TECHNICAL REFERENCE MANUAL

Volume 2:
Residential Measures

State of Pennsylvania

Act 129 Energy Efficiency and Conservation Program

&

Act 213 Alternative Energy Portfolio Standards

Issued May 2024

PENNSYLVANIA PUC

PUBLIC UTILITY COMMISSION

Table of Contents

2 RESIDENTIAL MEASURES

2.1 LIGHTING

2.1.1 RESIDENTIAL LED LIGHTING

Target Sector	Residential
Measure Unit	Light Bulb or Fixture
Measure Life	Replace on Burnout: 15 years[Source 1] Early Replacement: 2 years[Source 2]
Vintage	Replace on Burnout (Upstream, Kit) Early Replacement (Direct Install)

Savings for residential LED 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. Screw-based general service LED lamps are limited to direct install programs due to the US Department of Energy's codification of the 45 lumen per watt "backstop" requirement for general service lamps (GSLs). Linear LED fixtures are eligible measures while LED fixtures that effectively replace GSLs, such as downlighting, are not eligible.

ELIGIBILITY

Definition of Efficient Equipment

Table 2-1 provides a summary of the eligibility for residential LED lighting measures and program delivery channels.

Table 2-1: Eligibility for Residential LED Lighting

Efficient LED Lighting Product	Lumen Range	Program Delivery	Eligibility
GSL bulb type, below 310 lumens	Less than 310	All	Yes
GSL	310 to 3,300	Retail / upstream	No
		Kit	No
		Direct Install	Yes
GSL bulb type, above 3,300 lumens	Greater than 3,300	All	Yes
GSL, exempt bulb type / category	NA	All	Yes
Linear LED fixture	NA	All	Yes
All other fixtures	NA	All	No

Definition of Baseline Equipment

The baseline equipment varies by lighting product and delivery channel. GSLs[Source 3] are only eligible for direct install programs where the wattage of the existing bulb is known, and the existing bulb was in working condition; the baseline wattage is the wattage of the existing lamp removed by the program. For LED lamps outside the GSL lumen range (below 310 lumens or above 3,300 lumens) and/or exempt bulb type/categories, the baseline wattage is the manufacturer rated comparable wattage. Baseline wattages for linear LED fixtures are defined in Table 2-3. GSLs are defined in accordance with the US DOE's updated definition of GSLs effective July 8, 2022, which expanded GSLs to include previously exempt bulb types such as, but not limited to, reflector lamps, rough service lamps, shatter-resistant lamps, 3-way lamps, candelabra lamps, and vibration service lamps.Source 4

Algorithms

The general form of the equation for the residential LED lighting energy savings algorithm is:

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

$$\Delta \boldsymbol{kWh} = \frac{\boldsymbol{Watts_{base}} - \boldsymbol{Watts_{EE}}}{\mathbf{1,000}} \times (\mathbf{1} + \mathbf{L} \times \boldsymbol{IE_{kWh}}) \times \mathbf{ISR} \times \boldsymbol{HOU} \times \mathbf{365}$$

$$\Delta kW_{summer\ peak} = \frac{Watts_{base} - Watts_{EE}}{1{,}000} \times \left(1 + L \times IE_{kW\_s}\right) \times ISR \times CF_s$$

$$\Delta kW_{winter\ peak} = \frac{Watts_{base} - Watts_{EE}}{1{,}000} \times \left(1 + L \times IE_{kW\_w}\right) \times ISR \times CF_w$$

For linear LED fixtures, the following algorithm is used to calculate $Watts_{base}$ for use in the above formulas:

$$Watts_{base} = \frac{Lumens_{ee}}{Efficacy_{base}}$$

Definition of Terms

Table 2-2: Terms, Values, and References for Residential LED Lighting

Term	Unit	Value	Sources
$Watts_{base}$, Wattage of baseline case lamp/fixture	*Watts*	Direct install: EDC Data Gathering GSLs outside of EISA lumen range or exempt bulb type: Manufacturer rated comparable wattage Linear LED fixture: EDC Data Gathering ($Lumens_{ee}$) and Table 2-3 ($Efficacy_{base}$)	EDC data gathering, 3 and 4
$Watts_{EE}$, Wattage of efficient case lamp/fixture	*Watts*	EDC Data Gathering	EDC Data Gathering
HOU, Average hours of use per day per unit installed for residential use	$\frac{hours}{day}$	Table 2-4	7
L, Factor to adjust interactive effect factors to account for proportion of LEDs installed in interior locations	*%*	Interior: 100% Exterior: 0% Unknown: 90.3%	10
IE_{kWh}, HVAC Interactive Effect for LED energy for residential use	*None*	EDC Data Gathering Default = Table 2-5	6

Term	Unit	Value	Sources
IE_{kW_s}, Summer Interactive Demand Factor – applies to residential lighting in conditioned residential spaces.	*None*	EDC Data Gathering Default =Table 2-5	6
IE_{kW_w}, Winter Interactive Demand Factor – applies to residential lighting in conditioned residential spaces.	*None*	EDC Data Gathering Default =Table 2-5	6
ISR, In-service rate per incented product for residential use	*%*	Direct Install: 100% All other program delivery: EDC Data Gathering[1]	EDC Data Gathering
CF_s, Summer Coincidence Factor	*None*	0.101	5
CF_w, Winter coincidence factor	*None*	0.121	5
$Lumens_{ee}$, Lumen rating of the incentivized lighting product	*Lumens*	EDC Data Gathering	EDC Data Gathering
$Efficacy_{base}$, Efficacy of the baseline fixture type for linear fluorescents	*Lumens/watt*	Table 2-3	8, 9

VARIABLE INPUT VALUES

Baseline Wattage Values, Linear LEDs

For linear LEDs, baseline wattage is the least-efficient, commercially-available, commonly-installed technology available in the market. Linear LED baseline wattage ($Watts_{base}$) is calculated by dividing $Lumens_{ee}$ by $Efficacy_{base}$ (Table 2-3).

Table 2-3: Baseline Wattage, Linear Lamps & Fixtures

Efficient Lamp or Fixture	$Efficacy_{base}$ (Lumens/watt)
Linear Lamps, Fixtures, and Retrofit Kits, 2 ft	67.4
Linear Lamps, Fixtures, and Retrofit Kits, 3 ft	72.5
Linear Lamps, Fixtures, and Retrofit Kits, 4 ft	75.8
Linear Lamps, Fixtures, and Retrofit Kits, 5 ft	80.4
Linear Lamps, Fixtures, and Retrofit Kits, 8 ft	82.3

Hours of Use

Daily hours of use (HOU) are provided in Table 2-4. Specific room-based HOU may be used for programs where the room-type of installation is known and recorded; otherwise, the overall household or unknown room value should serve as the estimate.

[1] 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)

Table 2-4: Bulb and Fixture Hours of Use by Room

Room	HOU
Basement	1.7
Bathroom	2.3
Bedroom	1.8
Closet	0.6
Dining Room	2.7
Exterior	3.9
Hallway	1.9
Kitchen	3.9
Living Room	3.7
Other	1.7
Overall Household or Unknown Room	2.5

Interactive Effects Values
Default Energy and Demand HVAC Interactive Effects are provided in Table 2-5.

Table 2-5: Energy and Demand HVAC Interactive Effects by EDC

EDC	IE_{kWh}	IE_{kW_s}	IE_{kW_w}
PECO	-0.0007	0.1193	-0.0581
PPL	-0.0681	0.1046	-0.1480
Duquesne Light	0.0005	0.0957	-0.0291
FE (Met-Ed)	-0.0448	0.1193	-0.1242
FE (Penelec)	-0.0442	0.0736	-0.0872
FE (Penn Power)	-0.0102	0.1311	-0.0555
FE (WPP)	-0.0537	0.1001	-0.1163

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 129 Legislation caps measure life at 15 years. Assuming 3 hours of use a day, 15 years equals 16,425 hours. As of January 2024, average rated life hours for ENERGY STAR-qualified LEDs was >21,800 hours. Accessed January 2024. Weblink

2) Early replacement measure life calculated by multiplying one-half (the assumed proportion of remaining life) times the product of (1) the distribution of incandescent, halogen, and CFL bulbs from the Act 129 2023 Pennsylvania Residential Baseline Study (Weblink) and (2) the service lifetimes for incandescent, halogen, and CFL bulbs assumed in DOE Impact Statement for US Department of Energy Appliance and Equipment Standards Rulemakings and Notices. July 25, 2022. Weblink

3) US Department of Energy Appliance and Equipment Standards Rulemakings and Notices. July 25, 2022. Weblink

4) US Department of Energy Appliance and Equipment Standards Rulemakings and Notices. July 8, 2022. Weblink

5) Average "all bulb" probably of operation during PJM summer and winter peak periods calculated using load shapes from Statewide Evaluation Team for Pennsylvania Public Utilities Commission. (2014, January). Pennsylvania Statewide Act 129 2014 Commercial & Residential Light Metering Study. Appendix A Residential Load Shapes. Weblink

6) SWE Interactive Effect Calculator.

7) Statewide Evaluation Team (GDS Associates, Inc, Nexant, Research into Action, Apex Analytics LLC) for Pennsylvania Public Utilities Commission. (2014, January). 2014 Commercial & Residential Light Metering Study. Page 4, Table 1-1. Weblink

8) Grainger Lighting Product Web Pages: Weblink1, Weblink2

9) PA 2026 TRM Appendix C. Weblink

10) 9.7% of LEDs observed for Act 129 2023 Pennsylvania Residential Baseline Study were exterior. Weblink

2.1.2 Residential Occupancy Sensors

Target Sector	Residential
Measure Unit	Occupancy Sensor
Measure Life	8 years[Source 3]
Vintage	Retrofit

Savings for residential occupancy sensors inside residential homes are based on a straightforward algorithm that calculates savings based on the wattage of the bulb(s) or fixture(s) being controlled by the occupancy sensor, the daily run hours before installation, and the daily run hours after installation.

Eligibility

This protocol is for the installation of hard-wired or plug-in occupancy sensors in single-family homes or inside multifamily units. It can also be used to estimate savings from connected (aka "smart") lighting inside homes. Occupancy sensors installed outdoors or in multifamily common areas are not eligible under this protocol.

Algorithms

$$\Delta kWh = \frac{Watts_{controlled}}{1{,}000} \times (1 + IE_{kWh}) \times (RH_{old} - RH_{new}) \times 365 \times ISR$$

$$\Delta kW_{summer\ peak} = \frac{Watts_{controlled}}{1{,}000} \times (1 + IE_{kW\_s}) \times \left(\frac{RH_{old} - RH_{new}}{RH_{old}}\right) \times ISR \times CF_s$$

$$\Delta kW_{winter\ peak} = \frac{Watts_{controlled}}{1{,}000} \times (1 + IE_{kW\_w}) \times \left(\frac{RH_{old} - RH_{new}}{RH_{old}}\right) \times ISR \times CF_w$$

Definition of Terms

Table 2-6: Terms, Values, and References for Residential Occupancy Sensors

Term	Unit	Value	Source
$Watts_{controlled}$, Wattage of the bulb(s) or fixture(s) being controlled by the occupancy sensor	*W*	EDC Data Gathering, Hard-wired Default: 108W Plug-in Default: 9W	EDC Data Gathering, 7, 8
IE_{kWh}, HVAC Interactive Effect for lighting energy	*None*	Table 2-5	9
IE_{kW_s}, Summer Interactive Demand Factor – applies to residential lighting in conditioned residential spaces.	*None*	Table 2-5	9
IE_{kW_w}, Winter Interactive Demand Factor – applies to residential lighting in conditioned residential spaces.	*None*	Table 2-5	9
RH_{old}, Daily run hours before installation	*Hours*	2.5	1
RH_{new}, Daily run hours after installation	*Hours*	1.5 (60% of RH_{old})	2
ISR, In-service rate	*%*	EDC Data Gathering, Upstream Default: 95% Kit Hard-wired Default: 16% Kit Plug-in: EDC Data Gathering Direct Install Default: 100%	5, 6, 7
CF_s, Summer coincidence factor	*None*	0.101	4
CF_w, Winter coincidence factor	*None*	0.121	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) for Pennsylvania Public Utilities Commission. (2014, January). 2014 Commercial & Residential Light Metering Study. Weblink
2) Weighted average of percentage reduction by hours of use per room (excluding exterior and other). Navigant for Consortium for Energy Efficiency. (2014, January). Residential Lighting Controls Market Characterization. Page 19, Table 7.
3) California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020.
4) Average “all bulb” probably of operation during PJM summer and winter peak periods calculated using load shapes from Statewide Evaluation Team for Pennsylvania Public Utilities Commission. (2014, January). Pennsylvania Statewide Act 129 2014 Commercial & Residential Light Metering Study. Appendix A Residential Load Shapes. Weblink
5) Maryland EmPOWER Technical Reference Manual Volume 2 – Residential Measures. (2023, version 11.0). “Occupancy Sensor – Wall-Mounted”.
6) Weighted average of evaluated PY13 and PY14 outlet gasket ISRs from FirstEnergy kits.
7) Calculated as average number of bulbs-controlled times average bulb wattage. Average bulbs controlled is assumed to be the average bulbs per room found in the Act 129 2023 Pennsylvania Residential Baseline Study. Average bulb wattage is calculated by multiplying the distribution of bulb technologies (LED, CFL, linear fluorescent, incandescent, and halogen) found in the Act 129 2023 Pennsylvania Residential Baseline Study by the average wattage per technology reported in Buccitelli, N., Elliott, C., Schober, S., and Yamada, M. (2017, November). “2015 U.S. Lighting Market Characterization”. Page 54, Table 4.5. Navigant Consulting. Weblink
8) Mean, median, and mode wattage of ENERGY STAR-certified 60w equivalent LEDs. Accessed August 2023. Weblink
9) SWE Interactive Effect Calculator.

2.1.3 LED and Electroluminescent Nightlights

Target Sector	Residential
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. Zero demand savings are assumed 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.

Algorithms

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

$$\Delta kWh = \frac{(W_{base} \times HOU_{base} - W_{ee} \times HOU_{ee})}{1{,}000} \times ISR_{NL} \times 365$$

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

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

Definition of Terms

Table 2-7: 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 = 0.14	4

Default Energy Savings

$$LED\ \Delta kWh = \frac{(7 \times 12 - 1 \times 12)}{1{,}000} \times 0.14 \times 365\frac{days}{yr} = 3.7\ kWh$$

$$Electroluminescent\ \Delta kWh = \frac{(7 \times 12 - 0.03 \times 24)}{1{,}000} \times 0.14 \times 365\frac{days}{yr} = 4.3\ kWh$$

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. (2009, February). “LED, Electroluminescent & Fluorescent Night Lights”, Work Paper WPSCRELG0029 Rev. 1, pages 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) Weighted average of ISRs from surveys of FirstEnergy customers that received nightlights in kits in PY13 and PY14.

2.1.4 HOLIDAY LIGHTS

Target Sector	Residential
Measure Unit	One Strand of Holiday lights
Measure Life	10 years[Source 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. There are no demand savings as holiday lights are assumed to operate only at night during the holiday season.

ELIGIBILITY

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

ALGORITHMS

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

$$\Delta\, kWh_{C9} = \frac{[(INC_{C9} - LED_{C9}) \times \#Bulbs \times \#Strands \times HOU]}{1{,}000}$$

$$\Delta\, kWh_{C7} = \frac{[(INC_{C7} - LED_{C7}) \times \#Bulbs \times \#Strands \times HOU]}{1{,}000}$$

$$\Delta\, kWh_{mini} = \frac{[(INC_{mini} - LED_{mini}) \times \#Bulbs \times \#Strands \times HOU]}{1{,}000}$$

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

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

Key assumptions

1) All estimated values reflect the use of residential 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 2-8: 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*	0.35	1
LED_{C7}, Wattage of LED C7 bulbs	*Watts/Bulb*	0.08	1
INC_{C7}, Wattage of incandescent C7bulbs	*Watts/Bulb*	5.25	1
LED_{C9}, Wattage of LED C9 bulbs	*Watts/Bulb*	0.28	1
INC_{C9}, Wattage of incandescent C9 bulbs	*Watts/Bulb*	7.0	1
$\%_{Mini}$, Percentage of holiday lights that are "mini"	%	50%	2
$\%_{C7}$, Percentage of holiday lights that are "C7"	%	25%	2
$\%_{C9}$, Percentage of holiday lights that are "C9"	%	25%	2
$\#_{Bulbs}$, Number of bulbs per strand	*Bulbs/strand*	EDC Data Gathering Default Mini: 100 Default C7: 25 Default C9: 25	1
$\#_{Strands}$, Number of strands of lights per package	*Strands/package*	EDC Data Gathering Default: 1 strand	1
HOU, Annual hours of operation	*Hours/yr*	150	2

Default Savings

The default savings for installation of LED C9, C7, and mini lights is 25.2 kWh, 19.4 kWh, and 4.1 kWh, respectively. The weighted average savings are 13.2 kWh per strand.

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) Sample of 180 holiday lights gathered from HomeDepot.com and Walmart.com. Accessed March 2024.

2) Michigan Energy Measures Database. Accessed January 2024. Weblink

2.2 HVAC

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

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

This measure defines the methods for determining energy impact savings from installation of residential high-efficiency cooling and heating equipment. Input data to savings algorithms are based both on fixed assumptions and data supplied from the high-efficiency equipment AEPS application form or EDC data gathering.

Cooling savings may also be claimed under this measure for quality installation of properly sized new equipment.

Larger commercial air conditioning and heat pump applications are addressed 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). Cooling and heating savings claimed from proper sizing requires Manual J calculations, following of ENERGY STAR HVAC Quality Installation procedures, or similar calculations. Residential buildings with properly sized baseline equipment are excluded from claiming savings from proper sizing.

ALGORITHMS

This algorithm is used for the installation of ASHP and CAC measures:

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

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

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

$$\Delta kWh_{PSF} = \frac{CAPY_{cool}}{SEER_{ee}} \times PSF \times EFLH_{cool} + \frac{CAPY_{heat}}{HSPF_{ee}} \times PSF \times EFLH_{heat}$$

$$\Delta kW_{summer\ peak} = \Delta kW_{cool} + \Delta kW_{PSF\ cool}$$

$$\Delta kW_{cool} = CAPY_{cool} \times \left(\frac{OF_{cool}}{EER2_{base}} - \frac{1}{EER2_{ee}}\right) \times CF_{summer}$$

$$\Delta kW_{PSF\ cool} = \frac{CAPY_{cool}}{EER2_{ee}} \times PSF \times CF_{summer}$$

$$\Delta kW_{winter\ peak} = \Delta kW_{heat} + \Delta kW_{PSF\_heat}$$

$$\Delta kW_{heat} = CAPY_{hea} \times \left(\frac{OF_{heat}}{COP_{base}} - \frac{1}{COP_{ee}}\right) \times \frac{1}{3.412\frac{\text{BTU}}{\text{W·h}}} \times CF_{winter}$$

$$\Delta kW_{PSF\ heat} = \frac{CAPY_{heat}}{COP_{ee} \times 3.412\frac{\text{BTU}}{\text{W·h}}} \times PSF \times CF_{winter}$$

This algorithm is used for the installation of GSHP, PTAC and PTHP measures:

$$\Delta kWh = \Delta kWh_{cool} + \Delta kWh_{hea} + \Delta kWh_{PSF}$$

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

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

$$\Delta kWh_{PSF} = \frac{CAPY_{cool}}{SEER_{ee}} \times PSF \times EFLH_{cool} + \frac{CAPY_{heat}}{HSPF_{ee}} \times PSF \times EFLH_{heat}$$

$$\Delta kW_{summer\ peak} = \Delta kW_{cool} + \Delta kW_{PSF\_cool}$$

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

$$\Delta kW_{PSF\ cool} = \frac{CAPY_{cool}}{EER_{ee}} \times PSF \times CF_{summer}$$

$$\Delta kW_{winter\ peak} = \Delta kW_{hea} + \Delta kW_{PSF\_heat}$$

$$\Delta kW_{heat} = CAPY_{hea} \times \left(\frac{OF_{heat}}{COP_{base}} - \frac{1}{COP_{ee}}\right) \times \frac{1}{3.412\frac{\text{BTU}}{\text{W·h}}} \times CF_{winter}$$

$$\Delta kW_{PSF\,heat} = \frac{CAPY_{heat}}{COP_{ee} \times 3.412\frac{\text{BTU}}{\text{W}\cdot\text{h}}} \times PSF \times CF_{winter}$$

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:

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

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:

$$SEER = EER_g \times GSER$$

$$EER = EER_g$$

$$HSPF = COP_g \times 3.412\frac{\text{BTU}}{\text{W}\cdot\text{h}} \times GSOP$$

$$COP = COP_g$$

Qualifying: Package Terminal Heat Pumps, Package Terminal Air Conditioners

$$SEER = EER$$

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

DEFINITION OF TERMS

Table 2-9: 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	$kBTU/hr$	EDC Data Gathering	AEPS Application; EDC Data Gathering
$CAPY_{heat}$, The heating capacity of the heat pump being installed (Auxiliary electric resistance heat is not included)	$kBTU/hr$	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
$SEER2_{base}$, $SEER_{base}$, Seasonal Energy Efficiency Ratio of the Baseline Unit	$\frac{BTU}{W \cdot h}$	EDC Data Gathering,	EDC Data Gathering
		Default: see Table 2-10	2

Term	Unit	Value	Sources
SEER2ee, SEERee, Seasonal Energy Efficiency Ratio of the qualifying unit being installed	$\frac{BTU}{W \cdot h}$	EDC Data Gathering	AEPS Application; EDC Data Gathering
EER2base, EERbase, Energy Efficiency Ratio of the Baseline Unit	$\frac{BTU}{W \cdot h}$	EDC Data Gathering,	EDC Data Gathering
		Default: see Table 2-10	2
EER2ee, EERee, Energy Efficiency Ratio of the unit being installed	$\frac{BTU}{W \cdot h}$	EDC Data Gathering	EDC Data Gathering; AEPS Application
		Default: EERee:$-0.02 \times SEER^2 + 1.12 \times SEER$	3,4
EERg, 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	EDC Data Gathering
HSPF2base, HSPFbase, Heating Seasonal Performance Factor of the Baseline Unit	$\frac{BTU}{W \cdot h}$	EDC Data Gathering,	EDC Data Gathering
		Default: see Table 2-10	2
HSPF2ee, HSPFee, Heating Seasonal Performance Factor of the unit being installed	$\frac{BTU}{W \cdot h}$	EDC Data Gathering	AEPS Application; EDC Data Gathering
PSF, Proper Sizing Factor or the assumed savings due to proper sizing and proper installation	*Proportion*	Not properly sized or properly sized baseline equipment: 0 Properly sized: 0.05	5
COPbase, Coefficient of Performance of the baseline unit. This is a measure of the efficiency of a heat pump	*Proportion*	EDC Data Gathering	EDC Data Gathering
		Default: see Table 2-10	2
COPee, 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
OFcool, Oversize factor	*None*	EDC Data Gathering	EDC Data Gathering
		Default: see Table 2-12	6
OFheat, Oversize factor	*None*	EDC Data Gathering	EDC Data Gathering
		Default: see Table 2-12	7
GSER, Factor to convert EER_g to the equivalent HSPF of an air-source unit to enable comparisons to the baseline unit	$\frac{BTU}{W \cdot h}$	See Table 2-13	8
GSOP, Factor to convert COP_g to the equivalent COP of an air-source unit to enable comparisons to the baseline unit	*Proportion*	See Table 2-13	8

Term	Unit	Value	Sources
$EFLH_{cool}$, 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_{summer}, Demand Coincidence Factor during the summer months	*Proportion*	See *CF* in Vol. 1, App. A	9
CF_{winter}, Demand Coincidence Factor during the winter months	*Proportion*	See *CF* in Vol. 1, App. A	9

Note: Where appropriate, nameplate data collected for usage in savings calculations (i.e., SEER, EER, HSPF) should be converted to new efficiency metrics (i.e., SEER2, EER2, HSPF2) using conversion equations laid out in Vol. 1 App. A.

