actual air leakage will vary based on the condition of individual windows. Windows with compression seals (e.g. casement and awning windows) can achieve lower infiltration rates than sliding windows with felt seals.[Source 2] Currently, the NFRC states that most windows now range between 0.1 and 0.3 CFM/ft^2. [Source 3]

Repairs to wooden windows are recommended to include the following as part of the repair:[Source 4]

- Remove the sashes by removing the interior stops and parting bead of the window frame.
- Clean the frames and sashes of any flaking paint or other coatings that may impede the proper installation of gaskets and seals.
- Caulk and seal the corners and joints in the window frame. This includes all joints between the sill and jambs as well as between the casings and frames.
- Cut grooves into the sashes where new gaskets will be installed.
- Prime and paint the window frames and sashes.
- Install new gaskets around the perimeter of the sashes. V-groove type gaskets will likely work the best at the jambs and meeting rails, while bubble gaskets work well at the head and sill interface.
- Reinstall the sashes, meeting rails, and interior stops.
- As part of the work, if the weight pockets are retained, clean and lubricate pulleys, replace the sash cords or chains, and balance the weights as part of the work.
- The weight and balance system could also be abandoned and replaces with a spring-loaded tape balance. The weight pockets can then be insulated and sealed, improving the overall thermal performance of the window frame-to-rough opening interface.

Eligibility

To be eligible, the window's weatherstripping must be repaired or replaced in addition to an assessment—and possible repair—of the condition of the window sash.

Algorithms

The annual energy savings are obtained through the following formula. Any cooling savings resulting from this measure are considered negligible. Since the estimated savings are based on heating, there is no anticipated impact on demand during the peak period (June through August, 2 p.m. to 6 p.m.).

$$\Delta kWh = \frac{N \times 1.08 \times CFM \times IRF \times OF \times HDD \times 24\frac{hr}{day}}{HSPF}$$

Definition of Terms

Table 2-131: Terms, Values, and References for Residential Window Repair

Term	Unit	Values	Source
N , Number of windows	Windows	EDC Data Gathering	-
1.08 , Conversion factor that converts CFM air (at 70°F) to BTU/hr-°F	$\frac{BTU \times min}{hr \times °F \times ft^3}$	1.08	-
CFM , Infiltration of existing window	*CFM*	See Table 2-132	5, 7*
IRF , Infiltration reduction factor	None	60%	6
OF , Orientation factor, relating the prevailing wind direction to building façade orientation	None	25%	5*
HDD , Heating degree-days	*°F-day*	See HDD in Vol. 1, App F.	-
$HSPF$, Heating system efficiency	$\frac{BTU}{W \cdot h}$	EDC Data Gathering Default: see Table 2-133	1

Commented [SA32]: Franklin Energy

The description below mentions sources 5, 6, 7 and 8. There is no source 8 though.

* Assumes a typical window size of 24 inches by 48 inches (8 ft^2), that a repaired window has a 1 in 4 chance of being on the windward face of a building at a given time, and based on "Only windows on windward elevations exhibit air infiltration at any one time."Source 6 The infiltration rates are provided in Source 6. The infiltration rates in Source 6 reflect infiltration at 1.56 lb/ft^2 (25 mph winds), which is higher than 10 mph average wind speed for Pennsylvania's heating season (estimated at October through March). According to Ensewiler's Formula (see below), at wind speeds of 10 mph the pressure difference across a window is 0.26 lb/ft^2. Using the the fact that 0.1 CFM/ft^2 at 6.24 lb/ft^2 is equivalent to 0.04 CFM/ft^2 at 1.56 lb/ft^2 (Source 6), and the relationship between flow rate and pressure from Source 7 the infiltration rates were extrapolated to the values tabulated above.

Commented [SA33]: Franklin Energy

Recommend moving this text below the first set of equations.

$$P = 0.00256 \times V^2$$

Where,

P = Pressure difference across window, lb/ft^2

V = Wind velocity, mph

Source 8 establishes the relationship between flow rate and pressure:

$$q = C \times \Delta P^n$$

Where,

q = Flow rate per unit area, CFM/ft^2

C = flow coefficient, CFM/ft^2 × (lb/ft^2)^n

ΔP = pressure difference across window

n = flow exponent

Commented [SA34]: Franklin Energy

There does not appear to be a source 8 listed.

Is this from ASHRAE Fundamentals 2017 Section 16 Ventilation and Infiltration eqn. (40)?

Commented [SA35]: Franklin Energy

Needs to be divided by instead of multiplied for units to make sense.

Table 2-132: Existing Infiltration Assumptions

Window Type	Infiltration Rate (CFM/ft^2)
Non-weatherstripped hung or sliding window	6.0
Weatherstripped hung or sliding window OR non-weatherstripped awning or casement windows	2.4
Weatherstripped awning or casement windows	1.2

Table 2-133: Default Heating System Efficiency

Type	HSPF
Air-Source Heat Pump	8.2
Ground-Source Heat Pump	12.28
Ductless Mini-Split	8.9
Electric Resistance	3.412

Default Savings

There are no default savings for this measure.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) Pennsylvania Act 129 2018 Residential Baseline Study, http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-Phase3_Res_Baseline_Study_Rpt021219.pdf.
2) Krigger, John and Dorsi, Chris. *Residential Energy*, 4th Edition. 2004.
3) The National Fenestration Rating Council, "The NFRC Label," http://www.nfrc.org/WindowRatings/The-NFRC-Label.html
4) Baker, P. *Measure Guideline: Wood Window Repair, Rehabilitation and Replacement.* December 2012. http://www.nrel.gov/docs/fy13osti/55219.pdf
5) Wausau Window and Wall Systems, "Air Infiltration Energy Usage," http://www.wausauwindow.com/index.cfm?pid=51&pageTitle=Air-Infiltration-Energy-Usage
6) James, Shapiro, Flanders and Hemenway, Testing the Energy Performance of Wood Windows in Cold Climates, August 30, 1996. http://ohp.parks.ca.gov/pages/1054/files/testing%20windows%20in%20cold%20climates.pdf
7) Shaw, C.Y. and Jones, L. Air Tightness and Air Infiltration of School Buildings, 1979. http://web.mit.edu/parmstr/Public/NRCan/nrcc18030.pdf

2.7 WHOLE HOME

2.7.1 RESIDENTIAL NEW CONSTRUCTION

Target Sector	Residential Establishments
Measure Unit	Multiple
Measure Life	Varies
Vintage	New Construction

ELIGIBILITY

This protocol documents the energy savings attributed to improvements to the construction of residential homes above the baseline home as calculated by the appropriate energy modeling software or as determined by deemed savings values.

Commented [SA36]: Franklin Energy

Above code standard

ALGORITHMS

Insulation Up-Grades, Efficient Windows, Air Sealing, Efficient HVAC Equipment and Duct Sealing (Weather-Sensitive Measures):

Energy and peak demand savings due to improvements in the above mentioned measures in Multifamily New Construction programs will be an output of an energy modeling package that compares the as-designed building to a minimally code-compliant baseline building. The baseline building thermal envelope and/or system characteristics shall be based on the current state adopted International Energy Conservation Code (IECC) 2015.[65]

Modeled energy and peak demand savings shall be produced by a RESNET accredited software program[66] or by other models approved by the PA SWE. The latter include the Passive House accreditation software packages (Passive House Planning Package[67] and WUFI Passive[68]), though both tools require the user to separately model the code baseline reference design to calculate energy and demand savings.

The energy savings for weather-sensitive measures will be calculated from the software output using the following algorithm:

Energy savings of the qualified home (kWh)

$$= (Heating\ kWh_{\ base} - \ Heating\ kWh_{ee}) + (Cooling\ kWh_{\ base} - Cooling\ kWh_{ee})$$

The system peak electric demand savings for weather-sensitive measures will be calculated from the software output with the following algorithm, which is based on compliance and certification of the energy efficient home to the EPA's ENERGY STAR for New Homes' program standard:

Commented [SA37]: Franklin Energy

Building modeling

Peak demand of the baseline home $= PL_{base} / EER_{base}$

Peak demand of the qualifying home $= PL_{ee} / EER_{ee}$

Coincident system peak electric demand savings
$= (Peak\ demand\ of\ the\ baseline\ home - Peak\ demand\ of\ the\ qualifying\ home)$

[65] International Code Council, Inc. (2015). 2015 International Energy Conservation Code. Retrieved from International Code Council: https://codes.iccsafe.org/content/IECC2015?site_type=public
[66] See the RESNET National Registry of Accredited Rating Software Programs for a complete listing: http://www.resnet.us/professional/programs/energy_rating_software
[67] http://www.passivehouseacademy.com/index.php/shop-us
[68] http://www.phius.org/software-resources/wufi-passive-and-other-modeling-tools/wufi-passive-3-0

Hot Water, Lighting, and Appliances (Non-Weather-Sensitive Measures):

Quantification of additional energy and peak demand savings due to the installation of high-efficiency electric water heaters, lighting and other appliances may be done using the chosen modeling software or using the TRM algorithms presented for these measures elsewhere in this volume of the Manual.

When using the TRM algorithms, and where the TRM algorithms involve deemed savings, e.g. lighting, the savings in the baseline and qualifying homes should be compared to determine the actual savings of the qualifying home above the baseline.

Commented [SA38]: Franklin Energy

Code standard

In instances where model parameters or inputs do not match TRM algorithm inputs, additional data collection is necessary to use the TRM algorithms. One such example is lighting, where some models require an input of percent of lighting fixtures that are energy efficient whereas the TRM requires exact fixture counts and wattages.

It is also possible to have increases in consumption or coincident peak demand instead of savings for some non-weather sensitive measures. For example, if the amount of efficient lighting in a new home is less than the amount assumed in the baseline, the home will have higher energy consumption and coincident peak demand for lighting, even though it still qualifies for the program.

Definition of Terms

A summary of the input values and their data sources follows:

Table 2-134: Terms, Values, and References for Residential New Construction

Term	Unit	Value	Sources
$Heating\ kWh_{base}$, Annual heating energy consumption of the baseline home, from software.	kWh	Software Calculated	1
$Heating\ kWh_{ee}$, Annual heating energy consumption of the qualifying home, from software.	kWh	Software Calculated	2
$Cooling\ kWh_{base}$, Annual cooling energy consumption of the baseline home, from software.	kWh	Software Calculated	1
$Cooling\ kWh_{ee}$, Annual cooling energy consumption of the qualifying home, from software.	kWh	Software Calculated	2
PL_{base}, Estimated peak cooling load of the baseline home, from software.	$kBTU/hr$	Software Calculated	3
EER_{base}, Energy Efficiency Ratio of the baseline unit.	$\frac{BTU}{W \cdot h}$	EDC Data Gathering Default: $-0.0228 \times SEER_{base}^2 + 1.1522 \times SEER_{base}$	4
EER_{ee}, Energy Efficiency Ratio of the qualifying unit.	$\frac{BTU}{W \cdot h}$	EDC Data Gathering Default: $-0.0228 \times SEER_{ee}^2 + 1.1522 \times SEER_{ee}$	4
$SEER_{base}$, Seasonal Energy Efficiency Ratio of the baseline unit.	$\frac{BTU}{W \cdot h}$	13 14 (ASHP)	8
$SEER_{ee}$, SEER associated with the HVAC system in the qualifying home.	$\frac{BTU}{W \cdot h}$	EDC Data Gathering	6
PL_q, Estimated peak cooling load for the qualifying home constructed, from software.	$kBTU/hr$	Software Calculated	5

The following table lists the building envelope characteristics of the baseline reference home based on 2015 IECC for the three climate zones in Pennsylvania.

Table 2-135: Baseline Insulation and Fenestration Requirements by Component (Equivalent U-Factors)Source 12

IECC Climate Zone	Fenestration U-Factor	Skylight U-Factor	Ceiling U-Factor	Frame Wall U-Factor	Mass Wall U-Factor	Floor U-Factor	Basement Wall U-Factor	Slab R-Value & Depth	Crawl Space Wall U-Factor
4A	0.35	0.55	0.026	0.060	0.098	0.047	0.059	10, 2 ft	0.065
5A	0.32	0.55	0.026	0.060	0.082	0.033	0.050	10, 2 ft	0.055
6A	0.32	0.55	0.026	0.060	0.060	0.033	0.050	10, 4 ft	0.055

Climate Region D and York County are CZ4, Climate Region A and G are CZ6, everything else is CZ5.

Table 2-136: Energy Star Homes - User Defined Reference Home

Data Point	Value	Source
Air Infiltration Rate	3 ACH_{50} for the whole house	7
Duct Leakage	4 CFM_{25} (4 cubic feet per minute per 100 square feet of conditioned space when tested at 25 pascals)	7
Duct Insulation	Supply and return ducts in attics shall be insulated to a minimum of R-8 where ≥3" in diameter and a minimum of R-6 where <3" in diameter. All other ducts not located completely inside the building thermal envelope shall be insulated to a minimum of R-6 where ≥3" in diameter and a minimum of R-4.2 where <3" in diameter.	7
Duct Location	50% in conditioned space, 50% unconditioned space	Program Design
Mechanical Ventilation	A continuous whole-house ventilation system with efficiency of 2.8 CFM/Watt and airflow defined by Table M1507.3.3(1) of 2015 IRC	11
Appliances	Use Default	
Thermostat Setback	Maintain zone temperature down to 55 ºF (13 ºC) or up to 85 ºF (29 ºC)	7
Temperature Set Points	Heating: 70°F Cooling: 78°F	7
Heating Efficiency		
Furnace	80% AFUE	8
Gas Fired Steam Boiler	82% AFUE	8
Gas Fired Hot Water Boiler	84% AFUE	8
Oil Fired Steam Boiler	85% AFUE	8
Oil Fired Hot Water Boiler	86% AFUE	8
Combo Water Heater	76% AFUE (recovery efficiency)	8
Air Source or Geothermal Heat Pump	8.2 HSPF	7
PTAC / PTHP	Use value for air source heat pump	7
Cooling Efficiency		

Data Point	Value	Source
Central Air Conditioning	13.0 SEER	7
Air Source Heat Pump	14.0 SEER	7
Geothermal Heat Pump	14 SEER (12.2 EER)	7
PTAC / PTHP	Use value for central AC	7
Window Air Conditioners	Use value for central AC	7
Domestic WH Efficiency		
Electric	≥20 gal and ≤55 gal: EF = 0.9307 - 0.0002×(V_s) >55 gal and ≤120 gal: EF = 2.1171 - 0.0011×(V_s)	9
Natural Gas	≥20 gal and ≤55 gal: EF = 0.6483 – (0.0017×V_s) >55 gal and ≤100 gal: EF = 0.7897 – (0.0004× V_s) V_s: Rated Storage Volume – the water storage capacity of a water heater (in gallons)	7
Additional Water Heater Tank Insulation	None	

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) Calculation of annual energy consumption of a baseline home from the home energy rating tool based on the reference home energy characteristics.
2) Calculation of annual energy consumption of an energy efficient home from the home energy rating tool based on the qualifying home energy characteristics
3) Calculation of peak load of baseline home from the home energy rating tool based on the reference home energy characteristics.
4) "Methodology for Calculating Cooling and Heating Energy Input-Ratio (EIR) from the Rated Seasonal Performance Eefficiency (SEER OR HSPF)" (Kim, Baltazar, Haberl). April 2013 Accessed December 2018. http://oaktrust.library.tamu.edu/bitstream/handle/1969.1/152118/ESL-TR-13-04-01.pdf
5) Calculation of peak load of energy efficient home from the home energy rating tool based on the qualifying home energy characteristics.
6) SEER of HVAC unit in energy efficient qualifying home.
7) 2015 International Energy Conservation Code §R401-R404. https://codes.iccsafe.org/content/IECC2015/chapter-4-re-residential-energy-efficiency
8) Electronic Code of Federal Regulations, 10 CFR Part 430, Subpart C, §430.32, "Energy Conservation Program for Consumer Products: Energy and Water Conservation Standards." https://www.ecfr.gov/cgi-bin/retrieveECFR?&n=pt10.3.430#se10.3.430_132. Current as of November 13, 2018.

9) US Federal Standards for Residential Water Heaters. Effective April 16, 2015. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/27

10) 2015 International Energy Conservation Code Table R402.1.4 Equivalent U-Factors presents the R-Value requirements of Table R402.1.2 in an equivalent U-Factor format. Users may choose to follow Table R402.1.2 instead. 2015 IECC supersedes this table in case of discrepancy. Additional requirements per §R402 of 2015 IECC must be followed even if not listed here. https://codes.iccsafe.org/content/IECC2015/chapter-4-re-residential-energy-efficiency

11) 2015 International Residential Code, Table M1507.3.3(1): Continuous Whole-House Mechanical Ventilation System Airflow Rate Requirements. https://codes.iccsafe.org/content/IRC2015/chapter-15-exhaust-systems

2.7.2 Home Performance with ENERGY STAR

Target Sector	Residential Establishments
Measure Unit	Multiple
Measure Life	Years
Vintage	Retrofit

In order to implement Home Performance with ENERGY STAR, there are various standards an Implementation Conservation Service Provider must adhere to in order to deliver the program. These standards, along with operational guidelines on how to navigate through the HPwES program can be found on the ENERGY STAR website. Minimum requirements, Sponsor requirements, reporting requirements, and descriptions of the performance and prescriptive based options can be found in the v. 1.5 Reference Manual.[69] The program implementer must use software that meets a national standard for savings calculations from whole-house approaches such as home performance. The software program implementer must adhere to at least one of the following standards:

- A software tool whose performance has passed testing according to the National Renewable Energy Laboratory's HERS BESTEST software energy simulation testing protocol.[70]
- Software approved by the US Department of Energy's Weatherization Assistance Program.[71]
- RESNET approved rating software.[72]

There are numerous software packages that comply with these standards. Some examples of the software packages are REM/Rate, EnergyGauge, TREAT, and HomeCheck. These examples are not meant to be an exhaustive list of software approved by the bodies mentioned above.

Eligibility

The efficient condition is the performance of the residential home as modeled in the approved software after home performance improvements have been made. The baseline condition is the same home modeled prior to any energy efficiency improvements.

Algorithms

There are no algorithms associated with this measure as the energy savings are shown through modeling software. For modeling software that provides 8760 energy consumption data, the following algorithm may be used as guidance to determine demand savings:

$$\Delta \boldsymbol{kW_{peak}} = \left(Average\ kW_{PJM\ PEAK}\right)_{base} - \left(Averae\ kW_{PJM\ PEAK}\right)_{ee}$$

69 The HPwES Reference Manual may be found at https://www.energystar.gov/ia/home_improvement/downloads/HPwES_Sponsor_Guide_v1-5.pdf

70 A new standard for BESTEST-EX for existing homes is currently being developed - status is found at http://www.nrel.gov/buildings/bestest_Ex.html. The existing 1995 standard can be found at http://www.nrel.gov/docs/legosti/fy96/7332a.pdf

71 A listing of the approved software available at http://www.waptac.org

72 A listing of the approved software available at http://resnet.us

Definition of Terms

Table 2-137: Terms, Values, and References for Home Performance with ENERGY STAR

Term	Unit	Values	Source
$Average\ kW_{PJM\ PEAK}$, Average demand during the PJM Peak Period	kW	EDC Data Gathering	1

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) The coincident summer peak period is defined as the period between the hour ending 15:00 Eastern Prevailing Time[73] (EPT) and the hour ending 18:00 EPT during all days from June 1 through August 31, inclusive, that is not a weekend or federal holiday[74].

[73] This is same as the Daylight Savings Time (DST)
[74] PJM Manual 18B for Energy Efficiency Measurement & Verification

2.7.3 Low-Rise Multifamily New Construction

Target Sector	Residential Low-Rise Multifamily Buildings
Measure Unit	Multiple
Measure Life	Varies
Vintage	New Construction

Eligibility

This protocol documents the energy savings attributed to improvements to the construction of low-rise multifamily residential buildings (≥3 dwelling units and <4 stories) above the baseline building as calculated by the appropriate energy modeling software or as determined by deemed savings values.

Algorithms

Insulation Up-Grades, Efficient Windows, Air Sealing, Efficient HVAC Equipment and Duct Sealing (Weather-Sensitive Measures):

Energy and peak demand savings due to improvements in the above mentioned measures in Multifamily New Construction programs will be an output of an energy modeling package that compares the as-designed building to a minimally code-compliant baseline building. The baseline building thermal envelope and/or system characteristics shall be based on the current state adopted International Energy Conservation Code (IECC) 2015.[75]

Modeled energy and peak demand savings shall be produced by a RESNET accredited software program[76] or by other models approved by the PA SWE. The latter include the Passive House accreditation software packages (Passive House Planning Package[77] and WUFI Passive[78]), though both tools require the user to separately model the code baseline reference design to calculate energy and demand savings.

The energy savings for weather-sensitive measures will be calculated from the software output using the following algorithm:

Energy savings of the qualified building (kWh)

$$= \left(Heating\ kWh_{\ base} - Heating\ kWh_{q}\right) + \left(Cooling\ kWh_{\ base} - \ Cooling\ kWh_{q}\right)$$

The system peak electric demand savings for weather-sensitive measures will be calculated from the software output with the following algorithm, which is based on compliance and certification of the energy efficient home to the EPA’s ENERGY STAR for New Homes’ program standard:

Peak demand of the baseline multifamily building

$$= \frac{PL_{base}}{EER_{base}}$$

[75] International Code Council, Inc. (2015). 2015 International Energy Conservation Code. Retrieved from International Code Council: https://codes.iccsafe.org/content/IECC2015?site_type=public
[76] See the RESNET National Registry of Accredited Rating Software Programs for a complete listing: http://www.resnet.us/professional/programs/energy_rating_software
[77] http://www.passivehouseacademy.com/index.php/shop-us
[78] http://www.phius.org/software-resources/wufi-passive-and-other-modeling-tools/wufi-passive-3-0

Peak demand of the as-designed multifamily building

$$= \frac{PL_q}{EER_q}$$

Coincident system peak electric demand savings

$$= (Peak\ demand\ of\ the\ baseline\ multifamily\ building - Peak\ demand\ of\ the\ as - designed\ multifamily\ building)$$

Hot Water, Lighting, and Appliances (Non-Weather-Sensitive Measures):

Quantification of additional energy and peak demand savings due to the installation of high-efficiency electric water heaters, lighting and other appliances may be done using the chosen modeling software or using the TRM algorithms presented for these measures elsewhere in this volume or Volume 3: Commercial and Industrial Measures, as applicable, of the Manual. As a rule of thumb, in-unit measures are generally considered residential, and common areas and central systems (e.g., commercial-grade hot water) are generally considered commercial.

When using the TRM algorithms, and where the TRM algorithms involve deemed savings, e.g. lighting, the savings in the baseline and qualifying homes should be compared to determine the actual savings of the qualifying home above the baseline.

In instances where model parameters or inputs do not match TRM algorithm inputs, additional data collection is necessary to use the TRM algorithms. One such example is lighting, where some models require an input of percent of lighting fixtures that are energy efficient whereas the TRM requires exact fixture counts and wattages.

It is also possible to have increases in consumption or coincident peak demand instead of savings for some non-weather sensitive measures. For example, if the amount of efficient lighting in a new home is less than the amount assumed in the baseline, the home will have higher energy consumption and coincident peak demand for lighting, even though it still qualifies for the program.

Definition of Terms

Table 2-138: Terms, Values, and References for Low-Rise Multifamily New Construction

Term	Unit	Value	Sources
$Heating\ kWh_{base}$, Annual heating energy consumption of the baseline building, from software.	kWh	Software Calculated	1
$Heating\ kWh_q$, Annual heating energy consumption of the as-designed building, from software.	kWh	Software Calculated	2
$Cooling\ kWh_{base}$, Annual cooling energy consumption of the baseline building, from software.	kWh	Software Calculated	1
$Cooling\ kWh_q$, Annual cooling energy consumption of the as-designed building, from software.	kWh	Software Calculated	2
PL_{base}, Estimated peak cooling load of the baseline building, from software.	$kBTU/hr$	Software Calculated	3
EER_{base}, Energy Efficiency Ratio of the baseline equipment.	$\frac{BTU}{W \cdot h}$	EDC Data Gathering Default: $-0.0228 \times SEER_{base}{}^2 + 1.1522 \times SEER_{base}$	4

EER_q, Energy Efficiency Ratio of the qualifying equipment.	$\frac{BTU}{W \cdot h}$	EDC Data Gathering Default: $-0.0228 \times SEER_{ee}^2 + 1.1522 \times SEER_{ee}$	4
$SEER_{base}$, Seasonal Energy Efficiency Ratio of the baseline equipment.	$\frac{BTU}{W \cdot h}$	13 14 (ASHP)	5
$SEER_q$, SEER associated with the HVAC system in the as-designed building.	$\frac{BTU}{W \cdot h}$	EDC Data Gathering	7
PL_q, Estimated peak cooling load for the as-designed building constructed, from software.	$kBTU/hr$	Software Calculated	6

EVALUATION PROTOCOLS

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

SOURCES

1) Calculation of annual energy consumption of a baseline building from the building energy model based on the reference building energy characteristics.
2) Calculation of annual energy consumption of an energy efficient building from the building energy model based on the as-designed building energy characteristics.
3) Calculation of peak load of baseline building from the building energy model based on the reference building energy characteristics.
4) "Methodology for Calculating Cooling and Heating Energy Input-Ratio (EIR) from the Rated Seasonal Performance Eefficiency (SEER OR HSPF)" (Kim, Baltazar, Haberl). April 2013 Accessed December 2018. http://oaktrust.library.tamu.edu/bitstream/handle/1969.1/152118/ESL-TR-13-04-01.pdf
5) Electronic Code of Federal Regulations, 10 CFR Part 430, Subpart C, §430.32, "Energy Conservation Program for Consumer Products: Energy and Water Conservation Standards." https://www.ecfr.gov/cgi-bin/retrieveECFR?&n=pt10.3.430#se10.3.430_132. Current as of November 13, 2018.
6) Calculation of peak load of energy efficient building from the building energy model based on the as-designed building energy characteristics.
7) SEER of HVAC unit in energy efficient as-designed building.

2.7.4 ENERGY STAR MANUFACTURED HOMES

Target Sector	Manufactured homes
Measure Unit	Variable
Measure Life	15 Years Source 14
Vintage	New Construction

ELIGIBILITY

This measure applies to ENERGY STAR Manufactured Homes.

ALGORITHMS

Insulation Upgrades, Efficient Windows, Air Sealing, Efficient HVAC Equipment and Duct Sealing (Weather-Sensitive Measures):

Energy and peak demand savings due to improvements in the above measures in ENERGY STAR Manufactured Homes programs will be a direct output of accredited Home Energy Ratings (HERS) software that meets the applicable Mortgage Industry National Home Energy Rating System Standards. REM/Rate[79] is cited here as an example of an accredited software which can be used to estimate savings for this program. REM/Rate has a module that compares the energy characteristics of the energy efficient home to the baseline/reference home and calculates savings. For ENERGY STAR Manufactured Homes, the baseline building thermal envelope and/or system characteristics shall be based on the current Manufactured Homes Construction and Safety Standards (HUD Code). For this measure a manufactured home "means a structure, transportable in one or more sections, which in the traveling mode, is eight body feet or more in width or forty body feet or more in length, or, when erected on site, is three hundred twenty or more square feet, and which is built on a permanent chassis and designed to be used as a dwelling with or without a permanent foundation when connected to the required utilities, and includes the plumbing, heating, air conditioning, and electrical systems contained therein."Source 14

The energy savings for weather-sensitive measures will be calculated from the software output using the following algorithm:

Energy savings of the qualified home (kWh/yr)

ΔkWh $= (Heating\ kWh_{base} - Heating\ kWh_{ee}) + (Cooling\ kWh_{base} - Cooling\ kWh_{ee})$

The system peak electric demand savings for weather-sensitive measures will be calculated from the software output with the following algorithm, which is based on compliance and certification of the energy efficient home to the EPA's ENERGY STAR Manufactured Home' program standard:

Peak demand of the baseline home

$$= \frac{PL_b}{EER_b}$$

Peak demand of the qualifying home

$$= \frac{PL_q}{EER_q}$$

Coincident system peak electric demand savings (kW)

$\Delta kW_{peak} = (Peak\ demand\ of\ the\ baseline\ home - Peak\ dmand\ of\ the\ qualifying\ home)$

[79] See the RESNET's National Registry of Accredited Rating Software Programs for a complete list: http://www.resnet.us/professional/programs/energy_rating_software.

Hot Water, Lighting, and Appliances (Non-Weather-Sensitive Measures):

Quantification of additional energy and peak demand savings due to the installation of high-efficiency electric water heaters, lighting and other appliances may be based either on direct output of accredited Home Energy Ratings (HERS) software that meets the applicable Mortgage Industry National Home Energy Rating System Standards or on the algorithms presented for these measures in Volume 2 (Residential Measures) of this Manual. Where the TRM algorithms involve deemed savings, e.g. lighting, the savings in the baseline and qualifying homes should be compared to determine the actual savings of the qualifying home above the baseline.

In instances where REM/Rate calculated parameters or model inputs do not match TRM algorithm inputs, additional data collection is necessary to use the TRM algorithms. One such example is lighting. REM/Rate requires an input of percent of lighting fixtures that are energy efficient whereas the TRM requires an exact fixture count. Another example is refrigerators, where REM/Rate requires projected kWh consumed and the TRM deems savings based on the type of refrigerator.

Definition of Terms

Table 2-139: ENERGY STAR Manufactured Homes– References

Term	Unit	Value	Sources
$Heating\ kWh_{base}$, Annual heating energy consumption of the baseline home	kWh	Software Calculated	1
$Heating\ kWh_{ee}$, Annual heating energy consumption of the qualifying home	kWh	Software Calculated	1
$Cooling\ kWh_{base}$, Annual cooling energy consumption of the baseline home	kWh	Software Calculated	1
$Cooling\ kWh_{ee}$, Annual cooling energy consumption of the qualifying home	kWh	Software Calculated	1
PL_b, Estimated peak cooling load of the baseline home	$kBTU/h$	Software Calculated	1
EER_b, Energy Efficiency Ratio of the baseline unit.	$\frac{BTU}{W \cdot h}$	EDC Data Gathering Default: $-0.0228 \times SEER_{base}{}^2 + 1.1522 \times SEER_{base}$	2
EER_q, Energy Efficiency Ratio of the qualifying unit.	$\frac{BTU}{W \cdot h}$	EDC Data Gathering Default: $-0.0228 \times SEER_{ee}{}^2 + 1.1522 \times SEER_{ee}$	2
$SEER_b$, Seasonal Energy Efficiency Ratio of the baseline unit.	$\frac{BTU}{W \cdot h}$	13 14 (ASHP)	3
$SEER_q$, SEER associated with the HVAC system in the qualifying home.	$\frac{BTU}{W \cdot h}$	EDC Data Gathering	4
PL_q, Estimated peak cooling load for the qualifying home constructed, in kBTU/hr, from software.	$kBTU/h$	Software Calculated	1

The HUD Code defines required insulation levels as an average envelope U_0 factor per zone. In Pennsylvania zone 3 requirements apply with a required U_0-factor of 0.079. This value cannot be directly used to define a baseline envelope R-values because the U_0-factor is dependent on both the size of the manufactured homes and insulating levels together. However because manufactured homes are typically built to standard dimensions baseline U-factors can be estimated with reasonable accuracy.

Figure 2-5: Uo Baseline Requirements[80]

The HUD Code required insulation levels can be expressed as a set of estimated envelope parameters to be used in REM/Rate's user defined reference home function. Using typical manufactured home sizes these values are expressed below along with federal standard baseline parameters below in Table 2-140.

Table 2-140: ENERGY STAR Manufactured Homes - User Defined Reference Home

Data Point	Value[81]	Source
Walls	U-factor 0.090	6, 7
Ceilings	U-factor 0.045	6, 7
Floor	U-factor 0.045	6, 7
Windows	U-factor 0.59	6, 7
Doors	U-factor 0.33	6, 7
Air Infiltration Rate	10 ACH50	6
Duct Leakage	RESNET/HERS default	6
Duct Insulation	RESNET/HERS default	6
Duct Location	Supply 100% manufactured home belly, Return 100% conditioned space	8
Mechanical Ventilation	0.035 CFM/ft^2 Exhaust	7
Lighting Systems	0% CFL 10% pin based (Default assumption)	9
Appliances	Use Default	6
Thermostat Setback	Non-Programmable thermostat	6
Temperature Set Points	Heating: 70°F Cooling: 78°F	10

[80] 24 CFR Part 3280-MANUFACTURED HOMES CONSTRUCTION AND SAFETY STANDARD (http://www.gpo.gov/fdsys/pkg/CFR-2013-title24-vol5/pdf/CFR-2013-title24-vol5-part3280.pdf)
[81] Single and multiple family as noted.

Data Point	Value[81]	Source
Heating Efficiency		
Furnace	80% AFUE	3
Gas Fired Steam Boiler	82% AFUE	3
Gas Fired Hot Water Boiler	84% AFUE	3
Oil Fired Steam Boiler	85% AFUE	3
Oil Fired Hot Water Boiler	86% AFUE	3
Combo Water Heater	76% AFUE (recovery efficiency)	3
Electric Resistance	3.412 HSPF	7
Cooling Efficiency		
Central Air Conditioning	13.0 SEER	3
Air Source Heat Pump	14.0 SEER	3
Geothermal Heat Pump	14 SEER (12.2 EER)	3
PTAC / PTHP	Use value for central AC	3
Window Air Conditioners	Use value for central AC	3
Domestic WH Efficiency		
Electric	≥20 gal and ≤55 gal: $EF = 0.9307 - 0.0002 \times (V_s)$ >55 gal and ≤120 gal: $EF = 2.1171 - 0.0011 \times (V_s)$	11
Natural Gas	≥20 gal and ≤55 gal: $EF = 0.6483 – (0.0017 \times V_s)$ >55 gal and ≤100 gal: $EF = 0.7897 – (0.0004 \times V_s)$ V_s: Rated Storage Volume – the water storage capacity of a water heater (in gallons)	12
Additional Water Heater Tank Insulation	None	13

Evaluation Protocols

The most appropriate evaluation protocol for this measure is verification of installation coupled with EDC data gathering.

Sources

1) Calculation of annual energy and peak load consumption of a baseline home from the home energy rating tool based on the reference home energy characteristics.
2) "Methodology for Calculating Cooling and Heating Energy Input-Ratio (EIR) from the Rated Seasonal Performance Eefficiency (SEER OR HSPF)" (Kim, Baltazar, Haberl). April 2013 Accessed December 2018. http://oaktrust.library.tamu.edu/bitstream/handle/1969.1/152118/ESL-TR-13-04-01.pdf
3) Electronic Code of Federal Regulations, 10 CFR Part 430, Subpart C, §430.32, "Energy Conservation Program for Consumer Products: Energy and Water Conservation Standards." https://www.ecfr.gov/cgi-bin/retrieveECFR?&n=pt10.3.430#se10.3.430_132. Current as of November 13, 2018.

4) SEER of HVAC unit in energy efficient qualifying home.

5) Straub, Mary and Switzer, Sheldon. "Using Available Information for Efficient Evaluation of Demand Side Management Programs". Study by BG&E. The Electricity Journal. Aug/Sept, 2011. p. 95. http://www.sciencedirect.com/science/article/pii/S1040619011001941

6) ENERGY STAR QUALIFIED MANUFACTURED HOMES-Guide for Retailers with instructions for installers and HVAC contractors / June 2007 / (http://www.research-alliance.org/pages/es_retail.htm)

7) Electronic Code of Federal Regulations, 24 CFR Part 3280, Manufactured Home Construction and Safety Standards. https://www.ecfr.gov/cgi-bin/retrieveECFR?&n=pt24.5.3280 Accessed November 16, 2018.

8) Standard manufactured home construction

9) Not a requirement of the HUD Code.

10) 2015 International Energy Conservation Code §R401-R404.

11) US Federal Standards for Residential Water Heaters. Effective April 16, 2015. For a 40-gallon tank this is 0.948. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/27

12) US Federal Standards for Residential Water Heaters. Effective April 16, 2015. For a 40-gallon tank this is 0.615 http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/27

13) No requirement in code or federal regulation.

14) NREL, Northwest Energy Efficient Manufactured Housing Program Specification Development, T.Huges, B. Peeks February 2013. http://www.nrel.gov/docs/fy13osti/56761.pdf

2.7.5 Home Energy Reports

Target Sector	Residential Establishments
Measure Unit	Household
Measure Life	Specified in protocol
Vintage	Retrofit

Commented [SA39]: Franklin Energy

This is not immediately clear. It looks like Year 1 treatment has 1 year life and year 2 has 3 year life with decay?

Home Energy Report (HER) programs encourage conservation through greater awareness of consumption patterns and engagement with EDC resources to help reduce usage and lower bills. HER program vendors provide participants with account-specific information that allows customers to view various aspects of their energy use over time. Behavioral reports compare energy use of recipient homes with clusters of similar homes and businesses and provide comparisons with other efficient and average homes. This so-called "neighbor" comparison is believed to create cognitive dissonance in participants and spur them to modify their behavior to be more efficient. Reports also include a variety of seasonally appropriate energy-saving tips that are tailored for the home and are often used to promote other EDC program offerings. Historically, HERs have been largely issued on paper via the USPS, but EDCs and their vendors are increasingly moving toward email reports and digital portals to promote increased engagement and conserve resources. This protocol applies to residential HER programs regardless of delivery mode.

A growing list of evaluation studies, including analyses of HER persistence by the Phase II and Phase III Pennsylvania Statewide Evaluation team, have observed energy savings among HER recipient households for two years after HER exposure was discontinued. The persistence of HER savings has implications for calculation of first-year energy savings and cost-effectiveness. This protocol provides guidance to EDCs and their evaluation contractors for calculating first-year incremental savings and lifetime savings from HER programs using a multi-year measure life with "decay" perspective. This multi-year persistence perspective is a departure from prior phases of Act 129, which assumed a 1-year measure life for HER programs.

Because Act 129 goals are based on first-year incremental savings, accounting for persistence will yield reduced first-year compliance savings from EDC programs that continue to expose the same homes to HER messaging year after year. However, the multi-year perspective will improve the cost-effectiveness of new cohorts of HER recipients compared to a 1-year measure life assumption.

Commented [SA40]: Franklin Energy

At what point through the multi-year program are you applying a measure life impact? If you apply first year savings in Yr 1 and essentially in Yr 2 is Year 2 life savings get calculated for lifesaving with the accumulative, but decaying impact for savings?

If you were to continue treatment for year 4 is the savings claim increase because the decay from year 2 continues or it is then based on decay from year 3 treatment savings. Please clarify.

The core assumption in this protocol is an annual decay rate of 31.3%. To illustrate the concept of decay consider a hypothetical cohort of 20,000 treatment group homes that have been receiving HERs for two years. Table 2-141 shows the average kWh savings per treatment group home by year as measured through a billing analysis of the randomized control trial design.

Table 2-141: Home Energy Report Persistence Example

Year	Avg. kWh Savings per Home
1	150
2	200

For Year 3, the EDC can choose to either continue issuing HERs to the treatment group homes or stop treating them. If the EDC stops issuing HERs to the treatment group in Year 3, little or no cost will be incurred. If the EDC continues issuing HERs to the treatment group in Year 3, a full year of program delivery costs will be incurred. The key question is "what are the incremental energy savings associated with the decision to mail HERs in Year 3?" Table 2-142 shows the components of this calculation.

Table 2-142: Calculation of Avoided Decay and Incremental Annual Compliance Savings

Year	Avg. kWh Savings per Home	Avg. kWh Savings Absent Year 3 Treatment	Avg. kWh Savings with Year 3 Treatment
1	150		
2	200		
3		200×(1-0.313/2) = 168.7	210

In this hypothetical example the incremental first-year savings achieved by the HER program in Year 3 is 41.3 kWh (210 – 168.7). This is the sum of two separate factors.

- **Avoided Decay** = 31.3 kWh. The avoided decay is the difference between the Year 2 savings and the assumed annual rate of decay. Because the decay rate is assumed to be linear the average amount of decay over the year is equal to half of the decay at the end of the year. The 168.7 kWh value in Table 2-142 is an estimate of what would have happened absent any further program effort. Some kWh savings persist, but at a lower rate than observed in Year 2, when households were actively receiving HER messaging. By continuing to issue HERs in Year 3, the EDC avoids this savings decay.
- **Change in the Average Treatment Effect** = 10 kWh. The "Avg. kWh Savings with Year 3 Treatment" column of Table 2-142 shows an average kWh savings value of 210 kWh per household. This is an increase of 10 kWh over the Year 2 measurement of 200 kWh per household. Many HER programs show growth in the average rate of savings over time as participants continue to respond to the messaging. This component of the calculation of the calculation could also be negative if the Year 3 savings measurement was smaller than the Year 2 measurement. HER savings can fluctuate based on weather and the measurement is inherently noisy because of the small effect size.

The following algorithms and default assumptions provide guidance on calculating and reporting compliance savings from HER programs in Phase IV of Act 129. Several assumptions that straddle technical and policy considerations are listed below.

1) The change in perspective from a 1-year EUL to a multi-year with decay approach creates an issue of unaccounted for lifetime savings from Phase III HER programs. Specifically, HER cohorts that were active in PY12 will be assumed to have persistent savings in PY13 even though persistent savings were not accounted for in Phase III TRC calculations. This is unavoidable with a change in accounting methods and best handled at the beginning of a Phase IV. It has no bearing on Phase III compliance savings.

2) The assumed annual rate of decay for Act 129 HER programs is based on an analysis of mature programs where treatment group homes received HER messaging for multiple years. Studies have also consistently shown that it takes time for HER savings to mature. For Phase IV of Act 129, new HER cohorts will continue to assume a 1-year EUL during the first year of HER exposure. The persistence and decay assumptions outlined in this protocol will take effect for Year 2 of exposure. Years of exposure are mapped to Act 129 program years. If a cohort begins receiving HER messaging in December (halfway through the program year), that program year is still Year 1, and the following program year is Year 2 with regard to application of persistence assumptions.

3) The Phase IV HER accounting methodology may lead EDCs to modify their historic HER delivery approach of treating the same homes year after year. Doing so would lead to diminished cost-effectiveness in Year 3 and beyond. EDCs may instead organize their EE&C plans to 'rotate' through eligible households. Act 129 HER programs should always be delivered as a randomized control trial (RCT), but EDCs have significant flexilbility in designing

new HER cohorts. New cohorts can be composed of a mix of past HER recipients and control group homes or non-recipients. Randomization should ensure a balanced mix across the new treatment and control group and the billing analysis will capture the savings associated with exposing the new treatment group to HERs, but not the control group. When a new cohort is created, accounting always begins at Year 1, even if some of the treatment and control group homes have received HER messaging previously.

4) Over time, households close their EDC accounts. The most common reason is because the occupant is moving, but other possibilities exist. This account "churn" happens at a fairly predictable rate for an EDC service territory and can be forecasted with some degree of certainty. Calculating persistent HER savings in future program years requires both an assumption of the savings decay rate and an assumption of the churn rate.

Algorithms

The equations for incremental first-year savings from HER programs are:

Year 1 and 2 of HER Exposure:

$$\Delta kWh_Y = ATE * Treatment\ Accounts * Days$$

If an EDC elects to treat an HER cohort for a 3rd year or beyond the equation for incremental first-year savings is:

Year 3 and Beyond of HER Exposure:

$$\Delta kWh_Y = \left(ATE - ATE_{Y-1} * \left(1 - \frac{Decay}{2}\right)\right) * Treatment\ Accounts * Days$$

The equations for calculating lifetime savings from a program year of HER exposure are given below. For Year 1, the lifetime savings are equal to the first-year savings. For the Year 2 and beyond of HER exposure the lifetime savings include both the savings measured at the meter via billing analysis and persistent savings from future program years. The equations below do not include the discount rate, but EDC evaluation contractors should use an approved discount rate to calculate the net present value of future savings when performing the TRC test.

Year 1 of HER Exposure:

$$\Delta kWh_{lifetime} = ATE * Treatment\ Accounts * Days$$

Year 2 and Beyond of HER Exposure:

$$\Delta kWh_{lifetime} = \Delta kWh_Y + \sum_{X=1}^{X=3} \Delta kWh_Y * \left(\left(1 - Decay * (x - 0.5)\right) * (1 - Churn)^x\right)$$

Definition of Terms

Table 2-143: Terms, Values, and References for HER Persistence Protocol

Parameter	Unit	Value	Source
ΔkWh_Y, kWh savings per home in the program year being evaluated	*Total Incremental Annual kWh Savings of an HER cohort*	EDC Data Gathering	EDC Data Gathering
ATE, Average Treatment Effect	*kWh/day per household*	EDC Data Gathering	EDC Data Gathering

Treatment Accounts, number of active homes in the treatment group	*Households (EDC account number)*	EDC Data Gathering	EDC Data Gathering
Days, average number of post-treatment days in the analysis period per household	*Days*	EDC Data Gathering	EDC Data Gathering
Decay, Annual rate of decay of the HER effect when exposure is discontinued	-	31.3%	1
Churn, Average annual reduction in participating households due to account closures, move-out etc.	-	Default: 6% EDC Data Gathering	2

Evaluation Protocols

This protocol deals with the measure life and persistence aspects of HER programs. Chapter 6.1 of the Pennsylvania Evaluation Framework provides detailed guidance on other aspects of HER evaluation protocols.

Sources

1) Pennsylvania Statewide Evaluation Team. Residential Behavioral Program Persistence Study. http://www.puc.state.pa.us/Electric/pdf/Act129/SWE_Res_Behavioral_Program-Persistence_Study_Addendum2018.pdf
2) SWE Analysis of average annual churn rate among Phase III EDC cohorts.

2.8 MISCELLANEOUS

2.8.1 VARIABLE SPEED POOL PUMPS

Target Sector	Residential Establishments
Measure Unit	VFD Pool Pumps
Measure Life	10 years Source 4
Vintage	Replace on Burnout

In this measure a variable speed pool pump must be purchased and installed on a residential pool to replace an existing constant speed pool pump. Residential variable frequency drive pool pumps can be adjusted so that the minimal required flow is achieved for each application. Reducing the flow rate results in significant energy savings because pump power and pump energy usage scale with the cubic and quadratic powers of the flow rate respectively. Additional savings are achieved because the VSD pool pumps typically employ premium efficiency motors.

ELIGIBILITY

To qualify for this rebate a variable speed pool pump must be purchased and installed on a residential pool to replace an existing constant speed pool pump.

ALGORITHMS

This protocol documents the energy savings attributed to variable frequency drive pool pumps in various pool sizes. The target sector primarily consists of single-family residences. There are no demand savings for this measure.

$\Delta kWh \quad = kWh_{base} - kWh_{VFD}$

$kWh_{base} \quad = HOU_{ss} \times kW_{ss} \times Days$

$kWh_{VFD} \quad = \left[\left(HOU_{VFD,clean} \times kW_{VFD,clean}\right) + \left(HOU_{VFD,filter} \times kW_{VFD,filter}\right)\right] \times Days$

$\Delta kW \quad = \left(kW_{ss} - {kWh_{VFD}}\big/\left(\left(HOU_{VFD,clean} + HOU_{VFD,filter}\right) \times Days\right)\right) \times CF$

DEFINITION OF TERMS

Table 2-144: Terms, Values, and References for Variable Speed Pool Pumps

Term	Unit	Values	Source
HOU_{SS}, Hours of operation per day for Single Speed Pump. This quantity should be recorded by the applicant.	$\frac{hours}{day}$	EDC Data Gathering Default = 11.4	2
$HOU_{VFD,filter}$, Hours of operation per day for Variable Frequency Drive Pump on filtration mode.	$\frac{hours}{day}$	EDC Data Gathering Default = 10.0	2
$HOU_{VFD,clean}$, Hours of operation per day for Variable Frequency Drive Pump on cleaning mode.	$\frac{hours}{day}$	EDC Data Gathering Default = 2.0	2

Term	Unit	Values	Source
Days , Pool pump days of operation per year.	$\frac{days}{yr}$	122	2
kW_{SS} , Electric demand of single speed pump at a given flow rate. This quantity should be recorded by the applicant or looked up through the horsepower in Table 2-145.	*Kilowatts*	EDC Data Gathering Default =1.364 kW or See Table 2-145	1 or Table 2-145
$kW_{VFD,\ filter}$, Electric demand of variable frequency drive pump during filtration mode.	*Kilowatts*	EDC Data Gathering Default = 0.25	2
$kW_{VFD,\ clean}$, Electric demand of variable frequency drive pump during cleaning mode.	*Kilowatts*	EDC Data Gathering Default = 0.75	2
CF, Coincidence factor	None	EDC Data Gathering Default = 0.31	4

Average Single Speed Pump Electric Demand

Since this measure involves functional pool pumps, actual measurements of pump demand are encouraged. If this is not possible, then the pool pump power can be inferred from the nameplate horsepower. Table 2-145 shows the average service factor (over-sizing factor), motor efficiency, and electrical power demand per pump size based on California Energy Commission (CEC) appliance database for single speed pool pump.[Source 1] Note that the power to horsepower ratios appear high because many pumps, in particular those under 2 HP, have high 'service factors'. The true motor capacity is the product of the nameplate horsepower and the service factor.

Table 2-145: Single Speed Pool Pump Specification[82]

Pump Horse Power (HP)	Average Pump Service Factor	Average Pump Motor Efficiency	Average Pump Power (kW)
0.50	1.62	0.66	0.946
0.75	1.29	0.65	1.081
1.00	1.28	0.70	1.306
1.50	1.19	0.75	1.512
2.00	1.20	0.78	2.040
2.50	1.11	0.77	2.182
3.00	1.21	0.79	2.666

Electric Demand and Pump Flow Rate

The electric demand on a pump is related to pump flow rate, pool hydraulic properties, and the pump motor efficiency. For VFD pumps that have premium efficiency (92%) motors, a regression is used to relate electric demand and pump flow rates using the data from Southern California

[82] Averaged for all listed single-speed pumps in the last available version of the CEC appliance efficiency database. The powers are for 'CEC Curve A' which represents hydraulic properties of 2" PVC pipes rather than older, 1.5" copper pipes.

Edison's Innovative Designs for Energy Efficiency (InDEE) Program. This regression reflects the hydraulic properties of pools that are retrofitted with VSD pool pumps. The regression is:

Demand (W) $= 0.0978f^2 + 10.989f + 10.281$

Where f is the pump flow rate in gallons per minute. This regression can be used if the flow rate is known but the wattage is unknown. However, most VFD pool pumps can display instantaneous flow and power.

Default Savings

Default energy and demand savings are as follows:

ΔkWh = 1,409 kWh

ΔkW = 0.3195 kW

Evaluation Protocol

The most appropriate evaluation protocol for this measure is verification of installation coupled with survey on run time and speed settings. It may be helpful to work with pool service professionals in addition to surveying customers to obtain pump settings, as some customers may not be comfortable operating their pump controls. Working with a pool service professional may enable the evaluator to obtain more data points and more accurate data.

Sources

1) "CEC Appliances Database – Pool Pumps." *California Energy Commission.* Updated Feb 2008. Accessed March 2008. http://www.energy.ca.gov/appliances/database/historical_excel_files/2009-03-01_excel_based_files/Pool_Products/Pool_Pumps.zip
2) ENERGY STAR Pool Pump Calculator. Updated December 2013. kW values are derived from gallons/minute and Energy Factor (gallons/Wh) for each speed. Days of operation are for Pennsylvania (4 months/yr). https://www.energystar.gov/sites/default/files/asset/document/Pool%20Pump%20Calculator.xlsx
3) California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx . Accessed December 2018.
4) Derived from values for 2pm-6pm for all pool pumps in Pool Pump and Demand Response Potential, DR 07.01 Report, SCE Design and Engineering, Table 16. https://www.etcc-ca.com/sites/default/files/reports/dr07_01_pool_pump_demand_response_potential_report.pdf

2.9 Demand Response

The primary focus of this section of the TRM is to provide technical guidance for estimating the load impacts of demand response programs. The methods discussed are aimed at providing accurate estimates of the true load impacts at the program level. EDCs and CSPs may use alternate methods for quarterly reporting of ex ante impacts or to calculate financial settlements with participating customers, but the methods detailed in the TRM should be used to verify achievement of Phase IV demand reduction targets. In some instances, the analysis may be carried out at the individual customer level, however, the outcome of interest is the aggregate load reduction (MW) that is caused by the program.

2.9.1 Direct Load Control and Behavior-Based Demand Response Programs

Target Sector	Residential Establishments
Measure Unit	N/A
Measure Life	10 years
Measure Vintage	N/A

The protocols for Act 129 covering Direct Load Control (DLC) and Behavior-Based demand response programs are intended to give guidance to the EDCs when dispatching and evaluating the load impacts of an event over the course of Phase IV. In these programs, residential and small commercial customers either allow EDCs to remotely reduce equipment run time during peak hours (DLC programs) or reduce their loads voluntarily in response to a combination of incentive payments, messaging and/or other behavioral stimuli.

Behavior-based demand response programs are ones that have a goal of reducing electric load during peak load hours. Examples of behavior-based demand response programs include utility programs that request customers to reduce electric loads during peak load hours voluntarily, programs where customers are provided with real-time information on the cost of electricity and can then take action voluntarily to reduce electric loads during high cost hours and other similar information programs. For purposes of the Pennsylvania TRM, behavior-based demand response programs do not include utility information programs that are based on consumer education or marketing and have a goal of reducing electricity use on a year round basis, including non-peak load hours.

For DLC programs, the participants may elect to receive incentive payments for allowing a signaled device to control or limit the power draw of certain HVAC, electric water heating, or swimming pool pump equipment at a participant's home, contributing to the reduction of peak demand. For measurement purposes, peak demand reductions are defined as the difference between a customer's actual (measured) electricity demand, and an estimate of the amount of electricity the customer would have demanded in the absence of the program incentive. The estimate of this counterfactual outcome is referred to as the reference load throughout this protocol.

EDCs must use one of the evaluation approaches below when estimating peak period load reductions that result from DLC and behavior-based programs. The approaches are not equivalent in terms of their ability to produce accurate and robust results and are therefore listed in descending order of desirability. Because of these differences in performance, EDCs shall use Option 2 only under circumstances when Option 1 is infeasible and shall similarly use Option 3 only under circumstances where both Option 1 and Option 2 are infeasible. In situations where Option 1 and/or 2 are not utilized, justification(s) must be provided by the EDC. EDCs with interval meter data available should use it to estimate load impacts. For DLC and behavior-based programs where advanced metering infrastructure (AMI) data is not available for all participants, estimates based on a sample of metered homes is permissible at the discretion of the SWE.

1) An analysis based on an experimental design that makes appropriate use of random assignment so that the reference load is estimated using a representative control group of program participants.[83] The most common type of design satisfying this criteria is a randomized control trial (RCT), but other designs may also be used. The specific design used can be selected by the EDC evaluation contractor based on their professional experience. It is important to note that experimental approaches to evaluation generally require the ability to call events at the individual device level. An operations strategy must be determined ahead of time in order to ensure that an appropriate control group is available for the analysis.
2) A comparison group analysis where the loads of a group of non-participating customers that are similar to participating homes with respect to observable characteristics (e.g. electricity consumption) are used to estimate the reference load. A variety of matching techniques are available and the EDC evaluation contractor can choose the technique used to select the comparison group based on their professional judgment. If events are most likely to be called on hot days, hot non-event days should be used for statistical matching and very cool days should be excluded.[84] A good match will result in the loads of treatment and comparison group being virtually identical on non-event days. Difference-in-differences estimators should be used in the analysis to control for any remaining non-event day differences after matching.
3) A 'within-subjects' analysis where the loads of participating customers on non-event days[85] are used to estimate the reference load. This can be accomplished via a regression equation that relates loads to temperature and other variables that influence usage. The regression model should be estimated using hot days that would be similar to an event. Including cooler days in the model can degrade accuracy because it puts more pressure on accurately modeling the relationship between weather and load across a broad temperature spectrum, which is hard because the relationship is not linear. Reducing the estimating sample to relevant days reduces that modeling challenge, or a 'day-matching' technique with a day-of or weather adjustment to account for the more extreme conditions in place on event days. The weather conditions in place at the time of the event are always used to claim savings. Weather-normalized or extrapolation of impacts to other weather conditions is not permitted.

ELIGIBILITY

In order to be eligible for the direct load control program, a customer must have a signaled device used to control the operability of the equipment specified to be called upon during an event. All residential and small commercial customers are eligible to participate in the behavior-based program.

ALGORITHMS

The specific algorithms(s) used to estimate the demand impacts caused by DLC and behavior-based programs will depend on the specific method of evaluation used. In general, regression-

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[83] For discussion on the rationale of random assignment, see Shadish, et al. (*Experimental and quasi-experimental designs for generalized causal inference*, 2002), Khandker, et al. (*Handbook on impact evaluation: quantitative methods and practices*. World Bank Publications, 2010) and Todd, et al. (Evaluation, measurement and verification (EM&V) of residential behavior-based energy efficiency programs: issues and recommendations, 2012). More detailed technical discussions of the core evaluation issues and Options 1-3 are provided in the Phase III Evaluation Framework.

[84] Though including some amount of variability in temperatures is necessary for identifying the relationship between temperature and load, including too broad a spectrum of temperatures can reduce modeling accuracy due to the non-linear relationship between the variables. Focusing on hot, event-like days helps to isolate a linear piece of the relationship and enhances the ability of the model to predict accurately.

[85] Either Act 129 or PJM

based estimates are most preferred, due to their ability to produce more precise impact estimates and quantitative measures of uncertainty. Details on specific types of equations that can be used for each evaluation approach are provided in the Pennsylvania Evaluation Framework.

Annual peak demand savings must be estimated using individual customer data (e.g. account, meter, or site as defined by program rules) regardless of which evaluation method is used. Program savings are the sum of the load impacts across all participants. Equations 1 and 2 provide mathematical definitions of the average peak period load impact estimate that would be calculated using an approved method.

$$\Delta kW_{peak} = \frac{\sum_{i=1}^{n} \Delta kW_i}{n} \quad (1)$$

$$\Delta kW_i = kW_{Reference_i} - kW_{Metered_i} \quad (2)$$

Definition of Terms

Table 2-2: Definition of Terms for Estimating DLC and Behavior-based Load Impacts

Term	Unit	Values	Source
n, Number of DR hours during a program year for the EDC	*Hours*	EDC Data Gathering	EDC Data Gathering
ΔkW_i, Estimated load impact achieved by an LC participant in hour i. This term can be positive (a load reduction) or negative (a load increase).	*kW*	EDC Data Gathering	EDC Data Gathering
$kW_{Reference_i}$, Estimated customer load absent DR during hour i	*kW*	EDC Data Gathering	EDC Data Gathering
$kW_{Metered_i}$, Measured customer load during hour i	*kW*	EDC Data Gathering	EDC Data Gathering

Default Savings

Default savings are not available for DLC or behavior-based programs.

Evaluation Protocols and Required Reporting

Technical details of the evaluation protocols for Direct Load Control measures and Behavior-based DR programs are described in the Pennsylvania Evaluation Framework. The end result of following the protocols will be a common set of outputs that allow for an “apples-to-apples” comparison of load impacts across different DR resource options, event conditions and time. These outputs are designed to ensure that the documentation of methods and results allows knowledgeable reviewers to judge the quality and validity of the impact estimates.

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PENNSYLVANIA PUC
PUBLIC UTILITY COMMISSION

TECHNICAL REFERENCE MANUAL

Volume 3:
Commercial and Industrial Measures

State of Pennsylvania

Act 129 Energy Efficiency and Conservation Program

&

Act 213 Alternative Energy Portfolio Standards

April 2019

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3 COMMERCIAL AND INDUSTRIAL MEASURES

The following section of the TRM contains savings protocols for commercial and industrial measures.

3.1 LIGHTING

3.1.1 LIGHTING IMPROVEMENTS

Target Sector	Commercial and Industrial Establishments
Measure Unit	Lighting Equipment
Measure Life	New Linear Fluorescent Fixture: 15 years Lamp Only: LED, Screw-in: 15 years Lamp Only: Induction Lamps: 6 years Lamp Only: Metal Halide Lamps: 6 years Lamp Only: High Pressure Sodium Lamps: 12 years Lamp Only: Mercury Vapor Lamps: 6 years Lamp Only: T8 Lamps: 10 years Lamp Only: LED, Linear, Type A: 5 years Lamp Only: LED, Linear, Type B: 15 years Lamp Only: LED, Linear, Type C: 15 years Permanent Fixture Removal: 13 years Permanent Lamp Removal: 11 years Source 1
Measure Vintage	Early Replacement or Permanent Removal

ELIGIBILITY

Lighting improvements include fixture or lamp and ballast replacement and/or permanent removal in existing commercial and industrial customers' facilities.[86] Installed and removed lamps and fixtures are broken down into two distinct types based on common load shapes: Screw-based and Other General Service. Screw-based bulbs consist of self-ballasted incandescent, halogen, CFL, and LED bulbs; Other General Service Lighting consists of all other fixture and lamp types, including but not limited to linear fluorescents, metal halides, high intensity discharge lamps, and hardwired/pin-based CFLs and LEDs.

To be eligible for savings from permanent fixture and lamp removal, customer must have permanently removed unneeded, functional light fixtures, lamps, lamp holders, and/or ballasts in accordance with local regulations. The removal of non-operational equipment is not eligible for the defined savings.

Permanent lamp removal includes the permanent removal of existing 8', 4', 3' and 2' T8 fluorescent lamps. The savings are defined on a per-removed-lamp basis and don't include savings from lamp replacements.

[86] Permanent fixture and lamp removal savings do not include replacements. Customers are responsible for determining whether permanent fixture and/or lamp removal will maintain or exceed minimum lighting requirements. Recommended light levels are provided by the Illuminating Engineering Society of North America (IESNA).

Note that the Energy Policy Act of 2005 ("EPACT 2005") and Energy Independence and Security Act ("EISA") 2007, and subsequent federal rulemakings, introduced new efficacy standards for linear fluorescent bulbs and ballasts, effectively phasing out magnetic ballasts (effective October 1, 2010) and most T-12 bulbs (effective July 14, 2012). This induced a shift in what a participant would have purchased in the absence of the program because T-12 bulbs on magnetic ballasts are no longer viable options and, therefore, adjusts the baseline assumption. With this understanding, standard T-8s became the baseline for all T-12 linear fluorescent retrofits beginning June 1, 2016 (PY8). The comparable baseline for any removed standard T-12 fixture will be the T-8 fixture of the same length and lamp count. The comparable baseline for any removed high-output T-12 fixture will be the T-8 fixture of the same length and lamp count with a ballast factor equal to 0.98. The assumed T-8 baseline fixtures and wattages associated with the most common T-12 fixture configurations are presented in Table 3-1. For small business direct install programs where wattage of the existing T-12 fixture is known, and the existing fixture was in working condition, wattage of the existing fixture removed by the program may be used as the baseline wattage in lieu of the table below. In such cases, the lighting equipment must be replaced directly by an ICSP and not a lighting trade ally.

Table 3-1: Assumed T-8 Baseline Fixtures for Removed T-12 Fixtures

T-12 Lamp Length	T-12 Lamp Type	T-12 Lamp Count	Assumed T-8 Baseline Fixture Code	Assumed T-8 Baseline Wattage
24"	Standard	1	F21ILL	20
24"	Standard	2	F22ILL	33
24"	Standard	3	F23ILL	47
24"	Standard	4	F24ILL	61
36"	Standard	1	F31ILL	26
36"	Standard	2	F32ILL	46
36"	Standard	3	F33ILL	67
36"	Standard	4	F34ILL	87
48"	Standard	1	F41ILL	31
48"	Standard	2	F42ILL	59
48"	Standard	3	F43ILL	89
48"	Standard	4	F44ILL	112
48"	Standard	6	F46ILL	175
48"	Standard	8	F48ILL	224
60"	Standard	1	F51ILL	36
60"	Standard	2	F52ILL	72
72"	Standard	1	F61ILL	55
72"	Standard	2	F62ILL	111
96"	Standard	1	F81ILL	58
96"	Standard	2	F82ILL	109
96"	Standard	3	F83ILL	167

T-12 Lamp Length	T-12 Lamp Type	T-12 Lamp Count	Assumed T-8 Baseline Fixture Code	Assumed T-8 Baseline Wattage
96"	Standard	4	F84ILL	219
96"	Standard	6	F86ILL	328
96"	High-Output	1	F81LHL	85
96"	High-Output	2	F82LHL	160
96"	High-Output	3	F83LHL	253
96"	High-Output	4	F84LHL	320
96"	High-Output	6	F86LHL	506

Similarly, the EISA "backstop" provision introduced new efficacy standards for general service lamps (effective January 1, 2020) effectively requiring a minimum efficacy of 45 lm/W for most general service lamps. This induced a shift in what a participant would have purchased in the absence of the program because standard and halogen incandescent lamps are no longer viable options and, therefore, adjusts the baseline assumption. With this understanding, a generic general service lamp with an efficacy of 45 lm/W will become the assumed baseline for the majority of incandescent lamp retrofits beginning January 1, 2020.[87] The comparable baseline for any removed incandescent lamps will be a generic general service lamp with similar lumen output. The assumed generic general service lamp baseline lamps/fixtures and wattages associated with the most common incandescent lamp/fixture configurations are presented in Table 3-2.

Table 3-2: Assumed Generic GSL Baseline Lamps/Fixtures for Removed Incandescent Lamps/Fixtures

Removed Lamp/Fixture Description	Lamp Count	Baseline Fixture Code	Assumed Baseline Fixture Wattage
Incandescent, (1) 34W lamp	1	GSL8/1	8
Incandescent, (1) 40W ES lamp	1	GSL8/1	8
Incandescent, (1) 40W ES/LL lamp	1	GSL8/1	8
Incandescent, (1) 36W lamp	1	GSL8/1	8
Incandescent, (1) 40W lamp	1	GSL10/1	10
Incandescent, (1) 42W lamp	1	GSL11/1	11
Incandescent, (1) 45W lamp	1	GSL11/1	11
Incandescent, (1) 50W lamp	1	GSL13/1	13
Incandescent, (1) 52W lamp	1	GSL13/1	13
Incandescent, (1) 60W ES lamp	1	GSL13/1	13
Incandescent, (1) 60W ES/LL lamp	1	GSL13/1	13
Incandescent, (1) 54W lamp	1	GSL14/1	14
Incandescent, (1) 55W lamp	1	GSL14/1	14
Incandescent, (1) 60W lamp	1	GSL17/1	17
Incandescent, (1) 65W lamp	1	GSL18/1	18
Incandescent, (1) 67W lamp	1	GSL19/1	19

[87] By definition, general service lamps are limited to lamps with initial lumen output of greater than or equal to 310 lumens and less than or equal to 3,300 lumens, so very low and high output lamps are unaffected by this baseline shift.

Removed Lamp/Fixture Description	Lamp Count	Baseline Fixture Code	Assumed Baseline Fixture Wattage
Incandescent, (1) 75W ES lamp	1	GSL19/1	19
Incandescent, (1) 75W ES/LL lamp	1	GSL19/1	19
Incandescent, (1) 69W lamp	1	GSL19/1	19
Incandescent, (1) 72W lamp	1	GSL20/1	20
Incandescent, (1) 75W lamp	1	GSL23/1	23
Incandescent, (1) 80W lamp	1	GSL25/1	25
Incandescent, (1) 85W lamp	1	GSL26/1	26
Incandescent, (1) 100W ES lamp	1	GSL28/1	28
Incandescent, (1) 100W ES/LL lamp	1	GSL28/1	28
Incandescent, (1) 90W lamp	1	GSL28/1	28
Incandescent, (1) 93W lamp	1	GSL29/1	29
Incandescent, (1) 95W lamp	1	GSL30/1	30
Incandescent, (1) 100W lamp	1	GSL33/1	33
Incandescent, (1) 120W lamp	1	GSL40/1	40
Incandescent, (1) 125W lamp	1	GSL44/1	44
Incandescent, (1) 135W lamp	1	GSL48/1	48
Incandescent, (1) 150W ES lamp	1	GSL48/1	48
Incandescent, (1) 150W ES/LL lamp	1	GSL48/1	48
Incandescent, (1) 150W lamp	1	GSL58/1	58
Incandescent, (1) 170W lamp	1	GSL66/1	66
Incandescent, (2) 34W lamp	2	GSL8/2	16
Incandescent, (2) 40W lamp	2	GSL10/2	20
Incandescent, (2) 50W lamp	2	GSL13/2	26
Incandescent, (2) 52W lamp	2	GSL13/2	26
Incandescent, (2) 54W lamp	2	GSL14/2	28
Incandescent, (2) 55W lamp	2	GSL14/2	28
Incandescent, (2) 60W lamp	2	GSL17/2	34
Incandescent, (2) 65W lamp	2	GSL18/2	36
Incandescent, (2) 67W lamp	2	GSL19/2	38
Incandescent, (2) 75W lamp	2	GSL23/2	46
Incandescent, (2) 90W lamp	2	GSL28/2	56
Incandescent, (2) 95W lamp	2	GSL30/2	60
Incandescent, (2) 100W lamp	2	GSL33/2	66
Incandescent, (2) 120W lamp	2	GSL40/2	80
Incandescent, (2) 135W lamp	2	GSL48/2	96
Incandescent, (2) 150W lamp	2	GSL58/2	116
Incandescent, (3) 60W lamp	3	GSL17/3	51
Incandescent, (3) 67W lamp	3	GSL19/3	57
Incandescent, (3) 75W lamp	3	GSL23/3	69

Removed Lamp/Fixture Description	Lamp Count	Baseline Fixture Code	Assumed Baseline Fixture Wattage
Incandescent, (3) 90W lamp	3	GSL28/3	84
Incandescent, (3) 100W lamp	3	GSL33/3	99
Incandescent, (4) 60W lamp	4	GSL17/4	68
Incandescent, (4) 75W lamp	4	GSL23/4	92
Incandescent, (4) 100W lamp	4	GSL33/4	132
Incandescent, (5) 60W lamp	5	GSL17/5	85
Incandescent, (5) 100W lamp	5	GSL33/5	165
Halogen Incandescent, (1) 35W lamp	1	GSL12/1	12
Halogen Incandescent, (1) 40W lamp	1	GSL14/1	14
Halogen Incandescent, (1) 42W lamp	1	GSL14/1	14
Halogen Incandescent, (1) 45W lamp	1	GSL17/1	17
Halogen Incandescent, (1) 50W lamp	1	GSL19/1	19
Halogen Incandescent, (1) 52W lamp	1	GSL20/1	20
Halogen Incandescent, (1) 55W lamp	1	GSL24/1	24
Halogen Incandescent, (1) 60W lamp	1	GSL26/1	26
Halogen Incandescent, (1) 72W lamp	1	GSL33/1	33
Halogen Incandescent, (1) 75W lamp	1	GSL34/1	34
Halogen Incandescent, (1) 90W lamp	1	GSL41/1	41
Halogen Incandescent, (1) 100W lamp	1	GSL46/1	46
Halogen Incandescent, (1) 150W lamp	1	GSL69/1	69
Halogen Incandescent, (2) 45W lamp	2	GSL17/2	34
Halogen Incandescent, (2) 50W lamp	2	GSL19/2	38
Halogen Incandescent, (2) 55W lamp	2	GSL24/2	48
Halogen Incandescent, (2) 75W lamp	2	GSL34/2	68
Halogen Incandescent, (2) 90W lamp	2	GSL41/2	82
Halogen Incandescent, (2) 150W lamp	2	GSL69/2	138

See Appendix E for general eligibility requirements for solid state lighting products in commercial and industrial applications.

ALGORITHMS

For all lighting fixture improvements (without control improvements), the following algorithms apply:

$$\Delta kWh = (kW_{base} - kW_{ee}) \times \left[HOU \times (1 - SVG_{base}) \times \left(1 + IF_{energy}\right)\right]$$

$$\Delta kW_{peak} = (kW_{base} - kW_{ee}) \times [CF \times (1 - SVG_{base}) \times (1 + IF_{demand})]$$

Definition of Terms

Table 3-3: Terms, Values, and References for Lighting Improvements

Term	Unit	Values	Source
kW_{base}, Connected load of the baseline lighting as defined by project classification	*kW*	See Fixture Identities in Appendix C For Permanent Lamp Removal: Table 3-10	Appendix C 14
kW_{ee}, Connected load of the post-retrofit or energy–efficient lighting system	*kW*	See Fixture Identities in Appendix C For Permanent Fixture and/or Lamp Removal, $kW_{ee} = 0$	Appendix C
SVG_{base}, Savings factor for existing lighting control (percent of time the lights are off)	*None*	EDC Data Gathering	EDC Data Gathering
		Default: Table 3-4	Table 3-4
CF, Coincidence factor	*Decimal*	EDC Data Gathering	EDC Data Gathering
		Default Screw-based Bulbs: Table 3-5 Default Other General Service: Table 3-6	Table 3-5 and Table 3-6
HOU, Hours of Use – the average annual operating hours of the baseline lighting equipment, which if applied to full connected load will yield annual energy use.	$\frac{Hours}{Year}$	EDC Data Gathering	EDC Data Gathering
		Default Screw-based Bulbs: Table 3-5 Default Other General Service: Table 3-6 Default Street Lighting: Table 3-7	Table 3-5, Table 3-6, and Table 3-7
IF_{energy}, Interactive Energy Factor – applies to C&I interior lighting in space that has air conditioning, electric space hating, or refrigeration. This represents the secondary energy impacts which results from the decreased waste heat from efficient lighting.	*None*	Default: Table 3-8 and Table 3-9	Table 3-8 and Table 3-9
IF_{demand}, Interactive Demand Factor – applies to C&I interior lighting in space that has air conditioning or refrigeration only. This represents the secondary demand savings in cooling required which results from the decreased waste heat from efficient lighting.	*None*	Default: Table 3-8 and Table 3-9	Table 3-8 and Table 3-9

Other factors required to calculate savings are shown in Table 3-4, Table 3-5, Table 3-6, Table 3-7, Table 3-8, and Table 3-9. Note that if HOU is stated and verified by logging lighting hours of use groupings, actual hours should be applied. In addition, the site-specific CF must be used to calculate peak demand savings if actual hours are used. The IF factors shown in Table 3-8 and

Table 3-9 are to be used only when the facilities are air conditioned and only for fixtures in conditioned or refrigerated space. The HOU for refrigerated spaces are to be estimated or logged separately.