Table 2-10: Default Baseline Equipment Efficiency for High Efficiency Equipment

Baseline Equip.	Early Replacement				Replace on Burnout / New Construction			
	$SEER2_{base}$	$EER2_{base}$	$HSPF2_{base}$	COP_{base}	$SEER2_{base}$	$EER2_{base}$	$HSPF2_{base}$	COP_{base}
ASHP (Split systems)	14.1[a]	11.7[b]	7.2	2.5[c]	14.3	11.8[b]	7.5	2.6[c]
ASHP (Single-Package)					13.4	11.2[b]	6.7	2.3[c]
CAC (Split systems and Single-package)	13.2	11.1[b]	–	–	13.4	11.2[b]	–	–
Baseline Equip.	**Early Replacement**				**Replace on Burnout / New Construction**			
	$SEER_{base}$	EER_{base}	$HSPF_{base}$	COP_{base}	$SEER_{base}$	EER_{base}	$HSPF_{base}$	COP_{base}
Elec. Baseboard	–	–	3.4[d]	1.0	–	–	–	–
Elec. Furnace	–	–	3.2[d]	0.95	–	–	–	–
Space Heaters	–	–	3.4[d]	1.0	–	–	–	–
GSHP – Water-to-air, ground water	18.5[e]	18.0[f]	10.8[g]	3.7[f]	18.7[h]	18.0	10.2[i]	3.7
GSHP – Brine-to-air, ground loop					14.5[h]	14.1	9.5[i]	3.2
GSHP – Water-to-water, ground water					15.2[h]	16.3	8.9[i]	3.1
GSHP – Brine-to-water, ground loop					11.6[h]	12.1	7.6[i]	2.5
PTAC[j]	13.8 - (0.3 x $CAPY_{cool}$)		–	–	13.8 - (0.3 x $CAPY_{cool}$)		–	–
PTHP[j]	14.0 - (0.3 x $CAPY_{cool}$)		3.412 x (3.7 - 0.052 x $CAPY_{cool}$)	3.7 - (0.052 x $CAPY_{cool}$)	14.0 - (0.3 x $CAPY_{cool}$)		3.412 x (3.7 - 0.052 x $CAPY_{cool}$)	3.7 - (0.052 x $CAPY_{cool}$)

[a] Disaggregated ASHP values from the Act 129 2023 Pennsylvania Residential Baseline Study

[b] Value is calculated based on conversion equations laid out in Vol 1. Appendix A and EER = -0.02 x $SEER^2$ + 1.12 x SEER
[c] Value is calculated based on conversion equations laid out in Vol 1. Appendix A and COP = HSPF / 3.412.
[d] Equipment COPs vary between 0.95 and 1.00. Using the formula HSPF = COP x 3.412, a COP of 0.95 therefore equates to an HSPF of 3.241.
[e] Value calculated using the average of the GSER values listed in Table 2-11 and the following formula: SEER = EER x GSER.
[f] Value is from Act 129 2023 Pennsylvania Residential Baseline Study, but capped to current federal efficiency
[g] Value calculated using the average of the GSOP values listed in Table 2-11 and the following formula: HSPF = COP x 3.412 x GSOP
[h] Value calculated using the corresponding GSER value listed in Table 2-11 and the following formula: SEER = EER x GSER.
[i] Value calculated using the corresponding GSOP value listed in Table 2-11 and the following formula: HSPF = COP x 3.412 x GSOP
[j] 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.

Table 2-11: Proper Size Factors for High Efficiency Equipment

Proper Size Factor	ASHP	CAC	PTAC	PTHP	GSHP
$\Delta kW_{PSF\,cool}$	0	0.05	0.05	0	0
$\Delta kW_{PSF\,heat}$	0.05	0	0	0.05	0.05

Note: The implicit assumption is that ASHP, GSHP and PTHP have been sized to meet the heating load of the residential establishment and standalone AC systems have been sized to meet the cooling load

Table 2-12: Default Oversize Factors for High Efficiency Equipment

Qualifying	Oversize Factor	Existing						
		ASHP	CAC	Electric Baseboard	Electric Furnace	GSHP	RAC	Space Heaters
CAC, PTAC	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

Table 2-13: Conversion factors to derive Air-source equivalent metrics of a Ground source heat pump

GSHP Type	GSER	GSOP
Water-to-Air: Ground water	1.04	0.81
Brine-to-Air: Ground loop	1.03	0.87
Water-to-Water: Ground water	0.93	0.84
Brine-to-Water: Ground loop	0.96	0.89

Evaluation Protocols

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

SOURCES

1) California Electronic Technical Reference Manual. "SEER Rated AC and HP HVAC Equipment, Residential". Accessed February 2024. Weblink

2) For early replacement ASHP/CAC: NMR Group for the Pennsylvania Public Utility Commission. (2024, March). 2023 Pennsylvania Statewide Act 129 Residential Baseline Study. Sec 8.1.4 Table 87 and Sec 8.2.1 Table 97 and 98. Baseline findings are capped to current Federal Standards. Weblink
For new construction ASHP/CAC: Federal Code of Regulations 10 CFR 430.32(c). Weblink
For early replacement GSHP: existing systems were assumed to be two-thirds through an assumed 15-year equipment life. Therefore, the minimum required efficiency at the date of installation for an existing GSHP system is estimated to have been set by IECC 2015 requirements. The values in the table represent the minimum efficiency values from IECC 2015. Weblink .
For New Construction GSHP: IECC 2021 - Weblink Table 14
All PTAC and PTHP: Standard sizing minimums, Federal Code of Regulations 10 CFR 431.97(c): Weblink
As per IECC Residential code (Section R403.7), the requirements for all mechanical systems are stipulated to be federal minimums. Since there are no federal standards for Residential GSHP/PTAC/PTHPs, the C&I standards acts as a proxy.

3) Average EER for SEER 13 units as calculated by EER = -0.02 × SEER² + 1.12 × SEER based on Wassmer, M., (2003), "A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations" as cited in U.S. DOE Building America House Simulation Protocol, Revised 2010. Weblink

4) "Methodology for Calculating Cooling and Heating Energy Input-Ratio (EIR) from the Rated Seasonal Performance Efficiency (SEER OR HSPF)" (Kim, Baltazar, Haberl). April 2013 Accessed December 2018. Weblink

5) 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, page 4.

6) 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 and 40% oversizing of heat pumps. Thus, assuming for most baseline oversize factors to be unitary.
Neme, Proctor, Nadal, "National Energy Savings Potential From Addressing Residential HVAC Installation Problems". ACEEE, February 1, 1999. Weblink
Confirmed also by *Central Air Conditioning in Wisconsin, a compilation of recent field research.* Energy Center of Wisconsin. May 2008, amended December 15, 2010. Weblink
ACCA, "Verifying ACCA Manual S Procedures," Weblink

7) 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. $OF = \frac{20{,}472}{36{,}000} \approx 0.6$

8) Factors are derived from the conversion algorithms depicted in the Heat Pump – Water-to-air Ground Source (GSHP) Measure of the Version 11 of the NY TRM Weblink Substituting for defaults where applicable and borrowing current market data from the AHRI Database. Weblink

9) Based on the Phase III SWE team's analysis of regional HVAC runtime data collected from ecobee's Donate Your Data research service (Weblink) and updated based on the latest CDD and HDD values from NOAA's 15-year annual climate Normals (2006–2020) (Weblink)

2.2.2 High Efficiency Equipment for Midstream Delivery: ASHP, CAC, PTAC, PTHP

Target Sector	Residential
Measure Unit	CAC, ASHP, PTAC or PTHP Unit
Measure Life	15 Source 1
Vintage	Replace on Burnout, New Construction

This protocol defines the methods for determining the annual electric energy and peak demand savings from installation of residential high-efficiency cooling and heating equipment that is sold to trade allies and customers through commercial channels such as HVAC distributors, dealers, supply houses, and direct relationships with manufacturers. 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 HVAC equipment. Input data to savings algorithms are based both on stipulated code minimum baselines and operating assumption in combination with actual equipment properties recorded by the participating distributors. EDCs, their implementation CSPs, and participating distributors are expected to collect AHRI reference numbers and use the AHRI rated capacity and efficiency metrics to calculate savings. The algorithms for this measure path assume a 1:1 installation of a high-efficiency unit in lieu of a code minimum piece of HVAC equipment with the same capacity. Larger commercial air conditioning and heat pump applications are dealt with in Section 3 of Volume 3: Commercial and Industrial Measures of the 2026 Technical Reference Manual.

Eligibility

This protocol requires the purchase of a high-efficiency Central Air Conditioner (CAC), Air Source Heat Pump (ASHP), Cold Climate Heat Pump (ccHP), Packaged Terminal Air Conditioner (PTAC) or Packaged Terminal Heat Pump (PTHP). To be eligible under this protocol, the qualifying equipment must be purchased through a commercial channel (such as an HVAC contractor or distributor) for installation in a residential setting. The distributor will need to collect information on the installation address for verification purposes.

For the purposes of the midstream protocol, the minimum efficiency levels for each eligible unit type are defined by ENERGY STAR version 6.1 requirements as follows: Source 2

- **CAC**: greater than or equal to 15.2 SEER2
- **ASHP**: Greater than or equal to 15.2 SEER2 *or* 7.8 HSPF2 (Split systems)/7.2 HSPF2 (Single package systems)
- **ccHP**: Greater than or equal to 15.2 SEER2 *or* 8.5 HSPF2 (Non-ducted split systems)/8.1 HPSF2 (All other systems)
- **PTAC**: EER ≥ $14.0 - (0.3 \times CAPY_{cool})$
- **PTHP**: EER ≥ $14.0 - (0.3 \times CAPY_{cool})$ *or* HSPF = $3.412 \times (3.7 - 0.052 \times CAPY_{cool})$

Heat pump equipment (ASHP and PTHP) must meet at least one of the cooling or heating minimum efficiencies. This will allow EDCs to incentivize equipment which are engineered for heating performance over cooling efficiency.

ALGORITHMS

This algorithm is used for the installation of ASHP and CAC measures:

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

$$\Delta kWh_{cool} = CAPY_{cool} \times \left(\frac{OF_{cool}}{SEER2_{base}} - \frac{1}{SEER2_{ee}}\right) \times EFLH_{cool}$$

$$\Delta kWh_{heat} = CAPY_{hea} \times \left(\frac{OF_{hea}}{HSPF2_{base}} - \frac{1}{HSPF2_{ee}}\right) \times EFLH_{heat}$$

$$\Delta kW_{summer\ peak} = CAPY_{cool} \times \left(\frac{OF_{cool}}{EER\ \ base} - \frac{1}{EER2_{ee}}\right) \times CF_{summer}$$

$$\Delta kW_{winter\ peak} = CAPY_{heat} \times \left(\frac{OF_{cool}}{COP_{base}} - \frac{1}{COP_{ee}}\right) \times \frac{1}{3.412\frac{\text{BTU}}{\text{W·h}}} \times CF_{winter}$$

This algorithm is used for the installation of PTAC and PTHP measures:

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

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

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

$$\Delta kW_{summer\ peak} = CAPY_{cool} \times \left(\frac{OF_{cool}}{EER_{base}} - \frac{1}{EER_{ee}}\right) \times CF_{summer}$$

$$\Delta kW_{winter\ peak} = CAPY_{heat} \times \left(\frac{OF_{cool}}{COP_{base}} - \frac{1}{COP_{ee}}\right) \times \frac{1}{3.412\frac{\text{BTU}}{\text{W·h}}} \times CF_{winter}$$

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 2-14: Terms, Values, and References for High Efficiency Equipment: ASHP, ccHP, CAC, PTAC, PTHP

Term	Unit	Value	Sources
$CAPY_{cool}$, The cooling capacity of the equipment being installed	*kBTU/hr*	Rated Value from AHRI Certificate • **CAC, ASHP. ccHP**: Cooling Capacity at 95 degrees (F) • **PTAC, PTHP**: Cooling Capacity at 230V if dual voltage	3, EDC Data Gathering

Term	Unit	Value	Sources
$CAPY_{heat}$, The heating capacity of the heat pump being installed (Auxiliary electric heat resistance not included)	$kBTU/hr$	Rated Value from AHRI Certificate • **ASHP, ccHP**: Heating Capacity at 47 degrees (F) • **PTHP**: Heating Capacity at 230V if dual voltage	3, EDC Data Gathering
$SEER2_{base}$, $SEER_{base}$ Seasonal Energy Efficiency Ratio of the Baseline Unit	$\frac{BTU}{W \cdot h}$	See Table 2-10	4
$SEER2_{ee}$, $SEER_{ee}$ Seasonal Energy Efficiency Ratio of the qualifying unit being installed	$\frac{BTU}{W \cdot h}$	Rated Value from AHRI Certificate	3, EDC Data Gathering
$EER2_{base}$, EER_{base} Energy Efficiency Ratio of the Baseline Unit	$\frac{BTU}{W \cdot h}$	See Table 2-10	5
$EER2_{ee}$, EER_{ee} Energy Efficiency Ratio of the unit being installed	$\frac{BTU}{W \cdot h}$	Rated Value from AHRI Certificate. At • **CAC, ASHP, ccHP**: EER at 95 degrees (F) • **PTAC, PTHP**: EER at 230V if dual voltage	3; EDC Data Gathering
$HSPF2_{base}$, $HSPF_{base}$ Heating Seasonal Performance Factor of the Baseline Unit	$\frac{BTU}{W \cdot h}$	See Table 2-10	4
$HSPF2_{ee}$, $HSPF_{ee}$ Heating Seasonal Performance Factor of the unit being installed	$\frac{BTU}{W \cdot h}$	Rated Value from AHRI Certificate	3, EDC Data Gathering
COP_{ee}, Coefficient of Performance of the unit being installed. This is a measure of the efficiency of a PTHP	*Proportion*	Rated Value from AHRI Certificate	3, EDC Data Gathering
$EFLH_{cool}$, Equivalent Full Load Hours of operation during the cooling season for the average unit	$\frac{hours}{yr}$	See Table 2-15	6
$EFLH_{heat}$, Equivalent Full Load Hours of operation during the heating season for the average unit	$\frac{hours}{yr}$	See Table 2-15	6
CF_{summer}, Demand Coincidence Factor during the summer months	*Proportion*	See Table 2-15	6
CF_{winter}, Demand Coincidence Factor during the winter months	*Proportion*	See Table 2-15	6

Note: Where appropriate, nameplate data collected for usage in savings calculations (i.e., SEER, EER, HSPF) should be converted to new efficiency metrics (i.e., SEER2, EER2, HSPF2) using conversion equations laid out in Vol. 1 App. A

Table 2-15: EDC Climate Region Weighted Composite Factors

EDC	$EFLH_{cool}$	$EFLH_{heat}$	Summer CF	Winter CF
Duquesne	670	1,262	0.37	0.36
Met-Ed	870	1,122	0.44	0.33
Penelec	612	1,321	0.33	0.38
Penn Power	657	1,283	0.35	0.37
West Penn Power	675	1,265	0.37	0.37
PECO	972	1,027	0.48	0.29
PPL	764	1,198	0.41	0.35

The composite factors in Table *2-15: EDC Climate Region Weighted Composite Factors* are based on the climate dependent values from Appendix A of the 2026 Technical Reference Manual. Appendix A provides heating and cooling Equivalent Full Load Hours (EFLH) and Coincident Factors (CF) for each climate region, as well as climate region weights for each EDC, based on the overlap of the EDC territories and climate regions. EDCs are encouraged to use the factors for the installation location's climate region, if it is possible to identify the region based on the premise address. Otherwise, the composite factors can be used as the default value for each EDC. The composite factors were developed as a weighted average of the EFLH and CF climate region values and the EDC weights for each climate region.

Evaluation Protocols

Midstream program delivery reduces the data collection requirements of EDCs, their implementation CSPs, and program participants. However, EDC evaluation contractors should validate the make and model of a statistically representative sample of program-supported equipment. The EDC evaluation contractor should also confirm that the installation premise is (a) served by the EDC that supplied the incentive (b) metered on a residential or master-metered multifamily electric tariff, using the installation address collected by the distributor. EDC evaluation contractors may also choose to recalculate the weighted average EFLH values in Table 2-15: EDC Climate Region Weighted Composite Factors based on actual program participation.

Sources

1) California Electronic Technical Reference Manual. "SEER Rated AC and HP HVAC Equipment, Residential". Accessed February 2024. Weblink

2) U.S. EPA. (2022). ENERGY STAR Program Requirements Product Specification for Central Air Conditioner and Heat Pump Equipment. Eligibility Criteria Version 6.1. Weblink

3) AHRI Institute Directory of Certified Product Performance. Weblink

4) For ASHP, CAC: Federal Code of Regulations 10 CFR 430.32(c). Federal Code of Regulations 10 CFR 430.32(c). Weblink
For PTAC/PTHPs: Federal Code of Regulations 10 CFR 431.97(c): Weblink
As per IECC Residential code (Section R403.7), the requirements for all mechanical systems are stipulated to be federal minimums. Since there are no federal standards for Residential GSHP/PTAC/PTHPs, the C&I standards act as a proxy.

5) Average EER for SEER 13 units as calculated by $EER = -0.02 \times SEER^2 + 1.12 \times SEER$ based on Wassmer, M., (2003), "A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations" as cited in U.S. DOE Building America House Simulation Protocol, Revised 2010. Weblink

6) Based on the Phase III SWE team's analysis of regional HVAC runtime data collected from ecobee's Donate Your Data research service (Weblink) and updated based on the latest CDD and HDD values from NOAA's 15-year annual climate Normals (2006–2020) (Weblink)

2.2.3 High Efficiency Equipment: Ductless Heat Pumps with Midstream Delivery Option

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

ENERGY STAR Version 6.1 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. Equipment will be considered eligible if it meets the efficiency requirements in ENERGY STAR Version 6.1.[Source 2]

Cooling savings may also be claimed under this measure for quality installation of properly sized new equipment, though not for equipment delivered through midstream programs.

Eligibility

This protocol documents the energy savings attributed to ductless heat pumps. Eligible equipment must meet ENERGY STAR Version 6.1 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)
3) A lower-efficiency ductless heat pump system
4) A ducted heat pump
5) Electric furnace
6) A non-electric fuel-based system (Implicit assumption in the Midstream route that a non-electric fuel/no heat baseline will be replaced with a minimum efficiency electric 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 (See Table 2-16). 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. Cooling savings claimed from proper sizing requires Manual J calculations, following of ENERGY STAR HVAC Quality Installation procedures, or similar calculations. Residential buildings with properly sized baseline equipment are excluded from claiming savings from proper sizing.

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. Cooling savings from proper sizing cannot be claimed under midstream delivery programs.

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.