Table 3-4: Savings Control Factors Assumptions[88]

Strategy	Definition	Technology	Savings	Source
Switch	Manual On/Off Switch	Light Switch	0%	2
Occupancy	Adjusting light levels according to the presence of occupants	Occupancy Sensors	24%	
		Time Clocks	24%	
		Energy Management System	24%	
Daylighting	Adjusting light levels automatically in response to the presence of natural light	Photosensors	28%	
		Time Clocks	28%	
Personal Tuning	Adjusting individual light levels by occupants according to their personal preferences; applies, for example, to private offices, workstation-specific lighting in open-plan offices, and classrooms	Dimmers	31%	
		Wireless on-off switches	31%	
		Bi-level switches	31%	
		Computer based controls	31%	
		Pre-set scene selection	31%	
Institutional Tuning	Adjustment of light levels through commissioning and technology to meet location specific needs or building policies; or provision of switches or controls for areas or groups of occupants; examples of the former include high-end trim dimming (also known as ballast tuning or reduction of ballast factor), task tuning and lumen maintenance	Dimmable ballasts	36%	
		On-off or dimmer switches for non-personal tuning	36%	
Multiple Types	Includes combination of any of the types described above. Occupancy and personal tuning, daylighting and occupancy are most common.	Occupancy and personal tuning/ daylighting and occupancy	38%	

[88] Subject to verification by EDC Evaluation or SWE.

Table 3-5: Lighting HOU and CF by Building Type for Screw-Based Bulbs

Building Type	HOU	CF	Source
Education	2,944	0.39	6
Exterior (All Building Types)	3,604	0.11	3
Grocery	7,798	0.99	6
Health	2,476	0.47	6
Industrial Manufacturing – 1 Shift	2,857	0.96	3, 5
Industrial Manufacturing – 2 Shift	4,730	0.96	3, 5
Industrial Manufacturing – 3 Shift	6,631	0.96	3, 5
Institutional/Public Service	1,456	0.23	6
Lodging	2,925	0.38	6
Miscellaneous/Other	2,001	0.33	6
Multi-Family Common Areas	5,950	0.73	14
Office	1,420	0.26	6
Parking Garages	8,678	0.98	3
Restaurant	3,054	0.55	6
Retail	2,383	0.56	6
Street Lighting[89]	See Table 3-7	0.00	See Table 3-7
Warehouse	2,815	0.50	6

[89] Street Lighting" is generally municipally owned, operates from dusk to dawn, and is not connected to a specific facility. "Exterior Lighting" is connected to a specific facility and does not always operate from dusk to dawn. If an exterior lighting project cannot demonstrate that the lighting operates from dusk to dawn, the "Exterior Lighting" HOU should be used. However, if the exterior lighting operates from dusk to dawn, the "Street Lighting" HOU are the appropriate HOU.

Table 3-6: Lighting HOU and CF by Building Type for Other General Service Lighting

Building Type	HOU	CF	Source
Education	2,371	0.45	6
Exterior (All Building Types)	3,604	0.11	3
Grocery	6,471	0.93	6
Health	2,943	0.52	6
Industrial/Manufacturing - 1 Shift	2,857	0.96	3, 5
Industrial/Manufacturing - 2 Shift	4,730	0.96	3, 5
Industrial/Manufacturing - 3 Shift	6,631	0.96	3, 5
Institutional/Public Service	1,419	0.23	6
Lodging	3,579	0.45	6
Miscellaneous/Other	2,830	0.58	6
Multi-Family Common Areas	5,950	0.73	14
Office	2,294	0.48	6
Parking Garage	8,678	0.98	3
Restaurant	4,747	0.77	6
Retail	2,915	0.66	6
Street Lighting[90]	See Table 3-7	0.00	See Table 3-7
Warehouse	2,545	0.48	6

[90] Ibid.

Table 3-7: Street lighting HOU by EDC

EDC	HOU	Source
Duquesne	4,200	7
PECO	4,100	8
PPL	4,300	9
Met-Ed	4,200	10
Penelec	4,200	11
Penn Power	4,070	12
West Penn Power	4,200	13

Table 3-8: Interactive Factors for All Bulb Types

Term	Unit	Values	Source
IF_{demand}	*None*	Comfort Cooled = See Table 3-9	6
		Freezer spaces (-35 °F – 20 °F) = 0.50	4
		Medium-temperature refrigerated spaces (20 °F – 40 °F) = 0.29	
		High-temperature refrigerated spaces (40 °F – 60 °F) = 0.18	
		Un-cooled space = 0	
IF_{energy}	*None*	Comfort Cooled = See Table 3-9	6
		Freezer spaces (-35 °F – 20 °F) = 0.50	4
		Medium-temperature refrigerated spaces (20 °F – 40 °F) = 0.29	
		High-temperature refrigerated spaces (40 °F – 60 °F) = 0.18	
		Un-cooled space = 0	

Table 3-9: Interactive Factors for Comfort Cooled Spaces for All Building Types

Heating Fuel	IF_{energy}	IF_{demand}
Non-Electric Heat	0.031	0.192
Electric Heat	-0.142	0.192
Unknown	0.000	0.192

Table 3-10: Connected Load of the Baseline Lighting

Lamp Length	Wattage Removed (kW_{base}) per Lamp
	T8
8-foot	0.0386
4-foot	0.0194
3-foot	0.0146
2-foot	0.0098

Default Savings

There are no default savings associated with this measure.

Evaluation Protocols

Methods for Determining Baseline Conditions

The following are acceptable methods for determining baseline conditions when verification by direct inspection is not possible as may occur in a rebate program where customers submit an application and equipment receipts only after installing efficient lighting equipment, or for a retroactive project as allowed by Act 129. In order of preference:

- Examination of replaced lighting equipment that is still on site waiting to be recycled or otherwise disposed of
- Examination of replacement lamp and ballast inventories where the customer has replacement equipment for the retrofitted fixtures in stock. The inventory must be under the control of the customer or customer's agent
- Interviews with and written statements from customers, facility managers, building engineers or others with firsthand knowledge about purchasing and operating practices at the affected site(s) identifying the lamp and ballast configuration(s) of the baseline condition
- Interviews with and written statements from the project's lighting contractor or the customer's project coordinator identifying the lamp and ballast configuration(s) of the baseline equipment

Detailed Inventory Form

A detailed lighting inventory is required for all lighting improvement projects. The lighting inventory form will use the algorithms presented above to derive the total ΔkW and ΔkWh savings for each installed measure. Within a single project, to the extent there are multiple combinations of control strategies (SVG), hours of use (HOU), coincidence factors (CF) or interactive factors (IF), the ΔkW will be broken out to account for these different factors. This will be accomplished using Appendix C, a Microsoft Excel inventory form that specifies the lamp and ballast configuration using the "Fixture Identities" sheet and SVG, HOU, CF and IF values for each line entry. The inventory form will also specify the location and number of fixtures for reference and validation.

Appendix C was developed to automate the calculation of energy and demand impacts for retrofit lighting projects, based on a series of entries by the user defining key characteristics of the retrofit project. The "General Information" sheet is provided for the user to identify facility-specific details of the project that have an effect on the calculation of gross savings. Facility-specific details include contact information, electric utility, building area information, and operating schedule. The "Lighting Inventory" sheet is the main worksheet that calculates energy savings and peak demand reduction for the user-specified lighting fixture and controls improvements. This form follows the algorithms presented above and facilitates the calculation of gross savings for implementation and evaluation purposes. Each line item on this tab represents a specific area with common baseline fixtures, retrofit fixtures, controls strategy, space cooling, and space usage.

Baseline and retrofit fixture wattages are determined by selecting the appropriate fixture code from the “Fixture Identities” sheet. The sheet can also be used to find the appropriate code for a particular lamp-ballast combination by using the enabled auto-filter options. Actual wattages of fixtures determined by manufacturer’s equipment specification sheets or other independent sources may not be used unless (1) the manufacturer's cut sheet indicates that the difference in delta-watts of fixture wattages (i.e. difference in delta watts of baseline and “actual” installed efficient fixture wattage and delta watts of baseline and nearest matching efficient fixture in the “Fixture Identities” of Appendix C is more than 10% or (2) the corresponding fixture code is not listed in the “Fixture Identities” list. In these cases, alternate wattages for lamp-ballast combinations can be inputted using the appropriate cells within the “Fixture Identities” tab. Rows 9 through 28 provide a guided custom LED fixture generator to be used with non-self-ballasted LEDs. All other custom cut sheets should be inputted into rows 932 through 981. Documentation supporting the alternate wattages must be provided in the form of manufacturer-provided specification sheets or other industry accepted sources (e.g. ENERGY STAR listing, Design Lights Consortium listing, etc.). Submitted specification sheets must cite test data performed under standard ANSI procedures. These exceptions will be used as the basis for periodically updating the “Fixture Identities” to better reflect market conditions and more accurately represent savings.

Some EDC Implementation CSPs may have developed in-house lighting inventory forms that are used to determine reported savings estimates for projects and calculate rebate amounts. The Appendix C form is the preferred tool for reported and verified savings calculations. However, a ICSP lighting inventory form may be used for program delivery purposes provided it (1) includes all the same functionality, formulas, and calculation steps as the Appendix C form and (2) is approved by the SWE prior to being utilized to calculate reported savings. In the case where an ICSP tool produces a different savings estimate from the Appendix C calculator, the Appendix C result is considered to be the TRM-supported savings value. Appendix C will be updated periodically to include new fixtures and technologies available as may be appropriate. Additional guidance can be found in the “Manual” sheet of Appendix C.

Custom Hours of Use and Coincidence Factors

If the project cannot be described by the building type categories listed in Table 3-5 and Table 3-6, or if the facility’s actual lighting hours deviate by more than 10% from the tables, or if the project retrofitted only a portion of a facility’s lighting system for which whole building hours of use would not be appropriate, the deemed HOU and CF assumptions can be overridden by inputting custom operating schedules into the Lighting Operation Schedule portion of the “General Information” tab of Appendix C. The custom schedule inputs must be corroborated by an acceptable source such as posted hours, customer interviews, building monitoring system (BMS), or metered data.

For all projects, annual hours are subject to adjustment by EDC evaluators or SWE.

Metering – Projects with savings below 750,000 kWh

Metering is encouraged for projects with expected savings below 750,000 kWh but have high uncertainty, i.e. where hours are unknown, variable, or difficult to verify. Exact conditions of “high uncertainty” are to be determined by the EDC evaluation contractors to appropriately manage variance. Metering completed by the implementation contractor maybe leveraged by the evaluation contractor, subject to a reasonableness review. Sampling methodologies within a site are to be either discerned by the EDC evaluation contractor based on the characteristics of the facility in question or performed consistent with guidance the EDC EM&V contractor provides.

Metering – Projects with savings of 750,000 kWh or higher

For projects with expected savings of 750,000 kWh or higher, metering is required[91]. Installation of light loggers is the accepted method of metering, but trend data from BMS is an acceptable substitute. Metering completed by the implementation contractor may be leveraged by the evaluation contractor, subject to a reasonableness review. Sampling methodologies within a site are to be either discerned by the EDC evaluation contractor or communicated to implementation contractors based on the characteristics of the facility in question or performed consistent with guidance the EDC EM&V contractor provides.

When BMS data is used as a method of obtaining customer-specific data in lieu of metering, the following guidelines should be followed:

- Care should be taken with respect to BMS data, since the programmed schedule may not reflect regular hours of long unscheduled overrides of the lighting system, such as nightly cleaning in office buildings, and may not reflect how the lights were actually used, but only the times of day the common area lighting is commanded on and off by the BMS.
- The BMS trends should represent the actual status of the lights (not just the command sent to the lights), and the ICSP and EC are required to demonstrate that the BMS system is functioning as expected, prior to relying on the data for evaluation purposes.
- The BMS data utilized should be specific to the lighting systems, and should be required to be representative of the building areas included in the lighting project.

Sources

1) Measure life values were developed using rated life values of lamps and ballasts from Osram Sylvania's 2014 – 2015 Lamp & Ballast Catalog. The rated lives were divided by the average HOU for all building types. https://assets.sylvania.com/assets/onlinemedia/ihdp/Lamp-and-Ballast-Catalog
2) Williams, A., Atkinson, B., Garbesi, K., Rubinstein, F., "A Meta-Analysis of Energy Savings from Lighting Controls in Commercial Buildings", Lawrence Berkeley National Laboratory, September 2011.https://www.acuitybrands.com/-/media/Files/Acuity/Resources/Regulations%20Codes%20and%20Standards/LBNL%20study.pdf?la=en
3) Mid-Atlantic Technical Reference Manual v8.0, https://neep.org/sites/default/files/resources/Mid_Atlantic_TRM_V7_FINAL.pdf.
    a. Development of Interior Lighting Hours of Use and Coincidence Factor Values for EmPOWER Maryland DRAFT Final Impact Evaluation Deemed Savings (June 1, 2017 – May 31, 2018) Commercial & Industrial Prescriptive, Small Business, and Direct Install Programs, Navigant, March, 2018.
4) Efficiency Vermont Technical Reference User Manual (TRM), March 16, 2015. https://puc.vermont.gov/sites/psbnew/files/doc_library/ev-technical-reference-manual.pdf
5) UI and CL&P Program Savings Documentation for 2013 Program Year, United Illuminating Company, September 2012.
6) Pennsylvania Statewide Act 129 2014 Commercial & Residential Lighting Metering Study. Prepared for Pennsylvania Public Utilities Commission. January 13, 2015. http://www.puc.pa.gov/pcdocs/1340978.pdf

[91] The Commission allows the EDCs to use alternative methods for obtaining customer-specific data where customer processes do not support metering. The EDCs are required to provide supporting documentation to the SWE for review if there are any such exceptions.

7) Duquesne Light Schedule of Rates, Page 68, Released September 20, 2018. https://www.duquesnelight.com/docs/default-source/default-document-library/CurrentTariff.pdf?sfvrsn=e69ca442_44

8) PECO Energy Company Electric Service Tariff, Page 62, Released May 28, 2018. https://www.peco.com/SiteCollectionDocuments/PECOProposedTariffNo6Clean.PDF

9) PPL Electric Utilities General Tariff, Page 19Z.1A, Released September 20, 2018. https://www.pplelectric.com/~/media/pplelectric/at%20your%20service/docs/current-electric-tariff/master.pdf

10) Metropolitan Edison Company Electric Service Tariff, Page 86, Released August 22, 2018. https://www.firstenergycorp.com/content/dam/customer/Customer%20Choice/Files/PA/tariffs/Met-Ed-Tariff-52-Supp-56.pdf

11) Pennsylvania Electric Company Electric Service Tariff, Page 102, Released September 20, 2018. https://www.firstenergycorp.com/content/dam/customer/Customer%20Choice/Files/PA/tariffs/Penelec-Tariff-81-Supp-62.pdf

12) Pennsylvania Power Company Schedule of Rates, Rules and Regulations for Electric Service, Page 88, Released September 20, 2018. https://www.firstenergycorp.com/content/dam/customer/Customer%20Choice/Files/PA/tariffs/PP-Tariff-36-Supp-49.pdf

13) West Penn Power Company Tariff, Page 96, Released September 20, 2018. https://www.firstenergycorp.com/content/dam/customer/Customer%20Choice/Files/PA/tariffs/WPP-Tariff-40-Supp-45.pdf

14) Illinois Statewide Technical Reference Manual for Energy Efficiency v7.0. Multi-family common area value based on DEER 2008. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_7/Final_9-28-18/IL-TRM_Effective_010119_v7.0_Vol_2_C_and_I_092818_Final.pdf. Accessed December 2018.

15) Illinois Statewide Technical Reference Manual for Energy Efficiency v7.0. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_7/Final_9-28-18/IL-TRM_Effective_010119_v7.0_Vol_2_C_and_I_092818_Final.pdf. Accessed December 2018.

3.1.2 New Construction Lighting

Target Sector	Commercial and Industrial Establishments
Measure Unit	Lighting Equipment
Measure Life	15 years Source 1
Measure Vintage	New Construction

New Construction incentives are intended to encourage decision-makers in new construction projects to incorporate greater energy efficiency into their building design and construction practices that will result in a permanent reduction in electrical (kWh) usage above baseline practices. See Appendix E for general eligibility requirements for solid state lighting products in commercial and industrial applications.

Eligibility Requirements

New construction applies to new building projects wherein no structure or site footprint presently exists, addition or expansion of an existing building or site footprint, or major tenant improvements that change the use of the space. Eligible lighting equipment and fixture/lamp types include fluorescent fixtures (lamps and ballasts), compact fluorescent lamps, high intensity discharge (HID) lamps, interior and exterior LED lamps and fixtures, cold-cathode fluorescent lamps (CCFL), induction lamps, and lighting controls.

The baseline demand for calculating savings is determined using one of the two methods detailed in IECC 2015. The interior lighting baseline is calculated using either the Building Area Method as shown in Table 3-12 or the Space-by-Space Method as shown in Table 3-13. For exterior lighting, the baseline is calculated using the Baseline Exterior Lighting Power Densities as shown in Table 3-14. Table 3-14 does not distinguish between tradable and non-tradable exterior spaces. When analyzing exterior spaces, all exterior spaces must be included in savings calculations so that energy penalties from any over-lit spaces are properly accounted for in the facility-level savings estimates. The post-installation demand is calculated based on the installed fixtures using the "Fixture Identities" sheet in Appendix C.

Algorithms

For all new construction projects analyzed using the IECC 2015 **Building Area Method**, the following algorithms apply Source 2:

$$\Delta kWh = (kW_{base} - kW_{ee}) \times \left[HOU \times (1 - SVG_{base}) \times \left(1 + IF_{energy}\right)\right]$$

$$\Delta kW_{peak} = (kW_{base} - kW_{ee}) \times [CF \times (1 - SVG_{base}) \times (1 + IF_{demand})]$$

For all new construction projects analyzed using the IECC 2015 **Space-by-Space Method**, the following algorithms apply Source 2:

$$\Delta kWh = \sum_{i=1}^{n} \Delta kWh_1 + \Delta kWh_2 + \cdots \Delta kWh_n$$

$$\Delta kW_{peak} = \sum_{i=1}^{n} \Delta kW_{p1} + \Delta kW_{p2} + \cdots \Delta kW_{pn}$$

Where n is the number of spaces and:

$$\Delta kWh_1 = (kW_{base,1} - kW_{ee,1}) \times [HOU_1 \times (1 - SVG_{\text{base1}}) \times (1 + IF_{energy,1})]$$

$$\Delta kW_{p1} = (kW_{base,1} - kW_{ee,1}) \times [CF_1 \times (1 - SVG_{base1}) \times (1 + IF_{demand,1})]$$

Definition of Terms

Table 3-11: Terms, Values, and References for New Construction Lighting

Term	Unit	Values	Source
kW_{base}, The baseline space or building connected load as calculated by multiplying the space or building area by the appropriate Lighting Power Density (LPD) values specified in either Table 3-12 or Table 3-13	*kW*	Calculated based on space or building type and size.	Calculated Value
kW_{ee}, The calculated connected load of the energy efficient lighting	*kW*	Calculated based on specifications of installed equipment using Appendix C	Calculated Value
SVG_{base}, Baseline savings factor in accordance with code-required lighting controls (percent of time the lights are off)	*None*	Based on Code	EDC Data Gathering
		Default: Table 3-15	1
CF, Coincidence factor	*Decimal*	Based on Metering[92]	EDC Data Gathering
		Default Screw-based Bulbs: Table 3-5 Default Other General Service: Table 3-6	Table 3-5 and Table 3-6
HOU, Hours of Use – the average annual operating hours of the facility	$\frac{Hours}{Year}$	Based on Metering[93]	EDC Data Gathering
		Default Screw-based Bulbs: Table 3-5 Default Other General Service: Table 3-6	Table 3-5 and Table 3-6
IF_{energy}, Interactive Energy Factor	*None*	Default: Table 3-8 and Table 3-9	Table 3-8 and Table 3-9
IF_{demand}, Interactive Demand Factor	*None*	Default: Table 3-8 and Table 3-9	Table 3-8 and Table 3-9

[92] It is noted that if site-specific data is used to determine HOU, then the same data must be used to determine the site-specific CF. Similarly, if the default TRM HOU is used, then the default TRM CF must also be used in the savings calculations.
[93] Ibid.

Table 3-12: Lighting Power Densities from IECC 2015 Building Area Method Source 2

Building Area Type	LPD (W/ft^2)	Building Area Type	LPD (W/ft^2)
Automotive facility	0.80	Multifamily	0.51
Convention center	1.01	Museum	1.02
Courthouse	1.01	Office	0.82
Dining: bar lounge/leisure	1.01	Parking garage	0.21
Dining: cafeteria/fast food	0.90	Penitentiary	0.81
Dining: family	0.95	Performing arts theater	1.39
Dormitory	0.57	Police station	0.87
Exercise center	0.84	Post office	0.87
Fire station	0.67	Religious building	1.00
Gymnasium	0.94	Retail	1.26
Health care clinic	0.90	School/university	0.87
Hospital	1.05	Sports arena	0.91
Hotel/Motel	0.87	Town hall	0.89
Library	1.19	Transportation	0.70
Manufacturing facility	1.17	Warehouse	0.66
Motion picture theater	0.76	Workshop	1.19

Table 3-13: Lighting Power Densities from IECC 2015 Space-by-Space Method Source 2

Common Space Type	LPD (W/ft2)	Building Specific Space Types	LPD (W/ft2)
Atrium		**Facility for the visually impaired**	
Less than 40 feet in height	0.03 per foot in total height	In a chapel (and not used primarily by the staff)	2.21
Greater than 40 feet in height	0.40 + 0.02 per foot in total height	In a recreation room (and not used primarily by the staff)	2.41
Audience seating area		**Automotive (See Vehicle Maintenance Area above)**	
In an auditorium	0.63	Convention Center—exhibit space	1.45
In a convention center	0.82	Dormitory—living quarters	0.38
In a gymnasium	0.65	Fire Station—sleeping quarters	0.22
In a motion picture theater	1.14	**Gymnasium/fitness center**	
In a penitentiary	0.28	In an exercise area	0.72
In a performing arts theater	2.43	In a playing area	1.20
In a religious building	1.53	**Healthcare facility**	
In a sports arena	0.43	In an exam/treatment room	1.66

Common Space Type	LPD (W/ft2)	Building Specific Space Types	LPD (W/ft2)
Otherwise	0.43	In an imaging room	1.51
Banking activity area	1.01	In a medical supply room	0.74
Breakroom (See Lounge/Breakroom)		In a nursery	0.88
Classroom/lecture hall/training room		In a nurse's station	0.71
In a penitentiary	1.34	In an operating room	2.48
Otherwise	1.24	In a patient room	0.62
Conference/meeting/multipurpose room	1.23	In a physical therapy room	0.91
Copy/print room	0.72	In a recovery room	1.15
Corridor		**Library**	
In a facility for the visually impaired (and not used primarily by the staff)	0.92	In a reading area	1.06
In a hospital	0.79	In the stacks	1.71
In a manufacturing facility	0.41	**Manufacturing facility**	
Otherwise	0.66	In a detailed manufacturing area	1.29
Courtroom	1.72	In an equipment room	0.74
Computer room	1.71	In an extra high bay area (greater than 50' floor-to-ceiling height)	1.05
Dining area		In a high bay area (25-50' floor-to-ceiling height)	1.23
In a penitentiary	0.96	In a low bay area (less than 25' floor-to-ceiling height)	1.19
In a facility for the visually impaired (and not used primarily by the staff)	1.90	**Museum**	
In bar/lounge or leisure dining	1.07	In a general exhibition area	1.05
In cafeteria or fast food dining	0.65	In a restoration room	1.02
In family dining	0.89	Performing arts theater—dressing room	0.61
Otherwise	0.65	Post Office—Sorting Area	0.94
Electrical/mechanical room	0.95	**Religious buildings**	
Emergency vehicle garage	0.56	In a fellowship hall	0.64
Food preparation area	1.21	In a worship/pulpit/choir area	1.53
Guest room	0.47	**Retail facilities**	
Laboratory		In a dressing/fitting room	0.71
In or as a classroom	1.43	In a mall concourse	1.10
Otherwise	1.81	**Sports arena—playing area**	

Common Space Type	LPD (W/ft2)	Building Specific Space Types	LPD (W/ft2)
Laundry/washing area	0.60	For a Class I facility	3.68
Loading dock, interior	0.47	For a Class II facility	2.40
Lobby		For a Class III facility	1.80
In a facility for the visually impaired (and not used primarily by the staff)	1.80	For a Class IV facility	1.20
For an elevator	0.64	**Transportation facility**	
In a hotel	1.06	In a baggage/carousel area	0.53
In a motion picture theater	0.59	In an airport concourse	0.36
In a performing arts theater	2.00	At a terminal ticket counter	0.80
Otherwise	0.90	**Warehouse—storage area**	
Locker room	0.75	For medium to bulky, palletized items	0.58
Lounge/breakroom		For smaller, hand-carried items	0.95
In a healthcare facility	0.92		
Otherwise	0.73		
Office			
Enclosed	1.11		
Open plan	0.98		
Parking area, interior	0.19		
Pharmacy area	1.68		
Restroom			
In a facility for the visually impaired (and not used primarily by the staff)	1.21		
Otherwise	0.98		
Sales area	1.59		
Seating area, general	0.54		
Stairway (See space containing stairway)			
Stairwell	0.69		
Storage room	0.63		
Vehicle maintenance area	0.67		
Workshop	1.59		

Table 3-14: Baseline Exterior Lighting Power Densities Source 2

Space Description	Lighting Zones[94]			
	Zone 1	Zone 2	Zone 3	Zone 4
Base Site Allowance (Base allowance is usable in tradable or nontradable surfaces.)	500 W	600 W	750 W	1300 W
Uncovered Parking Areas				
Parking areas and drives	0.04 W/ft^2	0.06 W/ft^2	0.10 W/ft^2	0.13 W/ft^2
Building Grounds				
Walkways less than 10 feet wide	0.7 W/linear foot	0.7 W/linear foot	0.8 W/linear foot	1.0 W/linear foot
Walkways 10 feet wide or greater, plaza areas, special feature areas	0.14 W/ft^2	0.14 W/ft^2	0.16 W/ft^2	0.2 W/ft^2
Stairways	0.75 W/ft^2	1.0 W/ft^2	1.0 W/ft^2	1.0 W/ft^2
Pedestrian tunnels	0.15 W/ft^2	0.15 W/ft^2	0.2 W/ft^2	0.3 W/ft^2
Building Entrances and Exits				
Main entries	20 W/linear foot of door width	20 W/linear foot of door width	30 W/linear foot of door width	30 W/linear foot of door width
Other doors	20 W/linear foot of door width	20 W/linear foot of door width	20 W/linear foot of door width	20 W/linear foot of door width
Entry canopies	0.25 W/ft^2	0.25 W/ft^2	0.4 W/ft^2	0.4 W/ft^2
Sales Canopies				
Free-standing and attached	0.6 W/ft^2	0.6 W/ft^2	0.8 W/ft^2	1.0 W/ft^2
Outdoor Sales				
Open areas (including vehicle sales lots)	0.25 W/ft^2	0.25 W/ft^2	0.5 W/ft^2	0.7 W/ft^2
Street frontage for vehicle sales lots in addition to "open area" allowance	No allowance	10 W/linear foot	10 W/linear foot	30 W/linear foot
Building facades	No allowance	0.075 W/ft^2 of gross above-grade wall area	0.113 W/ft^2 of gross above-grade wall area	0.15 W/ft^2 of gross above-grade wall area

[94] Lighting Zone 1 includes developed areas of national parks, state parks, forest land, and rural areas. Zone 2 includes areas predominantly consisting of residential zoning, neighborhood business districts, light industrial with limited nighttime use and residential mixed-use areas. Zone 3 includes all other areas not classified as lighting zone 1, 2, or 4. Zone 4 includes high-activity commercial districts in major metropolitan areas as designated by the local land use planning authority.

Space Description	Lighting Zones[94]			
	Zone 1	Zone 2	Zone 3	Zone 4
Automated teller machines (ATM) and night depositories	270 W per location plus 90 W per additional ATM per location	270 W per location plus 90 W per additional ATM per location	270 W per location plus 90 W per additional ATM per location	270 W per location plus 90 W per additional ATM per location
Entrances and gatehouse inspection stations at guarded facilities	0.75 W/ft^2 of covered and uncovered area	0.75 W/ft^2 of covered and uncovered area	0.75 W/ft^2 of covered and uncovered area	0.75 W/ft^2 of covered and uncovered area
Loading areas for law enforcement, fire, ambulance and other emergency service vehicles	0.5 W/ft^2 of covered and uncovered area	0.5 W/ft^2 of covered and uncovered area	0.5 W/ft^2 of covered and uncovered area	0.5 W/ft^2 of covered and uncovered area
Drive-up windows/doors	400 W per drive-through	400 W per drive-through	400 W per drive-through	400 W per drive-through
Parking near 24-hour retail entrances	800 W per main entry	800 W per main entry	800 W per main entry	800 W per main entry

Table 3-15: Default Baseline Savings Control Factors Assumptions for New Construction Only[95]

Building Type	SVG_{base}
Education	17%
Exterior	0%
Grocery	5%
Health	8%
Industrial/Manufacturing – 1 Shift	0%
Industrial/Manufacturing – 2 Shift	0%
Industrial/Manufacturing – 3 Shift	0%
Institutional/Public Service	12%
Lodging	15%
Miscellaneous/Other	6%
Office	15%
Parking Garage	0%
Restaurant	5%
Retail	5%
Warehouse	14%
Custom	Based on Code

[95] Various lighting control strategies are required by IECC 2015 for multiple new construction space types. The percentage of connected load found in covered space types varies by commercial building type. The default values for SVG_{base} for new construction are estimated by building type and were determined by scaling the savings factor of 24% associated with occupancy sensors from Table 3-4 by the percentage of connected load found in covered space types. The percentage of connected load is based on Source 3. For example, education facilities have 69% of the load within the space types requiring occupancy sensors. As such, the baseline SVG_{base} becomes 0.69 * 0.24, or 0.17.

Default Savings

There are no default savings associated with this measure.

Evaluation Protocols

Detailed Inventory Form

A detailed inventory of all installed fixtures contributing to general light requirements is mandatory for participation in this measure. Lighting that need not be included in the inventory is as follows:

1) Display or accent lighting in galleries, museums, and monuments
2) Lighting that is integral to:
   a. Equipment or instrumentation and installed by its manufacturer,
   b. Refrigerator and freezer cases (both open and glass-enclosed),
   c. Equipment used for food warming and food preparation,
   d. Medical equipment, or
   e. Advertising or directional signage
3) Lighting specifically designed only for use during medical procedures
4) Lighting used for plant growth or maintenance
5) Lighting used in spaces designed specifically for occupants with special lighting needs
6) Lighting in retail display windows that are enclosed by ceiling height partitions.

A detailed lighting inventory is required for all lighting improvement projects. The lighting inventory form will use the algorithms presented above to derive the total ΔkW and ΔkWh savings for each installed measure. Within a single project, to the extent there are multiple combinations of control strategies (SVG), hours of use (HOU), coincidence factors (CF) or interactive factors (IF), the ΔkW will be broken out to account for these different factors. This will be accomplished using Appendix C, a Microsoft Excel inventory form that specifies the lamp and ballast configuration using the "Fixture Identities" sheet and SVG, HOU, CF and IF values for each line entry. The inventory form will also specify the location and number of fixtures for reference and validation.

Appendix C was developed to automate the calculation of energy and demand impacts for new construction lighting projects, based on a series of entries by the user defining key characteristics of the new construction project. The "General Information" sheet is provided for the user to identify facility-specific details of the project that have an effect on the calculation of gross savings. Facility-specific details include contact information, electric utility, building area information, and operating schedule. The "Lighting Inventory" sheet is the main worksheet that calculates energy savings and peak demand reduction for the user-specified lighting fixture and controls improvements. This form follows the algorithms presented above and facilitates the calculation of gross savings for implementation and evaluation purposes. Each line item on this tab represents a specific area with common baseline fixtures, retrofit fixtures, controls strategy, space cooling, and space usage.

Baseline and retrofit fixture wattages are determined by selecting the appropriate fixture code from the "Fixture Identities" sheet. The sheet can also be used to find the appropriate code for a particular lamp-ballast combination by using the enabled auto-filter options. Actual wattages of fixtures determined by manufacturer's equipment specification sheets or other independent sources may not be used unless (1) the manufacturer's cut sheet indicates that the difference in delta-watts of fixture wattages (i.e. difference in delta watts of baseline and "actual" installed efficient fixture wattage and delta watts of baseline and nearest matching efficient fixture in the "Fixture Identities" of Appendix C is more than 10% or (2) the corresponding fixture code is not listed in the "Fixture Identities" list. In these cases, alternate wattages for lamp-ballast combinations can be inputted using the appropriate cells within the "Fixture Identities" tab. Rows 9 through 28 provide a guided custom LED fixture generator to be used with non-self-ballasted LEDs. All other custom cut sheets should be inputted into rows 932 through 981. Documentation supporting the alternate wattages must be provided in the form of manufacturer-provided specification sheets or other industry accepted sources (e.g. ENERGY STAR listing, Design Lights Consortium listing, etc.). Submitted specification sheets must cite test data performed under standard ANSI procedures. These exceptions will be used as the basis for periodically updating the "Fixture Identities" to better reflect market conditions and more accurately represent savings.

Some EDC Implementation CSPs may have developed in-house lighting inventory forms that are used to determine reported savings estimates for projects and calculate rebate amounts. The Appendix C form is the preferred tool for reported and verified savings calculations. However, a ICSP lighting inventory form may be used for program delivery purposes provided it (1) includes all the same functionality, formulas, and calculation steps as the Appendix C form (2) is approved by the SWE prior to being utilized to calculate reported savings. In the case where an ICSP tool produces a different savings estimate from the Appendix C calculator, the Appendix C result is considered to be the TRM-supported savings value. Appendix C will be updated periodically to include new fixtures and technologies available as may be appropriate. Additional guidance can be found in the "Manual" sheet of Appendix C.

Custom Hours of Use and Coincidence Factors

If the project cannot be described by the building type categories listed in Table 3-5 and Table 3-6, or if the facility's actual lighting hours deviate by more than 10% from the tables, or if the project retrofitted only a portion of a facility's lighting system for which whole building hours of use would not be appropriate, the deemed HOU and CF assumptions can be overridden by inputting custom operating schedules into the Lighting Operation Schedule portion of the "General Information" tab of Appendix C. The custom schedule inputs must be corroborated by an acceptable source such as posted hours, customer interviews, building monitoring system (BMS), or metered data.

For all projects, annual hours are subject to adjustment by EDC evaluators or SWE.

Metering – Projects with savings below 750,000 kWh

Metering is encouraged for projects with expected savings below 750,000 kWh but have high uncertainty, i.e. where hours are unknown, variable, or difficult to verify. Exact conditions of "high uncertainty" are to be determined by the EDC evaluation contractors to appropriately manage variance. Metering completed by the implementation contractor maybe leveraged by the evaluation contractor, subject to a reasonableness review. Sampling methodologies within a site are to be either discerned by the EDC evaluation contractor based on the characteristics of the facility in question or performed consistent with guidance the EDC EM&V contractor provides.

Metering – Projects with savings of 750,000 kWh or higher

For projects with expected savings of 750,000 kWh or higher, metering is required[96]. Exceptions may be made and EDC data gathering may be substituted if necessary at the evaluation contractor's discretion in cases involving early occupancy. Otherwise, installation of light loggers is the accepted method of metering, but trend data from BMS is an acceptable substitute. Metering completed by the implementation contractor maybe leveraged by the evaluation contractor, subject to a reasonableness review. Sampling methodologies within a site are to be either discerned by the EDC evaluation contractor or communicated to implementation contractors based on the characteristics of the facility in question or performed consistent with guidance the EDC EM&V contractor provides.

[96] The Commission allows the EDCs to use alternative methods for obtaining customer-specific data where customer processes do not support metering. The EDCs are required to provide supporting documentation to the SWE for review if there are any such exceptions.

When BMS data is used as a method of obtaining customer-specific data in lieu of metering, the following guidelines should be followed:

- Care should be taken with respect to BMS data, since the programmed schedule may not reflect regular hours of long unscheduled overrides of the lighting system, such as nightly cleaning in office buildings, and may not reflect how the lights were actually used, but only the times of day the common area lighting is commanded on and off by the BMS.
- The BMS trends should represent the actual status of the lights (not just the command sent to the lights), and the ICSP and EC are required to demonstrate that the BMS system is functioning as expected, prior to relying on the data for evaluation purposes.
- The BMS data utilized should be specific to the lighting systems, and should be required to be representative of the building areas included in the lighting project.

Sources

1) Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007. http://www.iar.unicamp.br/lab/luz/ld/Arquitetural/interiores/ilumina%E7%E3o%20industrial/measure_life_GDS.pdf
2) International Energy Conservation Code 2015. International Code Council.
3) Pennsylvania Statewide Act 129 2014 Commercial & Residential Lighting Metering Study. Prepared for Pennsylvania Public Utilities Commission. January 13, 2015. http://www.puc.pa.gov/pcdocs/1340978.pdf

3.1.3 Lighting Controls

Target Sector	Commercial and Industrial Establishments
Measure Unit	Wattage Controlled
Measure Life	8 years Source 1
Measure Vintage	Retrofit and New Construction

Eligibility

Lighting controls turn lights on and off automatically, which are activated by time, light, motion, or sound. The measurement of energy savings is based on algorithms with key variables (e.g. coincidence factor (CF), hours of use (HOU) provided through existing end-use metering of a sample of facilities or from other utility programs with experience with these measures (i.e., % of annual lighting energy saved by lighting control). These key variables are listed in Table 3-16.

If a lighting improvement consists of solely lighting controls, the lighting fixture baseline is the existing fixtures with the existing lamps and ballasts or, if retrofitted, new fixtures with new lamps and ballasts as defined in Lighting Audit and Design Tool shown in Appendix C.

Algorithms

Algorithms for annual energy savings and peak demand savings are shown below.

$$\Delta kWh = kW_{controlled} \times HOU \times (SVG_{ee} - SVG_{base}) \times \left(1 + IF_{energy}\right)$$

$$\Delta kW_{peak} = kW_{controlled} \times (SVG_{ee} - SVG_{base}) \times (1 + IF_{demand}) \times CF$$

Definition of Terms

Table 3-16: Terms, Values, and References for Lighting Controls

Term	Unit	Values	Source
$kW_{controlled}$, Total lighting load connected to the new control in kilowatts. Savings are per controlled system. The total connected load per controlled system should be collected from the customer	*kW*	Lighting Audit and Design Tool in Appendix C	EDC Data Gathering
SVG_{ee}, Savings factor for installed lighting control (percent of time the lights are off)	*None*	Based on metering	EDC Data Gathering
		Default: Table 3-4	2
SVG_{base}, Baseline savings factor (percent of time the lights are off)	*None*	Retrofit Default: Table 3-4	2
		New Construction Default: Table 3-15	3
CF, Coincidence factor	*Decimal*	Based on metering[97]	EDC Data Gathering
		By building type and size	Table 3-5 and Table 3-6
HOU, Hours of Use – the average annual operating hours of the baseline lighting equipment (before the lighting controls are in place), which if applied to full connected load will yield annual energy use.	$\frac{Hours}{Year}$	Based on metering[98]	EDC Data Gathering
		By building type	Table 3-5 and Table 3-6
IF_{energy}, Interactive Energy Factor	*None*	Default: Table 3-8 and Table 3-9	Table 3-8 and Table 3-9
IF_{demand}, Interactive Demand Factor	*None*	Default: Table 3-8 and Table 3-9	Table 3-8 and Table 3-9

Default Savings

There are no default savings for this measure.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables.

[97] It is noted that if site-specific data is used to determine HOU, then the same data must be used to determine the site-specific CF. Similarly, if the default TRM HOU is used, then the default TRM CF must also be used in the savings calculations.
[98] Ibid.

It is noted that if site-specific data is used to determine HOU, then the same data must be used to determine the site-specific CF. Similarly, if the default TRM HOU is used, then the default TRM CF must also be used in the savings calculations. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx. Accessed December 2018.
2) Williams, A., Atkinson, B., Garbesi, K., Rubinstein, F., “A Meta-Analysis of Energy Savings from Lighting Controls in Commercial Buildings”, Lawrence Berkeley National Laboratory, September 2011. https://www.acuitybrands.com/-/media/Files/Acuity/Resources/Regulations%20Codes%20and%20Standards/LBNL%20study.pdf?la=en
3) Pennsylvania Statewide Act 129 2014 Commercial & Residential Lighting Metering Study. Prepared for Pennsylvania Public Utilities Commission. January 13, 2015. http://www.puc.pa.gov/pcdocs/1340978.pdf

3.1.4 LED Exit Signs

Target Sector	Commercial and Industrial Establishments
Measure Unit	LED Exit Sign
Measure Life	15 years Source 1
Measure Vintage	Early Replacement

Eligibility

This measure includes the early replacement of existing incandescent or fluorescent exit signs with a new LED exit sign. If the exit signs match those listed in Table 3-17, the default savings value for LED exit signs installed cooled spaces can be used without completing Appendix C.

See Appendix E for general eligibility requirements for solid state lighting products in commercial and industrial applications.

Algorithms

The algorithms shown below can be used to calculate annual energy savings and peak demand savings associated with this measure.

$$\Delta kWh = (kW_{base} - kW_{ee}) \times \left[HOU \times \left(1 + IF_{energy}\right)\right]$$

$$\Delta kW_{peak} = (kW_{base} - kW_{ee}) \times [CF \times (1 + IF_{demand})]$$

Definition of Terms

Table 3-17: Terms, Values, and References for LED Exit Signs

Term	Unit	Values	Source
kW_{base}, Connected load of baseline lighting as defined by project classification	*kW*	Actual Wattage	EDC Data Gathering
		Single-Sided Incandescent: 0.020 Dual-Sided Incandescent: 0.040 Single-Sided Fluorescent: 0.009 Dual-Sided Fluorescent: 0.020	Appendix C
$kW_{ee,}$ Connected load of the post-retrofit or energy-efficient lighting	*kW*	Actual Wattage	EDC Data Gathering
		Single-Sided: 0.002 Dual-Sided: 0.004	Appendix C
CF, Coincidence factor	*Decimal*	1.0	2
HOU, Hours of Use – the average annual operating hours of the baseline lighting equipment.	$\frac{Hours}{Year}$	8,760	2
IF_{energy}, Interactive Energy Factor	*None*	Default: Table 3-8 and Table 3-9	Table 3-8 and Table 3-9
IF_{demand}, Interactive Demand Factor	*None*	Default: Table 3-8 and Table 3-9	Table 3-8 and Table 3-9

Default Savings

Single-Sided LED Exit Signs replacing Incandescent Exit Signs in Cooled Spaces

$$\Delta kWh = 158\ kWh$$

$$\Delta kW_{peak} = 0.021\ kW$$

Dual-Sided LED Exit Signs replacing Incandescent Exit Signs in Cooled Spaces

$$\Delta kWh = 315\ kWh$$

$$\Delta kW_{peak} = 0.043\ kW$$

Single-Sided LED Exit Signs replacing Fluorescent Exit Signs in Cooled Spaces

$$\Delta kWh = 61\ kWh$$

$$\Delta kW_{peak} = 0.008\ kW$$

Dual-Sided LED Exit Signs replacing Fluorescent Exit Signs in Cooled Spaces

$$\Delta kWh = 140\ kWh$$

$$\Delta kW_{peak} = 0.019\ kW$$

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx. Accessed December 2018.
2) This assumes operation 24 hours per day, 365 days per year. Additionally, the load shape is assumed to be flat, so the coincidence factor is assumed to be 1.

3.1.5 LED Channel Signage

Target Sector	Commercial and Industrial Establishments
Measure Unit	LED Channel Signage
Measure Life	15 years Source 1
Measure Vintage	Early Replacement

Channel signage refers to the illuminated signs found inside and outside shopping malls to identify store names. Typically, these signs are constructed from sheet metal sides forming the shape of letters and a translucent plastic lens. Luminance is most commonly provided by single or double strip neon lamps, powered by neon sign transformers. Retrofit kits are available to upgrade existing signage from neon to LED light sources, substantially reducing the electrical power and energy required for equivalent sign luminance.

See Appendix E for general eligibility requirements for solid state lighting products in commercial and industrial applications.

Eligibility

This measure includes the replacement of neon and/or incandescent channel letter signs with efficient LED channel letter signs. This measure only applies to red LED systems because there is minimal to negative savings for other LED light colors.[Source 1] Retrofit kits or complete replacement LED signs are eligible. Measure the length of the sign as follows:

- Measure the length of each individual letter at the centerline. Do not measure the distance between letters.
- Add up the measurements of each individual letter to get the length of the entire sign being replaced.

Algorithms

The savings are calculated using the equations below and the assumptions in Table 3-18. Energy interactive effects are not included in the calculations for outdoor applications.

Indoor applications:

$$\Delta kWh = SL \times \Big[\big[kW_{base} \times \big(1 + IF_{energy}\big) \times HOU \times (1 - SVG_{base})\big] - \big[kW_{ee} \times \big(1 + IF_{energy}\big) \times HOU \times (1 - SVG_{ee})\big]\Big]$$

$$\Delta kW_{peak} = SL \times \big[[kW_{base} \times (1 + IF_{demand}) \times CF \times (1 - SVG_{base})] - [kW_{ee} \times (1 + IF_{demand}) \times CF \times (1 - SVG_{ee})]\big]$$

Outdoor applications:

$$\Delta kWh = SL \times \big[[kW_{base} \times HOU \times (1 - SVG_{base})] - [kW_{ee} \times HOU \times (1 - SVG_{ee})]\big]$$

$$\Delta kW_{peak} = SL \times \big[[kW_{base} \times CF \times (1 - SVG_{base})] - [kW_{ee} \times CF \times (1 - SVG_{ee})]\big]$$

Definition of Terms

Table 3-18: Terms, Values, and References for LED Channel Signage

Term	Unit	Values	Source
SL, Sign length	*Linear ft*	EDC Data Gathering	EDC Data Gathering
kW_{base}, kW of baseline lighting system	*kW/Linear ft*	0.0457	1
kW_{ee}, kW of post-retrofit or energy-efficient lighting system	*kW/Linear ft*	0.00127	1
CF, Coincidence factor	*Decimal*	EDC Data Gathering Default for Indoor Applications: Table 3-5 Default for Outdoor Applications: 0[99]	EDC Data Gathering Table 3-5
HOU, Annual hours of Use	$\frac{Hours}{Year}$	EDC Data Gathering Default: Table 3-5	EDC Data Gathering Table 3-5
IF_{energy}, Interactive Energy Factor	*None*	Default: Table 3-8 and Table 3-9	Table 3-8 and Table 3-9
IF_{demand}, Interactive Demand Factor	*None*	Default: Table 3-8 and Table 3-9	Table 3-8 and Table 3-9
SVG_{base}, Savings factor for existing lighting control (percent of time the lights are off), typically manual switch.	*None*	Default: Table 3-4	Table 3-4
SVG_{ee}, Savings factor for new lighting control (percent of time the lights are off).	*None*	Default: Table 3-4	Table 3-4

Default Savings

There are no default savings for this measure.

Evaluation Protocol

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables.

[99] The peak demand reduction is zero, as the exterior lighting applications are assumed to be in operation during off-peak hours and have a peak coincidence factor of 0.0.

It is noted that if site-specific data is used to determine HOU, then the same data must be used to determine the site-specific CF. Similarly, if the default TRM HOU is used, then the default TRM CF must also be used in the savings calculations. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) Southern California Edison Company, LED Channel Letter Signage (Red), Work Paper SCE13LG052, Revision 1, February 2, 2016.

3.1.6 LED Refrigeration Display Case Lighting

Target Sector	Commercial and Industrial Establishments
Measure Unit	Refrigeration Display Case Lighting
Measure Life	8 years Source 1
Measure Vintage	Early Replacement

This protocol applies to LED lamps with and without motion sensors installed in vertical display refrigerators, coolers, and freezers replacing T8 or T12 linear fluorescent lamps. The LED lamps produce less waste heat than the fluorescent baseline lamps, decreasing the cooling load on the refrigeration system and energy needed by the refrigerator compressor. Additional savings can be achieved from the installation of motion sensors which dim the lights when the space is unoccupied.

See Appendix E for general eligibility requirements for solid state lighting products in commercial and industrial applications.

Eligibility

This measure is targeted to non-residential customers who install LED case lighting with or without motion sensors on existing refrigerators, coolers, and freezers - specifically on vertical displays. The baseline equipment is assumed to be cases with uncontrolled T8 or T12 linear fluorescent lamps.[100]

Algorithms

Savings and assumptions are based on a per door basis.

$$\Delta kWh = \frac{(WATTS_{base} - WATTS_{ee})}{1{,}000} \times N_{doors} \times HOURS \times \left(1 + IF_{energy}\right)$$

$$\Delta kW_{peak} = \frac{(WATTS_{base} - WATTS_{ee})}{1{,}000} \times N_{doors} \times (1 + IF_{demand}) \times CF$$

100 Assumption of T12 retrofit baselines are limited to refrigeration display case lighting due to the specialized high CRI application.

Definition of Terms

Table 3-19: Terms, Values, and References for LED Refrigeration Case Lighting

Term	Unit	Values	Source
$WATTS_{base}$, Connected wattage of baseline fixtures for each door	*W*	EDC Data Gathering	EDC Data Gathering
$WATTS_{ee}$, Connected wattage of efficient fixtures for each door	*W*	EDC Data Gathering	EDC Data Gathering
N_{doors}, Number of doors	*None*	EDC Data Gathering	EDC Data Gathering
$HOURS$, Annual operating hours	$\frac{Hours}{Year}$	EDC Data Gathering Default: 6,471	1
IF_{energy}, Interactive Energy Factor	*None*	Default: Table 3-8	Table 3-8
IF_{demand}, Interactive Demand Factor	*None*	Default: Table 3-8	Table 3-8
CF, Coincidence factor	*Decimal*	0.99	2
$1{,}000$, Conversion factor from watts to kilowatts	$\frac{W}{kW}$	1,000	Conversion Factor

Default Savings

Default savings may be claimed using the algorithms above and the variable defaults. EDCs may also claim savings using customer specific data.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) Theobald, M. A., Emerging Technologies Program: Application Assessment Report #0608, LED Supermarket Case Lighting Grocery Store, Northern California, Pacific Gas and Electric Company, January 2006. http://www.etcc-ca.com/images/stories/pdf/ETCC_Report_204.pdf. Assumes 6,471 annual operating hours and 50,000 lifetime hours. Note that 6,471 is the assumed HOU for general service lighting in grocery settings.

2) Pennsylvania Statewide Act 129 2014 Commercial & Residential Lighting Metering Study. Prepared for Pennsylvania Public Utilities Commission. January 13, 2015. https://www.puc.pa.gov/pcdocs/1340978.pdf.

3.1.7 Lighting Improvements for Midstream Delivery Programs

Target Sector	Commercial and Industrial Establishments
Measure Unit	Lighting Equipment
Measure Life	Variable[101]
Measure Vintage	Replace on burnout or Early Replacement

Mid-Stream Lighting Overview

Significant changes in the lighting industry in recent years, particularly related to LED lamp products, have created an opportunity for utility programs to engage directly with commercial lighting suppliers to increase the adoption of energy efficient lighting technologies.

Lighting Improvements for Midstream Delivery Programs will offer incentives on eligible products sold to trade allies and customers through commercial sales channels such as distributors of lighting products. This complements other delivery channels (such as downstream rebates to trade allies and customers) by providing incentives to encourage distributors to stock, promote, and sell more efficient lighting. Midstream Delivery Programs should be used for one-for-one fixture replacement; if fixtures are being removed and not replaced, the contractor should go through the downstream program and complete Appendix C.

This protocol applies to efficient lighting delivered through a midstream channel. Code minimum baseline (where applicable) and least efficient readily available (replace on burnout) product were used to determine baseline wattage.

Eligibility

Measures covered by the Lighting Improvements for Midstream Delivery Programs protocol include fixture, lamp, or lamp and ballast replacement in existing commercial and industrial customers' facilities. The protocol is used for programs where EDCs pay incentives to qualified midstream participants including but not limited to distributors, for eligible LED lamps and fixtures. Retrofit measures where incentives are paid to customers or trade allies are covered by the Lighting Improvements protocol. New construction measures are covered by the New Construction Lighting protocol and excluded here. Lamps and fixtures included in this protocol are categorized as follows:

- Omnidirectional, directional, and decorative screw-based lamps
- LED lamps and fixtures
- Highbay and lowbay fixtures
- Highbay and lowbay fixtures with integrated controls
- Exterior area and wall pack fixtures
- Parking garage lighting

See Appendix E for general eligibility requirements for solid state lighting products in commercial and industrial applications.

Algorithms

For all lighting fixture improvements (without control improvements), the following algorithms apply:

[101] See Lighting Improvements measure.

$$\Delta kWh = (kW_{base} - kW_{ee}) \times HOU \times (1 - SVG_{base}) \times \left(1 + IF_{energy}\right) \times ISR$$

$$\Delta kW_{peak} = (kW_{base} - kW_{ee}) \times CF \times (1 - SVG_{base}) \times (1 + IF_{demand}) \times ISR$$

Definition of Terms

Table 3-20: Terms, Values, and References for Lighting Improvements for Midstream Delivery Programs

Term	Unit	Values	Source
kW_{base}, Wattage of baseline lighting	*kW*	Default: Table 3-21, Table 3-22, Table 3-23, and Table 3-24	Table 3-21, Table 3-22, Table 3-23, and Table 3-24
kW_{ee}, Wattage of incentivized lighting	*kW*	EDC Data Gathering	EDC Data Gathering
HOU, Hours of Use – the average annual operating hours of the lighting equipment, which if applied to full connected load will yield annual energy use.	$\frac{Hours}{Year}$	Default Screw-based Bulbs: Table 3-5 Default Other General Service: Table 3-6 Default Street Lighting: Table 3-7 EDC Data Gathering If building type unknown: 2,500 hours	Table 3-5, Table 3-6, and Table 3-7 EDC Data Gathering
CF, Coincidence Factor	*Decimal*	Default Screw-based Bulbs: Table 3-5 Default Other General Service: Table 3-6 If building type is unknown: 0.60	Table 3-5 and Table 3-6
SVG_{base}, Savings factor for existing lighting control (percent of time the lights are off)	*None*	Default: Table 3-25	1, 2
IF_{energy}, Interactive Energy Factor	*None*	Default: Table 3-8 and Table 3-9	Table 3-8 and Table 3-9
IF_{demand}, Interactive Demand Factor	*None*	Default: Table 3-8 and Table 3-9	Table 3-8 and Table 3-9
ISR, In Service Rate, the fraction of incentivized lamps or fixtures that are installed within three years of purchase	*%*	EDC Data Gathering Default = 98%	4

Table 3-21, Table 3-22, Table 3-23, and Table 3-24 are arranged by lamp type. When the lamp type is covered by codes or standards, those code/standard wattages apply. For lamps not covered by codes/standards, baseline wattage is the least-efficient, commercially-available, commonly-installed technology. The baseline wattage for LED lamps and fixtures measures is the wattage for the least efficient, standards compliant equipment commonly available in the market.

Efficient product wattages are manufacturer published values as collected by EDCs and ICSPs.

HOU and CF values in Table 3-5 and Table 3-6 use building types or EDC data gathering. Building type information must be collected by EDCs and ICSPs for all projects with a change in connected load above 20 KW.

Table 3-21: Baseline Wattage, Omnidirectional Lamps

Efficient Lamp or Fixture	Minimum Lumen	Maximum Lumen	Incandescent Equivalent (For Reference Only)	$Watts_{base}$ 2021-2026	Source
Omnidirectional, General Service Lamp, Screw-based	250	309	25	25	5, 6, 7
	310	449	25	8	
	450	749	40	13	
	750	1,049	60	20	
	1,050	1,489	75	28	
	1,490	1,999	100	39	
	2,000	2,600	125	51	
	2,601	3,000	150	62	
	3,001	3,300	200	70	
	3,301	3,999	200	200	
	4,000	6,000	300	300	

Table 3-22: Baseline Wattage, Decorative Lamps

Efficient Lamp or Fixture	Minimum Lumen	Maximum Lumen	Incandescent Equivalent (For Reference Only)	$Watts_{base}$ 2021-2026	Source
Decorative, Non-Globe, Screw-based	70	89	10	10	5, 6, 7
	90	149	15	15	
	150	299	25	25	
	300	309	40	29	
	310	499	40	9	
	500	699	60	13	
Decorative, Globe, Screw-based	250	309	25	25	5, 6, 7
	310	349	25	7	
	350	499	40	9	
	500	574	60	12	
	575	649	75	14	
	650	749	100	16	
	750	1,049	100	20	

Efficient Lamp or Fixture	Minimum Lumen	Maximum Lumen	Incandescent Equivalent (For Reference Only)	$Watts_{base}$ 2021-2026	Source
	1,049	1,300	150	26	

Table 3-23: Baseline Wattage, Directional Lamps

Efficient Lamp or Fixture	Minimum Lumen	Maximum Lumen	Incandescent Equivalent (For Reference Only)	$Watts_{base}$ 2021-2026	Source
Reflector Lamp; R, ER, BR, with screw-based, >=2.25" diameter	400	472	40	10	5, 6, 7
	473	524	45	11	
	525	714	50	14	
	715	937	65	18	
	938	1,259	75	24	
	1,260	1,399	90	30	
	1,400	1,739	100	35	
	1,740	2,174	120	43	
	2,175	2,624	150	53	
	2,625	2,999	175	62	
	3,000	3,300	200	70	
	3,301	4,500	200	200	
Reflector Lamp; R, ER, BR, with screw-based, diameter <2.25"	400	449	40	9	5, 6, 7
	450	499	45	11	
	500	649	50	13	
	650	1,199	65	21	
ER30, BR30, BR40, or ER40	400	449	40	9	5, 6, 7
	450	499	45	11	
	500	649	50	13	
	650	1,199	65	21	
R20	400	449	40	9	5, 6, 7
	450	719	45	13	
Reflector Lamp; PAR, MR, MRX	400	472	Custom[102]	10	5, 6, 7
	473	524		11	
	525	714		14	
	715	937		18	
	938	1,259		24	

[102] Use one of the following approaches to determine the incandescent equivalent for PAR, MR and MRX bulbs: (1) If the ENERGY STAR Qualified Products List (QPL) (https://data.energystar.gov/Active-Specifications/ENERGY-STAR-Certified-Light-Bulbs/v33x-ybr3) provides a value for "Wattage Equivalency (watts)," use that value. (2) If the product does not have the aforementioned value, enter the bulb's beam angle, center beam candle power, and diameter into the ENERGY STAR Center Beam Candle Power tool (http://energystar.supportportal.com/link/portal/23002/23018/Article/32655/).

Efficient Lamp or Fixture	Minimum Lumen	Maximum Lumen	Incandescent Equivalent (For Reference Only)	Watts$_{base}$ 2021-2026	Source
	1,260	1,399		30	
	1,400	1,739		35	
	1,740	2,174		43	
	2,175	2,624		53	
	2,625	2,999		62	
	3,000	3,300		70	
	3,301	4,500		200	
All reflector lamps < 400 lumen	200	309	20	20	5, 6, 7
	310	399	30	8	

Table 3-24: Baseline Wattage, Linear Lamps & Fixtures, HID Interior and Exterior Fixtures

Efficient Lamp or Fixture	Minimum Lumen	Maximum Lumen	Watts$_{base}$	Note	Source
Linear Lamp, 2 ft			16.5	Baseline is standard T8 lamp adjusted for fixture and ballast	Appendix C; 17 4 ft 2 lamp T8 fixture 59 watt/2 = 29.5 watt / lamp
Linear Lamp, < 3,200 lumen, 4 ft			29.5	Baseline is standard T8 lamp adjusted for fixture and ballast	
Linear Lamp, ≥ 3,200 lumen, 4 ft			54	Baseline is T5 HO	
Linear Lamp, 5 ft			40	Baseline is standard T8	
Linear Lamp, 6 ft			65	Baseline is standard T8	
Linear Lamp, 8 ft		4,000	59	Baseline is standard T8	
Linear Lamp, 8 ft HO	4,001		86	Baseline is HO T8	
Linear LED Fixture, 2 ft	1,500	3,500	33	Baseline is standard 2L T8	Linear LED Fixture Max Lumen = Number lamps x Lumen Output x Fixture Efficiency x Ballast Factor; where 4' T8 mean lumen = 3,199, fixture efficiency =
Linear LED Fixture, 2 ft	3,501	5,500	61	Baseline is standard 4L T8	
Linear LED Fixture, 4 ft		< 2,132	31	Baseline is standard 1L T8	
Linear LED Fixture, 4 ft	2,132	4,261	59	Baseline is standard 2L T8	

Efficient Lamp or Fixture	Minimum Lumen	Maximum Lumen	$Watts_{base}$	Note	Source
Linear LED Fixture, 4 ft	4,262	6,392	89	Baseline is standard 3L T8	74%, ballast factor = 0.90 5, 9, 10
Linear LED Fixture, 4 ft	6,393	9,400	112	Baseline is standard 4L T8	
Linear LED Fixture, 8 ft		< 3,290	58	Baseline is standard 1L T8	
Linear LED Fixture, 8 ft	3,291	6,580	109	Baseline is standard 2L T8	
Linear LED Fixture, 8 ft	6,581	9,870	167	Baseline is standard 3L T8	
Linear LED Fixture, 8 ft	9,871		219	Baseline is standard 4L T8	
Highbay & Lowbay LED Fixture	3,850	6,550	135	Average 150 watt HID lamp/ T8 HLO	LED Lumen Equivalent = HID Initial Lamp Lumen x HID LLD at 40% rated life x HID Fixture Efficiency HID LLD = 75.8%, HID Fixture Efficiency = 80.4%; survey of manufacturer data, MH, PSMH 9, 11, 12, 13, 14, 15
	6,551	9,300	168	Average 175 watt HID lamp/ T8 HLO	
	9,301	11,150	198	Average 200 watt HID lamp/ T8 HLO	
	11,151	12,200	236	Average 250 watt HID lamp/ T8 HLO	
	12,201	15,550	289	Average 320 watt HID lamp/ T8 HLO	
	15,551	20,100	367	Average 400 watt HID lamp/ T8 HLO	
	20,101	34,700	634	Average 750 watt HID lamp/ T8 HLO	
	34,701	57,250	901	Average 1,000 watt HID lamp/ T8 HLO	
Exterior Fixture (Pole, Wall Pack or Parking Garage)	250	4,650	133	100 watt HID lamp	LED Lumen Equivalent = HID Initial Lamp Lumen x HID LLD at 40% rated life x HID Fixture Efficiency x DLC adjustment DLC Adjust = 80/70 lumen/watt where 80 is DLC minimum for indoor highbay, 70 for outdoor, HID LLD = 75.8%, HID Fixture Efficiency = 81.5%; survey of
	4,651	7,900	215	175 watt HID lamp	
	7,901	11,050	295	250 watt HID lamp	
	11,051	24,700	462	400 watt HID lamp	
	24,701	40,750	843	750 watt HID lamp	

Efficient Lamp or Fixture	Minimum Lumen	Maximum Lumen	$Watts_{base}$	Note	Source
	40,751	54,650	1,090	1,000 watt HID lamp	manufacturer data, MH, PSMH, HPS 9, 11, 12, 13, 14, 15, 16

Table 3-25: Savings Control (SVG_{base}) Factors Assumptions[103,104,105]

Efficient Lamp or Fixture Type	Strategy	Definition	Technology	Savings	Sources
Fixture without integrated sensor/ control	Switch	Manual On/Off Switch	Light Switch	1.44%[106]	1, 2
Fixture with integrated sensor/control	Occupancy	Adjusting light levels according to the presence of occupants	Occupancy Sensors	24%	
Fixture with integrated sensor/control	Multiple Types	Includes combination of 2 or more of the types: *occupancy, daylighting, personal tuning, institutional tuning.*	Occupancy and personal tuning /daylighting, dimming and occupancy	38%	

DEFAULT SAVINGS

There are no default savings associated with this measure.

EVALUATION PROTOCOLS

For all projects selected for evaluation:

- EDCs have the option to collect building type data or use a default HOU for all building types, as shown in Table 3-20, above. This decision should be documented in the EM&V plan and handled consistently for all projects in program year.
- Using the SVG_{base} values appearing in
- Table 3-25 is acceptable for both implementation and evaluation (i.e., treat as deemed). However, EDCs are encouraged to collect customer-specific controls information where feasible.
- The default baseline wattage can be used to estimate savings provided that the distributor certifies the lamp type, lamp wattage, ballast type and fixture configuration (2 lamp, 4 lamp, etc.).

The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

103 Subject to verification by EDC Evaluation or SWE.
104 Subject to verification by EDC Evaluation or SWE.
105 Integrated control requires fixture to have built-in sensor or be prewired for sensor and sold with sensor.
106 The Pennsylvania Statewide Act 129 2014 SWE Commercial & and Residential Light Metering Study (Figure 4-16). On average 6 percent of commerical lighting load controlled by sensors including wall-mounted sensors. 6% x 24% = 1.44%.

Sources

1) Williams, A., Atkinson, B., Garbesi, K., Rubinstein, F., "A Meta-Analysis of Energy Savings from Lighting Controls in Commercial Buildings", Lawrence Berkeley National Laboratory, September 2011. http://eetd.lbl.gov/sites/all/files/a_meta-analysis_of_energy_savings_from_lighting_controls_in_commercial_buildings_lbnl-5095e.pdf
2) Pennsylvania Statewide Act 129 2014 Commercial & Residential Lighting Metering Study. Prepared for Pennsylvania Public Utilities Commission. January 13, 2015. http://www.puc.pa.gov/pcdocs/1340978.pdf
3) Efficiency Vermont Technical Reference User Manual (TRM), March 16, 2015. https://puc.vermont.gov/sites/psbnew/files/doc_library/ev-technical-reference-manual.pdf
4) Illinois Statewide Technical Reference Manual for Energy Efficiency v7.0, 4.5.4 LED Bulbs and Fixtures. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_7/Final_9-28-18/IL-TRM_Effective_010119_v7.0_Vol_2_C_and_I_092818_Final.pdf.
5) Energy Independence and Security Act ("EISA") of 2007. https://www.congress.gov/bill/110th-congress/house-bill/6. EISA requires all general service lamps sold on or after 1/1/2020 to meet efficacy requirements of 45 lm/W.
6) Energy Conservation Program: Energy Conservation Standards for General Service Lamps. 82 Fed. Reg. 12 (January 19, 2017). Federal Register: The Daily Journal of the United States. Amends the definition of general service lamps to cover the vast majority of screw-base lamps (including incandescent reflectors).
7) ENERGY STAR® Program Requirements for Lamps (Light Bulbs) V2.1. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V2.1%20Final%20Specification.pdf
8) ENERGY STAR® Lamps Center Beam Intensity Benchmark Tool. https://www.energystar.gov/sites/default/files/ESLampCenterBeamTool%20rev%202016-09-01.xlsx
9) Design Lights Consortium, Qualified Products List, www.designlights.org
10) US Department of Energy, CALiPER Benchmark Report. Performance of T12 and T8 Fluorescent Lamps and Troffers and LED Linear Replacement Lamps. Page 5. January 2009. http://www.pnl.gov/publications/abstracts.asp?report=251010.
11) Lamp and Ballast Catalogue, 2014-2015, Osram, www.osram-americas.com.
12) US Department of Energy, Lumen Maintenance and Light Loss Factors, September 2013, www.pnnl.gov/main/publications/external/technical_reports/PNNL-22727.pdf
13) GE Lamps and Ballasts Catalogue, 2015-2016, http://www.gelighting.com/LightingWeb/na/smart-catalog.jsp.
14) Lithonia, 2016, http://www.lithonia.com/psg/.
15) Eaton Cooper, http://www.cooperindustries.com/content/public/en/lighting.html.
16) DOE LED Lighting Facts, http://www.lightingfacts.com/.

3.2 HVAC

3.2.1 HVAC Systems

Target Sector	Commercial and Industrial Establishments
Measure Unit	HVAC System
Measure Life	15 years Source 1
Measure Vintage	Replace on Burnout, New Construction, or Early Replacement

Eligibility

The energy and demand savings for Commercial and Industrial HVAC systems is determined from the algorithms listed below. This protocol excludes water source, ground source, and groundwater source heat pumps measures that are covered in Section 3.2.3. All HVAC applications other than comfort cooling and heating, such as process cooling, are defined as non-standard applications and are ineligible for this measure.

Algorithms

Air Conditioning (central AC, air-cooled DX, split systems, and packaged terminal AC)

For A/C units < 65,000 Btu/hr, use SEER to calculate ΔkWh and convert SEER to EER to calculate ΔkW_{peak} using 11.3/13 as the conversion factor. For units rated in both EER and IEER, use IEER for energy savings calculations.

$$\Delta kWh = \left(\frac{Btu_{cool}}{hr} \times \frac{1\ kW}{1{,}000\ W}\right) \times \left(\frac{1}{EER_{base}} - \frac{1}{EER_{ee}}\right) \times EFLH_{cool}$$

$$= \left(\frac{Btu_{cool}}{hr} \times \frac{1\ kW}{1{,}000\ W}\right) \times \left(\frac{1}{IEER_{base}} - \frac{1}{IEER_{ee}}\right) \times EFLH_{cool}$$

$$= \left(\frac{Btu_{cool}}{hr} \times \frac{1\ kW}{1{,}000\ W}\right) \times \left(\frac{1}{SEER_{base}} - \frac{1}{SEER_{ee}}\right) \times EFLH_{cool}$$

$$\Delta kW_{peak} = \left(\frac{Btu_{cool}}{hr} \times \frac{1\ kW}{1{,}000\ W}\right) \times \left(\frac{1}{EER_{base}} - \frac{1}{EER_{ee}}\right) \times CF$$

Air Source and Packaged Terminal Heat Pump

For ASHP units < 65,000 Btu/hr, use SEER to calculate ΔkWh_{cool} and HSPF to calculate ΔkWh_{heat}. Convert SEER to EER to calculate ΔkW_{peak} using 11.3/13 as the conversion factor. For units rated in both EER and IEER, use IEER for energy savings calculations.

$$\Delta kWh = \Delta kWh_{cool} + \Delta kWh_{heat}$$

$$\Delta kWh_{cool} = \left(\frac{Btu_{cool}}{hr} \times \frac{1\ kW}{1{,}000\ W}\right) \times \left(\frac{1}{EER_{base}} - \frac{1}{EER_{ee}}\right) \times EFLH_{cool}$$

$$= \left(\frac{Btu_{cool}}{hr} \times \frac{1\ kW}{1{,}000\ W}\right) \times \left(\frac{1}{IEER_{base}} - \frac{1}{IEER_{ee}}\right) \times EFLH_{cool}$$

$$= \left(\frac{Btu_{cool}}{hr} \times \frac{1\ kW}{1{,}000\ W}\right) \times \left(\frac{1}{SEER_{base}} - \frac{1}{SEER_{ee}}\right) \times EFLH_{cool}$$

$$\Delta kWh_{heat} = \left(\frac{Btu_{heat}}{hr} \times \frac{1\ kW}{1{,}000\ W}\right) \times \frac{1}{3.412} \times \left(\frac{1}{COP_{base}} - \frac{1}{COP_{ee}}\right) \times EFLH_{heat}$$

$$= \left(\frac{Btu_{heat}}{hr} \times \frac{1\ kW}{1{,}000\ W}\right) \times \left(\frac{1}{HSPF_{base}} - \frac{1}{HSPF_{ee}}\right) \times EFLH_{heat}$$

$$\Delta kW_{peak} = \left(\frac{Btu_{cool}}{hr} \times \frac{1\ kW}{1{,}000\ W}\right) \times \left(\frac{1}{EER_{base}} - \frac{1}{EER_{ee}}\right) \times CF$$

Definition of Terms

Table 3-26: Terms, Values, and References for HVAC Systems

Term	Unit	Values	Source
$\frac{Btu_{cool}}{hr}$, Rated cooling capacity of the energy efficient unit	$\frac{Btu}{hr}$	Nameplate data (AHRI)	EDC Data Gathering
$\frac{Btu_{heat}}{hr}$, Rated heating capacity of the energy efficient unit	$\frac{Btu}{hr}$	Nameplate data (AHRI)	EDC Data Gathering
$IEER_{base}$, Integrated energy efficiency ratio of the baseline unit.	$\frac{Btu/hr}{W}$	Early Replacement: Nameplate data	EDC Data Gathering
		New Construction or Replace on Burnout: Default values from Table 3-27	See Table 3-27
$IEER_{ee}$, Integrated energy efficiency ratio of the energy efficient unit.	$\frac{Btu/hr}{W}$	Nameplate data (AHRI)	EDC Data Gathering
EER_{base}, Energy efficiency ratio of the baseline unit. For air-source AC and ASHP units < 65,000 $\frac{Btu}{hr}$, SEER should be used for cooling savings	$\frac{Btu/hr}{W}$	Early Replacement: Nameplate data	EDC Data Gathering
		New Construction or Replace on Burnout: Default values from Table 3-27	See Table 3-27

Term	Unit	Values	Source
EER_{ee}, Energy efficiency ratio of the energy efficient unit. For air-source AC and ASHP units < 65,000 $\frac{Btu}{hr}$, SEER should be used for cooling savings.	$\frac{Btu/hr}{W}$	Nameplate data (AHRI)	EDC Data Gathering
$SEER_{base}$, Seasonal energy efficiency ratio of the baseline unit. For units > 65,000 $\frac{Btu}{hr}$, EER should be used for cooling savings.	$\frac{Btu/hr}{W}$	Early Replacement: Nameplate data	EDC Data Gathering
		New Construction or Replace on Burnout: Default values from Table 3-27	See Table 3-27
$SEER_{ee}$, Seasonal energy efficiency ratio of the energy efficient unit. For units > 65,000 $\frac{Btu}{hr}$, EER should be used for cooling savings.	$\frac{Btu/hr}{W}$	Nameplate data (AHRI)	EDC Data Gathering
COP_{base}, Coefficient of performance of the baseline unit. For ASHP units < 65,000$\frac{Btu}{hr}$, HSPF should be used for heating savings.	None	Early Replacement: Nameplate data	EDC Data Gathering
		New Construction or Replace on Burnout: Default values from Table 3-27	See Table 3-27
COP_{ee}, Coefficient of performance of the energy efficient unit. For ASHP units < 65,000 $\frac{Btu}{hr}$ HSPF should be used for heating savings.	None	Nameplate data (AHRI)	EDC Data Gathering
$HSPF_{base}$, Heating seasonal performance factor of the baseline unit. For units > 65,000 $\frac{Btu}{hr}$, COP should be used for heating savings.	$\frac{Btu/hr}{W}$	Early Replacement: Nameplate data	EDC Data Gathering
		New Construction or Replace on Burnout: Default values from Table 3-27	See Table 3-27
$HSPF_{ee}$, Heating seasonal performance factor of the energy efficiency unit. For units > 65,000 $\frac{Btu}{hr}$, COP should be used for heating savings.	$\frac{Btu/hr}{W}$	Nameplate data (AHRI)	EDC Data Gathering
CF, Coincidence Factor	*Decimal*	EDC Data Gathering	EDC Data Gathering
		Default: Table 3-29	2
$EFLH_{cool}$, Equivalent Full Load Hours for the cooling season – The kWh during the entire operating season divided by the kW at design conditions.	$\frac{Hours}{Year}$	EDC Data Gathering	EDC Data Gathering
		Default: Table 3-28	2

Term	Unit	Values	Source
$EFLH_{heat}$, Equivalent Full Load Hours for the heating season – The kWh during the entire operating season divided by the kW at design conditions.	$\frac{Hours}{Year}$	EDC Data Gathering	EDC Data Gathering
		Default: Table 3-30	2
11.3/13, Conversion factor from SEER to EER, based on average EER of a SEER 13 unit	*None*	$\frac{11.3}{13}$	3
1,000, conversion from watts to kilowatts	$\frac{kW}{W}$	1,000	Conversion Factor
3.412, conversion factor from kWh to kBtu	$\frac{kBtu}{kWh}$	3.412	Conversion Factor

Table 3-27: HVAC Baseline Efficiencies

Equipment Type and Capacity	Subcategory or Rating Condition	Cooling Baseline		Heating Baseline		Source
		PY13-PY14	PY15-PY17	PY13-PY14	PY15-PY17	
Air-Source Air Conditioners						
< 65,000 Btu/h	Split System	13.0 SEER	13.0 SEER	N/A	N/A	5
	Single Package	14.0 SEER	14.0 SEER			
> 65,000 Btu/h and < 135,000 Btu/h	Split System and Single Package	11.2 EER	11.7 EER	N/A	N/A	5, 8, 9
		12.9 IEER	14.8 EER			
≥ 135,000 Btu/h and < 240,000 Btu/h	Split System and Single Package	11.0 EER	11.4 EER	N/A	N/A	5, 8, 9
		12.4 IEER	14.2 EER			
≥ 240,000 Btu/h and < 760,000 Btu/h	Split System and Single Package	10.0 EER	10.4 EER	N/A	N/A	5, 8, 9
		11.6 IEER	13.2 EER			
≥ 760,000 Btu/h	Split System and Single Package	9.7 EER	9.7 EER	N/A	N/A	5
		11.2 IEER	11.2 IEER			
Air-Source Heat Pumps						
< 65,000 Btu/h	Split System	14.0 SEER	14.0 SEER	8.2 HSPF	8.2 HSPF	5
	Single Package	14.0 SEER	14.0 SEER	8.0 HSPF	8.0 HSPF	
≥ 65,000 Btu/h and < 135,000 Btu/h	Split System and Single Package	11.0 EER	12.0 EER	3.3 COP	3.4 COP	5, 8, 9
		12.2 IEER	14.1 IEER			
≥ 135,000 Btu/h and < 240,000 Btu/h	Split System and Single Package	10.6 EER	10.7 EER	3.2 COP	3.3 COP	5, 8, 9
		11.6 IEER	13.5 IEER			
≥ 240,000 Btu/h	Split System and Single Package	9.5 EER	9.9 EER	3.2 COP	3.2 COP	5, 8, 9
		10.6 IEER	12.5 IEER			

Equipment Type and Capacity	Subcategory or Rating Condition	Cooling Baseline		Heating Baseline		Source
		PY13-PY14	PY15-PY17	PY13-PY14	PY15-PY17	
Packaged Terminal Systems (Nonstandard Size) - Replacement						
PTAC	N/A	10.9 - (0.213 x Cap / 1,000) EER	10.9 - (0.213 x Cap / 1,000) EER	N/A	N/A	5
PTHP	N/A	10.8 - (0.213 x Cap / 1,000) EER	10.8 - (0.213 x Cap / 1,000) EER	2.9 - (0.026 x Cap / 1,000) COP	2.9 - (0.026 x Cap / 1,000) COP	
Packaged Terminal Systems (Standard Size) – New Construction						
PTAC	N/A	14.0 - (0.300 x Cap / 1,000) EER	14.0 - (0.300 x Cap / 1,000) EER	N/A	N/A	5
PTHP	N/A	14.0 - (0.300 x Cap / 1,000) EER	14.0 - (0.300 x Cap / 1,000) EER	3.7 - (0.052 x Cap / 1,000) COP	3.7 - (0.052 x Cap / 1,000) COP	
Water-Cooled Air Conditioners						
< 65,000 Btu/h	Split System and Single Package	12.1 EER	12.1 EER	N/A	N/A	5
		12.3 IEER	12.3 IEER			
≥ 65,000 Btu/h and < 135,000 Btu/h	Split System and Single Package	12.1 EER	12.1 EER	N/A	N/A	
		13.9 IEER	13.9 IEER			
≥ 135,000 Btu/h and < 240,000 Btu/h	Split System and Single Package	12.5 EER	12.5 EER	N/A	N/A	
		13.9 IEER	13.9 IEER			
≥ 240,000 Btu/h and < 760,000 Btu/h	Split System and Single Package	12.4 EER	12.4 EER	N/A	N/A	
		13.6 IEER	13.6 IEER			
≥ 760,000 Btu/h	Split System and Single Package	12.2 EER	12.2 EER	N/A	N/A	
		13.5 IEER	13.5 IEER			
Evaporatively-Cooled Air Conditioners						
< 65,000 Btu/h	Split System and Single Package	12.1 EER	12.1 EER	N/A	N/A	5
		12.3 IEER	12.3 IEER			
≥ 65,000 Btu/h and < 135,000 Btu/h	Split System and Single Package	12.1 EER	12.1 EER	N/A	N/A	
		12.3 IEER	12.3 IEER			
≥ 135,000 Btu/h and < 240,000 Btu/h	Split System and Single Package	12.0 EER	12.0 EER	N/A	N/A	
		12.2 IEER	12.2 IEER			
≥ 240,000 Btu/h and < 760,000 Btu/h	Split System and Single Package	11.9 EER	11.9 EER	N/A	N/A	
		12.1 IEER	12.1 IEER			
≥ 760,000 Btu/h	Split System and Single Package	11.7 EER	11.7 EER	N/A	N/A	
		11.9 IEER	11.9 IEER			

Note: For non-PTAC/PTHP equipment at capacities greater than 65,000 Btu/h, subtract 0.2 from the required baseline efficiency rating value if unit has heating section other than electric resistance.

Table 3-28: Cooling EFLHs for Pennsylvania Cities

Space and/or Building Type	Allentown	Binghamton	Bradford	Erie	Harrisburg	Philadelphia	Pittsburgh	Scranton	Williamsport	Source
Education - College/University	640	440	369	478	657	734	594	533	595	2
Education - Other	267	163	139	185	310	345	273	217	239	2
Grocery	654	542	542	636	453	536	638	434	442	2
Health - Hospital	1,030	977	977	1,038	892	1,059	788	1,022	1,013	2
Health - Other	477	397	350	481	540	684	511	467	476	2
Industrial Manufacturing	570	361	309	411	616	682	530	445	478	2
Institutional/Public Service	753	516	455	607	820	1,087	706	629	685	2
Lodging	1,386	1,205	1,084	1,392	1,523	1,732	1,478	1,348	1,384	2
Multi-Family (Common Areas)	1,395	654	577	769	1,482	1,647	1,176	991	1,052	6,7
Office	458	213	323	412	565	704	721	500	466	2
Restaurant	550	429	374	513	590	791	632	522	594	2
Retail	735	535	464	620	742	911	816	603	648	2
Warehouse - Other	174	97	86	114	235	346	192	130	178	2
Warehouse - Refrigerated	3,130	3,048	3,010	3,080	3,163	3,200	3,116	3,094	3,135	2

Table 3-29: Cooling Demand CFs for Pennsylvania Cities

Space and/or Building Type	Allentown	Binghamton	Bradford	Erie	Harrisburg	Philadelphia	Pittsburgh	Scranton	Williamsport	Source
Education - College/University	0.48	0.40	0.37	0.38	0.48	0.51	0.48	0.45	0.49	2
Education - Other	0.12	0.09	0.07	0.09	0.18	0.19	0.18	0.13	0.15	
Grocery	0.33	0.26	0.26	0.27	0.24	0.26	0.27	0.21	0.24	
Health - Hospital	0.43	0.36	0.34	0.37	0.39	0.44	0.39	0.37	0.42	
Health - Other	0.26	0.25	0.23	0.27	0.30	0.34	0.32	0.28	0.29	
Industrial Manufacturing	0.51	0.37	0.33	0.39	0.55	0.60	0.53	0.45	0.48	
Institutional/Public Service	0.53	0.38	0.34	0.45	0.60	0.72	0.56	0.48	0.52	
Lodging	0.72	0.73	0.71	0.77	0.78	0.83	0.83	0.73	0.78	
Multi-Family (Common Areas)	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	4
Office	0.32	0.16	0.26	0.31	0.41	0.27	0.35	0.36	0.37	2
Restaurant	0.38	0.36	0.33	0.37	0.42	0.50	0.49	0.39	0.45	
Retail	0.52	0.45	0.42	0.46	0.53	0.57	0.56	0.47	0.49	
Warehouse - Other	0.18	0.11	0.10	0.13	0.24	0.30	0.23	0.15	0.20	
Warehouse - Refrigerated	0.50	0.47	0.45	0.48	0.52	0.53	0.51	0.48	0.51	

Table 3-30: Heating EFLHs for Pennsylvania Cities

Space and/or Building Type	Allentown	Binghamton	Bradford	Erie	Harrisburg	Philadelphia	Pittsburgh	Scranton	Williamsport	Source
Education - College/University	719	984	1,078	857	552	464	651	824	655	2
Education - Other	636	910	1,018	666	741	646	884	925	655	
Grocery	733	1,068	1,068	534	1,269	1,217	564	1,737	1,419	
Health - Hospital	147	81	71	95	361	345	418	106	154	
Health - Other	944	1,432	1,630	1,304	854	805	1,023	1,193	958	
Industrial Manufacturing	406	500	568	473	374	339	400	441	346	
Institutional/Public Service	1,178	1,489	1,719	1,437	1,098	1,121	1,163	1,401	1,066	
Lodging	2,371	3,219	3,846	3,077	2,159	2,017	2,411	2,591	2,403	
Multi-Family (Common Areas)	277	320	354	322	263	259	264	281	278	6,7
Office	321	159	527	422	330	281	344	329	340	2
Restaurant	1,151	1,865	2,109	1,687	1,040	993	1,340	1,501	1,241	
Retail	809	1,085	1,221	980	648	632	781	855	675	
Warehouse - Other	847	1,108	1,258	1,114	843	900	978	1,008	800	
Warehouse - Refrigerated	363	613	668	534	307	222	409	439	328	

Default Savings

There are no default savings for this measure.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx. Accessed December 2018.

2) EFLHs and CFs for Pennsylvania are calculated based on Nexant's eQuest modeling analysis 2014.

3) Average EER for SEER 13 units as calculated by EER = -0.02 × SEER² + 1.12 × SEER based on U.S. DOE Building America House Simulation Protocol, Revised 2010. http://www.nrel.gov/docs/fy11osti/49246.pdf
4) C&I Unitary HVAC Load Shape Project Final Report, Version 1.1, KEMA, 2011. https://neep.org/sites/default/files/resources/NEEP_HVAC_Load_Shape_Report_Final_August2_0.pdf
5) International Energy Conservation Code 2015, Table C403.2.3(1).
6) ENERGY STAR Air-Source Heat Pump Calculator. US Department of Energy. Updated July 2011.
7) Connecticut's 2018 Program Savings Document. Eversource Energy and UIL Holdings Corp. December 15, 2017. The EFLH values reported in this document were adjusted using full load hours (FLH) from Source 6 to account for differences in weather conditions.
8) U.S. Department of Energy. 10 CFR Part 431. Energy Efficiency Program for Certain Commercial and Industrial Equipment: Subpart F—Commercial Air Conditioners and Heat Pumps. Tables 3, 4, 7.
9) Federal standards do no establish post-1/1/2023 minimum EER requirements for air-source air conditioners and heat pumps. Minimum EER requirements have been estimated using average EER of units meeting minimum IEER requirements, by type and size category, from the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) Directory of Certified Product Performance. Accessed 1/3/2019. https://www.ahridirectory.org/ahridirectory/pages/home.aspx

3.2.2 Electric Chillers

Target Sector	Commercial and Industrial Establishments
Measure Unit	Electric Chiller
Measure Life	15 years Source 1
Measure Vintage	Replace on Burnout, New Construction, or Early Replacement

Eligibility

This protocol estimates savings for installing high efficiency electric chillers as compared to chillers that meet the minimum performance allowed by the current PA Energy Code. The measurement of energy and demand savings for chillers is based on algorithms with key variables (i.e., Efficiency, Coincidence Factor, and Equivalent Full Load Hours (EFLHs). These prescriptive algorithms and stipulated values are valid for standard comfort cooling applications, defined as unitary electric chillers serving a single load at the system or sub-system level. The savings calculated using the prescriptive algorithms need to be supported by a certification that the chiller is appropriately sized for site design load condition.

All other chiller applications, including existing multiple chiller configurations (including redundant or 'stand-by' chillers), existing chillers serving multiple load groups, and chillers in industrial applications are defined as non-standard applications and must follow a site-specific custom protocol. Situations with existing non-VFD chillers upgrading to VFD chillers may use the protocol algorithm. This protocol does not apply to VFD retrofits to an existing chiller. In this scenario, the IPLV of the baseline chiller (factory tested IPLV) would be known, but the IPLV for the old chiller/new VFD would be unknown. The algorithms, assumptions, and default factors in this section may be applied to new construction applications.

Commented [SA41]: Franklin Energy

Heat recovery chillers would also qualify as non-standard applications.

Algorithms

Commented [SA42]: Franklin Energy

It is worth noting that chillers that use glycol will need to use adjustments in the savings calculations. The equations listed in this measure would need to be multiplied by the following:

× GCC × GPC where GCC is the Gylcol Capacity Correction and GPC is the Gylcol Power Correction Factor.

See https://www.achrnews.com/articles/90946-does-your-chiller-need-antifreeze
Tables provides GCC at AHRI conditions

http://metersolution.com/wp-content/uploads/2013/02/Glycol-and-Efficiency.pdf
Provides Power correction factor

For Equipment with Efficiency Ratings in EER units

$$\Delta kWh = Tons_{ee} \times 12 \times \left(\frac{1}{IPLV_{base}} - \frac{1}{IPLV_{ee}}\right) \times EFLH$$

$$\Delta kW_{peak} = Tons_{ee} \times 12 \times \left(\frac{1}{EER_{base}} - \frac{1}{EER_{ee}}\right) \times CF$$

For Equipment with Efficiency Ratings in kW/ton units

$$\Delta kWh = Tons_{ee} \times (IPLV_{base} - IPLV_{ee}) \times EFLH$$

$$\Delta kW_{peak} = Tons_{ee} \times \left(\frac{kW}{ton_{base}} - \frac{kW}{ton_{ee}}\right) \times CF$$

Definition of Terms

Table 3-31: Terms, Values, and References for Electric Chillers

Term	Unit	Values	Source
$Tons_{ee}$, The capacity of the chiller at site design conditions accepted by the program	*ton*	Nameplate Data	EDC Data Gathering
12, conversion factor from tons cooling to kBtu/hr	$\frac{kBtu/hr}{ton}$	12	Conversion Factor
$\frac{kW}{ton_{base}}$, Design Rated Efficiency of the baseline chiller.	$\frac{kW}{ton}$	Early Replacement: Nameplate Data	EDC Data Gathering
		New Construction or Replace on Burnout: Default value from Table 3-32	See Table 3-32
$\frac{kW}{ton_{ee}}$, Design Rated Efficiency of the energy efficient chiller from the manufacturer data and equipment ratings in accordance with AHRI Standards.	$\frac{kW}{ton}$	Nameplate Data (AHRI Standards 550/590). At minimum, must satisfy standard listed in Table 3-32	EDC Data Gathering
EER_{base}, Energy Efficiency Ratio of the baseline unit.	$\frac{Btu/hr}{W}$	Early Replacement: Nameplate Data	EDC Data Gathering
		New Construction or Replace on Burnout: Default value from Table 3-32	See Table 3-32
EER_{ee}, Energy Efficiency Ratio of the efficient unit from the manufacturer data and equipment ratings in accordance with AHRI Standards.	$\frac{Btu/hr}{W}$	Nameplate Data (AHRI Standards 550/590). At minimum, must satisfy standard listed in Table 3-32	EDC Data Gathering
$IPLV_{base}$, Integrated Part Load Value of the baseline unit.	$\frac{Btu/hr}{W}$ or $\frac{kW}{ton}$	Early Replacement: Nameplate Data	EDC Data Gathering
		New Construction or Replace on Burnout: See Table 3-32	See Table 3-32
$IPLV_{ee}$, Integrated Part Load Value of the efficient unit.	$\frac{Btu/hr}{W}$ or $\frac{kW}{ton}$	Nameplate Data (AHRI Standards 550/590). At minimum, must satisfy standard listed in Table 3-32	EDC Data Gathering
CF, Coincidence factor	*Decimal*	See Table 3-34	2
$EFLH$, Equivalent Full Load Hours – The kWh during the entire operating season divided by the kW at design conditions. The most appropriate EFLH shall be utilized in the calculation.	$\frac{Hours}{Year}$	Based on Logging, BMS data or Modeling[107]	EDC Data Gathering
		Default values from Table 3-33	2

[107] Modeling is an acceptable substitute to metering and BMS data if modeling is conducted using building- and equipment-specific information at the site and the facility consumption is calibrated using 12 months of billing data (pre-retrofit).

Table 3-32: Electric Chiller Baseline Efficiencies[108]

Chiller Type	Size	Path A	Path B	Source
Air Cooled Chillers	< 150 tons	Full load: 10.100 EER	Full load: 9.700 EER	3
		IPLV: 13.700 EER	IPLV: 15.800 EER	
	≥ 150 tons	Full load: 10.100 EER	Full load: 9.700 EER	
		IPLV: 14.000 EER	IPLV: 16.100 EER	
Air-Cooled Chiller without Condenser	All capacities	Air-cooled chillers without condensers must be rated with matching condensers and comply with the air-cooled chiller efficiency requirements.		
Water Cooled Positive Displacement or Reciprocating Chiller	< 75 tons	Full load: 0.750 kW/ton	Full load: 0.780 kW/ton	
		IPLV: 0.600 kW/ton	IPLV: 0.500 kW/ton	
	≥ 75 tons and < 150 tons	Full load: 0.720 kW/ton	Full load: 0.750 kW/ton	
		IPLV: 0.560 kW/ton	IPLV: 0.490 kW/ton	
	≥ 150 tons and < 300 tons	Full load: 0.660 kW/ton	Full load: 0.680 kW/ton	
		IPLV: 0.540 kW/ton	IPLV: 0.440 kW/ton	
	≥ 300 tons and < 600 tons	Full load: 0.610 kW/ton	Full load: 0.625 kW/ton	
		IPLV: 0.520 kW/ton	IPLV: 0.410 kW/ton	
	≥ 600 tons	Full load: 0.560 kW/ton	Full load: 0.585 kW/ton	
		IPLV: 0.500 kW/ton	IPLV: 0.380 kW/ton	
Water Cooled Centrifugal Chiller	< 150 tons	Full load: 0.610 kW/ton	Full load: 0.695 kW/ton	
		IPLV: 0.550 kW/ton	IPLV: 0.440 kW/ton	
	≥ 150 tons and < 300 tons	Full load: 0.610 kW/ton	Full load: 0.635 kW/ton	
		IPLV: 0.550 kW/ton	IPLV: 0.400 kW/ton	
	≥ 300 tons and < 400 tons	Full load: 0.560 kW/ton	Full load: 0.595 kW/ton	
		IPLV: 0.520 kW/ton	IPLV: 0.390 kW/ton	
	≥ 400 tons and < 600 tons	Full load: 0.560 kW/ton	Full load: 0.585 kW/ton	
		IPLV: 0.500 kW/ton	IPLV: 0.380 kW/ton	
	≥ 600 tons	Full load: 0.560 kW/ton	Full load: 0.585 kW/ton	
		IPLV: 0.500 kW/ton	IPLV: 0.380 kW/ton	

[108] Chillers must satisfy efficiency requirements for both full load and IPLV efficiencies for either Path A or Path B. The table shows the efficiency ratings to be used for the baseline chiller efficiency in the savings estimation algorithm, which must be consistent with the expected operating conditions of the efficient chiller. For example, if the efficient chiller satisfies Path A and generally performs at part load, the appropriate baseline chiller efficiency is the IPLV value under Path A for energy savings. If the efficient chiller satisfies Path B and generally performs at full load, the appropriate baseline chiller efficiency is the full load value under Path B for energy savings. Generally, chillers operating above 70 percent load for a majority (50% or more) of operating hours should use Path A and chillers below 70% load for a majority of operating hours should use Path B. The "full load" efficiency from the appropriate Path A or B should be used to calculate the Peak Demand Savings as it is expected that the chillers would be under full load during the peak demand periods.

Table 3-33: Chiller EFLHs for Pennsylvania Cities

Space and/or Building Type	Allentown	Binghamton	Bradford	Erie	Harrisburg	Philadelphia	Pittsburgh	Scranton	Williamsport
Data Center - No Economizer	EDC Data Gathering								
Data Center - With Economizer	EDC Data Gathering								
Education - College/University	665	416	368	490	696	770	600	524	619
Education - Other	275	182	161	214	344	389	282	244	316
Health - Hospital	1,240	935	825	1,100	1,362	1,556	1,185	1,134	1,208
Health - Other	459	347	306	408	520	622	472	418	462
Industrial Manufacturing	708	449	395	527	700	780	631	574	614
Lodging	1,397	1,178	988	1,317	1,511	1,654	1,432	1,352	1,415
Office	446	334	295	393	521	586	443	410	453
Retail	749	518	457	609	836	897	699	659	742

Table 3-34: Chiller Demand CFs for Pennsylvania Cities

Space and/or Building Type	Allentown	Binghamton	Bradford	Erie	Harrisburg	Philadelphia	Pittsburgh	Scranton	Williamsport
Data Centers	EDC Data Gathering								
Education - College/University	0.42	0.28	0.23	0.31	0.43	0.46	0.41	0.34	0.40
Education - Other	0.11	0.08	0.07	0.09	0.18	0.18	0.17	0.12	0.17
Health - Hospital	0.50	0.45	0.42	0.48	0.50	0.54	0.48	0.48	0.50
Health - Other	0.24	0.20	0.16	0.22	0.28	0.30	0.28	0.23	0.26
Industrial Manufacturing	0.53	0.41	0.33	0.43	0.53	0.58	0.54	0.48	0.50
Lodging	0.62	0.59	0.54	0.61	0.68	0.69	0.71	0.60	0.68
Office	0.29	0.24	0.21	0.27	0.35	0.23	0.32	0.29	0.32
Retail	0.46	0.34	0.28	0.38	0.54	0.55	0.48	0.43	0.48

DEFAULT SAVINGS

There are no default savings for this measure.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx. Accessed December 2018.

2) Nexant's eQuest modeling analysis 2014.

3) International Energy Conservation Code 2015. Table C403.2.3(7).

3.2.3 Water Source and Geothermal Heat Pumps

Target Sector	Commercial and Industrial Establishments
Measure Unit	Geothermal Heat Pump
Measure Life	15 years Source 1
Measure Vintage	Replace on Burnout, New Construction, or Early Replacement

This protocol shall apply to ground source, groundwater source, water source heat pumps, and water source and evaporatively cooled air conditioners in commercial applications as further described below. This measure may apply to early replacement of an existing system, replacement on burnout, or installation of a new unit in a new or existing non-residential building for HVAC applications. The base case may employ a different system than the retrofit case.

Eligibility

In order for this characterization to apply, the efficient equipment is a high-efficiency groundwater source, water source, or ground source heat pump system that meets or exceeds the energy efficiency requirements of the International Energy Conservation Code (IECC) 2015, Table 403.2.3(1). The following retrofit scenarios are considered:

- Ground source heat pumps for existing or new non-residential HVAC applications
- Groundwater source heat pumps for existing or new non-residential HVAC applications
- Water source heat pumps for existing or new non-residential HVAC applications

These retrofits reduce energy consumption by the improved thermodynamic efficiency of the refrigeration cycle of new equipment, by improving the efficiency of the cooling and heating cycle, and by lowering the condensing temperature when the system is in cooling mode and raising the evaporating temperature when the equipment is in heating mode as compared to the base case heating or cooling system. It is expected that the retrofit system will use a similar conditioned-air distribution system as the base case system.

This protocol does not apply to heat pump systems coupled with non-heat pump systems such as chillers, rooftop AC units, boilers, or cooling towers. Projects that use unique, combined systems such as these should use a site-specific M&V plan (SSMVP) to describe the particulars of the project and how savings are calculated. All HVAC applications other than comfort cooling and heating, such as process cooling, are defined as non-standard applications and are ineligible for this measure.

Definition of Baseline Equipment

In order for this protocol to apply, the baseline equipment could be a standard-efficiency air source, water source, groundwater source, or ground source heat pump system, or an electric chiller and boiler system, or other chilled/hot water loop system. To calculate savings, the baseline system type is assumed to be an air source heat pump of similar size except for cases where the project is replacing a ground source, groundwater source, or water source heat pump; in those cases, the baseline system type is assumed to be a similar system at code.

Table 3-35: Water Source or Geothermal Heat Pump Baseline Assumptions

Baseline Scenario		Baseline Efficiency Assumptions
New Construction		Standard efficiency air source heat pump system
Retrofit	Replacing any technology besides a ground source, groundwater source, or water source heat pump	Standard efficiency air source heat pump system
	Replacing a ground source, groundwater source, or water source heat pump	Efficiency of the replaced geothermal system for early replacement only (if known), else code for a similar system

ALGORITHMS

There are three primary components that must be accounted for in the energy and demand calculations. The first component is the heat pump unit energy and power, the second is the circulating pump in the ground/water loop system energy and power, and the third is the well pump in the ground/water loop system energy and power. For projects where the retrofit system is similar to the baseline system, such as a standard efficiency ground source system replaced with a high efficiency ground source system, the pump energy is expected to be the same for both conditions and does not need to be calculated. The kWh savings should be calculated using the basic equations below. For baseline units rated in both EER and IEER, use IEER in place of EER where listed in the kWh savings calculations below, and use EER for the kW savings calculations.

For air-cooled base case units with cooling capacities less than 65 kBtu/h:

$$\Delta kWh = \Delta kWh_{cool} + \Delta kWh_{heat} + \Delta kWh_{pump}$$

$$\Delta kWh_{cool} = \left(\frac{Btu_{cool}}{hr} \times \frac{1\ kW}{1{,}000\ W}\right) \times \left\{\frac{1}{SEER_{base}} - \left(\frac{1}{EER_{ee} \times GSER}\right)\right\} \times EFLH_{cool}$$

$$\Delta kWh_{heat} = \left(\frac{Btu_{heat}}{hr} \times \frac{1\ kW}{1{,}000\ W}\right) \times \left\{\frac{1}{HSPF_{base}} - \left(\frac{1}{COP_{ee} \times 3.412}\right)\right\} \times EFLH_{heat}$$

$$\Delta kWh_{pump} = 0.746 \times \left\{\left\{HP_{basemotor} \times LF_{base} \times \left(\frac{1}{\eta_{basemotor}}\right) \times HOURS_{basepump}\right\} - \left\{HP_{eemotor} \times LF_{ee} \times \left(\frac{1}{\eta_{eemotor}}\right) \times HOURS_{eepump}\right\}\right\}$$

$$\Delta kW_{peak} = \Delta kW_{peak\ cool} + \Delta kW_{peak\ pump}$$

$$\Delta kW_{peak\ cool} = \left(\frac{Btu_{cool}}{hr} \times \frac{1\ kW}{1{,}000\ W}\right) \times \left(\frac{1}{EER_{base}} - \frac{1}{EER_{ee}}\right) \times CF_{cool}$$

$$\Delta kW_{peak\ pump} = 0.746 \times \left\{\left\{HP_{basemotor} \times LF_{base} \times \left(\frac{1}{\eta_{basemotor}}\right)\right\} - \left\{HP_{eemotor} \times LF_{ee} \times \left(\frac{1}{\eta_{eemotor}}\right)\right\}\right\} \times CF_{pump}$$

For air-cooled base case units with cooling capacities equal to or greater than 65 kBtu/h, and all other units:

$$\Delta kWh = \Delta kWh_{cool} + \Delta kWh_{heat} + \Delta kWh_{pump}$$

$$\Delta kWh_{cool} = \left(\frac{Btu_{cool}}{hr} \times \frac{1\ kW}{1{,}000\ W}\right) \times \left(\frac{1}{EER_{base}} - \frac{1}{EER_{ee}}\right) \times EFLH_{cool}$$

$$\Delta kWh_{heat} = \left(\frac{Btu_{heat}}{hr} \times \frac{1\ kW}{1{,}000\ W}\right) \times \frac{1}{3.412} \times \left(\frac{1}{COP_{base}} - \frac{1}{COP_{ee}}\right) \times EFLH_{heat}$$

$$\Delta kWh_{pump} = 0.746 \times \left\{\left\{HP_{basemotor} \times LF_{base} \times \left(\frac{1}{\eta_{basemotor}}\right) \times HOURS_{basepump}\right\} - \left\{HP_{eemotor} \times LF_{ee} \times \left(\frac{1}{\eta_{eemotor}}\right) \times HOURS_{eepump}\right\}\right\}$$

$$\Delta kW_{peak} = \Delta kW_{peak\ cool} + \Delta kW_{peak\ pump}$$

$$\Delta kW_{peak\ cool} = \left(\frac{Btu_{cool}}{hr} \times \frac{1\ kW}{1{,}000\ W}\right) \times \left(\frac{1}{EER_{base}} - \frac{1}{EER_{ee}}\right) \times CF_{cool}$$

$$\Delta kW_{peak\ pump} = 0.746 \times \left\{\left\{HP_{basemotor} \times LF_{base} \times \left(\frac{1}{\eta_{basemotor}}\right)\right\} - \left\{HP_{eemotor} \times LF_{ee} \times \left(\frac{1}{\eta_{eemotor}}\right)\right\}\right\} \times CF_{pump}$$

DEFINITION OF TERMS[109]

Table 3-36: Terms, Values, and References for Geothermal Heat Pumps

[109] The cooling efficiency ratings of the baseline and efficient units should be used not including pumps where appropriate.

Term	Unit	Value	Source
$\frac{Btu_{cool}}{hr}$, Rated cooling capacity of the energy efficient unit	$\frac{Btu}{hr}$	Nameplate data (AHRI)	EDC Data Gathering
$\frac{Btu_{heat}}{hr}$, Rated heating capacity of the energy efficient unit	$\frac{Btu}{hr}$	Nameplate data (AHRI) Use $\frac{Btu_{cool}}{hr}$ if the heating capacity is not known	EDC Data Gathering
$SEER_{base}$, the cooling SEER of the baseline unit	$\frac{Btu/hr}{W}$	Early Replacement: Nameplate data	EDC Data Gathering
		New Construction or Replace on Burnout: Default values from Table 3-27 and Table 3-39	See Table 3-27 and Table 3-39
$IEER_{base}$, Integrated energy efficiency ratio of the baseline unit.	$\frac{Btu/hr}{W}$	Early Replacement: Nameplate data	EDC Data Gathering
		Default: Table 3-27	See Table 3-27
EER_{base}, the cooling EER of the baseline unit	$\frac{Btu/hr}{W}$	Early Replacement: Nameplate data = $SEER_{base}$ X (11.3/13) if EER not available[110]	EDC Data Gathering
		New Construction or Replace on Burnout: Default values from Table 3-27 and Table 3-39	See Table 3-27 and Table 3-39
$HSPF_{base}$, Heating Season Performance Factor of the baseline unit	$\frac{Btu/hr}{W}$	Early Replacement: Nameplate data	EDC Data Gathering
		New Construction or Replace on Burnout: Default values from Table 3-27 and Table 3-39	See Table 3-27 and Table 3-39
COP_{base}, Coefficient of Performance of the baseline unit	*None*	Early Replacement: Nameplate data	EDC Data Gathering
		New Construction or Replace on Burnout: Default values from Table 3-27 and Table 3-39	See Table 3-39
EER_{ee}, the cooling EER of the new ground source, groundwater source, or water source heat pump being installed	$\frac{Btu/hr}{W}$	Nameplate data (AHRI) = $SEER_{ee}$ X (11.3/13) if EER not available[111]	EDC Data Gathering
COP_{ee}, Coefficient of Performance of the new ground source, groundwater source, or water source heat pump being installed	*None*	Nameplate data (AHRI)	EDC Data Gathering

110 11.3/13 = Conversion factor from SEER to EER, based on average EER of a SEER 13 unit.
111 11.3/13 = Conversion factor from SEER to EER, based on average EER of a SEER 13 unit.

Term	Unit	Value	Source
$EFLH_{cool}$, Cooling annual Equivalent Full Load Hours EFLH for Commercial HVAC for different occupancies	$\frac{Hours}{Year}$	Based on Logging, BMS data or Modeling[112]	EDC Data Gathering
		Default values from Table 3-28	3
$EFLH_{heat}$, Heating annual Equivalent Full Load Hours EFLH for Commercial HVAC for different occupancies	$\frac{Hours}{Year}$	Based on Logging, BMS data or Modeling[112]	EDC Data Gathering
		Default values from Table 3-30	3
CF_{cool}, Coincidence factor for Commercial HVAC	*Decimal*	See Table 3-29	3
CF_{pump}, Coincidence factor for ground source loop pump	*Decimal*	If unit runs 24/7/365, CF=1.0; If unit runs only with heat pump unit compressor, See Table 3-29	3
$HP_{basemotor}$, Horsepower of base case ground loop pump motor	*HP*	Ground source, groundwater source, or water source heat pump baseline: Nameplate ASHP baseline: 0	EDC Data Gathering
LF_{base}, Load factor of the base case ground loop pump motor; ratio of the peak running load to the nameplate rating of the pump motor.	*None*	Based on spot metering and nameplate	EDC Data Gathering
		Default: 75%	2
$\eta_{basemotor}$, efficiency of base case ground loop pump motor	*None*	Nameplate	EDC Data Gathering
		If unknown, assume the federal minimum efficiency requirements in Table 3-37	4
$\eta_{basepump}$, efficiency of base case ground loop pump at design point	*None*	Nameplate	EDC Data Gathering
		If unknown, assume program compliance efficiency in Table 3-38	See Table 3-38
$HOURS_{basepump}$, Run hours of base case ground loop pump motor	*Hours*	Based on Logging, BMS data or Modeling[113]	EDC Data Gathering
		$EFLH_{cool} + EFLH_{heat}$ [114] Default values from Table 3-28 and Table 3-30	3
$HP_{eemotor}$, Horsepower of retrofit case ground loop pump motor	*HP*	Nameplate	EDC Data Gathering
LF_{ee}, Load factor of the retrofit case ground loop pump motor; Ratio of	*None*	Based on spot metering and nameplate	EDC Data Gathering

Term	Unit	Value	Source
the peak running load to the nameplate rating of the pump motor.		Default: 75%	2
$\eta_{eemotor}$, efficiency of retrofit case ground loop pump motor	*None*	Nameplate	EDC Data Gathering
		If unknown, assume the federal minimum efficiency requirements in Table 3-37	Table 3-37
η_{eepump}, efficiency of retrofit case ground loop pump at design point	*None*	Nameplate	EDC Data Gathering
		If unknown, assume program compliance efficiency in Table 3-38	See Table 3-38
$HOURS_{eepump}$, Run hours of retrofit case ground loop pump motor	*Hours*	Based on Logging, BMS data or Modeling[114]	EDC Data Gathering
		$EFLH_{cool} + EFLH_{heat}$[113] Default values from Table 3-28 and Table 3-30	3
3.412, conversion factor from kWh to kBtu	$\frac{kBtu}{kWh}$	3.412	Conversion Factor
0.746, conversion factor from horsepower to kW	$\frac{kW}{hp}$	0.746	Conversion Factor
GSER, Factor used to determine the SEER of a GSHP based on its EER	*None*	1.02	5

Table 3-37: Federal Baseline Motor Efficiencies for NEMA Design A and NEMA Design B Motors

Motor HP	Motor Nominal Full-Load Efficiencies (percent)							
	2 Poles		4 poles		6 Poles		8 Poles	
	Enclosed	Open	Enclosed	Open	Enclosed	Open	Enclosed	Open
1	77.0	77.0	85.5	85.5	82.5	82.5	75.5	75.5
1.5	84.0	84.0	86.5	86.5	87.5	86.5	78.5	77.0
2	85.5	85.5	86.5	86.5	88.5	87.5	84.0	86.5
3	86.5	85.5	89.5	89.5	89.5	88.5	85.5	87.5
5	88.5	86.5	89.5	89.5	89.5	89.5	86.5	88.5

[112] Modeling is an acceptable substitute to metering and BMS data if modeling is conducted using building- and equipment-specific information at the site and the facility consumption is calibrated using 12 months of billing data (pre-retrofit).
[113] Modeling is an acceptable substitute to metering and BMS data if modeling is conducted using building- and equipment-specific information at the site and the facility consumption is calibrated using 12 months of billing data (pre-retrofit).
[114] $EFLH_{cool} + EFLH_{heat}$ represents the addition of cooling and heating annual equivalent full load hours for commercial HVAC for different occupancies, respectively.

7.5	89.5	88.5	91.7	91.0	91.0	90.2	86.5	89.5
10	90.2	89.5	91.7	91.7	91.0	91.7	89.5	90.2
15	91.0	90.2	92.4	93.0	91.7	91.7	89.5	90.2
20	91.0	91.0	93.0	93.0	91.7	92.4	90.2	91.0

Table 3-38: Ground/Water Loop Pump and Circulating Pump Efficiency[115]

HP	Minimum Pump Efficiency at Design Point (η_{pump})
1.5	65%
2	65%
3	67%
5	70%
7.5	73%
10	75%
15	77%
20	77%

[115] Based on program requirements submitted during protocol review.

Table 3-39: Default Baseline Equipment Efficiencies

Equipment Type and Capacity	Cooling Baseline	Heating Baseline	Source
Water to Air: Water Loop			
$< 17{,}000\ \frac{Btu}{hr}$	12.2 EER (86^0 F entering water)	4.3 COP (68^0 F entering water)	6
$\geq 17{,}000\ \frac{Btu}{hr}$ and $< 65{,}000\ \frac{Btu}{hr}$	13.0 EER (86^0 F entering water)	4.3 COP (68^0 F entering water)	
$\geq 65{,}000\ \frac{Btu}{hr}$ and $< 135{,}000\ \frac{Btu}{hr}$	13.0 EER (86^0 F entering water)	4.3 COP (68^0 F entering water)	
Water to Air: Ground Water			
$< 135{,}000\ \frac{Btu}{hr}$	18.0 EER (59^0 F entering water)	3.7 COP (50^0 F entering water)	6
Brine to Air: Ground Loop			
$< 135{,}000\ \frac{Btu}{hr}$	14.1 EER (77^0 F entering fluid)	3.2 COP (32^0 F entering fluid)	6
Water to Water: Water Loop			
$< 135{,}000\ \frac{Btu}{hr}$	10.6 EER (86^0 F entering water)	3.7 COP (68^0 F entering water)	6
Water to Water: Ground Water			
$< 135{,}000\ \frac{Btu}{hr}$	16.3 EER (59^0 F entering water)	3.1 COP (50^0 F entering water)	6
Brine to Water: Ground Loop			
$< 135{,}000\ \frac{Btu}{hr}$	12.1 EER (77^0 F entering fluid)	2.5 COP (32^0 F entering fluid)	6

Default Savings

There are no default savings for this measure.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020,

http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx. Accessed December 2018.

2) California Public Utility Commission. *Database for Energy Efficiency Resources* 2005.
3) Based on Nexant's eQuest modeling analysis 2014.
4) "Energy Conservation Program: Energy Conservation Standards for Commercial and Industrial Electric Motors; Final Rule," 79 Federal Register 103 (29 May 2014).
5) VEIC estimate. Extrapolation of manufacturer data.
6) International Energy Conservation Code 2015. Table C403.2.3(7).

3.2.4 Ductless Mini-Split Heat Pumps – Commercial < 5.4 tons

Target Sector	Commercial and Industrial Establishments
Measure Unit	Ductless Heat Pump
Measure Life	15 years Source 1
Measure Vintage	Replace on Burnout

ENERGY STAR ductless "mini-split" heat pumps (DHP) utilize high efficiency SEER/EER and HSPF energy performance factors of 15/12.5 and 8.5, respectively, or greater. This technology typically converts an electric resistance heated space into a space heated/cooled with a single or multi-zonal ductless heat pump system.

Eligibility

This protocol documents the energy savings attributed to ENERGY STAR ductless mini-split heat pumps with energy-efficiency performance of 15/12.5 SEER/EER and 8.5 HSPF or greater with inverter technology.[Source 2] The baseline heating system could be an existing electric resistance, a lower-efficiency ductless heat pump system, a ducted heat pump, packaged terminal heat pump (PTHP), electric furnace, or a non-electric fuel-based system. The baseline cooling system could be a standard efficiency heat pump system, central air conditioning system, packaged terminal air conditioner (PTAC), or room air conditioner. The DHP could be a new device in an existing space, a new device in a new space, or could replace an existing heating/cooling device. The DHP systems could be installed as a single-zone system (one indoor unit, one outdoor unit) or a multi-zone system (multiple indoor units, one outdoor unit). In addition, the old systems should be de-energized, completely uninstalled and removed in order to ensure that the full savings is realized. All HVAC applications other than comfort cooling and heating, such as process cooling, are defined as non-standard applications and are ineligible for this measure.

Algorithms

The savings depend on three main factors: baseline condition, usage, and the capacity of the indoor unit. The algorithms, shown below, are separated into two calculations: single zone and multi-zone ductless heat pumps. Convert SEER to EER to calculate ΔkW_{peak} using 11.3/13 as the conversion factor.

Single Zone:

$$\Delta kWh = \Delta kWh_{cool} + \Delta kWh_{heat}$$

$$\Delta kWh_{heat} = \frac{CAPY_{heat}}{1{,}000\,\frac{W}{kW}} \times \left(\frac{1}{HSPF_b} - \frac{1}{HSPF_e}\right) \times EFLH_{heat}$$

$$\Delta kWh_{cool} = \frac{CAPY_{cool}}{1{,}000\,\frac{W}{kW}} \times \left(\frac{1}{SEER_b} - \frac{1}{SEER_e}\right) \times EFLH_{cool}$$

$$\Delta kW_{peak} = \frac{CAPY_{cool}}{1{,}000\,\frac{W}{kW}} \times \left(\frac{1}{EER_b} - \frac{1}{EER_e}\right) \times CF$$

Multi-Zone:

$$\Delta kWh = \Delta kWh_{cool} + \Delta kWh_{heat}$$

$$\Delta kWh_{heat} = \left[\frac{CAPY_{heat}}{1{,}000\,\frac{W}{kW}} \times \left(\frac{1}{HSPF_b} - \frac{1}{HSPF_e}\right) \times EFLH_{heat}\right]_{ZONE1} + \left[\frac{CAPY_{heat}}{1{,}000\,\frac{W}{kW}} \times \left(\frac{1}{HSPF_b} - \frac{1}{HSPF_e}\right) \times EFLH_{heat}\right]_{ZONE2} \cdots + \left[\frac{CAPY_{heat}}{1{,}000\,\frac{W}{kW}} \times \left(\frac{1}{HSPF_b} - \frac{1}{HSPF_e}\right) \times EFLH_{heat}\right]_{ZONEn}$$

$$\Delta kWh_{cool} = \left[\frac{CAPY_{cool}}{1{,}000\,\frac{W}{kW}} \times \left(\frac{1}{SEER_b} - \frac{1}{SEER_e}\right) \times EFLH_{cool}\right]_{ZONE1} + \left[\frac{CAPY_{cool}}{1{,}000\,\frac{W}{kW}} \times \left(\frac{1}{SEER_b} - \frac{1}{SEER_e}\right) \times EFLH_{cool}\right]_{ZONE2} \cdots + \left[\frac{CAPY_{cool}}{1{,}000\,\frac{W}{kW}} \times \left(\frac{1}{SEER_b} - \frac{1}{SEER_e}\right) \times EFLH_{cool}\right]_{ZONEn}$$

$$\Delta kW_{peak} = \left[\frac{CAPY_{cool}}{1{,}000\,\frac{W}{kW}} \times \left(\frac{1}{EER_b} - \frac{1}{EER_e}\right) \times CF\right]_{ZONE1} + \left[\frac{CAPY_{cool}}{1{,}000\,\frac{W}{kW}} \times \left(\frac{1}{EER_b} - \frac{1}{EER_e}\right) \times CF\right]_{ZONE2} \cdots + \left[\frac{CAPY_{cool}}{1{,}000\,\frac{W}{kW}} \times \left(\frac{1}{EER_b} - \frac{1}{EER_e}\right) \times CF\right]_{ZONEn}$$

Definition of Terms

Table 3-40: Terms, Values, and References for DHP

Term	Unit	Values	Source
$CAPY_{cool}$, The cooling capacity of the indoor unit, given in $\frac{Btu}{hr}$ as appropriate for the calculation. This protocol is limited to units < 65,000 $\frac{Btu}{hr}$ (5.4 tons) $CAPY_{heat}$, The heating capacity of the indoor unit, given in $\frac{Btu}{hr}$ as appropriate for the calculation.	$\frac{Btu}{hr}$	Nameplate	EDC Data Gathering
$EFLH_{cool}$, Equivalent Full Load Hours for cooling $EFLH_{heat}$, Equivalent Full Load Hours for heating	$\frac{Hours}{Year}$	Based on Logging, BMS data or Modeling Default: Table 3-28 and Table 3-30	EDC Data Gathering 3

Term	Unit	Values	Source
$HSPF_b$, Heating Seasonal Performance Factor, heating efficiency of the baseline unit[116]	$\frac{Btu/hr}{W}$	Standard DHP: 8.2 Electric resistance: 3.412 ASHP: 8.2 PTHP (Replacements): 2.9 - (0.026 x Cap / 1,000) COP PTHP (New Construction): 3.7 - (0.052 x Cap / 1,000) COP Electric furnace: 3.241 For new space, no heat in an existing space, or non-electric heating in an existing space: use electric resistance: 3.412	4, 5, 7, 8, 9
$SEER_b$, Seasonal Energy Efficiency Ratio cooling efficiency of baseline unit[117]	$\frac{Btu/hr}{W}$	DHP, ASHP, or central AC: 14 Room AC: 11.3 PTAC (Replacements): 10.9 - (0.213 x Cap / 1,000) EER PTAC (New Construction): 14.0 - (0.300 x Cap / 1,000) EER PTHP (Replacements): 10.8 - (0.213 x Cap / 1,000) EER PTHP (New Construction): 14.0 - (0.300 x Cap / 1,000) EER For new space or no cooling in an existing space: use Room AC: 11.3	5, 6, 7
$HSPF_e$, Heating Seasonal Performance Factor, heating efficiency of the installed DHP	$\frac{Btu/hr}{W}$	Based on nameplate information. Should be at least ENERGY STAR.	EDC Data Gathering
$SEER_e$, Seasonal Energy Efficiency Ratio cooling efficiency of the installed DHP	$\frac{Btu/hr}{W}$	Based on nameplate information. Should be at least ENERGY STAR.	EDC Data Gathering
CF, Coincidence factor	*Decimal*	Default: Table 3-29	3

Default Savings

There are no default savings for this measure.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

116 Cap represents the rated cooling capacity of the product in Btu/h. If the unit's capacity is less than 7,000 Btu/h, 7,000 Btu/h is used in the calculation. If the unit's capacity is greater than 15,000 Btu/h, 15,000 Btu/h is used in the Calculation. Use HSPF = COP x 3.412.

117 Cap represents the rated cooling capacity of the product in Btu/h. If the unit's capacity is less than 7,000 Btu/h, 7,000 Btu/h is used in the calculation. If the unit's capacity is greater than 15,000 Btu/h, 15,000 Btu/h is used in the Calculation. Use SEER = EER x (13/11.3).

Sources

1) California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx. Accessed December 2018.

2) ENERGY STAR Air Source Heat Pumps and Central Air Conditioners Key Product Criteria. http://www.energystar.gov/index.cfm?c=airsrc_heat.pr_crit_as_heat_pumps

3) Based on Nexant's eQuest modeling analysis 2014.

4) COP = HSPF/3.412. HSPF = 3.412 for electric resistance heating, HSPF = 8.2 for standard DHP. Electric furnace COP typically varies from 0.95 to 1.00 and thereby assumed a COP 0.95 (HSPF = 3.241).

5) Air-Conditioning, Heating, and Refrigeration Institute (AHRI); the directory of the available ductless mini-split heat pumps and corresponding efficiencies (lowest efficiency currently available). Accessed 12/01/2018. https://www.ahridirectory.org/ahridirectory/pages/home.aspx

6) Code of Federal Regulations at 10 CFR 430.32(b). Assumes 10,000 Btu/hr unit with louvered sides. Note: As of 1/1/2014, room air conditioners are rated with the Combined Energy Efficiency Ratio (CEER) which incorporated the impact of standby power consumption. Because this metric is not comparable to SEER, the previous EER requirement is assumed and converted to SEER.

7) Package terminal air conditioners (PTAC) and package terminal heat pumps (PTHP) COP and EER minimum efficiency requirements is based on CAPY value. If the unit's capacity is less than 7,000 Btu/hr, use 7,000 Btu/hr in the calculation. If the unit's capacity is greater than 15,000 Btu/hr, use 15,000 Btu/hr in the calculation.

8) International Energy Conservation Code 2015. Table C403.2.3(2).

9) U.S. Department of Energy. 10 CFR Part 431. Energy Efficiency Program for Certain Commercial and Industrial Equipment: Subpart F—Commercial Air Conditioners and Heat Pumps. Table 7.

3.2.5 Fuel Switching: Small Commercial Electric Heat to Natural gas / Propane / Oil Heat

Target Sector	Commercial and Industrial Establishments
Measure Unit	Gas, Propane or Oil Heater
Measure Life	15 years Source 1
Measure Vintage	Replace on Burnout, Early Retirement, or New Construction

Eligibility

The energy and demand savings for small commercial fuel switching for heating systems is determined from the algorithms listed below. This protocol excludes water source, ground source, and groundwater source heat pumps.

The baseline for this measure is an existing commercial facility with an electric primary heating source. The heating source can be electric baseboards, packaged terminal heat pump (PTHP) units, electric furnace, or electric air source heat pump. The retrofit condition for this measure is the installation of a new standard efficiency natural gas, propane, or oil furnace or boiler. This algorithm does not apply to combination space and water heating units. This protocol applies to furnace measures with input rating of less than 225,000 Btu/hr and boiler measures with input rating of less than 300,000 Btu/hr.

EDCs may provide incentives for equipment with efficiencies greater than or equal to the applicable ENERGY STAR requirement per the following table.

Table 3-41: ENERGY STAR Requirements for Furnaces and Boilers

Equipment	ENERGY STAR Requirements	Source
Gas Furnace	AFUE rating of 95% or greater Furnace fan must have electronically commutated fan motor (ECM) Less than or equal to 2.0% air leakage	2
Oil Furnace	AFUE rating of 85% or greater Furnace fan must have electronically commutated fan motor (ECM) Less than or equal to 2.0% air leakage	
Gas Boiler	AFUE rating of 90% or greater	3
Oil Boiler	AFUE rating of 87% or greater	

Algorithms

The energy savings are the full energy consumption of the electric heating source minus the energy consumption of the fossil fuel furnace blower motor. The energy savings are obtained through the following formulas shown below. EDCs may use billing analysis using program participant data to claim measure savings, in lieu of using the defaults provided in this measure protocol. Billing analysis should be conducted using at least 12 months of billing data (pre- and post-retrofit).

Electric furnace or air source heat pump

For ASHP units < 65,000 Btu/hr, use HSPF instead of COP to calculate ΔkWh_{heat}.

$$\Delta kWh_{heat} = \left(\frac{Btu_{heat}}{hr} \times \frac{1\ kW}{1{,}000\ W}\right) \times \frac{1}{3.412} \times \frac{1}{COP_{base}} \times EFLH_{heat}$$

$$= \left(\frac{Btu_{heat}}{hr} \times \frac{1\ kW}{1{,}000\ W}\right) \times \frac{1}{HSPF_{base}} \times EFLH_{heat}$$

Baseboard heating, packaged terminal heat pump

$$\Delta kWh_{heat} = \frac{\frac{Btu_{heat}}{hr} \times EFLH_{heat}}{3{,}412\ \frac{Btu}{kWh} \times COP_{base}} - \frac{HP_{motor} \times 746\ \frac{W}{HP} \times EFLH_{heat}}{\eta_{motor} \times 1{,}000\ \frac{W}{kW}}$$

The motor consumption of a gas furnace is subtracted from the savings for a baseboard or PTHP heating system, as these existing systems do not require a fan motor while the replacement furnace does (the electric furnace and air source heat pumps require fan motors with similar consumption as a gas furnace and thus there is no significant change in motor load). For boilers, the annual pump energy consumption is negligible (<50 kWh per year) and not included in this calculation.[118]

There are no peak demand savings as it is a heating only measure.

Although there are significant electric savings, there is also an associated increase in fossil fuel energy consumption. While this fuel consumption does not count against PA Act 129 energy savings, it is expected to be used in the program TRC test. The increased fossil fuel energy is obtained through the following formula:

Fuel consumption with fossil fuel furnace or boiler:

$$Fuel\ Consumption\ (MMBTU) = \frac{\frac{Btu_{fuel}}{hr} \times EFLH_{heat}}{AFUE_{fuel} \times 1{,}000{,}000\ \frac{Btu}{MMBtu}}$$

[118] Pump motors are typically 1/25 HP. With 1,000 hours of runtime and 80% assumed efficiency, this translates to 37 kWh.

Definition of Terms

Table 3-42: Terms, Values, and References for Fuel Switching

Term	Unit	Values	Source
$\frac{Btu_{fuel}}{hr}$, Rated heating capacity of the new fossil fuel unit	$\frac{Btu}{hr}$	Nameplate data (AHRI)	EDC Data Gathering
$\frac{Btu_{heat}}{hr}$, Rated heating capacity of the existing electric unit	$\frac{Btu}{hr}$	Nameplate data (AHRI) Default: set equal to $\frac{Btu_{fuel}}{hr}$	EDC Data Gathering
COP_{base}, Efficiency rating of the baseline unit. For ASHP units < 65,000 Btu/hr, HSPF should be used for heating savings	*None*	Early Replacement: Nameplate data	EDC Data Gathering
		New Construction or Replace on Burnout: Default values from Table 3-27	See Table 3-27
$HSPF_{base}$, Heating seasonal performance factor of the baseline unit. For units >65,000 Btu/hr, COP should be used for heating savings	$\frac{Btu/hr}{W}$	Early Replacement: Nameplate data	EDC Data Gathering
		New Construction or Replace on Burnout: Default values from Table 3-27	See Table 3-27
$AFUE_{fuel}$, Annual Fuel Utilization Efficiency rating of the fossil fuel unit	*None*	Default: Table 3-41	2, 3
		Nameplate data (AHRI)	EDC Data Gathering
$EFLH_{heat}$, Equivalent Full Load Hours for the heating season – The kWh during the entire operating season divided by the kW at design conditions	$\frac{Hours}{Year}$	Based on Logging, EMS data or Modeling[119]	EDC Data Gathering
		Default: Table 3-30	4
HP_{Motor}, Gas furnace blower motor horsepower	*HP*	Default: ½ HP for furnace	Average blower motor capacity for gas furnace (typical range = ¼ HP to ¾ HP)
		Nameplate	EDC Data Gathering
η_{motor}, Efficiency of furnace blower motor	*None*	From nameplate	EDC Data Gathering
		Default: 0.50 for furnace	Typical efficiency of ½ HP blower motor for gas furnace

Default Savings

There are no default savings for this measure.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

[119] Modeling is an acceptable substitute to metering and BMS data if modeling is conducted using building- and equipment-specific information at the site and the facility consumption is calibrated using 12 months of billing data (pre-retrofit).

SOURCES

1) California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx. Accessed December 2018.
2) ENERGY STAR Program Requirements for Furnaces. https://www.energystar.gov/sites/default/files/Furnaces%20Version%204.1_Program%20Requirements.pdf
3) ENERGY STAR Program Requirements for Boilers. https://www.energystar.gov/sites/default/files/specs/Boilers%20Program%20Requirements%20Version%203%200.pdf
4) The Equivalent Full Load Hours (EFLH) for Pennsylvania are calculated based on Nexant's eQuest modeling analysis 2014.

3.2.6 Small C&I HVAC Refrigerant Charge Correction

Target Sector	Commercial and Industrial Establishments
Measure Unit	Tons of Refrigeration Capacity
Measure Life	10 years Source 1
Measure Vintage	Retrofit

This protocol describes the assumptions and algorithms used to quantify energy savings for refrigerant charging on packaged AC units and heat pumps operating in small commercial applications. The protocol herein describes a partially deemed energy savings and demand reduction estimation.

Eligibility

This protocol is applicable for small commercial and industrial customers, and applies to documented tune-ups for package or split systems up to 20 tons. All HVAC applications other than comfort cooling and heating, such as process cooling, are defined as non-standard applications and are ineligible for this measure.

Algorithms

This section describes the process of creating energy savings and demand reduction calculations.

Air Conditioning

For A/C units < 65,000 Btu/hr, use SEER to calculate ΔkWh and convert SEER to EER to calculate ΔkW_{peak} using 11.3/13 as the conversion factor. For A/C units > 65,000 Btu/hr, if rated in both EER and IEER, use IEER for energy savings calculations.

$$\Delta kWh = \left(EFLH_c \times \frac{CAPY_c}{1{,}000\frac{W}{kW}}\right) \times \left(\frac{1}{[EER \times RCF]} - \frac{1}{EER}\right)$$

$$\Delta kWh = \left(EFLH_c \times \frac{CAPY_c}{1{,}000\frac{W}{kW}}\right) \times \left(\frac{1}{[SEER \times RCF]} - \frac{1}{SEER}\right)$$

$$\Delta kW_{peak} = \left(CF \times \frac{CAPY_c}{1{,}000\frac{W}{kW}}\right) \times \left(\frac{1}{[EER \times RCF]} - \frac{1}{EER}\right)$$

Heat Pumps

For Heat Pump units < 65,000 Btu/hr, use SEER to calculate ΔkWh_{cool} and HSPF instead of COP to calculate ΔkWh_{heat}. Convert SEER to EER to calculate ΔkW_{peak} using 11.3/13 as the conversion factor. For Heat Pump units > 65,000 Btu/hr, if rated in both EER and IEER, use IEER to calculate ΔkWh_{cool}.

$$\Delta kWh = \Delta kWh_{cool} + \Delta kWh_{heat}$$

$$\Delta kWh_{cool} = \left(EFLH_c \times \frac{CAPY_c}{1{,}000 \frac{W}{kW}}\right) \times \left(\frac{1}{[IEER \times RCF]} - \frac{1}{IEER}\right)$$

$$\Delta kWh_{cool} = \left(EFLH_c \times \frac{CAPY_c}{1{,}000 \frac{W}{kW}}\right) \times \left(\frac{1}{[SEER \times RCF]} - \frac{1}{SEER}\right)$$

$$\Delta kWh_{heat} = \left(EFLH_h \times \frac{CAPY_h}{1{,}000 \frac{W}{kW}}\right) \times \frac{1}{3.412} \times \left(\frac{1}{[COP \times RCF]} - \frac{1}{COP}\right)$$

$$\Delta kWh_{heat} = \left(EFLH_h \times \frac{CAPY_h}{1{,}000 \frac{W}{kW}}\right) \times \left(\frac{1}{[HSPF \times RCF]} - \frac{1}{HSPF}\right)$$

$$\Delta kW_{peak} = \left(\frac{CAPY_c}{1{,}000 \frac{W}{kW}}\right) \times \left(\frac{1}{[EER \times RCF]} - \frac{1}{EER}\right) \times CF$$

Definition of Terms

Table 3-43: Terms, Values, and References for Refrigerant Charge Correction

Term	Unit	Values	Source
$CAPY_c$, Unit capacity for cooling	$\frac{Btu}{hr}$	From nameplate	EDC Data Gathering
$CAPY_h$, Unit capacity for heating	$\frac{Btu}{hr}$	From nameplate	EDC Data Gathering
EER, Energy Efficiency Ratio. For A/C and heat pump units < 65,000 $\frac{Btu}{hr}$, SEER should be used for cooling savings.	$\frac{Btu/hr}{W}$	From nameplate	EDC Data Gathering
		Default: Table 3-27	See Table 3-27
IEER, Integrated energy efficiency ratio of the baseline unit.	$\frac{Btu/hr}{W}$	From nameplate	EDC Data Gathering
		Default: Table 3-27	See Table 3-27
SEER, Seasonal Energy Efficiency Ratio. For A/C and heat pump units > 65,000 $\frac{Btu}{hr}$, EER should be used for cooling savings.	$\frac{Btu/hr}{W}$	From nameplate	EDC Data Gathering
		Default: Table 3-27	See Table 3-27
HSPF, Heating Seasonal Performance Factor. For heat pump units > 65,000 $\frac{Btu}{hr}$, COP should be used for heating savings.	$\frac{Btu/hr}{W}$	From nameplate	EDC Data Gathering
		Default: Table 3-27	See Table 3-27
COP, Coefficient of Performance. For heat pump units < 65,000 $\frac{Btu}{hr}$, HSPF should be used for heating savings.	*None*	From nameplate	EDC Data Gathering
		Default: Table 3-27	See Table 3-27
$EFLH_c$, Equivalent Full-Load Hours for mechanical cooling	$\frac{Hours}{Year}$	Default: Table 3-28	2
		Based on Logging, BMS data or Modeling[120]	EDC Data Gathering
$EFLH_h$, Equivalent Full-Load Hours for Heating	$\frac{Hours}{Year}$	See Table 3-30	2
RCF, COP Degradation Factor for Cooling	*None*	See Table 3-44	3
CF, Coincidence factor	*Decimal*	See Table 3-29	2
1,000, convert from watts to kilowatts	$\frac{W}{kW}$	1,000	Conversion Factor
11.3/13, Conversion factor from SEER to EER, based on average EER of a SEER 13 unit	*None*	$\frac{11.3}{13}$	4

Table 3-44: Refrigerant charge correction COP degradation factor (RCF) for various relative charge adjustments for both TXV metered and non-TXV units

% of nameplate charge added (removed)	RCF (TXV)	RCF (Orifice)	% of nameplate charge added (removed)	RCF (TXV)	RCF (Orifice)	% of nameplate charge added (removed)	RCF (TXV)	RCF (Orifice)	Source
60%	68%	13%	28%	95%	83%	(4%)	100%	100%	3
59%	70%	16%	27%	96%	84%	(5%)	100%	99%	
58%	71%	19%	26%	96%	85%	(6%)	100%	99%	
57%	72%	22%	25%	97%	87%	(7%)	99%	99%	
56%	73%	25%	24%	97%	88%	(8%)	99%	99%	
55%	74%	28%	23%	97%	89%	(9%)	99%	98%	
54%	76%	31%	22%	98%	90%	(10%)	99%	98%	
53%	77%	33%	21%	98%	91%	(11%)	99%	97%	
52%	78%	36%	20%	98%	92%	(12%)	99%	97%	
51%	79%	39%	19%	98%	92%	(13%)	99%	96%	
50%	80%	41%	18%	99%	93%	(14%)	98%	96%	
49%	81%	44%	17%	99%	94%	(15%)	98%	95%	
48%	82%	46%	16%	99%	95%	(16%)	98%	95%	
47%	83%	48%	15%	99%	95%	(17%)	98%	94%	
46%	84%	51%	14%	99%	96%	(18%)	98%	93%	
45%	85%	53%	13%	100%	97%	(19%)	98%	93%	
44%	86%	55%	12%	100%	97%	(20%)	97%	92%	
43%	86%	57%	11%	100%	98%	(21%)	97%	91%	
42%	87%	60%	10%	100%	98%	(22%)	97%	90%	
41%	88%	62%	9%	100%	98%	(23%)	97%	90%	
40%	89%	64%	8%	100%	99%	(24%)	97%	89%	
39%	89%	65%	7%	100%	99%	(25%)	96%	88%	
38%	90%	67%	6%	100%	99%	(26%)	96%	87%	
37%	91%	69%	5%	100%	100%	(27%)	96%	86%	
36%	91%	71%	4%	100%	100%	(28%)	96%	85%	
35%	92%	73%	3%	100%	100%	(29%)	95%	84%	
34%	92%	74%	2%	100%	100%	(30%)	95%	83%	
33%	93%	76%	1%	100%	100%	(31%)	95%	82%	
32%	94%	77%	(0%)	100%	100%	(32%)	95%	81%	
31%	94%	79%	(1%)	100%	100%	(33%)	95%	80%	
30%	95%	80%	(2%)	100%	100%	(34%)	94%	78%	
29%	95%	82%	(3%)	100%	100%	(35%)	94%	77%	

[120] Modeling is an acceptable substitute to metering and BMS data if modeling is conducted using building- and equipment-specific information at the site and the facility consumption is calibrated using 12 months of billing data (pre-retrofit).

Default Savings

There are no default savings for this measure.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx. Accessed December 2018.

2) Nexant's eQuest modeling analysis 2014.

3) Small HVAC Problems and Potential Savings Report, California Energy Commission, 2003. http://www.energy.ca.gov/2003publications/CEC-500-2003-082/CEC-500-2003-082-A-25.PDF

4) Average EER for SEER 13 units as calculated by EER = -0.02 × SEER² + 1.12 × SEER based on U.S. DOE Building America House Simulation Protocol, Revised 2010. http://www.nrel.gov/docs/fy11osti/49246.pdf

3.2.7 ENERGY STAR Room Air Conditioner

Target Sector	Commercial and Industrial Establishments
Measure Unit	Room Air Conditioner
Measure Life	9 years Source 1
Measure Vintage	Replace on Burnout, Early Retirement, or New Construction

Eligibility

This protocol is for ENERGY STAR Version 4.1 room air conditioner units installed in small commercial spaces. All HVAC applications other than comfort cooling and heating, such as process cooling, are defined as non-standard applications and are ineligible for this measure. Only ENERGY STAR units qualify for this protocol.

Algorithms

Algorithms for annual energy savings and peak demand savings are shown below.

$$\Delta kWh = \left(\frac{1}{1{,}000} \times \frac{Btu_{cool}}{hr}\right) \times \left(\frac{1}{CEER_{base}} - \frac{1}{CEER_{ee}}\right) \times EFLH_{cool} \times ELFH_{RAC:CAC}$$

$$\Delta kW_{peak} = \left(\frac{1}{1{,}000} \times \frac{Btu_{cool}}{hr}\right) \times \left(\frac{1}{CEER_{base}} - \frac{1}{CEER_{ee}}\right) \times CF$$

DEFINITION OF TERMS

Table 3-45: Terms, Values, and References for ENERGY STAR Room Air Conditioners

Term	Unit	Values	Source
$\frac{Btu_{cool}}{hr}$, Rated cooling capacity of the energy efficient unit	$\frac{Btu}{hr}$	Nameplate data (AHRI)	EDC Data Gathering
$CEER_{base}$, Combined Energy Efficiency ratio of the baseline unit	$\frac{Btu}{hr}$	New Construction or Replace on Burnout: Default values from Table 3-46 to Table 3-48	3, 4
		Early Replacement: Nameplate data	EDC Data Gathering
$CEER_{ee}$, Combined Energy Efficiency ratio of the energy efficiency unit	$\frac{Btu}{hr}$	Nameplate data (AHRI)	EDC Data Gathering
CF, Coincidence factor	*Fraction*	Default: Table 3-29	2
$EFLH_{cool}$, Equivalent Full Load Hours for the cooling season – kWh during the entire operating season divided by kW at design conditions.	$\frac{Hours}{Year}$	Based on Logging, BMS data or Modeling[121]	EDC Data Gathering
		Default: Table 3-28	2
$EFLH_{RAC:CAC}$, RAC ELFH to Central Air Conditioner (CAC) ELFH conversion	*Fraction*	0.31	5

Table 3-46 lists the minimum federal efficiency standards for room air conditioners and minimum ENERGY STAR efficiency standards for RAC units of various capacity ranges, with and without louvered sides. Units without louvered sides are also referred to as "through the wall" units or "built-in" units. Note that the new federal standards are based on the Combined Energy Efficiency Ratio metric (CEER), which is a metric that incorporates energy use in all modes, including standby and off modes.

[121] Modeling is an acceptable substitute to metering and BMS data if modeling is conducted using building- and equipment-specific information at the site and the facility consumption is calibrated using 12 months of billing data (pre-retrofit).

Table 3-46: RAC Federal Minimum Efficiency and ENERGY STAR Version 4.1 Standards

<table>
<tr><th>Capacity (Btu/h)</th><th>Federal Standard CEER, with louvered sides</th><th>ENERGY STAR CEER, with louvered sides</th><th>Federal Standard CEER, without louvered sides</th><th>ENERGY STAR CEER, without louvered sides</th></tr>
<tr><td>< 6,000</td><td rowspan="2">11.0</td><td rowspan="2">12.1</td><td rowspan="2">10.0</td><td rowspan="2">11.0</td></tr>
<tr><td>6,000 to 7,999</td></tr>
<tr><td>8,000 to 10,999</td><td rowspan="2">10.9</td><td rowspan="2">12.0</td><td>9.6</td><td>10.6</td></tr>
<tr><td>11,000 to 13,999</td><td>9.5</td><td>10.5</td></tr>
<tr><td>14,000 to 19,999</td><td>10.7</td><td>11.8</td><td>9.3</td><td>10.2</td></tr>
<tr><td>20,000 to 24,999</td><td>9.4</td><td rowspan="2">10.3</td><td rowspan="2">9.4</td><td rowspan="3">10.3</td></tr>
<tr><td>25,000 to 27,999</td><td>9.4</td></tr>
<tr><td>≥ 28,000</td><td>9.0</td><td>9.9</td><td>9.4</td></tr>
</table>

Table 3-47 lists the minimum federal efficiency standards and minimum ENERGY STAR efficiency standards for casement-only and casement-slider RAC units. Casement-only refers to a RAC designed for mounting in a casement window with an encased assembly with a width of ≤ 14.8 inches and a height of ≤ 11.2 inches. Casement-slider refers to a RAC with an encased assembly designed for mounting in a sliding or casement window with a width of ≤ 15.5 inches.

Table 3-47: Casement-Only and Casement-Slider RAC Federal Minimum Efficiency and ENERGY STAR Version 4.1 Standards

Casement	Federal Standard CEER	ENERGY STAR CEER
Casement-only	9.5	10.5
Casement-slider	10.4	11.4

Table 3-48 lists the minimum federal efficiency standards and minimum ENERGY STAR efficiency standards for reverse-cycle RAC units.