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

$$\Delta kWh_{cool} = CAPY_{cool} \times \left(\frac{OF_{cool} \times DLF}{SEER2_{base}} - \frac{1}{SEER2_{ee}}\right) \times EFLH_{cool,zone} \times n_{MS\ zones}$$

$$\Delta kWh_{heat} = CAPY_{heat} \times \left(\frac{OF_{heat} \times DLF}{HSPF2_{base}} - \frac{1}{HSPF2_{ee}}\right) \times EFLH_{heat,HP,zone} \times n_{MS\ zones}$$

$$\Delta kWh_{PSF} = \frac{CAPY_{cool}}{SEER_{ee}} \times PSF \times EFLH_{cool} + \frac{CAPY_{heat}}{HSPF2_{ee}} \times PSF \times EFLH_{heat}$$

$$\Delta kW_{summer\ peak} = \Delta kW_{cool} + \Delta kW_{PSF,cool}$$

$$\Delta kW_{cool} = CAPY_{cool} \times \left(\frac{OF_{cool} \times DLF}{EER2_{base}} - \frac{1}{EER2_{ee}}\right) \times CF_{summer} \times n_{MS\ zones}$$

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

$$\Delta kW_{winter\ peak} = \Delta kW_{heat} + \Delta kW_{PSF,heat}$$

$$\Delta kW_{heat} = CAPY_{heat} \times \left(\frac{OF_{heat} \times DLF}{COP_{base}} - \frac{1}{COP_{ee}}\right) \times \frac{1}{3.412\frac{\text{BTU}}{\text{W}\cdot\text{h}}} \times CF_{winter} \times n_{MS\ zones}$$

$$\Delta kW_{PSF,heat} = \frac{CAPY_{heat}}{COP_{ee}} \times PSF \times CF$$

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 2-16: 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	$kBTU/hr$	EDC Data Gathering	AEPS Application; EDC Data Gathering
$CAPY_{heat}$, The heating capacity of the heat pump being installed	$kBTU/hr$	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
$kW_{spaceheat}$, The heating capacity of the space heaters in watts.	kW	EDC Data Gathering	EDC Data Gathering
$SEER2_{base}$, Seasonal Energy Efficiency Ratio of the Baseline Unit	$\frac{BTU}{W \cdot h}$	EDC Data Gathering Default: Table 2-18 or Table 2-10 in Sec. 2.2.1 Midstream: 13.6	EDC Data Gathering; 3, 10
$SEER2_{ee}$, Seasonal Energy Efficiency Ratio of the qualifying unit being installed	$\frac{BTU}{W \cdot h}$	EDC Data Gathering	AEPS Application; EDC Data Gathering
$EER2_{base}$, Energy Efficiency Ratio of the Baseline Unit	$\frac{BTU}{W \cdot h}$	EDC Data Gathering Table 2-18 or Table 2-10 in Sec. 2.2.1 Midstream: 11.4	EDC Data Gathering; 3, 4, 5
$EER2_{ee}$, Energy Efficiency Ratio of the unit being installed	$\frac{BTU}{W \cdot h}$	EDC Data Gathering Default EER_{ee}: $-0.02 \times SEER_{ee}^2 + 1.12 \times SEER_{ee}$	EDC Data Gathering; AEPS Application; 4, 5
$HSPF2_{base}$, Heating Seasonal Performance Factor of the Baseline Unit	$\frac{BTU}{W \cdot h}$	EDC Data Gathering Default: Table 2-18 or Table 2-10 in 2.2.1 Midstream: 6.0	EDC Data Gathering; 3, 10
$HSPF2_{ee}$, Heating Seasonal Performance Factor of the unit being installed	$\frac{BTU}{W \cdot h}$	EDC Data Gathering	AEPS Application; EDC Data Gathering

Term	Unit	Value	Sources
PSF, Proper Sizing Factor or the assumed savings due to proper sizing and proper installation	*Proportion*	Midstream Delivery, properly size baseline equipment, or not properly sized: 0 Properly sized: 0.05	11
OF_{cool}, Oversize factor	None	EDC Data Gathering Default: Table 2-19 Midstream: 1.0	EDC Data Gathering; 6
OF_{heat}, Oversize factor	None	EDC Data Gathering Default: Table 2-19 Midstream: 1.0	EDC Data Gathering ; 7
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 2-19 Midstream, cooling: 1.02 Midstream, heating: 1.02	8, 10
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 2-17	
$n_{MS\ zones}$, 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 2-24	9
$EFLH_{heat,HP}$, 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 2-24: Midstream DHP – Composite EFLH Values	9
CF_{summer}, Demand Coincidence Factor during the summer months	*Proportion*	See *CF* in Vol. 1, App. A	9

Term	Unit	Value	Sources
CF_{winter}, Demand Coincidence Factor during the winter months	*Proportion*	See *CF* in Vol. 1, App. A	9

Note: Where appropriate, nameplate data collected for usage in savings calculations (i.e., SEER, EER, HSPF) should be converted to new efficiency metrics (i.e., SEER2, EER2, HSPF2) using conversion equations laid out in Vol. 1 App. A

Table 2-17: 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 2-18: Default Ductless Heat Pump Efficiencies

Baseline Equip.	Early Replacement			Replace on Burnout/New Construction		
	$SEER2_{base}$	$EER2_{base}$	$HSPF2_{base}$	$SEER2_{base}$	$EER2_{base}$	$HSPF2_{base}$
Ductless	14.3	11.3	7.5	14.3	11.7	7.5

Note: Early Replacement defaults, though stemming from the Act 129 2023 Pennsylvania Residential Baseline Study, have been capped to New Construction/Replace on Burnout values (Federal standards)

Table 2-19: Oversize and Duct Leakage Factors for High Efficiency Equipment

Factors	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	0	1	1	1	1	0	0.6
OF_{cool}	1	1	1	0	0	1	1	0

Midstream Composite Baseline Calculations

This measure estimates the baseline system using composite values calculated from historical participant data.

SEER2, EER2, and HSPF2 values are based on Table 2-8 new construction/replace on burnout vintages and the Act 129 2023 Pennsylvania Residential Baseline Study for early replacement vintages.[Source 3]

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 2-20: Midstream DHP – SEER2 and EER2 Baseline Splits through Table 2-24: Midstream DHP – Composite EFLH Values show the inputs for the calculation of each composite baseline value. The composite baseline values will be updated as needed from the downstream program participation data set. The split represents the approximate percentage of projects in the PECO and PPL territories 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.

The composite value represents the weighted average of the system type based on the relative system splits.

For “No existing cooling” and “Room AC Cooling” Types, we assume that the customer was initially upgrading to a Central Air Conditioning system and is incentivized to upgrade to a DHP. Similarly, for “No existing or non-electric heating” and “Standard DHP” types, the assumption is that the customer was upgrading to an “Air Source Heat Pump.”

Table 2-20: Midstream DHP – SEER2 and EER2 Baseline Splits

Cooling Type	$SEER2_{base}$	$EER2_{base}$	Split
Central AC	13.4	11.2	4%
DHP or ASHP	14.3	11.8	8%
No existing cooling for primary space	13.4	11.2	29%
No existing cooling for secondary space	13.4	11.2	30%
Room AC	13.4	11.2	30%
Composite	13.6	11.4	100%

Table 2-21: Midstream DHP – HSPF2 Baseline Splits

Heating Type	$HSPF2_{base}$	Split
ASHP	7.5	3%
Electric furnace	2.7	1%
Electric resistance or de facto space heaters	2.9	32%
No existing or non-electric heating	7.5	57%
Standard DHP	7.5	8%
Composite	6.0	100%

Table 2-22: Midstream DHP – DLFcool and Ofcool Baseline Splits

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

Table 2-23: Midstream DHP – DLFheat and Ofheat Baseline Splits

Heating Type	DLF_{heat}	OF_{heat}	Split
Central ASHP	1.15	1.0	6%
De facto Space Heaters	1.00	0.6	5%
Ductless Heat Pump	1.00	1.0	26%
Electric Baseboard	1.00	1.0	62%
Electric Furnace	1.15	1.0	1%
Composite	1.02	1.0	100%

Table 2-24: Midstream DHP – Composite EFLH Values

Reference City	Climate Region	Composite $EFLH_{cool}$	Composite $EFLH_{heat}$
Allentown	C	497	1,008
Binghamton, NY	A	253	1,305
Bradford	G	201	1,325
Erie	I	410	1,131
Harrisburg	E	562	959
Philadelphia	D	637	850
Pittsburgh	H	439	1,069
Scranton	B	427	1,089
Williamsport	F	433	1,083

Evaluation Protocols

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

Sources

1) California Electronic Technical Reference Manual. “Ductless Heat Pump, Residential”. Accessed February 2024. Weblink

2) U.S. EPA. (2022). ENERGY STAR Program Requirements Product Specification for Central Air Conditioner and Heat Pump Equipment. Eligibility Criteria Version 6.1. Weblink

3) For Early Replacement: NMR Group for the Pennsylvania Public Utility Commission. (2024, March). 2023 Pennsylvania Statewide Act 129 Residential Baseline Study. Pages

105,114,115,116 Tables 87,96,97,98. Weblink
For new Construction: Federal Code of Regulations 10 CFR 430: Weblink

4) Average EER for SEER 13 units as calculated by EER = -0.02 × SEER² + 1.12 × SEER based on Wassmer, M., (2003), "A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations" as cited in U.S. DOE Building America House Simulation Protocol, Revised 2010. Weblink

5) "Methodology for Calculating Cooling and Heating Energy Input-Ratio (EIR) from the Rated Seasonal Performance Efficiency (SEER OR HSPF)" (Kim, Baltazar, Haberl). April 2013 Accessed December 2018. Weblink

6) Based on REM/Rate modeling using models from the PA 2012. Models assume 50% over-sizing of air conditioners and 40% oversizing of heat pumps.

   Neme, Proctor, Nadal, "National Energy Savings Potential From Addressing Residential HVAC Installation Problems". ACEEE, February 1, 1999. Weblink
   Central Air Conditioning in Wisconsin, a compilation of recent field research. Energy Center of Wisconsin. May 2008, amended December 15, 2010. Weblink
   ACCA, "Verifying ACCA Manual S Procedures," Weblink

7) 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. $OF = \frac{20{,}472}{36{,}000} \approx 0.6$

8) Engineering judgement: Conservative assumption for duct leakage to be around 15%. ENERGY STAR. "Duct Sealing". Accessed March 2024. CIEE/PG&E. (2002, May). Residential HVAC and Distribution Research Implementation. Page 6. Weblink

9) Based on the Phase III SWE team's analysis of regional HVAC runtime data collected from ecobee's Donate Your Data research service (Weblink) and updated based on the latest CDD and HDD values from NOAA's 15-year annual climate Normals (2006–2020) (Weblink)

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

11) 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, page 4.

2.2.4 ECM Circulation Fans

Target Sector	Residential
Measure Unit	ECM Circulation Fan
Measure Life	5 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.

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

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

$\Delta kW_{summer\ peak} = ECM_{kW} \times CF_{summer}$

$\Delta kW_{winter\ peak} = ECM_{kW} \times CF_{winter}$

Definition of Terms

Table 2-25: 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_{summer}, Demand Coincidence Factor during the summer months	*Proportion*	See *CF* in Vol. 1, App. A	3
CF_{winter}, Demand Coincidence Factor during the winter months	*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) California Electronic Technical Reference Manual. “Brushless Fan Motor Replacement”. Residential. Accessed January 2024. Weblink
2) Cadmus for the Public Service Commission of Wisconsin. (2014, November). “Focus on Energy Evaluated Deemed Savings Changes”, Table 3 Description of Variables for Furnaces with ECM. Weblink
3) Based on the Phase III SWE team’s analysis of regional HVAC runtime data collected from ecobee’s Donate Your Data research service. Weblink Updated based on the latest CDD and HDD values from NOAA’s 15-year annual climate Normals (2006–2020). Weblink

2.2.5 GSHP Desuperheaters

Target Sector	Residential
Measure Unit	GSHP Desuperheater
Measure Life	15 years[Source 1]
Vintage	Retrofit

Eligibility

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

Algorithms

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

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

$$\Delta kW_{summer\ peak} = \Delta kWh \times ETDF_{summer}$$

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

Definition of Terms

Table 2-26: Terms, Values, and References for GSHP Desuperheater

Term	Unit	Value	Sources
EF_{SH}, Energy Factor per desuperheater	*None*	0.17	2, 3
HW, Daily hot water use	*Gallons/Day*	45.5	7
T_{hot}, Hot Water Temperature	*°F*	119	4
T_{cold}, Cold Water Temperature	*°F*	52	5
UEF_{base}, Uniform Energy Factor of Electric Water Heater	*None*	EDC Data Gathering, Default: 0.92	EDC Data Gathering, 6
$ETDF_{summer}$, Energy to Demand Factor	*kW/kWh/year*	Table 2-27	8

Table 2-27: Energy to Demand Factor for GSHP Desuperheater

Building Type	$ETDF_{summer}$
Mobile Home	0.0001011
Multi-Family with 2 - 4 Units	0.0001006
Multi-Family with 5+ Units	0.0001007
Single-Family Attached	0.0001026
Single-Family Detached	0.0001070

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) NY TRM (October 2023, V11) Heat PUMP – Water-to-Air Ground Source (GSHP) Appendix P, Effective Useful Life (EUL, Single and Multi-Family Residential Measures, Heat Pump – Ground Source. Weblink
The Desuperheater is assumed to have an equal EUL of a GSHP (25 Years). With the rulings of Act 129 the EUL for this measure will be capped at 15 years.

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

3) 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).

4) Pennsylvania Statewide Residential End-Use and Saturation Study, 2014. Weblink

5) 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. Weblink
Methodology follows Missouri TRM 2017 Volume 2: Commercial and Industrial Measures. page 78. Weblink

6) The default value of 0.92 UEF for electric water heater is from NMR Group for the Pennsylvania Public Utility Commission. (2024, March). 2023 Pennsylvania Statewide Act 129 Residential Baseline Study. Page 128, Table 110. Weblink

7) "Residential End Uses of Water, Version 2." *Water Research Foundation.* (Apr 2016), page 5. Weblink

8) Wilson et al. 2021. End-Use Load Profiles for the U.S. Building Stock: Methodology and Results of Model Calibration, Validation, and Uncertainty Quantification. NREL/TP-5500-80889. Weblink

2.2.6 Air Conditioner & Heat Pump Maintenance

Target Sector	Residential
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

This algorithm is used for the maintenance of ASHP, DHP and CAC measures:

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

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

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

$$\Delta kW_{summer\ peak} = \frac{CAPY_{cool}}{EER2_{base}} \times MF \times CF_{summer}$$

$$\Delta kW_{winter\ peak} = \frac{CAPY_{heat}}{COP_{base}} \times \frac{1}{3.412\frac{BTU}{W \cdot h}} \times MF \times CF_{winter}$$

This algorithm is used for the maintenance of GSHP, PTAC and PTHP measures:

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

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

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

$$\Delta kW_{summer\ peak} = \frac{CAPY_{cool}}{EER_{base}} \times MF \times CF_{summer}$$

$$\Delta kW_{winter\ peak} = \frac{CAPY_{heat}}{COP_{base}} \times \frac{1}{3.412\frac{BTU}{W \cdot h}} \times MF \times CF_{winter}$$

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:

$$SEER = EER_g \times GSER$$

$$EER = EER_g$$

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

$$COP = COP_g$$

PTAC and PTHP

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

DEFINITION OF TERMS

Table 2-28: 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	$kBTU/hr$	EDC Data Gathering	AEPS Application; EDC Data Gathering
$CAPY_{heat}$, The heating capacity of the heat pump being installed	$kBTU/hr$	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	EDC Data Gathering
		Default: See Early Replacement values in Table 2-10	4
$HSPF_{base}$, Heating Seasonal Performance Factor of the Baseline Unit	$\frac{BTU}{W \cdot h}$	EDC Data Gathering	EDC Data Gathering
		Default: See Early Replacement values in Table 2-10	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	EDC Data Gathering
		Default: 16.6	4
EER_{base}, Energy Efficiency Ratio of the Baseline Unit	$\frac{BTU}{W \cdot h}$	EDC Data Gathering	EDC Data Gathering
		Default: See Early Replacement values in Table 2-10	4
COP_g, Coefficient of Performance. This is a measure of the efficiency of a ground source heat pump	*None*	EDC Data Gathering	AEPS Application; EDC Data Gathering

Term	Unit	Value	Sources
		Default: 3.6	4
GSER, Factor used to determine the SEER of a GSHP based on its EER_g	$\frac{BTU}{W \cdot h}$	See Table 2-13	5
GSOP, Factor to convert COP_g to the equivalent COP of an air-source unit to enable comparisons to the baseline unit	*Proportion*	See Table 2-13	5
CF_{summer}, Demand Coincidence Factor during the summer months	*Proportion*	See *CF* in Vol. 1, App. A	3
CF_{winter}, Demand Coincidence Factor during the winter months	*Proportion*	See *CF* in Vol. 1, App. A	3

Note: Where appropriate, nameplate data collected for usage in savings calculations (i.e., SEER, EER, HSPF) should be converted to new efficiency metrics (i.e., SEER2, EER2, HSPF2) using conversion equations laid out in Vol. 1 App. A

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 Electronic Technical Reference Manual. “Refrigerant Charge – Residential” and “Clean Condenser Coils – Residential” listed in the CPUC Support Table “Effective Useful Life and Remaining Useful Life”. Accessed December 2023. Weblink

2) Energy Center of Wisconsin. (2008, May). “Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research”. Weblink

3) Based on the Phase III SWE team’s analysis of regional HVAC runtime data collected from ecobee’s Donate Your Data research service (Weblink) and updated based on the latest CDD and HDD values from NOAA’s 15-year annual climate Normals (2006–2020) (Weblink)

4) NMR Group for the Pennsylvania Public Utility Commission. (2024, March). 2023 Pennsylvania Statewide Act 129 Residential Baseline Study Weblink. Due to small sample size for GSHP in Act 129 2023 Pennsylvania Residential Baseline Study this value is lowest efficiency value from BEopt v3.0.1.0.

5) Factors are derived from the conversion algorithms depicted in the Heat Pump – Water-to-air Ground Source (GSHP) Measure of the Version 11 of the NY TRM Weblink

2.2.7 Room Air Conditioners

Target Sector	Residential
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 exceeding efficiency criteria prescribed by federal standards.

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.

RAC units are rated using a CEER (Combined Energy Efficiency Ratio), which incorporates standby power into the calculation. This will be the value used in the savings algorithm.

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

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

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

Definition of Terms

Table 2-29: Terms, Values, and References

Term	Unit	Value	Sources
CAPY, The cooling capacity of the room air conditioner (RAC) being installed	$\frac{kBTU}{h}$	EDC Data Gathering	EDC Data Gathering
		Default = 7.2	2
CEER_{base} → $CEER_{base}$, Combined Energy Efficiency ratio of the baseline unit	$\frac{BTU}{W \cdot h}$	Federal Standard Values Table 2-30: RAC (without reverse cycle) Federal Minimum CEER Standards**Error! Reference source not found.**, Table 2-31, or Table 2-32**Error! Reference source not found.** Default = 16.0	3
$CEER_{ee}$, Combined Energy efficiency ratio of the RAC being installed	$\frac{BTU}{W \cdot h}$	EDC Data Gathering	EDC Data Gathering

$EFLH_{RAC}$, Equivalent full load hours of the RAC being installed	$\frac{hours}{year}$	See $EFLH_{RAC}$ in Vol. 1, App. A	4
CF_{summer}, Demand Coincidence Factor during the summer months	*Proportion*	See *CF* in Vol. 1, App. A	4

Table 2-30: RAC (without reverse cycle) Federal Minimum CEER Standards**Error! Reference source not found.** lists the minimum federal efficiency standards as of May 2026 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.

Table 2-30: RAC (without reverse cycle) Federal Minimum CEER Standards

Capacity (kBTU/h)	Federal Minimum CEER	
	With Louvered Sides	**Without Louvered Sides**
<6	13.1	12.8
6<8	13.7	
8<11	16.0	14.1
11<14		13.9
14<20		13.7
20<28	13.8	13.8
≥28	13.2	

Table 2-31 lists the minimum federal 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 2-31: Casement-Only and Casement-Slider RAC Federal Minimum CEER Standards

Casement	Federal Minimum CEER
Casement-only	13.9
Casement-slider	15.3

Table 2-32**Error! Reference source not found.** lists the minimum federal efficiency standards for reverse-cycle RAC units.

Table 2-32: Reverse-Cycle RAC Federal Minimum CEER Standards

Capacity (kBTU/h)	Federal Minimum CEER	
	With Louvered Sides	**Without Louvered Sides**
< 14	n/a	13.7
≥ 14		12.8
< 20	14.4	n/a

≥ 20	13.7	

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 Electronic Technical Reference Manual. “Room Air Conditioner, Residential”. Accessed August 2023. Weblink
2) NMR Group for the Pennsylvania Public Utility Commission. (2024, March). 2023 Pennsylvania Statewide Act 129 Residential Baseline Study. Sec 8.2.2 Table 104. Statewide average for all housing types. Weblink
3) Federal code of regulation. Room air conditioners. 10 C.F.R. § 430.32 (b)(2). Weblink
4) Based on the Phase III SWE team’s analysis of regional HVAC runtime data collected from ecobee’s Donate Your Data research service (Weblink) and updated based on the latest CDD and HDD values from NOAA’s 15-year annual climate Normals (2006–2020) (Weblink)

2.2.8 Room AC (RAC) Retirement

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

This measure is defined as retirement and recycling 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

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*.

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

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

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

Replacement and Recycling

For this approach, the efficient RAC 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.

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

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

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

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.

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

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

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

Definition of Terms

Table 2-33: Terms, Values, and References for Room AC Retirement

Term	Unit	Value	Sources
CAPY, Rated cooling capacity (size) of the RAC unit.	$\frac{kBTU}{h}$	EDC Data Gathering	EDC Data Gathering
		Default: 7.2	2
EER$_{RetRAC}$, The Energy Efficiency Ratio of the unit being retired-recycled	$\frac{BTU}{W \cdot h}$	EDC Data Gathering	EDC Data Gathering
		Default: 9.8	2
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	3
CF_{summer}, Demand Coincidence Factor during the summer months	*Proportion*	See *CF* in Vol. 1, App. A	3
EER$_{ee}$, The Energy Efficiency Ratio for an energy efficient RAC	$\frac{BTU}{W \cdot h}$	EDC Data Gathering	EDC Data Gathering
CEER$_{base}$, Combined Energy Efficiency ratio of the baseline unit	$\frac{BTU}{W \cdot h}$	Federal Standard Values in Table 2-30: RAC (without reverse cycle) Federal Minimum CEER Standards**Error! Reference source not found.**, Table 2-31, or Table 2-32**Error! Reference source**	4

		not found. Default = 16.0	
$CEER_{ee}$, Combined Energy efficiency ratio of the RAC being installed	$\frac{BTU}{W \cdot h}$	EDC Data Gathering	EDC Data Gathering

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 Electronic Technical Reference Manual. "Room Air Conditioner, Residential". Accessed August 2023. Weblink

2) NMR Group for the Pennsylvania Public Utility Commission. (2024, March). 2023 Pennsylvania Statewide Act 129 Residential Baseline Study. Sec 8.2.2 Table 104. Statewide average for all housing types. Weblink

3) Based on the Phase III SWE team's analysis of regional HVAC runtime data collected from ecobee's Donate Your Data research service, Weblink and updated based on the latest CDD and HDD values from NOAA's 15-year annual climate Normals (2006–2020) (Weblink)

4) Federal code of regulation. Room air conditioners. 10 C.F.R. § 430.32 (b)(2). Weblink

2.2.9 WINDOW HEAT PUMP

Target Sector	Residential
Measure Unit	Window Heat Pump
Measure Life	9 years[Source 1]
Vintage	Early Replacement

Window heat pumps for single-room applications could provide an energy-and-cost saving alternative to built-in or portable electric resistance heating in the residential market. Window heat pumps are more energy-efficient than resistance heaters because of their ability to extract thermal energy from the environment that is freely available.

ELIGIBILITY

This protocol documents the energy savings attributed to window heat pumps. Eligible equipment must meet direct-install 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)
    a. This baseline is for participants with broken-beyond-repair oil heating systems who are heating their homes with portable electric space heaters.
3) Electric furnace

Cooling savings may be claimed if the window heat pump exceeds efficiency criteria prescribed by federal standards.

ALGORITHMS

The energy savings algorithms depend on three main factors: baseline condition, usage (secondary heating system), and the capacity of the unit.

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

$$\Delta kWh_{heat} = CAPY_{heat} \times \frac{1}{3.412} \times \left(\frac{OF_{heat}}{COP_{base}} - \frac{1}{COP_{ee}}\right) \times EFLH_{heat,HP}.$$

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

$$\Delta kW_{peak\ summer} = CAPY_{cool} \times \left(\frac{1}{CEER_{base}} - \frac{1}{CEER_{ee}}\right) \times CF_{summer}$$

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

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:

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

Definition of Terms

Table 2-34: Terms, Values, and References for Window Heat Pumps

Term	Unit	Value	Sources
$CAPY_{heat}$, The heating capacity of the heat pump being installed	$kBTU/hr$	EDC Data Gathering	AEPS Application; EDC Data Gathering
$CAPY_{cool}$, The cooling capacity of the heat pump being installed	$kBTU/hr$	EDC Data Gathering	AEPS Application; EDC Data Gathering
$CEER_{base}$, Combined Energy Efficiency ratio of the baseline unit	$\frac{BTU}{W \cdot h}$	Federal Standard Values in Table 2-37	2
$CEER_{ee}$, Combined Energy efficiency ratio of the window heat pump (WHP) being installed	$\frac{BTU}{W \cdot h}$	EDC Data Gathering	EDC Data Gathering
COP_{base}, Heating Seasonal Performance Factor of the Baseline Unit	Proportion	EDC Data Gathering	EDC Data Gathering
		Default: Table 2-35	3
COP_{ee}, Heating Seasonal Performance Factor of the unit being installed	Proportion	EDC Data Gathering	AEPS Application; EDC Data Gathering
OF_{heat}, Oversize factor	None	EDC Data Gathering	EDC Data Gathering
		Default: Table 2-36	4
$EFLH_{RAC}$, 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	5
$EFLH_{heat,HP}$, Equivalent Full Load Hours of operation during the heating season for the average unit	$\frac{hours}{yr}$	See Table 2-38	6
CF_{summer}, Demand Coincidence Factor during the summer months	*Proportion*	See *CF* in Vol. 1, App. A	5
CF_{winter}, Demand Coincidence Factor during the winter months	*Proportion*	See *CF* in Vol. 1, App. A	5

Table 2-35: Default Baseline Equipment Efficiency

	Early Replacement
Baseline Equip.	COP_{base}
Elec. Baseboard	1.00
Elec. Furnace	0.95
Space Heaters	1.00

Table 2-36: Oversize Factors for High Efficiency Equipment

	Electric Baseboard	Electric Furnace	Space Heaters
OF_{heat}	1.0	1.0	0.5

Table 2-37: Reverse-Cycle RAC Federal Minimum Efficiency Standards

Capacity (kBTU/h)	Federal Standard CEER, with louvered sides	Federal Standard CEER, without louvered sides
< 14	n/a	13.7
≥ 14		12.8
< 20	14.4	n/a
≥ 20	13.7	

Table 2-38: EFLHheat for Window Heat Pumps

Climate Region	Reference City	$EFLH_{heat,HP}$
C	Allentown	219
A	Binghamton, NY	171
G	Bradford	164
I	Erie	209
E	Harrisburg	238
D	Philadelphia	257
H	Pittsburgh	211
B	Scranton	201
F	Williamsport	208

Default Savings

There are no default savings for this measure.

Evaluation Protocols

For most installations, the appropriate evaluation protocol is to verify installation coupled with assignment of stipulated energy savings. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1) California Electronic Technical Reference Manual. “Room Air Conditioner, Residential”. Accessed March 2024. Weblink
2) Federal code of regulation. Room air conditioners. 10 C.F.R. § 430.32 (b)(2). Weblink

3) Using the relation HSPF=COP×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.

4) Assumptions used to calculate a default value for de facto heating system oversize factor: A 1500W portable electric space heater in use in the home with capacity of $1.5kW \times 3412\frac{BTU}{kW{\cdot}h} = 5{,}118\,BTU/h$, replaced by window heat pump with heating capacity of 10,000 Btu/h, $OF = \frac{5{,}118}{10{,}000} \approx 0.5$.

5) Based on the Phase III SWE team's analysis of regional HVAC runtime data collected from ecobee's Donate Your Data research service (Weblink) and updated based on the latest CDD and HDD values from NOAA's 15-year annual climate Normals (2006–2020) (Weblink)

6) At outdoor air temperatures below 40°F, window heat pumps switch from heat pump heating to electric resistance heating. (Weblink). $EFLH_{heat,HP}$ values are calculated by multiplying Secondary HP $EFLH_{heat}$ values presented in Volume 1 Appendix A by the ratio of annual heating degree hours (base 65°F) during times when outdoor air temperature is between 40°F and 65°F and the annual heating degree hours (base 65°F) during all times when outdoor air temperature is below 65°F.

2.2.10 Duct Sealing & Duct Insulation

Target Sector	Residential
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 (BPI) "Guidance on Estimating Distribution Efficiency",[Source 2] which are summarized in Table 2-40 and Table 2-41 for convenience.
    a. Duct location, including percentage of duct work found within the conditioned space
    b. Duct leakage evaluation. The duct leakage assessment values are based on an assumption of 6.5% of assumed air handler flow (tight); 21% (average); or 35% (leaky).[Source 6]
    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 2-40 that match the duct system, and if the majority of the duct system is in conditioned space add the matching value from Table 2-41, not to exceed 100%.

$$\Delta kWh_{cooling} = \frac{\left(1-\frac{DE_{pre(cool)}}{DE_{post(cool)}}\right) \times EFLH_{cool} \times CAPY_{cool}}{SEER2}$$

$$\Delta kWh_{heating} = \frac{\left(1 - \frac{DE_{pre(heat)}}{DE_{post(heat)}}\right) \times EFLH_{hea} \times CAPY_{heat}}{HSPF2}$$

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

$$\Delta\, kWh/yr_{cooling} = \frac{\left(\frac{\Delta CFM25_{25DB}}{\frac{CAPY_{cool}}{12^{kBTUh}/_{ton}} \times TCFM} \times EFLH_{cool} \times CAPY_{cool}\right)}{SEER2}$$

$$\Delta\, kWh/yr_{heating} = \frac{\left(\frac{\Delta CFM25_{25DB}}{\frac{CAPY_{heat}}{12^{kBTUh}/_{ton}} \times TCFM} \times EFLH_{heat} \times CAPY_{heat}\right)}{HSPF2}$$

Summer Coincident Peak Demand Savings

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

$$\Delta kW_{winter\ peak} = \frac{\Delta kWh_{heating}}{EFLH_{heat}} \times CF_{winter}$$

Definition of Terms

Table 2-39: Terms, Values, and References for Duct Sealing

Term	Unit	Value	Source
CF_{summer}, Demand Coincidence Factor during the summer months	*Proportion*	See *CF* in Vol. 1, App. A	4
CF_{winter}, Demand Coincidence Factor during the winter months	*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

Term	Unit	Value	Source
$CAPY_{heat}$, 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	Conversion factor
SEER2, SEER, Efficiency of cooling equipment	$\frac{BTU}{W \cdot h}$	EDC Data Gathering Default: See Early Replacement values in Table 2-10 in Sec. 2.2.1	5
HSPF2, HSPF, Efficiency of Heating Equipment	*None*	EDC Data Gathering Default: See Early Replacement values in Table 2-10 in Sec. 2.2.1	5
$EFLH_{cool}$, 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 2-40, Table 2-41 Not to exceed 100%	2
DE_{pre}, Distribution efficiency before duct sealing and insulation	*None*	Table 2-40, Table 2-41 Not to exceed 100%	2

Note: Where appropriate, nameplate data collected for usage in savings calculations (i.e., SEER, EER, HSPF) should be converted to new efficiency metrics (i.e., SEER2, EER2, HSPF2) using conversion equations laid out in Vol. 1 App. A

Table 2-40: 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 2-41: 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%	11%	4%	9%	2%	2%	3%	3%	6%	11%	3%	5%
R-2	4%	6%	5%	7%	1%	1%	1%	2%	3%	5%	2%	3%
R-4+	3%	4%	3%	5%	1%	1%	1%	1%	2%	4%	1%	3%
R-8+	3%	3%	2%	3%	1%	1%	1%	1%	2%	2%	1%	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 Electronic Technical Reference Manual. "Duct Sealing". Residential. Accessed August 2023. (Capped at 15 years in accordance with Act 129) Weblink

2) Building Performance Institute. (n.d.). Distribution Efficiency Table. Weblink (Reproduced by permission)

3) Resnet Energy Services Network. (2012, May 12). Standard for Testing Airtightness of Building, Dwelling Unit, and Sleeping Unit Enclosures; Airtightness of Heating and Cooling Air Distribution Systems; and Airflow of Mechanical Ventilation Systems Standards for Performance Testing. Weblink

4) Based on the Phase III SWE team's analysis of regional HVAC runtime data collected from ecobee's Donate Your Data research service. Weblink Updated based on the latest CDD and HDD values from NOAA's 15-year annual climate Normals (2006–2020). Weblink

5) NMR Group for the Pennsylvania Public Utility Commission. (2024, March). 2023 Pennsylvania Statewide Act 129 Residential Baseline Study. Sec 8.1.4 Table 87 and Sec 8.2.1 Table 97 & 98. Baseline findings are capped to current Federal Standards. Weblink (Due to small sample sizes, GSHP is lowest efficiency value from BEopt v2.8.0, and PTAC and PTHP are minimum federal standard efficiencies)

6) Communication with Building Performance Institute.

2.2.11 Air Handler Filter Whistles

Target Sector	Residential
Measure Unit	Filter whistle (to promote regular filter change-out)
Measure Life	5 years[Source 1]
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 2]

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 A/C 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

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

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

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

$$\Delta kW_{summer\ peak} = \Delta kWh_{cool} \div EFLH_{cool} \times CF_{summer}$$

$$\Delta kW_{winter\ peak} = \Delta kWh_{heat} \div EFLH_{heat} \times CF_{winter}$$

Definition of Terms

Table 2-42: Terms, Values, and References for Air Handler Filter Whistle

Term	Unit	Value	Sources
kW_{motor}, Average motor full load electric demand	kW	0.377	3
$EFLH_{heat}$, Estimated Full Load Hours (Heating)	$\frac{hours}{yr}$	See $EFLH_{heat}$ in Vol. 1, App. A	4
$EFLH_{cool}$, Estimated Full Load Hours (Cooling)	$\frac{hours}{yr}$	See $EFLH_{cool}$ in Vol. 1, App. A	4
EI, Efficiency Improvement	%	15%	5, 6
ISR, In-service Rate	%	EDC Data Gathering Default = 7%	7
CF_{summer}, Demand Coincidence Factor during the summer months	*Proportion*	See *CF* in Vol. 1, App. A	4
CF_{winter}, Demand Coincidence Factor during the winter months	*Proportion*	See *CF* in Vol. 1, App. A	4

Default Savings

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

Table 2-43: Default Air Handler Filter Whistle Savings

Climate Region	Reference City	Heating			Cooling	
		ASHP kWh	Furnace kWh	Winter kW	kWh	Summer kW
C	Allentown	4.75	3.27	0.0014	3.01	0.0017
A	Binghamton, NY	6.00	4.63	0.0018	1.53	0.0010
G	Bradford	6.12	4.71	0.0018	1.21	0.0009
I	Erie	5.27	3.74	0.0015	2.48	0.0012
E	Harrisburg	4.53	3.10	0.0013	3.40	0.0017
D	Philadelphia	4.07	2.70	0.0011	3.85	0.0019
H	Pittsburgh	5.00	3.51	0.0014	2.65	0.0015
B	Scranton	5.09	3.59	0.0015	2.58	0.0014
F	Williamsport	5.06	3.60	0.0015	2.62	0.0016

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

2) Your Filter Connection, “What is a Furnace Filter Whistle?”. Accessed December, 2018. Weblink

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

4) Based on the Phase III SWE team’s analysis of regional HVAC runtime data collected from ecobee’s Donate Your Data research service (Weblink) and updated based on the latest CDD and HDD values from NOAA’s 15-year annual climate Normals (2006–2020) (Weblink)

5) 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.

6) 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.

7) Based on the SWE team’s analysis of weighted average of ISRs from surveys of FirstEnergy customers that received air handler filter whistles in kits in PY13 and PY14.

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	9 years[Source 1]
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[Source 2] 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 operating 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 2-44: 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, Default
Thermostat installed by contractor affiliated with EDC program (ICSP or trade ally)	EDC or Participant	Professional	EDC Data Gathering, Default
Thermostat installed by licensed electrical or HVAC contractor - invoice, work order, etc. provided	Participant	Professional	EDC Data Gathering, Default
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

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). A peak demand saving factor (PDSF) is applied to the ESF_{cool} and ESF_{heat} assumptions so the peak demand savings values per thermostat also vary by installation type.

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.

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

$$\Delta kWh_{cool} = CAPY_{cool} \times \frac{EFLH_{cool}}{SEER2 \times Eff_{duct}} \times ESF_{cool}$$

$$\Delta kWh_{heat,HP} = CAPY_{HP} \times \frac{EFLH_{hea\ ,HP}}{HSPF2 \times Eff_{duct}} \times ESF_{heat}$$

$$\Delta kWh_{heat,elecfurrn} = CAPY_{elecfurn} \times \frac{EFLH_{hea\ ,non-}}{HSPF \times Eff_{duct}} \times ESF_{heat} \times DF$$

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

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
Savings from connected thermostats installed in systems with ducted air conditioning and/or heating have been shown to generally follow cooling and/or heating load, however the percent reduction during the system peak hours is expected to be lower than during off-peak hours. The PDSF term reduces the ESF_{cool} and ESF_{heat} values used to calculate energy savings by 50%. Peak demand savings are a function of the system size, efficiency, installation type, and coincidence factor.

$$\Delta kW_{summer\ peak} = \frac{CAPY_{cool}}{EER2 \times Eff_{duct}} \times ESF_{cool} \times PDSF \times CF_{summer}$$

For Heat Pumps:

$$\Delta kW_{winter\ peak} = \frac{\Delta kWh_{heat,HP}}{EFLH_{heat,HP}} \times PDSF \times CF_{winter}$$

For Non-heat Pumps:

$$\Delta kW_{winter\ peak} = \frac{\Delta kWh_{heat,elecfurrn/fuelfurn}}{EFLH_{heat,non-HP}} \times PDSF \times CF_{winter}$$

Definition of Terms

Table 2-45: Residential Electric HVAC Calculation Assumptions

Term	Unit	Value	Sources
$CAPY_{cool}$, Capacity of air conditioning unit	$\frac{kBTU}{h}$	EDC Data Gathering of Nameplate data	EDC Data Gathering
		Default = 31.9 / unit	3
$CAPY_{HP}$, Normal heat capacity of Heat Pump System.	$\frac{kBTU}{h}$	EDC Data Gathering of Nameplate Data	EDC Data Gathering
		Default = 31.9 / unit	3
$CAPY_{elecfurn}$, Normal heat capacity of Electric Furnace systems	$\frac{kBTU}{h}$	EDC Data Gathering of Nameplate data	EDC Data Gathering
		Default 78.1 / unit	3
SEER2, Seasonal Energy Efficiency Ratio	$\frac{BTU}{W \cdot h}$	EDC Data Gathering of Nameplate data	EDC Data Gathering
		Default: see Table 2-10	3

Term	Unit	Value	Sources
EER2, Energy Efficiency Ratio	$\frac{BTU}{W \cdot h}$	EDC Data Gathering of Nameplate data	EDC Data Gathering
		Default: see Table 2-10	3
HSPF2, *HSPF*, Heating Seasonal Performance Factor	$\frac{BTU}{W \cdot h}$	EDC Data Gathering of Nameplate data	EDC Data Gathering
		Default = see Table 2-10	3
Eff_{duct}, Duct System Efficiency	*None*	0.83	4
$EFLH_{cool}$, Equivalent Full Load Hours for Cooling	$\frac{hours}{yr}$	See $EFLH_{cool}$ in Vol. 1, App. A	5
$EFLH_{heat,HP}$, Equivalent Full Load Hours for ASHP Systems	$\frac{hours}{yr}$	See $EFLH_{heat,HP}$ in Vol. 1, App. A	5
$EFLH_{heat,non\text{-}HP}$, Equivalent Full Load Hours for Electric or Gas Furnaces	$\frac{hours}{yr}$	See $EFLH_{heat,non\text{-}HP}$ in Vol. 1, App. A	5
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
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 = 68%	3
$\%_{Manual}$, % central AC systems with a manual thermostat	*None*	EDC Data Gathering	EDC Data Gathering
		Forced Air Default = 32%	3
ESF_{cool}, cooling energy saving factor	*None*	See Table 2-46	Composite of multiple sources
ESF_{heat}, heating energy saving factor	*None*	See Table 2-47	Composite of multiple sources
PDSF, peak demand savings factor relative to ESF_{cool}	*None*	EDC Data Gathering Default = 50%	6
CF_{summer}, Demand Coincidence Factor during the summer months	*Proportion*	See *CF* in Vol. 1, App. A	4

Term	Unit	Value	Sources
CF_{winter}, Demand Coincidence Factor during the winter months	*Proportion*	See *CF* in Vol. 1, App. A	4
DF, Derate Factor for Electric Resistance Heating Systems	*None*	0.85	Professional Judgement

Note: Where appropriate, nameplate data collected for usage in savings calculations (i.e., SEER, EER, HSPF) should be converted to new efficiency metrics (i.e., SEER2, EER2, HSPF2) using conversion equations laid out in Vol. 1 App. A

Table 2-46 and

Table **2-47** 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 2-46: Cooling Energy Savings Factors (ESFcool)

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	7.4%[b]	7.4%[b]
Professional Installation	Manual	11.3%[c]	11.3%[c]
	Conventional Programmable	9.3%[d]	9.3%[d]

[a] *Source 7*

[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, 7.4%=((11.3%×0.32 + 9.3%×0.68) + 4.8%) / 2*

[c] *Average of cooling savings estimates from multiple studies. Sources: 8, 9, 10, 11*

[d] *The ESF values are for programmable thermostats based of DEER 2005's cooling savings for climate zone 16.*

Table 2-47: Heating Energy Savings Factors (ESFheat)

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	7.7%[b]	7.7%[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: 10, 12*

[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, 7.7%=((11.5%×0.32 + 7.9%×0.68) + 6.4%) / 2*

[c] *Average of four heating savings estimates from multiple studies. Sources: 9, 11, 13*

[d] *The ESF value are for programmable thermostats based of DEER 2005's cooling savings for climate zone 16.*

DEFAULT SAVINGS

Table 2-48 through Table 2-50 provide deemed energy savings values by program type, HVAC system type, and baseline thermostat style using statewide average EFLH values. Table 2-51 provides deemed peak demand savings by program type, HVAC system type, and baseline thermostat style using statewide average CF values. If an EDC wishes to calculate default savings specific to their service territory, the climate region weights in Table 1-6 and the EFLH values in Table 1-8 can be used with the algorithms and assumptions in this protocol. The values in Table 1-6 and Table 1-8 are also included in the MS Excel Appendix A calculator (Climate Dependent Values). In an upstream program delivery model, an EDC may not be able to collect the HVAC system type for each participating household. Table 2-52 provides default HVAC system type shares, by EDC, from the Act 129 2023 Pennsylvania Residential Baseline Study which can be used to derive EDC-specific default savings values for upstream program delivery.

Table 2-48: Default Statewide Cooling Savings (kWh/yr)

Program Type	Baseline	ASHP Cooling	CAC Cooling
Upstream buy-down (Customer Self-Installation)	Unknown Mix Default	86	92
Customer Self-Installation with Education	Unknown Mix Default	132	141
Professional Installation	Manual	202	215
	Conventional programmable	166	177

Table 2-49: Default Statewide Heating Savings (kWh/yr)

Program Type	Baseline	ASHP	Electric Furnace	Fossil Fuel Furnace (Fan Only)
Upstream buy-down (Customer Self-Installation)	Unknown Mix Default	440	1,476	44
Customer Self-Installation with Education	Unknown Mix Default	529	1,775	53
Professional Installation	Manual	791	2,651	79
	Conventional programmable	543	1,821	54

Table 2-50: Default Statewide Total Heating and Cooling Savings (kWh/yr)

Program Type	Baseline	ASHP	CAC w/ Electric Furnace	CAC w/ Gas (Fan)
Upstream buy-down (Customer Self-Installation)	Unknown Mix Default	526	1,567	136
Customer Self-Installation with Education	Unknown Mix Default	661	1,916	194
Professional Installation	Manual	992	2,867	295
	Conventional programmable	709	1,999	232

Table 2-51: Default Statewide Peak Demand Savings (kW/yr)

Program Type	Baseline	ASHP		CAC w/ Electric Furnace		CAC w/ Gas Furnace (Fan Only)	
		Summer Peak	Winter Peak	Summer Peak	Winter Peak	Summer Peak	Winter Peak
Upstream buy-down (Customer Self-Installation)	Unknown Mix Default	0.028	0.064	0.030	0.301	0.030	0.009
Customer Self-Installation with Education	Unknown Mix Default	0.044	0.077	0.046	0.362	0.046	0.011
Professional Installation	Manual	0.067	0.116	0.070	0.541	0.070	0.016
	Conventional programmable	0.055	0.079	0.058	0.372	0.058	0.011

Table 2-52: HVAC System Type Shares by EDC for Upstream Program Delivery

EDC	ASHP	CAC w/ Electric Furnace	CAC w/ Gas
PECO	43.75%	0.00%	56.25%
PPL	50.00%	0.00%	50.00%
Duquesne	9.52%	4.76%	85.71%
FE: Met-Ed	19.05%	9.52%	71.43%
FE: Penelec	22.22%	0.00%	77.78%
FE: Penn Power	13.64%	4.55%	81.82%
FE: West Penn	29.41%	0.00%	70.59%

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 choose 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) California Electronic Technical Reference Manual. “Smart Thermostat Residential”. Accessed August 2023. Weblink
2) ENERGY STAR Program Requirements for Connected Thermostat Products V1.0. Weblink
3) NMR Group for the Pennsylvania Public Utility Commission. (2024, March). 2023 Pennsylvania Statewide Act 129 Residential Baseline Study Weblink
4) Better Duct Systems for Home Heating and Cooling, U.S. Department of Energy. Assuming for an improved duct system with insulation levels at R-8 and leakage at 5% of the system fan flow. Weblink
5) Based on the Phase III SWE team’s analysis of regional HVAC runtime data collected from ecobee’s Donate Your Data research service (Weblink) and updated based on the latest CDD and HDD values from NOAA’s 15-year annual climate Normals (2006–2020) (Weblink)
6) Engineering judgement with data referenced from Guidehouse’s econometric analysis in optimizing Connected Thermostats placed in the Illinois Statewide Technical Reference Manual. (2023, version 11.0). Weblink
7) Navigant Consulting, Inc. for the Illinois Stakeholder Advisory Group. (2016). Illinois Smart Thermostat – Annual and Seasonal kWh Savings – Impact Findings
8) EnerNOC for Xcel Energy. (2014). In-Home Smart Devices Pilot Program Impact Evaluation Results, 2012-2013. Weblink
9) The Cadmus Group, Inc. for Vectren Corporation. (2015). Evaluation of the 2013–2014 Programmable and Smart Thermostat Program. Weblink
10) Apex Analytics LLC for Energy Trust of Oregon. (2016). Energy Trust of Oregon Smart Thermostat Pilot Evaluation. Weblink
11) The Cadmus Group, Inc. for The Electric and Gas Program Administrators of Massachusetts. (2012). Wi-Fi Programmable Controllable Thermostat Pilot Program Evaluation. Weblink

12) Navigant Consulting, Inc. for the Illinois Stakeholder Advisory Group. (2015). Residential Smart Thermostats: Impact Analysis – Gas Preliminary Findings.