Table 3-48: Reverse-Cycle RAC Federal Minimum Efficiency Standards and ENERGY STAR Version 4.1 Standards

<table>
<tr><th>Capacity (Btu/h)</th><th>Federal Standard CEER, with louvered sides</th><th>ENERGY STAR EER, with louvered sides</th><th>Federal Standard CEER, without louvered sides</th><th>ENERGY STAR EER, without louvered sides</th></tr>
<tr><td>< 14,000</td><td rowspan="2">N/A</td><td rowspan="2">N/A</td><td>9.3</td><td>10.2</td></tr>
<tr><td>≥ 14,000</td><td>8.7</td><td>9.6</td></tr>
<tr><td>< 20,000</td><td>9.8</td><td>10.8</td><td rowspan="2">N/A</td><td rowspan="2">N/A</td></tr>
<tr><td>≥ 20,000</td><td>9.3</td><td>10.2</td></tr>
</table>

Default Savings

There are no default savings for this measure.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx. Accessed December 2018.
2) Based on Nexant's eQuest Modeling Analysis 2014.
3) Federal standards: U.S. Department of Energy. Federal Register. 164th ed. Vol. 76, August 24, 2011. http://www.gpo.gov/fdsys/pkg/FR-2013-07-16/pdf/FR-2013-07-16.pdf
4) ENERGY STAR Program Requirements Product Specification for Room Air Conditioners. https://www.energystar.gov/sites/default/files/asset/document/ENERGY%20STAR%20Version%204.1%20Room%20Air%20Conditioners%20Specification.pdfhttps://www.energystar.gov/sites/default/files/asset/document/ENERGY%20STAR%20Version%204.1%20Room%20Air%20Conditioners%20Specification.pdf
5) RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008.

3.2.8 Controls: Guest Room Occupancy Sensor

Target Sector	Commercial and Industrial Establishments
Measure Unit	Occupancy Sensor
Measure Life	15 years Source 1
Measure Vintage	Retrofit

This protocol applies to the installation of a control system in hotel guest rooms to automatically adjust the temperature setback during unoccupied periods. Savings are based on the management of the guest room's set temperatures and controlling the HVAC unit for various occupancy modes. The savings are per guestroom controlled, rather than per sensor, for multi-room suites.

Eligibility

This measure is targeted to hotel customers whose guest rooms are equipped with energy management thermostats replacing manual heating/cooling temperature set-point and fan On/Off/Auto thermostat controls. Acceptable baseline conditions are hotel guest rooms with manual heating/cooling temperature set-point and fan On/Off/Auto thermostat controls. Efficient conditions are hotel/motel guest rooms with energy management controls of the heating/cooling temperature set-points and operation state based on occupancy modes.

Algorithms

Energy savings estimates are deemed using the tables below. Estimates were derived using an EnergyPlus model of a motel.[Source 2] Model outputs were normalized to the installed capacity and reported here as kWh/Ton and coincident peak kW/Ton. Motels and hotels show differences in shell performance, number of external walls per room and typical heating and cooling efficiencies, thus savings values are presented for hotels and motels separately. Savings also depend on the size and type of HVAC unit, and whether housekeeping staff are directed to set-back/turn-off the thermostats when rooms are unrented.

$$\Delta kWh = CAPY \times ESF$$

$$\Delta kW_{peak} = CAPY \times DSF$$

Definition of Terms

Table 3-49: Terms, Values, and References for Guest Room Occupancy Sensors

Term	Unit	Values	Source
$CAPY$, Cooling capacity of controlled unit in tons	*ton*	EDC Data Gathering	EDC Data Gathering
ESF, Energy savings factor	$\frac{kWh}{ton}$	See Table 3-50 and Table 3-51	2
DSF, Demand savings factor	$\frac{kW}{ton}$	See Table 3-52 and Table 3-53	2

Table 3-50: Energy Savings for Guest Room Occupancy Sensors – Motels

HVAC Type	Baseline	ESF (kWh/ton)
PTAC with Electric Resistance Heating	Housekeeping Setback	559
	No Housekeeping Setback	1,877
PTAC with Gas Heating	Housekeeping Setback	85
	No Housekeeping Setback	287
PTHP	Housekeeping Setback	260
	No Housekeeping Setback	1,023

Table 3-51: Energy Savings for Guest Room Occupancy Sensors – Hotels

HVAC Type	Baseline	ESF (kWh/ton)
PTAC with Electric Resistance Heating	Housekeeping Setback	322
	No Housekeeping Setback	1,083
PTAC with Gas Heating	Housekeeping Setback	259
	No Housekeeping Setback	876
PTHP	Housekeeping Setback	283
	No Housekeeping Setback	1,113
Central Hot Water Fan Coil with Electric Resistance Heating	Housekeeping Setback	245
	No Housekeeping Setback	822
Central Hot Water Fan Coil with Gas Heating	Housekeeping Setback	182
	No Housekeeping Setback	615

Table 3-52: Peak Demand Savings for Guest Room Occupancy Sensors – Motels

HVAC Type	Baseline	DSF (kW/ton)
PTAC with Electric Resistance Heating	Housekeeping Setback	0.10
	No Housekeeping Setback	0.28
PTAC with Gas Heating	Housekeeping Setback	0.10
	No Housekeeping Setback	0.28
PTHP	Housekeeping Setback	0.10
	No Housekeeping Setback	0.28

Table 3-53: Peak Demand Savings for Guest Room Occupancy Sensors – Hotels

HVAC Type	Baseline	DSF (kW/ton)
PTAC with Electric Resistance Heating	Housekeeping Setback	0.04
	No Housekeeping Setback	0.10
PTAC with Gas Heating	Housekeeping Setback	0.03
	No Housekeeping Setback	0.08
PTHP	Housekeeping Setback	0.03
	No Housekeeping Setback	0.09
Central Hot Water Fan Coil with Electric Resistance Heating	Housekeeping Setback	0.03
	No Housekeeping Setback	0.08
Central Hot Water Fan Coil with Gas Heating	Housekeeping Setback	0.02
	No Housekeeping Setback	0.06

Default Savings

There are no default savings for this measure.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx. Accessed December 2018.

2) S. Keates, ADM Associates Workpaper: "Suggested Revisions to Guest Room Energy Management (PTAC & PTHP)", 11/14/2013 and spreadsheet summarizing the results: 'GREM Savings Summary_IL TRM_1_22_14.xlsx.' Five cities in IL were part of this study. Values in this protocol are based on the model for the city of Belleville, IL due to the similarity in the weather heating and cooling degree days with the city of Philadelphia, PA.

3.2.9 Controls: Economizer

Target Sector	Commercial and Industrial Establishments
Measure Unit	Economizer
Measure Life	10 years Source 1
Measure Vintage	Replace on Burnout, New Construction, or Retrofit

Dual enthalpy economizers regulate the amount of outside air introduced into the ventilation system based on the relative temperature and humidity of the outside and return air. If the enthalpy (latent and sensible heat) of the outside air is less than that of the return air when space cooling is required, then outside air is allowed in to reduce or eliminate the cooling requirement of the air conditioning equipment. Since the economizers will not be saving energy during peak hours, the demand savings are zero.

Eligibility

This measure is targeted to non-residential establishments whose HVAC equipment is not equipped with a functional economizer. The baseline condition is an HVAC unit with no economizer installed or with a non-functional/disabled economizer. The efficient condition is an HVAC unit with an economizer and dual enthalpy (differential) control. New construction installations are only eligible when not already required by IECC 2015 energy code.

Algorithms

Replace on Burnout or New Construction

$$\Delta kWh = \frac{SF \times AREA \times FCH_r \times 12 \frac{kBtu/hr}{ton}}{Eff}$$

$$\Delta kW_{peak} = 0$$

Retrofit

$$\Delta kWh = SF \times AREA \times FCH_r \times kW_{ton}$$

$$\Delta kW_{peak} = 0$$

Definition of Terms

Table 3-54: Terms, Values, and References for Economizers

Term	Unit	Values	Source
SF, Savings factor; Annual cooling load savings per unit area of conditioned space in the building when compared with a baseline HVAC system with no economizer.	$\frac{tons}{ft^2}$	0.002	2
$AREA$, Area of conditioned space served by controlled unit	ft^2	EDC Data Gathering	EDC Data Gathering
FCH_r, Free cooling hours with outdoor temperature between 60 F and 70 F. Typical operating hour conditions are defined below with standard climate zones for PA.	$\frac{Hours}{Year}$	See Table 3-55	3
Eff, Efficiency of existing HVAC equipment. Depending on the size and age, this will either be the SEER, IEER, or EER (use EER only if SEER or IEER are not available)	$\frac{Btu/hr}{W}$	EDC Data Gathering Default: Table 3-27	See Table 3-27
kW_{ton}, Efficiency of the existing HVAC equipment rated in kilowatts per ton cooling	$\frac{kW}{ton}$	EDC Data Gathering	EDC Data Gathering
		1.12	4

Table 3-55: FCH_r for PA Climate Zones and Various Operating Conditions

Location	FCH_r by Operating Schedule			
	1 Shift, 5 days per week	2 Shift, 5 days per week	3 Shift, 5 days per week	24/7
Allentown	444	691	1,119	1,787
Binghamton	396	615	997	1,643
Bradford	354	550	892	1,469
Erie	406	641	1,033	1,652
Harrisburg	402	645	1,066	1,861
Philadelphia	432	663	1,098	1,772
Pittsburgh	422	635	997	1,708
Scranton	487	738	1,169	1,870
Williamsport	407	642	1,066	1,786

Default Savings

Default savings may be claimed using the algorithms above and the variable defaults along with required EDC data gathering of customer data.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx. Accessed December 2018.

2) Bell Jr., Arthur A., 2007. *HVAC Equations, Data, and Rules of Thumb*, second edition, pages 51-52. Assuming 500 CFM/ton (total heat of 300-500 cfm/ton @20F delta) and interior supply flow of 1 CFM/Sq Ft as rule of thumb for all spaces, divide 1 by 500 to get 0.002 ton/Sq Ft savings factor used. This is the assumed cooling load per sq ft of a typical space and what the economizer will fully compensate for during free cooling temperatures.

3) Hours calculated based on local TMY weather data with outdoor temperature between 60°F and 70°F.

4) Pennsylvania Act 129 2018 Non-Residential Baseline Study, http://www.puc.pa.gov/Electric/pdf/Act129/SWE-Phase3_NonRes_Baseline_Study_Rpt021219.pdf

3.2.10 Computer Room Air Conditioner

Target Sector	Commercial and Industrial Establishments
Measure Unit	Computer Room Air Conditioner unit
Measure Life	15 years Source 1
Measure Vintage	Replace on Burnout, New Construction, or Early Replacement

This protocol builds upon the existing HVAC Systems protocol to include computer room air conditioners, given their specific baseline efficiency requirements.

Eligibility

The energy and demand savings for Commercial and Industrial HVAC systems are determined from the algorithms shown below. Newly-installed computer room air conditioner (CRAC) systems that exceed the baseline efficiencies (in SCOP) outlined in Table 3-57 are eligible for this measure. VFDs and other CRAC measures can be found in other sections of the TRM.

Algorithms

SCOP is the only recognized efficiency metric for data center equipment. Energy and demand savings should be calculated according to the specifications of the newly-installed equipment and the mandated baseline efficiencies listed in Table 3-57.

$$\Delta kWh = \left(\frac{Btu_{cool,sensible}}{hr} \times \frac{1\ kW}{1{,}000\ W}\right) \times \frac{1\ \text{Wh}}{3.412\ \text{Btu}} \times \left(\frac{1}{SCOP_{base}} - \frac{1}{SCOP_{ee}}\right) \times EFLH_{cool}$$

$$\Delta kW_{peak} = \left(\frac{Btu_{cool,sensible}}{hr} \times \frac{1\ kW}{1{,}000\ W}\right) \times \frac{1\ \text{Wh}}{3.412\ \text{Btu}} \times \left(\frac{1}{SCOP_{base}} - \frac{1}{SCOP_{ee}}\right) \times CF$$

Definition of Terms

Table 3-56: Terms, Values, and References for Computer Room Air Conditioners

Term	Unit	Values	Source
$\frac{Btu_{cool,sensible}}{hr}$, Rated cooling capacity of the energy efficient unit	$\frac{Btu}{hr}$	Nameplate data (AHRI)	EDC Data Gathering
$SCOP_{base}$, Sensible Coefficient of Performance of the baseline unit.	None	Early Replacement: Nameplate data	EDC Data Gathering
		New Construction or Replace on Burnout: Default values from Table 3-57	2
$SCOP_{ee}$, Sensible Coefficient of Performance of the energy efficient unit.	None	Nameplate data (AHRI)	EDC Data Gathering
CF, Coincidence factor	*Decimal*	Default = 1.0 or EDC Data Gathering	3
$EFLH_{cool}$, Equivalent Full Load Hours for the cooling season – the kWh during the entire operating season divided by the kW at design conditions	$\frac{Hours}{Year}$	Based on Logging, BMS data or Modeling	EDC Data Gathering
1,000, conversion from kilowatts to watts	$\frac{W}{kW}$	1,000	Conversion Factor
$\frac{1}{3.412}$, conversion from Btu to watt-hours	$\frac{Wh}{Btu}$	$\frac{1}{3.412}$	Conversion Factor

Table 3-57: Computer Room Air Conditioner Baseline Efficiencies

Equipment Type	Net Sensible Cooling Capacity[a]	Minimum SCOP-127[b] Efficiency Downflow units / Upflow units
Air conditioners, air-cooled	$< 65{,}000 \frac{Btu}{hr}$	2.20 / 2.09
	$\geq 65{,}000 \frac{Btu}{hr}$ and $< 240{,}000 \frac{Btu}{hr}$	2.10 / 1.99
	$\geq 240{,}000 \frac{Btu}{hr}$	1.90 / 1.79
Air conditioners, water-cooled	$< 65{,}000 \frac{Btu}{hr}$	2.60 / 2.49
	$\geq 65{,}000 \frac{Btu}{hr}$ and $< 240{,}000 \frac{Btu}{hr}$	2.50 / 2.39
	$\geq 240{,}000 \frac{Btu}{hr}$	2.40 / 2.29
Air conditioners, water-cooled with fluid economizer	$< 65{,}000 \frac{Btu}{hr}$	2.55 / 2.44
	$\geq 65{,}000 \frac{Btu}{hr}$ and $< 240{,}000 \frac{Btu}{hr}$	2.45 / 2.34
	$\geq 240{,}000 \frac{Btu}{hr}$	2.35 / 2.24
Air conditioners, glycol-cooled (rated at 40% propylene glycol)	$< 65{,}000 \frac{Btu}{hr}$	2.50 / 2.39
	$\geq 65{,}000 \frac{Btu}{hr}$ and $< 240{,}000 \frac{Btu}{hr}$	2.15 / 2.04
	$\geq 240{,}000 \frac{Btu}{hr}$	2.10 / 1.99
Air conditioners, glycol-cooled (rated at 40% propylene glycol) with fluid economizer	$< 65{,}000 \frac{Btu}{hr}$	2.45 / 2.34
	$\geq 65{,}000 \frac{Btu}{hr}$ and $< 240{,}000 \frac{Btu}{hr}$	2.10 / 1.99
	$\geq 240{,}000 \frac{Btu}{hr}$	2.05 / 1.94

a) Net sensible cooling capacity. The total gross cooling capacity less the latent cooling less the energy to the air movement system. (Total Gross – Latent – Fan Power)
b) Sensible coefficient of performance (SCOP-127): a ratio calculated by dividing the net sensible cooling capacity in watts by the total power input in watts (excluding re-heaters and humidifiers) at conditions defined in ASHRAE Standard 127. The net sensible cooling capacity is the gross sensible capacity minus the energy dissipated into the cooled space by the fan system.

Default Savings

There are no default savings for this measure.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Phase II Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

7) California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx. Accessed December 2018.

8) U.S. Department of Energy. 10 CFR Part 431. Energy Efficiency Program for Certain Commercial and Industrial Equipment: Subpart F—Commercial Air Conditioners and Heat Pumps. Table 12.

9) Xcel Energy, Data Center Efficiency Deemed Savings 2016. https://www.xcelenergy.com/staticfiles/xe/PDF/Regulatory/CO-DSM/CO-Rates-and-Reg-DSM-Data-Center-Efficiency-Deemed-Savings-2016.pdf

3.2.11 Computer Room Air Conditioner/Handler Electronically Commutated Plug Fans

Target Sector	Commercial and Industrial Establishments
Measure Unit	Fan Size (HP) Installed
Measure Life	15 years Source 1
Measure Vintage	Replace on Burnout, Early Replacement, Retrofit, New Construction

Data centers have significant cooling loads, due to the large internal heat gains from IT equipment. Cooling for these spaces is typically provided by computer room air conditioners (CRAC) or computer room air handlers (CRAH). CRAH units differ from CRAC units by supplying cooling via chilled water instead of direct-expansion.

Since CRAH units lack compressors and condensers, fan energy comprises the majority of their energy usage.[Source 2] This document is concerned with installing or replacing the existing fans with electronically commutated (EC) plug fans. The term "plug fan" refers to a fan with no housing, typically utilizing an airfoil, backward inclined or backward curved impeller design.[Source 3]

Baseline fans are typically centrifugal, belt-driven fans mounted in the CRAC unit, powered by three-phase AC motors. The proposed upgrade is to replace these with EC plug fans which are direct-driven and can be mounted in-unit or underfloor. Underfloor mounting offers additional energy savings by providing a more efficient airflow path and reducing resistance on the blower.

Eligibility

This measure requires the installation of EC plug fans in CRAC and CRAH units. This applies to new construction applications where EC plug fans were specified instead of belt-driven fans or retrofit applications in which conventional, belt-driven fans were replaced with EC plug fans.

Commented [SA43]: Franklin Energy

Installing any mechanism that could potentially modify the airflow of the supply fan on a DX system (CRAC units) has potential to freeze the coil. At a minimum, it should be recommended that any installation of any ECM on a CRAC unit should be verified with the manufacturer.
This measure doesn't suggest this, but ECMs inherently allows for potentially reduced airflow.

Algorithms

The annual energy and peak demand savings are obtained through the following formulas shown below. These formulas are adopted from Xcel Energy's Deemed Savings Technical Assumptions for the Data Center Efficiency Program.[Source 4]

$$\Delta kWh = \Delta Fan\ Power \times \left[HOU_{Fan} + \left(\frac{3{,}413}{12{,}000} \times \eta_{cooling}\right) \times HOU_{Fan}\right]$$

$$\Delta kW_{peak} = \Delta Fan\ Power \times \left(1 + \frac{3{,}413}{12{,}000} \times \eta_{cooling}\right) \times CF$$

$$\Delta Fan\ Power = HP \times (1 - CLF) \times 0.746 \times UF$$

$$CLF = \left(\frac{\eta_{base\ fan} \times \eta_{base\ belt} \times \eta_{base\ motor}}{\eta_{EC\ fan} \times \eta_{EC\ drive} \times \eta_{EC\ motor}}\right) - UDSF$$

Definition of Terms

Table 3-58: Terms, Values, and References for CRAC/CRAH EC Plug Fans

Term	Unit	Values	Source
$\eta_{base\ fan}$, Efficiency of baseline centrifugal, forward-curved fans	None	EDC Data Gathering Default = 53.81%	4
$\eta_{base\ belt}$, Efficiency of baseline belt	None	EDC Data Gathering Default = 95%	6
$\eta_{base\ motor}$, Efficiency of baseline AC motor	None	EDC Data Gathering Default = 91.18%	4
$\eta_{EC\ fan}$, Efficiency of EC plug fan	None	EDC Data Gathering Default = 65.97%	4
$\eta_{EC\ drive}$, Efficiency of EC motor drive	None	EDC Data Gathering Default = 99.5%	4
$\eta_{EC\ motor}$, Efficiency of EC motor	None	EDC Data Gathering Default = 88.96%	4
$UDSF$, Underfloor distribution savings factor	None	If fans are located: In Unit = 0% Underfloor = 13.3%	5
CLF, Comparison Load Factor. This term compares the baseline and EC system efficiencies and accounts for underfloor location (if applicable) to provide an estimate of the load on the EC system.	None	Calculated	4
$\Delta Fan\ Power$, Fan power reduction	kW	Calculated	4
HP, Fan power replaced	HP	EDC Data Gathering	-
UF, % of CRAC/CRAH units in use	None	EDC Data Gathering Default = 83%	7
$\eta_{cooling}$, Efficiency of cooling system	kW/ton	EDC Data Gathering Default = 0.95	*
HOU_{Fan}, Annual hours of fan operation	Hours/year	EDC Data Gathering Default = 8,760	**
0.746, kilowatt to hp conversion factor	kW/HP	0.746	-
$3{,}413$, Btu to kWh conversion factor	Btu/kWh	3,413	-
$12{,}000$, Btu to ton (cooling) conversion factor	Btu/ton	12,000	-
CF, Coincidence factor	None	EDC Data Gathering Default = 1.0	**
* Assumes an average of air-cooled chillers and DX (all sizes) and water-cooled DX efficiencies. Water-cooled chillers were excluded from the average since they are assumed to be baseline for data centers greater than 1 MW. Source 7, pages 32, 36 and 38. ** Assumes data center CRAC/CRAH fans operates continuously. This is consistent with the HVAC hours for data			

center applications. Additionally, the CRAC/CRAH fans are assumed to operating regardless of economizer operation.

Default Savings

Table 3-59: Default 'per HP' Savings for CRAC/CRAH EC Plug Fans

Location of Plug Fan	Energy Savings (kWh/HP)	Peak Demand Reduction (kW/HP)
In Unit	1,390	0.1587
Underfloor	2,306	0.2633
If Unknown	1,848	0.2110

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) U.S. Department of Energy, Energy Savings Potential and Opportunities for High-Efficiency Electric Motors in Residential and Commercial Equipment, December 2013. https://energy.gov/sites/prod/files/2014/02/f8/Motor%20Energy%20Savings%20Potential%20Report%202013-12-4.pdf

2) Emerson Network Power, Technical Note: Using EC Plug Fans to Improve Energy Efficiency of Chilled Water Cooling Systems in Large Data Centers, http://shared.liebert.com/SharedDocuments/White%20Papers/PlugFan_Low060608.pdf

3) ASHRAE, 2016 ASHRAE Handbook: HVAC Systems and Equipment.

4) Xcel Energy Data Center Efficiency Program, Deemed Savings Technical Assumptions, https://www.xcelenergy.com/staticfiles/xe/PDF/Regulatory/CO-DSM/CO-Rates-and-Reg-DSM-Data-Center-Efficiency-Deemed-Savings-2016.pdf

5) Technical Note: Using EC Plug Fans to Improve Energy Efficiency of Chilled Water Cooling Systems in Large Data Centers, by Emerson Power Network (http://shared.liebert.com/SharedDocuments/White%20Papers/PlugFan_Low060608.pdf) [UDSF value derived from EC Plug Fans vs. VFD savings table on page 5, savings from base at 100% speed.]

6) U.S. Department of Energy, Replace V-Belts with Notched or Synchronous Belt Drives, November 2012. http://www.nrel.gov/docs/fy13osti/56012.pdf

7) Integral Group, Energy Efficiency Baselines for Data Centers, March 1, 2013. http://www.pge.com/includes/docs/pdfs/mybusiness/energysavingsrebates/incentivesbyindustry/hightech/data_center_baseline.pdf (Usage factor assumes 5 of 6 units operating, based on a "Redundancy = N+1" and "Safety factor on capacity = design load * 1.20")

3.2.12 Computer Room Air Conditioner/Handler VSD on AC Fan Motors

Target Sector	Commercial and Industrial Establishments
Measure Unit	Size (HP) of Fan
Measure Life	15 years Source 1
Measure Vintage	Retrofit, New Construction

Data centers have significant cooling loads, due to the large internal heat gains from IT equipment. Cooling for these spaces is typically provided by computer room air conditioners (CRAC) or computer room air handlers (CRAH). CRAH units differ from CRAC units by supplying cooling via chilled water instead of direct-expansion.

Since CRAH units lack compressors and condensers, fan energy comprises the majority of their energy usage.Source 2 In addition to saving fan energy, cooling load is also reduced, resulting from the decreased energy consumption by motors within the conditioned space. This measure protocol is concerned with installing or upgrading to variable speed drives (VSDs) on existing CRAC or CRAH units.

Eligibility

This measure requires the installation of a VSD to control AC fan motors in CRAC and CRAH units. This applies to new construction and retrofit applications where constant speed AC fan motors are retrofitted with VSD controls.

Commented [SA44]: Franklin Energy

Installing any mechanism that could potentially modify the airflow of the supply fan on a DX system (CRAC units) has potential to freeze the coil. At a minimum, it should be recommended that any installation of any VFD on a CRAC unit should be verified with the manufacturer.

Algorithms

The annual energy and peak demand savings are obtained through the following formulas:

$$\Delta kWh_{fan} = HP \times \frac{LF}{\eta_{motor}} \times 0.746 \times ESF \times UF \times HOU$$

$$\Delta kWh_{cooling} = \Delta kWh_{fan} \times \frac{3{,}413}{12{,}000} \times \eta_{cooling}$$

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

$$\Delta kW_{peak} = \frac{\Delta kWh_{total}}{HOU} \times CF$$

Definition of Terms

Table 3-60: Terms, Values, and References for CRAC/CRAH VSD on AC Fan Motors

Term	Unit	Values	Source
HP, Fan motor power	HP	EDC Data Gathering	-
LF, Load factor of fan motor	None	EDC Data Gathering Default = 75%	4
η_{motor}, Efficiency of AC motor	None	EDC Data Gathering Default = 91.18%	4
0.746, HP to kW conversion factor	kW/HP	0.746	-
HOU, Annual hours of fan operation	Hours/year	8,760	4
ESF, Energy savings factor	None	0.40	5
UF, % of CRAC/CRAH units in use (usage factor)	None	EDC Data Gathering Default = 83%	4
$3{,}143$, conversion factor from BTU/hr to kW	BTU/hr-kW	3,143	-
$12{,}000$, conversion factor from BTUs/hr to tons of cooling	BTU/hr-ton	12,000	-
CF, Coincidence factor	None	EDC Data Gathering Default = 1	4
$\eta_{cooling}$, Efficiency of cooling system	kW/ton	EDC Data Gathering Default = 0.95	3

Default Savings

Default savings for this measure are shown in the table below.

Table 3-61: Default Savings for CRAC/CRAH VSD on AC Fan Motors

Annual Energy Savings (kWh/HP)	Peak Demand Reduction (kW/HP)
2,267	0.2588

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) Efficiency Vermont Technical Reference User Manual (TRM), March 16, 2015. (15 years is given for non-process VSDs.) https://puc.vermont.gov/sites/psbnew/files/doc_library/ev-technical-reference-manual.pdf
2) *Technical Note: Using EC Plug Fans to Improve Energy Efficiency of Chilled Water Cooling Systems in Large Data Centers*, Emerson Network Power. Page 2. http://shared.liebert.com/SharedDocuments/White%20Papers/PlugFan_Low060608.pdf
3) Integral Group, Energy Efficiency Baselines for Data Centers, March 1, 2013. http://www.pge.com/includes/docs/pdfs/mybusiness/energysavingsrebates/incentivesbyindustry/hightech/data_center_baseline.pdf (Usage factor derived from an assumption that 5 of 6 units operating, based on a "Redundancy = N+1" and "Safety factor on capacity = design load * 1.20". Cooling system efficiency assumes an average of air-cooled chillers and DX (all sizes) and water-cooled DX efficiencies. Water-cooled chillers were excluded from the average since they are assumed to be baseline for data centers greater than 1 MW.)
4) Xcel Energy Data Center Efficiency Program, Deemed Savings Technical Assumptions, https://www.xcelenergy.com/staticfiles/xe/PDF/Regulatory/CO-DSM/CO-Rates-and-Reg-DSM-Data-Center-Efficiency-Deemed-Savings-2016.pdf
5) Electric Power Research Institute. Energy savings factor comes from a conservative estimate based on reducing fan speed to approximately 85% (0.85^3= 0.61 under ideal conditions). Supported by EPRI case study: EPRI "was able to reduce is fan power use by 77%." http://www.datacenterknowledge.com/archives/2011/11/21/focus-on-fans-delivers-cost-savings-on-cooling/

3.2.13 Circulation Fan: High-Volume Low-Speed

Target Sector	Commercial and Industrial Establishments
Measure Unit	Number of Fans Installed
Measure Life	15 years [Source 1]
Measure Vintage	Replace on Burnout, Early Replacement, Retrofit, New Construction

This protocol covers energy and demand savings associated with the installation of high-volume low-speed (HVLS) circulating fans to replace conventional circulating fans. HVLS fans generally range from 8 feet to 24 feet in diameter and move more cubic feet of air per Watt than conventional circulating fans.[Source 2] This IMP is for use in Commercial and Industrial applications only. For Agricultural applications, please refer to TRM Measure 4.1.5 High Volume Low Speed Fans.

Until recently, there was not a practical standard for determining performance (airflow rate, power consumption, efficiency, thrust or efficacy) of HVLS fans.[Source 3] *ANSI/AMCA Standard 230-15 Laboratory Methods of Testing Air Circulating Fans for Rating and Certification* now provides a uniform testing procedure that includes HVLS fans. However, based on a late-2018 review of product specifications the results of this standard are not yet incorporated into product documentation.

Eligibility

This measure requires the installation of HVLS fans (diameters ranging from 8 to 24 feet) in either new construction or retrofit applications where conventional circulating fans are replaced.

Algorithms

The annual energy and peak demand savings are obtained through the following formulas:

$$\Delta kW = \frac{W_{conventional} - W_{HVLS}}{1{,}000}$$

$$\Delta kWh = \Delta kW \ x \ HOU$$

$$\Delta kW_{peak} = CF \times \Delta kW$$

Definition of Terms

Table 3-62: Terms, Values, and References for HVLS Fans

Term	Unit	Values	Source
$W_{conventional}$, Conventional fan wattage	*W*	EDC Data Gathering	4
		Default values in Table 3-63	
W_{HVLS}, HVLS fan wattage	*W*	EDC Data Gathering	4
		Default values in Table 3-63	
HOU, Annual hours of fan operation	*Hours/year*	EDC Data Gathering	5
		Default values in Table 3-64	
1,000, Conversion factor	$\frac{watts}{kilowatt}$	1,000	-
CF, Coincidence factor	*None*	Default values in Table 3-29	5

Table 3-63: Default Values for Conventional and HVLS Fan Wattages

Fan Diameter (ft)	$W_{conventional}$	W_{HVLS}
≥ 8 and < 10	2,227	377
≥ 10 and < 12	2,784	471
≥ 12 and < 14	3,341	565
≥ 14 and < 16	3,898	659
≥ 16 and < 18	4,497	761
≥ 18 and < 20	5,026	850
≥ 20 and < 24	5,555	940
≥ 24	6,613	1,119

Table 3-64: Default Hours of Use by Building Type and Region

Space and/or Building Type	Allentown	Binghamton	Bradford	Erie	Harrisburg	Philadelphia	Pittsburgh	Scranton	Williamsport
Education - College/University	1,359	1,424	1,447	1,335	1,208	1,198	1,244	1,356	1,250
Education - Other	902	1,073	1,158	851	1,051	991	1,157	1,142	894
Grocery	1,387	1,610	1,610	1,170	1,722	1,753	1,202	2,171	1,861
Health - Hospital	1,177	1,058	1,048	1,133	1,253	1,404	1,206	1,128	1,167
Health - Other	1,421	1,829	1,980	1,785	1,394	1,489	1,534	1,660	1,434
Industrial Manufacturing	976	861	876	884	989	1,021	929	886	824
Institutional/Public Service	1,931	2,005	2,174	2,044	1,918	2,208	1,869	2,030	1,751
Lodging	3,757	4,424	4,930	4,469	3,682	3,749	3,889	3,939	3,787
Multi-Family (Common Areas)	1,672	974	931	1,091	1,745	1,906	1,440	1,272	1,330
Office	778	372	850	834	895	984	1,064	828	806
Restaurant	1,701	2,294	2,483	2,200	1,630	1,784	1,972	2,023	1,835
Retail	1,544	1,620	1,686	1,600	1,390	1,543	1,597	1,458	1,323
Warehouse - Other	1,021	1,205	1,344	1,228	1,078	1,246	1,170	1,138	978
Warehouse - Refrigerated	3,493	3,661	3,678	3,614	3,470	3,422	3,525	3,533	3,463

Default Savings

There are no default savings for this measure.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) State of Wisconsin. Focus on Energy Evaluation, Business Program: Measure Life Study Final Report: August 25, 2009. Appendix B, Pages 65-66. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2) Survey of available HVLS fans from the following manufacturers: Big Ass Fans, Go Fan Yourself, Kelley, MacroAir, Patterson Fan Company and Rite-Hite.

3) Taber, Christian. *The Thrust of ANSI/AMCA Standard 230-15, Circulator Fan Performance Testing Standards.* ASHRAE Journal, September 2015. http://bookstore.ashrae.biz/journal/download.php?file=2015Sept_028-039_Taber.pdf

4) The wattage information for fan diameters of 8 feet through 14 feet have been extrapolated from existing wattage data in *IPL Energy Efficiency Programs 2009 Evaluation*, KEMA Inc. Appendix H, Table H-17. February 14, 2012.

5) Hours of use are assumed to match the HOU of Circulating fans (the sum of $EFLH_{Heat}$ and $EFLH_{Cool}$). EFLHs and CFs for Pennsylvania are calculated based on Nexant's eQuest modeling analysis 2014.

3.3 Motors and VFDs

3.3.1 Premium Efficiency Motors

Target Sector	Commercial and Industrial Establishments
Measure Unit	Motor
Measure Life	15 years Source 1
Measure Vintage	Replace on Burnout, New Construction, or Early Replacement

Eligibility

For constant speed and uniformly loaded motors, the prescriptive measurement and verification protocols described below apply to the replacement of old motors with new energy efficient motors of the same rated horsepower and for New Construction. Replacements where the old motor and new motor have different horsepower ratings are considered custom measures. Motors with variable speeds, variable loading, or industrial-specific applications are also considered custom measures.

Note that the Coincidence Factor (CF) and Run Hours of Use (RHRS) for motors specified below do not take into account systems with multiple motors serving the same load, such as duplex motor sets with a lead-lag setup. Under these circumstances, a custom measure protocol is required.

Algorithms

The energy and demand savings for this measure depend on the size and efficiency of the efficient motor, calculated according to the following algorithms:

$$\Delta kWh = kWh_{base} - kWh_{ee}$$

$$kWh_{base} = 0.746 \times HP \times \frac{LF}{\eta_{base}} \times RHRS$$

$$kWh_{ee} = 0.746 \times HP \times \frac{LF}{\eta_{ee}} \times RHRS$$

$$\Delta kW_{peak} = kW_{base} - kW_{ee}$$

$$kW_{base} = 0.746 \times HP \times \frac{LF}{\eta_{base}} \times CF$$

$$kW_{ee} = 0.746 \times HP \times \frac{LF}{\eta_{ee}} \times CF$$

Definition of Terms

Table 3-65: Terms, Values, and References for Premium Efficiency Motors

Term	Unit	Value	Source
HP, Rated horsepower of the baseline and energy efficient motor	*HP*	Nameplate	EDC Data Gathering
0.746, Conversion factor for HP to kWh	*kWh/HP*	0.746	Conversion factor
$RHRS$[122], Annual run hours of the motor	$\frac{Hours}{Year}$	Based on logging, panel data or modeling[123]	EDC Data Gathering
		Default: Table 3-68 to Table 3-72	2
LF[122], Load Factor. Ratio between the actual load and the rated load. Variable loaded motors should use custom measure protocols.	*None*	Based on spot metering and nameplate	EDC Data Gathering
		Default, fans: 0.76 Default, pumps: 0.79	3
η_{base}, Efficiency of the baseline motor. If a new motor was purchased as an alternative to rewinding an old motor, the nameplate efficiency of the old motor may be used as the baseline.	*None*	Early Replacement: Nameplate	EDC Data Gathering
		New Construction or Replace on Burnout: Default comparable standard motor. See Table 3-66 and Table 3-67	4
η_{ee}, Efficiency of the energy-efficient motor	*None*	Nameplate	EDC Data Gathering
CF, Coincidence factor	*Decimal*	EDC Data Gathering	EDC Data Gathering
		Table 3-68 to Table 3-72	2

122 Default value can be used by EDC but it is subject to metering and adjustment by evaluators or SWE.
123 Modeling is an acceptable substitute to metering and panel data if modeling is conducted using building- and equipment-specific information at the site and the facility consumption is calibrated using 12 months of billing data (pre-retrofit).

Table 3-66: Baseline Efficiencies for NEMA Design A and NEMA Design B Motors

Motor HP	Motor Nominal Full-Load Efficiencies (percent)							
	2 Pole (3600 RPM)		4 pole (1800 RPM)		6 Pole (1200 RPM)		8 Pole (900 RPM)	
	Enclosed	Open	Enclosed	Open	Enclosed	Open	Enclosed	Open
1	77.0	77.0	85.5	85.5	82.5	82.5	75.5	75.5
1.5	84.0	84.0	86.5	86.5	87.5	86.5	78.5	77.0
2	85.5	85.5	86.5	86.5	88.5	87.5	84.0	86.5
3	86.5	85.5	89.5	89.5	89.5	88.5	85.5	87.5
5	88.5	86.5	89.5	89.5	89.5	89.5	86.5	88.5
7.5	89.5	88.5	91.7	91.0	91.0	90.2	86.5	89.5
10	90.2	89.5	91.7	91.7	91.0	91.7	89.5	90.2
15	91.0	90.2	92.4	93.0	91.7	91.7	89.5	90.2
20	91.0	91.0	93.0	93.0	91.7	92.4	90.2	91.0
25	91.7	91.7	93.6	93.6	93.0	93.0	90.2	91.0
30	91.7	91.7	93.6	94.1	93.0	93.6	91.7	91.7
40	92.4	92.4	94.1	94.1	94.1	94.1	91.7	91.7
50	93.0	93.0	94.5	94.5	94.1	94.1	92.4	92.4
60	93.6	93.6	95.0	95.0	94.5	94.5	92.4	93.0
75	93.6	93.6	95.4	95.0	94.5	94.5	93.6	94.1
100	94.1	93.6	95.4	95.4	95.0	95.0	93.6	94.1
125	95.0	94.1	95.4	95.4	95.0	95.0	94.1	94.1
150	95.0	94.1	95.8	95.8	95.8	95.4	94.1	94.1
200	95.4	95.0	96.2	95.8	95.8	95.4	94.5	94.1
250	95.8	95.0	96.2	95.8	95.8	95.8	95.0	95.0
300	95.8	95.4	96.2	95.8	95.8	95.8	N/A	N/A
350	95.8	95.4	96.2	95.8	95.8	95.8	N/A	N/A
400	95.8	95.8	96.2	95.8	N/A	N/A	N/A	N/A
450	95.8	96.2	96.2	96.2	N/A	N/A	N/A	N/A
500	95.8	96.2	96.2	96.2	N/A	N/A	N/A	N/A

Table 3-67: Baseline Motor Efficiencies for NEMA Design C Motors

Motor HP	Motor Nominal Full-Load Efficiencies (percent)					
	4 Pole (1800 RPM)		6 Pole (1200 RPM)		8 Pole (900 RPM)	
	Enclosed	Open	Enclosed	Open	Enclosed	Open
1	85.5	85.5	82.5	82.5	75.5	75.5
1.5	86.5	86.5	87.5	86.5	78.5	77.0
2	86.5	86.5	88.5	87.5	84.0	86.5
3	89.5	89.5	89.5	88.5	85.5	87.5
5	89.5	89.5	89.5	89.5	86.5	88.5
7.5	91.7	91.0	91.0	90.2	86.5	89.5
10	91.7	91.7	91.0	91.7	89.5	90.2
15	92.4	93.0	91.7	91.7	89.5	90.2
20	93.0	93.0	91.7	92.4	90.2	91.0
25	93.6	93.6	93.0	93.0	90.2	91.0
30	93.6	94.1	93.0	93.6	91.7	91.7
40	94.1	94.1	94.1	94.1	91.7	91.7
50	94.5	94.5	94.1	94.1	92.4	92.4
60	95.0	95.0	94.5	94.5	92.4	93.0
75	95.4	95.0	94.5	94.5	93.6	94.1
100	95.4	95.4	95.0	95.0	93.6	94.1
125	95.4	95.4	95.0	95.0	94.1	94.1
150	95.8	95.8	95.8	95.4	94.1	94.1
200	96.2	95.8	95.8	95.4	94.5	94.1

Table 3-68: Default RHRS and CFs for Supply Fan Motors in Commercial Buildings[124]

Facility Type	Parameter	Allentown	Binghamton	Bradford	Erie	Harrisburg	Philadelphia	Pittsburgh	Scranton	Williamsburg
Education - College / University	CF	0.43	0.30	0.24	0.32	0.44	0.47	0.42	0.38	0.44
	Run Hours	6,042	6,054	6,126	6,139	5,860	5,966	5,982	5,876	5,905
Education - Other	CF	0.12	0.08	0.07	0.09	0.17	0.18	0.18	0.12	0.15
	Run Hours	4,380	4,583	4,718	4,572	4,313	4,384	4,415	4,490	4,377
Grocery	CF	0.24	0.21	0.19	0.22	0.24	0.26	0.29	0.21	0.24
	Run Hours	6,708	6,764	6,810	6,738	6,692	6,669	6,718	6,725	6,710
Health - Hospital	CF	0.43	0.24	0.29	0.39	0.45	0.51	0.45	0.40	0.41
	Run Hours	8,760	8,760	8,760	8,760	8,760	8,760	8,760	8,760	8,760
Health - Other	CF	0.24	0.21	0.17	0.23	0.29	0.31	0.29	0.25	0.28
	Run Hours	8,760	8,760	8,760	8,760	8,760	8,760	8,760	8,760	8,760
Industrial Manufacturing	CF	0.48	0.34	0.28	0.38	0.53	0.57	0.50	0.43	0.46
	Run Hours	3,831	3,981	4,080	3,977	3,769	3,838	3,869	3,902	3,829
Institutional / Public Service	CF	0.53	0.38	0.34	0.45	0.60	0.72	0.56	0.47	0.52
	Run Hours	5,188	5,223	5,248	5,217	5,172	5,186	5,201	5,207	5,184
Lodging	CF	0.64	0.64	0.60	0.65	0.71	0.71	0.73	0.65	0.71
	Run Hours	8,760	8,760	8,760	8,760	8,760	8,760	8,760	8,760	8,760

[124] Operating hours subject to adjustment with data provided by EDCs and accepted by SWE.

Facility Type	**Parameter**	**Allentown**	**Binghamton**	**Bradford**	**Erie**	**Harrisburg**	**Philadelphia**	**Pittsburgh**	**Scranton**	**Williamsburg**
Office	CF	0.30	0.26	0.21	0.28	0.37	0.39	0.35	0.32	0.34
	Run Hours	4,195	4,473	4,699	4,441	4,087	4,063	4,240	4,228	4,139
Restaurant	CF	0.38	0.19	0.28	0.37	0.42	0.50	0.49	0.39	0.45
	Run Hours	6,282	2,680	6,487	6,365	6,252	6,226	6,300	6,315	6,286
Retail	CF	0.50	0.40	0.36	0.44	0.53	0.56	0.54	0.45	0.49
	Run Hours	5,137	5,188	5,234	5,158	5,108	5,092	5,146	5,149	5,134
Warehouse - Other	CF	0.18	0.11	0.10	0.13	0.24	0.30	0.23	0.15	0.20
	Run Hours	5,037	5,189	5,259	5,222	4,980	5,168	5,110	5,188	5,028
Warehouse - Refrigerated	CF	0.50	0.46	0.43	0.48	0.52	0.53	0.51	0.48	0.51
	Run Hours	4,041	4,041	4,041	4,041	4,041	4,041	4,041	4,041	4,041

Table 3-69: Default RHRS and CFs for Chilled Water Pump (CHWP) Motors in Commercial Buildings[125]

Facility Type	Parameter	Allentown	Binghamton	Bradford	Erie	Harrisburg	Philadelphia	Pittsburgh	Scranton	Williamsburg
Education – College / University	CF	0.41	0.27	0.23	0.30	0.42	0.45	0.40	0.33	0.40
	Run Hours	4,007	3,436	3,096	3,641	4,057	4,311	3,916	3,828	3,872
Education - Other	CF	0.10	0.08	0.07	0.09	0.18	0.18	0.17	0.12	0.16
	Run Hours	2,721	1,849	1,631	2,175	2,730	3,505	2,676	2,310	2,573
Health - Hospital	CF	0.46	0.38	0.31	0.42	0.50	0.54	0.48	0.44	0.47
	Run Hours	5,588	4,801	4,167	5,109	5,717	6,086	5,593	5,266	5,628
Health - Other	CF	0.24	0.20	0.16	0.22	0.28	0.30	0.28	0.23	0.26
	Run Hours	3,892	3,093	2,592	3,456	4,104	4,535	3,900	3,710	3,818
Industrial Manufacturing	CF	0.53	0.40	0.32	0.43	0.53	0.58	0.54	0.48	0.50
	Run Hours	1,735	1,306	1,086	1,448	1,742	1,891	1,606	1,558	1,633
Lodging	CF	0.61	0.58	0.53	0.60	0.66	0.67	0.69	0.59	0.66
	Run Hours	5,845	5,042	4,444	5,198	6,045	6,161	5,686	5,655	5,776
Office	CF	0.29	0.25	0.20	0.27	0.35	0.36	0.33	0.29	0.32
	Run Hours	1,789	1,402	1,189	1,585	1,804	2,036	1,739	1,638	1,711
Retail	CF	0.46	0.33	0.28	0.38	0.53	0.54	0.47	0.42	0.47
	Run Hours	2,957	2,416	2,012	2,653	3,085	3,225	2,795	2,735	2,898

[125] Operating hours subject to adjustment with data provided by EDCs and accepted by SWE.

Table 3-70: Default RHRS and CFs for Cooling Tower Fan (CTF) Motors in Commercial Buildings[126]

Facility Type	Parameter	Allentown	Binghamton	Bradford	Erie	Harrisburg	Philadelphia	Pittsburgh	Scranton	Williamsburg
Education – College / University	CF	0.41	0.26	0.23	0.30	0.42	0.45	0.40	0.33	0.39
	Run Hours	4,006	3,435	3,096	3,641	4,057	4,309	3,914	3,827	3,871
Education - Other	CF	0.11	0.08	0.07	0.09	0.18	0.18	0.17	0.12	0.17
	Run Hours	2,742	1,851	1,634	2,178	2,744	3,517	2,685	2,313	2,604
Health - Hospital	CF	0.45	0.37	0.31	0.41	0.49	0.54	0.47	0.44	0.46
	Run Hours	5,587	4,798	4,165	5,107	5,714	6,084	5,591	5,263	5,626
Health - Other	CF	0.24	0.20	0.16	0.22	0.28	0.30	0.28	0.23	0.26
	Run Hours	3,894	3,093	2,593	3,457	4,106	4,537	3,902	3,711	3,819
Industrial Manufacturing	CF	0.53	0.40	0.32	0.43	0.54	0.59	0.54	0.48	0.50
	Run Hours	1,735	1,306	1,086	1,448	1,742	1,891	1,606	1,558	1,633
Lodging	CF	0.61	0.58	0.53	0.61	0.67	0.68	0.70	0.59	0.66
	Run Hours	5,844	5,039	4,442	5,197	6,043	6,159	5,683	5,652	5,773
Office	CF	0.29	0.25	0.20	0.27	0.35	0.36	0.33	0.29	0.32
	Run Hours	1,789	1,402	1,189	1,585	1,804	2,036	1,739	1,638	1,711
Retail	CF	0.46	0.33	0.28	0.38	0.53	0.54	0.47	0.42	0.47
	Run Hours	2,957	2,416	2,012	2,653	3,085	3,226	2,795	2,736	2,898

126 Operating hours subject to adjustment with data provided by EDCs and accepted by SWE.

Table 3-71: Default RHRS and CFs for Heating Hot Water Pump (HHWP) Motors in Commercial Buildings[127]

Facility Type	Parameter	Allentown	Binghamton	Bradford	Erie	Harrisburg	Philadelphia	Pittsburgh	Scranton	Williamsburg
Education – College / University	CF	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.01
	Run Hours	4,548	5,271	5,900	5,036	4,250	4,014	4,572	4,638	4,487
Education - Other	CF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Run Hours	3,651	4,251	4,722	4,080	3,492	3,341	3,705	3,830	3,658
Health - Hospital	CF	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
	Run Hours	8,760	8,760	8,760	8,760	8,760	8,760	8,760	8,760	8,760
Health - Other	CF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Run Hours	5,934	6,627	7,170	6,280	5,823	5,477	5,991	6,223	6,045
Industrial Manufacturing	CF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Run Hours	1,258	1,684	1,944	1,555	1,184	1,028	1,287	1,393	1,277
Lodging	CF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Run Hours	6,469	7,072	7,587	6,829	6,155	6,077	6,574	6,628	6,387
Office	CF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Run Hours	3,214	3,876	4,446	3,611	3,014	2,690	3,246	3,336	3,169
Retail	CF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Run Hours	2,676	3,183	3,568	2,960	2,561	2,398	2,908	2,841	2,660

[127] Operating hours subject to adjustment with data provided by EDCs and accepted by SWE.

Table 3-72: Default RHRS and CFs for Condenser Water Pump Motors in Commercial Buildings[128]

Facility Type	Parameter	Allentown	Binghamton	Bradford	Erie	Harrisburg	Philadelphia	Pittsburgh	Scranton	Williamsburg
Education - College / University	CF	0.41	0.26	0.20	0.30	0.42	0.45	0.40	0.33	0.39
	Run Hours	3,527	2,938	2,466	3,063	3,602	4,030	3,749	3,500	3,489
Education - Other	CF	0.11	0.08	0.07	0.09	0.18	0.18	0.17	0.12	0.17
	Run Hours	2,448	1,733	1,529	2,039	2,539	3,346	2,409	2,164	2,423
Health - Hospital	CF	0.45	0.37	0.29	0.41	0.49	0.54	0.47	0.44	0.46
	Run Hours	3,950	3,546	3,293	3,698	3,687	4,168	4,093	3,713	3,670
Health - Other	CF	0.24	0.20	0.16	0.22	0.28	0.30	0.28	0.23	0.26
	Run Hours	3,675	3,100	2,585	3,394	3,725	4,304	3,571	3,687	3,722
Industrial Manufacturing	CF	0.53	0.40	0.32	0.43	0.54	0.59	0.54	0.48	0.50
	Run Hours	1,735	1,305	1,084	1,445	1,737	1,889	1,602	1,558	1,632
Lodging	CF	0.61	0.58	0.53	0.61	0.67	0.68	0.70	0.59	0.66
	Run Hours	5,544	4,591	3,939	4,766	5,569	5,886	5,239	5,353	5,328
Office	CF	0.29	0.25	0.20	0.27	0.35	0.36	0.33	0.29	0.32
	Run Hours	1,781	1,389	1,177	1,569	1,792	2,027	1,730	1,631	1,702
Retail	CF	0.46	0.33	0.28	0.38	0.53	0.54	0.47	0.42	0.47
	Run Hours	2,889	2,381	1,986	2,616	3,025	3,185	2,757	2,702	2,847

[128] Operating hours subject to adjustment with data provided by EDCs and accepted by SWE.

Default Savings

There are no default savings for this measure.

Evaluation Protocols

Motor projects achieving expected kWh savings of 250,000 kWh or higher must[129] be metered to calculate *ex ante* and/or *ex post* savings. Metering is not mandatory where the motors in question are constant speed and hours can be easily verified through a building automation system schedule that clearly shows motor run time.

Sources

1) California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx. Accessed December 2018.
2) Phase II SWE team modeling, described in the 2015 Tentative Order Section E.3.c, http://www.puc.pa.gov/pcdocs/1311852.docx. Accessed December 2018.
3) Regional Technical Forum. *Proposed Standard Savings Estimation Protocol for Ultra-Premium Efficiency Motors.* November 5, 2012. Appendix C, Table 6.
4) "Energy Conservation Program: Energy Conservation Standards for Commercial and Industrial Electric Motors; Final Rule," 79 Federal Register 103 (29 May 2014). https://www.gpo.gov/fdsys/pkg/FR-2014-05-29/html/2014-11201.htm

[129] The Commission allows the EDCs to use alternative methods for obtaining customer-specific data where customer processes do not support metering. The EDCs are required to provide supporting documentation to the SWE for review if there are any such exceptions.

3.3.2 Variable Frequency Drive (VFD) Improvements

Target Sector	Commercial and Industrial Establishments
Measure Unit	Variable Frequency Drive
Measure Life	15 years Source 1
Measure Vintage	New Construction or Retrofit

Eligibility

The following protocol for the measurement of energy and demand savings applies to the installation of Variable Frequency Drives (VFDs) in standard commercial building applications – supply and return fans, cooling tower fans, chilled water pumps, and heating water pumps. The baseline condition is a motor without a VFD control. The efficient condition is a motor with a VFD control.

Installations of new equipment with VFDs which are required by energy codes adopted by the State of Pennsylvania are not eligible for incentives.

Algorithms

The energy and demand savings associated with this measure depend on the size of the affected motor and the motor's load profile. Savings are calculated using the following algorithms:

$$\Delta kWh = kWh_{base} - kWh_{ee}$$

$$kWh_{base} = 0.746 \times HP \times \frac{LF}{\eta_{motor}} \times RHRS \times \sum_{0\%}^{100\%} (\%FF \times PLR_{base})$$

$$kWh_{ee} = 0.746 \times HP \times \frac{LF}{\eta_{motor}} \times RHRS \times \sum_{0\%}^{100\%} (\%FF \times PLR_{ee})$$

$$\Delta kW_{peak} = kW_{base} - kW_{ee}$$

$$kW_{base} = 0.746 \times HP \times \frac{LF}{\eta_{motor}} \times PLR_{base,FFpeak}$$

$$kW_{ee} = 0.746 \times HP \times \frac{LF}{\eta_{motor}} \times PLR_{ee,FFpeak}$$

DEFINITION OF TERMS

Table 3-73: Terms, Values, and References for VFDs

Term	Unit	Values	Source
HP, Rated horsepower of the motor	*HP*	Nameplate	EDC Data Gathering
0.746, Conversion factor for HP to kWh	*kWh/HP*	0.746	Conversion factor
$RHRS$[130], Annual run hours of the baseline motor	$\frac{Hours}{Year}$	Based on logging, panel data, or modeling	EDC Data Gathering
		Default: Table 3-68 to Table 3-72	2
LF[130], Load Factor. Ratio between the actual load and the rated load.	*None*	Based on spot metering and nameplate	EDC Data Gathering
		Default: 76% for fans 79% for pumps	3
η_{motor}, Motor efficiency at the full-rated load. For VFD installations, this can be either an energy efficient motor or standard efficiency motor.	*Percent*	Nameplate	EDC Data Gathering
$\%FF$[130], Percentage of runtime spent within a given flow fraction range	*Percent*	Based on logging, panel data, or modeling	EDC Data Gathering
		Default: Table 3-74	4
PLR_{base}, Part load ratio for a given flow fraction range based on the baseline flow control type	*Percent*	Default: Table 3-75 to Table 3-76	4
PLR_{ee}, Part load ratio for a given flow fraction range with installed VFD	*Percent*	Default: Table 3-75 to Table 3-76	4
$PLR_{base,FFpeak}$, Part load ratio for the average flow fraction during the peak period on the baseline flow control type	*Percent*	Based on logging, panel data, or modeling	EDC Data Gathering
		Default: $PLR_{base,90\%}$	5
$PLR_{ee,FFpeak}$, Part load ratio for the average flow fraction during the peak period on the efficient flow control type	*Percent*	Based on logging, panel data, or modeling	EDC Data Gathering
		Default: $PLR_{ee,90\%}$	5

130 Default value can be used by EDC but is subject to metering and adjustment by evaluators or SWE.

Table 3-74: Default Load Profiles for HVAC Fans and Pumps

Equipment Type	Flow Fraction (%)										
	0	10	20	30	40	50	60	70	80	90	100
HVAC Fan	0%	0%	0%	0%	0%	10%	20%	30%	20%	15%	5%
HVAC Pump	0%	0%	0%	5%	10%	20%	30%	20%	10%	5%	0%

Table 3-75: Supply/Return and Cooling Tower Fan Power Part Load Ratios

Control Type	Flow Fraction (%)										
	0	10	20	30	40	50	60	70	80	90	100
Constant Volume	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Two-Speed	0.50	0.50	0.50	0.50	0.50	0.50	1.00	1.00	1.00	1.00	1.00
Air Foil/Backward Incline	0.56	0.53	0.53	0.57	0.64	0.72	0.80	0.89	0.96	1.02	1.05
Air Foil/Backward Incline with Inlet Guide Vanes	0.47	0.53	0.56	0.57	0.59	0.60	0.62	0.67	0.74	0.85	1.00
Forward Curved	0.20	0.22	0.26	0.30	0.37	0.45	0.54	0.65	0.77	0.91	1.06
Forward Curved with Inlet Guide Vanes	0.20	0.21	0.22	0.23	0.26	0.31	0.39	0.49	0.63	0.81	1.04
Variable Frequency Drive	0.05	0.05	0.05	0.08	0.13	0.20	0.30	0.43	0.60	0.80	1.03

Table 3-76: HVAC Pump Power Part Load Ratios

Control Type	Flow Fraction (%)										
	0	10	20	30	40	50	60	70	80	90	100
Constant Volume	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Throttle Valve	0.55	0.61	0.67	0.73	0.78	0.82	0.87	0.90	0.94	0.97	1.00
Variable Frequency Drive	0.27	0.19	0.14	0.13	0.15	0.21	0.30	0.43	0.60	0.79	1.03

Default Savings

There are no default savings for this measure.

Evaluation Protocol

Methods for Determining Baseline Conditions

The following are acceptable methods for determining baseline motor control conditions when verification by direct inspection is not possible as may occur in a rebate program where customers submit an application and equipment receipts only after installing the variable frequency drive(s), or for a retroactive project as allowed by Act 129. In order of preference:

- Examination of disengaged baseline motor control equipment or equipment that has been removed but is still on site waiting to be recycled or otherwise disposed of

- Interviews with and written statements from customers, facility managers, building engineers or others with firsthand knowledge about operating practices at the affected site(s) identifying the baseline motor control strategy
- Interviews with and written statements from the project's mechanical contractor identifying the baseline motor control strategy

Appendix D: Motor and VFD Calculator

Appendix D: Motor and VFD Calculator was developed to automate the calculation of energy and demand impacts for retrofit VFD projects, based on a series of entries by the user defining key characteristics of the retrofit project. The "General Information" sheet is provided for the user to identify facility-specific details of the project that have an effect on the calculation of gross savings. Facility-specific details include contact information, electric utility, and facility type. The "VFD Inventory" sheet is the main worksheet that calculates energy savings and peak demand reduction for the user-specified motors and motor control improvements. This form follows the algorithms presented above and facilitates the calculation of gross savings for implementation and evaluation purposes. Each line item on this tab represents a single type of motor.

Custom Load Profiles

Default fan and pump load profiles as defined in Table 3-74 are included in the calculator, but users may also customize the load profile to reflect site specific conditions. Annual motor run hours may also be customized. For all projects, annual hours are subject to adjustment by EDC evaluators or SWE.

Metering

VFD projects achieving expected kWh savings of 250,000 kWh or higher must[131] be metered to calculate *ex ante* and/or *ex post* savings. Metering is not mandatory where hours can be easily verified through a building automation system schedule that clearly shows motor run time.

SOURCES

1) California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx. Accessed December 2018.
2) Phase II SWE team modeling, described in the 2015 Tentative Order Section E.3.c, http://www.puc.pa.gov/pcdocs/1311852.docx. Accessed December 2018.
3) Regional Technical Forum. *Proposed Standard Savings Estimation Protocol for Ultra-Premium Efficiency Motors.* November 5, 2012. Appendix C, Table 6.
4) California Municipal Utilities Association. *Savings Estimation Technical Reference Manual* 2016.
5) 2019 Illinois Statewide Technical Reference Manual for Energy Efficiency Version 7.0. Volume 2: Commercial and Industrial Measures. September 28, 2018. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_7/Final_9-28-18/IL-TRM_Effective_010119_v7.0_Vol_2_C_and_I_092818_Final.pdf

[131] The Commission allows the EDCs to use alternative methods for obtaining customer-specific data where customer processes do not support metering. The EDCs are required to provide supporting documentation to the SWE for review if there are any such exceptions.

3.3.3 ECM Circulating Fan

Target Sector	Commercial and Industrial Establishments
Measure Unit	ECM Circulating Fan
Measure Life	15 years Source 1
Measure Vintage	Early Replacement

This protocol covers energy and demand savings associated with retrofit of existing shaded-pole (SP) or permanent-split capacitor (PSC) circulator fan motors in an air handling unit with an electronically commutated motor (ECM).

Eligibility

This measure is targeted to non-residential customers whose air handling equipment currently uses a SP or PSC fan motor rather than an ECM. This measure applies only to circulating fan motors of 1 HP or less. Motors larger than 1 HP are governed by NEMA standards and would see little to no efficiency benefit by adding an ECM. Additionally, new construction and replace-on-burnout vintages are not eligible to participate, as ECM technology is required in new equipment by federal efficiency standards.Source 2

The targeted fan can supply heating or cooling only, or both heating and cooling. A default savings option is offered if motor input wattage is not known. However, these parameters should be collected by EDCs for greatest accuracy. Acceptable baseline conditions are an existing circulating fan with a SP or PSC fan motor 1 HP or less. Efficient conditions are a circulating fan with an ECM.

Algorithms

The energy and demand savings associated with this measure depend on the wattage of the baseline and efficient motor. Unknown motor wattages can be estimated using the motor efficiency values listed in Table 3-78. Savings are calculated using the following algorithms:

$$\Delta kWh = \Delta kWh_{heat} + \Delta kWh_{cool}$$

$$\Delta kW_{peak} = \Delta kW_{cool}$$

Heating

$$\Delta kWh_{heat} = \frac{(WATTS_{base} - WATTS_{ee})}{1{,}000} \times LF \times EFLH_{heat}$$

$$\Delta kW_{heat} = 0$$

Commented [SA45]: Franklin Energy

Would this also apply to exhaust fans?

Commented [SA46]: Franklin Energy

Where the AHU provides outside air or exhaust the hours may be building operational hours or where continuous operation is required for filtration (hospital fan coil units in occupied patients' rooms where required by code for example) the hours may be 8760 x nominal occupancy rate.

Reference for Clean Air Ventilation hours Table 2-7: Commercial Fan Energy Consumption for Selected Applications https://www.energy.gov/sites/prod/files/2015/10/f27/bto_pumpfan_report_oct2015.pdf

Exhaust fans hours are also provided in the above link.

Cooling

Interactive factors should be applied for motors that supply cooling to account for the reduced cooling load associated with the lower wattage ECM motor. Interactive factors do not apply if the motor is located outside of the conditioned air pathway.

$$\Delta kWh_{cool} = \frac{(WATTS_{base} - WATTS_{ee})}{1{,}000} \times LF \times EFLH_{cool} \times (1 + IF_{kWh})$$

$$\Delta kW_{cool} = \frac{(WATTS_{base} - WATTS_{ee})}{1{,}000} \times LF \times CF \times (1 + IF_{kW})$$

Motor Wattage

Motor wattage may be estimated if unknown using this algorithm.

$$WATTS = \frac{0.746 \times HP}{\eta_{motor}}$$

Commented [SA47]: Franklin Energy

Where the AHU provides outside air or exhaust the hours may be building operational hours or where continuous operation is required for filtration (hospital fan coil units in occupied patients' rooms where required by code for example) the hours may be 8760 x nominal occupancy rate.

Reference for Clean Air Ventilation hours Table 2-7: Commercial Fan Energy Consumption for Selected Applications https://www.energy.gov/sites/prod/files/2015/10/f27/bto_pumpfan_report_oct2015.pdf

Exhaust fans hours are also provided in the above link.

Definition of Terms

Table 3-77: Terms, Values, and References for ECM Circulating Fans

Term	Unit	Values	Source
$WATTS_{base}$, Baseline watts	W	Nameplate data	EDC Data Gathering
$WATTS_{ee}$, Energy efficient watts	W	Nameplate data	EDC Data Gathering
LF, Load factor	*None*	Default: 0.9	3
$EFLH_{heat}$, Equivalent Full-Load Hours for heating only	$\frac{Hours}{year}$	Based on logging, panel data, or modeling	EDC Data Gathering
		Default: Table 3-30	4
$EFLH_{cool}$, Equivalent Full-Load Hours for cooling only	$\frac{Hours}{year}$	Based on logging, panel data, or modeling	EDC Data Gathering
		Default: Table 3-28	4
CF, Coincidence Factor	*Decimal*	Based on logging, panel data, or modeling	EDC Data Gathering
		Default: Table 3-29	4
IF_{kWh}, Energy Interactive Factor	*None*	Default: 26.2%	5
IF_{kW}, Demand Interactive Factor	*None*	Default: 30%	6
HP, Rated horsepower of the motor	*HP*	Nameplate	EDC Data Gathering
η_{motor}, Default motor efficiency for motor type.	*Percent*	Default: Table 3-78	7

0.746, Conversion factor for HP to kWh	*kWh/HP*	0.746	Conversion factor

Table 3-78: Default Motor Efficiency by Motor Type

Motor Type	Assumed Efficiency
SP	0.40
PSC	0.50
ECM	0.70

Default Savings

Default savings may be claimed using the algorithms above and the variable defaults. EDCs may also claim savings using customer specific data.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx. Accessed December 2018.

2) Federal standards: U.S. Department of Energy, Federal Register. 164th ed. Vol. 79, July 3, 2014. https://www.govinfo.gov/content/pkg/FR-2014-07-03/pdf/FR-2014-07-03.pdf

3) New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs – Residential Multi-Family, and Commercial/Industrial Measures. Version 6. April 16, 2018.

4) Phase II SWE team modeling, described in the 2015 Tentative Order Section E.3.c, http://www.puc.pa.gov/pcdocs/1311852.docx. Accessed December 2018.

5) Assuming that the waste heat is within the conditioned air stream, then the energy associated with removing the waste heat during the year is approximated as the inverse of the COP, or 3.412/SEER = 0.30 if one uses 13 as a default value for cooling system SEER.

6) Assuming that the waste heat is within the conditioned air stream, then the energy associated with removing the waste heat during peak times is approximated as the inverse of the COP, or 3.412/EER = 0.30 if one uses 11.3 as a default value for cooling system EER.

7) DOE Building Technologies Office. *Energy Savings Potential and Opportunities for High-Efficiency Electric Motors in Residential and Commercial Equipment.* https://www.energy.gov/sites/prod/files/2014/02/f8/Motor%20Energy%20Savings%20Potential%20Report%202013-12-4.pdf. Accessed December 2018.

3.3.4 VSD on Kitchen Exhaust Fan

Target Sector	Commercial and Industrial Establishments
Measure Unit	VSD on Kitchen Exhaust Fan
Measure Life	15 years Source 1
Measure Vintage	Retrofit

Installation of variable speed drives (VSD) on commercial kitchen exhaust fans allows the variation of ventilation based on cooking load and/or time of day.

Eligibility

This measure is targeted to non-residential customers whose kitchen exhaust fans are equipped with a VSD that varies the exhaust rate of kitchen ventilation based on the energy and effluent output from the cooking appliances (i.e., the more heat and smoke/vapors generated, the more ventilation needed). This involves installing a temperature sensor in the hood exhaust collar and/or an optic sensor on the end of the hood that sense cooking conditions which allows the system to automatically vary the rate of exhaust to what is needed by adjusting the fan speed.
The baseline equipment is kitchen ventilation that has a constant speed ventilation motor.

The energy efficient condition is a kitchen ventilation system equipped with a VSD and demand ventilation controls and sensors.

Algorithms

Annual energy and demand savings values are based on monitoring results from five different types of sites, as summarized in the PG&E work paper.Source 2 The sites included an institutional cafeteria, a casual dining restaurant, a hotel kitchen, a supermarket kitchen, and a university dining facility. Units are based on savings per total exhaust fan rated horsepower. Savings values are applicable to new and retrofit units.

$$\Delta kWh = HP \times 4{,}423$$

$$\Delta kW_{peak} = HP \times 0.55$$

Definition of Terms

Table 3-79: Terms, Values, and References for VSD on Kitchen Exhaust Fans

Term	Unit	Values	Source
$4{,}423$, Annual energy savings per total exhaust fan horsepower	$\frac{kWh}{HP}$	4,423	2, 3
0.55, Coincident peak demand savings per total exhaust fan horsepower	$\frac{kW}{HP}$	0.55	2, 3
HP, Horsepower rating of the exhaust fan	*HP*	Nameplate data	EDC Data Gathering

Default Savings

Savings for this measure are partially deemed based on motor horsepower.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx. Accessed December 2018.
2) PGE Workpaper, Commercial Kitchen Demand Ventilation Controls, PGECOFST116. June 30, 2014
3) SDGE Workpaper, Work Paper WPSDGENRCC0019, Commercial Kitchen Demand Ventilation Controls, Revision 2. December 24, 2016.

3.3.5 ECM Circulator Pump

Target Sector	Commercial and Industrial Establishments
Measure Unit	Per Pump
Measure Life	15 years Source 1
Measure Vintage	Replace on Burnout, Early Replacement, Retrofit, New Construction

This protocol covers energy and demand savings associated with replacing single-speed induction motor circulator pumps with electronically commutated motor (ECM)—also called brushless permanent magnet (BPM) motor—circulator pumps. Circulator pumps are used to circulate water for space heating in residential and commercial buildings. Typical applications include baseboard and radiant floor heating systems that utilize a primary/secondary loop system in multifamily residences and small commercial buildings. Circulator pumps for domestic hot water applications are commonly used in multifamily and commercial buildings to shorten the amount of time it takes for hot water to reach the occupants on upper floors and those with long piping runs. These recirculator pumps can be operated continuously or be controlled by a timer or an aquastat, which turns on the pump only when the temperature of the return line falls below a certain set point.Source 1 Circulator pumps that use ECMs are more efficient because they lack brushes that add friction to the motor and have the ability to modulate their speed to match the load.

Commented [SA48]: Franklin Energy

Another application is Freeze Protection for HW coils. It these applications assume the pumps operate anytime the outside air is below freezing and the building is occupied. See attached pdf.

Eligibility

This measure targets non-residential customers who purchase and install an ECM or BPM circulator pump, replacing single-speed induction motor circulator pumps in space heating and hot water applications.

Algorithms

Algorithms are defined for heating circulation pumps and domestic hot water recirculation pumps separately. Both algorithms depend on the wattage of the ECM motor.

Heating Circulation Pumps

$$\Delta kWh = (Watts_{base} - Watts_{ee}) \times \frac{1kW}{1{,}000W} \times EFLH_{heat}$$

$$\Delta kW_{peak} = 0\ kW$$

$$Watts_{base} = Watts_{ee} \div SF$$

Commented [SA49]: Franklin Energy

We recommend adding Load Factor (LF) to be consistent with the approach of other pumping measures. This should only be added to the Wattsee. The value may need to be adjusted based upon if the values in reference were based upon metered data or name plate values.

DHW Recirculation Pumps

Some DHW recirculation pumps incorporate aquastat controls, so replacing the singe-speed motor may also result in a reduction in hours of use. The following algorithm allows for hours of use that differ between the baseline and energy efficient scenarios.

$$\Delta kWh = (Watts_{base} \times HOU_{DHW-base} - Watts_{ee} \times HOU_{DHW-ee}) \times \frac{1kW}{1{,}000W}$$

$$\Delta kW_{peak} = (Watts_{base} \times CF_{base} - Watts_{ee} \times CF_{ee}) \times \frac{1kW}{1{,}000W}$$

$$Watts_{base} = Watts_{ee} \div SF$$

Commented [SA50]: Franklin Energy

We recommend adding Load Factor (LF) to be consistent with the approach of other pumping measures. This should only be added to the Wattsee. The value may need to be adjusted based upon if the values in reference were based upon metered data or name plate values.

ECM Motor Wattage

ECM motor wattage may be estimated if unknown using this algorithm.

$$WATTS_{ee} = \frac{0.746 \times HP}{\eta_{ee}}$$

DEFINITION OF TERMS

Table 3-80: Terms, Values, and References for ECM Circulator Pumps

Term	Unit	Values	Source
$WATTS_{ee}$, Energy efficient watts	W	Nameplate data	EDC Data Gathering
$WATTS_{base}$, Baseline watts	W	Calculated	N/A
SF, Savings factor	None	18%	2
$EFLH_{heat}$, Equivalent Full-Load Hours for heating only	$\frac{Hours}{year}$	Based on logging, panel data, or modeling	EDC Data Gathering
		Default: Table 3-30	3
$HOU_{DHW-base}$, Average annual pump run hours for baseline DHW recirculating pump	$\frac{Hours}{year}$	Based on logging, panel data, or modeling	EDC Data Gathering
		For continuously running pump: 8,760 For timer or aquastat-controlled pumps: 2,190	4
HOU_{DHW-ee}, Average annual pump run hours for ECM DHW recirculating pump	$\frac{Hours}{year}$	Based on logging, panel data, or modeling	EDC Data Gathering
		For continuously running pump: 8,760 For timer or aquastat-controlled pumps: 2,190	4
CF_{base}, Coincidence factor for baseline DHW recirculating pump	$\frac{Hours}{year}$	Based on logging, panel data, or modeling	EDC Data Gathering
		For continuously running pump: 1.0 For timer or aquastat-controlled pumps: 0.25	4
CF_{ee}, Coincidence factor for ECM DHW recirculating pump	$\frac{Hours}{year}$	Based on logging, panel data, or modeling	EDC Data Gathering
		For continuously running pump: 1.0 For timer or aquastat-controlled pumps: 0.25	4
HP, Rated horsepower of the motor	HP	Nameplate	EDC Data Gathering
0.746, Conversion factor for HP to kWh	kWh/HP	0.746	Conversion factor
η_{ee}, Efficiency of ECM motor	Percent	85%	5

DEFAULT ENERGY SAVINGS

Default savings may be claimed using the algorithms above and the variable defaults. EDCs may also claim savings using customer specific data.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx. Accessed December 2018.
2) Cadmus. Impact Evaluation of the 2011–2012 ECM Circulator Pump Pilot Program. Table 2. Pump Spot Measurements. October 18, 2012.
3) Phase II SWE team modeling, described in the 2015 Tentative Order Section E.3.c, http://www.puc.pa.gov/pcdocs/1311852.docx. Accessed December 2018.
4) DHW Recirculation System Control Strategies. Final Report 99-1. Pg. 3-30. January 1999. Hours of use for pumps with an aquastat control in multifamily applications.
5) Average efficiency levels for ECM fans calculated using a market average for the product category.

3.3.6 High Efficiency Pumps

Target Sector	Commercial and Industrial Establishments, Agricultural
Measure Unit	Pump
Measure Life	13.3 years Source 1
Measure Vintage	Replace on Burnout, New Construction, or Early Replacement

Eligibility

All pumps manufactured after January 27, 2020 must comply with the DOE's energy conservation standard as described in 10 CFR 431 Subpart Y.[Source 2] This standard is applicable to the following cleanwater pump types:

- End Suction Closed Coupled (ESCC)
- End Suction Frame Mounted (ESFM)
- In-Line (IL)
- Radially Split Multi-Stage In-Line Diffuser Casing (RSV)
- Submersible Turbine (ST)

This measure does not apply to dedicated-purpose pool pumps. Savings for dedicated pool pumps should follow the guidance in Section 1.16 of this TRM. This standard requires that pumps tested for compliance with the standard and labeled with a Pump Energy Index (PEI). Compliant pumps will achieve a PEI of 1.0 or less. Pumps that achieve lower PEI values will save energy.

For conversions from constant speed to variable speed pumping, a constant speed PEI can only be used as the baseline in scenarios where variable pumping is not required according to energy codes adopted by the State of Pennsylvania. Default hours of use and coincidence factor values are provided for chilled water, heating water, and condenser water pumps only.

Commented [SA51]: Franklin Energy

This measure does not apply to circulator pumps either. Circulator pumps are to be covered under a separate pump standard.

Commented [SA52]: Franklin Energy

Variable Load PEI values cannot be used in constant load applications. PEI values must be for the same duty point, gpm and head.

Algorithms

The energy and demand savings for this measure depend on the size and efficiency of the motor driving the pump, as well as the pump PEI. Savings are calculated according to the following algorithms:

$$\Delta kWh = kWh_{base} - kWh_{ee}$$

$$kWh_{base} = 0.746 \times HP \times \frac{LF}{\eta} \times PEI_{base} \times RHRS$$

$$kWh_{ee} = 0.746 \times HP \times \frac{LF}{\eta} \times PEI_{ee} \times RHRS$$

$$\Delta kW_{peak} = kW_{base} - kW_{ee}$$

$$kW_{base} = 0.746 \times HP \times \frac{LF}{\eta} \times PEI_{base} \times CF$$

$$kW_{ee} = 0.746 \times HP \times \frac{LF}{\eta} \times PEI_{ee} \times CF$$

Commented [SA53]: Franklin Energy

Motor efficiency should only be considered when the rating is for a pump only.

Definition of Terms

Table 3-81: Terms, Values, and References for Premium Efficiency Motors

Term	Unit	Value	Source
HP, Rated horsepower of the baseline and energy efficient motor	*HP*	Nameplate	EDC Data Gathering
0.746, Conversion factor for HP to kWh	*kWh/HP*	0.746	Conversion factor
$RHRS$[132], Annual run hours of the motor	$\frac{Hours}{Year}$	Based on logging, panel data or modeling[133]	EDC Data Gathering
		Default: Table 3-69, Table 3-70, Table 3-72	3
LF, Load Factor. Ratio between the actual load and the rated load. Variable loaded motors should use custom measure protocols.	*None*	Based on spot metering and nameplate	EDC Data Gathering
		Default: 0.79 for pumps	4
η, Efficiency of the motor.	*None*	Nameplate	EDC Data Gathering
		Default: Table 3-66 and Table 3-67	5
PEI_{base}, Baseline pump energy index.	*None*	Default: Table 3-82	1
PEI_{ee}, Rated pump energy index of installed high efficiency pump or pumping package.	*None*	Nameplate	EDC Data Gathering
CF, Coincidence factor	*Decimal*	EDC Data Gathering	EDC Data Gathering
		Default: Table 3-69, Table 3-70, Table 3-72	3

[132] Default value can be used by EDC but it is subject to metering and adjustment by evaluators or SWE.
[133] Modeling is an acceptable substitute to metering and panel data if modeling is conducted using building- and equipment-specific information at the site and the facility consumption is calibrated using 12 months of billing data (pre-retrofit).

Table 3-82: Baseline Pump Energy Indicies

Pump Type	PEI_{base}	
	Constant Speed	Variable Speed
ESCC, 1800 RPM	1.00	0.49
ESCC, 3600 RPM	0.96	0.51
ESFM, 1800 RPM	0.98	0.49
ESFM, 3600 RPM	0.99	0.51
IL	0.99	0.50
RSV	0.98	0.50
ST	0.96	0.60

Default Energy Savings

There are no default savings for this measure.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) Regional Technical Forum. UES Measure – Efficient Pumps. Commercial/Industrial/Agricultural Pumps v1.1 Workbook. https://rtf.nwcouncil.org/measure/efficient-pumps. Accessed January 2019.
2) U.S. Department of Energy. 10 CFR Part 431. Energy Efficiency Program for Certain Commercial and Industrial Equipment: Subpart Y—Pumps.
3) Phase II SWE team modeling, described in the 2015 Tentative Order Section E.3.c, http://www.puc.pa.gov/pcdocs/1311852.docx. Accessed December 2018.
4) Regional Technical Forum. *Proposed Standard Savings Estimation Protocol for Ultra-Premium Efficiency Motors.* November 5, 2012. Appendix C, Table 6.
5) "Energy Conservation Program: Energy Conservation Standards for Commercial and Industrial Electric Motors; Final Rule," 79 Federal Register 103 (29 May 2014). https://www.gpo.gov/fdsys/pkg/FR-2014-05-29/html/2014-11201.htm

3.4 Domestic Hot Water

3.4.1 Heat Pump Water Heaters

Target Sector	Commercial and Industrial Establishments
Measure Unit	Heat Pump Water Heater
Measure Life	10 years Source 1
Measure Vintage	New Construction, Replace on Burnout, Early Retirement

Heat pump water heaters take heat from the surrounding air and transfer it to the water in the tank, unlike conventional electrical water heaters which use resistive heating coils to heat the water.

Eligibility

This protocol documents the energy savings attributed to heat pump water heaters with uniform energy factors meeting the minimum ENERGY STAR criteria.Source 2 However, uniform energy factors that exceed the ENERGY STAR minimums are accommodated with the partially deemed scheme. The measure described here involves the installation of a heat pump water heater instead of a code minimum electric water heater. It is important to note that federal standards require efficiency levels only achievable by heat pump water heaters at certain tank sizes. Therefore, the baseline condition is effectively an electric resistance water heater at smaller tank sizes and code minimum heat pump water heater for larger tank sizes. It does not cover systems where the heat pump is a pre-heater or is combined with other water heating sources. More complicated installations can be treated as custom projects.

Mid-Stream Domestic Hot Water Overview

Commercial Heat Pump Water Heaters for Midstream Delivery Programs will offer incentives on eligible products sold to trade allies and customers through commercial sales channels such as distributors of heat pump water heating products. This complements other delivery channels (such as downstream rebates to trade allies and customers) by providing incentives to encourage distributors to stock, promote, and sell more-efficient systems. In a Midstream Delivery program, less information is available about the business and installation setting so additional default values are required to calculate energy and peak demand savings.

Algorithms

The energy savings calculation compares performance ratings for heat pump and code minimum water heaters and uses typical hot water usages. The energy savings are obtained through the following formula:

$$\Delta kWh = \frac{\left\{\left(\frac{1}{UEF_{base}} - \left(\frac{1}{UEF_{proposed}} \times \frac{1}{F_{adjust}}\right)\right) \times GPY \times 8.3\ \frac{lb}{gal} \times 1.0\ \frac{Btu}{lb \cdot {}^{\circ}F} \times (T_{hot} - T_{cold})\right\}}{3{,}412\ \frac{Btu}{kWh}}$$

The demand reduction is taken as the annual energy savings multiplied by the ratio of the average energy usage between 2PM and 6PM on summer weekdays to the total annual energy usage (ETDF), and discounted by the resistive discount factor.

$$\Delta kW_{peak} = ETDF \times Energy\ Savings$$

The Energy to Demand Factor uses hourly load data for specific types of buildings to create loadshapes.[Source 3] Pennsylvania's summer peak is defined as non-holiday weekdays from 2PM to 6PM for June, July, and August. From those load shapes, the ETDF is calculated as follows and provided in Table 3-83:

$$ETDF = \frac{Average\ Usage_{Summer\ WD\ 2\text{-}6\ PM}}{Annual\ Energy\ Usage}$$

Gallons Per Year per square foot estimates are provided in Table 3-83. Multiplying GPY per square foot for the appropriate building type times the square footage of the area served by the water heater will provide the needed GPY.

$$GPY = GPY\ per\ Square\ Foot \times Square\ Footage\ Served$$

Table 3-83: Typical water heating Gallons per Year and Energy to Demand Factors

Commercial Prototype Building	GPY per Square Foot	ETDF
Education - Other	3.81	0.0002545
Health - Hospital	4.97	0.0002011
Health - Other	3.09	0.0003020
Institutional/Public Service	5.90	---
Lodging	17.33	0.0001210
Miscellaneous/Other	2.04	0.0002590
Office	1.33	0.0002490
Restaurant	94.04	0.0001525
Retail	0.80	0.0002560
Warehouse - Refrigerated	0.22	0.0003018

Heat Pump COP Adjustment Factor

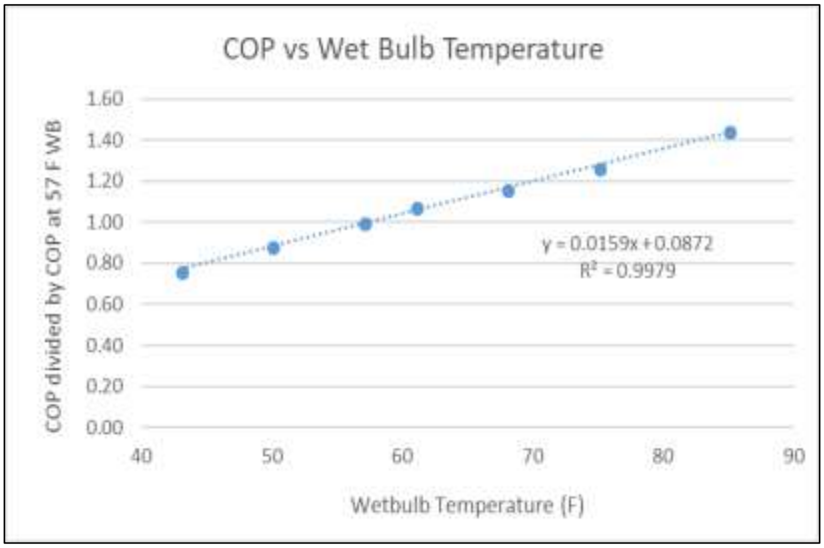
Heat pump performance is temperature and humidity dependent. The Uniform Energy Factors are determined from a DOE testing procedure that is carried out at 57°F wet bulb temperature. However, the average outdoor wet bulb temperature in PA is closer to 43°F [Source 4], while the average wet bulb temperature in conditioned spaces typically ranges from 50°F to 80°F.

Figure 3-1 below shows relative coefficient of performance (COP) compared to the COP at rated conditions.[Source 5] According to the plotted profile, the following adjustments provided in Table 3-84 are recommended. For midstream delivery programs, the heat pump water heater placement location will be unknown. The Pennsylvania 2018 baseline study did not report on water heater installation location, and a wider investigation did not reveal any other research with this detailed breakdown of data. Due to the lack of information, the midstream delivery program will use a COP Adjustment Factor value of 1.0 (e.g., no adjustment).

Table 3-84: COP Adjustment Factors, F_{adjust}

Heat Pump Placement	Typical WB Temperature °F	COP Adjustment Factor (F_{adjust})
Unconditioned Space	43	0.77
Conditioned Space	68	1.16
Kitchen	85	1.45
Unknown (Midstream Delivery)	57	1.00

Figure 3-1: Dependence of COP on Outdoor Wet Bulb Temperature



Definition of Terms

Table 3-85: Terms, Values, and References for Heat Pump Water Heaters

Term	Unit	Values	Source
UEF_{base}, Uniform Energy Factor of baseline water heater	*None*	See Table 3-86	6
$UEF_{proposed}$, Uniform Energy Factor of proposed efficient water heater	*None*	Default: ≤ 55 Gallons: 2.0 > 55 Gallons: 2.2	2
		Nameplate	EDC Data Gathering
T_{hot}, Temperature of hot water	*°F*	119	9
T_{cold}, Temperature of cold water supply	*°F*	52	8
$ETDF$, Energy to Demand Factor	None	Default: Table 3-83	3
F_{adjust}, COP Adjustment factor	*None*	Default: Table 3-84	5, 10
SF, Square footage	ft^2	Default Unknown/Midstream: 4,000	7
		EDC Data Gathering	EDC Data Gathering
GPY, Average annual gallons per year	*Gallons*	Default: Table 3-83	Calculation
		EDC Data Gathering	EDC Data Gathering

Uniform Energy Factors Based on Storage Volume

For water heaters delivered through midstream channels, the storage volume of the baseline system will be assumed to be the same as that of the proposed system. The storage volume can be determined from the manufacturer and model number of the incented heat pump water heater.

The current Federal Standards for electric water heater Uniform Energy Factors vary based on draw pattern. This standard, which went into effect at the end of 2016, replaces the old federal standard equal to 0.96 – (0.0003*Rated Storage in Gallons) for tanks equal to or smaller than 55 gallons and 2.057 – (0.00113*Rated Storage) for tanks larger than 55 gallons. The following table shows the Uniform Energy Factors for various storage volumes. Formulas provided assume a medium draw pattern.

Table 3-86: Minimum Baseline Uniform Energy Factor Based on Storage Volume

Rated Storage Volume	Uniform Energy Factor
≥ 20 gal and ≤ 55 gal	0.9307 − (0.0002 × Vr)
> 55 gal and ≤ 120 gal	2.1171 − (0.0011 × Vr)

Default Savings

The default savings presented below represent the installation of heat pump electric water heaters in the case that the business type, square footage, and location are unknown, and the Uniform Energy Factor is the Energy Star minimum. For ≤ 55 gallons, default savings assume a 40-gallon tank. For > 55 gallons, default savings assume an 80-gallon tank. Remaining default values used in this calculation can be found in Table 3-85.

Table 3-87: Default Energy Savings

Location Installed	Storage Volume (gallons)	ΔkWh
Unknown (Midstream Delivery)	≤ 55	776.4
	> 55	50.9

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx. Accessed November 13, 2018
2) ENERGY STAR Product Specifications for Residential Water Heaters Version 3.2. Effective April 16, 2015. https://www.energystar.gov/sites/default/files/Water%20Heaters%20Final%20Version%203.2_Program%20Requirements_0.pdf
3) GPY per square foot is found in the Technical Support Document: Energy Efficiency Program For Consumer Products And Commercial And Industrial Equipment: Commercial Water Heating Equipment. Table 7.3.1, p.186. ETDF values are calculated from load data provided in Appendix 7B, p. 230. April 18, 2016
4) SWE analysis of TMY3 data for PA weather stations.
5) The performance curve is developed using the NREL's Heat Pump Water Heater Technology Assessment Based on Laboratory Research and Energy Simulation Models'. Methodology can be seen: https://www.nrel.gov/docs/fy12osti/51433.pdf. Values are more easily viewed: https://www.nrel.gov/docs/fy14osti/52635.pdf The performance curve is developed using the NREL's The COP adjustment values are an average of COP adjustment for Unit A, B, D, and E, where values are taken from the average tank temperature at 57 degrees F.
6) U.S. Federal Standards for Residential Water Heaters. Current as of November 23, 2018. https://www.ecfr.gov/cgi-bin/text-idx?SID=80dfa785ea350ebeee184bb0ae03e7f0&mc=true&node=se10.3.430_132&rgn=div8
7) 2018 Pennsylvania Non-Residential End Use & Saturation Study.

8) Natural Resources Conservation Service. October 6, 2018. https://wcc.sc.egov.usda.gov/nwcc/rgrpt?report=daily_scan_por&state=PA

9) 2014 End Use & Saturation Study. April 4, 2014. http://www.puc.pa.gov/Electric/pdf/Act129/SWE-2014_PA_Statewide_Act129_Non-Residential_EndUse_Saturation_Study.pdf

10) Assuming a 45% relative humidity, atmospheric pressure at the sea level value of 29.9 inHg, and the ground temperature calculation of 52 degrees F (Source 8), unconditioned wet bulb temperature is estimated to be 43 degrees F.

3.4.2 Low Flow Pre-Rinse Sprayers for Retrofit Programs and Time of Sale Programs

Target Sector	Commercial and Industrial Establishments
Measure Unit	Pre-Rinse Sprayer
Measure Life	8 years Source 1
Measure Vintage	Retrofit, Early Replacement, or Replace on Burnout

Eligibility

This protocol documents the energy savings and demand reductions attributed to efficient low flow pre-rinse sprayers in grocery and food service applications including fast food restaurants, full service restaurants, and other. The most likely areas of application are kitchens in restaurants and hotels. Only premises with electric water heating may qualify for this incentive. In addition, the replacement pre-rinse spray nozzle must use less than 1.6 gallons per minute with a cleanability performance of 26 seconds per plate or less.[Source 2] Low flow pre-rinse sprayers reduce hot water usage and save energy associated with water heating.

The baseline for the Retrofit/Early Replacement vintage is assumed to be a 2.25 GPM and 2.15 GPM for food service and grocery applications respectively.[Source 3] The baseline for the Replace on Burnout (Time of Sale) vintage is assumed to be 1.6 GPM.[Source 2]

Algorithms

The energy savings and demand reduction are calculated through the protocols documented below.

$$\Delta kWh = \frac{\left((\mathrm{F_{base}} \times U_{base}) - (F_{ee} \times U_{ee})\right) \times 365\,\frac{days}{yr} \times 8.3\,\frac{lbs}{gal} \times 1\,\frac{Btu}{lb \cdot {}^{\circ}\mathrm{F}} \times (T_h - T_c)}{UEF \times 3{,}412\,\frac{Btu}{kWh}}$$

The demand reduction is taken as the annual energy savings multiplied by the ratio of the average energy usage between 2PM and 6PM on summer weekdays to the total annual energy usage.

$$\Delta kW_{peak} = ETDF \times Energy\ Savings$$

The Energy to Demand Factor uses hourly load data for specific types of buildings to create loadshapes.[Source 4] Pennsylvania's summer peak is defined as non-holiday weekdays from 2PM to 6PM for June, July, and August. From those load shapes, the ETDF is calculated as follows and provided in Table 3-88:

$$ETDF = \frac{Average\ Usage_{Summer\ WD\ 2-6\ PM}}{Annual\ Energy\ Usage}$$

Table 3-88: Typical Energy to Demand Factors

Commercial Prototype Building	ETDF
Quick-service Restaurant	0.000186
Full-service Restaurant	0.0001189
Standalone Retail (Grocery)	0.000237
Default - Unknown	0.000259

DEFINITION OF TERMS

The parameters in the above equation are listed in Table 3-89 below.

Table 3-89: Terms, Values, and References for Low Flow Pre-Rinse Sprayers

Term	Unit	Values	Source
F_{base}, Baseline flow rate of sprayer	GPM	EDC Data Gathering	EDC Data Gathering
		Default: Table 3-90	2, 3
F_{ee}, Post measure flow rate of sprayer	GPM	EDC Data Gathering	EDC Data Gathering
		Default: Table 3-90	2, 3
U_{base}, Baseline water usage duration	$\frac{min}{day}$	EDC Data Gathering	EDC Data Gathering
		Default: Table 3-90	5
U_{ee}, Post measure water usage duration	$\frac{min}{day}$	EDC Data Gathering	EDC Data Gathering
		Default: Table 3-90	5
T_h, Temperature of hot water	$°F$	Default: 127.5	6
T_c, Incoming cold water temperature	$°F$	52	9
$UEF_{electric}$, Uniform energy factor of existing electric water heater system	None	EDC Data Gathering	EDC Data Gathering
		0.9	7
ETDF, Energy to demand factor	None	Default: Table 3-83	4
Days per year pre-rinse spray valve is used at the site	Days	365	3
Specific mass in pounds of one gallon of water	$\frac{lb}{gal}$	8.3	8
Specific heat of water	$\frac{Btu}{lb * °F}$	1.0	8
Btu per kWh	$\frac{\text{Btu}}{\text{kWh}}$	3,412	Conversion Factor

Commented [SA54]: Franklin Energy

This value seems low for efficiency of electric water heater. IL TRM uses a 97% efficiency factor based on IECC 2012/2015 performance requirement for electric resistance water heaters.

Commented [SA55]: Franklin Energy

We would expect some reduction from holidays and facilities not open for 7 days per week. IL TRM uses a 6 days per week and corresponding 312 days/year for this value.

Table 3-90: Flow Rate and Usage Duration by Program

Program: Application	Flow Rate (GPM)		Usage Duration (min/day)	
	F_{base}	F_{ee}	U_{base}	U_{ee}
Retrofit: Food service applications	2.25	1.12	32.4	43.8
Retrofit: Grocery	2.15	1.12	4.8	6
Time of Sale: Limited Service (Fast Food) Restaurant	1.6	1.12	32.4	43.8
Time of Sale: Full Service Restaurant	1.6	1.12	32.4	43.8
Time of Sale: Other	1.6	1.12	26.4	36

Commented [SA56]: Franklin Energy

This column is showing a usage increase with the installation of energy efficiency PRSV. It appears that this is sourced from reference #5. Our understanding has been that more efficient spray valves should use less water with the same amount of time required in pre- and post- installation. Are there more studies that support this? (IL TRM shows the same hours per day of usage between base case and energy efficient case; source used is PG&E savings estimates, algorithms, sources (2005), Food Service Pre-Rinse Spray Valves with review of 2010 Ohio Technical Reference Manual and Act on Energy Business Program Technical Resource Manual Rev05.)

DEFAULT SAVINGS

For retrofit programs, the default savings for the installation of a low flow pre-rinse sprayer compared to a standard efficiency sprayer is 268 kWh/year for pre-rinse sprayers installed in grocery stores and 1,776 kWh/year for pre-rinse sprayers installed in food service building types such as restaurants. The deemed demand reductions for the installation of a low flow pre-rinse sprayer compared to a standard efficiency sprayer is 0.06 kW for pre-rinse sprayers installed in grocery stores and 0.27 kW for pre-rinse sprayers installed in food service building types such as restaurants.

The default savings for the installation of a low flow pre-rinse sprayer compared to a standard efficiency sprayer for all Pre-Rinse Sprayer programs are listed in Table 3-91. The chosen ETDF values for the default demand savings depend on the application. Specifically, Retrofit: Groceries and Time of Sale: Other use the Default: Unknown ETDF estimate; Time of Sale: Full Service and Limited Service use their respective ETDF values; and Retrofit Food Service uses an average of the Full and Quick service ETDF values.

Table 3-91: Low Flow Pre-Rinse Sprayer Default Savings

Application	ΔkWh	ΔkW_{peak}
Retrofit: Food Service	1,776	0.27
Retrofit: Groceries	268	0.06
Time of Sale: Limited Service (Fast Food) Restaurant	207	0.04
Time of Sale: Full Service Restaurant	207	0.02
Time of Sale: Other	143	0.04

EVALUATION PROTOCOL

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) Impact Evaluation of Massachusetts Prescriptive Gas Pre-Rinse Spray Valve Measure, DNV-GL, 2014. http://ma-eeac.org/wordpress/wp-content/uploads/Prescriptive-Gas-Pre-Rinse-Spray-Valve-Measure-Impact-Evaluation.pdf

2) The Energy Policy Act (EPAct) of 2005 sets the maximum flow rate for pre-rinse spray valves at 1.6 GPM at 60 pounds per square inch of water pressure when tested in accordance with ASTM F2324-03. This performance standard went into effect January 1, 2006. http://www.psc.state.ga.us/electric/federal/EPA/EPA2005.pdf

3) *Impact and Process Evaluation Final Report for California Urban Water Conservation Council 2004-5 Pre-Rinse Spray Valve Installation Program (Phase 2),* SBW Consulting, 2007, Table 3-4, p. 23. http://www.allianceforwaterefficiency.org/WorkArea/DownloadAsset.aspx?id=976

4) Technical Support Document: Energy Efficiency Program For Consumer Products And Commercial And Industrial Equipment: Commercial Water Heating Equipment. ETDF values are calculated from load data provided in Appendix 7B, p. 230. April 18, 2016

5) *Impact and Process Evaluation Final Report for California Urban Water Conservation Council 2004-5 Pre-Rinse Spray Valve Installation Program (Phase 2),* SBW Consulting, 2007, Table 3-6, p. 24. http://www.allianceforwaterefficiency.org/WorkArea/DownloadAsset.aspx?id=976

6) *Impact and Process Evaluation Final Report for California Urban Water Conservation Council 2004-5 Pre-Rinse Spray Valve Installation Program (Phase 2),* SBW Consulting, 2007, Table 3-5, p. 23. http://www.allianceforwaterefficiency.org/WorkArea/DownloadAsset.aspx?id=976

7) 2018 Pennsylvania Non-Residential End Use & Saturation Study.

8) The Engineering ToolBox. "Water-Thermal Properties." http://www.engineeringtoolbox.com/water-thermal-properties-d_162.html

9) Natural Resources Conservation Service. October 6, 2018. https://wcc.sc.egov.usda.gov/nwcc/rgrpt?report=daily_scan_por&state=PA

10) Hours based on PG&E savings estimates, algorithms, sources (2005), Food Service Pre-Rinse Spray Valves with review of 2010 Ohio Technical Reference Manual and Act on Energy Business Program Technical Resource Manual Rev05. http://s3.amazonaws.com/zanran_storage/amppartners.org/ContentPages/2464316647.pdf

3.4.3 Fuel Switching: Electric Resistance Water Heaters to Gas/Propane

Target Sector	Commercial and Industrial Establishments
Measure Unit	Water Heater
Measure Life	Tankless: 20 years ≤ 75,000 Btu/h: 11 years >75,000 Btu/h: 15 years Source 1
Measure Vintage	Early Replacement or Replace on Burnout

Eligibility

Natural gas and propane water heaters generally offer the customer lower costs compared to standard electric water heaters. Additionally, they typically see an overall energy savings when looking at the source energy of the electric unit versus the fossil fuel unit.

This protocol documents the energy savings attributed to converting from a standard electric tank water heater to an ENERGY STAR natural gas water heater. If a customer submits a rebate for a product that has applied for ENERGY STAR Certification but has not yet been certified, the savings will be counted for that product contingent upon its eventual certification as an ENERGY STAR measure. If at any point the product is rejected by ENERGY STAR, the product is then ineligible for the program and savings will not be counted.

Algorithms

The energy savings calculation utilizes average performance data for available small commercial standard electric and natural gas water heaters and typical water usage. Because there is little electric energy associated with a natural gas or propane water heater, the energy savings are the full energy utilization of the electric water heater. The energy savings are obtained through the following formula:

$$\Delta kWh = \frac{\left\{\left(\frac{1}{UEF_{base}}\right) \times GPY \times 8.3\frac{lb}{gal} \times 1\frac{Btu}{lb \cdot {}^{\circ}F} \times (T_{hot} - T_{cold})\right\}}{3{,}412\frac{Btu}{kWh}}$$

Although there is a significant electric savings, there is an associated increase in fossil fuel energy consumption. While this fossil fuel consumption does not count against PA Act 129 energy savings, it is expected to be used in the program TRC test. The increased fossil fuel usage is obtained through the following formula:

$$Fuel\ Consumption\ (MMBtu) = \frac{\left\{\left(\frac{1}{UEF_{fuel,inst}}\right) \times GPY \times 1\frac{Btu}{lb \cdot {}^{\circ}F} \times 8.3\frac{lb}{gal} \times (T_{hot} - T_{cold})\right\}}{1{,}000{,}000\ \frac{Btu}{MMBtu}}$$

Where UEF_{fuel} changes depending on the fossil fuel used by the water heater.

For resistive water heaters, the demand reduction is taken as the annual energy savings multiplied by the ratio of the average energy usage between 2PM and 6PM on summer weekdays to the total annual energy usage.

$$\Delta kW_{peak} = ETDF \times Energy\ Savings$$

The Energy to Demand Factor uses hourly load data for specific types of buildings to create loadshapes.Source 2 Pennsylvania's summer peak is defined as non-holiday weekdays from 2PM to 6PM for June, July, and August. From those load shapes, the ETDF is calculated as follows and provided in Table 3-83:

$$ETDF = \frac{Average\ Usage_{summer\ WD\ 2-6PM}}{Annual\ Energy\ Usage}$$

Gallons Per Year per square foot estimates are provided in Table 3-83. Multiplying GPY per square foot for the appropriate building type times the square footage of the area served by the water heater will provide the needed GPY.

$$\text{GPY} = GPY\ per\ Square\ Foot \times Square\ Footage\ Served$$

DEFINITION OF TERMS

The parameters in the above equations are listed in Table 3-92.

Table 3-92: Terms, Values, and References for Commercial Water Heater Fuel Switching

Term	Unit	Values	Source
UEF_{base}, Uniform energy factor of baseline electric water heater	*None*	Default: 0.9	3
		Nameplate	EDC Data Gathering
UEF_{fuel}, Uniform energy factor of installed natural gas water heater	*None*	Default: Table 3-93	4, 5
		Nameplate	EDC Data Gathering
SF, Square Footage	ft^2	Default: 4,000	3
		EDC Data Gathering	EDC Data Gathering
GPY, Average annual gallons per year	*Gallons*	Default: Table 3-83	2
		EDC Data Gathering	EDC Data Gathering
T_{hot}, Temperature of hot water	*°F*	119	6
T_{cold}, Temperature of cold water supply	*°F*	52	7
ETDF, Energy To Demand Factor	*None*	Default: Table 3-83	2

Table 3-93: Minimum Baseline Uniform Energy Factor for Gas Water Heaters

	Rated Storage Volume or Type	Uniform Energy Factor
≤ 75,000 Btu/h	≤ 55 gal	≥ 0.67
	> 55 gal	≥ 0.77
	Tankless	≥ 0.90
> 75,000 Btu/h	Storage or Tankless	≥ 0.94

DEFAULT SAVINGS

The default savings for the replacement of an electric water heater with a fossil fuel unit in various applications are listed below. For the default savings, the algorithm uses default values provided in Table 3-92 for baseline UEF and Typical Square Feet, and Gallons per Year per Square Foot from Table 3-83.

Table 3-94: Water Heating Fuel Switch Energy Savings Algorithms

Building Type	ΔkWh	Fuel Consumption (MMBtu)
Unknown (Midstream Delivery)	1,475.1	$4.53 * \left(\frac{1}{UEF_{fuel,inst}}\right)$

EVALUATION PROTOCOLS

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

SOURCES

1) California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx. Accessed November 13, 2018

2) GPY per square foot is found in the Technical Support Document: Energy Efficiency Program For Consumer Products And Commercial And Industrial Equipment: Commercial Water Heating Equipment. Table 7.3.1, p.186. ETDF values are calculated from load data provided in Appendix 7B, p. 230. April 18, 2016

3) 2018 Pennsylvania Non-Residential End Use & Saturation Study.

4) ENERGY STAR Program Requirements Produce Specification for Commercial Water Heaters Version 2.0. https://www.energystar.gov/sites/default/files/Program%20Requirements_Commercial%20Water%20Heaters_Final%20Version%202.0_12%2029%2017.pdf

5) Commission Order page 30 of the 2016 TRC Test Final Order requires fuel switching to ENERGY STAR measures, not standard efficiency measures. The Uniform Energy Factor

has therefore been updated to reflect the Energy Star standard for natural gas or propane storage water heaters. ENERGY STAR Product Specification for Residential Water Heaters Version 3.2. https://www.energystar.gov/sites/default/files/Water%20Heaters%20Final%20Version%203.2_Program%20Requirements_0.pdf

6) 2014 SWE Residential Baseline Study. http://www.puc.pa.gov/Electric/pdf/Act129/SWE-2014_PA_Statewide_Act129_Residential_Baseline_Study.pdf

7) Natural Resources Conservation Service. October 6, 2018. https://wcc.sc.egov.usda.gov/nwcc/rgrpt?report=daily_scan_por&state=PA

3.5 Refrigeration

3.5.1 ENERGY STAR Refrigeration/Freezer Cases

Target Sector	Commercial and Industrial Establishments
Measure Unit	Refrigeration/Freezer Case
Measure Life	12 years Source 1
Measure Vintage	Replace on Burnout

Eligibility

This protocol estimates savings for installing high efficiency refrigeration and freezer cases that exceed ENERGY STAR efficiency standards. Eligible refrigerators and freezers are self-contained with vertical-closed transparent or solid doors. The measurement of energy and demand savings is based on algorithms with volume as the key variable.

Algorithms

Annual energy savings and peak demand savings calculations are shown below.

$$\Delta kWh = (kWh_{base} - kWh_{ee}) \times \frac{days}{year}$$

$$\Delta kW_{peak} = \frac{(kWh_{base} - kWh_{ee})}{24}$$

Definition of Terms

Table 3-95: Terms, Values, and References for High-Efficiency Refrigeration/Freezer Cases

Term	Unit	Values	Source
kWh_{base}, The unit energy consumption of a standard unit	$\frac{kWh}{day}$	See Table 3-96	2
kWh_{ee}, The unit energy consumption of the ENERGY STAR-qualified unit	$\frac{kWh}{day}$	See Table 3-96	3
V, Internal Volume	ft^3	EDC data gathering	EDC data gathering
$\frac{days}{year}$, days per year	$\frac{days}{year}$	EDC data gathering Default: 365	Conversion Factor

Table 3-96: Refrigeration & Freezer Case Efficiencies

Volume (ft^3)	Transparent Door $\frac{kWh_{ee}}{day}$	Transparent Door $\frac{kWh_{base}}{day}$	Solid Door $\frac{kWh_{ee}}{day}$	Solid Door $\frac{kWh_{base}}{day}$
Refrigerators				
V < 15	0.095*V + 0.445	0.10*V + 0.86	0.022*V + 0.97	0.05*V + 1.36
15 ≤ V < 30	0.05*V + 1.12		0.066*V + 0.31	
30 ≤ V < 50	0.076*V + 0.34		0.04*V + 1.09	
50 ≤ V	0.105*V – 1.111		0.024*V + 1.89	
Freezers				
V < 15	0.232*V + 2.36	0.29*V + 2.95	0.022*V + 0.97	0.22*V + 1.38
15 ≤ V < 30			0.066*V + 0.31	
30 ≤ V < 50			0.04*V + 1.09	
50 ≤ V			0.024*V + 1.89	

Commented [SA57]: Franklin Energy

The Solid Door Freezers are using Solid Door Refrigerator efficient kWh/Day. The ENERGY STAR V4.0 for freezers equations are below

Solid Door $\frac{kWh_{ee}}{day}$	Solid Door $\frac{kWh_{base}}{day}$
~~0.022~~0.21*V + 0.9~~7~~	0.22*V + 1.38
0.~~066~~12*V + ~~0.31~~2.248	
0.~~04~~285*V ~~+ 1.09~~ 2.703	
0.~~024~~142*V + ~~1.89~~4.445	

Default Savings

There are no default savings for this measure.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx. Accessed December 2018.

2) Energy Conservation Program: Energy Conservation Standards for Commercial Refrigeration Equipment. Final Rule. Table I.1. https://www.regulations.gov/document?D=EERE-2010-BT-STD-0003-0104

3) ENERGY STAR Program Requirements for Commercial Refrigerators and Freezers. Version 4.0 https://www.energystar.gov/sites/default/files/Commercial%20Refrigerators%20and%20Freezers%20V4%20Spec%20Final%20Version_0.pdf

3.5.2 High-Efficiency Evaporator Fan Motors for Walk-In or Reach-In Refrigerated Cases

Target Sector	Commercial and Industrial Establishments
Measure Unit	Evaporator Fan Motor
Measure Life	15 years Source 1
Measure Vintage	Early Replacement

Eligibility

This protocol covers energy and demand savings associated with the replacement of existing shaded-pole (SP) evaporator fan motors or Permanent Split Capacitor (PSC) motors in walk-in or reach-in refrigerated display cases with an Electronically Commutated motor (ECM) or a Permanent Magnet Synchronous (PMS) motor. The baseline condition assumes the evaporator fan motor is uncontrolled (i.e., it runs continuously). This measure is not applicable for new construction or replace on burnout projects. Savings are calculated per motor replaced.

There are two sources of energy and demand savings through this measure:

1) The direct savings associated with replacement of an inefficient motor with a more efficient one;
2) The indirect savings of a reduced cooling load on the refrigeration unit due to less heat gain from the more efficient evaporator fan motor in the air-stream.

Algorithms

The algorithms below are adapted from the Commercial Refrigeration Loadshape Project, a research effort from NEEP, Cadmus, and the Demand Management Institute.Source 2 The report notes that savings show minimal variation with the time of day or day type, thus peak demand savings are simply annual energy savings divided by 8,760.

$$\Delta kWh = (kW_{base} - kW_{ee}) * \%ON_{Uncontrolled} * 8{,}760 * WHF_e$$

$$kW_{base} = HP_{base} * 0.746/\eta_{base}$$

$$kW_{ee} = HP_{ee} * 0.746/\eta_{ee}$$

$$\Delta kW_{peak} = \frac{\Delta kWh}{8{,}760}$$

Definition of Terms

Table 3-97: Terms, Values, and References for High-Efficiency Evaporator Fan Motors

Term	Unit	Values	Source
kW_{base}, Input wattage of the baseline motor	kW	Nameplate	EDC Data Gathering
		Calculated value	Calculated value
kW_{ee}, Input wattage of the efficient motor	kW	Nameplate	EDC Data Gathering
		Calculated value	Calculated value
$\%ON_{Uncontrolled}$, Effective runtime of the motor without controls	None	EDC Data Gathering	EDC Data Gathering
		Default: 97.8%	2
8,760, Operating hours per year	$Hours$	8,760	Conversion factor
WHF_e, Waste heat factor for energy; represents the increased savings due to reduced waste heat from motors that must be rejected by the refrigeration equipment	None	SP Base, Cooler: 1.38 PSC Base, Cooler: 1.19 SP Base, Freezer 1.76 PSC Base, Freezer: 1.38	3
HP_{base}, Rated horsepower of the baseline motor	HP	Nameplate	EDC Data Gathering
HP_{ee}, Rated horsepower of the efficient motor	HP	Nameplate	EDC Data Gathering
η_{base}, Motor efficiency of the baseline motor	None	Default for SP: 30% Default for PSC: 60%	4
η_{ee}, Motor efficiency of the efficient motor	None	Default for ECM: 70% Default for PMS: 73%	4, 5
0.746, Conversion factor	kW/HP	0.746	Conversion factor

Commented [SA58]: Franklin Energy

The source information seems high. Evaporator fans will not run when the evaporator is in defrost mode, otherwise it would be increasing the temperature of the space.

Default Savings

There are no default savings for this measure.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx. Accessed December 2018.
2) Commercial Refrigeration Loadshape Project, Northeast Energy Efficiency Partnerships, October 2015. https://neep.org/commercial-refrigeration-loadshape-report-10-2015-0. Average wattage per rated horsepower (0.758 kW/HP) is based on an average of 66 ECMs. This represents a conservative estimate for PMS motors, as they are slightly more efficient than ECMs.
3) In cases where the baseline is an SP motor, waste heat factor is calculated by dividing the annual energy savings (kWh/HP) for "Equipment and Interactive" (shown in Table 43 of the report referenced in Source 2) by annual energy savings (kWh/HP) for the "Equipment Only" equipment type (also shown in Table 43). According to the DOE report noted in Source 4, PSC motors are approximately twice as efficient as SP motors. Thus, PSC motors will create less waste heat. The default waste heat factors for PSC motor baselines suppose PSC motors create half as much waste heat as SP motors.
4) Department of Energy. "Energy Savings Potential and Opportunities for High-Efficiency Electric Motors in Residential and Commercial Equipment." December 2013. Motor efficiencies for the baseline motors are drawn from Table 2.1, which provides peak efficiency ranges for a variety of motors. The motor efficiency for an ECM is drawn from the discussion in 2.4.3. https://www.energy.gov/sites/prod/files/2014/02/f8/Motor%20Energy%20Savings%20Potential%20Report%202013-12-4.pdf
5) Fricke, B. and B. Becker, Oak Ridge National Laboratory. "Q-Sync Motors in Commercial Refrigeration: Preliminary Test Results and Projected Benefits." ORNL/TM-2015/466. 2015. PMS motor efficiency estimated to be 0.73. See Table 1. http://info.ornl.gov/sites/publications/files/Pub58600.pdf.

3.5.3 Controls: Evaporator Fan Controllers

Target Sector	Commercial and Industrial Establishments
Measure Unit	Evaporator Fan Controller
Measure Life	15 years Source 1
Measure Vintage	Retrofit

This measure is for the installation of evaporator fan controls in walk-in coolers or freezers with no pre-existing controls. An evaporator fan controller is a device or system that lowers airflow across an evaporator when there is no refrigerant flow through the evaporator (i.e., when the compressor is in an off-cycle). Evaporator fans run constantly to provide cooling when the compressor is running, and to provide air circulation when the compressor is not running. The equations specified in the Algorithms section are for fans that are turned off and/or cycled.

A fan controller saves energy by reducing fan usage, by reducing the refrigeration load resulting from the heat given off by the fan and by reducing compressor energy resulting from the electronic temperature control. This protocol documents the energy savings attributed to evaporator fan controls.

Eligibility

This protocol documents the energy savings attributed to installation of evaporator fan controls in medium-temperature walk-in or reach-in coolers and low temperature walk-in or reach-in freezers. The baseline case is assumed to be a shaded pole (SP) motor without controls or an electronically-commutated motor (ECM) without controls.

Algorithms

The algorithms used in this section are adapted from NEEP's Commercial Refrigeration Loadshape Project.[Source 2]

$$\Delta kWh = kW * (\%ON_{Uncontrolled} - \%ON_{Controlled}) * 8{,}760 * WHF_e$$

$$kW = HP * 0.746/\eta$$

$$\Delta kW_{peak} = \Delta kWh * CF$$

Definition of Terms

Table 3-98: Terms, Values, and References for Evaporator Fan Controllers

Term	Unit	Values	Source
kW, Input wattage of the SP or ECM motor	*kW*	Nameplate	EDC Data Gathering
		Calculated value	Calculated value
$\%ON_{Uncontrolled}$, Effective runtime of the uncontrolled motor	*None*	EDC Data Gathering Default: 97.8%	EDC Data Gathering 2
$\%ON_{Controlled}$, Effective runtime of the controlled motor	*None*	EDC Data Gathering Unknown control style: 66.5% ON/OFF control style: 63.6% Micropulse control style: 69.2%	EDC Data Gathering 2
8,760, Numbers of operating hours per year	*Hours*	8,760	Conversion factor
WHF_e, Waste heat factor for energy; represents the increased savings due to reduced waste heat from motors that must be rejected by the refrigeration equipment	*None*	Cooler: 1.38 Freezer 1.76	3
HP, Rated horsepower of the motor	*HP*	Nameplate	EDC Data Gathering
η, Motor efficiency of the SP or ECM motor	None	Default for SP: 30% Default for ECM: 70%	4
0.746, Conversion factor	kW/HP	0.746	Conversion factor
CF, Coincidence factor	*None*	Unknown control style: 0.094 ON/OFF control style: 0.087 Micropulse control style: 0.102	5

Commented [SA59]: Franklin Energy

Source information seems high. Evaporator fans will not run when the evaporator is in defrost mode, otherwise it would be increasing the temperature of the space.

Default Savings

There are no default savings for this measure.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate

evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx. Accessed December 2018.

2) Commercial Refrigeration Loadshape Project, Northeast Energy Efficiency Partnerships, October 2015. https://neep.org/commercial-refrigeration-loadshape-report-10-2015-0. The average kW per rated HP values are taken from Table 28. The effective runtime values are taken from Table 34.

3) Waste heat factor is calculated by dividing the annual energy savings (kWh/HP) for “Equipment and Interactive” (shown in Table 43 of the report referenced in Source 2) by annual energy savings (kWh/HP) for the “Equipment Only” equipment type (also shown in Table 43).

4) Department of Energy. “Energy Savings Potential and Opportunities for High-Efficiency Electric Motors in Residential and Commercial Equipment.” December 2013. Motor efficiency for SP motors is drawn from Table 2.1, which provides peak efficiency ranges for a variety of motors. The motor efficiency for an ECM is drawn from the discussion in 2.4.3. https://www.energy.gov/sites/prod/files/2014/02/f8/Motor%20Energy%20Savings%20Potential%20Report%202013-12-4.pdf

5) Coincidence factors are developed by dividing the PJM summer peak kW/HP savings for evaporator fan controls (shown in Table 47 of the report referenced in Source 2) by the average annual energy savings (kWh/HP) for evaporator fan controls (shown in Table 43 of the report referenced in Source 2).

3.5.4 Controls: Floating Head Pressure Controls

Target Sector	Commercial and Industrial Establishments
Measure Unit	Floating Head Pressure Control
Measure Life	15 years Source 1
Measure Vintage	Retrofit

Installers conventionally design a refrigeration system to condense at a set pressure-temperature point, typically 90 ºF. By installing a floating head pressure control[134] (FHPCs) condenser system, the refrigeration system can change condensing temperatures in response to different outdoor temperatures. This means that the minimum condensing head pressure from a fixed setting (180 psig for R-22) is lowered to a saturated pressure equivalent at 70 ºF or less. Either a balanced-port or electronic expansion valve that is sized to meet the load requirement at a 70 ºF condensing temperature must be installed. Alternatively, a device may be installed to supplement the refrigeration feed to each evaporator attached to a condenser that is reducing head pressure.

Eligibility

This protocol documents the energy savings attributed to FHPCs applied to a single-compressor refrigeration system in commercial applications. The baseline case is a refrigeration system without FHPC whereas the efficient case is a refrigeration system with FHPC. FHPCs must have a minimum Saturated Condensing Temperature (SCT) programmed for the floating head pressure control of ≤ 70 ºF. The use of FHPC would require balanced-port expansion valves, allowing satisfactory refrigerant flow over a range of head pressures. The compressor must be 1 HP or larger.

Algorithms

There are no peak savings associated with this measure. Annual energy savings algorithms are shown below.

$$\Delta kWh = HP_{compressor} \times \frac{kWh}{HP}$$

If the refrigeration system is rated in tonnage:

$$\Delta kWh = \frac{4.715}{COP} \times Tons \times \frac{kWh}{HP}$$

[134] Also called a flood back control.

Definition of Terms

Table 3-99: Terms, Values, and References for Floating Head Pressure Controls

Term	Unit	Values	Source
$HP_{compressor}$, Rated horsepower (HP) per compressor	*HP*	Nameplate	EDC Data Gathering
$\frac{kWh}{HP}$, Annual savings per HP	$\frac{kWh}{HP}$	See Table 3-100, Table 3-101	2, 3, 4
COP, Coefficient of Performance	*None*	Based on design conditions	EDC Data Gathering
		Default: Condensing Unit; Refrigerator (Medium Temp: 28 °F – 40 °F): 2.51 Freezer (Low Temp: -20 °F – 0 °F): 1.30 Remote Condenser; Refrigerator (Medium Temp: 28 °F – 40 °F): 2.50 Freezer (Low Temp: -20 °F – 0 °F): 1.46	5
$Tons$, Refrigeration tonnage of the system	*ton*	EDC Data Gathering	EDC Data Gathering
4.715, Conversion factor to convert from ton to HP	$\frac{HP}{ton}$	Engineering Estimate	6

Table 3-100: Annual Savings kWh/HP by Location

Climate Zone	Condensing Unit (kWh/HP)			Remote Condenser (kWh/HP)		
	Refrigerator (Medium Temp)	Freezer (Low Temp)	Default (Temp Unknown)	Refrigerator (Medium Temp)	Freezer (Low Temp)	Default (Temp Unknown)
Allentown	630	767	672	380	639	460
Binghamton	728	835	761	491	674	548
Bradford	765	860	794	534	686	581
Erie	681	802	719	438	657	506
Harrisburg	585	737	632	330	623	421
Philadelphia	546	710	597	286	609	386
Pittsburgh	617	759	661	366	634	449
Scranton	686	806	723	443	659	510
Williamsport	663	790	702	417	651	490

Table 3-101: Default Condenser Type Annual Savings kWh/HP by Location

Climate Zone	Unknown Condenser Type Default (kWh/HP)		
	Refrigerator (Medium Temp)	Freezer (Low Temp)	Temp Unknown
Allentown	505	703	566
Binghamton	610	755	655
Bradford	650	773	688
Erie	559	730	612
Harrisburg	458	680	527
Philadelphia	416	660	492
Pittsburgh	491	697	555
Scranton	564	732	616
Williamsport	540	720	596

Default Savings

There are no default savings for this measure.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) Floating Head Pressure Controls for Single Compressor Systems, V1.6. Accessed from RTF website https://rtf.nwcouncil.org/measure/floating-head-pressure-controls-single-compressor-systems on October 26, 2018.
2) Technical Forum (RTF) as part of the Northwest Power & Conservation Council, Deemed Measures List. Grocery Floating Head Pressure Controls for Single Compressor Systems, FY2010, V1. Using RTF Deemed saving estimates for the NW climate zone, data was extrapolated to Pennsylvania climate zones by using cooling degree days comparison based on the locale. https://rtf.nwcouncil.org/measure/floating-head-pressure-controls-single-compressor-systems
3) Default based on the Pennsylvania Act 129 2018 Non-Residential Baseline Study (http://www.puc.pa.gov/Electric/pdf/Act129/SWE-Phase3_NonRes_Baseline_Study_Rpt021219.pdf), which found a split of roughly 69% medium temperature displays and 31% low temperature displays.
4) No data available to predict if condensing units or remote condensers will be more prevalent, assumed 50/50 split, based on discussion with Portland Energy Conservation, Inc. (PECI) GrocerySmart staff.
5) The given COP values are averaged based on the data from Regional Technical Forum (RTF) as part of the Northwest Power & Conservation Council, Deemed Measures List. Grocery Floating Head Pressure Controls for Single Compressor Systems, December 2016, V1.6
6) Conversion factor for compressor horsepower per ton: http://www.engineeringtoolbox.com/refrigeration-formulas-d_1695.html

3.5.5 Controls: Anti-Sweat Heater Controls

Target Sector	Commercial and Industrial Establishments
Measure Unit	Case door
Measure Life	12 years Source 1
Measure Vintage	Retrofit

Eligibility

Anti-sweat door heaters (ASDH) prevent condensation on cooler and freezer doors. Anti-sweat heater (ASH) controls sense the humidity in the store outside of reach-in, glass door refrigerated cases and turn off anti-sweat heaters during periods of low humidity. Without controls, anti-sweat heaters run continuously whether they are necessary or not.

There are two commercially available control strategies – (1) ON/OFF controls and (2) micro pulse controls that respond to a call for heating, which is typically determined using either a door moisture sensor or an indoor air temperature and humidity sensor to calculate the dew point. In the first strategy, the ON/OFF controls turn the heaters on and off for minutes at a time, resulting in a reduction in run time. In the second strategy, the micro pulse controls pulse the door heaters for fractions of a second, in response to the call for heating. Savings are realized from the reduction in energy used by not having the heaters running at all times. In addition, secondary savings result from reduced cooling load on the refrigeration unit when the heaters are off.

The baseline condition is assumed to be a commercial glass door cooler or refrigerator with heaters running 24 hours a day, seven days per week (24/7). Non-glass doors are not eligible. The savings given below are based on adding controls to doors with uncontrolled heaters utilizing either ON/OFF or micro pulse controls. The savings calculated from these algorithms is on a per door basis for two temperatures: Refrigerator/Coolers and Freezers. A default value to be used when the case service temperature is unknown is also calculated.

Algorithms

Algorithms for annual energy savings and peak demand savings are shown below.

$$\Delta kWh = kW_d \times (\%ON_{NONE} - \%ON_{CONTROL}) \times N \times 8760 \times WHF_e$$

$$\Delta kW_{peak} = kW_d \times CF \times WHF_d$$

Definition of Terms

Table 3-102: Terms, Values, and References for Anti-Sweat Heater Controls

Term	Unit	Values	Source
N, Number of reach-in refrigerator or freezer doors controlled by sensors	*Doors*	# of doors	EDC Data Gathering
kW_d, Connected load kW per connected door	$\frac{kW}{Door}$	EDC Data Gathering Default: 0.13	2
$\%ON_{NONE}$, Effective runtime of uncontrolled ASDH	*None*	EDC Data Gathering Default: 90.7%	2
$\%ON_{CONTROL}$, Effective runtime of ASDH with controls	*None*	Unknown control style: 45.6% ON/OFF control style: 58.9% Micropulse control style: 42.8%	2
8,760, Hours in a year	*Hours*	8,760	Conversion Factor
WHF_e, Waste heat factor for energy; represents the increased savings due to reduced waste heat from heaters that must be rejected by the refrigeration equipment	*None*	Cooler: 1.25 Freezer 1.50	3
WHF_d, Waste heat factor for energy; represents the increased savings due to reduced waste heat from heaters that must be rejected by the refrigeration equipment	*None*	Cooler: 1.25 Freezer 1.50	3
CF, Coincidence factor	*None*	Unknown control style: 0.44 ON/OFF control style: 0.32 Micropulse control style: 0.45	4

Default Savings

Table 3-103: Per Door Savings with ASDH

Description	Unknown Control	On/Off Control	Micropulse Control
Refrigerator/Cooler			
Energy Impact (kWh/door)	642	453	682
Peak Demand Impact (kW/door)	0.072	0.052	0.073
Freezer			
Energy Impact (kWh/door)	770	543	818
Peak Demand Impact (kW/door)	0.086	0.062	0.088

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx. Accessed December 2018.

2) Commercial Refrigeration Loadshape Project, Northeast Energy Efficiency Partnerships, October 2015. https://neep.org/commercial-refrigeration-loadshape-report-10-2015-0

3) Waste heat factor is calculated by dividing the PJM Summer Peak kW equipment and interactive savings for ASDH by the equipment savings from Table 52 of the report referenced in Source 2.

4) Coincidence factors developed by dividing the PJM Summer Peak kW Savings for ASDH Controls from Table 52 of the referenced report (0.057 kW/door for unknown control style, 0.041 kW/door for on/off controls, and 0.058 kW/door for micropulse controls) by the average wattage of ASDH per connected door (0.13 kW).

3.5.6 Controls: Evaporator Coil Defrost Control

Target Sector	Commercial and Industrial Establishments
Measure Unit	Evaporator Coil Defrost Control
Measure Life	10 years [Source 1]
Measure Vintage	Retrofit

This protocol applies to electric defrost control on small commercial walk-in cooler and freezer systems. A freezer refrigeration system with electric defrost is set to run the defrost cycle periodically throughout the day. A defrost control uses temperature and pressure sensors to monitor system processes and statistical modeling to learn the operation and requirements of the system. When the system calls for a defrost cycle, the controller determines if it is necessary and skips the cycle if it is not.

Eligibility

This measure is targeted to non-residential customers whose equipment uses electric defrost controls on small commercial walk-in freezer systems. Acceptable baseline conditions are existing small commercial walk-in coolers or freezers without defrost controls. Efficient conditions are small commercial walk-in coolers or freezers with defrost controls installed.

Algorithms

Algorithms for annual energy savings and peak demand savings are shown below.

$$\Delta kW_{peak} = FANS \times kW_{DE} \times SVG \times BF$$

$$\Delta kWh = \Delta kW_{peak} \times HOURS$$

Definition of Terms

Table 3-104: Terms, Values, and References for Evaporator Coil Defrost Controls

Term	Unit	Values	Source
$FANS$, Number of evaporator fans	*Fan*	EDC Data Gathering	EDC Data Gathering
kW_{DE}, kW of defrost element	*kW*	EDC Data Gathering Default: 0.9	EDC Data Gathering, 2
SVG, Savings percentage for reduced defrost cycles	*None*	30%	3
BF, Savings factor for reduced cooling load from eliminating heat generated by the defrost element	*None*	Coolers: 1.3 Freezers: 1.67	4
$HOURS$, Average annual full load defrost hours	$\frac{Hours}{year}$	EDC Data Gathering Default: 487	EDC Data Gathering, 5

Default Savings

Default savings may be claimed using the algorithms above and the variable defaults. EDCs may also claim savings using customer specific data.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) Energy & Resource Solutions (2005). Measure Life Study. Prepared for Massachusetts Joint Utilities. Estimate from Heatcraft based on expected component expected life. The only moving part is a relay which has a cycle life that is well over 15 years based on the frequency of the relay operation.

2) Efficiency Vermont Technical Reference User Manual (TRM), March 16, 2015. Pg. 170. The total Defrost Element kW is proportional to the number of evaporator fans blowing over the coil. The typical wattage of the defrost element is 900W per fan.

   https://puc.vermont.gov/sites/psbnew/files/doc_library/ev-technical-reference-manual.pdf

3) Smart defrost kits claim 30-40% savings (with 43.6% savings by third party testing by Intertek Testing Service). MasterBilt Demand defrost claims 21% savings for northeast. Smart Defrost Kits are more common so the assumption of 30% is a conservative estimate. https://www.heatcraftrpd.com/PDF/Sales%20Brochures/SB-IN-SMARTDEFROST.pdf

4) ASHRAE Handbook 2014 Refrigeration, Section 15.14 Figure 24.

5) Demand Defrost Strategies in Supermarket Refrigeration Systems, Oak Ridge National Laboratory, 2011. The refrigeration system is assumed to be in operation every day of the year, while savings from the evaporator coil defrost control will only occur during set defrost cycles. This is assumed to be (4) 20-minute cycles per day, for a total of 487 hours. https://info.ornl.gov/sites/publications/files/pub31296.pdf

3.5.7 Variable Speed Refrigeration Compressor

Target Sector	Commercial and Industrial Establishments
Measure Unit	VSD Refrigeration Compressor
Measure Life	15 years Source 1
Measure Vintage	Retrofit

Variable speed drive (VSD) compressors are used to control and reduce the speed of the compressor during times when the refrigeration system does not require the motor to run at full capacity. VSD control is an economical and efficient retrofit option for existing compressor installations. The performance of variable speed compressors can more closely match the variable refrigeration load requirements thus minimizing energy consumption.

Eligibility

This measure, VSD control for refrigeration systems and its eligibility targets applies to retrofit construction in the commercial and industrial building sectors; it is most applicable to grocery stores or food processing applications with refrigeration systems. This protocol is for a VSD control system replacing a slide valve control system.

Algorithms

The savings algorithms are shown below. There are two distinct sets of algorithms – one for if the refrigeration system is rated in tonnage, and another for if the refrigeration system is rated in horsepower.

If the refrigeration system is rated in tonnage:

$$\Delta kWh = Tons \times ES_{value}$$

$$\Delta kW_{peak} = Tons \times DS_{value}$$

If the refrigeration system is rated in horsepower:

$$\Delta kWh = 0.212 \times \frac{1}{COP} \times HP_{compressor} \times ES_{value}$$

$$\Delta kW_{peak} = 0.212 \times \frac{1}{COP} \times HP_{compressor} \times DS_{value}$$

Definition of Terms

Table 3-105: Terms, Values, and References for VSD Compressors

Term	Unit	Values	Sources
$Tons$, Refrigeration tonnage of the system	*ton*	EDC Data Gathering	EDC Data Gathering
$HP_{compressor}$, Rated horsepower per compressor	*HP*	EDC Data Gathering	EDC Data Gathering
ES_{value}, Energy savings value in kWh per ton	$\frac{kWh}{ton}$	1,696	2
DS_{value}, Demand savings value in kW per ton	$\frac{kW}{ton}$	0.22	2
0.212, Conversion factor to convert from HP to ton	$\frac{ton}{HP}$	0.212	3
COP	None	EDC Data Gathering Default = 1.80	4

Default Savings

There are no default savings for this measure.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx. Accessed December 2018.

2) 2005 DEER (Database for Energy Efficiency Resources). This measure considered the associated savings by vintage and by climate zone for compressors. The deemed value was an average across all climate zones and all vintages (excluding new construction). http://www.deeresources.com/index.php/deer2005

3) Conversion factor for HP to ton is 0.212. From https://www.advancedconverter.com/unit-conversions/power-conversion/tons-to-horsepower

4) Navigant Consulting Inc., "*Energy Savings Potential and R&D Opportunities for Commercial Refrigeration,*" U.S. Department of Energy, September 2009. Table 4-4. https://www1.eere.energy.gov/buildings/pdfs/commercial_refrigeration_equipment_research_opportunities.pdf. COP value of 1.80 is a weighted average of the COP values from reach-in coolers (2.04) and freezers (1.25). A split of 69/31 is assumed based on the Pennsylvania Act 129 Non-Residential Baseline Study.

Commented [SA60]: Franklin Energy

Consider using consistent COP source for all work papers. Floating Head Pressure Controls uses 2.5 for coolers and 1.3 or 1.46 for freezers

3.5.8 Strip Curtains for Walk-In Freezers and Coolers

Target Sector	Commercial and Industrial Establishments
Measure Unit	Walk-in unit door
Measure Life	4 years Source 1
Measure Vintage	Retrofit

Strip curtains are used to reduce the refrigeration load associated with the infiltration of non-refrigerated air into the refrigerated spaces of walk-in coolers or freezers.

The primary cause of air infiltration into walk-in coolers and freezers is the air density difference between two adjacent spaces of different temperatures. The total refrigeration load due to infiltration through the main door into the unit depends on the temperature differential between the refrigerated and non-refrigerated airs, the door area and height, and the duration and frequency of door openings. The avoided infiltration depends on the efficacy of the newly installed strip curtains as infiltration barriers.[135] The calculation of the refrigeration load due to air infiltration and the energy required to meet that load is rather straightforward, but relies on critical assumptions regarding the aforementioned operating parameters. Algorithms and assumptions in this protocol are drawn from a Strip Curtains measure maintained by the RTF, which calculates savings using the formulas outlined in ASHRAE's Refrigeration Handbook for calculating refrigeration load from infiltration by air exchange.Source 2

Eligibility

This protocol documents the energy savings attributed to strip curtains applied on walk-in cooler and freezer doors in commercial applications. The most likely areas of application are large and small grocery stores, supermarkets, restaurants, and refrigerated warehouses. The baseline case is a walk-in cooler or freezer that previously had no strip curtain installed. The efficient equipment is a strip curtain added to a walk-in cooler or freezer. Strip curtains must be at least 0.06 inches thick. Low temperature strip curtains must be used on low temperature applications.

Algorithms

Algorithms for annual energy savings and peak demand savings are shown below.

$$\Delta kWh = \frac{\Delta kWh}{ft^2} \times A$$

$$\Delta kW_{peak} = \frac{\Delta kW}{ft^2} \times A$$

[135] We define *curtain efficacy* as the fraction of the potential airflow that is blocked by an infiltration barrier. For example, a brick wall would have an efficacy of 1.0, while the lack of any infiltration barrier corresponds to an efficacy of 0.

Definition of Terms

Table 3-106: Terms, Values, and References for Strip Curtains

Term	Unit	Values	Source
$\frac{\Delta kWh}{ft^2}$, Average annual kWh savings per square foot of infiltration barrier	$\frac{\Delta kWh}{ft^2}$	Default: Table 3-108	2
$\frac{\Delta kW}{ft^2}$, Average kW savings per square foot of infiltration barrier	$\frac{\Delta kW}{ft^2}$	Default: Table 3-108	2
A, Doorway area	ft^2	EDC Data Gathering Default: Table 3-107	2

Table 3-107: Doorway Area Assumptions

Type	Doorway Area, ft^2
Grocery - Cooler	21
Grocery - Freezer	21
Convenience Store - Cooler	21
Convenience Store - Freezer	21
Restaurant - Cooler	21
Restaurant - Freezer	21
Refrigerated Warehouse - Cooler	120

Default Savings

The default savings values, per square foot, are listed in Table 3-108. Default square footage values by facility type are listed in Table 3-107. The defaults are drawn from a Strip Curtains measure maintained by the RTF.

Table 3-108: Default Energy Savings and Demand Reductions for Strip Curtains per Square Foot

Type	Energy Savings, $\frac{\Delta kWh}{ft^2}$	Demand Savings, $\frac{\Delta kW}{ft^2}$
Grocery - Cooler	123	0.0160
Grocery - Freezer	535	0.0659
Convenience Store - Cooler	19	0.0025
Convenience Store - Freezer	31	0.0038
Restaurant - Cooler	24	0.0031
Restaurant - Freezer	129	0.0158
Refrigerated Warehouse - Cooler	410	0.0532

EVALUATION PROTOCOLS

The most appropriate evaluation protocol for this measure is verification of installation coupled with assignment of stipulated energy savings according to store type. The strip curtains are not expected to be installed directly. As such, the program tracking / evaluation effort must capture the following key information:

- Fraction of strip curtains installed in each of the categories (e.g. freezer / cooler and store type)
- Doorway area

The rebate forms should track the above information. During the M&V process, interviews with site contacts should track this fraction, and savings should be adjusted accordingly.

SOURCES

1) California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx. Accessed December 2018.

2) Database for UES Measures, Regional Technical Forum. Strip Curtains, version 1.7. December 2016. https://rtf.nwcouncil.org/measure/strip-curtains

3.5.9 Night Covers for Display Cases

Target Sector	Commercial and Industrial Establishments
Measure Unit	Display Case
Measure Life	5 years Source 1
Measure Vintage	Retrofit

Eligibility

This measure documents the energy savings associated with the installation of night covers on existing open-type refrigerated display cases, where covers are deployed during the facility's unoccupied hours in order to reduce refrigeration energy consumption. These types of display cases can be found in small and medium to large size grocery stores. The air temperature is below 0 °F for low-temperature display cases, between 0 °F to 30 °F for medium-temperature display cases, and between 35 °F to 55 °F for high-temperature display cases.[Source 2] The main benefit of using night covers on open display cases is a reduction of infiltration and radiation cooling loads. It is recommended that these covers have small, perforated holes to decrease moisture buildup.

Algorithms

There are no demand savings for this measure because the covers will not be in use during the peak period. The annual energy savings are obtained through the calculation shown below.[Source 3]

$$\Delta kWh = W \times SF \times HOU$$

Definition of Terms

Table 3-109: Terms, Values, and References for Night Covers

Term	Unit	Values	Source
W, Width of the opening that the night covers protect	*ft*	EDC Data Gathering	EDC Data Gathering
SF, Savings factor based on the temperature of the case	$\frac{kW}{ft}$	Default: Table 3-110	3
HOU, Annual hours that the night covers are in use	$\frac{Hours}{Year}$	EDC Data Gathering	EDC Data Gathering

Table 3-110: Savings Factors

Cooler Case Temperature	Savings Factor
Low Temperature (-35 F to -5 F)	0.03 kW/ft
Medium Temperature (0 F to 30 F)	0.02 kW/ft
High Temperature (35 F to 55 F)	0.01 kW/ft

The demand and energy savings assumptions are based on analysis performed by Southern California Edison (SCE). SCE conducted this test at its Refrigeration Technology and Test Center (RTTC). The RTTC's sophisticated instrumentation and data acquisition system provided detailed tracking of the refrigeration system's critical temperature and pressure points during the test period. These readings were then utilized to quantify various heat transfer and power related parameters within the refrigeration cycle. The results of SCE's test focused on three typical scenarios found mostly in supermarkets.

Default Savings

There are no default savings for this measure.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx. Accessed December 2018.

2) Massachusetts Technical Reference Manual, October 2015, pg. 261. http://ma-eeac.org/wordpress/wp-content/uploads/2016-2018-Plan-1.pdf

3) CL&P Program Savings Documentation for 2016 Program Year (2015). Pg. 96. Factors based on Southern California Edison (1997). *Effects of the Low Emissive Shields on Performance and Power Use of a Refrigerated Display Case*. https://neep.org/sites/default/files/2015_10_01_2016%20Program%20Savings%20Document.pdf

Commented [SA61]: Franklin Energy

This is an older source, but values seem to be consistent with other programs.

3.5.10 Auto Closers

Target Sector	Commercial and Industrial Establishments
Measure Unit	Walk-in Cooler and Freezer Door
Measure Life	8 years Source 1
Measure Vintage	Retrofit

The auto-closer should be applied to the main insulated opaque door(s) of a walk-in cooler or freezer. Auto-closers on freezers and coolers can reduce the amount of time that doors are open, thereby reducing infiltration and refrigeration loads. These measures are for retrofit of doors not previously equipped with auto-closers, and assume the doors have strip curtains.

Eligibility

This protocol documents the energy savings attributed to installation of auto closers in walk-in coolers and freezers. The auto-closer must be able to firmly close the door when it is within one inch of full closure. The walk-in door perimeter must be ≥ 16 feet.

Algorithms

The energy and demand savings for this measure were developed based on an SCE working paper regarding refrigerated storage auto closers.[Source 2] The paper notes that, "energy savings were determined through building simulation in eQUEST 3.65 Refrigeration. Only the Grocery building type was simulated, and its savings were used for other building types because walk-in coolers and freezers generally have the same characteristics regardless of building type." Additionally, it is noted that peak demand savings were calculated by averaging the demand during the DEER peak period. This period varies by California climate zone.

Main Cooler Doors

$$\Delta kWh = \Delta kWh_{cooler}$$

$$\Delta kW_{peak} = \Delta kW_{cooler}$$

Main Freezer Doors

$$\Delta kWh = \Delta kWh_{freezer}$$

$$\Delta kW_{peak} = \Delta kW_{freezer}$$

Definition of Terms

Table 3-111: Terms, Values, and References for Auto Closers

Term	Unit	Values	Source
ΔkWh_{cooler}, Annual kWh savings for main cooler doors	kWh	Table 3-112	2
ΔkW_{cooler}, Summer peak kW savings for main cooler doors	kW	Table 3-112	2
$\Delta kWh_{freezer}$, Annual kWh savings for main freezer doors	kWh	Table 3-112	2
$\Delta kW_{freezer}$, Summer peak kW savings for main freezer doors	kW	Table 3-112	2

Default Savings

Table 3-112: Refrigeration Auto Closers Default Savings

Reference City	Cooler		Freezer	
	kWh_{cooler}	kW_{cooler}	$kWh_{freezer}$	$kW_{freezer}$
All PA cities	737	0.463	1,997	0.488

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx. Accessed December 2018.

2) Southern California Edison, "Refrigerated Storage Auto Closer", Workpaper SCE17RN024, Measure R79 (Cooler) & R80 (Freezer). http://www.deeresources.net/workpapers. The energy savings were extrapolated via a regression model that predicted the savings for each of California's 16 climate zones based on HDD and CDD. Average HDD and CDD for the nine Pennsylvania weather cities were plugged into the regression model. Peak demand savings from the SCE study could not be modeled as a function of HDD and CDD, so the peak demand savings from the California climate zone most similar to the Pennsylvania weather cities (in terms of CDD and HDD) were chosen (zone 16).

Commented [SA62]: Franklin Energy

We recommend keeping a consistent location of assumptions/process throughout TRM measures. Some have it with the source (here) and some have it in the algorithm section (Suction Pipe Insulation).

3.5.11 Door Gaskets for Walk-in and Reach-in Coolers and Freezers

Target Sector	Commercial and Industrial Establishments
Measure Unit	Door Gasket
Measure Life	4 years Source 1
Measure Vintage	Replace on Burnout

The following protocol for the measurement of energy and demand savings is applicable to commercial refrigeration and applies to the replacement of worn-out gaskets with new better-fitting gaskets. Applicable gaskets include those located on the doors of walk-in and/or reach-in coolers and freezers.

Tight fitting gaskets inhibit infiltration of warm, moist air into the cold refrigerated space, thereby reducing the cooling load. Aside from the direct reduction in cooling load, the associated decrease in moisture entering the refrigerated space also helps prevent frost on the cooling coils. Frost build-up adversely impacts the coil's, heat transfer effectiveness, reduces air passage (lowering heat transfer efficiency), and increases energy use during the defrost cycle. Therefore, replacing defective door gaskets reduces compressor run time and improves the overall effectiveness of heat removal from a refrigerated cabinet.

Eligibility

This protocol applies to the main doors of both low temperature ("freezer" – below 32 °F) and medium temperature ("cooler" – above 32 °F) walk-ins and reach-ins.

Algorithms

The demand and energy savings assumptions are based on analysis performed by Southern California Edison. The energy savings and demand reduction are obtained through the following calculations:

$$\Delta kWh = \frac{\Delta kWh}{Door} \times Doors$$

$$\Delta kW_{peak} = \frac{\Delta kW}{Door} \times Doors$$

Definition of Terms

Table 3-113: Terms, Values, and References for Door Gaskets

Term	Unit	Values	Source
$\frac{\Delta kWh}{Door}$, Annual energy savings per gasket door	$\frac{\Delta kWh}{Door}$	Table 3-114	2
$\frac{\Delta kW}{Door}$, Demand savings per gasket door	$\frac{\Delta kW}{Door}$	Table 3-114	2
Doors, Total number of gasket doors replaced	*Doors*	As Measured	EDC Data Gathering

Default Savings

The default savings values below are drawn from a door gasket replacement measure maintained by the RTF.[Source 2] Energy and demand savings are derived from a mixture of logger data and a direct impact evaluation. Savings for freezers are less than savings for coolers for reach-ins but not walk-ins – this is largely due to HVAC interactions captured in the study.