13) Apex Analytics LLC for Energy Trust of Oregon. (2014). Energy Trust of Oregon Nest Thermostat Heat Pump Control Pilot Evaluation. Weblink

2.2.13 Furnace Maintenance

Target Sector	Residential
Measure Unit	Per Furnace
Measure Life	3 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.

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

Definition of Terms

Table 2-53: 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 $EFLH_{heat,non-HP}$ in Vol. 1, App. A	3
ESF, Energy savings factor	None	2%	4

DEFAULT SAVINGS

Table 2-54:Default Savings per Input kBTU/h for Furnace Maintenance

Climate Region	Reference City	Energy Savings (kWh per 1 input kBTU/h)
C	Allentown	6.22
A	Binghamton, NY	8.82
G	Bradford	8.98
I	Erie	7.13
E	Harrisburg	5.90
D	Philadelphia	5.14
H	Pittsburgh	6.68
B	Scranton	6.84
F	Williamsport	6.85

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) Engineering judgement based off other HVAC Tune up measures.

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 (Weblink) and updated based on the latest CDD and HDD values from NOAA's 15-year annual climate Normals (2006–2020) (Weblink)

4) State of Minnesota, Technical Reference Manual for Energy Conservation Improvement Programs, Version 2.0. Weblink

2.2.14 ENERGY STAR Bathroom Exhaust Fan

Target Sector	Residential
Measure Unit	Exhaust Fan Unit
Measure Life	15 years[Source1]
Vintage	Replace on Burnout, New Construction

This measure is for the purchase and installation of a bathroom exhaust fan meeting ENERGY STAR eligibility criteria. The amount of energy savings depends on whether the fan is used for spot ventilation or for continuous mechanical ventilation due to reduced air-infiltration from a tighter building shell. This measure assumes fan capacities between 10 and 200 CFM rated at a sound level of less than 2.0 sones at 0.1 inches of water column static pressure. When claiming savings associated with continuous operation, eligible installations should be sized to provide the mechanical ventilation rate indicated by ASHRAE 62.2.

Eligibility

This protocol documents the energy savings attributed to purchasing an exhaust-only bathroom ventilation fan meeting ENERGY STAR eligibility criteria instead of a bathroom ventilation fan that does not meet ENERGY STAR criteria. For continuous ventilation, the fan shall be rated for and providing continuous ventilation in accordance with ASHRAE 62.2.[2] ENERGY STAR specifications are provided below.[Source 2]

Table 2-55: ENERGY STAR Eligibility Criteria for Bathroom Exhaust Fans

Fan Capacity (CFM)	Minimum Efficacy (CFM/Watt)	Maximum Sound Level (sones)
10-89	2.8	2.0
90-200	3.5	2.0

Algorithms

The energy savings algorithms are shown below. The key variables affecting the energy savings are the rated size (CFM) and efficiencies.

$$\Delta kWh = \left(CFM \times \frac{\frac{1}{\eta Baseline \frac{CFM}{W}} - \frac{1}{\eta Efficient \frac{CFM}{W}}}{1{,}000} \right) \times Hours$$

$$\Delta kW_{summer\ peak} = \Delta kWh \times ETDF_s$$
$$\Delta kW_{winter\ peak} = \Delta kWh \times ETDF_w$$

[2] ASHRAE 62.2 recommends a minimum of 20 CFM for continuous bathroom ventilation. Weblink

Definition of Terms

Table 2-56: Terms, Values, and References for ENERGY STAR Bathroom Exhaust Fan

Term	Unit	Values	Source
CFM, Fan flow rate	*CFM*	Table 2	3, 4
Hours, Hours of operation	*Hours/year*	Continuous = 8,760 Spot = EDC Data Gathering or 840	5
ηBaseline, Baseline fan efficacy	*CFM/W*	Table 2	4
ηEfficient, Efficient fan efficacy	*CFM/W*	EDC Data Gathering or Table 2	EDC Data Gathering, 3, 4
$ETDF_s$, Summer energy to Demand Factor	$\frac{kW}{kWh}$	Continuous = 0.0001142 Spot = 0.0001113	6
$ETDF_w$, Winter energy to Demand Factor	$\frac{kW}{kWh}$	Continuous = 0.0001142 Spot = 0.0001790	6

Table 2-57: Assumptions for ENERGY STAR Bathroom Exhaust Fan

Usage Profile	CFM Range	CFM	ηBaseline	ηEfficient
Spot	≤89	71.3	1.7	5.3
Spot	90-200	115.9	2.7	5.9
Continuous	n/a	43.8	1.8	9.5

Default Savings

Default savings are as follows, with unknown usage defaulting to spot usage based on fan capacity (CFM):

Table 2-58: Default Bathroom Exhaust Fan Energy Savings

Usage Profile	CFM Range	$\Delta kWh/yr$	$\Delta kW_{summer\ peak}$	$\Delta kW_{winter\ peak}$
Spot or Unknown	≤89	23.9	0.0027	0.0043
Spot or Unknown	90-200	19.6	0.0022	0.0035
Continuous	n/a	172.8	0.0197	0.0197

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) Estimate is based on 25 years for whole-house fans and 19 for thermostatically-controlled attic fans from GDS Associates for The New England State Program Working Group. (2007, June). Residential and Commercial/Industrial Lighting and HVAC Measures. Weblink. Limited to PA Act 129 maximum of 15 years.

2) U.S. EPA. (2015). ENERGY STAR Program Requirements Product Specification for Residential Ventilating Fans Eligibility Criteria Version 4.2. Weblink

3) Guidehouse analysis reviewing average CFM and fan efficacy for ENERGY STAR-rated bathroom ventilation fans at the lowest setting in the 10-200 CFM range. Weblink accessed 2/9/22.

4) Guidehouse analysis reviewing average CFM and fan efficacy for units both eligible and ineligible for ENERGY STAR qualification. Weblink. Accessed 2/9/22.

5) Spot operation hours per year are assumed to coincide with lighting HOU for bathrooms (2.3 hours per day * 365.25 days per year). Statewide Evaluation Team for Pennsylvania Public Utilities Commission (2014, January). 2014 Commercial & Residential Light Metering Study. Weblink

6) Wilson et al. 2021. End-Use Load Profiles for the U.S. Building Stock: Methodology and Results of Model Calibration, Validation, and Uncertainty Quantification. NREL/TP-5500-80889. Weblink

2.3 DOMESTIC HOT WATER

2.3.1 HEAT PUMP WATER HEATERS

Target Sector	Residential
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 consider interactive effects between the water heater and HVAC system when installed inside conditioned space. The energy savings are obtained through the following formula:

$$\Delta kWh = \frac{\left(\frac{1}{UEF_{base}} - \frac{1}{UEF_{ee} \times F_{derate}}\right) \times HW \times 365 \times 8.3 \times (T_{out} - T_{in})}{3412} + \Delta kWh_{ie,cool} - \Delta kWh_{ie,hea}$$

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 2-62 will account for reduced performance due to cooler annual temperatures.
- If installation location is unknown (such as with midstream delivery programs), use the 'Unknown' value for F_{derate} in Table 2-62 and both interactive effects will equal zero.

$$\Delta kWh_{ie,cool} = \frac{HW \times 8.3 \times (T_{out} - T_{in}) \times EFLH_{cool}}{24 \times SEER2 \times 1000}$$

$$\Delta kWh_{ie,heat} = \frac{HW \times 8.3 \times (T_{out} - T_{in}) \times EFLH_{hea}}{24 \times HSPF2 \times 1000}$$

$$\Delta kW_{summer\ peak} = \Delta kWh \times ETDF_s$$

$$\Delta kW_{winter\ peak} = \Delta kWh \times ETDF_w$$

Definition of Terms

Table 2-59: Terms, Values, and References for Heat Pump Water Heater

Term	Unit	Values	Source
UEF_{base}, Uniform Energy Factor of baseline water heater	*Proportion*	See Table 2-61 Default: 0.92 (50 gal., medium draw)	3
UEF_{ee}, Uniform Energy Factor of proposed efficient water heater	*Proportion*	EDC Data Gathering Default Integrated HPWH: 3.30 Default Integrated HPWH, 120 Volt. 15 Amp Circuit: 2.20 Default Split-system HPWH: 2.20	2
F_{derate}, COP De-rating factor	*Proportion*	Table 2-62	9, and discussion below
HW, Hot water used per day in gallons	$\frac{gallons}{day}$	45.5	5
V_r, Rated storage volume of baseline water heater	*gallons*	EDC Data Gathering	EDC Data Gathering
T_{out}, Temperature of hot water	*°F*	119	7
T_{in}, Temperature of cold water supply	*°F*	53	8
$EFLH_{cool}$, Equivalent Full Load Hours for cooling	$\frac{hours}{yr}$	See *EFLH_{cool}* in Vol. 1, App. A	10
$EFLH_{heat}$, Equivalent Full Load Hours for heating	$\frac{hours}{yr}$	See *EFLH_{heat}* in Vol. 1, App. A	10
$HSPF2$, Heating Seasonal Performance Factor of heating equipment	$\frac{BTU}{W \cdot h}$	EDC Data Gathering Default see Table 2-60	6
$SEER2$, Seasonal Energy Efficiency Ratio of cooling equipment	$\frac{BTU}{W \cdot h}$	EDC Data Gathering Default see Table 2-60	6
$ETDF_s$, Summer Energy to Demand Factor	$\frac{kW}{kWh}$	0.0001057	11
$ETDF_w$, Winter Energy to Demand Factor	$\frac{kW}{kWh}$	0.0001761	11

Table 2-60: Default Cooling and Heating System Efficiencies

Type	SEER2	HSPF2
Central Air Conditioner	13.2	N/A
Room Air Conditioner	10.6[a]	N/A
Air-Source Heat Pump	14.1	7.2
Ground-Source Heat Pump	18.5	10.8
Ductless Mini-Split	17.6	8.6
Electric Resistance	N/A	3.412

[a]CEER

Table 2-61: Minimum Baseline Uniform Energy Factors Based on Rated Storage Volume and Draw Pattern

Rated Storage Volume (gallons)	Draw Pattern	UEF Calculation
>=20 gal and <=55 gal	Very Small	$0.8808-(0.0008 \times V_r)$
	Low	$0.9254-(0.0003 \times V_r)$
	Medium	$0.9307-(0.0002 \times V_r)$
	High	$0.9349-(0.0001 \times V_r)$
>55 gal and <=120 gal	Very Small	$1.9236-(0.0011 \times V_r)$
	Low	$2.0440-(0.0011 \times V_r)$
	Medium	$2.1171-(0.0011 \times V_r)$
	High	$2.2418-(0.0011 \times V_r)$

Heat Pump Water Heater UEF De-rating 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. The heat pump performance is temperature and humidity dependent, therefore 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 4] 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) comparable to Pennsylvania. Average temperatures are based on average weather data from weatherbase.com for the climate reference cities referenced elsewhere in this TRM.

Table 2-62: UEF De-rating Factor for Various Installation Locations

Installation Location	F_{derate}
Inside Conditioned Space	0.98
Unconditioned Garage	0.85
Unconditioned Basement	0.72
Unknown[Source 4]	0.87

Default Savings

Default savings for the installation of heat pump water heaters *not located inside conditioned space* or for which *installation location is unknown* are provided below.

Table 2-63: Default Savings for Heat Pump Water Heaters Located in Unconditioned or Unknown Space

Installation Location	Efficient Water Heater Type	ΔkWh	$\Delta kW_{summer\ peak}$	$\Delta kW_{winter\ peak}$
Unconditioned Garage	Integrated HPWH	1,948	0.2058652	0.3429788
	Integrated HPWH, 120 Volt 15 Amp Circuit	1,472	0.1556275	0.2592811
	Split-system HPWH	1,472	0.1556275	0.2592811
Unconditioned Basement	Integrated HPWH	1,776	0.1877238	0.3127546
	Integrated HPWH, 120 Volt 15 Amp Circuit	1,215	0.1284155	0.2139448
	Split-system HPWH	1,215	0.1284155	0.2139448
Unknown	Integrated HPWH	1,969	0.2081750	0.3468270
	Integrated HPWH, 120 Volt 15 Amp Circuit	1,505	0.1590922	0.2650533
	Split-system HPWH	1,505	0.1590922	0.2650533

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) California Electronic Technical Reference Manual. "Heat Pump Water Heater, Residential". Accessed January 2024. Weblink

2) ENERGY STAR (2023). Program Requirements for Residential Water Heaters Version 5.0. U.S. EPA. Weblink

3) 10 CFR 430.32(d). Weblink

4) NEEA. (2019, April) "Residential Building Stock Assessment II: Single-Family Homes Report." Page 73, Table 113. Weblink

5) Water Research Foundation. (2016). Residential End Uses of Water, Version 2. Page 5. Weblink

6) NMR Group for the Pennsylvania Public Utility Commission. (2024, March). 2023 Pennsylvania Statewide Act 129 Residential Baseline Study. Page 115, Table 97, page 120,

Table 103. Weblink. Air source heat pump and ductless mini-split efficiencies calculated using Act 129 2023 Pennsylvania Residential Baseline Study data. Federal minimum efficiencies for GSHP due to small sample size for GSHP in baseline study.

7) Pennsylvania Act 129 2014 Residential Baseline Study. Section 4.6.1, page 60, Table 4-64. Weblink

8) Using Rock Spring, PA (Site 2036) as a proxy, the mean soil temperature at 40-inch depth is 52.502. Calculated using Daily SCAN Standard - Period of Record data from December 2003 to December 2023 from the Natural Resource Conservation Service Database. Weblink. Methodology follows Missouri TRM 2017 Volume 2: Commercial and Industrial Measures. (2017, March). "2.6.1 Water Heater". Page 78. Weblink

9) Fluid Market Strategies for NEEA. (2013, October). NEEA Heat Pump Water Heater Field Study Report. Weblink Values for Fderate are 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). (Note: when this source discusses "ducted" versus "non-ducted" systems it refers to the water heater's heat pump exhaust, not to the HVAC ducts.)

10) Based on the Phase III SWE team's analysis of regional HVAC runtime data collected from ecobee's Donate Your Data research service. Weblink

11) Wilson et al. 2021. End-Use Load Profiles for the U.S. Building Stock: Methodology and Results of Model Calibration, Validation, and Uncertainty Quantification. NREL/TP-5500-80889. Weblink

2.3.2 SOLAR WATER HEATERS

Target Sector	Residential
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 electric 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:

$$\Delta kWh = \frac{\left(\frac{1}{UEF_{base}} - \frac{1}{UEF_{ee}}\right) \times HW \times 365 \times 8.3 \times (T_{out} - T_{in})}{3412}$$

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.

$$\Delta kW_{summer\ peak} = \Delta kWh \times ETDF_s$$

$$\Delta kW_{winter\ peak} = \Delta kWh \times ETDF_w$$

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 2-64: Terms, Values, and References for Solar Water Heater

Term	Unit	Values	Source
UEF_{base}, Uniform Energy Factor of baseline electric water heater	*Proportion*	EDC Data Gathering	EDC Data Gathering
		Default = 0.92	3
UEF_{ee}, Year-round average Uniform 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	4
T_{out}, Temperature of hot water	$°F$	119	5
T_{in}, Temperature of cold water supply	$°F$	53	6
$ETDF_s$, Summer Energy to Demand Factor	$\frac{kW}{kWh}$	0.0001057	7
$ETDF_w$, Winter Energy to Demand Factor	$\frac{kW}{kWh}$	0.0001761	7

Default Savings

Default energy and demand savings are as follows:

ΔkWh = 1880.5 kWh

$\Delta kW_{summer\ peak}$ = 0.1988 kW

$\Delta kW_{winter\ peak}$ = 0.3312 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 Electronic Technical Reference Manual. “Solar Thermal Water Heating System, Residential”. Accessed Jan 2024. Weblink

2) The average energy factor for all solar water heaters with collector areas of 50 ft^2 or smaller is from Weblink

3) Value is mean UEF for standard electric standalone water heaters from Act 129 2023 Pennsylvania Residential Baseline Study, Weblink

4) Water Research Foundation. (2016). Residential End Uses of Water, Version 2. Page 5. Weblink

5) Pennsylvania Act 129 2014 Residential Baseline Study. Section 4.6.1, Page 60, Table 4-64. Weblink

6) Using Rock Spring, PA (Site 2036) as a proxy, the mean soil temperature at 40-inch depth is 52.502. Calculated using Daily SCAN Standard - Period of Record data from December 2003 to December 2023 from the Natural Resource Conservation Service Database. Weblink. Methodology follows Missouri TRM 2017 Volume 2: Commercial and Industrial Measures. (2017, March). “2.6.1 Water Heater”. Page 78. Weblink

7) Wilson et al. 2021. End-Use Load Profiles for the U.S. Building Stock: Methodology and Results of Model Calibration, Validation, and Uncertainty Quantification. NREL/TP-5500-80889. Weblink

2.3.3 Water Heater Tank Wrap

Target Sector	Residential
Measure Unit	Tank
Measure Life	7 years[Source 6]
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.[Source 7]

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.

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

$$\Delta kW_{summer\ peak} = \Delta kWh \times ETDF_s$$

$$\Delta kW_{winter\ peak} = \Delta \mathrm{kWh} \times \mathrm{ETDF_w}$$

Definition of Terms

Table 2-65: Terms, Values, and References for Water Heater Tank Wrap

Term	Unit	Value	Source
HOU, Annual hours of use for water heater tank	$\frac{hours}{year}$	8,760	-
η_{Elec}, Thermal efficiency of electric heater element	*Proportion*	0.98	3
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 2-66	-
A_{insul}, Surface area of storage tank after addition of tank wrap	ft^2	See Table 2-66	-
$T_{setpoint}$, Temperature of hot water in tank	˚F	119	4

Term	Unit	Value	Source
$T_{ambient}$, Temperature of ambient air	$^{\circ}F$	70	5
$ETDF_S$, Summer Energy to Demand Factor	$\frac{kW}{kWh}$	0.0001046	8
$ETDF_W$, Winter Energy to Demand Factor	$\frac{kW}{kWh}$	0.0001755	8

Table 2-66: Default Savings by Water Heater Capacity

Capacity (gal)	R_{base}	R_{insul}	A_{base} (ft^2)	A_{insul} (ft^2)	ΔkWh	$\Delta kW_{summer\ peak}$	$\Delta kW_{winter\ peak}$
30	8	16	19.16	20.94	139.4	0.0145	0.0244
30	10	18	19.16	20.94	96.6	0.0101	0.0170
30	12	20	19.16	20.94	70.6	0.0074	0.0124
30	8	18	19.16	20.94	158.1	0.0165	0.0277
30	10	20	19.16	20.94	111.6	0.0117	0.0196
30	12	22	19.16	20.94	82.8	0.0087	0.0145
40	8	16	23.18	25.31	168.9	0.0177	0.0296
40	10	18	23.18	25.31	117.1	0.0122	0.0205
40	12	20	23.18	25.31	85.5	0.0089	0.0150
40	8	18	23.18	25.31	191.5	0.0200	0.0336
40	10	20	23.18	25.31	135.1	0.0141	0.0237
40	12	22	23.18	25.31	100.3	0.0105	0.0176
50	8	16	24.99	27.06	183.9	0.0192	0.0323
50	10	18	24.99	27.06	127.8	0.0134	0.0224
50	12	20	24.99	27.06	93.6	0.0098	0.0164
50	8	18	24.99	27.06	208.0	0.0218	0.0365
50	10	20	24.99	27.06	147.1	0.0154	0.0258
50	12	22	24.99	27.06	109.4	0.0114	0.0192
80	8	16	31.84	34.14	237.0	0.0248	0.0416
80	10	18	31.84	34.14	165.3	0.0173	0.0290
80	12	20	31.84	34.14	121.5	0.0127	0.0213
80	8	18	31.84	34.14	267.4	0.0280	0.0469
80	10	20	31.84	34.14	189.6	0.0198	0.0333
80	12	22	31.84	34.14	141.4	0.0148	0.0248

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. 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. Weblink

4) Pennsylvania Act 129 2014 Residential Baseline Study. Section 4.6.1, page 60, Table 4-64. Weblink

5) Pennsylvania Act 129 2014 Residential Baseline Study. Section 5.4.4, page 104. Weblink

6) California Electronic Technical Reference Manual. "Water Heater Tank Wrap". Accessed December 2023. Weblink

7) U.S. Department of Energy. (2018). Do-It-Yourself Savings Project: Insulate Water Heater Tank. Weblink

8) Wilson et al. 2021. End-Use Load Profiles for the U.S. Building Stock: Methodology and Results of Model Calibration, Validation, and Uncertainty Quantification. NREL/TP-5500-80889. Weblink

2.3.4 WATER HEATER TEMPERATURE SETBACK

Target Sector	Residential
Measure Unit	Water Heater Temperature
Measure Life	2 years[Source 9]
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:

$$\Delta kWh = \frac{(T_{hot\ i} - T_{hot\ f})}{3412} \times \left(\frac{A_{tank} \times 8760}{R_{tank} \times \eta_{elec}} + \frac{Cycles_{wash} \times V_{HW} \times 8.3}{UEF_{WH}}\right)$$

$$\Delta kW_{summer\ peak} = ETDF_S \times \Delta kWh$$

$$\Delta kW_{winter\ peak} = ETDF_W \times \Delta kWh$$

Definition of Terms

Table 2-67: Terms, Values, and References for Water Heater Temperature Setback

Term	Unit	Values	Source
T_{hot_i}, Temperature setpoint of water heater initially	°F	EDC Data Gathering Default: 130	5
T_{hot_f}, Temperature setpoint of water heater after setback	°F	EDC data collection Default: 119	10
A_{tank}, Surface Area of water heater tank	ft^2	EDC Data Gathering Default: 24.99	50 gal. value in Table 2-66
R_{tank}, R value of water heater tank	$\frac{hr \cdot °F \cdot ft^2}{BTU}$	EDC Data Gathering Default: 12	8
η_{elec}, Thermal efficiency of electric heater element (equiv. to COP for HPWH)	Proportion	Electric Storage: 0.98 HPWH: 3.11	1, 2
$Cycles_{wash}$, Number of clothes washer cycles per year	$\frac{cycles}{yr}$	Clothes washer present: 178 No clothes washer: 0	4
V_{HW}, Volume of hot water used per cycle by clothes washer	$\frac{gallons}{cycle}$	25	3
UEF_{WH}, Uniform Energy Factor of water heater	Proportion	EDC data collection Default: Electric Storage= 0.92 HPWH= 3.20	6
$ETDF_S$, Summer Energy To Demand Factor (defined above)	$\frac{kW}{kWh}$	0.0001057	7
$ETDF_W$, Winter Energy To Demand Factor	$\frac{kW}{kWh}$	0.0001761	7

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 2-68, below.