Table 3-114: Door Gasket Savings Per Door for Walk-in and Reach-in Coolers and Freezers

Type	Coolers		Freezers	
	$\Delta kW/_{Door}$	$\Delta kWh/_{Door}$	$\Delta kW/_{Door}$	$\Delta kWh/_{Door}$
Reach-in	0.032	248	0.032	243
Walk-in	0.027	204	0.045	347

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx. Accessed December 2018.

2) Database for UES Measures, Regional Technical Forum. Door Gasket Replacement, version 1.5. December 2016. https://rtf.nwcouncil.org/measure/door-gasket-replacement

3.5.12 Special Doors with Low or No Anti-Sweat Heat for Reach-In Freezers and Coolers

Target Sector	Commercial and Industrial Establishments
Measure Unit	Per Door
Measure Life	12 years Source 1
Measure Vintage	Retrofit

Traditional clear glass display case doors consist of two-pane glass (three-pane in low and medium temperature cases) and aluminum doorframes and door rails. Glass heaters may be included to eliminate condensation on the door or glass. The door heaters are traditionally designed to overcome the highest humidity conditions as cases are built for nation-wide applications. New low heat/no heat door designs incorporate heat reflective coatings on the glass, gas inserted between the panes, non-metallic spacers to separate the glass panes, and/or non-metallic frames (such as fiberglass). Using low-heat or no-heat doors can reduce the energy consumption of the case by using lower wattage heaters or a reduced number of total heaters per door. The savings results from reduced electric energy consumed by the heaters, and from the reduced cooling load on the refrigeration system.

This protocol documents the energy savings attributed to the installation of special glass doors with low/no anti-sweat heaters for reach-in coolers or freezers. The primary focus of this rebate measure is on new cases to incent customers to specify advanced doors when they are purchasing refrigeration cases.

Eligibility

For this measure, a no-heat/low-heat clear glass door must be installed on an upright display case. It is limited to door heights of 57 inches or more. Doors must have either heat reflective treated glass, be gas filled, or both. The baseline is assumed to be standard energy doors.

Algorithms

The energy savings and demand reduction are obtained through the following calculations adopted from the Wisconsin Focus on Energy 2018 TRM. Source 2

$$\Delta kWh = \frac{1}{1{,}000} \times (Watts_{base} - Watts_{ee}) * \left(1 + \frac{1}{COP}\right) * HOU$$

$$\Delta kW_{peak} = \frac{\Delta kWh}{HOU}$$

Definition of Terms

Table 3-115: Terms, Values, and References for Special Doors with Low or No Anti-Sweat Heat

Term	Unit	Values	Source
$\frac{1}{1,000}$, Conversion from watts to kW	$\frac{kW}{W}$	$\frac{1}{1,000}$	Conversion factor
$Watts_{base}$, Wattage of standard door heaters	*W*	Nameplate Input Wattage	EDC Data Gathering
$Watts_{ee}$, Wattage of low-heat or no-heat doors	*W*	Nameplate Input Wattage	EDC Data Gathering
COP, Coefficient of performance	*None*	Coolers: 2.04 Freezers: 1.25	3
HOU, Annual hours of use	*Hours*	EDC Data Gathering Default: 8,760	Conversion factor

Default Savings

There are no default savings for this measure.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx. Accessed December 2018.

2) Wisconsin Focus on Energy 2018 Technical Reference Manual, Refrigeration: Energy-Efficient Case Doors. Page 577. https://www.focusonenergy.com/sites/default/files/TRM%202018%20Final%20Version%20Dec%202017_1.pdf

3) Navigant Consulting Inc., "*Energy Savings Potential and R&D Opportunities for Commercial Refrigeration,*" U.S. Department of Energy, September 2009. Table 4-4. https://www1.eere.energy.gov/buildings/pdfs/commercial_refrigeration_equipment_research_opportunities.pdf

3.5.13 Suction Pipe Insulation for Walk-In Coolers and Freezers

Target Sector	Commercial and Industrial Establishments
Measure Unit	Per Linear Foot of Insulation
Measure Life	11 years Source 1
Measure Vintage	Retrofit

This measure applies to the installation of insulation on existing bare suction lines (the larger diameter lines that run from the evaporator to the compressor) that are located outside of the refrigerated space for walk-in coolers and freezers. Insulation impedes heat transfer from the ambient air to the suction lines, thereby reducing undesirable system superheat. This decreases the load on the compressor, resulting in decreased compressor operating hours, and energy savings.

Eligibility

This protocol documents the energy savings attributed to insulation of bare refrigeration suction pipes. The following are the eligibility requirements:

- Must insulate bare refrigeration suction lines 1-5/8 inches in diameter or less on existing equipment only;
- Medium temperature lines require 3/4 inch of flexible, closed-cell, nitrite rubber or an equivalent insulation;
- Low temperature lines require 1-inch of insulation that is in compliance with the specifications above; and
- Insulation exposed to the outdoors must be protected from the weather (i.e. jacketed with a medium-gauge aluminum jacket). Source 2

Algorithms

The demand and energy savings assumptions are based analysis performed by Southern California Edison (SCE). Source 1 Measure savings per linear foot of insulation installed on bare suction lines in Restaurants and Grocery Stores are provided in Table 3-117. These savings were extrapolated via a regression model that predicted the savings for each of California's 16 climate zones based on CDD. Average CDD for the nine Pennsylvania weather cities was plugged into the regression models.

$$\Delta kWh = \frac{\Delta kWh}{ft} \times L$$

$$\Delta kW_{peak} = \frac{\Delta kW}{ft} \times L$$

Definition of Terms

Table 3-116: Terms, Values, and References for Insulate Bare Refrigeration Suction Pipes

Term	Unit	Values	Source
$\frac{\Delta kWh}{ft}$, Annual energy savings per linear foot of insulation	$\frac{\Delta kWh}{ft}$	Default: Table 3-117	1
$\frac{\Delta kW}{ft}$, Demand savings per linear foot of insulation	$\frac{\Delta kW}{ft}$	Default: Table 3-117	1
L, Total insulation length	*ft*	As Measured	EDC Data Gathering

Default Savings

Table 3-117 shows default savings *per linear foot* for this measure. To calculate annual energy savings and peak demand savings, multiply the values shown in Table 3-117 by the total insulation length ($\boldsymbol{L}$).

Table 3-117: Insulate Bare Refrigeration Suction Pipes Savings per Linear Foot

City	Medium-Temperature Walk-in Coolers		Low-Temperature Walk-in Freezers	
	ΔkW/ft	ΔkWh/ft	ΔkW/ft	ΔkWh/ft
All PA cities	0.005	24.8	0.016	85.5

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) Southern California Edison Company, "Insulation of Bare Refrigeration Suction Lines", Work Paper SCE13RN003. http://www.deeresources.net/workpapers

2) Commonwealth Edison Refrigeration Incentives Worksheet 2018. https://www.comed.com/WaysToSave/ForYourBusiness/Documents/RefrigerationWorksheet.pdf

3.5.14 Refrigerated Display Cases with Doors Replacing Open Cases

Target Sector	Commercial and Industrial Establishments
Measure Unit	Refrigerated Display Case
Measure Life	12 years Source 1
Measure Vintage	Early Replacement

This measure considers the replacement of existing vertical open display cases with new closed display cases. The baseline equipment is an average existing medium temperature vertical open display case. The doors on the new cases must be no sweat (also known as zero heat). The display cases should be medium temperature (typically for dairy, meats, or beverages) as opposed to low temperature (typically for frozen food and ice cream). This calculation quantifies the infiltration savings seen by the compressor. Lighting or other upgrades should be considered as separate projects.

Eligibility

The eligible equipment is a new case with no sweat doors that meets federal standard requirements. If a lighting retrofit is included with the new case, it must consume the same amount of energy or less than the old lighting. Upgrades to lighting or other system components should be processed separately. Horizontal cases are not eligible and should be processed as custom.

Algorithms

Deemed energy savings per linear foot of case are based on a project that compared a typical open refrigerated display case line-up to a typical glass-doored refrigerated display case line-up. Source 2

$$\Delta kWh = Energy\ Savings \times Case\ Width$$

$$\Delta kW_{peak} = \frac{Energy\ Savings}{8760} \times Case\ Width$$

Definition of Terms

Table 3-118: Terms, Values, and References for Refrigerated Display Cases with Doors Replacing Open Cases

Term	Unit	Values	Source
$Energy\ Savings$, Deemed energy savings per linear foot of case	$\frac{kWh}{ft}$	404.4	2
$Case\ Width$, Width of case opening in feet	ft	EDC Data Gathering	EDC Data Gathering

Default Savings

There are no default savings for this measure.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx. Accessed December 2018.

2) Fricke, Brian and Becker, Bryan, "Energy Use of Doored and Open Vertical Refrigerated Display Cases" (2010). International Refrigeration and Air Conditioning Conference. Paper 1154. Values derived from Table 1 and the relative width of the display cases used in the study (without anti-sweat heaters). Energy savings assume 365.25 days of annual operation. Demand savings assume flat energy savings throughout the day. http://docs.lib.purdue.edu/iracc/1154

3.5.15 Adding Doors to Existing Refrigerated Display Cases

Target Sector	Commercial and Industrial Establishments
Measure Unit	Refrigerated Display Case
Measure Life	12 years Source 1
Measure Vintage	Retrofit

This measure considers adding doors to existing vertical open display cases. The baseline equipment is an existing vertical display case of medium temperature with no doors. The display cases should be medium temperature (typically for dairy, meats, or beverages) as opposed to low temperature (typically for frozen food and ice cream). The added doors may be no sweat (also known as zero heat) or they may contain anti-sweat heaters. This calculation quantifies infiltration savings which are realized at the compressor due to reduced load. Lighting or other upgrades should be considered as separate projects.

Eligibility

The eligible retrofit equipment is either no sweat doors or doors with anti-sweat heaters. If a lighting retrofit is included with the new doors, it must consume the same amount of energy or less energy than the old lighting. Upgrades to lighting or other system components should be processed separately. Horizontal cases are not eligible and should be processed as custom.

Algorithms

Deemed energy savings per linear foot of case are based on a project that compared a typical open refrigerated display case line-up to a typical glass-doored refrigerated display case line-up.[2]

$$\Delta kWh = Energy\ Savings \times Case\ Width$$

$$\Delta kW_{peak} = \frac{Energy\ Savings}{8760} \times Case\ Width$$

Definition of Terms

Table 3-119: Terms, Values, and References for Adding Doors to Refrigerated Display Cases

Term	Unit	Values	Source
$Energy\ Savings$, Deemed energy savings per linear foot of case	$\frac{kWh/yr}{ft}$	Doors with Anti-Sweat Heaters = 277.7 No Sweat Doors = 499.2	2
$Case\ Width$, Width of case opening in feet	ft	EDC Data Gathering	EDC Data Gathering

Default Savings

There are no default savings for this measure.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx. Accessed December 2018.

2) Fricke, Brian and Becker, Bryan, "Energy Use of Doored and Open Vertical Refrigerated Display Cases" (2010). International Refrigeration and Air Conditioning Conference. Paper 1154. Values derived from daily compressor energy consumption for two stores in study as shown in Table 1 (ignoring the lighting load shown in the table), as well as the widths of the cases in the two stores. Energy savings assume 365.25 days of annual operation. Demand savings assume flat energy savings throughout the day. http://docs.lib.purdue.edu/iracc/1154

Commented [SA63]: Franklin Energy

Incorrect methodology. This study compared a brand new doored display case to a brand new open multideck case. If utilizing Source 2 for this work paper, the correct methodology would be to utilize the open multideck energy usage and reduce the infiltration by 68% (correlates to 87% reduction in compressor power demand – paragraph 3 in 1. Introduction in source 2)

3.5.16 Air-Cooled Refrigeration Condenser

Target Sector	Commercial and Industrial Establishments
Measure Unit	Refrigeration Condenser
Measure Life	15 years Source 1
Measure Vintage	Replace on Burnout, Early Replacement, Retrofit, New Construction

This measure involves installing an efficient, close-approach (“Approach” or “TD” refers to the temperature difference between the design condensing temperature and the design ambient outdoor temperature.) air-cooled refrigeration system condenser, which saves energy by reducing condensing temperatures and improving the efficiency of the condenser fan system.

Eligibility

This protocol documents energy savings attributed to providing an efficient air-cooled refrigeration system condenser for commercial and industrial refrigeration applications. This measure requires new equipment with an approach temperature of 13ºF or less on low-temperature applications and an approach temperature of 8ºF or less on medium-temperature applications. Specific fan power must be greater than or equal to 85 Btu/hr of heat rejection capacity per watt of fan power.

Algorithms

The baseline condition is assumed to be a standard efficiency air-cooled refrigeration system condenser with a 20ºF approach temperature on low-temperature applications and a 15ºF approach temperature on medium-temperature applications. The baseline equipment incorporates a fan with 45 Btu/hr of heat rejection capacity per watt of fan power. The unit energy savings and peak demand reduction are obtained through the following formulas:

$$\Delta kWh = \frac{tons}{unit} \times \frac{\Delta kWh}{ton}$$

$$\Delta kW_{peak} = \frac{tons}{unit} \times \frac{\Delta kW}{ton}$$

Definition of Terms

Table 3-120: Terms, Values, and References for Air-Cooled Refrigeration Condensers

Term	Unit	Values	Source
$tons/unit$, Capacity of refrigeration system compressor	Tons	EDC Data Gathering	-
$\frac{\Delta kWh}{ton}$, Change in unit energy consumption	kWh/ton	Default: Table 3-121	2
$\frac{\Delta kW}{ton}$, Change in unit power demand	kW/ton	Default: Table 3-121	2

Default Savings

The unit energy and peak demand savings per ton of compressor capacity were approximated for Pennsylvania cities based on an extrapolation from New York state data, calculated from a DOE-2.2 simulation of a prototypical grocery store, which include refrigerated and non-refrigerated food sales convenience stores and specialty food sales.[Source 2] The New York TRM assumes that grocery stores and convenience stores are the primary application for this measure, which is a reasonable assumption for applications in Pennsylvania as well. The energy savings were modified using proxy variables for outdoor air temperature, which has a direct effect on the energy savings that can be achieved with this measure using a linear regression model. The proxy variables, chosen as heating and cooling equivalent full-load hours (EFLH, as defined Table 3-28), were used to approximate the relationship between the projected energy savings in New York cities and the outdoor temperature in those cities. Using a linear regression analysis, data was extrapolated to estimate the energy savings that can be achieved in Pennsylvania cities. For peak demand reduction, a similar methodology was used, applying EFLH cooling data only, as peak demand reduction occurs during cooling season. The unit energy and peak demand savings per ton of capacity for seven different cities (grocery/convenience stores only) in Pennsylvania are shown below. The EDC should use the system capacity data collected to derive the final savings estimate.

Table 3-121: Default Savings for Air-Cooled Refrigeration Condensers

City	Annual Energy Savings per Ton of Capacity ($\Delta\ \mathrm{kWh}/_{\mathrm{ton}}$)	Peak Demand Savings per Ton of Capacity ($\Delta\ kW/_{ton}$)
Allentown	1,307	0.1252
Binghamton	1,290	0.1430
Bradford	1,296	0.1429
Erie	1,318	0.1244
Harrisburg	1,318	0.1171
Philadelphia	1,312	0.1204
Pittsburgh	1,308	0.1245
Scranton	1,318	0.1164
Williamsport	1,323	0.1167

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx. Accessed December 2018.

2) New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs – Residential, Multi-family, and Commercial/Industrial Measures. Version 3. New York State Department of Public Service. June 1, 2015. http://www3.dps.ny.gov/W/PSCWeb.nsf/ca7cd46b41e6d01f0525685800545955/06f2fee55575bd8a852576e4006f9af7/$FILE/TRM%20Version%203%20-%20June%201,%202015.pdf

3.5.17 Refrigerated Case Light Occupancy Sensors

Target Sector	Commercial and Industrial Establishments
Measure Unit	Per watt of controlled lighting
Measure Life	8 years Source 1
Measure Vintage	Replace on Burnout, Early Replacement, Retrofit, or New Construction

This protocol documents the energy savings attributed to installing occupancy sensors to control LED refrigerated case lighting. Energy savings can be achieved from the installation of sensors which dim or turn off the lights when the space or aisle is unoccupied. Energy savings result from a combination of reduced lighting energy as well reduced cooling load within the case.

Eligibility

This measure requires the installation of motion-based lighting controls that allow the LED case lighting to be dimmed or turned off completely during unoccupied conditions.

Algorithms

The algorithm shown below shall be used to calculate the annual energy savings for this measure. There are no peak demand savings associated with this measure, as the savings are assumed to occur off-peak.

$$\Delta kWh = \frac{WATTS}{1{,}000} \times HOURS \times RRF \times (1 + IF_e)$$

Definition of Terms

Table 3-122: Terms, Values, and References for Refrigerated Case Light Occupancy Sensors

Term	Unit	Values	Source
$WATTS$, Connected wattage of controlled refrigerated lighting fixtures	W	EDC Data Gathering	EDC Data Gathering
$HOURS$, Annual operating hours	Hours/year	EDC Data Gathering Default = 6,205	4
IF_e, Interactive effects factor for energy to account for cooling savings from offset refrigeration load	None	Refrigerator and cooler = 0.29 Freezer = 0.50	3
RRF, Runtime reduction factor	None	EDC Data Gathering 24-hr facilities = 0.39 18-hr facilities = 0.29	2
1,000, Conversion factor	W/kW	1,000	Conversion factor

DEFAULT SAVINGS

Default savings per controlled watt are shown below.

Table 3-123: Default energy and demand savings values, per watt of controlled lighting

Value	Medium-Temp Applications		Low-Temp Applications	
	24 hr/day facilities	18 hr/day facilities	24 hr/day facilities	18 hr/day facilities
Annual kWh savings per controlled watt	3.1	2.3	3.6	2.7
Peak kW savings per controlled watt	0.0003	0.0003	0.0004	0.0004

EVALUATION PROTOCOLS

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

SOURCES

1) California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx. Accessed December 2018.
2) Database for UES Measures, Regional Technical Forum, Display Case Motion Sensors, v3.3. https://nwcouncil.box.com/s/brl01usbhxvtrjbp0i2xcqk016lndfd1
3) 2021 Pennsylvania TRM. Table 3-8: Interactive Factors for All Bulb Types.
4) Theobald, M. A., Emerging Technologies Program: Application Assessment Report #0608, LED Supermarket Case Lighting Grocery Store, Northern California, Pacific Gas and Electric Company, January 2006. Assumes 6,205 annual operating hours and 50,000 lifetime hours. Most case lighting runs continuously (24/7) but some can be controlled. 6,205 annual hours of use can be used to represent the mix. Using grocery store hours of use (4,660 hr) is too conservative since case lighting is not tied to store lighting. http://www.etcc-ca.com/sites/default/files/OLD/images/stories/pdf/ETCC_Report_204.pdf

3.5.18 Refrigeration Economizers

Target Sector	Commercial and Industrial Establishments
Measure Unit	Economizer
Measure Life	15 years Source 1
Measure Vintage	Retrofit

Eligibility

This measure applies to economizers installed on a walk-in refrigeration system. Economizers bring in outside air when weather conditions allow, rather than operating the compressor, thereby saving energy. This measure includes economizers with evaporator fan controls plus a circulation fan and without a circulation fan.

Walk-in refrigeration system evaporator fans run 24 hours per day for 365 days per year to provide cooling when the compressor is running and air circulation when the compressor is not running. However, evaporator fans are inefficient for air circulation, and it is more efficient to install an evaporator fan control system to turn off the evaporator fans when the compressor is not running and turn on an efficient 35-watt fan to provide air circulation.

Commented [SA64]: Frankline Energy

Except during active defrost; based on defrost controls work paper, (4) 20 minute defrosts per day. Fans run 22.67 hrs per day

Algorithms

With Fan Control Installed

$$\Delta kWh = [HP \times kWh_{cond}] + \left[\left((kW_{evap} \times N_{fans}) - kW_{Circ}\right) \times HRS \times DC_{Comp} \times BF\right] - [kW_{econ} \times DC_{econ} \times HRS]$$

$$\Delta kW_{peak} = 0\ kW$$

Without Fan Control Installed

$$\Delta kWh = [HP \times kWh_{cond}] - [kW_{econ} \times DC_{econ} \times HRS]$$

$$\Delta kW_{peak} = 0\ kW$$

Definition of Terms

Table 3-124: Terms, Values, and References for Refrigeration Economizers

Term	Unit	Values	Source
HP, Horsepower of the compressor	*HP*	Nameplate	EDC Data Gathering
kWh_{cond}, Condensing unit savings, per hp	kWh/HP	Default values from Table 3-125	2
kW_{evap}, Connected load kW of each evaporator fan	kW	Nameplate Input Wattage	EDC Data Gathering
		Default: 0.123 kW	3
N_{fans}, Number of fans	*None*	EDC Data Gathering	EDC Data Gathering
kW_{Circ}, Connected load of the circulating fan	kW	EDC Data Gathering	EDC Data Gathering
		Default: 0.035 kW	4
HRS, Annual hours that the economizer operates	$\frac{Hours}{Year}$	Default values from Table 3-125	5
DC_{Comp}, Duty cycle of the compressor	*None*	50%	6
BF, bonus factor for reduced cooling load from running the evaporator fan less	*None*	Default: 1.3	7
kW_{econ}, Connected load of the economizer fan	kW	Nameplate Input Wattage	EDC Data Gathering
		Default: 0.227 kW	8
DC_{econ}, Duty cycle of the economizer fan on days that are cool enough for the economizer to be working	*None*	EDC Data Gathering	EDC Data Gathering
		Default: 63%	9

Table 3-125: Hours and kWh Savings per HP for Refrigeration Economizers

City	Hours	kWh_{cond} Condensing unit savings, per HP		
		Hermetic / Semi-Hermetic	Scroll	Discus
Allentown	1,674	835	737	698
Binghamton	2,254	1,098	969	918
Bradford	2,721	1,306	1,153	1,092
Eerie	1,931	955	842	799
Harrisburg	1,458	766	676	641
Philadelphia	1,223	625	551	523
Pittsburg	1,614	819	723	685
Scranton	1,860	924	816	773
Williamsport	1,741	852	752	713

Default Savings

There are no default savings for this measure.

Evaluation Protocol

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) Efficiency Vermont Technical Reference User Manual (TRM), March 16, 2015. "Refrigeration Economizer" measure, page 129. https://puc.vermont.gov/sites/psbnew/files/doc_library/ev-technical-reference-manual.pdf. Accessed December 2018.
2) Analysis based on TMY3 weather bin data for each location. Assume 5HP compressor size used to develop kWh/HP value. No floating head pressure controls and compressor is located outdoors.
3) Illinois Statewide Technical Reference Manual v7.0, 4.6.8 Refrigeration Economizers. Based on a weighted average of 80% shaded pole motors at 132 watts and 20% PSC motors at 88 watts. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_7/Final_9-28-18/IL-TRM_Effective_010119_v7.0_Vol_2_C_and_I_092818_Final.pdf. Accessed December 2018.
4) Wattage of fan used by Freeaire and Cooltrol. This fan is used to circulate air in the cooler when the evaporator fan is turned off. As such, it is not used when fan control is not present.

5) Economizer hours are based on a 38° F cooler setpoint, with a 5-degree economizer deadband. They were calculated by using TMY3 weather bin data for each location (number of hours < 33° F at each location is the Hours value).
6) A 50% duty cycle is assumed based on examination of duty cycle assumptions from Richard Travers (35%-65%), Cooltrol (35%-65%), Natural Cool (70%), Pacific Gas & Electric (58%). Also, manufacturers typically size equipment with a built-in 67% duty factor and contractors typically add another 25% safety factor, which results in a 50% overall duty factor (as referenced by the Efficiency Vermont, Technical Reference User Manual).
7) Bonus factor (1 + 1/3.5) assumes COP of 3.5, based on the average of standard reciprocating and discus compressor efficiencies with a Saturated Suction Temperature of 20°F and a condensing temperature of 90°F.
8) The 227 watts for an economizer is calculated from the average of three manufacturers: Freeaire (186 Watts), Cooltrol (285 Watts), and Natural Cool (218 Watts).
9) Average of two manufacturer estimates of 50% and 75%.

Commented [SA65]: Franklin Energy

COP seems high based on values used for other measures. Consider utilizing consistent COP for cooler or freezer applications. Based on temperature information in work paper, economizers are for coolers – COP used in other work papers is closer to 2.5 (Floating Head Pressure Controls)

3.6 APPLIANCES

3.6.1 ENERGY STAR CLOTHES WASHER

Target Sector	Commercial and Industrial Establishments
Measure Unit	Clothes Washer
Measure Life	11.3 years for Multifamily; 7.1 years for Laundromats Source 1
Measure Vintage	Replace on Burnout

This protocol discusses the calculation methodology and the assumptions regarding baseline equipment, efficient equipment, and usage patterns used to estimate annual energy savings expected from the replacement of a standard clothes washer with an ENERGY STAR clothes washer with a minimum Modified Energy Factor (MEF_{J2}) of ≥ 2.2 $(ft^3 \times cycle)/kWh$. Source 2 The Federal efficiency standard is ≥ 1.35 $(ft^3 \times cycle)/kWh$ for Top Loading washers and ≥ 2.0 $(ft^3 \times cycle)/kWh$ for Front Loading washers. Source 1

ELIGIBILITY

This protocol documents the energy savings attributed to efficient clothes washers meeting ENERGY STAR or better in small commercial applications. This protocol is limited to clothes washers in laundry rooms of multifamily complexes and commercial Laundromats.

ALGORITHMS

The general form of the equation for the ENERGY STAR Clothes Washer measure savings algorithm is:

$$Total\ Savings = Number\ of\ Clothes\ Washers \times Savings\ per\ Clothes\ Washer$$

To determine resource savings, the per-unit estimates in the algorithms will be multiplied by the number of clothes washers.

Per unit energy and demand savings are obtained through the following calculations:

$$\Delta kWh = \left[\left(HE_{t,base} + ME_{t,base} + D_{e,base}\right) - \left(HE_{t,ee} + ME_{t,ee} + D_{e,ee}\right)\right] \times N$$

$$\Delta kW_{peak} = \Delta kWh \times UF$$

Where:

$$D_e = LAF \times WGHT_{max} \times DEF \times DUF \times (\mathrm{RMC} - 4\%)$$

$$\mathrm{RMC} = (-0.156 \times MEF_{J2}) + 0.734$$

$$HE_t = \left(\frac{Cap}{MEF_{J2}}\right) - ME_t - D_e$$

The algorithms used to calculate energy savings are taken from the Energy Conservation Program: Test Procedures for Clothes Washers; Final rule.[Source 3] Commercial clothes washer per-cycle energy consumption is composed of three components: water-heating energy, machine energy, and drying energy. DOE established the annual energy consumption of commercial clothes washers by multiplying the per-cycle energy and water use by the number of cycles per year.

In the above equations, MEF_{J2} is the Modified Energy Factor, which is the energy performance metric for clothes washers. MEF_{J2} is defined as:

> *MEF_{J2} is the quotient of the capacity of the clothes container, C, divided by the total clothes washer energy consumption per cycle, with such energy consumption expressed as the sum of the machine electrical energy consumption, M, the hot water energy consumption, E, and the energy required for removal of the remaining moisture in the wash load, D. The higher the value, the more efficient the clothes washer is. The equation is shown below and the metric units are ft3/kWh/cycle:*
> $MEF_{J2} = \frac{C}{M+E+D}$. [Source 2]

The following steps should be taken to determine per-cycle energy consumption for top-loading and front-loading commercial clothes washers for both old and new clothes washers. Per-cycle energy use is disaggregated into water heating, machine, and clothes drying.

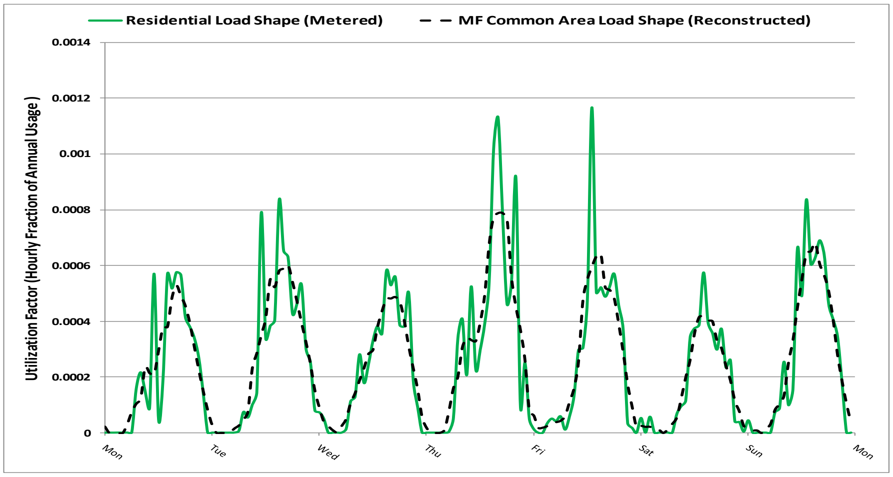
1) Calculate the remaining moisture content (RMC) based on the relationship between RMC and MEF.
2) Calculate the per-cycle clothes-drying energy use using the equation that determines the per-cycle energy consumption for the removal of moisture.
3) Use the per-cycle machine energy use value of 0.133 $kWh/cycle$ for MEFs up to 1.40 and 0.114 $kWh/cycle$ for MEFs greater than 1.40.[Source 1]
4) With the per-cycle clothes dryer and machine energy known, determine the per-cycle water-heating energy use by first determining the total per-cycle energy use (the clothes container volume divided by the MEF) and then subtracting from it the per-cycle clothes-drying and machine energy.

The utilization factor, (UF) is equal to the average energy usage between noon and 8PM on summer weekdays to the annual energy usage. The utilization rate is derived as follows:

1) Obtain normalized, hourly load shape data for residential clothes washing.
2) Smooth the load shape by replacing each hourly value with a 5-hour average centered about that hour. This step is necessary because the best available load shape data exhibits erratic behavior commonly associated with metering of small samples. The smoothing out effectively simulates diversification.
3) Take the UF to be the average of all load shape elements corresponding to the hours between noon and 8PM on weekdays from June to September.

The value is obtained using the June-September, weekday noon to 8 PM average of the normalized load shape values associated with residential clothes washers. As an example the following example if provided from PG&E service territory (northern CA). Although Northern CA is far from PA, the load shape data is the best available at the time and the temporal dependence of washer usage is not expected to have a strong geographical dependency. Figure 3-2 shows the utilization factor for each hour of a sample week in July. Because the load shape data derived from monitoring of in-house clothes washers is being imputed to multifamily laundry room washers (which have higher utilization rates), it is important to check that the resulting minutes of usage per hour is significantly smaller than 60. If the minutes of usage per hour approaches 60, then it should be assumed that the load shape for multi-family laundry room clothes washers must be different than the load shape for in-house clothes washers. The maximum utilization per hour is 36.2 minutes.[Source 4]

Figure 3-2: Utilization factor for a sample week in July[136]



[136] The solid green profile is derived from a normalized load shape based on metering of residential in-unit dryers. The dashed black profile is a smoothed version of the green profile and represents the utilization factors for common laundry facilities in multifamily establishments.

DEFINITION OF TERMS

Table 3-126: Terms, Values, and References for Commercial Clothes Washers

Term	Unit	Values	Source
MEF_{J2}, Base Federal Standard Modified Energy Factor	*None*	Top loading: 1.35 Front loading: 2.0	1
MEF_{J2}, Modified Energy Factor of ENERGY STAR Qualified Washing Machine	*None*	Nameplate	EDC Data Gathering
	None	Default: 2.2	2
HE_t, Per-cycle water heating consumption	$\frac{kWh}{cycle}$	Calculation	Calculation
D_e, Per-cycle energy consumption for removal of moisture i.e. dryer energy consumption	$\frac{kWh}{cycle}$	Calculation	Calculation
ME_t, Per-cycle machine electrical energy consumption	$\frac{kWh}{cycle}$	0.114	1
Cap_{base}, Capacity of baseline clothes washer	ft^3	Nameplate	EDC Data Gathering
		Default: 3.44	5
Cap_{ee}, Capacity of efficient clothes washer	ft^3	Nameplate	EDC Data Gathering
		Default: 3.44	5
LAF, Load adjustment factor	*None*	0.52	1
DEF, Nominal energy required for clothes dryer to remove moisture from clothes	$\frac{kWh}{lb}$	0.5	1
DUF, Dryer usage factor, percentage of washer loads dried in a clothes dryer	*None*	0.91	3
$WGHT_{max}$, Maximum test-load weight	$\frac{lbs}{cycle}$	14.1	3
RMC, Remaining moisture content	lbs	Calculation	Calculation
N, Number of cycles per year	*Cycle*	Multifamily: 1,074 Laundromats: 1,483	1
UF, Utilization Factor	*None*	0.0002382	4

DEFAULT SAVINGS

The default savings for the installation of a washing machine with a MEF_{J2} of 2.2 or higher is dependent on the energy source for the washer. Table 3-128 through Table 3-131 show savings for ENERGY STAR washing machines with different combinations of water heater and dryer types in multifamily buildings and laundromats. The values are based on the difference between the baseline clothes washer meeting federal efficiency standards and that of a front loading washer[137] which meets ENERGY STAR standards of ≥ 2.2 $(ft^3 \times cycle)/kWh$.

[137] ENERGY STAR-qualified commercial clothes washers are likely to be front-loading units because there are no top-loading commercial clothes washers at this time which have been certified by DOE as meeting the standards.

For clothes washers where fuel mix is unknown, calculate default savings using the algorithms below and EDC specific saturation values. For EDCs where saturation information is not accessible, use "Default values" described in Table 3-128 through Table 3-131.

$$ESav_{cw} = kWh_{gwh-gd} \times \%GWH - GD_{cw} + kWh_{gwh-ed} \times \%GWH - ED_{cw} + kWh_{ewh-gd} \times \%EWH - GD_{cw} + kWh_{ewh-ed} \times \%EWH - ED_{cw}$$

Where:

kWh_{gwh-gd}	= Energy savings for clothes washers with gas water heater and non-electric dryer fuel from tables below
kWh_{gwh-ed}	= Energy savings for clothes washers with gas water heater and electric dryer fuel from tables below
kWh_{ewh-gd}	= Energy savings for clothes washers with electric water heater and non-electric dryer fuel from tables below
kWh_{ewh-ed}	= Energy savings for clothes washers with electric water heater and electric dryer fuel from tables below
$\%GWH - GD_{cw}$	= Percent of clothes washers with gas water heater and non-electric dryer fuel
$\%GWH - ED_{cw}$	= Percent of clothes washers with gas water heater and electric dryer fuel
$\%EWH - GD_{cw}$	= Percent of clothes washers with electric water heater and non-electric dryer fuel
$\%EWH - ED_{cw}$	= Percent of clothes washers with electric water heater and electric dryer fuel

Table 3-127: Fuel Shares for Water Heaters and Dryers

Equipment Type	Electric	Non-Electric
Water Heaters Source 6	34%	66%
Clothes Dryers Source 7	52%	48%

Table 3-128: Default Savings for Replacing Top-Loading Clothes Washer in Multifamily Buildings with ENERGY STAR Clothes Washer

Fuel Source	Cycles/ Year	Energy Savings (kWh)	Peak Demand Savings (kW)
Electric Hot Water Heater, Electric Dryer	1,074	630	0.15
Electric Hot Water Heater, Gas Dryer	1,074	436	0.104
Gas Hot Water Heater, Electric Dryer	1,074	193	0.046
Gas Hot Water Heater, Gas Dryer	1,074	0	0
Default (34% Electric WH 52% Electric Dryer)	1,074	248.6	0.059

Table 3-129: Default Savings for Replacing Front-Loading Clothes Washer in Multifamily Buildings with ENERGY STAR Clothes Washer

Fuel Source	Cycles/ Year	Energy Savings (kWh)	Peak Demand Savings (kW)
Electric Hot Water Heater, Electric Dryer	1,074	168	0.04
Electric Hot Water Heater, Gas Dryer	1,074	113	0.027
Gas Hot Water Heater, Electric Dryer	1,074	55	0.013
Gas Hot Water Heater, Gas Dryer	1,074	0	0
Default (34% Electric WH 40% Electric Dryer)	1,074	67	0.016

Table 3-130: Default Savings for Replacing Top-Loading Clothes Washer in Laundromats with ENERGY STAR Clothes Washer

Fuel Source	Cycles/ Year	Energy Savings (kWh)	Peak Demand Savings (kW)
Electric Hot Water Heater, Electric Dryer	1,483	870	0.207
Electric Hot Water Heater, Gas Dryer	1,483	603	0.144
Gas Hot Water Heater, Electric Dryer	1,483	267	0.064
Gas Hot Water Heater, Gas Dryer	1,483	0	0
Default (0% Electric WH 0% Electric Dryer)	1,483	0	0

Table 3-131: Default Savings for Replacing Front-Loading Clothes Washer in Laundromats with ENERGY STAR Clothes Washer

Fuel Source	Cycles/ Year	Energy Savings (kWh)	Peak Demand Savings (kW)
Electric Hot Water Heater, Electric Dryer	1,483	232	0.055
Electric Hot Water Heater, Gas Dryer	1,483	155	0.037
Gas Hot Water Heater, Electric Dryer	1,483	77	0.018
Gas Hot Water Heater, Gas Dryer	1,483	0	0
Default (0% Electric WH 0% Electric Dryer)	1,483	0	0

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with

verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) Energy Conservation Program: Energy Conservation Standards for Commercial Clothes Washers; Final Rule. https://www.regulations.gov/document?D=EERE-2012-BT-STD-0020-0037
2) Energy Star Clothes Washers Key Product Criteria. https://www.energystar.gov/products/appliances/clothes_washers/key_product_criteria
3) Energy Conservation Program: Test Procedures for Clothes Washers; Final rule. https://www.regulations.gov/document?D=EERE-2013-BT-TP-0009-0009
4) Annual hourly load shapes taken from Energy Environment and Economics (E3), Reviewer2: http://www.ethree.com/cpuc_cee_tools.html. The average normalized usage for the hours noon to 8 PM, Monday through Friday, June 1 to September 30 is 0.000243
5) Based on the average commercial clothes washer volume of all units meeting ENERGY STAR criteria listed in the ENERGY STAR database of certified products accessed on 11/15/2018. https://www.energystar.gov/productfinder/product/certified-commercial-clothes-washers/results.
6) Pennsylvania Act 129 2018 Non-Residential Baseline Study, http://www.puc.pa.gov/Electric/pdf/Act129/SWE-Phase3_NonRes_Baseline_Study_Rpt021219.pdf
7) Pennsylvania Act 129 2018 Residential Baseline Study, http://www.puc.pa.gov/Electric/pdf/Act129/SWE-Phase3_Res_Baseline_Study_Rpt021219.pdf

3.6.2 ENERGY STAR Bathroom Ventilation Fan in Commercial Applications

Target Sector	Commercial and Industrial Establishments
Measure Unit	Number of Fans Installed
Measure Life	12 years Source 1
Measure Vintage	Replace on Burnout, Early Replacement, Retrofit, New Construction

This protocol covers the energy and demand savings associated with installing ENERGY STAR certified bathroom ventilation fans to replace conventional bathroom ventilation fans in a non-residential application. ENERGY STAR certifies ventilation fans based on minimum efficacy (CFM/W) and maximum allowable sound level (sones). This certification may include fans that are appropriate for light commercial applications but does not include whole-house fans or attic ventilators.[Source 2]

Eligibility

This measure requires the installation of an ENERGY STAR certified bathroom ventilation fan in a commercial or industrial facility. See Table 3-132 for minimum efficacy and maximum sound level eligibility requirements.

Table 3-132: Criteria for ENERGY STAR Certified Residential Bathroom Fans Source 2

Product Type	Rated Airflow Range (CFM)	Minimum Efficacy Level (CFM/W)*	Maximum Allowable Sound Level (Sones)*
Bathroom and Utility Room Fans	10 – 89	2.8	2.0
	90 – 200	3.5	2.0
	201 - 500	4.0	3.0
*Products will meet requirements at all speeds, based on static pressure reference measurement as specified in Section 4.C. of the ENERGY STAR specification.[Source 2]			

Algorithms

The annual energy and peak demand savings are obtained through the following formulas:

$$\Delta kWh = CFM * \left(\frac{1}{\eta_{base}} - \frac{1}{\eta_{ee}}\right) * HOU * \frac{1}{1{,}000}$$

$$\Delta kW_{peak} = CFM * \left(\frac{1}{\eta_{base}} - \frac{1}{\eta_{ee}}\right) * CF * \frac{1}{1{,}000}$$

Definition of Terms

Table 3-133: Terms, Values, and References for ENERGY STAR Bathroom Ventilation Fans

Term	Unit	Values	Source
CFM, Nominal capacity of the exhaust fan	CFM	EDC Data Gathering Default ranges in Table 3-134	3
η_{base}, Baseline fan efficacy	CFM/W	EDC Data Gathering Default = 2.6	4
η_{ee}, ENERGY STAR fan efficacy	CFM/W	EDC Data Gathering Default = 5.1	4
HOU, Annual hours of use	Hours/year	EDC Data Gathering Default = 2,870	5
$\frac{1}{1{,}000}$, watts to kilowatt conversion factor	$\frac{kW}{W}$	$\frac{1}{1{,}000}$	-
CF, Coincidence factor	None	EDC Data Gathering Default = 0.62	6

Default Savings

Table 3-134: Default Savings for ENERGY STAR Bathroom Ventilation Fans in Commercial Applications

Capacity Range (CFM)	Assumed Capacity (CFM)	Energy Savings (kWh)	Peak Demand Reduction (kW)
10 – 89	70	37.9	0.0082
90 – 150	110	59.5	0.0129
151 – 250	175	94.7	0.0205
251 – 500	350	189.4	0.0409

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) Analysis of Standard Options for Residential Exhaust Fans, Page 3. Davis Energy Group. April 27, 2004. http://www.energy.ca.gov/appliances/2003rulemaking/documents/case_studies/CASE_Res_Exhaust_Fans.pdf
2) ENERGY STAR® Program Requirements Product Specification for Residential Ventilating Fans, Eligibility Criteria Version 4.0. Effective October 1, 2015. https://www.energystar.gov/sites/default/files/asset/document/Vent%20Fans%20V4%200%20Specification_Clarification_0.pdf
3) Efficiency Vermont, Technical Reference User Manual (TRM), March 16, 2015. Pages 52-53. Typical sizes assumed within the ranges given in Table 3-134.
4) Default fan efficacies are based on average values for non-ENERGY STAR and ENERGY STAR, 10-500 CFM Bathroom Exhaust Fans from the Home Ventilating Institute's *HVI-Certified Products Directory*. Updated November 1, 2016. http://hvi.org/proddirectory/index.cfm Accessed November 10, 2016.
5) Efficiency Vermont, Technical Reference User Manual (TRM), March 16, 2015. Page 52. Median run-hours of fans installed through Efficiency Vermont custom projects 2008-2011.
6) 0.62 represents the simple average of all coincidence factors listed in the 2015 Mid-Atlantic TRM. Estimated assuming coincidence factors from EmPOWER Maryland DRAFT Final Impact Evaluation Report Evaluation Year 4 (June 1, 2012 – May 31, 2013) Commercial & Industrial Prescriptive & Small Business Programs, Navigant, March 31, 2014 weighted by building type floor space for the Northeast census region from the Commercial Building Energy Consumption Survey, US Energy Information Administration, 2003.

3.7 Food Service Equipment

3.7.1 ENERGY STAR Ice Machines

Target Sector	Commercial and Industrial Establishments
Measure Unit	Ice Machine
Measure Life	8 Years Source 1
Measure Vintage	Replace on Burnout

Eligibility

This measure applies to the installation of a high-efficiency ice machine as either a new item or replacement for an existing unit. The machine must be air-cooled batch-type or continuous ice makers to qualify, which can include self-contained, ice-making heads, or remote-condensing units. The baseline equipment is a commercial ice machine that meets federal equipment standards. The efficient machine must conform to the minimum ENERGY STAR efficiency requirements and meet the ENERGY STAR requirements for water usage given under the same criteria.

Algorithms

The energy savings are dependent on the capacity of ice produced on a daily basis and the duty cycle. A machine's capacity is generally reported as an ice harvest rate, or amount of ice produced each day.

$$\Delta kWh = \frac{(kWh_{base} - kWh_{ee})}{100} \times H \times 365 \times D$$

$$\Delta kW_{peak} = \frac{\Delta kWh}{8760 \times D} \times CF$$

Definition of Terms

The reference values for each component of the energy impact algorithm are shown in Table 3-135. A default duty cycle (D) is provided as based on referenced values from several studies, however, EDC data gathering may be used to adjust the duty cycle for custom applications.

Table 3-135: Terms, Values, and References for High-Efficiency Ice Machines

Term	Unit	Values	Source
kWh_{base}, Baseline ice machine energy usage per 100 lbs. of ice	$\frac{kWh}{100\ lbs}$	Table 3-136, Table 3-137	2
kWh_{ee}, High-efficiency ice machine energy usage per 100 lbs. of ice	$\frac{kWh}{100\ lbs}$	Table 3-138, Table 3-139	3
H, Ice harvest rate per 24 hrs.	$\frac{lbs}{day}$	Manufacturer Specs	EDC Data Gathering
D, Duty cycle of ice machine expressed as a percentage of time machine produces ice	*None*	Custom	EDC Data Gathering
		Default: 0.57	4
365, Days per year	$\frac{Days}{year}$	365	Conversion Factor
100, Conversion to obtain energy per pound of ice	$\frac{lbs}{100\ lbs}$	100	Conversion Factor
8760, Hours per year	$\frac{Hours}{year}$	8,760	Conversion Factor
Ice Machine Type	*None*	Manufacturer Specs	EDC Data Gathering
CF, Coincidence Factor	*Decimal*	0.937	4

Table 3-136: Batch-Type Ice Machine Baseline Efficiencies

Ice Machine Type	Ice Harvest Rate (H) $\left(\frac{lbs}{day}\right)$	Baseline Energy Use per 100 lbs. of Ice (kWh_{base})
Ice-Making Head	< 300	10 - 0.01233*H
	≥ 300 and < 800	7.05 - 0.0025*H
	≥ 800 and < 1,500	5.55 - 0.00063*H
	≥ 1,500 and < 4,000	4.61
Remote-Condensing w/out remote compressor	≥ 50 and < 1,000	7.97 - 0.00342*H
	≥ 1,000 and < 4,000	4.55
Remote-Condensing with remote compressor	< 942	7.97 - 0.00342*H
	≥ 942 and < 4,000	4.75
Self-Contained	< 110	14.79 - 0.0469*H
	≥ 110 and < 200	12.42 - 0.02533*H
	≥ 200 and < 4,000	7.35

Table 3-137: Continuous Type Ice Machine Baseline Efficiencies

Ice Machine Type	Ice Harvest Rate (H) $\left(\frac{lbs}{day}\right)$	Baseline Energy Use per 100 lbs. of Ice (kWh_{base})
Ice-Making Head	< 310	9.19 - 0.00629*H
	≥ 310 and < 820	8.23 - 0.0032*H
	≥ 820 and < 4,000	5.61
Remote-Condensing w/out remote compressor	< 800	9.7 - 0.0058*H
	≥ 800 and < 4,000	5.06
Remote-Condensing with remote compressor	< 800	9.9 - 0.0058*H
	≥ 800 and < 4,000	5.26
Self-Contained	< 200	14.22 - 0.03*H
	≥ 200 and < 700	9.47 - 0.00624*H
	≥ 700 and < 4,000	5.1

Table 3-138: Batch-Type Ice Machine ENERGY STAR Efficiencies

Ice Machine Type	Ice Harvest Rate (H) $\left(\frac{lbs}{day}\right)$	Baseline Energy Use per 100 lbs. of Ice (kWh_{ee})
Ice-Making Head	H < 300	≤ 9.20 – 0.01134H
	300 ≤ H ≤ 800	≤ 6.49 – 0.0023H
	800 ≤ H ≤ 1,500	≤ 5.11 – 0.00058H
	1,500 ≤ H ≤ 4,000	≤ 4.24
Remote-Condensing Unit	H < 988	≤ 7.17 – 0.00308H
	988 ≤ H ≤ 4,000	≤ 4.13
Self-Contained (SCU)	H < 110	≤ 12.57 – 0.0399H
	110 ≤ H ≤ 200	≤ 10.56 – 0.0215H
	200 ≤ H ≤ 4,000	≤ 6.25

Table 3-139: Continuous Type Ice Machine ENERGY STAR Efficiencies

Ice Machine Type	Ice Harvest Rate (H) $\left(\frac{lbs}{day}\right)$	Baseline Energy Use per 100 lbs. of Ice (kWh_{ee})
Ice-Making Head	H < 310	≤ 7.90 – 0.005409H
	310 ≤ H ≤ 820	≤ 7.08 – 0.002752H
	820 ≤ H ≤ 4,000	≤ 4.82
Remote-Condensing Unit	H < 800	≤ 7.76 – 0.00464H
	800 ≤ H ≤ 4,000	≤ 4.05
Self-Contained (SCU)	H < 110	≤ 12.37 – 0.0261H
	200 ≤ H ≤ 700	≤ 8.24 – 0.005492H
	700 ≤ H ≤ 4,000	≤ 4.44

Default Savings

There are no default savings associated with this measure.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) ENERGY STAR. US Environmental Protection Agency and US Department of Energy. ENERGY STAR Commercial Kitchen Equipment Calculator.

2) Energy Conservation Program: Energy Conservation Standards for Automatic Commercial Ice Makers; Final Rule. Federal Register / Vol. 80, No. 18. January 28, 2015.

3) Commercial Ice Maker Key Product Criteria Version 3.0. https://www.energystar.gov/index.cfm?c=comm_ice_machines.pr_crit_comm_ice_machines

4) Illinois Statewide Technical Reference Manual v7.0 cites a default duty cycle of 57%. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_7/Final_9-28-18/IL-TRM_Effective_010119_v7.0_Vol_2_C_and_I_092818_Final.pdf. Accessed December 2018.

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3.7.2 Controls: Beverage Machine Controls

Target Sector	Commercial and Industrial Establishments
Measure Unit	Machine Control
Measure Life	5 years Source 1, 2
Measure Vintage	Retrofit

Eligibility

This measure is intended for the addition of control systems to existing, non-ENERGY STAR, beverage vending machines. The applicable machines contain refrigerated, non-perishable beverages that are kept at an appropriate temperature. The control systems are intended to reduce energy consumption due to lighting and refrigeration during times of lower customer sales. Typical control systems contain a passive infrared occupancy sensor to shut down the machine after a period of inactivity in the area. The compressor will power on for one to three hour intervals, sufficient to maintain beverage temperature, and when powered on at any time will be allowed to complete at least one cycle to prevent excessive wear and tear. This measure should not be applied to ENERGY STAR qualified vending machines, as they already have built-in controls

The baseline equipment is taken to be an existing standard refrigerated beverage vending machine that does not contain control systems to shut down the refrigeration components and lighting during times of low customer use.

Algorithms

Energy savings are dependent on decreased machine lighting and cooling loads during times of lower customer sales. The savings will be dependent on the machine environment, noting that machines placed in locations such as day-use offices will result in greater savings than those placed in high-traffic areas such as hospitals that operate around the clock. The algorithm below takes into account varying scenarios and can be taken as representative of a typical application.

$$\Delta kWh = \frac{Watts_{base}}{1{,}000} * HOURS * ESF$$

$$\Delta kW_{peak} = 0$$

There are no peak demand savings because this measure is aimed to reduce demand during times of low beverage machine use, which will typically occur during off-peak hours.

Definition of Terms

Table 3-140: Terms, Values, and References for Beverage Machine Controls

Term	Unit	Values	Source
$Watts_{base}$, Wattage of beverage machine	*W*	EDC Data Gathering Default for refrigerated beverage vending machine: 400 Default for glass front refrigerated cooler: 460	EDC Data Gathering 1
$HOURS$, Annual hours of operation	$\frac{Hours}{Year}$	EDC Data Gathering Default: 8,760	EDC Data Gathering
ESF, Energy savings factor	*None*	EDC Data Gathering Default for refrigerated beverage vending machine: 46% Default for glass front refrigerated cooler: 30%	EDC Data Gathering 1

Default Savings

The decrease in energy consumption due to the addition of a control system will depend on the number of hours per year during which lighting and refrigeration components of the beverage machine are powered down. The average decrease in energy use from refrigerated beverage vending machines with control systems installed is 46%.[Source 1] It should be noted that various studies found savings values ranging between 30-65%, most likely due to differences in customer occupation.

The default annual energy savings is shown below. Where it is determined that the default energy saving factor (ESF) or default baseline energy consumption ($Watts_{base}$) is not representative of specific applications, EDC data gathering can be used to determine an application-specific energy savings factor (ESF) and/or baseline energy consumption ($Watts_{base}$) for use in the Energy Savings algorithm.

Table 3-141: Default Savings for Beverage Machine Controls

Equipment Type	Annual Energy Savings (ΔkWh)	Peak Demand Savings (ΔkW_{peak})
Refrigerated beverage vending machine	1,611.8	0
Glass front refrigerated cooler	1,208.9	0

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) Illinois Statewide Technical Reference Manual v7.0, September 28, 2018, 4.6.2 Beverage and Snack Machine Controls, which sources USA Technologies Energy Management Product Sheets, July 2006; cited September 2009. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_7/Final_9-28-18/IL-TRM_Effective_010119_v7.0_Vol_2_C_and_I_092818_Final.pdf

2) Deru, M., et al., (2003), *Analysis of NREL Cold-Drink Vending Machines for Energy Savings*, National Renewable Energy Laboratory, NREL/TP-550-34008, http://www.nrel.gov/docs/fy03osti/34008.pdf

3.7.3 Controls: Snack Machine Controls

Target Sector	Commercial and Industrial Establishments
Measure Unit	Machine Control
Measure Life	5 years Source 1
Measure Vintage	Retrofit

A snack machine controller is an energy control device for non-refrigerated snack vending machines. The controller turns off the machine's lights based on times of inactivity. This protocol is applicable for conditioned indoor installations.

Eligibility

This measure is targeted to non-residential customers who install controls to non-refrigerated snack vending machines. Acceptable baseline conditions are non-refrigerated snack vending machines. Efficient conditions are non-refrigerated snack vending machines with controls.

Algorithms

The energy savings for this measure result from reduced lighting operation.

$$\Delta kWh = \frac{Watts_{base}}{1{,}000} * HOURS * ESF$$

$$\Delta kW_{peak} = 0$$

Definition of Terms

Table 3-142: Terms, Values, and References for Snack Machine Controls

Term	Unit	Values	Source
$Watts_{base}$, Wattage of vending machine	W	EDC Data Gathering Default: 85	EDC Data Gathering 2
$HOURS$, Annual hours of operation	$\frac{Hours}{Year}$	EDC Data Gathering Default: 8,760	EDC Data Gathering
ESF, Energy savings factor	*None*	46%	2

Default Savings

Default energy savings for this measure are 342.5 kWh.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) Measure Life Study, prepared for the Massachusetts Joint Utilities, Energy & Resource Solutions, November 2005.

2) Illinois Statewide Technical Reference Manual v7.0, September 28, 2018. Hours of operation assume operation 24 hours per day, 365 days per year. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_7/Final_9-28-18/IL-TRM_Effective_010119_v7.0_Vol_2_C_and_I_092818_Final.pdf. Accessed December 2018.

3.7.4 ENERGY STAR Electric Steam Cooker

Target Sector	Commercial and Industrial Establishments
Measure Unit	Electric Steam Cooker
Measure Life	12 years Source 1
Measure Vintage	Replace on Burnout

Eligibility

This measure applies to the installation of electric ENERGY STAR steam cookers as either a new item or replacement for an existing unit. Gas steam cookers are not eligible. The steam cookers must meet minimum ENERGY STAR efficiency requirements. A qualifying steam cooker must meet a minimum cooking efficiency of 50 percent and meet idle energy rates specified by pan capacity.

The baseline equipment is a unit with efficiency specifications that do not meet the minimum ENERGY STAR efficiency requirements.

Algorithms

The savings depend on three main factors: pounds of food steam cooked per day, pan capacity, and cooking efficiency.

$$\Delta kWh = \left(\Delta kWh_{cooking} + \Delta kWh_{idle}\right) \times 365$$

$$\Delta kWh_{cooking} = lbsFood \times EnergyToFood \times \left(\frac{1}{Eff_{base}} - \frac{1}{Eff_{ee}}\right)$$

$$\Delta kWh_{idle} = Daily\ kWh_{base} - Daily\ kWh_{ee}$$

$$Daily\ kWh_{base} = \left(Power_{idle,base} \times (1 - \%HOURS_{consteam}) + \%HOURS_{consteam} \times CAPY_{base} \times Qty_{pans} \times \left(\frac{EnergyToFood}{Eff_{base}}\right)\right) \times \left(HOURS_{op} - \left(\frac{lbsFood}{CAPY_{base} \times Qty_{pans}}\right)\right)$$

$$Daily\ kWh_{ee} = Power_{idle,ee} \times (1 - \%HOURS_{consteam}) + \%HOURS_{consteam} \times CAPY_{ee} \times Qty_{pans} \times \left(\frac{EnergyToFood}{Eff_{ee}}\right) \times \left(HOURS_{op} - \left(\frac{lbsFood}{CAPY_{ee} \times Qty_{pans}}\right)\right)$$

$$\Delta kW_{peak} = \frac{\Delta kWh}{EFLH} \times CF$$

Definition of Terms

Table 3-143: Terms, Values, and References for ENERGY STAR Electric Steam Cookers

Term	Unit	Values	Source
$lbsFood$, Pounds of food cooked per day in the steam cooker	lbs	Nameplate	EDC Data Gathering
		Default values in Table 3-144	*2*
$EnergyToFood$, ASTM energy to food ratio; energy (kilowatt-hours) required per pound of food during cooking	$\frac{kWh}{pound}$	0.0308	1
Eff_{ee}, Cooking energy efficiency of the new unit	*None*	Nameplate	EDC Data Gathering
		Default values in Table 3-144	1
Eff_{base}, Cooking energy efficiency of the baseline unit	*None*	See Table 3-144	1
$Power_{idle,base}$, Idle power of the baseline unit	kW	See Table 3-144	4
$Power_{idle,ee}$, Idle power of the new unit	kW	Nameplate	EDC Data Gathering
		Default values in Table 3-144	4
$HOURS_{op}$, assumed daily hours of operation	*Hours*	Nameplate	EDC Data Gathering
		12 hours	1
$\%HOURS_{consteam}$, Percentage of idle time per day the steamer is in continuous steam mode instead of timed cooking. The power used in this mode is the same as the power in cooking mode.	*None*	40%	1
$CAPY_{base}$, Production capacity per pan of the baseline unit	$\frac{lb}{hr}$	See Table 3-144	1
$CAPY_{ee}$, Production capacity per pan of the new unit	$\frac{lb}{hr}$	See Table 3-144	1
Qty_{pans}, Quantity of pans in the unit	*None*	Nameplate	EDC Data Gathering
$EFLH$, Equivalent full load hours per year	$\frac{Hours}{Year}$	4,380	1
CF, Coincidence factor	*Decimal*	0.9	3

Default Savings

Table 3-144: Default Values for Electric Steam Cookers by Number of Pans

# of Pans	Parameter	Baseline Model	Efficient Model	Savings
3	$Power_{idle}$ (kW)	1.000	0.40	---
	$CAPY\ (lb/hr)$	23.3	16.7	---
	$lbsFood$	100	100	---
	Eff	30%	50%	---
	ΔkWh	---	---	9,504
	ΔkW_{peak}	---	---	1.95
4	$Power_{idle}$ (kW)	1.325	0.53	---
	$CAPY\ (lb/hr)$	23.3	16.7	---
	$lbsFood$	128	128	---
	Eff	30%	50%	---
	ΔkWh	---	---	10,172
	ΔkW_{peak}	---	---	2.09
5	$Power_{idle}$ (kW)	1.675	0.67	---
	$CAPY\ (lb/hr)$	23.3	16.7	---
	$lbsFood$	160	160	---
	Eff	30%	50%	---
	ΔkWh	---	---	10,875
	ΔkW_{peak}	---	---	2.23
6	$Power_{idle}$ (kW)	2.000	0.80	---
	$CAPY\ (lb/hr)$	23.3	16.7	---
	$lbsFood$	192	192	---
	Eff	30%	50%	---
	ΔkWh	---	---	11,515
	ΔkW_{peak}	---	---	2.37

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) ENERGY STAR. US Environmental Protection Agency and US Department of Energy. ENERGY STAR Commercial Kitchen Equipment Calculator.

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https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator_0.xlsx

2) Food Service Technology Center (FSTC) 2012, *Commercial Cooking Appliance Technology Assessment*. Pounds of Food Cooked per Day based on the default value for a 3 pan steam cooker (100 lbs from FSTC) and scaled up based on the assumption that steam cookers with a greater number of pans cook larger quantities of food per day.

3) New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs v6, effective date January 1, 2019

4) Illinois Statewide Technical Reference Manual v7.0, September 28, 2018. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_7/Final_9-28-18/IL-TRM_Effective_010119_v7.0_Vol_2_C_and_I_092818_Final.pdf. Accessed December 2018.

3.7.5 ENERGY STAR Combination Oven

Target Sector	Commercial and Industrial Establishments
Measure Unit	Number of Ovens Installed
Measure Life	12 years Source 1
Measure Vintage	Replace on Burnout, Early Replacement, Retrofit, New Construction

A combination oven is a convection oven that includes the added capability to inject steam into the oven cavity and typically offers at least three distinct cooking modes.

Eligibility

To qualify for this measure, the installed equipment must be a new electric combination oven that meets the ENERGY STAR idle rate and cooking efficiency requirements as specified in Table 3-145.Source 2 *P* represents the pan capacity of the oven.

Table 3-145: Combination Oven Eligibility Requirements

Fuel Type	Operation	Idle Rate (kW)	Cooking-Energy Efficiency (%)
Electric	Steam Mode Convection Mode	≤ 0.133P + 0.6400 ≤ 0.080P + 0.4989	≥ 55 ≥ 76

Algorithms

The following algorithms are used to quantify the annual energy and coincident peak demand savings, accounting for the convection-mode cooking energy, the steam-mode cooking energy, and the idle-mode energy consumption.

$$\Delta kWh = (\Delta CookingEnergy_{ConvElec} + \Delta CookingEnergy_{SteamElec} + \Delta IdleEnergy_{ConvElec} + \Delta IdleEnergy_{SteamElec}) * Days * \frac{1}{1{,}000}$$

$$\Delta kW_{peak} = \Delta kWh \,/\, (HOURS * DAYS) * CF$$

Where:

$$\Delta CookingEnergy_{ConvElec} = LB_{Elec} * (EFOOD_{ConvElec} \,/\, ElecEFF_{ConvBase} - EFOOD_{ConvElec} \,/\, ElecEFF_{ConvEE}) * \%_{Conv}$$

$$\Delta CookingEnergy_{SteamElec} = LB_{Elec} * (EFOOD_{SteamElec}/ElecEFF_{SteamBase} - EFOOD_{SteamElec}/ElecEFF_{SteamEE}) * \%_{Steam}$$

$$\Delta IdleEnergy_{ConvElec} = [(ElecIDLE_{ConvBase} * (HOURS - LB_{Elec}/ElecPC_{ConvBase}) * \%_{Conv}) - (ElecIDLE_{ConvEE} * (HOURS - LB_{Elec}/ElecPC_{ConvEE}) * \%_{Conv})]$$

$$\Delta IdleEnergy_{SteamElec} = [(ElecIDLE_{SteamBase} * (HOURS - LB_{Elec}/ElecPC_{SteamBase}) * \%_{Steam}) - (ElecIDLE_{SteamEE} * (HOURS - LB_{Elec}/ElecPC_{SteamEE}) * \%_{Steam})]$$

Definition of Terms

Table 3-146: Terms, Values, and References for ENERGY STAR Combination Ovens

Term	Unit	Values	Source
P, Pan capacity - The number of steam table pans the combination oven is able to accommodate as per the ASTM F-1495-05 standard specification.	Pans	EDC Data Gathering	EDC Data Gathering
$\Delta CookingEnergy_{ConvElec}$, change in total daily cooking energy consumed by electric oven in convection mode	Wh/day	Calculated	1
$\Delta CookingEnergy_{SteamElec}$, change in total daily cooking energy consumed by electric oven in steam mode	Wh/day	Calculated	1
$\Delta IdleEnergy_{ConvElec}$, change in total daily idle energy consumed by electric oven in convection mode	Wh/day	Calculated	1
$\Delta IdleEnergy_{SteamElec}$, change in total daily idle energy consumed by electric oven in convection mode	Wh/day	Calculated	1
$HOURS$, average daily operating hours	Hours/day	EDC Data Gathering Default = 12 hours	1
$DAYS$, annual days of operation	Days/yr	EDC Data Gathering Default = 365	1
$EFOOD_{ConvElec}$, energy absorbed by food product for electric oven in convection mode	W-hr/lb	EDC Data Gathering Default = 73.2	1
LB_{Elec}, estimated mass of food cooked per day for electric oven	lbs/day	EDC Data Gathering Default = 200 (If P < 15) or 250 (If P ≥ 15)	1
$ElecEFF$, cooking energy efficiency of electric oven	%	EDC Data Gathering Default: Table 3-147	1
$\%_{Conv}$, percentage of time in convection mode	%	EDC Data Gathering Default = 50	1

Term	Unit	Values	Source
$EFOOD_{SteamElec}$, energy absorbed by food product for electric oven in steam mode	W-hr/lb	EDC Data Gathering Default = 30.8	1
$\%_{steam}$, percentage of time in steam mode	%	$1 - \%_{conv}$	1
$ElecIDLE_{ConvBase}$, Idle energy rate of baseline electric oven in convection mode	W	EDC Data Gathering Default: Table 3-148	1
$ElecIDLE_{SteamBase}$, Idle energy rate of baseline electric oven in steam mode	W	EDC Data Gathering Default: Table 3-148	1
$ElecPC_{ConvBase}$, production capacity of baseline electric oven in convection mode	lbs/hr	EDC Data Gathering Default: Table 3-149	1
$ElecPC_{SteamBase}$, production capacity of baseline electric oven in steam mode	lbs/hr	EDC Data Gathering Default: Table 3-149	1
$ElecIDLE_{ConvEE}$, Idle energy rate of ENERGY STAR electric oven in convection mode	W	$= (0.08 * \mathrm{P} + 0.4989) * 1{,}000$	1
$ElecPC_{ConvEE}$, Production capacity of ENERGY STAR electric oven in convection mode	lbs/hr	EDC Data Gathering Default: Table 3-150	1
$ElecPC_{SteamEE}$, Production capacity of ENERGY STAR electric oven in steam mode	lbs/hr	EDC Data Gathering Default: Table 3-150	1
$ElecIDLE_{SteamEE}$, Idle energy rate of ENERGY STAR electric oven in steam mode	W	$= (0.133 * \mathrm{P} + 0.64) * 1{,}000$	1
$\frac{1}{1{,}000}$, W to kW conversion factor	kW/W	$\frac{1}{1{,}000}$	1
CF, Coincidence factor	None	EDC Data Gathering Default = 0.9	3

Table 3-147: Default Baseline and Efficient-Case Values for ElecEFF

Value	Base	EE
$ElecEFF_{Conv}$	72%	76%
$ElecEFF_{Steam}$	49%	55%

Table 3-148: Default Baseline Values for ElecIDLE

Pan Capacity	Convection Mode ($ElecIDLE_{ConvBase}$)	Steam Mode ($ElecIDLE_{SteamBase}$)
< 15	1,320	5,260
≥ 15	2,280	8,710

Table 3-149: Default Baseline Values for ElecPC

Pan Capacity	Convection Mode ($ElecPC_{ConvBase}$)	Steam Mode ($ElecPC_{SteamBase}$)
< 15	79	126
≥ 15	166	295

Table 3-150: Default Efficient-Case Values for ElecPC

Pan Capacity	Convection Mode ($ElecPC_{ConvEE}$)	Steam Mode ($ElecPC_{SteamEE}$)
< 15	119	177
≥ 15	201	349

Default Savings

There are no default savings for this measure.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) ENERGY STAR, Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment. http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx.
2) ENERGY STAR, Program Requirements Product Specification for Commercial Ovens Eligibility Criteria Version 2.2, https://www.energystar.gov/products/commercial_food_service_equipment/commercial_ovens/key_product_criteria.
3) New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs v6, effective date January 1, 2019

3.7.6 ENERGY STAR Commercial Convection Oven

Target Sector	Commercial and Industrial Establishments
Measure Unit	Number of Convection Ovens Installed
Measure Life	12 years [Source 1]
Measure Vintage	Replace on Burnout, Early Replacement, Retrofit, New Construction

Commercial convection ovens that meet ENERGY STAR requirements[Source 2] utilize improved gaskets for faster and more uniform cooking processes to achieve higher heavy load cooking efficiencies and lower idle energy rates, making them on average about 20 percent more efficient than standard models. The baseline equipment is assumed to be a standard efficiency convection oven with a heavy load efficiency of 65% for both full size (i.e., a convection oven that is capable of accommodating full-size sheet pans measuring 18 x 26 x 1-inch) and 68% for half size (i.e., a convection oven that is capable of accommodating half-size sheet pans measuring 18 x 13 x 1-inch) electric ovens.

Eligibility

This measure targets non-residential customers who purchase and install an electric convection oven that meets ENERGY STAR specifications rather than a non-ENERGY STAR unit. The energy efficient convection oven can be new or rebuilt.

Algorithms

The annual energy savings calculation utilizes the idle energy rate of an ENERGY STAR electric convection oven and a typical electric convection oven, along with estimated annual hours of operation for cooking activities. The energy savings and peak demand reductions are obtained through the following formulas shown below.[Source 1, 2]

$$\Delta kWh = kWh_{base} - kWh_{ee}$$

$$kWh_i = (kWh_{cooking,i} + kWh_{idle,i}) \times DAYS$$

$$kWh_{cooking,i} = LB \times \frac{E_{food}}{EFF_i}$$

$$kWh_{idle,i} = IDLE_i \times (HOURS_{DAY} - \frac{LB}{PC_i})$$

$$\Delta kW_{peak} = \frac{(\Delta kWh)}{HOURS_{DAY} \times DAYS} \times CF$$

Definition of Terms

Table 3-151: Terms, Values, and References for ENERGY STAR Commercial Electric Convection Ovens

Term	Unit	Values	Source
i, Either "base" or "ee" depending on whether the calculation of energy consumption is being performed for the baseline or efficient case, respectively.	None	EDC Data Gathering	---
kWh_{base}, Annual energy usage of the baseline equipment calculated using baseline values	kWh/yr	Calculated	---
kWh_{ee}, Annual energy usage of the efficient equipment calculated using efficient values	kWh/yr	Calculated	---
$kWh_{cooking}$, Daily cooking energy consumption	kWh/day	Calculated	---
kWh_{idle}, Daily idle energy consumption	kWh/day	Calculated	---
$HOURS_{DAY}$, Average daily operating hours	Hours/day	EDC Data Gathering Default = 12	1
$DAYS$, Annual days of operation	Days/yr	EDC Data Gathering Default = 365	1
E_{food}, ASTM energy to food; amount of energy absorbed by the food per pound during cooking	kWh/lb	EDC Data Gathering Default = 0.0732	1
LB, Pounds of food cooked per day	lbs/day	EDC Data Gathering Default = 100	1
EFF, Heavy load cooking energy efficiency	%	EDC Data Gathering Default: Table 3-152	1, 2
$IDLE$, Idle demand rate	kW	Default: Table 3-152	1, 2
PC, Production capacity	lbs/hr	EDC Data Gathering Default: Table 3-152	1, 2
CF, Coincidence factor	None	EDC Data Gathering Default = 0.9	3

Table 3-152: Electric Oven Performance Metrics: Baseline and Efficient Default Values

Parameter	Half Size		Full Size	
	Baseline Model	Efficient Model	Baseline Model	Efficient Model
IDLE	1.03	1.0	2.0	1.6
EFF	68%	71%	65%	71%
PC	45	50	90	90

Default Savings

Table 3-153: Default Unit Savings and Demand Reduction for ENERGY STAR Commercial Electric Convection Ovens.

Parameter	ENERGY STAR Convection Oven Savings	
	ΔkWh	ΔkW
Half Size	192	0.040
Full Size	1,937	0.398

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment. http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx

2) ENERGY STAR Commercial Ovens Version 2.2 Specification. https://www.energystar.gov/products/commercial_food_service_equipment/commercial_ovens/key_product_criteria

3) New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs v6, effective date January 1, 2019

3.7.7 ENERGY STAR Commercial Fryer

Target Sector	Commercial Establishments
Measure Unit	Number of Commercial Fryers Installed
Measure Life	12 years Source 1
Measure Vintage	Replace on Burnout, Early Replacement, Retrofit, New Construction

Commercial fryers that meet ENERGY STAR specifications offer shorter cook times and higher production rates through advanced burner and heat exchanger designs. Standard sized fryers that have earned the ENERGY STAR are about 14 percent more energy efficient than standard models and large vat commercial fryers that have earned the ENERGY STAR are up to 35 percent more energy efficient than non-certified models.

Eligibility

This measure applies to electric ENERGY STAR fryers installed in a commercial kitchen. To qualify for this measure, the customer must install a commercial electric fryer that has earned the ENERGY STAR label.