Table 2-68: Default Energy Savings and Demand Reductions

Type	$Cycles_{wash}$	η_{elec}	UEF_{WH}	ΔkWh	$\Delta kW_{summer\ peak}$	$\Delta kW_{winter\ peak}$
Electric Storage	0	0.98	1.03	60.0	0.0063	0.0106
Electric Storage w/Clothes Washer	200	0.98	1.03	189.9	0.0199	0.0333
HPWH	0	3.11	2.80	18.9	0.0020	0.0033
HPWH w/Clothes Washer	251	3.11	2.80	67.0	0.0070	0.0117

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) AHRI Directory. All electric storage water heaters have a recovery efficiency of 0.98. Weblink
2) If HPWH UEF is known but COP of HPWH compressor is unknown, assume compressor efficiency is UEF/0.9. This yields a default COP of 3.11. Maryland EmPOWER Technical Reference Manual. (2023, version 11.0). "Water Heater Temperature Setback".
3) United States Department of Energy. Reduce Hot Water Use for Energy Savings. Weblink
4) U.S. Department of Energy. (2023). 2020 Residential Energy Consumption Survey. Weblink Calculated using "Frequency of clothes washer use" and "Frequency of dryer use" data for Pennsylvania.
5) Engineering assumption
6) NMR Group for the Pennsylvania Public Utility Commission. (2024, March). 2023 Pennsylvania Statewide Act 129 Residential Baseline Study. Section 8.3.5, page 128, Table 110. Weblink

7) Wilson et al. 2021. End-Use Load Profiles for the U.S. Building Stock: Methodology and Results of Model Calibration, Validation, and Uncertainty Quantification. NREL/TP-5500-80889. Weblink

8) Conservative estimate of R-12

9) Illinois Statewide Technical Reference Manual for Energy Efficiency Version. (2023, version 11.0). "5.4.6 Water Heater Temperature Setback". Weblink

10) Pennsylvania Act 129 2014 Residential Baseline Study. Section 4.6.1, page 60, Table 4-64. Weblink

2.3.5 Water Heater Pipe Insulation

Target Sector	Residential
Measure Unit	Water Heater
Measure Life	11 years[Source 1]
Vintage	Retrofit

This measure relates to the installation of foam insulation on exposed pipe in unconditioned space. The baseline for this measure is a standard efficiency 50 gallon electric water heater (UEF=0.92) with an annual energy usage of 2,939 kWh. See 2.3.1 Heat Pump Water Heaters section for baseline water heater consumption formula and assumptions.

Eligibility

This protocol documents the energy savings for an electric water heater attributable to insulating exposed pipe in unconditioned space to R-3 or above.

Algorithms

The algorithms below calculate the total savings resulting from adding insulation to uninsulated pipes.

$$\Delta kWh = \left(\frac{1}{R_{exist}} - \frac{1}{R_{new}}\right) \times C_{inside} \times L_{effective} \times \left(T_{setpoint} - T_{ambient}\right) \times \frac{1}{\eta_{elec}} \times HOU \times \frac{1}{3412} \times ISR$$

$$L_{effective} = L_{horizontal} + (\alpha \times L_{vertical})$$

$$\Delta kW_{summer\ peak} = \Delta kWh \times ETDF_s$$

$$\Delta kW_{winter\ peak} = \Delta kWh \times ETDF_w$$

Definition of Terms

Table 2-69: Terms, Values, and References for Water Heater Pipe Insulation

Term	Unit	Value	Source
R_{exist}, Pipe heat loss coefficient of existing uninsulated pipe	$\frac{hr \cdot °F \cdot ft^2}{BTU}$	See Table	2
$R_{new} = R_{exist} + R\ value\ of\ new\ insulation$, Pipe heat loss coefficient of new insulated pipe	$\frac{hr \cdot °F \cdot ft^2}{BTU}$	EDC Data Gathering	-
C_{inside}, Inside circumference of pipe	ft	EDC Data Gathering See Table 2-66	7, 8

Term	Unit	Value	Source
$L_{horizontal}$, Length of pipe from water heating source which runs horizontally	ft	EDC Data Gathering	-
$L_{vertical}$, Length of pipe from water heating source which runs horizontally	ft	EDC Data Gathering	-
α, Horizontal to Vertical Adjustment Factor	*None*	See Table 2-70	6
$T_{setpoint}$, Temperature of hot water in tank	°F	119	10
$T_{ambient}$, Temperature of ambient air	˚F	70	3
η_{elec}, Thermal efficiency of electric heater element	*Proportion*	0.98	4
HOU, Annual hours of use for water heater tank	$\frac{hours}{yr}$	8760	-
ISR, In-service rate	%	EDC Data Gathering Direct Install Default: 100%	-
$ETDF_S$, Summer Energy To Demand Factor	$\frac{kW}{kWh}$	0.0001046	5
$ETDF_W$, Winter Energy To Demand Factor	$\frac{kW}{kWh}$	0.0001755	5

Table 2-70: Existing R-Values, Inside Circumference, and Horizontal to Vertical Adjustment Factor of Common Water Pipe Sizes and Materials

Type and Size	R_{exist}	C_{inside}	α
½" Copper Pipe	0.444	0.1427	0.67
¾" Copper Pipe	0.521	0.2055	0.72
½" PEX	0.332	0.1270	0.73
¾" PEX	0.374	0.1783	0.77

Evaluation Protocols

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

Sources

1) California Electronic Technical Reference Manual. "Water Heater Pipe Wrap, Residential". Accessed December 2023. Weblink

2) Illinois Statewide Technical Reference Manual. (2023, version 11.0). "5.4.1 Domestic Hot Water Pipe Insulation". Weblink

3) Pennsylvania Act 129 2014 Residential Baseline Study. Section 5.4.4, page 104. Weblink

4) AHRI Directory. All electric storage water heaters have a recovery efficiency of 0.98. Weblink

5) Wilson et al. 2021. End-Use Load Profiles for the U.S. Building Stock: Methodology and Results of Model Calibration, Validation, and Uncertainty Quantification. NREL/TP-5500-80889. Weblink

6) In cases with zero wind, heat loss (and therefore) savings is larger from horizontal pipe configurations than vertical pipe configurations due, perhaps to the way in which convective losses are handled. Given that most DHW pipe insulation installations begin with a vertical orientation from the water heater, an adjustment to the engineering calculation is needed. An analysis performed by the IL-TRM Technical Advisory Committee of the 3E PLUS tool by NAIMA yielded adjustment factors for horizontal to vertical loss and savings values. Weblink

7) Thomas, Varkie C. Pipe Sizing Charts Tables. Energy Models. Weblink

8) The Engineering Toolbox. (2018). ASTM F876 - PEX Tube – Dimensions. Weblink

9) Cadmus for PPL Electric Utilities. (2022, September). PPL Electric Utilities Annual Report to the Pennsylvania Public Utility Commission Phase IV of Act 129 PY13 Annual Report (June 1, 2021 – May 31, 2022). Appendix I. Evaluation Detail – Energy Efficient Homes Component, page I-6, Table I-5. Weblink

10) Pennsylvania Act 129 2014 Residential Baseline Study. Section 4.6.1, page 60, Table 4-64. Weblink

2.3.6 Low-Flow Faucet Aerators

Target Sector	Residential
Measure Unit	Aerator
Measure Life	10 years Source 1
Vintage	Retrofit, New Construction

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.

Eligibility

This protocol documents the energy savings attributable to low-flow aerators in residential applications. Laminar flow restrictors are also eligible. The maximum flow rate of qualifying equipment is 1.5 gallons per minute. 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:

$$\Delta kWh = \frac{(GPM_{base} - GPM_{low}) \times 8.3 \times (T_{out} - T_{in})}{3412 \times RE} \times \frac{DF \times T_{person-day} \times N_{persons} \times 365}{N_{faucets-home}} \times ISR \times ELEC$$

$$\Delta kW_{summer\ peak} = \Delta kWh \times ETDF_s$$

$$\Delta kW_{winter\ peak} = \Delta kWh \times ETDF_w$$

Definition of Terms

Table 2-71: Low-Flow Faucet Aerator Calculation Assumptions

Term	Unit	Value	Source
GPM_{base}, Average baseline aerator flow rate (GPM)	$\frac{gallons}{minute}$	EDC Data Gathering or Default = 2.2	2
GPM_{low}, Average efficient aerator flow rate (GPM)	$\frac{gallons}{minute}$	EDC Data Gathering	-
T_{out}, Average mixed water temperature flowing from the faucet (ºF)	˚F	Kitchen=93.0 Bathroom=86.0 Unknown= 87.8	5
T_{in}, Average temperature of water entering the house (ºF)	˚F	53	6
RE, Recovery efficiency of electric water heater	*Proportion*	Default: Standard: 0.98 HPWH: 3.93	7

Term	Unit	Value	Source
		Unknown: 1.22	
DF, Percentage of water flowing down drain	%	Kitchen=75% Bathroom=90% Unknown=79.5%	8
$T_{person\text{-}day}$, Average time of hot water usage per person per day (minutes)	$\frac{minutes}{person \cdot day}$	Kitchen=4.5 Bathroom=1.6 Unknown=2.7	3
$N_{persons}$, Average number of persons per household	$\frac{persons}{household}$	Default SF=2.6 Default MF=1.7 Default Unknown=2.4 Or EDC Data Gathering	9
$N_{faucets-home}$, Average number of faucets in the home	$\frac{faucets}{home}$	EDC Data Gathering, Default see Table 2-72	4
ISR, In-Service Rate	%	EDC Data Gathering, Kit Delivery Default: 26% Direct Install Default: 100%	10
$ELEC$, Percentage of homes with electric water heat	%	Default: Unknown=47% Or EDC Data Gathering: Electric = 100% Fossil Fuel = 0%	4
$ETDF_S$, Summer Energy to Demand Factor	$\frac{kW}{kWh}$	SF: 0.0001057 MF: 0.0001006 Unknown: 0.0001046	11
$ETDF_W$, Winter Energy to Demand Factor	$\frac{kW}{kWh}$	SF: 0.0001761 MF: 0.0001733 Unknown: 0.0001755	11

Table 2-72: Average Number of Faucets per Home

Faucet Type	Single-Family	Multifamily	Unknown
Kitchen	1.2	1.1	1.2
Bathroom	2.6	1.4	2.0
Unknown	1.9	1.2	1.7

Evaluation Protocols

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

Sources

1) California Electronic Technical Reference Manual. "Faucet Aerator, Residential". Accessed November 2023. Weblink

2) 10 CFR 430.32(o). Weblink

3) Cadmus and Opinion Dynamics Evaluation Team for Michigan Evaluation Working Group. (2013, June). Showerhead and Faucet Aerator Meter Study. 2.7 min/person/day for unknown aerator location calculated as weighted average of kitchen and bathroom min/person/day by average kitchens and bathrooms per home from the Act 129 2023 Pennsylvania Residential Baseline Study.

4) NMR Group for the Pennsylvania Public Utility Commission. (2024, March). 2023 Pennsylvania Statewide Act 129 Residential Baseline Study. Page 122, Table 105 (ELEC). Page 130, Table 112 ($N_{faucets\text{-}home}$). Weblink Single-family average faucets calculated as weighted average of single-family attached and single-family detached using Act 129 2023 Pennsylvania Residential Baseline Study data.

5) Cadmus and Opinion Dynamics Evaluation Team for Michigan Evaluation Working Group. (2013, June). Showerhead and Faucet Aerator Meter Study. Table 7. 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 × 93 + 3 × 86) / (1 + 3) = 87.8.

6) Using Rock Spring, PA (Site 2036) as a proxy, the mean soil temperature at 40-inch depth is 52.502. Calculated using Daily SCAN Standard - Period of Record data from December 2003 to December 2023 from the Natural Resource Conservation Service Database. Weblink. Methodology follows Missouri TRM 2017 Volume 2: Commercial and Industrial Measures. (2017, March). "2.6.1 Water Heater". Page 78. Weblink

7) AHRI Directory. All electric storage water heaters have a recovery efficiency of 0.98. Average recovery efficiency for heat pump water heaters is 3.93. Accessed December 2023. Weblink 1.22 for unknown type calculated as the weighted average of electric resistance and HPWH recover efficiencies by the relative proportions of electric resistance and HPWHs from the Act 129 2023 Pennsylvania Residential Baseline Study.

8) Illinois Statewide Technical Reference Manual. (2013, version 11.0). "5.4.4 Low Flow Faucet Aerators". Weblink. Faucet usages are at times dictated by volume and 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 assumes that 70% of household water runs through the kitchen faucet and 30% through the bathroom (0.7×0.75+0.3×0.9)=0.795.

9) U.S. Census Bureau, 2017-2021 American Community Survey 5-Year Estimates. Weblink

10) Weighted average of ISRs from surveys of FirstEnergy customers that received aerators in kits in PY13 and PY14.

11) Wilson et al. 2021. End-Use Load Profiles for the U.S. Building Stock: Methodology and Results of Model Calibration, Validation, and Uncertainty Quantification. NREL/TP-5500-80889. Weblink

2.3.7 Low-Flow Showerheads

Target Sector	Residential
Measure Unit	Showerhead
Measure Life	10 years[Source 1]
Vintage	Retrofit, New Construction

This measure relates to the installation of a low-flow (generally 1.5 GPM) showerhead in bathrooms in homes with an 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.

Algorithms

The annual energy savings are obtained through the following formula:

$$\Delta kWh = \frac{(GPM_{base} - GPM_{low}) \times 8.3 \times (T_{out} - T_{in})}{3412 \times RE} \times \frac{T_{person-day} \times N_{persons} \times N_{showers-day} \times 365}{N_{showerheads-hom}} \times ISR \times ELEC$$

$$\Delta kW_{summer\ peak} = \Delta kWh \times ETDF_s$$

$$\Delta kW_{winter\ peak} = \Delta\ kWh \times ETDF_w$$

Definition of Terms

Table 2-73: Terms, Values, and References for Low-Flow Showerhead

Term	Unit	Value	Source
GPM_{base}, Gallons per minute of baseline showerhead	$\frac{gallons}{minute}$	EDC Data Gathering or Default = 2.5	2
GPM_{low}, Gallons per minute of low-flow showerhead	$\frac{gallons}{minute}$	EDC Data Gathering	EDC Data Gathering
T_{out}, Assumed temperature of water used by showerhead	° *F*	101	7
T_{in}, Assumed temperature of water entering house	° *F*	53	8
RE, Recovery efficiency of electric water heater	*Proportion*	Default: Electric resistance: 0.98 HPWH: 3.93 Unknown: 1.22	9
$T_{person-day}$, Average time of shower usage per person (minutes)	$\frac{minutes}{day}$	7.8	3

Term	Unit	Value	Source
$N_{persons}$, Average number of persons per household	$\frac{persons}{household}$	EDC Data Gathering or Default SF=2.6 Default MF=1.7 Default unknown=2.4	4
$N_{showers-day}$, Average number of showers per person per day	$\frac{showers}{person \cdot day}$	0.6	5
$N_{showerheads-home}$, Average number of showers in the home	$\frac{showers}{home}$	EDC Data Gathering or Default SF=1.9 Default MF=1.2 Default unknown = 1.7	6
ISR, In-Service Rate	%	EDC Data Gathering, Kit Default = 21% Direct Install Default = 100%	EDC Data Gathering, 10
$ELEC$, Percentage of homes with electric water heat	%	EDC Data Gathering or Default: Unknown=47% Electric = 100% Fossil Fuel = 0%	6
$ETDF_S$, Summer Energy to Demand Factor	$\frac{kW}{kWh}$	SF: 0.0001057 MF: 0.0001006 Unknown: 0.0001046	11
$ETDF_W$, Winter Energy to Demand Factor	$\frac{kW}{kWh}$	SF: 0.0001761 MF: 0.0001733 Unknown: 0.0001755	11

Evaluation Protocols

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

Sources

1) California Electronic Technical Reference Manual. “Low-Flow Showerheads”. Accessed December 2023. Weblink

2) 10 CFR 430.32(p). Weblink

3) Cadmus and Opinion Dynamics Evaluation Team for Michigan Evaluation Working Group. (2013, June). Showerhead and Faucet Aerator Meter Study. Table 6. 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.

4) U.S. Census Bureau, 2017-2021 American Community Survey 5-Year Estimates. Weblink

5) Cadmus and Opinion Dynamics Evaluation Team for Michigan Evaluation Working Group. (2013, June). Showerhead and Faucet Aerator Meter Study. Table 8. 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, the 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) NMR Group for the Pennsylvania Public Utility Commission. (2024, March). 2023 Pennsylvania Statewide Act 129 Residential Baseline Study. Page 122, Table 105 (ELEC). Page 130, Table 112 ($N_{faucets\text{-}home}$). Weblink

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

8) Using Rock Spring, PA (Site 2036) as a proxy, the mean soil temperature at 40-inch depth is 52.502. Calculated using Daily SCAN Standard - Period of Record data from December 2003 to December 2023 from the Natural Resource Conservation Service Database. Weblink. Methodology follows Missouri TRM 2017 Volume 2: Commercial and Industrial Measures. (2017, March). “2.6.1 Water Heater”. Page 78. Weblink

9) AHRI Directory. All electric storage water heaters have a recovery efficiency of 0.98. Average recovery efficiency for heat pump water heaters is 3.93. Accessed December 2023. Weblink 1.22 for unknown type calculated as the weighted average of electric resistance and HPWH recover efficiencies by the relative proportions of electric resistance and HPWHs from the Act 129 2023 Pennsylvania Residential Baseline Study.

10) Weighted average of ISRs from surveys of FirstEnergy customers that received showerheads in kits in PY13 and PY14.

11) Wilson et al. 2021. End-Use Load Profiles for the U.S. Building Stock: Methodology and Results of Model Calibration, Validation, and Uncertainty Quantification. NREL/TP-5500-80889. Weblink

2.3.8 Thermostatic Shower Restriction Valves

Target Sector	Residential
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. Savings associated with this measure may be combined with a low-flow showerhead as the sum of the savings of the two measures.

Algorithms

The annual energy savings are obtained through the following formula:

$$\Delta kWh = \frac{GPM_{base} \times 8.3 \times (T_{out} - T_{in})}{3412 \times RE} \times \frac{BehavioralWasteSeconds \times (N_{persons} \times N_{showers-da}) \times 365}{60 \times N_{showerheads-home}} \times ISR \times ELEC$$

$$\Delta kW_{summer\ peak} = \Delta kWh \times ETDF_s$$

$$\Delta kW_{winter\ peak} = \Delta\ kWh \times ETDF_w$$

Definition of Terms

Table 2-74: 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: 2.0	5
T_{out}, Assumed temperature of water used by showerhead	$°F$	EDC Data Gathering or Default: 104	6
T_{in}, Assumed temperature of water entering house	$°F$	53	7
RE, Recovery efficiency of electric water heater	*Proportion*	Default: Electric resistance: 0.98 HPWH: 3.93 Unknown: 1.22	8
$BehavioralWasteSeconds$, Time	*sec*	EDC Data Gathering or Default = 59	6

Parameter	Unit	Value	Source
$N_{persons}$, Average number of persons per household	$\frac{persons}{household}$	EDC Data Gathering or Default: SF=2.6 MF=1.7 Unknown=2.4	3
$N_{Showers\text{-}Day}$, Average number of showers per person per day	$\frac{showers}{person \cdot day}$	0.6	4
$N_{showerheads-home}$, Average number of showerhead fixtures in the home	*units*	EDC Data Gathering or Default: SF=1.9 MF=1.2 Unknown = 1.7	5
ISR, In-Service Rate	%	EDC Data Gathering Default, direct install: 100%	EDC Data Gathering
$ELEC$, Percentage of homes with electric water heat	%	EDC Data Gathering or Default: Electric = 100% Fossil Fuel = 0.0% Unknown=47%	5
$ETDF_S$, Summer Energy to Demand Factor	$\frac{kW}{kWh}$	SF: 0.0001057 MF: 0.0001006 Unknown: 0.0001046	9
$ETDF_W$, Winter Energy to Demand Factor	$\frac{kW}{kWh}$	SF: 0.0001761 MF: 0.0001733 Unknown: 0.0001755	9

DEFAULT SAVINGS

Default savings values should only be used for direct install delivery. For other delivery methods, EDCs must estimate and apply an ISR appropriate to the delivery method.

Table 2-75: Default Savings for Thermostatic Restriction Valve

Housing Type	Water Heater Fuel (% electric)	Water Heater Type	ΔkWh	$\Delta kW_{summer\ peak}$	$\Delta kW_{winter\ peak}$
Single Family	100%	Electric Resistance	74.6	0.0079	0.0131
	100%	HPWH	18.6	0.0020	0.0033
	100%	Unknown	59.9	0.0063	0.0106
	47%	Unknown	28.2	0.0030	0.0050
Multifamily	100%	Electric Resistance	77.2	0.0078	0.0134
	100%	HPWH	19.3	0.0019	0.0033
	100%	Unknown	62.0	0.0062	0.0108
	47%	Unknown	29.2	0.0029	0.0051
Unknown	47%	Unknown	29.1	0.0030	0.0051

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: $[10{,}000 \text{ cycles} / (N_{persons} \text{ x } N_{showers\text{-}day} \text{ x } 365)] = [10{,}000 / (2.5 \text{ x } 0.6 \text{ x } 365)] = 18 \text{ years}$. 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) Cadmus and Opinion Dynamics Evaluation Team. Showerhead and Faucet Aerator Meter Study. For Michigan Evaluation Working Group. June 2013.
3) U.S. Census Bureau, 2017-2021 American Community Survey 5-Year Estimates. Weblink
4) 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.
5) NMR Group for the Pennsylvania Public Utility Commission. (2024, March). 2023 Pennsylvania Statewide Act 129 Residential Baseline Study. Page 122, Table 105 (ELEC). Page 130, Table 115 (GPM_{base}, $N_{showerheads\text{-}home}$). Weblink
6) 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).
7) Using Rock Spring, PA (Site 2036) as a proxy, the mean soil temperature at 40-inch depth is 52.502. Calculated using Daily SCAN Standard - Period of Record data from December 2003 to December 2023 from the Natural Resource Conservation Service Database. Weblink. Methodology follows Missouri TRM 2017 Volume 2: Commercial and Industrial Measures. (2017, March). "2.6.1 Water Heater". Page 78. Weblink
8) AHRI Directory. All electric storage water heaters have a recovery efficiency of 0.98. Average recovery efficiency for heat pump water heaters is 3.93. Accessed December 2023. Weblink 1.22 for unknown type calculated as the weighted average of electric resistance and HPWH recover efficiencies by the relative proportions of electric resistance and HPWHs from the Act 129 2023 Pennsylvania Residential Baseline Study.
9) Wilson et al. 2021. End-Use Load Profiles for the U.S. Building Stock: Methodology and Results of Model Calibration, Validation, and Uncertainty Quantification. NREL/TP-5500-80889. Weblink

2.3.9 Drain Water Heat Recovery Units

Target Sector	Residential
Measure Unit	Drain Water Heat Recovery Unit
Measure Life	15 years[Source 1]
Vintage	Retrofit, New Construction

This measure relates to the installation of a vertical drain water heat recovery unit in homes with electric water heaters. Drain water heat recovery units capture waste heat from drain water and use it to preheat cold water that is delivered to the fixture's mixing valve, the water heater, or both. Savings are calculated per drain water heat recovery unit.