Algorithms

The annual energy savings calculation utilizes the idle energy rate of ENERGY STAR electric fryers and a typical electric fryer, along with estimated annual hours of operation for cooking activities. Energy savings estimates are provided for both standard and large vat fryers. The unit energy savings and peak demand reduction are obtained through the following formulas:

$$\Delta kWh = kWh_{base} - kWh_{ee}$$

$$kWh_i = (kWh_{cooking,i} + kWh_{idle,i}) \times DAYS$$

$$kWh_{cooking,i} = LB \times \frac{E_{food}}{EFF_i}$$

$$kWh_{idle,i} = IDLE_i \times (HOURS_{Day} - \frac{LB}{PC_i})$$

$$\Delta kW_{peak} = [\Delta kWh \;/\; (HOURS_{Day}\ x\ DAYS)]\ x\ CF$$

Definition of Terms

Table 3-154: Terms, Values, and References for ENERGY STAR Commercial Fryers

Term	Unit	Values	Source
i, Either "base" or "ee" depending on whether the calculation of energy consumption is being performed for the baseline or efficient case, respectively.	None	EDC Data Gathering	---
kWh_{base}, Annual energy usage of the baseline equipment calculated using baseline values	kWh/year	Calculated	---
kWh_{ee}, Annual energy usage of the efficient equipment calculated using efficient values	kWh/year	Calculated	---
$kWh_{cooking}$, Daily cooking energy consumption	kWh/day	Calculated	---
kWh_{idle}, Daily idle energy consumption	kWh/day	Calculated	---
$HOURS_{Day}$, Average daily operating hours	Hours/day	EDC Data Gathering See Table 3-155	1
$DAYS$, Annual days of operation	Days/year	EDC Data Gathering Default = 365	1
E_{food}, ASTM energy to food; amount of energy absorbed by the food per pound during cooking	kWh/lb	EDC Data Gathering Default = 0.167	1
LB, Pounds of food cooked per day	lb/day	EDC Data Gathering Default = 150	1
EFF, Heavy load cooking energy efficiency	%	See Table 3-155	2
$IDLE$, Idle energy rate	kW	See Table 3-155	2
PC, Production capacity	lb/hr	See Table 3-155	1
CF, Coincidence factor	None	EDC Data Gathering Default: 0.9	3

Table 3-155: Electric Fryer Performance Metrics: Baseline and Efficient Default Values

Parameter	Standard Fryer		Large Vat Fryer	
	Baseline Model	Energy Efficient Model	Baseline Model	Energy Efficient Model
$HOURS_{Day}$	16	16	12	12
$IDLE$	1.2	0.80	1.35	1.10
EFF	75%	83%	70%	80%
PC	65	70	100	110

Default Savings

Table 3-156: Default for ENERGY STAR Commercial Electric Fryers

Equipment Type	ΔkWh	ΔkW_{peak}
Standard Fryer	3,126	0.48
Large Vat Fryer	2,536	0.52

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) ENERGY STAR, Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment. http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx.

2) US EPA. Effective October 1, 2016. ENERGY STAR® Program Requirements Product Specification for Commercial Fryers Eligibility Criteria. https://www.energystar.gov/products/commercial_food_service_equipment/commercial_fryers/key_product_criteria

3) New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs v6, effective date January 1, 2019.

3.7.8 ENERGY STAR Commercial Hot Food Holding Cabinet

Target Sector	Commercial and Industrial Establishments
Measure Unit	Number of Hot Food Holding Cabinets Installed
Measure Life	12 years [Source 1]
Measure Vintage	Replace on Burnout, Early Replacement, Retrofit, New Construction

Commercial electric hot food holding cabinet models that meet ENERGY STAR requirements incorporate better insulation to reduce heat loss and may also offer additional energy saving devices such as more precise controls, full-perimeter door gaskets, magnetic door handles, or dutch doors. The insulation of the cabinet also offers better temperature uniformity within the cabinet from top to bottom. This means that qualified hot food holding cabinets are more efficient at maintaining food temperature while using less energy. The baseline equipment is assumed to be a standard efficiency hot food holding cabinet that is not ENERGY STAR certified.

Eligibility

This measure targets non-residential customers who purchase and install a hot food holding cabinet that meets ENERGY STAR specifications rather than a non-ENERGY STAR unit. The energy efficient hot food holding cabinet can be new or rebuilt. It can include glass or solid door cabinets (fully closed compartment with one or more doors).

Algorithms

The annual energy savings calculation utilizes idle energy rates of ENERGY STAR hot food holding cabinet and a typical hot food holding cabinet, along with estimated annual hours of operation. The unit energy savings and peak demand reduction are obtained through the following formulas:

$$\Delta kWh = (IDLE_{base} - IDLE_{ee}) \times 0.001 \times HOURS_{Day} \times DAYS$$

$$\Delta kW_{peak} = [\Delta kWh \; / \; (HOURS_{Day} \; x \; DAYS)] \; x \; CF$$

Definition of Terms

Table 3-157: Terms, Values, and References for ENERGY STAR Commercial Hot Food Holding Cabinets

Term	Unit	Values	Source
$Idle_{base}$, Idle energy rate of the baseline equipment	Watts	EDC Data Gathering (see Table 3-158 Default = 600	1, 2
$Idle_{ee}$, Idle energy rate of the efficient equipment	Watts	EDC Data Gathering (see Table 3-158) Default = 284	1, 2
0.001, Conversion of W to kW	kW/W	0.001	Conversion Factor
$HOURS_{Day}$, Average daily operating hours	Hours/day	EDC Data Gathering Default = 15	1
$DAYS$, annual days of operation	Days/Year	EDC Data Gathering Default = 365	1
V, the internal volume of the holding cabinet	ft^3/unit	EDC Data Gathering	EDC Data Gathering
CF, Coincidence factor	None	0.9	3

Table 3-158: Hot Food Holding Cabinet Performance Metrics: Default Baseline and Efficient Value Equations

Internal Volume	Product Idle Energy Consumption Rate	
	Baseline Model ($IDLE_{base}$)	Efficient Model ($IDLE_{ee}$)
0 < V < 13	40 x V	21.5 x V
13 ≤ V < 28	40 x V	2.0 x V + 254.0
28 ≤ V	40 x V	3.8 x V + 203.5

Default Savings

There are no default savings for this measure.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) ENERGY STAR, Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment. http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx.
2) ENERGY STAR® Program Requirements Product Specification for Commercial Hot Food Holding Cabinets Eligibility Criteria Version 2.0, effective October 1, 2011 https://www.energystar.gov/products/commercial_food_service_equipment/commercial_hot_food_holding_cabinets/key_product_criteria
3) New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs v6, effective date January 1, 2019.

3.7.9 ENERGY STAR Commercial Dishwasher

Target Sector	Commercial and Industrial Establishments
Measure Unit	Dishwasher
Measure Life	10 years Source 1
Measure Vintage	Replace on Burnout or New Construction

This measure describes the energy savings from installing an ENERGY STAR commercial dishwasher in applicable commercial settings. The measure includes stationary rack machines (undercounter; single tank door-type; pot, pan, and utensil; and glasswashing) and conveyor machines (rack and rackless/flight type, multi and single tank). Products must meet idle energy rate and water consumption limits, as determined by both machine type and sanitation approach (chemical/low temp versus high temp).

Eligibility

To be eligible, commercial dishwashers must meet the Version 2.0 ENERGY STAR Program Requirements for Commercial Dishwashers, effective February 1, 2013.Source 2

Algorithms

Electric energy savings are composed of three parts: electric energy savings from the building water heater, electric energy savings from the booster water heater, and idle electric energy savings. Note that if a building only has a natural gas water heater, then there will still be savings from reduction in idle energy.

$$\Delta kWh = \Delta kWh_{WaterHeater} + \Delta kWh_{BoosterHeater} + \Delta kWh_{Idle}$$

$$\Delta kWh_{WaterHeater} = \left((WU_{base} - WU_{ee}) \times RW \times Days\right) \times \frac{\Delta T_{in} \times 1.0\frac{Btu}{lb\cdot°F} \times 8.2\frac{lb}{gal}}{RE \times 3{,}412\frac{kWh}{Btu}}$$

$$\Delta kWh_{BoosterHeater} = \left((WU_{base} - WU_{ee}) \times RW \times Days\right) \times \frac{\Delta T_{in} \times 1.0\frac{Btu}{lb\cdot°F} \times 8.2\frac{lb}{gal}}{RE \times 3{,}412\frac{kWh}{Btu}}$$

$$kWh_{Idle} = \left(kW_{base} \times Days \times (HD - RW \times WT/60\frac{Min}{Hr}\right) - \left(kW_{ee} \times Days \times (HD - \frac{(RW \times WT)}{60\frac{Min}{Hr}}\right)$$

$$\Delta kW_{peak} = \frac{\Delta kWh}{HD \times Days} \times CF$$

Definition of Terms

Table 3-159: Terms, Values, and References for ENERGY STAR Commercial Dishwashers

Term	Unit	Values	Source
WU_{base}, Water use per rack of baseline dishwasher, varies by machine type and sanitation method	*Gallons*	EDC Data Gathering	EDC Data Gathering
		Default: Table 3-160	3
WU_{ee}, Water use per rack of ENERGY STAR dishwasher, varies by machine type and sanitation method	*Gallons*	EDC Data Gathering	EDC Data Gathering
		Default: Table 3-160	3
RW, Number of racks washed per day, varies by machine type and sanitation method	$\frac{Racks\ Washed}{Day}$	EDC Data Gathering	EDC Data Gathering
		Default: Table 3-160	3
$Days$, Annual days of dishwasher consumption per year	$\frac{Days}{Year}$	EDC Data Gathering	EDC Data Gathering
		Default = 365	3
ΔT_{in}, Temperature rise in water delivered by building water heater or booster water heater, value varies by type of water heater source	*°F*	EDC Data Gathering	EDC Data Gathering
		Building WH = 70 Booster WH = 40	3
RE, Recovery efficiency of electric water heater	Decimal	0.98	3
kW_{base}, Idle power draw of baseline dishwasher, varies by machine type and sanitation method	*kW*	EDC Data Gathering	EDC Data Gathering
		Default: Table 3-160	3
HD, Hours per day of dishwasher operation	$\frac{Hours}{Day}$	EDC Data Gathering	EDC Data Gathering
		Default = 18	3
WT, Wash time per dishwasher, varies by machine type and sanitation method	*Minutes*	EDC Data Gathering	EDC Data Gathering,
		Default: Table 3-160	3
kW_{ee}, Idle power draw of ENERGY STAR dishwasher, varies by machine type and sanitation method	*kW*	EDC Data Gathering	EDC Data Gathering
		Default: Table 3-160	3
Density of Water	*lb/gallon*	8.2	4
CF, Coincidence factor	*None*	0.9	5

Table 3-160 shows the default values for water user per rack, racks washed per day, wash time per dishwasher, and idle power draws by machine type and sanitation method.

Table 3-160: Default Inputs for ENERGY STAR Commercial Dishwasher

Machine Type	WU_{base}	WU_{ee}	RW	WT	kW_{base}	kW_{ee}
Low Temperature						
Under Counter	1.73	1.19	75	2.0	0.50	0.50
Stationary Single Tank Door	2.10	1.18	280	1.5	0.60	0.60
Single Tank Conveyor	1.31	0.79	400	0.3	1.60	1.50
Multi Tank Conveyor	1.04	0.54	600	0.3	2.00	2.00
High Temperature						
Under Counter	1.09	0.86	75	2.0	0.76	0.50
Stationary Single Tank Door	1.29	0.89	280	1.0	0.87	0.70
Single Tank Conveyor	0.87	0.70	400	0.3	1.93	1.50
Multi Tank Conveyor	0.97	0.54	600	0.2	2.59	2.25
Pot, Pan, and Utensil	0.70	0.58	280	3.0	1.20	1.20

DEFAULT SAVINGS

Using the defaults provided above, the savings per component are shown in Table 3-161.

Table 3-161: Default Energy Savings for ENERGY STAR Commercial Dishwashers

Machine Type	$\Delta kWh_{WaterHeater}$	$\Delta kWh_{BoosterHeater}$	ΔkWh_{Idle}	ΔkWh (if Electric Water Heater and Booster Water Heater)
Low Temperature				
Under Counter	2,540	N/A	0	2,540
Stationary Single Tank Door	16,153	N/A	0	16,153
Single Tank Conveyor	13,042	N/A	584	13,626
Multi Tank Conveyor	18,811	N/A	0	18,811
High Temperature				
Under Counter	1,082	618	1,471	3,171
Stationary Single Tank Door	7,023	4,013	827	11,863
Single Tank Conveyor	4,264	2,436	2,511	9,212
Multi Tank Conveyor	16,178	9,244	1,986	27,408
Pot, Pan, and Utensil	2,107	1,204	0	3,311

Evaluation Protocol

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) 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
2) ENERGY STAR® Program Requirements Product Specification for Commercial Dishwashers Eligibility Criteria Version 2.0, effective February 1, 2013 https://www.energystar.gov/products/commercial_food_service_equipment/commercial_dishwashers/key_product_criteria
3) ENERGY STAR, Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment. http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx.
4) Dishwasher inlet temperature assumed at 140 degrees F. https://water.usgs.gov/edu/density.html
5) New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs v6, effective date January 1, 2019

3.7.10 ENERGY STAR Commercial Griddle

Target Sector	Commercial and Industrial Establishments
Measure Unit	Electric Griddle
Measure Life	12 years Source 1
Measure Vintage	Replace on Burnout

Eligibility

This measure applies to the installation of electric ENERGY STAR griddles as either a new item or replacement for an existing unit. The griddles must meet minimum ENERGY STAR efficiency requirements and be on the ENERGY STAR qualified products list. Commercial griddles that are ENERGY STAR qualified are about 10% to 11% more energy efficient than standard models, due to the use of highly conductive or reflective plate materials, improved thermostatic controls, and strategic placement of thermocouples.

The baseline equipment is a unit with efficiency specifications that do not meet the minimum ENERGY STAR efficiency requirements.

Algorithms

Energy savings for griddles come from increased efficiency during three modes: cooking, idle, and preheating. Algorithms for annual energy savings and peak demand savings are shown below.

$$\Delta kWh = \left(\Delta Wh_{Cooking} + \Delta Wh_{Idle} + \Delta Wh_{PreHeat}\right) \times Days * \frac{1}{1{,}000}$$

$$\Delta Wh_{Cooking} = Lb_F \times EnergyToFood \times \left(\frac{1}{Eff_{base}} - \frac{1}{Eff_{ee}}\right)$$

$$\Delta Wh_{Idle} = \left[I_{base} \times A \times \left(OH - \frac{Lb_F}{PC_{base} \times A} - \frac{PHN \times PHT}{60\frac{min}{hr}}\right)\right] - \left[I_{ee} \times A \times \left(OH - \frac{Lb_F}{PC_{ee} \times A} - \frac{PHN \times PHT}{60\frac{min}{hr}}\right)\right]$$

$$\Delta Wh_{PreHeat} = \frac{PHN \times PHT}{60\frac{min}{hr}} \times A \times \left(PHR_{base} - PHR_{ee}\right)$$

$$\Delta kW_{peak} = \frac{\Delta kWh \times CF}{Days \times OH}$$

Definition of Terms

Table 3-162: Terms, Values, and References for ENERGY STAR Griddles

Term	Unit	Values	Source
$Days$, Operating days per year	*Days/year*	EDC Data Gathering	EDC Data Gathering
		Default = 365	2
Lb_F, Pounds of food cooked per day	*lbs*	EDC Data Gathering	EDC Data Gathering
		Default = 100	2
$EnergyToFood$, ASTM energy to food	$\frac{Wh}{lb}$	Default = 139	2
Eff_{base}, Baseline cooking efficiency	%	EDC Data Gathering	EDC Data Gathering
		Default = 65%	2
Eff_{ee}, ENERGY STAR cooking efficiency	%	EDC Data Gathering	EDC Data Gathering
		Default = 70%	2
I_{base}, Baseline idle energy rate	$\frac{W}{ft^2}$	EDC Data Gathering	EDC Data Gathering
		Default = 400	2
I_{ee}, ENERGY STAR idle energy rate	$\frac{W}{ft^2}$	EDC Data Gathering	EDC Data Gathering
		Default = 320	3
A, Area of griddle	ft^2	EDC Data Gathering	EDC Data Gathering
		Default = 2ft x 3ft = 6ft^2	2
OH, Operating hours per day	$\frac{Hours}{Day}$	EDC Data Gathering	EDC Data Gathering
		Default = 12	2
PC_{base}, Baseline production capacity	$\frac{lb}{hours \cdot ft^2}$	EDC Data Gathering	EDC Data Gathering
		Default = 5.83	2
PC_{ee}, ENERGY STAR production capacity	$\frac{lb}{hours \cdot ft^2}$	EDC Data Gathering	EDC Data Gathering
		Default = 6.67	2
PHN, Number of preheats per day	$\frac{Preheats}{Day}$	EDC Data Gathering	EDC Data Gathering
		Default = 1	4
PHT, Time to preheat	$\frac{Min}{Preheat}$	EDC Data Gathering	EDC Data Gathering
		Default = 15	4
PHR_{base}, Baseline preheat rate	$\frac{W}{ft^2}$	EDC Data Gathering	EDC Data Gathering
		Default = 2,667	4
PHR_{ee}, ENERGY STAR preheat rate	$\frac{W}{ft^2}$	EDC Data Gathering	EDC Data Gathering
		Default = 1,333	4
CF, Coincidence factor	*None*	0.9	5

Default Savings

Table 3-163 provides the default savings, using the default values in Table 3-162.

Table 3-163: Default Savings for ENERGY STAR Griddles

$\Delta kWh_{Cooking}$	ΔkWh_{Idle}	$\Delta kWh_{PreHeat}$	Energy Savings (kWh)	Peak Demand Savings (kW)
1,527	3,583	2,001	2,596	0.533

Evaluation Protocol

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx. Accessed December 2018.

2) ENERGY STAR, Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment. http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx.

3) ENERGY STAR Commercial Griddles Specification Tier 2 specifications effective January 1, 2011. https://www.energystar.gov/products/commercial_food_service_equipment/commercial_griddles/key_products_criteria

4) Illinois Statewide Technical Reference Manual v7.0, September 28, 2018. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_7/Final_9-28-18/IL-TRM_Effective_010119_v7.0_Vol_2_C_and_I_092818_Final.pdf. Accessed December 2018.

5) New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs v6, effective date January 1, 2019

3.8 Building Shell

3.8.1 Wall and Ceiling Insulation

Target Sector	Commercial and Industrial Establishments
Measure Unit	Wall and Ceiling Insulation
Measure Life	15 years Source 1
Measure Vintage	New Construction or Retrofit

Wall and ceiling insulation is one of the most important aspects of the energy system of a building.

An R-value indicates the insulation's resistance to heat flow – the higher the R-value, the greater the insulating effectiveness. The R-value depends on the type of insulation and its material, thickness, and density. When calculating the R-value of a multilayered installation, add the R-values of the individual layers.

Eligibility

This measure applies to non-residential buildings or common areas in multifamily complexes heated and/or cooled using electricity. Existing construction buildings are required to meet or exceed the code requirement. New construction buildings must exceed the code requirement. Eligibility may vary by PA EDC. Buildings with Central AC systems or Air Source Heat Pumps (ASHP) are eligible. Buildings cooled with other systems (e.g., chilled water systems) are not eligible.

Algorithms

The savings depend on the area and R-value of baseline and upgraded walls/ceilings, heating and/or cooling system type and size, and location.

$$\Delta kWh = \Delta kWh_{cool} + \Delta kWh_{heat}$$

$$\Delta kWh_{cool} = \left(\frac{CDD \times 24}{Eff \times 1{,}000}\right) \times \left[A_{ceiling}\left(\frac{1}{Ceiling\ R_i} - \frac{1}{Ceiling\ R_f}\right) + A_{wall}\left(\frac{1}{WallR_i} - \frac{1}{Wall\ R_f}\right)\right]$$

$$\Delta kWh_{heat} = \left(\frac{HDD \times 24}{COP \times 3{,}412}\right) \times \left[A_{ceiling}\left(\frac{1}{Ceiling\ R_i} - \frac{1}{Ceiling\ R_f}\right) + A_{wall}\left(\frac{1}{WallR_i} - \frac{1}{Wall\ R_f}\right)\right]$$

$$\Delta kW_{peak} = \frac{\Delta kWh_{cool}}{EFLH_{cool}} \times CF$$

Definition of Terms

Table 3-164: Terms, Values, and References for Wall and Ceiling Insulation

Term	Unit	Values	Source
$A_{ceiling}$, Area of the ceiling/attic insulation that was installed	ft^2	EDC Data Gathering	EDC Data Gathering
A_{wall}, Area of the wall insulation that was installed	ft^2	EDC Data Gathering	EDC Data Gathering
HDD, Heating degree days with a 65 degree base	$°F \cdot Days$	See Table 7 in Appendix A	2
CDD, Cooling degree days with a 65 degree base	$°F \cdot Days$	See Table 7 in Appendix A	2
24, Hours per day	$\frac{Hours}{Day}$	24	Conversion Factor
$1{,}000$, Watts per kilowatt	$\frac{W}{kW}$	1,000	Conversion Factor
$3{,}412$, Btu per kWh	$\frac{Btu}{kWh}$	3,412	Conversion Factor
$Ceiling\ R_i$, the R-value of the ceiling insulation and support structure before the additional insulation is installed	$\frac{°F \cdot ft^2 \cdot hr}{Btu}$	Default: Table 3-165	EDC Data Gathering; 3
$Wall\ R_i$, the R-value of the wall insulation and support structure before the additional insulation is installed	$\frac{°F \cdot ft^2 \cdot hr}{Btu}$	Default: Table 3-165	EDC Data Gathering; 3
$Ceiling\ R_f$, Total R-value of all ceiling/attic insulation after the additional insulation is installed	$\frac{°F \cdot ft^2 \cdot hr}{Btu}$	EDC Data Gathering	EDC Data Gathering
$Wall\ R_f$, Total R-value of all wall insulation after the additional insulation is installed	$\frac{°F \cdot ft^2 \cdot hr}{Btu}$	EDC Data Gathering	EDC Data Gathering
$EFLH_{cool}$, Equivalent full load cooling hours	$\frac{Hours}{Year}$	Based on Logging, BMS data or Modeling[138]	EDC Data Gathering
		Default: Table 3-28	4
CF, Coincidence factor	*Decimal*	Default: Table 3-29	4
Eff, Efficiency of existing cooling equipment. Depending on the size and age, this will either be the SEER, IEER, or EER (use EER only if SEER or IEER are not available)[139]	$\frac{Btu/hr}{W}$	EDC Data Gathering	EDC Data Gathering
		Default: Table 3-27	Table 3-27
COP, Efficiency of the heating system	*None*	EDC Data Gathering	EDC Data Gathering
		Default: Table 3-27	Table 3-27

[138] Modeling is an acceptable substitute to metering and BMS data if modeling is conducted using building- and equipment-specific information at the site and the facility consumption is calibrated using 12 months of billing data (pre-retrofit).
[139] Site-specific design values should be used in the calculation wherever possible, to avoid overestimating the savings using the default minimally compliant EERs.

Table 3-165: Initial R-Values

Structure	R_i-Value (New Construction)	R_i-Value (Existing)
Ceiling	38	EDC Data Gathering
Wall	20	EDC Data Gathering

Default Savings

There are no default savings for this measure.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx. Accessed December 2018. Capped based on the requirements of the Pennsylvania Technical Reference Manual.
2) SWE analysis of TMY3 data for PA weather stations.
3) The initial R-value for new construction buildings is based on IECC 2015 code for climate zone 5. https://codes.iccsafe.org/content/IECC2015/chapter-4-ce-commercial-energy-efficiency
4) Based on results from Nexant's eQuest modeling analysis 2014.

3.9 CONSUMER ELECTRONICS

3.9.1 ENERGY STAR OFFICE EQUIPMENT

Target Sector	Commercial and Industrial Establishments
Measure Unit	Office Equipment
Measure Life	See Table 3-167
Measure Vintage	Replace on Burnout

ELIGIBILITY

This protocol estimates savings for installing ENERGY STAR office equipment compared to standard efficiency equipment. The measurement of energy and demand savings is based on a deemed savings value multiplied by the quantity of the measure.

ALGORITHMS

The general form of the equation for the ENERGY STAR Office Equipment measure savings' algorithms is:

$$Number\ of\ Units\ \times Savings\ per\ Unit$$

To determine resource savings, the per unit estimate in the algorithms will be multiplied by the number of units. Per unit savings are primarily derived from the ENERGY STAR calculator for office equipment.

ENERGY STAR Desktop Computer

$$\Delta kWh = ESAV_{deskcom}$$

$$\Delta kW_{peak} = DSAV_{deskcom}$$

ENERGY STAR Laptop Computer

$$\Delta kWh = ESAV_{lapcom}$$

$$\Delta kW_{peak} = DSAV_{lapcom}$$

ENERGY STAR Fax Machine

$$\Delta kWh = ESav_{fax}$$

$$\Delta kW_{peak} = DSav_{fax}$$

ENERGY STAR Copier

$$\Delta kWh = ESav_{cop}$$

$$\Delta kW_{peak} = DSav_{cop}$$

ENERGY STAR Printer

$$\Delta kWh = ESav_{pri}$$

$$\Delta kW_{peak} = DSav_{pri}$$

ENERGY STAR Multifunction

$$\Delta kWh = ESav_{mul}$$

$$\Delta kW_{peak} = DSav_{mul}$$

ENERGY STAR Monitor

$$\Delta kWh = ESav_{mon}$$

$$\Delta kW_{peak} = DSav_{mon}$$

ENERGY STAR Desktop Phone

$$\Delta kWh = ESav_{deskpho}$$

$$\Delta kW_{peak} = DSav_{deskpho}$$

ENERGY STAR Conference Phone

$$\Delta kWh = ESav_{confpho}$$

$$\Delta kW_{peak} = DSav_{confpho}$$

DEFINITION OF TERMS

Table 3-166: Terms, Values, and References for ENERGY STAR Office Equipment

Term	Unit	Values	Source
$ESav_{\mathrm{deskcom}}$, Electricity savings per purchased ENERGY STAR desktop computer $ESav_{\mathrm{lapcom}}$, Electricity savings per purchased ENERGY STAR laptop computer $ESav_{fax}$, Electricity savings per purchased ENERGY STAR fax machine $ESav_{cop}$, Electricity savings per purchased ENERGY STAR copier $ESav_{pri}$, Electricity savings per purchased ENERGY STAR printer $ESav_{mul}$, Electricity savings per purchased ENERGY STAR multifunction machine $ESav_{mon}$, Electricity savings per purchased ENERGY STAR monitor $ESav_{deskpho}$, Electricity savings per purchased ENERGY STAR desktop phone $ESav_{confpho}$, Electricity savings per purchased ENERGY STAR conference phone	kWh	See Table 3-168	1
$\mathrm{D}Sav_{\mathrm{deskcom}}$, Summer demand savings per purchased ENERGY STAR desktop computer $\mathrm{D}Sav_{\mathrm{lapcom}}$, Summer demand savings per purchased ENERGY STAR laptop computer $\mathrm{D}Sav_{fax}$, Summer demand savings per purchased ENERGY STAR fax machine $\mathrm{D}Sav_{cop}$, Summer demand savings per purchased ENERGY STAR copier $\mathrm{D}Sav_{pri}$, Summer demand savings per purchased ENERGY STAR printer $\mathrm{D}Sav_{mul}$, Summer demand savings per purchased ENERGY STAR multifunction machine $\mathrm{D}Sav_{mon}$, Summer demand savings per purchased ENERGY STAR monitor $ESav_{deskpho}$, Summer demand savings per purchased ENERGY STAR desktop phone $ESav_{confpho}$, Summer demand savings per purchased ENERGY STAR conference phone	kW	See Table 3-168	2

Measures lives for ENERGY STAR office equipment are shown in Table 3-167.

Table 3-167: ENERGY STAR Office Equipment Measure Life

Equipment	Commercial Life (years)	Source
Desktop Computer	4	1
Laptop Computer	4	
Monitor	7	
Desktop Phone	7	
Conference Phone	7	
Fax	6	
Multifunction Device	6	
Printer	6	
Copier	6	

Default Savings

Table 3-168: ENERGY STAR Office Equipment Energy and Demand Savings Values

Measure	Energy Savings (ESav)	Summer Peak Demand Savings (DSav)	Source
Desktop Computer	124	0.0167	1, 2
Laptop Computer	37	0.0050	1, 2
Fax Machine (laser)	16	0.0022	1, 2
Copier (monochrome)			1, 2
1-25 images/min	73	0.0098	
26-50 images/min	151	0.0203	
51+ images/min	162	0.0218	
Printer (laser, monochrome)			1, 2
1-10 images/min	26	0.0035	
11-20 images/min	73	0.0098	
21-30 images/min	104	0.0140	
31-40 images/min	156	0.0210	
41-50 images/min	133	0.0179	
51+ images/min	329	0.0443	
Multifunction (laser, monochrome)			1, 2
1-10 images/min	78	0.0105	
11-20 images/min	147	0.0198	
21-44 images/min	253	0.0341	
45-99 images/min	422	0.0569	
100+ images/min	730	0.0984	
Monitor			1, 2
Less than 12 inches	5	0.0007	
12.0 – 16.9 inches	6	0.0008	
17.0 – 22.9 inches	9	0.0012	
23.0 – 24.9 inches	8	0.0011	
25.0 – 60.9 inches	22	0.0030	
Desktop Phone	11	0.0015	1, 2
Conference Phone	12	0.0016	1, 2

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

SOURCES

1) ENERGY STAR Qualified Office Equipment Savings Calculator (Referenced latest version released in October 2016). Default values were used. As of December 1, 2018, the published ENERGY STAR Office Equipment Calculator does not reflect the current specification for computers (ENERGY STAR® Program Requirements Product Specification for Computers Eligibility Criteria Version 7.1). V7.1 introduced modest improvements to both desktop and laptop computer efficiency. As a result, the savings values for computers presented in this measure entry reflect savings for V6-compliant models. This characterization should be updated when an updated ENERGY STAR Office Equipment Calculator becomes available.
2) Using a commercial office equipment load shape, the percentage of total savings that occur during the PJM peak demand period was calculated and multiplied by the energy savings.

3.9.2 Office Equipment – Network Power Management Enabling

Target Sector	Commercial and Industrial Establishments
Measure Unit	One copy of licensed software installed on a PC workstation
Measure Life	5 years Source 1
Measure Vintage	Retrofit

A number of strategies are available to save energy in desktop computers. One class of products uses software implemented at the network level for desktop computers that manipulates the internal power settings of the central processing unit (CPU) and of the monitor. These power settings are an integral part of a computer's operating system (most commonly, Microsoft Windows) including "on", "standby", "sleep", and "off" modes and can be set by users from their individual desktops.

Most individual computer users are unfamiliar with these energy-saving settings, hence settings are normally set by an IT administrator to minimize user complaints related to bringing the computer back from standby, sleep, or off modes. However, these default settings use a large amount of energy during times when the computer is not in active use. Studies have shown that energy consumed during non-use periods is large and is often the majority of total energy consumed.

Qualifying software must control desktop computer and monitor power settings within a network from a central location.

Eligibility

The default savings reported in Table 3-170 are applicable to any software that manages workstations in a networked environment. Such softwares should be capable of the following:

- The software should have wake-on-LAN capability to allow networked workstations to be remotely wakened from or placed into any power-saving mode and to remotely boot or shut down ACPI-compliant workstations.
- The software should have the capability to give the IT administrator easily-accessible central control over the power management settings of networked workstations that optionally overrides settings made by users.
- The software should be capable of applying specific power management policies to network groups, utilizing existing network grouping capabilities.
- The software should be compatible with multiple operating systems and hardware configurations on the same network.
- The software should have the capability to monitor workstation keyboard, mouse, CPU and disk activity in determining workstation idleness.

Algorithms

The general form of the equation for the Network Power Management measure savings algorithms is:

$$Number\ of\ Workstations\ \times Savings\ per\ Workstation$$

To determine resource savings, the per unit estimate in the algorithms will be multiplied by the number of units. Per unit savings are primarily derived from the ENERGY STAR calculator for office equipment.

Network Power Management: Workstation with Desktop Computer and Monitor

$$\Delta kWh = ESAV_{desktop}$$

$$\Delta kW_{peak} = DSAV_{desktop}$$

Network Power Management: Workstation with Laptop Computer and Monitor

$$\Delta kWh = ESAV_{laptop}$$

$$\Delta kW_{peak} = DSAV_{laptop}$$

Definition of Terms

Table 3-169: Terms, Values, and References for ENERGY STAR Office Equipment

Term	Unit	Values	Source
$ESAV_{\text{desk}}$, Electricity savings per purchased ENERGY STAR desktop computer	kWh	See Table 3-170	2
$ESAV_{\text{laptop}}$, Electricity savings per purchased ENERGY STAR laptop computer	kWh	See Table 3-170	2
$DSAV_{\text{desktop}}$, Summer demand savings per purchased ENERGY STAR desktop computer	kW	See Table 3-170	3
$DSAV_{\text{laptop}}$, Summer demand savings per purchased ENERGY STAR laptop computer	kW	See Table 3-170	3

Default Savings

The energy savings per unit includes the power savings from the PC as well as the monitor. Default savings are based on the Low Carbon IT Savings Calculator sourced from the ENERGY STAR website.

Table 3-170: Network Power Controls, Per Unit Summary Table

Measure	Unit	Energy Savings ($ESAV$)	Peak Demand Savings ($DSAV$)
Network PC Plug Load Power Management Software	Workstation – Desktop Computer with Monitor	392	0.0527
Network PC Plug Load Power Management Software	Workstation – Laptop Computer with Monitor	237	0.0319

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with

verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) Illinois Statewide Technical Reference Manual v7.0, http://www.ilsag.info/technical-reference-manual.html. The reference uses 10 years, however, given the rapid changes in the technology industry, there is quite a lot of uncertainty about the measure life and a more conservative value was used (i.e. half the published measure life): Table VI.1: Dimetrosky, S., Luedtke, J. S., & Seiden, K. (2005). Surveyor Network Energy Manager: Market Progress Evaluation Report, No. 2 (Northwest Energy Efficiency Alliance report #E05-136). Portland, OR: Quantec, LLC).
2) ENERGYSTAR calculator: Low Carbon IT Savings Calculator: https://www.energystar.gov/sites/default/files/asset/document/LowCarbonITSavingsCalc.xlsx
3) Using a commercial office equipment load shape, the percentage of total savings that occur during the PJM peak demand period was calculated and multiplied by the energy savings.

3.9.3 Advanced Power Strips

Target Sector	Commercial and Industrial Establishments
Measure Unit	Per Advanced Power Strip
Measure Life	7 years Source 1
Measure Vintage	Retrofit

Commented [SA68]: Franklin Energy

EUL is 7 years in C&I, but 5 years in residential. Is there a reason for this?

Plug and process loads (PPLs) are building electrical loads that are not related to lighting, heating, ventilation, cooling, and water heating, and typically do not provide comfort to the occupants. PPLs in commercial buildings account for almost 33% of U.S. commercial building electricity use. Minimizing PPLs is a critical part of the design and operation of an energy-efficient building.

Advanced Power Strips (APS) are power strips that contain a number of power-saver sockets. There are two types of APS: Tier 1 and Tier 2.

Tier 1 APS have a master control socket arrangement and will shut off the items plugged into the controlled power-saver sockets when they sense that the appliance plugged into the master socket has been turned off. Conversely, the appliance plugged into the master control socket has to be turned on and left on for the devices plugged into the power-saver sockets to function.

Tier 2 APS deliver additional functionality beyond that of a Tier 1 unit, as Tier 2 units manage both standby and active power consumption. The Tier 2 APS manage standby power consumption by turning off devices from a control event. Active power consumption is managed by the Tier 2 unit by monitoring a user’s engagement or presence in a room by either or both infrared remote signals sensing or motion sensing. If after a period of user absence or inactivity, the Tier 2 unit will shut off all items plugged into the controlled outlets, thus saving energy.

Eligibility

This protocol documents the energy savings attributed to the installation of APS. The protocol considers usage of APS with office workstations.

Algorithms

The annual energy savings are calculated for office workstations for both Tier 1 strips and Tier 2 strips. If the presence of power management either at the local-level or network-level is not known, the average energy reduction percentage shall be used.

Tier 1 Smart Strip:

$$\Delta kWh = Annual\_Usage_{workstation} \times ERP_{t1\_workstation}$$

Commented [SA69]: Franklin Energy

Residential includes ISR. ISR is typically low on APS and including may be a more accurate method of estimating savings

Tier 2 Smart Strip:

$$\Delta kWh = Annual\_Usage_{workstation} \times ERP_{t2\_OS\_workstation}$$

Definition of Terms

Table 3-171: Terms, Values, and References for Smart Strip Plug Outlets

Term	Unit	Value	Source
$Annual\_Usage_{workstation}$, Annual consumption of workstation	*kWh*	543 kWh	2
$\%ERP$, Energy Reduction Percent	%	Default: Table 2-107	2, 3

Commented [SA70]: Franklin Energy

Source appears to assume 8760hr annual without shutdown or sleep times. Mentions CRT and Fluorescent backit LCD screens which are both uncommon today.

Table 3-172: Impact Factors for APS Strip Types

Strip Type	End-Use	ERP
Tier 1	Workstation	24.7%
Tier 1	Workstation with power management (network or local)	4.0%
Tier 1	Workstation with unknown power management	14.3%
Tier 2 Occupancy Sensor	Workstation	30.0%
Tier 2 Occupancy Sensor	Workstation with power management (network or local)	4.0%
Tier 2 Occupancy Sensor	Workstation with unknown power management	17.0%

Commented [SA71]: Franklin Energy

ERP for unknown appears to split workstation with power management and workstations without power management 50-50

PC's include power management software which is enabled by default and would require manually disabling to fall into "without power management". Therefore the unknown situation should be weighted heavily toward "Workstation with power management" ERP value.

Default Savings

The default savings calculated based on the parameters identified above are provided in Table 3-173.

Table 3-173: Default Savings for APS Strip Types

Strip Type	Use	Energy Savings (kWh)
Tier 1	Workstation	134
Tier 1	Workstation with power management (network or local)	22
Tier 1	Workstation with unknown power management	78
Tier 2 Occupancy Sensor	Workstation	163
Tier 2 Occupancy Sensor	Workstation with power management (network or local)	22
Tier 2 Occupancy Sensor	Workstation with unknown power management	92

Evaluation Protocols

The most appropriate evaluation protocol for this measure is verification of installation coupled with assignment of stipulated energy savings.

Sources

5. Illinois Statewide Technical Reference Manual v7.0, http://www.ilsag.info/technical-reference-manual.html. Demand savings are assumed to be zero as equipment is expected to be operating during peak period.
6. NREL/TP-5500-51708, "Selecting a Control Strategy for Plug and Process Loads", September 2012, https://www.nrel.gov/docs/fy12osti/51708.pdf
7. Acker, B., Duarte, C., and Wymelenberg, K., "Office Space Plug Load Profiles and Energy Savings Interventions". University of Idaho. 2012. https://aceee.org/files/proceedings/2012/data/papers/0193-000277.pdf

3.9.4 ENERGY STAR SERVERS

Target Sector	Commercial and Industrial Establishments
Measure Unit	Variable
Measure Life	4 years Source 1
Measure Vintage	Replace on Burnout

According to energystar.gov, data centers consume approximately 2% of the electricity in the United States. Servers and mainframes in these data centers provide the email service, information storage, and other information technology services to the businesses that run them. A large proportion (40%) of servers and mainframes are located not in large data centers, but in closets within individual businesses. ENERGY STAR certified servers and mainframes can cut energy usage by 30% on average, and each watt saved at the server or mainframe level can translate to 1.9 watts saved when interactive effects are included.

ELIGIBILITY

This measure applies to the replacement of existing servers in a data center or server closet with new ENERGY STAR servers of similar computing capacity. On average, ENERGY STAR servers are 30% more efficient than standard servers. To qualify for this measure, the installed equipment must be a server system or mainframe that has earned the ENERGY STAR label.Source 2

ALGORITHMS

Annual energy savings and peak demand savings can be calculated using the algorithms shown below. The demand reduction associated with this measure is assumed to be constant since the servers operate 24 hours per day, 365 days per year.

$$kW_{es} = \sum_{ES=1}^{n} kW_{es,idle} + \left[U_{es} \times \left(\frac{kW_{es,idle}}{b} - kW_{es,idle}\right)\right]$$

$$\Delta kWh = \left[\frac{1}{(1-a)} - 1\right] \times kW_{es} \times 8{,}760\ \frac{hours}{year}$$

$$\Delta kW_{peak} = \left[\frac{1}{(1-a)} - 1\right] \times kW_{es}$$

Definition of Terms

Table 3-174: Terms, Values, and References for ENERGY STAR Servers

Term	Unit	Values	Source
kW_{es}, Active power draw of ENERGY STAR server	*kW*	EDC Data Gathering Calculated value	EDC Data Gathering Calculated value
$kW_{es,idle}$, Power draw of ENERGY STAR server in idle mode	*kW*	EDC Data Gathering	3
U_{es}, Utilization of ENERGY STAR server	*None*	EDC Data Gathering Default: Table 3-175	EDC Data Gathering 4, 5, 6
a, Percentage ENERGY STAR server is more efficient than “standard” or “typical” unit	*None*	Fixed = 30% or most current ENERGY STAR specification	7
b, Ratio of idle power to full load power for an ENERGY STAR server	*None*	EDC Data Gathering Default: Table 3-176	EDC Data Gathering 8
n, Number of ENERGY STAR servers	*Servers*	EDC Data Gathering	EDC Data Gathering

Table 3-175: ENERGY STAR Server Utilization Default Assumptions

Server Category	Installed Processors	U_{es} (%)
A, B	1	15%
C, D	2	40%

Table 3-176: ENERGY STAR Server Ratio of Idle Power to Full Load Power Factors

Server Category	Installed Processors	Managed Server[140]	Ratio of ES Idle/ES Full Load (b)
A	1	No	52.1%
B	1	Yes	53.2%
C	2	No	61.3%
D	2	Yes	55.8%

[140] Managed Server: A computer server that is designed for a high level of availability in a highly managed environment. For purposes of this specification, a managed server must meet all of the following criteria (from ENERGY STAR server specification 2.0): (A) is designed to be configured with redundant power supplies; and (B) contains an installed dedicated management controller (e.g., service processor).

Default Savings

Default savings may be claimed using the algorithms above and the variable defaults. EDCs may also claim savings using customer specific data.

Evaluation Protocols

When possible, perform M&V to assess the energy consumption. However, where metering of IT equipment in a data center is not allowed, follow the steps outlined.

- Invoices should be checked to confirm the number and type of ENERGY STAR servers purchased.
- If using their own estimate of active power draw, kW_{es}, the manager should provide a week's worth of active power draw data gathered from the uninterruptible power supply, PDUs, in-rack smart power strips, or the server itself.
- Idle power draws of servers, $kW_{es,idle}$, should be confirmed in the "Idle Power Typical or Single Configuration (W)" on the ENERGY STAR qualified product list.[Source 3]
- If not using the default values listed in Table 3-175, utilization rates should be confirmed by examining the data center's server performance software.

Sources

1) The three International Data Corporation (IDC) studies indicate organizations replace their servers once every three to five years.
    a. IDC (February 2012). "The Cost of Retaining Aging IT Infrastructure." Sponsored by HP. Online. http://mjf.ie/wp-content/uploads/white-papers/IDC-White-Paper_the-cost-of-retaining-aging-IT-infrastructure.pdf
    b. IDC (2010). "Strategies for Server Refresh." Sponsored by Dell. Online. http://i.dell.com/sites/content/business/smb/sb360/en/Documents/server-refresh-strategies.pdf
    c. DC (August 2012). "Analyst Connection: Server Refresh Cycles: The Costs of Extending Life Cycles." Sponsored by HP/Intel. Online. http://resources.itworld.com/ccd/assets/31122/detaill
2) ENERGY STAR Program Requirements for Enterprise Servers Version 2.0 Specifications. https://www.energystar.gov/ia/partners/prod_development/revisions/downloads/computer_servers/Program_Requirements_V2.0.pdf
3) An ENERGY STAR qualified server has an "Idle Power Typical or Single Configuration (W)" listed in the qualified product list for servers. The EDC should use the server make and model number to obtain the $kW_{es,idle}$ variable used in the algorithms. The ENERGY STAR qualified server list is located at here: http://www.energystar.gov/productfinder/product/certified-enterprise-servers/results .
4) Utilization of a server can be derived from a data center's server performance software. This data should be used, instead of the default values listed in Table 3-176, when possible.
5) The estimated utilization of the ENERGY STAR server for servers with one processor was based on the average of two sources, as follows.
    a. Glanz, James. Power Pollution and The Internet, The New York Times, September 22, 2012. This article cited to sources of average utilization rates between 6 to 12%.
    b. Stakeholders interviewed during the development of the ENERGY STAR server specification reported that the average utilization rate for servers with 1 processor is approximately 20%.

6) The estimated utilization of the ENERGY STAR server for servers with two processors was based on the average of two sources, as follows.

   a. Using Virtualization to Improve Data Center Efficiency, Green Grid White Paper, Editor: Richard Talaber, VMWare, 2009. A target of 50% server utilization is recommended when setting up a virtual host.

   b. Stakeholders interviewed during the development of the ENERGY STAR server specification reported that the average utilization rate for servers with two processors is approximately 30%.

7) The default percentage savings on the ENERGY STAR server website was reported to be 30% on May 20th, 2014.

8) In December 2013, ENERGY STAR stopped including full load power data as a field in the ENERGY STAR certified product list. In order to full load power required in the Uniform Methods Project algorithm for energy efficient servers, a ratio of idle power to full load power was estimated. The idle to full load power ratios were estimated based on the ENERGY STAR qualified product list from November 18th, 2013. The ratios listed in Table 3-176 are based on the average idle to full load ratios for all ENERGY STAR qualified servers in each server category.

3.9.5 Server Virtualization

Target Sector	Commercial and Industrial Establishments
Measure Unit	Per server
Measure Life	4 years Source 1
Measure Vintage	Replace on Burnout

According to energystar.gov, data centers consume approximately 2% of the electricity in the United States. Servers in these data centers provide the email service, information storage, and other information technology services to the businesses that run them. Most servers are installed for one specific function, for example email. This leads to up to 90% of servers in the US running at 5-10% utilization. Server virtualization allows companies to consolidate excess servers performing multiple tasks into a single physical server, saving the associated energy of the servers removed.

Eligibility

To qualify for this rebate, servers must be consolidated to increase utilization of the remaining servers, and the virtualized servers must be either a) removed or b) physically disconnected from power.

Algorithms

Annual energy savings and peak demand savings can be calculated using the algorithms shown below. The demand reduction associated with this measure is assumed to be constant since the servers operate 24 hours per day, 365 days per year.

$$\Delta kWh = (kW_{base} - kW_{ee}) \times 8{,}760\ \frac{hours}{year}$$

$$\Delta kW_{peak} = (kW_{base} - kW_{ee})$$

$$kW_{ee} = \sum_{1}^{m} U_{vh} \times \left(\frac{kW_{vh,idle}}{b} - kW_{vh,idle}\right) + kW_{vh,idle}$$

$$kW_{base} = \sum_{1}^{n} U_{sa} \times \left(\frac{kW_{sa,idle}}{b} - kW_{sa,idle}\right) + kW_{sa,idle}$$

Definition of Terms

Table 3-177: Terms, Values, and References for Server Virtualization

Term	Unit	Values	Source
sa, Single application servers, number 1 to *n*	Servers	EDC Data Gathering	EDC Data Gathering
$kW_{sa,idle}$, Power draw of virtualized server in idle mode	kW	EDC Data Gathering	2
U_{sa}, Average annual utilization of single application server, number 1 to *n*	None	EDC Data Gathering Default: Table 3-178	EDC Data Gathering 3, 4, 5
vh, Virtual host server (virtualized + remaining), number 1 to *m*	Servers	EDC Data Gathering (max = 4 for type A, B, max = 1 for type C, D)	EDC Data Gathering
U_{vh}, Average annual virtual host server utilization	None	EDC Data Gathering Default: *m* * utilization in Table 3-178	EDC Data Gathering 3, 4, 5
$kW_{vh,idle}$, Power draw of virtualized server in idle mode	kW	EDC Data Gathering	2
b, Ratio of idle power to full load power for server	None	EDC Data Gathering Default: Table 3-179	EDC Data Gathering 6

Table 3-178: Server Utilization Default Assumptions

Server Category	Installed Processors	U (%)
A, B	1	15%
C, D	2	40%

As noted, these Utilization numbers are likely higher than standard server utilizations; however, the post-virtualization server utilization will likely be higher.

Table 3-179: ENERGY STAR Server Ratio of Idle Power to Full Load Power Factors

Server Category	Installed Processors	Managed Server[141]	Ratio of ES Idle/ES Full Load (b)
A	1	No	52.1%
B	1	Yes	53.2%
C	2	No	61.3%
D	2	Yes	55.8%

Default Savings

Default savings may be claimed using the algorithms above and the variable defaults. EDCs may also claim savings using customer specific data.

Evaluation Protocols

When possible, perform M&V to assess the energy consumption. However, where metering of IT equipment in a data center is not allowed, follow the steps outlined.

- Invoices should be checked to confirm the number and type of servers virtualized.
- If not using the default values listed in Table 3-178, utilization rates should be confirmed by examining the data center's server performance software.

Sources

1) The three International Data Corporation (IDC) studies indicate organizations replace their servers once every three to five years
    a. IDC (February 2012). "The Cost of Retaining Aging IT Infrastructure." Sponsored by HP. Online. http://mjf.ie/wp-content/uploads/white-papers/IDC-White-Paper_the-cost-of-retaining-aging-IT-infrastructure.pdf
    b. IDC (2010). "Strategies for Server Refresh." Sponsored by Dell. Online. http://i.dell.com/sites/content/business/smb/sb360/en/Documents/server-refresh-strategies.pdf
    c. DC (August 2012). "Analyst Connection: Server Refresh Cycles: The Costs of Extending Life Cycles." Sponsored by HP/Intel. Online. http://resources.itworld.com/ccd/assets/31122/detaill
2) An ENERGY STAR qualified server has an "Idle Power Typical or Single Configuration (W)" listed in the qualified product list for servers. The EDC should use the server make and model number to obtain the $kW_{es,idle}$ variable used in the algorithms. The ENERGY STAR qualified server list is located at here: http://www.energystar.gov/productfinder/product/certified-enterprise-servers/results.
3) Utilization of a server can be derived from a data center's server performance software. This data should be used, instead of the default values listed in Table 3-178, when possible.
4) The estimated utilization of the ENERGY STAR server for servers with one processor was based on the average of two sources, as follows.

[141] Managed Server: A computer server that is designed for a high level of availability in a highly managed environment. For purposes of this specification, a managed server must meet all of the following criteria (from ENERGY STAR server specification 2.0): (A) is designed to be configured with redundant power supplies; and (B) contains an installed dedicated management controller (e.g., service processor).

a. Glanz, James. Power Pollution and The Internet, The New York Times, September 22, 2012. This article cited to sources of average utilization rates between 6 to 12%.

b. Stakeholders interviewed during the development of the ENERGY STAR server specification reported that the average utilization rate for servers with 1 processor is approximately 20%.

5) The estimated utilization of the ENERGY STAR server for servers with two processors was based on the average of two sources, as follows.

a. Using Virtualization to Improve Data Center Efficiency, Green Grid White Paper, Editor: Richard Talaber, VMWare, 2009. A target of 50% server utilization is recommended when setting up a virtual host.

b. Stakeholders interviewed during the development of the ENERGY STAR server specification reported that the average utilization rate for servers with two processors is approximately 30%.

6) In December 2013, ENERGY STAR stopped including full load power data as a field in the ENERGY STAR certified product list. In order to full load power required in the Uniform Methods Project algorithm for energy efficient servers, a ratio of idle power to full load power was estimated. The idle to full load power ratios were estimated based on the ENERGY STAR qualified product list from November 18th, 2013. The ratios listed in Table 3-179 are based on the average idle to full load ratios for all ENERGY STAR qualified servers in each server category.

3.10 Compressed Air

3.10.1 Cycling Refrigerated Thermal Mass Dryer

Target Sector	Commercial and Industrial Establishments
Measure Unit	Cycling Refrigerated Thermal Mass Dryer
Measure Life	15 years Source 1
Measure Vintage	Early Replacement

When air is compressed, water vapor in the air condenses and collects in liquid form. Some of this condensate collects in the air distribution system and can contaminate downstream components such as air tools with rust, oil, and pipe debris. Refrigerated air dryers remove the water vapor by cooling the air to its dew point and separating the condensate. Changes in production and seasonal variations in ambient air temperature lead to partial loading conditions on the dryer. Standard air dryers use a hot gas bypass system that is inefficient at partial loads. A Cycling Thermal Mass Dryer uses a thermal storage medium to store cooling capacity when the system is operated at partial loads allowing the dryer refrigerant compressor to cycle.

Eligibility

This measure is targeted to non-residential customers whose equipment is a non-cycling refrigerated air dryer with a capacity of 600 cfm or below.

Acceptable baseline conditions are a non-cycling (e.g., continuous) air dryer with a capacity of 600 cfm or below. The replacement of desiccant, deliquescent, heat-of-compression, membrane, or other types of dryers does not qualify under this measure.

Efficient conditions are a cycling thermal mass dryer with a capacity of 600 cfm or below.

Algorithms

$$\Delta kWh = ((CFM \times HP_{compressor} \times \frac{kW_{dryer}}{\text{CFM}} \times HOURS \times (1 - APC)) \times RTD)$$

$$\Delta kW_{peak} = \frac{\Delta kWh}{HOURS} * CF$$

Definition of Terms

Table 3-180: Terms, Values, and References for Cycling Refrigerated Thermal Mass Dryers

Term	Unit	Values	Source
CFM, Compressor output per HP	$\frac{CFM}{HP}$	EDC Data Gathering Default: 4	EDC Data Gathering 2
$HP_{compressor}$, Nominal HP rating of the air compressor motor	*HP*	Nameplate data	EDC Data Gathering
kW_{dryer}/CFM, Ratio of dryer kW to compressor CFM	$\frac{kW}{CFM}$	EDC Data Gathering Default: 0.0087	EDC Data Gathering 3
RTD, Chilled coil response time derate	*Hours*	EDC Data Gathering Default: 0.925	EDC Data Gathering 3
APC, Average compressor operating capacity	*None*	EDC Data Gathering Default: 65%	EDC Data Gathering 4
$HOURS$, Annual hours of compressor operation	$\frac{Hours}{year}$	EDC Data Gathering Default: Table 3-181	EDC Data Gathering 5
CF, Coincidence factor	*Decimal*	EDC Data Gathering Default: Table 3-181	EDC Data Gathering 5

Table 3-181: Default Hours and Coincidence Factors by Shift Type

Shift Type	Hours Per Year	CF	Description
Single Shift (8/5)	1,976	0.24*	7 AM – 3 PM, weekdays, minus some holidays and scheduled downtime
2-shift (16/5)	3,952	0.95	7 AM – 11 PM, weekdays, minus some holidays and scheduled downtime
3-shift (24/5)	5,928	0.95	24 hours per day, weekdays, minus some holidays and scheduled downtime
4-shift (24/7)	8,320	0.95	24 hours per day, 7 days a week minus some holidays and scheduled downtime

* Note: This value is derived by adjusting the coincidence factor to account for assumed compressor operation (7 a.m. to 3 p.m.) during only one of the four hours of peak period (2 p.m. to 6 p.m.). 0.95 * (1/4) = 0.2375.

Default Savings

Default savings per compressor motor HP for four shift types are shown below. EDCs may also claim savings using customer specific data.

Table 3-182: Default Savings per HP for Cycling Refrigerated Thermal Mass Dryers

Shift Type	Annual Energy Savings ($\Delta kWh/HP$)	Peak Demand Savings ($\Delta kW_{peak}/HP$)
Single Shift (8/5)	22.3	0.003
2-shift (16/5)	44.5	0.011
3-shift (24/5)	66.8	0.011
4-shift (24/7)	93.7	0.011

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) Measure Life Study prepared for the Massachusetts Joint Utilities. Energy and Resource Solutions, 2005. https://www.focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf. Accessed on June 2018.
2) Manufacturer's data suggests that CFM output per compressor HP ranges from 4 to 5.
3) Conversion factor based on a linear regression analysis of the relationship between air compressor full load capacity and non-cycling dryer full load kW assuming that the dryer is sized to accommodate the maximum compressor capacity. Efficiency Vermont, Technical Reference Manual 2014-87. http://puc.vermont.gov/sites/psbnew/files/doc_library/ev-technical-reference-manual.pdf
4) Based on an analysis of load profiles from 50 facilities using air compressors 40 HP and below. Efficiency Vermont Technical Reference User Manual (TRM), March 16, 2015. http://puc.vermont.gov/sites/psbnew/files/doc_library/ev-technical-reference-manual.pdf
5) Hours account for holidays and scheduled downtime. The CF is drawn from the summer period, which is when the PA peak kW peak is calculated. Efficiency Vermont Technical Reference User Manual (TRM), March 16, 2015. http://puc.vermont.gov/sites/psbnew/files/doc_library/ev-technical-reference-manual.pdf

3.10.2 Air-Entraining Air Nozzle

Target Sector	Commercial and Industrial Establishments
Measure Unit	Air-entraining Air Nozzle
Measure Life	15 years Source 1
Measure Vintage	Early Replacement

Air entraining air nozzles use compressed air to entrain and amplify atmospheric air into a stream, increasing pressure with minimal compressed air use. This decreases the compressor work necessary to provide the nozzles with compressed air. Air entraining nozzles can also reduce noise in systems with air at pressures greater than 30 psig.

Eligibility

This measure is targeted to non-residential customers whose compressed air equipment uses stationary air nozzles in a production application with an open copper tube of 1/8” or 1/4” orifice diameter.

Energy efficient conditions require replacement of an inefficient, non-air entraining air nozzle with an energy efficient air-entraining air nozzle that use less than 15 CFM at 100 psi for industrial applications.

Algorithms

$$\Delta kWh = (CFM_{base} - CFM_{ee}) \times COMP \times HOURS \times \%\, USE$$

$$\Delta kW_{peak} = \frac{\Delta kWh}{HOURS} * CF$$

Definition of Terms

Table 3-183: Terms, Values, and References for Air-entraining Air Nozzles

Term	Unit	Values	Source
CFM_{base}, Baseline nozzle air mass flow	*CFM* $\left(\frac{ft^3}{min}\right)$	EDC Data Gathering Default: Table 3-184	2
CFM_{ee}, Energy efficient nozzle air mass flow	*CFM* $\left(\frac{ft^3}{min}\right)$	EDC Data Gathering Default: Table 3-185	3
$COMP$, Ratio of compressor kW to CFM	$\frac{kW}{CFM}$	EDC Data Gathering Default: Table 3-186	4
$HOURS$, Annual hours of compressor operation	$\frac{Hours}{year}$	EDC Data Gathering Default: Table 3-187	6
$\%\,USE$, Percent of hours when nozzle is in use	*None*	EDC Data Gathering Default: 5%	5
CF, Coincidence Factor	*Decimal*	EDC Data Gathering Default: Table 3-187	6

Table 3-184: Baseline Nozzle Mass Flow

Nozzle Diameter	Air Mass Flow (CFM) @ 80 psi
1/8"	21
1/4"	58

Table 3-185: Air Entraining Nozzle Mass Flow

Nozzle Diameter	Air Mass Flow (CFM) @ 80 psi
1/8"	6
1/4"	11

Table 3-186: Average Compressor kW / CFM (COMP)

Compressor Control Type	Average Compressor kW/CFM (COMP)
Modulating w/ Blowdown	0.32
Load/No Load w/ 1 gal/CFM Storage	0.32
Load/No Load w/ 3 gal/CFM Storage	0.30
Load/No Load w/ 5 gal/CFM Storage	0.28
Variable Speed w/ Unloading	0.23

Table 3-187: Default Hours and Coincidence Factors by Shift Type

Shift Type	Hours Per Year	CF	Description
Single Shift (8/5)	1,976	0.24*	7 AM – 3 PM, weekdays, minus some holidays and scheduled downtime
2-shift (16/5)	3,952	0.95	7 AM – 11 PM, weekdays, minus some holidays and scheduled downtime
3-shift (24/5)	5,928	0.95	24 hours per day, weekdays, minus some holidays and scheduled downtime
4-shift (24/7)	8,320	0.95	24 hours per day, 7 days a week minus some holidays and scheduled downtime
* Note: This value is derived by adjusting the coincidence factor to account for assumed compressor operation (7 a.m. to 3 p.m.) during only one of the four hours of peak period (2 p.m. to 6 p.m.). 0.95 * (1/4) = 0.2375.			

Default Savings

Default savings may be claimed using the algorithms above and the variable defaults. EDCs may also claim savings using customer specific data.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) PA Consulting Group (2009). Business Programs: Measure Life Study. Prepared for State of Wisconsin Public Service Commission. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf

2) Machinery's Handbook, 25th Ed. Ed by Erik Oberg (Et Al). Industrial Press, Inc. ISBN-10: 0831125756 Survey of Engineered Nozzle Suppliers.

3) Survey of Engineered Nozzle Suppliers.

4) Efficiency Vermont Technical Reference User Manual (TRM), March 16, 2015. The average compressor kW/CFM values were calculated using DOE part load curves and load profile data from 50 facilities employing compressors less than or equal to 40 hp. http://puc.vermont.gov/sites/psbnew/files/doc_library/ev-technical-reference-manual.pdf

5) Assumes 50% handheld air guns and 50% stationary air nozzles. Manual air guns tend to be used less than stationary air nozzles, and a conservative estimate of 1 second of blow-off per minute of compressor run time is assumed. Stationary air nozzles are commonly more wasteful as they are often mounted on machine tools and can be manually operated resulting in the possibility of a long term open blow situation. An assumption of 5 seconds of blow-off per minute of compressor run time is used.

6) Hours account for holidays and scheduled downtime. The CF is drawn from the summer period, which is when the PA peak kW peak is calculated. Efficiency Vermont Technical Reference User Manual (TRM), March 16, 2015. http://puc.vermont.gov/sites/psbnew/files/doc_library/ev-technical-reference-manual.pdf

3.10.3 No-Loss Condensate Drains

Target Sector	Commercial and Industrial Establishments
Measure Unit	No-loss Condensate Drain
Measure Life	5 years Source 1
Measure Vintage	Early Replacement

When air is compressed, water vapor in the air condenses and collects in the system. The water must be drained to prevent corrosion to the storage tank and piping system, and to prevent interference with other components of the compressed air system such as air dryers and filters. Many drains are controlled by a timer and are opened for a fixed amount of time on regular intervals regardless of the amount of condensate. When the drains are opened compressed air is allowed to escape without doing any purposeful work. No-loss Condensate Drains are controlled by a sensor that monitors the level of condensate and only open when there is a need to drain condensate. They close before compressed air is allowed to escape.

Eligibility

This measure is targeted to non-residential customers whose equipment is a timed drain that operates on a pre-set schedule.

Acceptable baseline conditions are compressed air systems with standard condensate drains operated by a solenoid and timer.

Energy efficient conditions are systems retrofitted with new No-loss Condensate Drains properly sized for the compressed air system.

Algorithms

The following algorithms apply for No-loss Condensate Drains.

$$\Delta kWh = ALR \times COMP \times OPEN \times AF \times PNC$$

$$\Delta kW_{peak} = \frac{\Delta kWh}{HOURS} * CF$$

Definition of Terms

Table 3-188: Terms, Values, and References for No-loss Condensate Drains

Term	Unit	Values	Source
ALR, Air Loss Rate; an hourly average rate for the timed drain dependent on drain orifice diameter and system pressure.	*CFM* $\left(\frac{ft^3}{min}\right)$	EDC Data Gathering Default: Table 3-189	EDC Data Gathering 2
$COMP$, Compressor kW / CFM; the amount of electrical demand in KW required to generate one cubic foot of air at 100 PSI.	$\frac{kW}{CFM}$	EDC Data Gathering Default: Table 3-190	EDC Data Gathering 3
$OPEN$, Hours per year drain is open	$\frac{Hours}{year}$	EDC Data Gathering Default: 146	EDC Data Gathering 4
AF, Adjustment Factor; accounts for periods when compressor is not running and the system depressurizes due to leaks and operation of time drains.	*None*	EDC Data Gathering Default: Table 3-191	EDC Data Gathering 5
PNC, Percent Not Condensate; accounts for air loss through the drain after the condensate has been cleared and the drain remains open.	*None*	EDC Data Gathering Default: 0.75	EDC Data Gathering 5
$HOURS$, Annual hours of compressor operation	$\frac{Hours}{year}$	EDC Data Gathering Default: Table 3-192	EDC Data Gathering 6
CF, Coincidence factor	$Decimal$	EDC Data Gathering Default: Table 3-192	EDC Data Gathering 6

Table 3-189: Average Air Loss Rates (ALR)

Pressure (psig)	Orifice Diameter (inches)					
	1/64	1/32	1/16	1/8	1/4	3/8
70	0.29	1.16	4.66	18.62	74.4	167.8
80	0.32	1.26	5.24	20.76	83.1	187.2
90	0.36	1.46	5.72	23.1	92	206.6
95	0.38	1.51	6.02	24.16	96.5	216.8
100	0.4	1.55	6.31	25.22	100.9	227
105	0.42	1.63	6.58	26.31	105.2	236.7
110	0.43	1.71	6.85	27.39	109.4	246.4
115	0.45	1.78	7.12	28.48	113.7	256.1
120	0.46	1.86	7.39	29.56	117.9	265.8
125	0.48	1.94	7.66	30.65	122.2	275.5
For well-rounded orifices, values should be multiplied by 0.97. For sharp orifices, values should be multiplied by 0.61. When the baseline value is unknown, use 100.9 CFM[142].						

Table 3-190: Average Compressor kW/CFM (COMP)

Compressor Control Type	Average Compressor kW/CFM (COMP)
Modulating w/ Blowdown	0.32
Load/No Load w/ 1 gal/CFM Storage	0.32
Load/No Load w/ 3 gal/CFM Storage	0.30
Load/No Load w/ 5 gal/CFM Storage	0.28
Variable Speed w/ Unloading	0.23

[142] Based on market activity as reported by several compressed air equipment vendors.

Table 3-191: Adjustment Factor (AF)

Compressor Operating Hours	AF
Single Shift – 2080 Hours	0.62
2-Shift – 4160 Hours	0.74
3-Shift – 6240 Hours	0.86
4-Shift – 8320 Hours	0.97

Table 3-192: Default Hours and Coincidence Factors by Shift Type

Shift Type	Hours Per Year	CF	Description
Single Shift (8/5)	1,976	0.24*	7 AM – 3 PM, weekdays, minus some holidays and scheduled downtime
2-shift (16/5)	3,952	0.95	7 AM – 11 PM, weekdays, minus some holidays and scheduled downtime
3-shift (24/5)	5,928	0.95	24 hours per day, weekdays, minus some holidays and scheduled downtime
4-shift (24/7)	8,320	0.95	24 hours per day, 7 days a week minus some holidays and scheduled downtime
* Note: This value is derived by adjusting the coincidence factor to account for assumed compressor operation (7 a.m. to 3 p.m.) during only one of the four hours of peak period (2 p.m. to 6 p.m.). 0.95 * (1/4) = 0.2375.			

Default Savings

Default savings may be claimed using the algorithms above and the variable defaults. EDCs may also claim savings using customer specific data.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) Efficiency Vermont Technical Reference User Manual (TRM), March 16, 2015. http://puc.vermont.gov/sites/psbnew/files/doc_library/ev-technical-reference-manual.pdf

2) US DOE Compressed Air Tip Sheet #3, August 2004, from Fundamentals for Compressed Air Systems Training offered by the Compressed Air Challenge. https://www.energy.gov/sites/prod/files/2014/05/f16/compressed_air3.pdf

3) The average compressor kW/CFM values were calculated using DOE part load curves and load profile data from 50 facilities employing compressors less than or equal to 40 hp. Efficiency Vermont, Technical Reference Manual 2014-87. http://puc.vermont.gov/sites/psbnew/files/doc_library/ev-technical-reference-manual.pdf

4) Assumes 10 seconds per 10-minute interval. Efficiency Vermont Technical Reference User Manual (TRM), March 16, 2015. http://puc.vermont.gov/sites/psbnew/files/doc_library/ev-technical-reference-manual.pdf
5) Based on observed data. Efficiency Vermont Technical Reference User Manual (TRM), March 16, 2015. http://puc.vermont.gov/sites/psbnew/files/doc_library/ev-technical-reference-manual.pdf
6) Accounts for holidays and scheduled downtime. Efficiency Vermont, Technical Reference Manual 2014-87. The CF is drawn from the summer period, which is when the PA peak kW peak is calculated. http://puc.vermont.gov/sites/psbnew/files/doc_library/ev-technical-reference-manual.pdf

3.10.4 Air Tanks for Load/No Load Compressors

Target Sector	Commercial and Industrial Establishments
Measure Unit	Receiver Tank Addition
Measure Life	15 years Source 1
Measure Vintage	Early Replacement

This measure protocol applies to the installation of air receivers with pressure/flow controls to load/no load compressors. Load/no load compressors unload when there is low demand. The process of unloading is done over a period of time to avoid foaming of the lubrication oil. Using a storage tank with pressure/flow control will buffer the air demands on the compressor. Reducing the number of cycles in turn reduces the number of transition times from load to no load and saves energy. The baseline equipment is a load/no load compressor with a 1 gal/cfm storage ratio or a modulating compressor with blowdown.

Eligibility

This measure protocol applies to the installation of air receivers with pressure/flow controls to load/no load compressors. The high efficiency equipment is a load/no load compressor with a minimum storage ratio of 4 gallons of storage per cfm.

Algorithms

$$\Delta kWh = \frac{HP \times 0.746 \times HOURS \times LF \times LR}{\eta}$$

$$\Delta kW_{peak} = \frac{\Delta kWh}{HOURS} \times CF$$

Definition of Terms

Table 3-193: Terms, Values, and References for Air Tanks for Load/No Load Compressors

Term	Unit	Values	Source
HP, Horsepower of compressor motor	HP	Nameplate	EDC Data Gathering
0.746, Conversion factor	$\frac{kW}{HP}$	0.746	Conversion factor
$HOURS$, Annual hours of compressor operation	hr	Based on logging, panel data or modeling Default: Table 3-194	EDC Data Gathering 2
LF, Load factor, average load on compressor motor	Fraction	Default = 0.92	3
LR, Load reduction	Fraction	Default = 0.10	5
η, Efficiency of compressor motor	Fraction	Default = 0.91	4
CF, Coincidence factor	Fraction	Based on logging, panel data or site contact interview Default: Table 3-194	EDC Data Gathering 2

Table 3-194: Default Hours and Coincidence Factors by Shift Type

Shift Type	Hours Per Year	CF	Description
Single Shift (8/5)	1,976	0.24*	7 AM – 3 PM, weekdays, minus some holidays and scheduled downtime
2-shift (16/5)	3,952	0.95	7 AM – 11 PM, weekdays, minus some holidays and scheduled downtime
3-shift (24/5)	5,928	0.95	24 hours per day, weekdays, minus some holidays and scheduled downtime
4-shift (24/7)	8,320	0.95	24 hours per day, 7 days a week minus some holidays and scheduled downtime
* Note: This value is derived by adjusting the coincidence factor to account for assumed compressor operation (7 a.m. to 3 p.m.) during only one of the four hours of peak period (2 p.m. to 6 p.m.). 0.95 * (1/4) = 0.2375.			

Default Savings

Default savings per compressor motor HP for four shift types are shown below. EDCs may also claim savings using customer specific data.

Table 3-195: Default Savings per HP for Air Tanks for Load/No Load Compressors

Shift Type	Annual Energy Savings ($\Delta kWh/HP$)	Peak Demand Savings ($\Delta kW_{peak}/HP$)
Single Shift (8/5)	149.0	0.018
2-shift (16/5)	298.1	0.072
3-shift (24/5)	447.1	0.072
4-shift (24/7)	627.5	0.072

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) PA Consulting Group (2009). Business Programs: Measure Life Study. Prepared for State of Wisconsin Public Service Commission. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2) Accounts for holidays and scheduled downtime. The CF is drawn from the summer period, which is when the PA peak kW peak is calculated. Efficiency Vermont Technical Reference User Manual (TRM), March 16, 2015. http://puc.vermont.gov/sites/psbnew/files/doc_library/ev-technical-reference-manual.pdf
3) Cascade Energy, Prepared for Regional Technical Forum. *Standard Savings Estimation Protocol for Ultra-Premium Efficiency Motors*. November 2012. Load factor for air compressors and average motor efficiency. https://rtf.nwcouncil.org/meeting/rtf-meeting-november-14-2012
4) Average efficiency for 1800 RPM ODP motors with 75% and 100% load factors. Cascade Energy, Prepared for Regional Technical Forum. *Standard Savings Estimation Protocol for Ultra-Premium Efficiency Motors*. November 2012. Load factor for air compressors and average motor efficiency. https://rtf.nwcouncil.org/meeting/rtf-meeting-november-14-2012
5) United States Department of Energy, Advanced Manufacturing Office. *Improving Compressed Air System Performance, a Sourcebook for Industry, Third Edition*. March 2016. Compressed air storage. https://www.energy.gov/sites/prod/files/2016/03/f30/Improving%20Compressed%20Air%20Sourcebook%20version%203.pdf

3.10.5 Variable-Speed Drive Air Compressor

Target Sector	Commercial and Industrial Establishments
Measure Unit	Compressor Motor
Measure Life	10 years Source 1
Measure Vintage	Replace on Burnout, Early Replacement, Retrofit, New Construction

Variable-Speed Drive (VSD) Air Compressors use a variable speed drive on the motor to match motor output to the load, resulting in greater efficiency than fixed-speed air compressors. Baseline compressors choke off inlet air to modulate the compressor output, resulting in increased energy consumption and peak demand.