Eligibility

This protocol documents the energy savings attributable to installing a vertical drain water heat recovery unit to a drainpipe. The target sector primarily consists of residences.

Algorithms

The algorithms for annual energy savings and peak demand savings are shown below:

$$\Delta kWh = \frac{(T_{out} - T_{in}) \times 8.3 \times GPHD \times 365 \times SF}{3412 \times RE}$$

$$\Delta kW_{summer\ peak} = \Delta kWh \times ETDF_S$$

$$\Delta kW_{winter\ peak} = \Delta kWh \times ETDF_W$$

Definition of Terms

Table 2-76: Terms, Values, and References for Drain Water Heat Recovery Units

Term	Unit	Value	Source
T_{out}, Assumed temperature of water used by showerhead	$°F$	101	2
T_{in}, Assumed temperature of water entering house	$°F$	53	3
$GPHD$, Gallons of hot water use per household per day	$\frac{gallons}{day}$	Shower only: 17.8 Whole house: 45.5	4
SF, Water heating energy savings factor	%	30%	5
RE, Recovery efficiency of electric water heater	*Proportion*	Default: Resistance: 0.98 HPWH: 3.93 Unknown: 1.22	6
$ETDF_S$, Summer Energy to Demand Factor	$\frac{kW}{kWh}$	SF: 0.0001057 MF: 0.0001006 Unknown: 0.0001046	7
$ETDF_W$, Winter Energy to Demand Factor	$\frac{kW}{kWh}$	SF: 0.0001761 MF: 0.0001733 Unknown: 0.0001755	7

Default Savings

Table 2-77: Default Savings for Drain Water Heat Recovery Unit

Housing Type	Water Heater Type	Shower Only			Whole House		
		Energy Savings (kWh)	Peak Demand Savings (kW)		Energy Savings (kWh)	Peak Demand Savings (kW)	
			Summer	Winter		Summer	Winter
Single Family	Resistance	232.2	0.0245	0.0409	593.6	0.0627	0.1045
	HPWH	57.9	0.0061	0.0102	148.0	0.0156	0.0261
	Unknown Electric	186.5	0.0197	0.0329	476.8	0.0504	0.0840
Multifamily	Resistance	232.2	0.0234	0.0402	593.6	0.0597	0.1029
	HPWH	57.9	0.0058	0.0100	148.0	0.0149	0.0257
	Unknown Electric	186.5	0.0188	0.0323	476.8	0.0480	0.0826
Unknown	Resistance	232.2	0.0243	0.0408	593.6	0.0621	0.1042
	HPWH	57.9	0.0061	0.0102	148.0	0.0155	0.0260
	Unknown Electric	186.5	0.0195	0.0327	476.8	0.0499	0.0837

Evaluation Protocols

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

Sources

1) Sachs, H., Talbot J., Kaufman N. (2012, February) "Emerging Hot Water Technologies and Practices for Energy Efficiency as of 2011". Page 69. ACEEE. Weblink. Note that measure life is defined as 30 years; however, PA Act 129 Legislation caps measure life at 15 years.
2) Cadmus and Opinion Dynamics for Michigan Evaluation Working Group. (2013, June). Showerhead and Faucet Aerator Meter Study Memorandum. Temperature sensors provided the mixed water temperature readings resulting in an average of 101ºF.
3) Using Rock Spring, PA (Site 2036) as a proxy, the mean soil temperature at 40-inch depth is 52.502. Calculated using Daily SCAN Standard - Period of Record data from December 2003 to December 2023 from the Natural Resource Conservation Service Database. Weblink.
4) DeOreo, W., Mayer, P., Dziegielewski, B., Kiever, J. for Water Research Foundation. (2016, April). "Residential End Uses of Water, Version 2 Executive Report." Page 5, Table 1. Weblink
5) Heat Recovery from Wastewater Using a Gravity-Film Heat Exchanger, Department of Energy Federal Energy Management Program. U.S. DOE Federal Energy Management Program report DOE/EE-0247 Revised. July, 2005. Lower end of 30 – 50% range estimated

for different devices and installation configurations (equal, unequal to water heater, and unequal to shower). Weblink

6) AHRI Directory. All electric storage water heaters have a recovery efficiency of 0.98. Average recovery efficiency for heat pump water heaters is 3.93. Accessed December 2023. Weblink 1.22 for unknown type calculated as the weighted average of electric resistance and HPWH recover efficiencies by the relative proportions of electric resistance and HPWHs from the Act 129 2023 Pennsylvania Residential Baseline Study.

7) Wilson et al. 2021. End-Use Load Profiles for the U.S. Building Stock: Methodology and Results of Model Calibration, Validation, and Uncertainty Quantification. NREL/TP-5500-80889. Weblink

2.3.10 Smart Water Heater Controls

Target Sector	Residential
Measure Unit	Water Heater Controller
Measure Life	11 years[Source 1]
Vintage	Replace on Burnout, New Construction

Smart water heater controls prevent the unnecessary heating of water. They use analytics to learn household water use patterns and heat water only at times of anticipated need. Smart controllers also have a user interface to allow manual control settings (i.e., scheduling) and help customers understand and act on water heating energy usage. The controllers reduce unnecessary reheat during periods of low demand while the water heater idles and the temperature drifts within an acceptable range.

Smart Water Heater Controls add a web-enabled control box that functions as a junction box to an electric tank's power source, so it turns on/off the power to the tank per the control algorithm or customer commands. Smart Water Heater Controls will have functions that are located in the home and on the Internet (the cloud). Homes with Wi-Fi can enable full operating capabilities or utilize a cellular option. While compatible with the device, gas water heaters are not eligible for savings for this measure.

Eligibility

This measure documents the energy savings resulting from Smart Water Heater Control with professional installation with electric resistance or heat pump storage water heaters. 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 term in the parentheses corresponds to tank loss savings.

$$\Delta kWh = \frac{\Delta T}{3412} \times \left(\frac{A_{tank} \times 8760}{R_{tank} \times \eta_{elec}} + \frac{Cycles_{wash} \times V_{HW} \times 8.3}{UEF_{WH}}\right)$$

Clothes washers will draw the same amount of water for a load regardless of temperature, where, for example, with a shower, the user will just adjust the valve to get their desired temperature if the incoming hot water is cooler. Therefore, there are extra savings for clothes washers, but not other uses.

Demand savings result from reduced hours of operation of the heating element, rather than a reduced connected load.

$$\Delta kW_{summer\ peak} = ETDFs \times \Delta kWh$$
$$\Delta kW_{winter\ peak} = ETDFw \times \Delta kWh$$

Alternatively, if an EDC configures the smart water heater to reduce demand savings by avoiding reheat during the peak demand period, peak demand savings will be calculated using the telemetry data from the devices via a SWE-approved estimation method.

Definition of Terms

Table 2-78: Terms, Values, and References for Smart Water Heater Controls

Term	Unit	Values	Source
ΔT, change in the average hot water weekly temperature draw using the smart water heater control compared to the baseline water heater	°F	5.4	8
R_{tank}, R value of water heater tank	$\frac{hr \cdot °F \cdot ft^2}{BTU}$	EDC Data Gathering Default: 12	3
A_{tank}, Surface Area of water heater tank	ft^2	EDC Data Gathering Default: 24.99	50 gal. value in Table 2-66
η_{elec}, Thermal efficiency of electric heater element	*Proportion*	Electric Storage: 0.98 HPWH: 3.11	4; 5
V_{HW}, Volume of hot water used per cycle by clothes washer	$\frac{gallons}{cycle}$	20	6
$Cycles_{wash}$, Number of clothes washer cycles per year	$\frac{cycles}{yr}$	Clothes washer present: 178 No clothes washer: 0	7
UEF_{WH}, Uniform Energy Factor of water heater	*Proportion*	EDC data collection Default: Electric Storage= 0.92 HPWH= 3.20	2
$ETDFs$, Energy To Demand Factor (summer, defined above)	$\frac{kW}{kWh}$	0.0001046	9
$ETDFw$, Energy To Demand Factor (winter, defined above)	$\frac{kW}{kWh}$	0.0001755	9

DEFAULT SAVINGS

The energy savings and demand reductions are prescriptive according to the above formula.

Table 2-79: Default Energy Savings and Demand Reductions

Type	ΔkWh	$\Delta kW_{summer\ peak}$	$\Delta kW_{winter\ peak}$
Electric Storage	29.46	0.00308	0.00517
Electric Storage w/ Clothes Washer	47.65	0.00498	0.00836
HPWH	9.28	0.00097	0.00163
HPWH w/ Clothes Washer	23.90	0.00250	0.00419

SOURCES

1) California Electronic Technical Reference Manual. “Storage Water Heater, Residential”. Accessed March 2024. Weblink

2) NMR Group for the Pennsylvania Public Utility Commission. (2024, March). 2023 Pennsylvania Statewide Act 129 Residential Baseline Study. Section 8.3.5, page 128, Table 110. Weblink

3) Conservative estimate of R-12

4) AHRI Directory. All electric storage water heaters have a recovery efficiency of .98. Weblink

5) If HPWH UEF is known but COP of HPWH compressor is unknown, assume compressor efficiency is UEF/0.9. This yields a default COP of 3.11. Maryland EmPOWER Technical Reference Manual. (2023, version 11.0). “Water Heater Temperature Setback”.

6) ENERGY STAR. Clothes Washers. Accessed March 2024. Weblink

7) U.S. Energy Information Administration. (2023). 2020 Residential Energy Consumption Survey. Weblink. Calculated using “Frequency of clothes washer use” and “Frequency of dryer use” data for Pennsylvania.

8) Gunn, K., Kalensky, D., Schoenbauer, B., Haynor, A. (2018, April). “Field Study of an Intelligent, Networked, Retrofittable Water Heater Controller”. Page 44. Gas Technology Institute for Minnesota Department of Commerce, Division of Energy Resources. Weblink

9) Wilson et al. 2021. End-Use Load Profiles for the U.S. Building Stock: Methodology and Results of Model Calibration, Validation, and Uncertainty Quantification. NREL/TP-5500-80889. Weblink

2.4 Appliances

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.[3]

2.4.1 ENERGY STAR Refrigerators

Target Sector	Residential
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% more efficient than the minimum federal government standard. The ENERGY STAR Most Efficient is a certification that identifies the most efficient products among those that qualify for ENERGY STAR. ENERGY STAR Most Efficient refrigerators must be at least 15% 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. If the volume and configuration of the refrigerator is known, the baseline model's annual energy consumption (kWh_{base}) may be determined using Table 2-81-81. 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 efficient model's annual energy consumption may be determined using Table 2-81-81.

ENERGY STAR Refrigerator

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

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

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

ENERGY STAR Most Efficient Refrigerator

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

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

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

[3] 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 2-80: 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 2-81	EDC Data Gathering, 2, 7
kWh_{ee}, Annual energy consumption of ENERGY STAR qualified unit	*kWh/yr*	EDC Data Gathering Default = Table 2-83	EDC Data Gathering, 3
kWh_{me}, Annual energy consumption of ENERGY STAR Most Efficient qualified unit	*kWh/yr*	EDC Data Gathering Default = Table 2-83	EDC Data Gathering, 4
$ETDF_s$, Summer peak Energy to Demand Factor	$\frac{kW}{kWh}$	0.0001354	5
$ETDF_w$, Winter peak Energy to Demand Factor	$\frac{kW}{kWh}$	0.0001014	5

Refrigerator energy use is characterized by configuration (top freezer, bottom freezer, etc.), volume, whether defrost is manual or automatic, and whether there is an automatic icemaker, 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 2-81-81. 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 2-82 for ENERGY STAR and ENERGY STAR Most Efficient maximum energy usage 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:

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

I = 1 for a product with an automatic icemaker and 0 for a product without an automatic icemaker. See Table 2-82 for door coefficients.

Table 2-81: Federal Standard Maximum Annual Energy Consumption[4]

Refrigerator Category	9/15/14 - 1/30/29	1/31/29 - 1/30/30	As of 1/31/30
1. Refrigerator-freezers and refrigerators other than all-refrigerators with manual defrost.	7.99 × AV + 225.0		6.79 x AV + 191.3

[4] 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	9/15/14 - 1/30/29	1/31/29 - 1/30/30	As of 1/31/30
1A. All-refrigerators—manual defrost.	6.79 × AV + 193.6		5.77AV + 164.6
2. Refrigerator-freezers—partial automatic defrost	7.99 × AV + 225.0		(6.79 x AV + 191.3) × K2
3. Refrigerator-freezers—automatic defrost with top-mounted freezer without an automatic icemaker.	8.07 × AV + 233.7		6.86 x AV + 198.6 + 28I
3-BI. Built-in refrigerator-freezer—automatic defrost with top-mounted freezer without an automatic icemaker.	9.15 × AV + 264.9	8.24 x AV + 238.4 + 28I	
3I. Refrigerator-freezers—automatic defrost with top-mounted freezer with an automatic icemaker without through-the-door ice service.	8.07 × AV + 317.7		
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		
3A. All-refrigerators—automatic defrost.	7.07 × AV + 201.6		(6.01 x AV + 171.4) × K3A
3A-BI. Built-in All-refrigerators—automatic defrost.	8.02 × AV + 228.5	(7.22 x AV + 205.7) x K3ABI	
4. Refrigerator-freezers—automatic defrost with side-mounted freezer without an automatic icemaker.	8.51 × AV + 297.8		(7.28 x AV + 254.9) × K4 + 28I
4-BI. Built-In Refrigerator-freezers—automatic defrost with side-mounted freezer without an automatic icemaker.	10.22 × AV + 357.4	(8.79 x AV + 307.4) × K4BI + 28I	
4I. Refrigerator-freezers—automatic defrost with side-	8.51 × AV + 381.8		

Refrigerator Category	9/15/14 - 1/30/29	1/31/29 - 1/30/30	As of 1/31/30
mounted freezer with an automatic icemaker without through-the-door ice service.			
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		
5. Refrigerator-freezers—automatic defrost with bottom-mounted freezer without an automatic icemaker.	8.85 × AV + 317.0		(7.61 x AV + 272.6) × K5 + 28I
5-BI. Built-In Refrigerator-freezers—automatic defrost with bottom-mounted freezer without an automatic icemaker.	9.40 × AV + 336.9	(8.65 x AV + 309.9) × K5BI + 28I	
5I. Refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker without through-the-door ice service.	8.85 × AV + 401.0		
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		
5A. Refrigerator-freezer—automatic defrost with bottom-mounted freezer with through-the-door ice service.	9.25 × AV + 475.4	(7.76 x AV + 351.9) × K5A	
5A-BI. Built-in refrigerator-freezer—automatic defrost with bottom-mounted freezer with through-the-door ice service.	9.83 × AV + 499.9	(8.21 x AV + 370.7) × K5ABI	

Refrigerator Category	9/15/14 - 1/30/29	1/31/29 - 1/30/30	As of 1/31/30
6. Refrigerator-freezers—automatic defrost with top-mounted freezer with through-the-door ice service.	8.40 × AV + 385.4		7.14 x AV + 280.0
7. Refrigerator-freezers—automatic defrost with side-mounted freezer with through-the-door ice service.	8.54 × AV + 432.8		(7.31 x AV + 322.5) × K7
7-BI. Built-In Refrigerator-freezers—automatic defrost with side-mounted freezer with through-the-door ice service.	10.25 × AV + 502.6	(8.82 x AV + 384.1) × K7BI	
11. Compact refrigerator-freezers and refrigerators other than all-refrigerators with manual defrost.	9.03 × AV + 252.3	7.68 × AV + 214.5	
11A.Compact all-refrigerators—manual defrost.	7.84 × AV + 219.1	6.66 × AV + 186.2	
12. Compact refrigerator-freezers—partial automatic defrost	5.91 × AV + 335.8	(5.32 × AV + 302.2) × K12	
13. Compact refrigerator-freezers—automatic defrost with top-mounted freezer.	11.80 × AV + 339.2	10.62 × AV + 305.3 + 28I	
13I. Compact refrigerator-freezers—automatic defrost with top-mounted freezer with an automatic icemaker.	11.80 × AV + 423.2		
13A. Compact all-refrigerators—automatic defrost.	9.17 × AV + 259.3	(8.25 × AV + 233.4) × K13A	
14. Compact refrigerator-freezers—automatic defrost with side-mounted freezer.	6.82 × AV + 456.9	6.14 × AV + 411.2 + 28I	
14I. Compact refrigerator-freezers—automatic defrost with side-mounted freezer	6.82 × AV + 540.9		

Refrigerator Category	9/15/14 - 1/30/29	1/31/29 - 1/30/30	As of 1/31/30
with an automatic icemaker.			
15. Compact refrigerator-freezers—automatic defrost with bottom-mounted freezer.	11.80 × AV + 339.2	10.62 × AV + 305.3 + 28I	
15I. Compact refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker.	11.80 × AV + 423.2		

Table 2-82: Door Coefficients for Federal Standard Energy Consumption Algorithms

Door Coefficient	Products with a Transparent Door	Products without a Transparent Door with a Door-in-Door	Products without a Transparent Door or Door-in-Door with Added External Doors
K2	1.0	1.0	1 + 0.02 x (N_d[5] – 1)
K3A	1.1	1.0	1.0
K3ABI	1.1	1.0	1.0
K4	1.1	1.06	1 + 0.02 x (N_d – 2)
K4BI	1.1	1.06	1 + 0.02 x (N_d – 2)
K5	1.1	1.06	1 + 0.02 x (N_d – 2)
K5BI	1.1	1.06	1 + 0.02 x (N_d – 2)
K5A	1.1	1.06	1 + 0.02 x (N_d – 3)
K5ABI	1.1	1.06	1 + 0.02 x (N_d – 3)
K7	1.1	1.06	1 + 0.02 x (N_d – 2)
K7BI	1.1	1.06	1 + 0.02 x (N_d – 2)
K12	1.0	1.0	1 + 0.02 x (N_d – 1)
K13A	1.1	1.0	1.0

Table 2-83: ENERGY STAR and ENERGY STAR Most Efficient Maximum Annual Energy Consumption

Refrigerator Category	ENERGY STAR Maximum Energy Usage in kWh/yr	ENERGY STAR Most Efficient Maximum Energy Usage in kWh/yr
1. Refrigerator-freezers and refrigerators other than all-	7.19 × AV + 202.5	AV ≤ 81.1, AEC_{MAX}[6] ≤ 5.83 × AV + 164.3 AV > 81.1, AEC_{MAX} ≤ 637

[5] N_d is the number of external doors. The maximum N_d values are 2 for K12 and K2, 3 for K9BI, and 5 for all other K values.
[6] Maximum annual energy consumption.