Eligibility

To qualify for this measure, a participating commercial or industrial establishment must install or retrofit a ≤ 40 HP compressor with variable speed control. Projects involving compressors larger than 40 HP should be treated as custom projects.

Algorithms

Savings are calculated using representative baseline and efficient demand numbers for compressor capacities according to the facility's load shape and runtime. Demand curves are derived from DOE data for a variable speed compressor versus a modulating compressor. The following formulas are used to quantify the annual energy and coincident peak demand savings.

$$\Delta kWh = 0.9 \times HP_{compressor} \times HOURS \times (CLF_{base} - CLF_{VSD})$$

$$\Delta kW_{peak} = \Delta kWh / HOURS * CF$$

Definition of Terms

Table 3-196: Terms, Values, and References for Variable-Speed Drive Air Compressors

Term	Unit	Values	Source
$HOURS$, compressor total hours of operation below depending on shift	Hours/yr	EDC Data Gathering Default: Table 3-197	2
$HP_{compressor}$, compressor motor nominal HP	HP	Nameplate	EDC Data Gathering
CLF_{base}, baseline compressor factor	None	EDC Data Gathering Default = 0.890	3
CLF_{VSD}, efficient compressor factor	None	EDC Data Gathering Default = 0.705	3
CF, Coincidence factor	None	Default: Table 3-197	2
0.9, Compressor motor nominal HP to full load kW conversion factor.	kW/HP	Default = 0.9	4

Commented [SA72]: Franklin Energy

The baseline of this measure is modulation control right now, which is too aggressive in most cases. Most TRMs use a mix of control types or load/no-load as baseline.

Table 3-197: Default Hours and Coincidence Factors by Shift Type

Shift Type	Hours Per Year	CF	Description
Single Shift (8/5)	1,976	0.24*	7 AM – 3 PM, weekdays, minus some holidays and scheduled downtime
2-shift (16/5)	3,952	0.95	7 AM – 11 PM, weekdays, minus some holidays and scheduled downtime
3-shift (24/5)	5,928	0.95	24 hours per day, weekdays, minus some holidays and scheduled downtime
4-shift (24/7)	8,320	0.95	24 hours per day, 7 days a week minus some holidays and scheduled downtime
* Note: This value is derived by adjusting the coincidence factor to account for assumed compressor operation (7 a.m. to 3 p.m.) during only one of the four hours of peak period (2 p.m. to 6 p.m.). 0.95 * (1/4) = 0.2375.			

Default Savings

Default savings per compressor motor HP for four shift types are shown below. EDCs may also claim savings using customer specific data.

Table 3-198: Default Savings per HP for Variable-Speed Drive Air Compressors

Shift Type	Annual Energy Savings ($\Delta kWh/HP$)	Peak Demand Savings ($\Delta kW_{peak}/HP$)
Single Shift (8/5)	329.0	0.040
2-shift (16/5)	658.0	0.158
3-shift (24/5)	987.0	0.158
4-shift (24/7)	1,385.3	0.158

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) Illinois Statewide Technical Reference Manual v7.0, Section 4.7.1, p. 542, http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_7/Final_9-28-18/IL-TRM_Effective_010119_v7.0_Vol_2_C_and_I_092818_Final.pdf
2) Accounts for holidays and scheduled downtime. The CF is drawn from the summer period, which is when the PA peak kW peak is calculated. Efficiency Vermont, Technical Reference Manual 2014-87. http://puc.vermont.gov/sites/psbnew/files/doc_library/ev-technical-reference-manual.pdf
3) Compressor factors were developed using DOE part load data for different compressor control types as well as load profiles from 50 facilities employing air compressors less than or equal to 40 hp. Efficiency Vermont Technical Reference User Manual (TRM), March 16, 2015. http://puc.vermont.gov/sites/psbnew/files/doc_library/ev-technical-reference-manual.pdf
4) Conversion factor based on a linear regression analysis of the relationship between air compressor motor nominal horsepower and full load kW from power measurements of 72 compressors at 50 facilities. Efficiency Vermont Technical Reference User Manual (TRM), March 16, 2015. http://puc.vermont.gov/sites/psbnew/files/doc_library/ev-technical-reference-manual.pdf

3.10.6 Compressed Air Controller

Target Sector	Commercial and Industrial Establishments
Measure Unit	Per Compressed Air System
Measure Life	15 years Source 1
Measure Vintage	New Construction or Retrofit

Eligibility

The following protocol for the measurement of energy and demand savings applies to the installation of a compressed air pressure or flow controller for compressed air systems in commercial or industrial facilities.

A pressure/flow controller can greatly increase the control of an air storage system. These units, also called demand valves, precision flow controllers, or pilot-operated regulators, are precision pressure regulators that allow the airflow to fluctuate while maintaining a constant pressure to the facility's air distribution piping network. Installing a pressure/flow controller on the downstream side of an air storage receiver creates a pressure differential entering and leaving the vessel. This pressure differential stores energy in the form of readily available compressed air, which can be used to supply the peak air demand for short duration events, in place of using more compressor horsepower to feed this peak demand. The benefits of having a pressure/flow controller include:

- Reducing the kilowatts of peak demand, especially with multiple compressor configurations.
- Saving kilowatt-hours by allowing the compressor to run at most efficient loads, then turn itself off in low demand and no demand periods.
- Saving kilowatt-hours by reducing plant air pressure to the minimum allowable. This leads to reduced loads on the electric motors and greater system efficiency. For every 2 psi reduced in the system, 1% of energy is saved.
- Maintaining a reduced, constant pressure in the facility wastes less air due to leakage, and less volume is required by the compressor.
- Ensuring quality control of the process by the constant pressure: machines can produce an enhanced product quality when the pressure is allowed to fluctuate.

The baseline condition is having no existing pressure/flow controller and an existing compressed air system with a total compressor motor capacity ≥ 40 hp. The efficient condition is a motor with a VFD control. This protocol is not applicable for compressed air systems with total motor nameplate capacity < 40 hp. This measure is not replacing drop-line regulators or filter-regulator lubricators.

Commented [SA73]: Franklin Energy

This description appears to be wrong. It is a flow controller, nota VFD.

Commented [SA74]: Franklin Energy

Existing storage size is critical for this measure. It is recommened to add the storage requirement for this one. At least 3gal/cfm is needed for the flow controller to operate effectively.

Algorithms

$$\Delta kWh = HP \times \frac{0.746}{\eta_{motor}} \times LF \times HOURS \times \%Decrease$$

$$\Delta kW_{peak} = \Delta kWh / HOURS \times CF$$

Definition of Terms

Table 3-199: Terms, Values, and References for Compressed Air Controllers

Term	Unit	Values	Source
HP, total air compressor motor nameplate horsepower	HP	Nameplate	EDC Data Gathering
0.746, conversion factor from kW to HP	kW/HP	Constant	Constant
$HOURS$, average annual run hours of compressed air system	$\frac{Hours}{Year}$	Based on logging, panel data or modeling Default: Table 3-200	EDC Data Gathering 1
LF, load factor; ratio between the actual load on the compressor motor and the rated load	%	Based on spot metering and nameplate Default: 0.92	EDC Data Gathering 2
η_{motor}, compressor motor efficiency at the full-rated load	%	Nameplate Default: 0.91	EDC Data Gathering 3
$\%Decrease$, percentage decrease in power input	%	Default: 5%	4
CF, Coincidence factor	Decimal	EDC Data Gathering Default: Table 3-200	EDC Data Gathering 1

Commented [SA75]: Franklin Energy

This factor is similar with the factor in VFD air compressor measure. 0.89 is used in that one. It is recommended to keep these factors consistent in one TRM.

Commented [SA76]: Franklin Energy

This efficiency is too low for most cases. Flow controllers are usually used for large compressed air systems. We take 100hp as an example. The Pre-EPAct eff is 92.3%, EPAct is 94.5%, and NEMA Premium is 95.4%. Therefore, it is suggested to use 0.95 herein.

Table 3-200: Default Hours and Coincidence Factors by Shift Type

Shift Type	Hours Per Year	CF	Description
Single Shift (8/5)	1,976	0.24*	7 AM – 3 PM, weekdays, minus some holidays and scheduled downtime
2-shift (16/5)	3,952	0.95	7 AM – 11 PM, weekdays, minus some holidays and scheduled downtime
3-shift (24/5)	5,928	0.95	24 hours per day, weekdays, minus some holidays and scheduled downtime
4-shift (24/7)	8,320	0.95	24 hours per day, 7 days a week minus some holidays and scheduled downtime

* Note: This value is derived by adjusting the coincidence factor to account for assumed compressor operation (7 a.m. to 3 p.m.) during only one of the four hours of peak period (2 p.m. to 6 p.m.). 0.95 * (1/4) = 0.2375.

Default Savings

Default savings per compressor motor HP for four shift types are shown below. EDCs may also claim savings using customer specific data.

Table 3-201: Default Savings per HP for Compressed Air Controllers

Shift Type	Annual Energy Savings ($\Delta kWh/HP$)	Peak Demand Savings ($\Delta kW_{peak}/HP$)
Single Shift (8/5)	74.5	0.009
2-shift (16/5)	149.0	0.036
3-shift (24/5)	223.5	0.036
4-shift (24/7)	313.7	0.036

Evaluation Protocol

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

3) Accounts for holidays and scheduled downtime. The CF is drawn from the summer period, which is when the PA peak kW peak is calculated. Efficiency Vermont Technical Reference User Manual (TRM), March 16, 2015. http://puc.vermont.gov/sites/psbnew/files/doc_library/ev-technical-reference-manual.pdf

4) Cascade Energy, Prepared for Regional Technical Forum. *Standard Savings Estimation Protocol for Ultra-Premium Efficiency Motors*. November 2012. Load factor for air compressors and average motor efficiency. https://rtf.nwcouncil.org/meeting/rtf-meeting-november-14-2012

5) Average efficiency for 1800 RPM ODP motors with 75% and 100% load factors. Cascade Energy, Prepared for Regional Technical Forum. *Standard Savings Estimation Protocol for Ultra-Premium Efficiency Motors*. November 2012 https://rtf.nwcouncil.org/meeting/rtf-meeting-november-14-2012

6) United States Department of Energy. *Improving Compressed Air System Performance: A Sourcebook for Industry.* p. 20. November 2003.

3.10.7 Compressed Air Low Pressure Drop Filters

Target Sector	Commercial and Industrial Establishments
Measure Unit	Per Compressed Air System
Measure Life	10 years Source 1
Measure Vintage	New Construction or Retrofit

Eligibility

The following protocol for the measurement of energy and demand savings applies to the installation of low pressure drop air filters for compressed air systems in commercial and industrial facilities. Low pressure drop filters remove solids and aerosols from compressed air systems with a longer life and lower pressure drop than standard coalescing filters, resulting in better efficiencies.

The baseline condition is a standard coalescing filter with a pressure drop of 3 psi when new and 5 psi or more at element change. The efficient condition is a low pressure drop filter with pressure drop not exceeding 1 psi when new and 3 psi at element change.

Algorithms

$$\Delta kWh = \text{HP} \times 0.746 \times DP \times SF \times HOURS$$

$$\Delta kW_{peak} = \Delta kWh / HOURS \times CF$$

Commented [SA77]: Franklin Energy

It is recommened to apply load factor in this calculation. Otherwise, the savings calc is too aggressive.

Definition of Terms

Table 3-202: Terms, Values, and References for Compressed Air Low Pressure Drop Filters

Term	Unit	Values	Source
HP, total air compressor motor nameplate horsepower	*HP*	Nameplate	EDC Data Gathering
0.746, conversion factor	$\frac{kW}{HP}$	0.746	Conversion factor
DP, reduced filter pressure loss	*psi*	Default: 2.0	3
SF, savings factor	*%/psi*	Default: 0.005	4
$HOURS$, compressed air system total annual hours of operation	$\frac{Hours}{Year}$	Default: Table 3-203	5
		Based on logging and panel data	EDC Data Gathering
CF, Coincidence factor	*Decimal*	EDC Data Gathering	EDC Data Gathering
		Default: Table 3-203	5

Table 3-203: Default Hours and Coincidence Factors by Shift Type

Shift Type	Hours Per Year	CF	Description
Single Shift (8/5)	1,976	0.24*	7 AM – 3 PM, weekdays, minus some holidays and scheduled downtime
2-shift (16/5)	3,952	0.95	7 AM – 11 PM, weekdays, minus some holidays and scheduled downtime
3-shift (24/5)	5,928	0.95	24 hours per day, weekdays, minus some holidays and scheduled downtime
4-shift (24/7)	8,320	0.95	24 hours per day, 7 days a week minus some holidays and scheduled downtime
* Note: This value is derived by adjusting the coincidence factor to account for assumed compressor operation (7 a.m. to 3 p.m.) during only one of the four hours of peak period (2 p.m. to 6 p.m.). 0.95 * (1/4) = 0.2375.			

Default Savings

Default savings per compressor motor HP for four shift types are shown below. EDCs may also claim savings using customer specific data.

Table 3-204: Default Savings per HP for Compressed Air Low Pressure Drop Filters

Shift Type	Annual Energy Savings ($\Delta kWh/HP$)	Peak Demand Savings ($\Delta kW_{peak}/HP$)
Single Shift (8/5)	14.7	0.002
2-shift (16/5)	29.5	0.007
3-shift (24/5)	44.2	0.007
4-shift (24/7)	62.1	0.007

Evaluation Protocol

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) Based on survey of manufacturer claims (Zeks, Van Air, Quincy), as recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018. Illinois Technical Reference Manual v.7.0 Volume 2. September 2018. Page 545.

2) Illinois Statewide Technical Reference Manual v.7.0 Volume 2. September 2018. Page 546. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_7/Final_9-28-18/IL-TRM_Effective_010119_v7.0_Vol_2_C_and_I_092818_Final.pdf

3) Assumed pressure will be reduced from a roughly 3 psi pressure drop through a filter to less than 1 psi, for a 2 psi savings.

4) "Optimizing Pneumatic Systems for Extra Savings," Compressed Air Best Practices, DOE Compressed Air Challenge, 2010. (1% reduction in power per 2 psi reduction in system pressure is equal to 0.5% reduction per 1 psi, or a savings factor of 0.005)

5) Accounts for holidays and scheduled downtime. The CF is drawn from the summer period, which is when the PA peak kW peak is calculated. Efficiency Vermont Technical Reference User Manual (TRM), March 16, 2015. http://puc.vermont.gov/sites/psbnew/files/doc_library/ev-technical-reference-manual.pdf

3.10.8 Compressed Air Mist Eliminators

Target Sector	Commercial and Industrial Establishments
Measure Unit	Per Air Mist Eliminator
Measure Life	5 years Source 1
Measure Vintage	New Construction or Retrofit

Eligibility

The following protocol for the measurement of energy and demand savings applies to the installation of mist eliminator air filters for compressed air systems in commercial and industrial facilities.

Large compressed air systems require air filtration for proper operation. These filters remove oil mist from the supply air of lubricated compressors, protecting the distribution system and end-use devices. While these filters are important to the operation of the system, they do have a pressure drop across them, and thus require a slightly higher operating pressure. Typical coalescing oil filters will operate with a 2 psig to 10 psig pressure drop. Mist eliminator air filters operate at a 0.5 psig pressure drop that increases to 3 psig over time before replacement is recommended.

This reduction in pressure drop allows the compressed air system to operate at a reduced pressure and, in turn, reduces the energy consumption of the system. In general, the energy consumption will decrease by 1% for every 2 psig the operating pressure is reduced.[143] Lowering the operating pressure has the secondary benefit of decreasing the demand of all unregulated usage, such as leaks and open blowing. The equipment is mist eliminator air filters. The compressed air system must be greater than 50 HP to qualify, and the mist eliminator must have less than a 1 psig pressure drop and replace a coalescing filter.

The baseline condition is a standard coalescing filter. The efficient condition is a mist eliminator air filter that replaces a standard coalescing filter. This protocol is not applicable for compressed air systems with total air compressor nameplate horsepower < 50 HP or mist eliminators with ≥ 1 psig pressure drop.

Algorithms

$$\Delta kWh = HP \times \frac{0.746}{\eta_{motor}} \times LF \times HOURS \times \%Savings$$

$$\%Savings = Total_{PR} \times RS$$

$$\Delta kW_{peak} = \Delta kWh / HOURS \times CF$$

[143] Cascade Energy. Proposed Standard Savings Estimation Protocol for Ultra-Premium Efficiency Motors. November 5, 2012.

Definition of Terms

Table 3-205: Terms, Values, and References for Compressed Air Mist Eliminators

Term	Unit	Values	Source
HP, Rated horsepower of the air compressor motor	*HP*	Nameplate	EDC Data Gathering
0.746, conversion factor from horsepower to kW	*kW/HP*	Constant	Constant
η_{motor}, compressor motor efficiency at the full-rated load	*%*	Nameplate Default: 0.91	EDC Data Gathering 2
LF, load factor; ratio between the actual load on the compressor motor and the rated load	*%*	Based on spot metering and nameplate Default: 0.92	EDC Data Gathering 3
$HOURS$, average annual run hours of the compressed air system	$\frac{Hours}{Year}$	Based on logging, panel data or modeling Default: Table 3-206	EDC Data Gathering 4
$\%Savings$, percentage of energy saved	*%*	Default: 2%	5
$Total_{PR}$, total pressure reduction from replacing filter	$psig$	Default: 4 psig	5
RS, percentage of energy saved for each psig reduced	*%/psig*	Default: 0.5%	6
CF, Coincidence factor	*Decimal*	EDC Data Gathering Default: Table 3-206	EDC Data Gathering 4

Commented [SA78]: Franklin Energy

This efficiency is too low for most cases. Flow controllers are usually used for large compressed air systems. We take 100hp as an example. The Pre-EPAct eff is 92.3%, EPAct is 94.5%, and NEMA Premium is 95.4%. Therefore, it is suggested to use 0.95 herein.

Recommend keeping this value consistent among measures.

Table 3-206: Default Hours and Coincidence Factors by Shift Type

Shift Type	Hours Per Year	CF	Description
Single Shift (8/5)	1,976	0.24*	7 AM – 3 PM, weekdays, minus some holidays and scheduled downtime
2-shift (16/5)	3,952	0.95	7 AM – 11 PM, weekdays, minus some holidays and scheduled downtime
3-shift (24/5)	5,928	0.95	24 hours per day, weekdays, minus some holidays and scheduled downtime
4-shift (24/7)	8,320	0.95	24 hours per day, 7 days a week minus some holidays and scheduled downtime
* Note: This value is derived by adjusting the coincidence factor to account for assumed compressor operation (7 a.m. to 3 p.m.) during only one of the four hours of peak period (2 p.m. to 6 p.m.). 0.95 * (1/4) = 0.2375.			

Default Savings

Default savings per compressor motor HP for four shift types are shown below. EDCs may also claim savings using customer specific data.

Table 3-207: Default Savings per HP for Compressed Air Mist Eliminators

Shift Type	Annual Energy Savings ($\Delta kWh/HP$)	Peak Demand Savings ($\Delta kW_{peak}/HP$)
Single Shift (8/5)	29.8	0.004
2-shift (16/5)	59.6	0.014
3-shift (24/5)	89.4	0.014
4-shift (24/7)	125.5	0.014

Evaluation Protocol

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) Based on product warranty period Sullair Corporation. *Compressed Air Filtration and Mist Eliminators Datasheet*. http://www.amcompair.com/products/brochures/sullair_brochures/_Sullair%20filtration.pdf

2) Average efficiency for 1800 RPM ODP motors with 75% and 100% load factors. Cascade Energy, Prepared for Regional Technical Forum. *Standard Savings Estimation Protocol for Ultra-Premium Efficiency Motors*. November 2012. https://rtf.nwcouncil.org/meeting/rtf-meeting-november-14-2012

3) Cascade Energy, Prepared for Regional Technical Forum. *Standard Savings Estimation Protocol for Ultra-Premium Efficiency Motors*. November 2012. Load factor for air

compressors and average motor efficiency. https://rtf.nwcouncil.org/meeting/rtf-meeting-november-14-2012

4) Accounts for holidays and scheduled downtime. The CF is drawn from the summer period, which is when the PA peak kW peak is calculated. Efficiency Vermont Technical Reference User Manual (TRM), March 16, 2015. http://puc.vermont.gov/sites/psbnew/files/doc_library/ev-technical-reference-manual.pdf

5) Sullair Corporation. *Compressed Air Filtration and Mist Eliminators Datasheet*. http://www.amcompair.com/products/brochures/sullair_brochures/_Sullair%20filtration.pdf

6) United States Department of Energy. *Improving Compressed Air System Performance: A Sourcebook for Industry*. p. 20. November 2003.

3.11 MISCELLANEOUS

3.11.1 HIGH EFFICIENCY TRANSFORMER

Target Sector	Commercial, Industrial, and Agricultural Establishments
Measure Unit	Transformer
Measure Life	15 years Source 1
Measure Vintage	Retrofit, New Construction

ELIGIBILITY

Distribution transformers are used in some multi-family, commercial and industrial applications to step down power from distribution voltage to be used in HVAC or process loads (220V or 480V) or to serve plug loads (120V).

Distribution transformers that are more efficient than the required minimum federal standard efficiency qualify for this measure. If there is no specific standard efficiency requirement, the transformer does not qualify (because the baseline cannot be defined). For example, although the federal standards increased the minimum required efficiency in 2016, most transformers with a NEMA premium or CEE Tier 2 rating will still achieve energy conservation. Standards are defined for low-voltage dry-type distribution transformers (up to 333kVA single-phase and 1000kVA 3-phase.

The baseline equipment is a transformer that meets the minimum federal efficiency requirement. Standards are developed by the DOE and published in Federal Register 10CFR 431. Transformers more efficient than the federal minimum standard are eligible. This includes CEE Tier II (single or three phase) and most NEMA premium efficiency rated products. Projects with liquid-immersed distribution transformers and medium voltage dry type transformer energy savings should be treated as custom projects.

Commented [SA79]: Franklin Energy

It is worth noting that the IL TRM treasts these as both prescriptive.

ALGORITHMS

$$\Delta kWh = Losses_{base} - Losses_{ee}$$

$$Losses_{base} = PowerRating \times LF \times PF \times \left(\frac{1}{EFF_{base}} - 1\right) \times 8760$$

$$Losses_{ee} = PowerRating \times LF \times PF \times \left(\frac{1}{EFF_{ee}} - 1\right) \times 8760$$

$$\Delta kW_{peak} = \Delta kWh/8760$$

Definition of Terms

Table 3-208: Terms, Values, and References for High Efficiency Transformers

Term	Unit	Values	Source
$PowerRating$, kVA rating of the transformer	*kVA*	EDC Data Gathering	EDC Data Gathering
EFF_{base}, Baseline total efficiency rating of federal minimum standard transformer	*Percent*	Default: Table 3-209	2
EFF_{ee}, Installed total efficiency rating of the transformer	*Percent*	EDC Data Gathering	EDC Data Gathering Source 3
LF, Load factor for the transformer	*Percent*	EDC Data Gathering Default: 35%	EDC Data Gathering 4
PF, Power factor for the load served by the transformer	*Decimal*	EDC Data Gathering[144]	EDC Data Gathering
		Default: 1.0	5

Table 3-209: Baseline Efficiencies for Low-Voltage Dry-Type Distribution Transformers

Single-phase		Three-phase	
kVA	**Efficiency (%)**	**kVA**	**Efficiency (%)**
15	97.70	15	97.89
25	98.00	30	98.23
37.5	98.20	45	98.40
50	98.30	75	98.60
75	98.50	112.5	98.74
100	98.60	150	98.83
167	98.70	225	98.94
250	98.80	300	99.02
333	98.90	500	99.14
---	---	750	99.23
---	---	1,000	99.28

Commented [SA80]: Franklin Energy

Because the measure is suitable for C&I, if unknown, 22% could be used for commercial loads and 45% for industrial load.

Guidelines on The Calculation and Use of Loss Factors, Electric Authority, Te Mana Hiko, February 14, 2013

[144] Use the actual power factor for the network segment served.

Default Savings

There are no default savings for this measure.

Evaluation Protocol

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) US DOE lists the lifetime at 32 years. The maximum measure life allowed by the PA TRM is 15 years. US Department of Energy, "Energy Conservation Program: Energy Conservation Standards for Distribution Transformers; Final Rule", 10 CFR Part 431, Published April 18, 2013, Effective as of January 1, 2016.
2) US Department of Energy, "Energy Conservation Program: Energy Conservation Standards for Distribution Transformers; Final Rule", 10 CFR Part 431, Published April 18, 2013, Compliance effective as of January 1, 2016.
3) Use the efficiency rating calculated by the appropriate DOE test method, generally at 35% load factor. Energy Conservation Program: Test Procedures for Distribution Transformers; Final Rule. Effective May 30, 2006.
4) Unity power factor for used as default value, as used in the test procedures provided by US DOE. Energy Conservation Program: Test Procedures for Distribution Transformers; Final Rule. Effective May 30, 2006.

3.11.2 Engine Block Heat Timer

Target Sector	Commercial, Industrial, and Agricultural Establishments
Measure Unit	Engine Block Heater Timer
Measure Life	15 years Source 1
Measure Vintage	Retrofit

Eligibility

This protocol documents the energy savings attributed to installation of engine block heater timers in commercial, industrial, and agricultural establishments. The baseline for this measure is an engine block heater in use without a timer.

Algorithms

Engine block heater timers save energy by reducing the time that engine block heaters operate. Typically, block heaters are plugged in throughout the night. Using timers allows the heater to come on at a preset time during the night, rather than being on throughout the night. Because this measure does not affect peak period usage, there are no peak demand savings associated with the measure.

$$\Delta kWh = P * Hours * Days * UF$$

Definition of Terms

Table 3-210: Terms, Values, and References for Engine Block Heater Timer

Term	Unit	Values	Source
P, Average power consumption of engine block heater	kW	EDC Data Gathering	EDC Data Gathering
		Default = 1.3	2
$Hours$, Reduction in number of hours block heater is used per night	Hours/day	EDC Data Gathering	EDC Data Gathering
		Default = 9	2
$Days$, Number of operating days per year	Days/year	EDC Data Gathering	EDC Data Gathering
		Default = 65	2
UF, Usage factor	None	EDC Data Gathering	EDC Data Gathering
		Default = 0.97	2

Default Savings

Default savings for this measure are shown in the table below.

Table 3-211: Default Savings for Engine Block Heater Timer

Energy Savings (kWh)	Peak Demand Reduction (kW)
737.7	0

Evaluation Protocol

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) Gutierrez, Alfredo. Circulating Block Heater. Prepared for the California Technical Forum. http://static1.squarespace.com/static/53c96e16e4b003bdba4f4fee/t/556f7c9ee4b0b65c3515c80c/1433369758093/Circulating+Block+Heater+Presentation_ver+2.pdf

2) Wisconsin Focus on Energy 2018 Technical Reference Manual. Public Service Commission of Wisconsin. The Cadmus Group, Inc. 2018. Pg. 590. https://www.focusonenergy.com/sites/default/files/TRM%202018%20Final%20Version%20Dec%202017_1.pdf

3.11.3 High Frequency Battery Chargers

Target Sector	Commercial and Industrial Establishments
Measure Unit	Charger
Measure Life	15 years Source 1
Measure Vintage	New Construction, Replace on Burnout

Eligibility

This measure applies to industrial high frequency battery chargers, used for industrial equipment such as fork lifts, replacing existing SCR (silicon controlled rectifier) or ferroresonant charging technology. High frequency battery chargers are used for industrial equipment such as fork lifts. They have a greater efficiency than silicon controlled rectifier (SCR) or ferroresonant chargers.

Commented [SA81]: Franklin Energy

This second sentence seems to be somewhat redundant. Recommend rewording as needed.

The baseline equipment is a SCR or ferroresonant battery charger system with minimum 8-hour shift operation five days per week. The energy efficient equipment is a high frequency battery charger system with a minimum power conversion efficiency of 90% and 8-hour shift operation five days per week.

Algorithms

Algorithms for annual energy savings and peak demand savings are shown below.

$$\Delta kWh = (CAP \times DOD) \times CHG \times \left(\frac{CR_{base}}{PC_{base}} - \frac{CR_{ee}}{PC_{ee}}\right) \times (1 + IF_e)$$

$$\Delta kW_{peak} = \left(\frac{PF_{base}}{PC_{base}} - \frac{PF_{ee}}{PC_{ee}}\right) \times Volts_{DC} \times \frac{Amps_{DC}}{1{,}000} \times (1 + IF_d) \times CF$$

Definition of Terms

Table 3-212: Terms, Values, and References for High Frequency Battery Chargers

Term	Unit	Values	Source
CAP, Capacity of battery	*kWh*	EDC Data Gathering	EDC Data Gathering
		Default: 35	2
DOD, Depth of discharge	*Percent*	Default: 80%	3
CHG, Number of charges per year	*N*	EDC Data Gathering	EDC Data Gathering
		Default: Table 3-213	4
CR_{base}, Baseline charge return factor	*Decimal*	Default: 1.2485	3, 5
PC_{base}, Baseline power conversion efficiency	*Decimal*	Default: 0.84	3
CR_{ee}, Efficient charge return factor	*Decimal*	Default: 1.107	3
PC_{ee}, Efficient power conversion efficiency	*Decimal*	Default: 0.89	3
IF_e, Waste heat factor to account for cooling and heating energy impacts from reduced waste heat from the battery charger	*Decimal*	Default: Table 3-8 and Table 3-9	6
PF_{base}, Power factor of baseline charger	*Decimal*	Default: 0.9095	3
PF_{ee}, Power factor of high frequency charger	*Decimal*	Default: 0.9370	3
$Volts_{DC}$, DC rated voltage of charger	*V*	EDC Data Gathering	EDC Data Gathering
		Default: 48	7
$Amps_{DC}$, DC rated amerage of charger	*A*	EDC Data Gathering	EDC Data Gathering
		Default: 81	7
1,000, Conversion factor	$\frac{W}{kW}$	1,000	Conversion Factor
IF_d, Waste heat factor for demand to account for cooling energy savings from reduced waste heat from the battery charger	*Decimal*	Default: Table 3-8 and Table 3-9	6
CF, Coincidence factor	*Decimal*	Default: 0.5	8

Commented [SA82]: Franklin Energy

IF factor in Table 3-8 and 3-9 is to account for cooling and heating energy impacts from reduced waste heat from bulb, which may not be suitable for the battery charger.

Commented [SA83]: Franklin Energy

IF factor in Table 3-8 and 3-9 is to account for cooling and heating energy impacts from reduced waste heat from bulb, which may not be suitable for the battery charger.

Commented [SA84]: Franklin Energy

If the operation just has one shift, demand savings are not guaranteed during the peak hours. If the operation has 3-4 shifts per day, charging definitely happens during peak-demand hours. Therefore, IL TRM recommends that 0 CF for 1-2 shifts and 1.0 CF for 3-4 shifts.

Table 3-213: Default Values for Number of Charges Per Year

Operation Facility Schedule (hours per day / days per week)	Number of Charges Per Year
Single Shift (8/5)	260
2-Shift (16/5)	520
3-Shift (24/5)	780
4-Shift (24/7)	1,092

Default Savings

Default savings for this measure are shown in the table below.

Table 3-214: Default Savings for High Frequency Battery Charging

Space Conditioning Type	Unit	Operation Facility Schedule (hours per day / days per week)			
		Single Shift (8/5)	2-Shift (16/5)	3-Shift (24/5)	4-Shift (24/7)
Comfort Cooled and Non-Electric Heat	kWh	1,820.0	3,640.1	5,460.1	7,644.2
	kW	0.069	0.069	0.069	0.069
Comfort Cooled and Electric Heat	kWh	1,514.6	3,029.3	4,543.9	6,361.5
	kW	0.069	0.069	0.069	0.069
Comfort Cooled and Unknown Heat	kWh	1,765.3	3,530.6	5,296.0	7,414.4
	kW	0.069	0.069	0.069	0.069
Freezer Spaces	kWh	2,648.0	5,296.0	7,943.9	11,121.5
	kW	0.087	0.087	0.087	0.087
Medium-Temperature Refrigerated Spaces	kWh	2,277.3	4,554.5	6,831.8	9,564.5
	kW	0.075	0.075	0.075	0.075
High-temperature Refrigerated Spaces	kWh	2,083.1	4,166.2	6,249.2	8,748.9
	kW	0.069	0.069	0.069	0.069
Uncooled Warehouse	kWh	1,765.3	3,530.6	5,296.0	7,414.4
	kW	0.058	0.058	0.058	0.058

Evaluation Protocol

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) Ecos Consulting. Analysis of Standards Options for Battery Charger Systems. Prepared for the California IOUs. October 2010. Page 45.
2) Jacob V. Renquist, Brian Dickman, and Thomas H. Bradley, "Economic Comparison of fuel cell powered forklifts to battery powered forklifts", International Journal of Hydrogen Energy Volume 37, Issue 17, (2012): 2
3) Ryan Matley, "Measuring Energy Efficiency Improvements in Industrial Battery Chargers", (ESL-IE-09-05-32, Energy Technology Conference, New Orleans, LA, May 12-15, 2009), 4.
4) Values are based on an estimated one charge per 8-hour workday.
5) Average of SCR and ferroresonant.
6) Pennsylvania Statewide Act 129 2014 Commercial & Residential Lighting Metering Study. Prepared for Pennsylvania Public Utilities Commission. January 13, 2015. http://www.puc.pa.gov/pcdocs/1340978.pdf
7) Voltage and ampere rating based on the assumption of 35kWh battery with a normalized average amp-hour capacity of 760 Ah charged over a 7.5-hour charge cycle. Pacific Gas & Electric, "Emerging Technologies Program Application Assessment Report #0808", Industrial Battery Charger Energy Savings Opportunities. May 29, 2009. Page 8, Table 3.
8) Assumption of 50/50 split between charging/operation during PJM peak period.

3.12 Demand Response

3.12.1 Load Curtailment for Commercial and Industrial Programs

Target Sector	Commercial and Industrial Establishments
Measure Unit	N/A
Measure Life	1 year
Measure Vintage	Demand Response

In a C&I Load Curtailment (LC) program, end-use customers are provided a financial incentive to reduce the amount of electricity they take from the EDC during Demand Response events. This temporary reduction in electricity consumption can be achieved in a number of ways. The specific load curtailment actions taken by program participants are outside of the scope of this protocol. Load curtailment is a dispatchable, event-based resource because the load impacts are only expected to occur on days when DR events are called. This is fundamentally different from non-dispatchable DR options such as dynamic pricing or permanent load shifting. This protocol only applies to dispatchable resources.

Peak demand reductions associated with DR resources are defined as the difference between a customer's actual (measured) electricity demand and the amount of electricity the customer would have demanded in the absence of the DR program incentive. The latter is inherently counterfactual because it never occurred and therefore cannot be measured and must be estimated. This estimate of how much electricity would have been consumed absent the DR program is analogous to the baseline condition for an energy efficiency measure. In this protocol, this estimate is referred to as the reference load.

The reference load used to determine impacts from a LC program participant during a DR event shall be estimated using one of the following methods.[145] The methods are in hierarchical order of preference based on expected accuracy. The EDCs are strongly encouraged to utilize the first three methodologies to verify achievement of demand reductions targets for the phase. In scenarios where an EDC determines a Customer Baseline (CBL) approach is more appropriate, the EDC should provide sound reasoning for the choice of the CBL approach as opposed to the first three methodologies.

1) A comparison group analysis where the loads of a group of non-participating customers that are similar to participating customers with respect to observable characteristics (e.g. non-event weekday consumption) are used to estimate the reference load. A variety of matching techniques are available and the EDC evaluation contractor can choose the technique used to select the comparison group based on their professional judgment. The primary objective of statistical matching is to eliminate bias in the reference load during the most relevant load hours. The most relevant hours are those during the event, but hours immediately prior to and immediately following the event period are also important. As such, matching methods should focus on finding customers with loads during these critical hours that are as close as possible to the loads of participating customers for days that have weather and perhaps other conditions very similar to event days. If events are most likely to be called on hot days, hot non-event days should be used for statistical matching (and very cool days should be excluded). If need be, difference-in-differences techniques can be utilized to eliminate any pre-existing differences in consumption between the treatment and matched control group during estimation.

[145] Detailed technical guidance for matching techniques is provided in the Evaluation Framework.

2) A 'within-subjects' regression analysis where the loads of participating customers on non-event days are used to estimate the reference load. The regression equation should include temperature and other variables that influence usage as explanatory variables. This method is superior to the baseline methods discussed in (4).
3) A hybrid Regression-Matching method where matching is used for most customers and regression methods are used to predict reference loads for any large customers who are too unique to have a good matching candidate. This approach allows for matching methods to be used when good matches are available without dropping unique customers who do not have valid matches from the analysis. The hybrid approach is also superior to the baseline methods discussed in (4).
4) A CBL approach with a weather adjustment to account for the more extreme conditions in place on event days. In this approach, the reference load is estimated by calculating the average usage in the corresponding hours for selected days leading up to or following an event day. Multiplicative or additive same-day adjustments for the CBL are prohibited because of the day-ahead event notification. A variety of CBL methods are available to be used and the EDC contractor should provide justification for the specific method that is selected. Reference loads should generally be calculated separately for each participant, but aggregation of accounts or meters is permissible at the discretion of the EDC evaluation contractor. CBL methods are the least preferred of the four approaches, but may produce valid results in situations where customer loads are fairly constant and are not highly sensitive to weather conditions.

The weather conditions in place at the time of the event are always used to claim savings. Weather-normalized or extrapolation of impacts to other weather conditions is not permitted.

Other curtailment event days – either Act 129 or PJM – should be removed when estimating the reference load for an Act 129 event day.

Where feasible, matching-based methods are capable of effectively removing selection bias and providing accurate impact estimates that are comparable to results from a randomized experiment and are generally superior to within-subjects approaches.[146] Because of this, in situations where large and representative control pools are available, it is suggested that the comparison group approach be used.

ELIGIBILITY

In order to be eligible for an EDC Load Curtailment program, a customer must have an hourly or sub-hourly revenue meter. Interval demand readings are necessary to calculate the reference load and estimate load impacts from DR events. Sub-metered loads may be used for accounts which do not have interval meters at the discretion of the SWE.

ALGORITHMS

Annual peak demand savings must be estimated using individual customer data (e.g. account, meter, or site as defined by program rules) regardless of which evaluation method is used. Program savings are the sum of the load impacts across all participants. The equations below provide mathematical definitions of the average peak period load impact estimate that would be calculated using an approved method.

$$\Delta kW_{peak} = \frac{\sum_{i=1}^{n} \Delta kW_i}{n}$$

[146] See the Evaluation Framework for a discussion of the advantages of matching over within-subjects methods.

$\Delta kW_i \quad = kW\_Reference_i - kW\_Metered_i$

Definition of Terms

Table 3-215: Terms, Values, and References for C&I Load Curtailment

Term	Unit	Values	Source
n, Number of DR hours during a program year for the EDC	Hours	EDC Data Gathering	EDC Data Gathering
ΔkW_i, Estimated load impact achieved by an LC participant in hour i. This term can be positive (a load reduction) or negative (a load increase).	kW	EDC Data Gathering	EDC Data Gathering
$kW\_Reference_i$, Estimated customer load absent DR during hour i	kW	EDC Data Gathering	EDC Data Gathering
$kW\_Metered_i$, Measured customer load during hour i	kW	EDC Data Gathering	EDC Data Gathering

Default Savings

There are no default savings for this measure.

Evaluation Protocols

The evaluation protocols for the Load Curtailment measure follow the calculation methodologies described in this document. Evaluation of the measure should rely on a census of program participants unless a sampling approach (either of days or participants) is approved by the SWE. Detailed protocols for implementing the methodologies described above and the outputs that must be produced are provided in the Evaluation Framework.

4 AGRICULTURAL MEASURES

4.1 AGRICULTURAL

4.1.1 AUTOMATIC MILKER TAKEOFFS

Target Sector	Agriculture
Measure Unit	Milker Takeoff System
Measure Life	10 years Source 1
Measure Vintage	Retrofit

ELIGIBILITY

The following protocol for the calculation of energy and demand savings applies to the installation of automatic milker takeoffs on dairy milking vacuum pump systems. Automatic milker takeoffs shut off the suction on teats once a minimum flow rate is achieved. This reduces the load on the vacuum pump.

This measure requires the installation of automatic milker takeoffs to replace pre-existing manual takeoffs on dairy milking vacuum pump systems. Equipment with existing automatic milker takeoffs is not eligible. In addition, the vacuum pump system serving the impacted milking units must be equipped with a variable speed drive (VSD) to qualify for incentives. Without a VSD, little or no savings will be realized.

ALGORITHMS

The annual energy savings are obtained through the following formulas:

$$\Delta kWh = COWS \times ESC$$

$$\Delta kW_{peak} = \Delta kWh \times ETDF$$

DEFINITION OF TERMS

Table 4-1: Terms, Values, and References for Automatic Milker Takeoffs

Term	Unit	Values	Source
$COWS$, Number of cows milked per day (not the number of individual milkings; each cow is assumed to be milked twice per day)	*Cows*	Based on customer application	EDC Data Gathering
ESC, Annual Energy Savings per cow	$\frac{kWh}{cow}$	34	2, 3, 4, 5, 6
$ETDF$, Energy to Demand factor	$\frac{kW}{kWh}$	0.00017	7

Default Savings

There are no default savings for this protocol.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) Idaho Power Demand Side Management Potential Study – Volume II Appendices, Nexant, 2009.
2) The ESC was calculated based on the following assumptions:
    a. Average herd size is 102 cows in PA (Source 3)
    b. The typical dairy vacuum pump size for the average herd size is 10 horsepower (Source 4)
    c. Based on the herd size, average pump operating hours are estimated at 10 hours per day (or 0.10 hours per cow per day) (Source 5)
    d. A 12.5% annual energy saving factor (Source 6)
3) Chuck Nicholson, Mark Stephenson, Andrew Novakovic: "Study to Support Growth and Competitiveness of the Pennsylvania Dairy Industry", 2017. https://dairymarkets.org/Growth_and_Competitiveness_Study_DRAFT_Final_Report_June_2018.pdf
4) Average dairy vacuum pump size was estimated based on the Minnesota Dairy Project literature.
5) Mark Mayer, David Kammel: "Dairy Modernization Works for Family Farms", 2008. https://joe.org/joe/2010october/rb7.php. The paper asserts an average of 22.7 cows milked per hour prior to modernization. This TRM adopts a conservative estimate of 20 cows milked per hour. Annual pump operating hours are based on the assumption that 20 cows are milked per hour and two milkings occur per day.
6) Savings are based on the assumption that automatic milker take-offs eliminate open vacuum pump time associated with milker take-offs separating from the cow or falling off during the milking process. The following conservative assumptions were made to determine energy savings associated with the automatic milker take-offs:
    a. There is 30 seconds of open vacuum pump time for every 8 cows milked.
    b. The vacuum pump has the ability to turn down during these open-vacuum pump times from a 90% VFD speed to a 40% VFD speed.
    c. Additionally, several case studies from the Minnesota Dairy Project include dairy pump VFD and automatic milker take-off energy savings that are estimated at 50-70% pump savings. It is assumed that the pump VFD savings are 46%, therefore the average remaining savings can be attributed to automatic milker take-offs.
7) Regional Technical Forum (RTF) as part of the Northwest Power & Conservation Council, Deemed Measures List. Agricultural: Variable Frequency Drives-Dairy, FY2012, V1.2. https://rtf.nwcouncil.org/measure/dairy-milking-machines-vacuum-pump

4.1.2 Dairy Scroll Compressors

Target Sector	Agriculture
Measure Unit	Compressor
Measure Life	15 years Source 1
Measure Vintage	Replace on Burnout or New Construction

Eligibility

The following protocol for the calculation of energy and demand savings applies to the installation of a scroll compressor to replace an existing reciprocating compressor or the installation of a scroll compressor in a new construction application. The compressor is used to cool milk for preservation and packaging. The energy and demand savings per cow will depend on the installed scroll compressor energy efficiency ratio (EER), operating days per year, and the presence of a precooler in the refrigeration system.

This measure requires the installation of a scroll compressor to replace an existing reciprocating compressor or to be installed in a new construction application. Existing farms replacing existing scroll compressors are not eligible.

Algorithms

The energy and peak demand savings are dependent on the presence of a precooler in the system, and are obtained through the following formulas:

$$\Delta kWh = \left(\frac{CBTU}{EER_{base}} - \frac{CBTU}{EER_{ee}}\right) \times \frac{1 \cdot kW}{1{,}000 \cdot W} \times DAYS \times COWS$$

$$\Delta kW_{peak} = \Delta kWh \times ETDF$$

Definition of Terms

Table 4-2: Terms, Values, and References for Dairy Scroll Compressors

Term	Unit	Values	Source
EER_{base}, Baseline compressor efficiency	$\frac{Btu}{hr \cdot W}$	Baseline compressor manufacturers data based upon customer application	EDC Data Gathering
		Default: 5.85	2
EER_{ee}, Installed compressor efficiency	$\frac{Btu}{hr \cdot W}$	From nameplate	EDC Data Gathering
$CBTU$, Heat load of milk per cow per day for a given refrigeration system	$\frac{Btu}{Cow \cdot day}$	System without precooler: 2,864 System with precooler: 922	3, 4
$DAYS$, Milking days per year	*Days*	Based on customer application	EDC Data Gathering
		Default: 365 days/year	4, 5
$COWS$, Average number of cows milked per day (not the number of individual milkings; each cow is assumed to be milked twice per day)	*Cows*	Based on customer application	EDC Data Gathering
$ETDF$, Energy to Demand factor	$\frac{kW}{kWh}$	0.00017	6

Default Savings

There are no default savings for this measure.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) PA Consulting Group for the State of Wisconsin Public Service Commission, Focus on Energy Evaluation. Business Programs: Measure Life Study. August 25, 2009. Appendix B https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf

2) Based on the average EER data for a variety of reciprocating compressors from Emerson Climate Technologies. https://climate.emerson.com/en-us/products

3) Based on a specific heat value of 0.93 $\frac{Btu}{lb \cdot °F}$ and density of 8.7 lb/gallon for whole milk. American Society of Heating Refrigeration and Air-conditioning Engineers Refrigeration Handbook, 2010, Ch.19.5.
4) Based on delta T (temperature difference between the milk leaving the cow and the cooled milk in tank storage) of 59 °F for a system with no pre-cooler and 19 °F for a system with a pre-cooler. It was also assumed that an average cow produces 6 gallons of milk per day. KEMA 2009 Evaluation of IPL Energy Efficiency Programs, Appendix F, pg. 347. http://alliantenergy.com/wcm/groups/wcm_internet/@int/documents/document/mdaw/mdey/~edisp/012895.pdf
5) Based on typical dairy parlor operating hours referenced for agriculture measures in California. California Public Utility Commission. Database for Energy Efficiency Resources (DEER) 2005. The DEER database assumes 20 hours of operation per day but is based on much larger dairy farms (e.g. herd sizes > 300 cows). Therefore, the DEER default value was lowered to 8 hours per day.
6) Regional Technical Forum (RTF) as part of the Northwest Power & Conservation Council, Deemed Measures List. Agricultural: Variable Frequency Drives-Dairy, FY2012, V1.2. https://rtf.nwcouncil.org/measure/dairy-milking-machines-vacuum-pump

4.1.3 High Efficiency Ventilation Fans with and without Thermostats

Target Sector	Agriculture
Measure Unit	Fan
Measure Life	10 years Source 1
Measure Vintage	Replace on Burnout or New Construction

Eligibility

The following protocol for the calculation of energy and demand savings applies to the installation of high efficiency ventilation fans to replace standard efficiency ventilation fans or the installation of a high efficiency ventilation fans in a new construction application. The high efficiency fans move more cubic feet of air per watt compared to standard efficiency ventilation fans. Adding a thermostat control will reduce the number of hours that the ventilation fans operate. This protocol does not apply to circulation fans.

This protocol applies to: (1) the installation of high efficiency ventilation fans in either new construction or retrofit applications where standard efficiency ventilation fans are replaced, and/or (2) the installation of a thermostat controlling either new efficient fans or existing fans. Default values are provided for dairy and swine applications. Other facility types are eligible; however, data must be collected for all default values. Note that savings are calculated per fan.

Algorithms

The annual energy savings are obtained through the following formulas:

$$\Delta kWh = \left(\frac{1}{Eff_{std}} - \frac{1}{Eff_{high}}\right) \times CFM \times HOURS \times \frac{1}{1{,}000}$$

$$\Delta kW_{peak} = \Delta kWh \times ETDF$$

Definition of Terms

Table 4-3: Terms, Values, and References for Ventilation Fans

Term	Unit	Values	Source
Eff_{std}, Efficiency of the standard efficiency fan at a static pressure of 0.1 inches water	$\frac{cfm}{W}$	Based on customer application	EDC Data Gathering
		Default: Table 4-4	2
Eff_{high}, Efficiency of the high efficiency fan at a static pressure of 0.1 inches water	$\frac{cfm}{W}$	Based on customer application.	EDC Data Gathering
		Default: Table 4-4	2, 3, 4
$HOURS$, operating hours per year of the fan	*Hours*	Based on customer application	EDC Data Gathering
		Default without thermostat: Table 4-5 Default with thermostat: Table 4-6	2, 5
CFM, cubic feet per minute of air movement	$\frac{ft^3}{min}$	Based on customer application. This can vary for pre- and post-installation if the information is known for the pre-installation case.	EDC Data Gathering
		Default: Table 4-4	2
1,000, watts per kilowatt	$\frac{watts}{kilowatt}$	1,000	Conversion Factor
$ETDF$, Energy to Demand factor	$\frac{kW}{kWh}$	0.000197	Engineering calculations

Table 4-4: Default values for standard and high efficiency ventilation fans for dairy and swine facilities

Fan Size (inches)	High Efficiency Fan (cfm/W at 0.1 inches water)	Standard Efficiency Fan (cfm/W at 0.1 inches water)	CFM
14 - 23	12.4	9.2	3,600
24 - 35	15.3	11.2	6,274
36 - 47	19.2	15.0	10,837
48 - 61	22.7	17.8	22,626

Table 4-5: Default Hours for Ventilation Fans by Facility Type by Location (No Thermostat)

Facility Type	Allentown	Binghamton	Bradford	Erie	Harrisburg	Philadelphia	Pittsburgh	Scranton	Williamsport
Dairy - Stall Barn	5,071	4,596	4,336	4,807	5,163	5,390	5,010	4,843	5,020
Dairy – Free-Stall or Cross-Ventilated Barn	3,299	2,665	2,365	2,984	3,436	3,732	3,231	2,985	3,241
Hog Nursery or Sow House	5,864								
Hog Finishing House	4,729								

Table 4-6: Default Hours for Ventilation Fans by Facility Type by Location (With Thermostat)

Facility Type	Allentown	Binghamton	Bradford	Erie	Harrisburg	Philadelphia	Pittsburgh	Scranton	Williamsport
Dairy - Stall Barn	3,457	3,562	3,526	3,458	3,367	3,285	3,441	3,594	3,448
Dairy – Free-Stall or Cross-Ventilated Barn	1,685	1,663	1,574	1,635	1,640	1,627	1,662	1,736	1,669
Hog Nursery or Sow House	3,235	2,581	2,139	2,879	3,541	3,685	3,132	2,979	3,198
Hog Finishing House*	4,729	4,729	4,729	4,729	4,729	4,729	4,729	4,729	4,729
* Hog finishing house ventilation needs are based on humidity; therefore a thermostat will not reduce the number of hours the fans operate.									

DEFAULT SAVINGS

There are no default savings for this measure.

EVALUATION PROTOCOLS

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with

verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx. Accessed December 2018.

2) KEMA. 2009 Evaluation of IPL Energy Efficiency Programs, Appendix F, 2008. See Table H-5. http://alliantenergy.com/wcm/groups/wcm_internet/@int/documents/document/mdaw/mdey/~edisp/012895.pdf

3) Pennsylvania State University. Tunnel Ventilation for Tie Stall Dairy Barns. 2004. Downloaded from https://extension.psu.edu/tunnel-ventilation-for-tie-stall-dairy-barns. Static pressure reference point for dairy barns comes from page 3. The recommended static pressure is 0.125 to 0.1-inch water gauge.

4) Iowa State University. Mechanical Ventilation Design Worksheet for Swine Housing. 1999. Downloaded from http://www.extension.iastate.edu/Publications/PM1780.pdf. Static pressure reference point for swine housing comes from page 2. The recommended static pressure is 0.125 to 0.1 inches water for winter fans and 0.05 to 0.08 inches water for summer fans. A static pressure of 0.1 inches water was assumed for dairy barns and swine houses as it is a midpoint for the recommended values.

5) Based on the methodology in KEMA's evaluation of the Alliant Energy Agriculture Program (Source 1). Updated the hours for dairies and thermostats using TMY3 temperature data for PA, as fan run time is dependent on ambient dry-bulb temperature. For a stall barn, it was assumed 33% of fans are on 8,760 hours per year, 67% of fans are on when the temperature is above 50 degrees Fahrenheit, and 100% of the fans are on when the temperature is above 70 degrees Fahrenheit. For a cross-ventilated or free-stall barn, it was assumed 10% of fans are on 8,760 hours per year, 40% of fans are on when the temperature is above 50 degrees Fahrenheit, and 100% of the fans are on when the temperature is above 70 degrees Fahrenheit. The hours for hog facilities are based on humidity. These hours were not updated as the methodology and temperatures for determining these hours was not described in KEMA's evaluation report and could not be found elsewhere. However, Pennsylvania and Iowa are in the same ASHRAE climate zone (5A) and so the Iowa hours provide a good estimate for hog facilities in Pennsylvania.

4.1.4 Heat Reclaimers

Target Sector	Agriculture
Measure Unit	Heat Reclaimer
Measure Life	15 years Source 1
Measure Vintage	Replace on Burnout or New Construction

Eligibility

The following protocol for the calculation of energy and demand savings applies to the installation of heat recovery equipment on dairy parlor milk refrigeration systems. The heat reclaimers recover heat from the refrigeration system and use it to pre-heat water used for sanitation, sterilization and cow washing.

This measure requires the installation of heat recovery equipment on dairy parlor milk refrigeration systems to heat hot water. This measure only applies to dairy parlors with electric water heating equipment.

Algorithms

The annual energy and peak demand savings are dependent on the presence of a precooler in the refrigeration system, and are obtained through the following formulas:

$$\Delta kWh = \frac{ES}{\eta_{water\ heater}} \times DAYS \times COWS \times HEF$$

$$\Delta kW_{peak} = \Delta kWh \times ETDF$$

Definition of Terms

Table 4-7: Terms, Values, and References for Heat Reclaimers

Term	Unit	Values	Source
ES, Energy savings for specified system	$\frac{kWh}{cow \cdot day}$	System with precooler = 0.29 System without precooler = 0.38	2, 3
$DAYS$, Milking days per year	$\frac{days}{year}$	Based on customer application	EDC Data Gathering
		Default: 365	3
$COWS$, Average number of cows milked per day (not the number of individual milkings; each cow is assumed to be milked twice per day)	*Cows*	Based on customer application	EDC Data Gathering
HEF, Heating element factor	*None*	Heat reclaimers with no back-up heat = 1.0 Heat reclaimers with back-up heating elements = 0.50	4
$\eta_{water\ heater}$, Electric water heater efficiency	*None*	Electric tank water heater = 0.90 Heat pump water heater = 2.0	5
$ETDF$, Energy to Demand factor	$\frac{kW}{kWh}$	0.00017	6

Default Savings

There are no default savings for this measure.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) State of Wisconsin. Focus on Energy Evaluation, Business Program: Measure Life Study Final Report: August 25, 2009. Appendix B. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2) Based on a specific heat value of 0.93 Btu/lb deg F and density of 8.7 lb/gallon for whole milk. American Society of Heating Refrigeration and Air-conditioning Engineers Refrigeration Handbook, 2010, Ch.19.5.
3) Based on a delta T (temperature difference between the milk leaving the cow and the cooled milk in tank storage) of 59°F for a system without a pre-cooler and 19°F for a system with a

pre-cooler. It was also assumed that a cow produces 6 gallons of milk per day (based on two milkings per day), requires 2.2 gallons of hot water per day, and the water heater delta T (between ground water and hot water) is 70°F. Evaluation of Alliant Energy Agriculture Program, Appendix F, 2008.

4) Some smaller dairy farms may not have enough space for an additional water storage tank and will opt to install a heat reclaimer with a back-up electric resistance element. The HEF used in the savings algorithm is a conservative savings de-ration factor to account for the presence of back-up electric resistance heat. The HEF is based on the assumption that the electric resistance element in a heat reclaimer will increase the incoming ground water temperature by 40-50 °F before the water is heated by the heat reclaim coil.

5) Pennsylvania Act 129 2018 Non-Residential Baseline Study, http://www.puc.pa.gov/Electric/pdf/Act129/SWE-Phase3_NonRes_Baseline_Study_Rpt021219.pdf

6) Regional Technical Forum (RTF) as part of the Northwest Power & Conservation Council, Deemed Measures List. Agricultural: Variable Frequency Drives-Dairy, FY2012, V1.2. https://rtf.nwcouncil.org/measure/dairy-milking-machines-vacuum-pump

4.1.5 High Volume Low Speed Fans

Target Sector	Agriculture
Measure Unit	Fan
Measure Life	15 years Source 1
Measure Vintage	Replace on Burnout or New Construction

Eligibility

The following protocol for the calculation of energy and demand savings applies to the installation of High Volume Low Speed (HVLS) fans to replace conventional circulating fans. HVLS fans are a minimum of 16 feet long in diameter and move more cubic feet of air per watt than conventional circulating fans. Default values are provided for dairy, poultry, and swine applications. Other facility types are eligible, however, the operating hours assumptions should be reviewed and modified as appropriate.

Algorithms

The annual energy and peak demand savings are obtained through the following formulas:

$$\Delta kW = \frac{(W_{conventional} - W_{hvls})}{1{,}000}$$

$$\Delta kWh = \Delta kW \times HOURS$$

$$\Delta kW_{peak} = \Delta \mathrm{kW} \times CF$$

Definition of Terms

Table 4-8: Terms, Values, and References for HVLS Fans

Term	Unit	Values	Source
$W_{conventional}$, Wattage of the removed conventional fans	*W*	Based on customer application	EDC Data Gathering
		Default: Table 4-9	2
W_{hvls}, Wattage of the installed HVLS fan	*W*	Based on customer application	EDC Data Gathering
		Default: Table 4-9	2
$HOURS$, annual hours of operation of the fans	*Hours*	Based on customer application	EDC Data Gathering
		Default: Table 4-10	3
$1{,}000$, watts per kilowatt	$\frac{watts}{kilowatts}$	1,000	Conversion factor
CF, Coincidence factor	*Decimal*	1.0	3

Table 4-9: Default Values for Conventional and HVLS Fan Wattages

Fan Size (ft)	W_{hvls}	$W_{conventional}$
≥ 16 and < 18	761	4,497
≥ 18 and < 20	850	5,026
≥ 20 and < 24	940	5,555
≥ 24	1,119	6,613

Table 4-10: Default Hours by Location for Dairy/Poultry/Swine Applications

Location	$Hours$
Allentown	2,459
Binghamton	1,526
Bradford	1,340
Erie	2,124
Harrisburg	2,718
Philadelphia	2,914
Pittsburgh	2,296
Scranton	2,154
Williamsport	2,371

DEFAULT SAVINGS

There are no default savings for this measure.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) State of Wisconsin. Focus on Energy Evaluation, Business Program: Measure Life Study Final Report: August 25, 2009. Appendix B. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2) KEMA. 2009 Evaluation of IPL Energy Efficiency Programs, Appendix F Group I Programs Volume 2. See Table H-17.
3) Number of hours above 65 degrees Fahrenheit. Based on TMY3 data. The coincidence factor has been set at 1.0 as the SWE believes all hours during the peak window will be above 65 degrees Fahrenheit.

Commented [SA85]: Franklin Energy

Just a comment--Some TRMs, Such as Iowa use different temperatures for different animal types. Example. 70 for Dairy and 60 for hog based on the Dairy Farm Energy Management Guide, Southern California Edison February 2004. An average is probably fine.

4.1.6 Livestock Waterer

Target Sector	Agriculture
Measure Unit	Livestock Waterer System
Measure Life	10 years Source 1
Measure Vintage	Replace on Burnout or New Construction

Eligibility

The following protocol for the calculation of energy and demand savings applies to the installation of energy-efficient livestock waterers. In freezing climates no or low energy livestock waterers are used to prevent livestock water from freezing. These waterers are closed watering containers that typically use super insulation, relatively warmer ground water temperatures, and the livestock's use of the waterer to keep water from freezing.

This measure requires the installation of an energy efficient livestock watering system that is thermostatically controlled and has factory-installed insulation with a minimum thickness of two inches. Savings algorithms are for one unit.

Algorithms

No demand savings are expected for this measure, as the energy savings occur during the winter months. The annual energy savings are obtained through the following formula*:*

$$\Delta kWh = OPRHS \times ESW \times HRT$$

Definition of Terms

Table 4-11: Terms, Values, and References for Livestock Waterers

Term	Unit	Values	Source
$OPRHS$, Annual operating hours	*Hours*	Allentown = 1,498 Binghamton = 2,083 Bradford = 2,510 Erie = 1,778 Harrisburg = 1,309 Philadelphia = 1,090 Pittsburgh = 1,360 Scranton = 1,718 Williamsport = 1,575	2
ESW, Change in connected load (deemed)	$\frac{Kilowatts}{waterer}$	0.50	3, 4, 5
HRT, % heater run time	*None*	80%	6

Default Savings

There are no default savings for this measure.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) State of Wisconsin. Focus on Energy Evaluation, Business Program: Measure Life Study Final Report: August 25, 2009. Appendix B. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2) Based on TMY3 data for various climate zones in Pennsylvania. The annual operating hours represent the annual hours when the outdoor air dry-bulb temperature is less than 32 °F, and it is assumed that the livestock waterer electric resistance heaters are required below this temperature to prevent water freezing.
3) Field Study of Electrically Heated and Energy Free Automated Livestock Water Fountains - Prairie Agricultural Machinery Institute, Alberta and Manitoba, 1994.
4) Facts Automatic Livestock Waterers Fact Sheet, December 2008. http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex5421/$file/716c52.pdf
5) Connecticut Farm Energy Program: Energy Best Management Practices Guide, 2010. http://www.ctfarmenergy.org/Pdfs/CT_Energy_BMPGuide.pdf
6) The Regional Technical Forum (RTF) analyzed metered data from three baseline livestock waterers and found the average run time of electric resistance heaters in the waterers to be approximately 80% for average monthly temperatures similar to Pennsylvania climate zones. This run time factor accounts for warmer make-up water being introduced to the tank as livestock drinking occurs. https://rtf.nwcouncil.org/measure/dairy-milking-machines-vacuum-pump

4.1.7 Variable Speed Drive (VSD) Controller on Dairy Vacuum Pumps

Target Sector	Agriculture
Measure Unit	Dairy Vacuum Pump VSD
Measure Life	15 years [Source 1]
Measure Vintage	Retrofit or New Construction

Eligibility

The following protocol for the calculation of energy and demand savings applies to the installation of a variable speed drive (VSD) and controls on a dairy vacuum pump. The vacuum pump operates during the milk harvest and equipment washing on a dairy farm. The vacuum pump creates negative air pressure that draws milk from the cow and assists in the milk flow from the milk receiver to either the bulk tank or the receiver bowl.

Dairy vacuum pumps are more efficient with VSDs since they enable the motor to speed up or slow down depending on the pressure demand. The energy savings for this measure is based on pump capacity and hours of use of the pump.

This measure requires the installation of a VSD and controls on dairy vacuum pumps, or the purchase of dairy vacuum pumps with variable speed capability. Pre-existing pumps with VSD's are not eligible for this measure.

Algorithms

The annual energy savings are obtained through the following formulae:

$$\Delta kWh = HP \times \left(\frac{0.746\ kW}{HP}\right) \times \frac{LF}{\eta_{motor}} \times ESF \times DHRS \times ADAYS$$

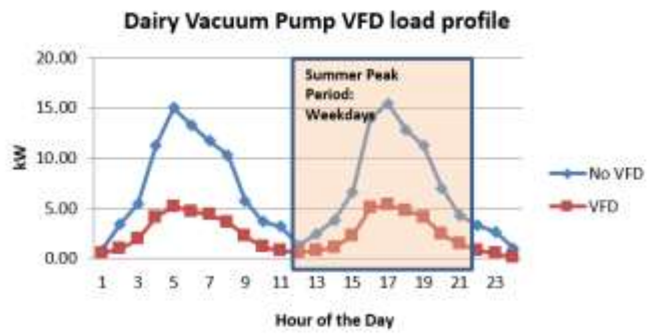
$$\Delta kW_{peak} = \Delta kWh \times ETDF$$

Energy to Demand Factor

An average of pre and post kW vacuum pump power meter data from five dairy farms in the Pacific Northwest are used to create the vacuum pump demand load profile in Figure 4-1.[Source 2] Because dairy vacuum pump operation does not vary based on geographical location, the average peak demand reduction obtained from these five sites can be applied to Pennsylvania. There are no seasonal variations in cow milking times, as dairy farms milk cows year round, so the load profile below applies to 365 days of operation. The average percent demand reduction for these five sites during the coincident peak demand period of June through September between noon and 8 pm is 46%, which is consistent with the energy savings factors and demand savings estimated for the sources cited in this protocol.

Based on this data, the energy to demand factor is estimated by dividing the average peak coincident demand kW reduction by ΔkWh savings for a 1 horsepower motor. The result is an energy to demand factor equal to 0.00014. Note that this value has been adapted from a definition of peak period that differs from the definition in Pennsylvania.

Figure 4-1: Typical Dairy Vacuum Pump Coincident Peak Demand Reduction



Definition of Terms

Table 4-12: Terms, Values, and References for VSD Controller on Dairy Vacuum Pump

Term	Unit	Values	Source
$Motor\ HP$, Rated horsepower of the motor	*HP*	Nameplate	EDC Data Gathering
0.746, conversion factor from horsepower to kW	$\frac{kW}{HP}$	0.746	Conversion Factor
LF, Load Factor. Ratio between the actual load and the rated load. The default value is 0.90	*None*	Based on spot metering and nameplate	EDC Data Gathering
		Default: 90%[147]	3
η_{motor}, Motor efficiency at the full-rated load. For VFD installations, this can be either an energy efficient motor or standard efficiency motor.	*None*	Nameplate	EDC Data Gathering
ESF, Energy Savings Factor. Percent of baseline energy consumption saved by installing VFD.	*None*	46%	4, 5
$DHRS$, Daily run hours of the motor	*Hours/Day*	Based on customer application	EDC Data Gathering
		Default: 8	4, 5
$ADAYS$, Annual operating days	*Days*	Based on customer application	EDC Data Gathering
		Default: 365	4, 5
$ETDF$, Energy to Demand factor	$\frac{kW}{kWh}$	0.00014	5

Default Savings

There are no default savings for this measure.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020,

[147] Default Value can be used by EDC but is subject to metering and adjustment by evaluators or SWE.

http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx. Accessed December 2018.

2) Regional Technical Forum (RTF) as part of the Northwest Power & Conservation Council, Deemed Measures List. Agricultural: Variable Frequency Drives-Dairy, FY2012, V1.2. Accessed from RTF website http://rtf.nwcouncil.org/measures/Default.asp on February 27, 2013. Pre and post power meter data for five sites were used to establish RTF energy savings for this measure, and raw data used to generate the load profile referenced in this protocol can be found in the zip file on the "BPA Case Studies" tab.

3) Southern California Edison, Dairy Farm Energy Management Guide: California, p. 11, 2004.

4) California Public Utility Commission. *Database for Energy Efficiency Resources (DEER)* 2005. The DEER database assumes 20 hours of operation per day, but is based on much larger dairy farms (e.g. herd sizes > 300 cows). Therefore, the DEER default value was lowered to 8 hours per day, as the average heard size is significantly less in Pennsylvania. Regional Technical Forum (RTF) as part of the Northwest Power & Conservation Council, Deemed Measures List. Agricultural: Variable Frequency Drives-Dairy, FY2012, V1.2. Accessed from RTF website http://rtf.nwcouncil.org/measures/Default.asp on February 27, 2013.

5) Regional Technical Forum (RTF) as part of the Northwest Power & Conservation Council, Deemed Measures List. Agricultural: Variable Frequency Drives-Dairy, FY2012, V1.2. https://rtf.nwcouncil.org/measure/dairy-milking-machines-vacuum-pump

4.1.8 Low Pressure Irrigation System

Target Sector	Agriculture and Golf Courses
Measure Unit	Irrigation System
Measure Life	5 years Source 1
Measure Vintage	Replace on Burnout or New Construction

Eligibility

The following protocol for the measurements of energy and demand savings applies to the installation of a low-pressure irrigation system, which reduces the amount of energy required to apply the same amount of water as a baseline system.

The amount of energy saved per acre will depend on the actual operating pressure decrease, the pumping plant efficiency, the amount of water applied, and the number of nozzle, sprinkler or micro irrigation system conversions made to the system.

This measure requires a minimum of 50% reduction in irrigation pumping pressure through the installation of a low-pressure irrigation system in agriculture or golf course applications. The pressure reduction can be achieved in several ways, such as nozzle or valve replacement, sprinkler head replacement, alterations or retrofits to the pumping plant, or drip irrigation system installation, and is left up to the discretion of the owner. Pre and post retrofit pump pressure measurements are required.

Algorithms

The annual energy savings are obtained through the following formulas:

Agriculture applications:

$$\Delta kWh = \frac{\{ACRES \times (PSI_{base} - PSI_{eff}) \times GPM1\}}{1{,}714 \frac{PSI \times GPM}{HP} \times \eta_{motor}} \times \left(\frac{0.746\ kW}{HP}\right) \times OPRHS$$

$$\Delta kW_{peak} = \Delta kWh \times ETDF$$

Golf Course applications:

$$\Delta kWh = \frac{\{(PSI_{base} - PSI_{eff}) \times GPM2\}}{1{,}714 \frac{PSI \times GPM}{HP} \times \eta_{motor}} \times \left(\frac{0.746\ kW}{HP}\right) \times DHRS \times ADAYS$$

No peak demand savings may be claimed for golf course applications as watering typically occurs during non-peak demand hours.

Definition of Terms

Table 4-13: Terms, Values, and References for Low Pressure Irrigation Systems

Term	Unit	Values	Source
$ACRES$, Number of acres irrigated	*Acres*	Based on customer application	EDC Data Gathering
PSI_{base}, Baseline pump pressure, must be measured and recorded prior to installing low-pressure irrigation equipment.	*Pounds per square inch (psi)*	Based on pre retrofit pressure measurements taken by the installer	EDC Data Gathering
PSI_{eff}, Installed pump pressure, must be measured and recorded after the installation of low-pressure irrigation equipment by the installer.	*Pounds per square inch (psi)*	Based on post retrofit pressure measurements taken by the installer	EDC Data Gathering
$GPM1$, Pump flow rate per acre for agriculture applications.	*Gallons per minute (gpm) per acre*	Based on pre retrofit flow measurements taken by the installer	EDC Data Gathering
$GPM2$, Pump flow rate for pumping system for golf courses.	*Gallons per minute (gpm)*	Based on pre retrofit flow measurements taken by the installer	EDC Data Gathering
$1{,}714$, Constant used to calculate hydraulic horsepower for conversion between horsepower and pressure and flow	$\frac{PSI \times GPM}{HP}$	$1{,}714$	Conversion Factor
$OPHRS$, Average irrigation hours per growing season for agriculture	*Hours*	Based on customer application	EDC Data Gathering
$DHRS$, Hours of watering per day for golf courses	*Hours/Day*	Based on customer application	EDC Data Gathering
$ADAYS$, Annual operating days of irrigation for golf courses	*Days*	Based on customer application	EDC Data Gathering
η_{motor}, Pump motor efficiency	*None*	Based on customer application	EDC Data Gathering
		Look up pump motor efficiency based on the pump nameplate horsepower (HP) from customer application and nominal efficiencies defined in Table 3-66 and Table 3-67	2
$ETDF$, Energy to demand factor	$\frac{kW}{kWh}$	0.0026	3, 4

Default Savings

There are no default savings for this measure.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx. Accessed December 2018.

2) Table 3-66 and Table 3-67 contain federal motor efficiency values by motor size and type. If existing motor nameplate data is not available, these tables will be used to establish motor efficiencies. The CF was only estimated for agricultural applications, and was determined by using the following formula $CF = \frac{\Delta kW\ savings\ per\ acre}{\frac{\Delta kWh}{yr}\ savings\ per\ acre}$.

3) Pennsylvania census data was used to estimate an average ΔkW savings/acre and ΔkWh/yr/savings/acre value. Pamela Kanagy. Farm and Ranch Irrigation. Pennsylvania Agricultural Statistics 2009-2010. http://www.nass.usda.gov/Statistics_by_State/Pennsylvania/Publications/Annual_Statistical_Bulletin/2009_2010/fris.pdf

4) Irrigation Water Withdrawals, 2015 by the U.S. Geological Society. Table 7. https://pubs.usgs.gov/circ/1441/circ1441.pdf