Refrigerator Category	ENERGY STAR Maximum Energy Usage in kWh/yr	ENERGY STAR Most Efficient Maximum Energy Usage in kWh/yr
refrigerators with manual defrost		
1A. All-refrigerators—manual defrost	6.11 × AV + 174.2	
2. Refrigerator-freezers—partial automatic defrost	7.19 × AV + 202.5	AV ≤ 81.1, AEC_{MAX} ≤ 5.83 × AV + 164.3 AV > 81.1, AEC_{MAX} ≤ 637
3. Refrigerator-freezers—automatic defrost with top-mounted freezer without an automatic icemaker	7.26 × AV + 210.3	
3–BI. Built-in refrigerator-freezer—automatic defrost with top-mounted freezer without an automatic icemaker	8.24 × AV + 238.4	
3I. Refrigerator-freezers—automatic defrost with top-mounted freezer with an automatic icemaker without through-the-door ice service	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	8.24 × AV + 322.4	
3A. All-refrigerators—automatic defrost	6.36 × AV + 181.4	
3A–BI. Built-in All-refrigerators—automatic defrost	7.22 × AV + 205.7	
4. Refrigerator-freezers—automatic defrost with side-mounted freezer without an automatic icemaker	7.66 × AV + 268.0	AV ≤ 67.6, AEC_{MAX} ≤ 6.21 × AV + 217.4 AV > 67.6, AEC_{MAX} ≤ 637

Refrigerator Category	ENERGY STAR Maximum Energy Usage in kWh/yr	ENERGY STAR Most Efficient Maximum Energy Usage in kWh/yr
4–BI. Built-In Refrigerator-freezers—automatic defrost with side-mounted freezer without an automatic icemaker	9.20 × AV + 321.7	AV ≤ 67.6, AEC_{MAX} ≤ 6.21 × AV + 217.4 AV > 67.6, AEC_{MAX} ≤ 637
4I. Refrigerator-freezers—automatic defrost with side-mounted freezer with an automatic icemaker without through-the-door ice service	7.66 × AV + 352.0	AV ≤ 54.0, AEC_{MAX} ≤ 6.21 × AV + 301.4 AV > 54.0, AEC_{MAX} ≤ 637
4I–BI. Built-In Refrigerator-freezers—automatic defrost with side-mounted freezer with an automatic icemaker without through-the-door ice service	9.20 × AV + 405.7	AV ≤ 54.0, AEC_{MAX} ≤ 6.21 × AV + 301.4 AV > 54.0, AEC_{MAX} ≤ 637
5. Refrigerator-freezers—automatic defrost with bottom-mounted freezer without an automatic icemaker	7.97 × AV + 285.3	AV ≤ 62.8, AEC_{MAX} ≤ 6.46 × AV + 231.4 AV > 62.8, AEC_{MAX} ≤ 637
5–BI. Built-In Refrigerator-freezers—automatic defrost with bottom-mounted freezer without an automatic icemaker	8.46 × AV + 303.2	AV ≤ 62.8, AEC_{MAX} ≤ 6.46 × AV + 231.4 AV > 62.8, AEC_{MAX} ≤ 637
5I. Refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker without through-the-door ice service	7.97 × AV + 369.3	AV ≤ 49.8, AEC_{MAX} ≤ 6.46 × AV + 315.4 AV > 49.8, AEC_{MAX} ≤ 637
5I–BI. Built-In Refrigerator-freezers—automatic defrost with bottom-mounted freezer	8.46 × AV + 387.2	AV ≤ 49.8, AEC_{MAX} ≤ 6.46 × AV + 315.4 AV > 49.8, AEC_{MAX} ≤ 637

Refrigerator Category	ENERGY STAR Maximum Energy Usage in kWh/yr	ENERGY STAR Most Efficient Maximum Energy Usage in kWh/yr
with an automatic icemaker without through-the-door ice service		
5A. Refrigerator-freezer—automatic defrost with bottom-mounted freezer with through-the-door ice service	$8.33 \times AV + 436.3$	$AV \le 39.6$, $AEC_{MAX} \le 6.75 \times AV + 369.7$ $AV > 39.6$, $AEC_{MAX} \le 637$
5A–BI. Built-in refrigerator-freezer—automatic defrost with bottom-mounted freezer with through-the-door ice service	$8.85 \times AV + 458.3$	$AV \le 39.6$, $AEC_{MAX} \le 6.75 \times AV + 369.7$ $AV > 39.6$, $AEC_{MAX} \le 637$
6. Refrigerator-freezers—automatic defrost with top-mounted freezer with through-the-door ice service	$7.56 \times AV + 355.3$	
7. Refrigerator-freezers—automatic defrost with side-mounted freezer with through-the-door ice service	$7.69 \times AV + 397.9$	$AV \le 47.9$, $AEC_{MAX} \le 6.23 \times AV + 338.6$ $AV > 47.9$, $AEC_{MAX} \le 637$
7–BI. Built-In Refrigerator-freezers—automatic defrost with side-mounted freezer with through-the-door ice service	$9.23 \times AV + 460.7$	$AV \le 47.9$, $AEC_{MAX} \le 6.23 \times AV + 338.6$ $AV > 47.9$, $AEC_{MAX} \le 637$
11. Compact refrigerator-freezers and refrigerators other than all-refrigerators with manual defrost	$8.13 \times AV + 227.1$	$AEC_{MAX} \le 6.32 \times AV + 176.6$
11A.Compact all-refrigerators—manual defrost	$7.06 \times AV + 197.2$	$AEC_{MAX} \le 5.49 \times AV + 153.4$
12. Compact refrigerator-	$5.32 \times AV + 302.2$	$AEC_{MAX} \le 4.14 \times AV + 235.1$

Refrigerator Category	ENERGY STAR Maximum Energy Usage in kWh/yr	ENERGY STAR Most Efficient Maximum Energy Usage in kWh/yr
freezers—partial automatic defrost		
13. Compact refrigerator-freezers—automatic defrost with top-mounted freezer	10.62 × AV + 305.3	AEC_{MAX} ≤ 8.26 × AV + 237.4
13I. Compact refrigerator-freezers—automatic defrost with top-mounted freezer with an automatic icemaker	10.62 × AV + 389.3	AEC_{MAX} ≤ 8.26 × AV + 321.4
13A. Compact all-refrigerators—automatic defrost	8.25 × AV + 233.4	AEC_{MAX} ≤ 6.42 × AV + 181.5
14. Compact refrigerator-freezers—automatic defrost with side-mounted freezer	6.14 × AV + 411.2	AEC_{MAX} ≤ 4.77 × AV + 319.8
14I. Compact refrigerator-freezers—automatic defrost with side-mounted freezer with an automatic icemaker	6.14 × AV + 495.2	AEC_{MAX} ≤ 4.77 × AV + 403.8
15. Compact refrigerator-freezers—automatic defrost with bottom-mounted freezer	10.62 × AV + 305.3	AEC_{MAX} ≤ 8.26 × AV + 237.4
15I. Compact refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker	10.62 × AV + 389.3	AEC_{MAX} ≤ 8.26 × AV + 321.4

Default Savings

Table 2-84 displays the default savings for prevalent configurations of ENERGY STAR refrigerators. Default savings assume no special doors (i.e. door coefficient=1). Note that there are zero default savings for ENERGY STAR refrigerator categories 3I, 5I, 5A after 1/30/29, and there are zero default savings for ENERGY STAR refrigerator categories 3, 5, and 7 after 1/30/30. Table

2-85 displays the default savings for prevalent configurations of ENERGY STAR Most Efficient refrigerators.

Table 2-84: Default Savings Values for ENERGY STAR Refrigerators

Refrigerator Category	Assumed Adjusted Volume of Unit (cubic feet)Source 6	Time Period	ΔkWh/yr	$\Delta kW_{summer\ peak}$	$\Delta kW_{winter\ peak}$
3. Refrigerator-freezers—automatic defrost with top-mounted freezer without an automatic icemaker.	18.6	9/15/14 - 1/30/30	38	0.0052065	0.0038991
3I. Refrigerator-freezers—automatic defrost with top-mounted freezer with an automatic icemaker without through-the-door ice service.	21.9	9/15/14 - 1/30/29	41	0.0055680	0.0041698
5. Refrigerator-freezers—automatic defrost with bottom-mounted freezer without an automatic ice maker	29.8	9/15/14 - 1/30/30	49	0.0066335	0.0049677
5I. Refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker without through-the-door ice service.	18.6	9/15/14 - 1/30/29	59	0.0079979	0.0059896
5A. Refrigerator-freezer—automatic defrost with bottom-mounted freezer with through-the-door ice service.	21.9	9/15/14 - 1/30/29	64	0.0086118	0.0064493
7. Refrigerator-freezers—automatic defrost with side-mounted freezer with through-the-door ice service.	29.8	9/15/14 - 1/30/30	60	0.0081494	0.0061030

Table 2-85: Default Savings Values for ENERGY STAR Most Efficient Refrigerators

Refrigerator Category	Assumed Adjusted Volume of Unit (cubic feet)Source 6	Time Period	ΔkWh/yr	$\Delta kW_{summer\ peak}$	$\Delta kW_{winter\ peak}$
5. Refrigerator-freezers—automatic defrost with bottom-mounted freezer without an automatic ice maker	29.8	9/15/14 - 1/30/30	133	0.0179489	0.0134418
		As of 1/31/30	64	0.0086381	0.0064690
5I. Refrigerator-freezers—automatic defrost with bottom-	18.6	9/15/14 - 1/30/29	160	0.0216548	0.0162171

Refrigerator Category	Assumed Adjusted Volume of Unit (cubic feet)Source 6	Time Period	ΔkWh/yr	$\Delta kW_{summer\ peak}$	$\Delta kW_{winter\ peak}$
mounted freezer with an automatic icemaker without through-the-door ice service.		As of 1/31/29	21	0.0028388	0.0021260
5A. Refrigerator-freezer—automatic defrost with bottom-mounted freezer with through-the-door ice service.	21.9	9/15/14 - 1/30/29	172	0.0233271	0.0174695
		As of 1/31/29	9	0.0012321	0.0009227
7. Refrigerator-freezers—automatic defrost with side-mounted freezer with through-the-door ice service.	29.8	9/15/14 - 1/30/30	163	0.0220597	0.0165203
		As of 1/31/30	16	0.0021705	0.0016254

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 Electronic Technical Reference Manual. “Refrigerator or Freezer, Residential”. Accessed December 2023. Weblink
2) 10 CFR 430.32 (a). Weblink
3) U.S. EPA. (2014). ENERGY STAR Program Requirements Product Specifications for Consumer Refrigeration Products Version 5.1. Weblink
4) U.S. EPA. (2023). ENERGY STAR Most Efficient 2024 Consumer Refrigeration Products Recognition Criteria. Weblink
5) Wilson et al. 2021. End-Use Load Profiles for the U.S. Building Stock: Methodology and Results of Model Calibration, Validation, and Uncertainty Quantification. NREL/TP-5500-80889. Weblink
6) Average adjusted volume of ENERGY STAR-certified refrigerators by configuration. Accessed December 2023. Weblink
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2.4.2 ENERGY STAR FREEZERS

Target Sector	Residential
Measure Unit	Freezer
Measure Life	11 years Source 3
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% 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. If the volume and configuration of the freezer is known, the baseline model's annual energy consumption (kWh_{base}) may be determined using Table 2-86-86. 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 2-87Table 2-87 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

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

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

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

DEFINITION OF TERMS

Table 2-86: 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 2-87	EDC Data Gathering, 1
kWh_{ee}, Annual energy consumption of ENERGY STAR qualified unit	kWh/yr	EDC Data Gathering Default = Table 2-89	EDC Data Gathering, 2
$ETDF_s$, Summer Energy to Demand Factor	$\frac{kW}{kWh}$	0.0001387	6

Term	Unit	Value	Source
$ETDF_W$, Winter Energy to Demand Factor	$\frac{kW}{kWh}$	0.0000998	6

Freezer energy use is characterized by configuration (upright, chest), 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 2-86-86. 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 2-87 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 $\text{AV} = 1.76 \times \text{Freezer Volume}$.

Table 2-87: Federal Standard Maximum Annual Energy Consumption[7]

<table>
<tr><th>Freezer Category</th><th>9/15/14 - 1/30/29</th><th>1/31/29 - 1/30/30</th><th>As of 1/31/30</th></tr>
<tr><td>8. Upright freezers with manual defrost</td><td colspan="3">5.57 × AV + 193.7</td></tr>
<tr><td>9. Upright freezers with automatic defrost without an automatic icemaker</td><td colspan="2">8.62 × AV + 228.3</td><td>(7.33 × AV + 194.1) × K9 + 28I</td></tr>
<tr><td>9I. Upright freezers with automatic defrost with an automatic icemaker</td><td>8.62 × AV + 312.3</td><td colspan="2"></td></tr>
<tr><td>9–BI. Built-In Upright freezers with automatic defrost without an automatic icemaker</td><td>9.86 × AV + 260.9</td><td colspan="2">(9.37 × AV + 247.9) × K9BI + 28I</td></tr>
<tr><td>9I–BI. Built-in upright freezers with automatic defrost with an automatic icemaker</td><td>9.86 × AV + 344.9</td><td colspan="2"></td></tr>
<tr><td>9A-BI. NEW PRODUCT CLASS: Upright built-in freezer with auto defrost and through-door-ice</td><td></td><td colspan="2">9.86 × AV + 288.9</td></tr>
<tr><td>10. Chest freezers and all other freezers except compact freezers</td><td colspan="3">7.29 × AV + 107.8</td></tr>
<tr><td>10A. Chest freezers with automatic defrost</td><td colspan="3">10.24 × AV + 148.1</td></tr>
</table>

[7] 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.

Freezer Category	9/15/14 - 1/30/29	1/31/29 - 1/30/30	As of 1/31/30
16. Compact upright freezers with manual defrost	8.65 × AV + 225.7	7.35 × AV + 191.8	
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	7.86 × AV + 107.8	

Table 2-88: Door Coefficients for Federal Standard Energy Consumption Algorithms

Door Coefficient	Products with a Transparent Door	Products without a Transparent Door with a Door-in-Door	Products without a Transparent Door or Door-in-Door with Added External Doors
K9	1.0	1.0	$1 + 0.02 \times (N_d - 1)$
K9BI	1.0	1.0	$1 + 0.02 \times (N_d - 1)$

Table 2-89: ENERGY STAR and ENERGY STAR Most Efficient Maximum Annual Energy Consumption

Freezer Category	ENERGY STAR Maximum Energy Usage in kWh/yr	ENERGY STAR Most Efficient Maximum Energy Usage in kWh/yr
8. Upright freezers with manual defrost	5.01 × AV + 174.3	AV ≤ 99.9, AEC_{MAX} ≤ 4.73 * AV + 164.6 AV > 99.9, AEC_{MAX} ≤ 637
9. Upright freezers with automatic defrost without an automatic icemaker	7.76 × AV + 205.5	AV ≤ 65.9, AEC_{MAX} ≤ 6.90 * AV + 182.6 AV > 65.9, AEC_{MAX} ≤ 637
9I. Upright freezers with automatic defrost with an automatic icemaker	7.76 × AV + 289.5	AV ≤ 53.7, AEC_{MAX} ≤ 6.90 * AV + 266.6 AV > 53.7, AEC_{MAX} ≤ 637
9–BI. Built-In Upright freezers with automatic defrost without an automatic icemaker	8.87 × AV + 234.8	AV ≤ 65.9, AEC_{MAX} ≤ 6.90 * AV + 182.6 AV > 65.9, AEC_{MAX} ≤ 637
9I–BI. Built-in upright freezers with automatic defrost with an automatic icemaker	8.87 × AV + 318.8	AV ≤ 53.7, AEC_{MAX} ≤ 6.90 * AV + 266.6 AV > 53.7, AEC_{MAX} ≤ 637
10. Chest freezers and all other freezers except compact freezers	6.56 × AV + 97.0	AV ≤ 88.0, AEC_{MAX} ≤ 6.20 * AV + 91.6 AV > 88.0, AEC_{MAX} ≤ 637

Freezer Category	ENERGY STAR Maximum Energy Usage in kWh/yr	ENERGY STAR Most Efficient Maximum Energy Usage in kWh/yr
10A. Chest freezers with automatic defrost	9.22 × AV + 133.3	AV ≤ 58.7, AEC_{MAX} ≤ 8.70 * AV + 125.9 AV > 58.7, AEC_{MAX} ≤ 637
16. Compact upright freezers with manual defrost	7.79 × AV + 203.1	AEC_{MAX} ≤ 6.92 * AV + 180.6
17. Compact upright freezers with automatic defrost	9.15 × AV + 316.7	AEC_{MAX} ≤ 8.14 * AV + 281.5
18. Compact chest freezers	8.33 × AV + 123.1	AEC_{MAX} ≤ 7.4 * AV + 109.4

DEFAULT SAVINGS

Table 2-90 displays the default savings for prevalent configurations of ENERGY STAR freezers. Default savings assume no special doors (i.e. door coefficient=1). Note that there are zero default savings for ENERGY STAR freezer category 16 after 1/30/29, and zero default savings for ENERGY STAR freezer category 9 after 1/30/30. Table 2-90 displays the default savings for prevalent configurations of ENERGY STAR Most Efficient refrigerators.

Table 2-90: Default Savings Values for ENERGY STAR Freezers

Freezer Category	Assumed Adjusted Volume of Unit (cubic feet)[Source 5]	Time Period	ΔkWh/yr	$\Delta kW_{summer\ peak}$	$\Delta kW_{winter\ peak}$
9. Upright freezers with automatic defrost without an automatic icemaker	28.6	9/15/14 - 1/30/30	47	0.0065764	0.0047320
16. Compact upright freezers with manual defrost	5.5	9/15/14 - 1/30/29	27	0.0037872	0.0027251

Table 2-91: Default Savings Values for ENERGY STAR Most Efficient Freezers

Freezer Category	Assumed Adjusted Volume of Unit (cubic feet)	Time Period	ΔkWh	$\Delta kW_{summer\ peak}$	$\Delta kW_{winter\ peak}$
9. Upright freezers with automatic defrost without an automatic icemaker	28.6	9/15/14 - 1/30/30	95	0.0131667	0.0094740
		As of 1/31/30	24	0.0033021	0.0023760
16. Compact upright freezers with manual defrost	5.5	9/15/14 - 1/30/29	55	0.0075682	0.0054456
		As of 1/31/29	14	0.0018797	0.0013526

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) 10 CFR 430.32 (a) Weblink

2) U.S. EPA. (2014). ENERGY STAR Program Requirements Product Specifications for Consumer Refrigeration Products Version 5.1. Weblink

3) California Electronic Technical Reference Manual. “Refrigerator or Freezer, Residential”. Accessed December 2023. Weblink

4) ENERGY STAR-Certified Freezers. Accessed December 2023. Weblink

5) Average adjusted volume of ENERGY STAR-certified freezers by configuration. Accessed March 2024. Weblink

6) Wilson et al. 2021. End-Use Load Profiles for the U.S. Building Stock: Methodology and Results of Model Calibration, Validation, and Uncertainty Quantification. NREL/TP-5500-80889. Weblink

2.4.3 REFRIGERATOR / FREEZER RECYCLING WITH AND WITHOUT REPLACEMENT

Target Sector	Residential
Measure Life	**Without Replacement:**[Source 1] Refrigerator: 5 years Freezer: 4 years **With Replacement:** 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.[8] 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.

ALGORITHMS

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

Energy Savings

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

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

[8] 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.

Unit Energy Consumption[Source 2]

Annual energy consumption (UEC) of the existing refrigerator or freezer can be calculated using the algorithms below. Actual program year recycled refrigerator/freezer data provides a more accurate annual ex ante savings estimate than default values due to the changing mix of recycled appliance models from year-to-year.

The kWh_{ee} of the efficient refrigerator/freezer may be determined using manufacturers' test data for the given model. If test data are not available, the algorithms in Table 2-83 and Table 2-89 may be used to determine the efficient refrigerator's or freezer's annual energy consumption.

Note that if the unit is being recycled without replacement, the kWh_{ee} variable takes on the value of zero. The kWh_{ee} variable only applies to direct install replacement of the recycled refrigerator or freezer unit.

$$\begin{aligned} UEC_{Refrigerator} = \ & 365.25\ days \\ & \times \Big(0.582 + 0.027 \times AGE + 1.055 \times PRE1990 \\ & + 0.067 \times V - 1.977 \times CONFIG_{single-door} + 1.071 \times CONFIG_{side-by-side} \\ & + 0.605 \times PRIMARY + 0.02 \times \left(UNCONDITIONED \times CDD \div 365.25 \frac{days}{year}\right) \\ & - 0.045 \times \left(UNCONDITIONED \times HDD \div 365.25 \frac{days}{year}\right)\Big) \end{aligned}$$

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

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 8, 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 3] 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 4.4 of the DOE, Uniform Methods Project protocol.[Source 2]

Peak Demand Savings

Use the below algorithms to calculate peak demand savings.

$$\Delta kW_{summer\ peak} = \Delta kWh \times ETDF_s$$

$$\Delta kW_{winter\ peak} = \Delta kWh \times ETDF_w$$

Definition of Terms

Table 2-92: Terms, Values, and References for Refrigerator and Freezer Recycling

Term	Unit	Values	Source
N, The number of refrigerators or freezers recycled through the program	*None*	EDC Data Gathering	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%	EDC Data Gathering, 3
$ETDF_S$, Summer Energy to Demand Factor	$\frac{kW}{kWh/yr}$	Refrigerator = 0.0001354 Freezer = 0.0001387	4
$ETDF_W$, Winter Energy to Demand Factor	$\frac{kW}{kWh/yr}$	Refrigerator = 0.0001014 Freezer = 0.0000998	4
AGE, age of appliance	*years*	EDC Data Gathering	EDC Data Gathering
PRE1990, Fraction of appliances manufactured before 1990	*%*	EDC Data Gathering	EDC Data Gathering
V, Total Volume of recycled unit	ft^3	EDC Data Gathering	EDC Data Gathering
$CONFIG_{single\text{-}door}$, Fraction of refrigerators with single-door configuration	*%*	EDC Data Gathering	EDC Data Gathering
$CONFIG_{side\text{-}by\text{-}side}$, Fraction of refrigerators with side-by-side configuration	*%*	EDC Data Gathering	EDC Data Gathering
$CONFIG_{chest}$, Fraction of freezers with chest configuration	*%*	EDC Data Gathering	EDC Data Gathering
PRIMARY, Fraction of appliances in primary use (in absence of program)	*%*	EDC Data Gathering	EDC Data Gathering
UNCONDITIONED, Fraction of appliances located in Unconditioned space	*%*	EDC Data Gathering Default: Refrigerator=12% Freezer=52%	EDC Data Gathering, 7
CDD, Cooling degree days	*°F-day/year*	See CDD65 in Vol. 1, App. A	8
HDD, Heating degree days	*°F-day/year*	See HDD65 in Vol. 1, App. A	8
kWh_{ee}, Annual energy consumption of ENERGY STAR qualified unit	*kWh/yr*	EDC Data Gathering Refrigerator Default: See Table 2-84 In Sec. 2.4.1 ENERGY STAR Refrigerators Freezer Default: See Table 2-90 in Sec. 2.4.2 ENERGY STAR Freezers	EDC Data Gathering, 6

Measure Life

The measure lives for refrigerators and freezers recycled without replacement are 5 years and 4 years, respectively, from the California Electronic Technical Reference Manual. 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 14 years (see the ENERGY STAR Refrigerators section). 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 5]

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 14-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 the ENERGY STAR Refrigerators section with an adjusted volume of 20 ft^3, annual savings would be 578 kWh for the RUL of the existing baseline unit and 49 kWh for the remaining EUL.[9]

In the case of a non-low-income program there is an RUL of 5 years for the existing unit (1/3 * 14= 5) and a remaining EUL of the efficient unit of 9 years (2/3 * 14 = 9). The lifetime savings are equal to 3,331 kWh (578 kWh/yr * 5 yrs + 49 kWh / yr * 9 yrs), resulting in an adjusted measure life of 6 years: 3,331 kWh / 578 kWh/yr = 6 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 4,056 kWh (578 kWh/yr * 6 yrs + 49 kWh / yr * 12 yrs), resulting in an adjusted measure life of 7 years: 4,056 kWh / 578 kWh/yr = 7 years.

Averaging the two lifetime savings values results in an adjusted measure life of 6 years (3,694 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 Electronic Technical Reference Manual. "Refrigerator or Freezer, Residential". Accessed December 2023. Weblink

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

2) Keeling, J., Bruchs, D. (2017). "Chapter 7: Refrigerator Recycling Evaluation Protocol. The Uniform Methods Project: Methods for Determining Energy-Efficiency Savings for Specific Measures". Section 4.4. National Renewable Energy Laboratory. Weblink

3) Based on a Cadmus survey of 510 PPL participants in PY8.

4) Wilson et al. 2021. End-Use Load Profiles for the U.S. Building Stock: Methodology and Results of Model Calibration, Validation, and Uncertainty Quantification. NREL/TP-5500-80889. Weblink

5) Seiden, K., Bruchs, D., Peters, J., Moran, D., Burdick, M. (2006, July). "2004–2005 Final Report: A Measurement and Evaluation Study of the 2004-2005 Limited Income Refrigerator Replacement & Lighting Program". Weblink

6) U.S. EPA. (2014). ENERGY STAR Program Requirements Product Specifications for Consumer Refrigeration Products Version 5.1. Weblink

7) Proportion of refrigerators and freezers calculated using data gathered for Act 129 2023 Pennsylvania Residential Baseline Study.

8) Based on the Phase III SWE team's analysis of regional HVAC runtime data collected from ecobee's Donate Your Data research service (Weblink) and updated based on the latest CDD and HDD values from NOAA's 15-year annual climate Normals (2006–2020) (Weblink)

2.4.4 Low-Capacity Refrigerator / Freezer Recycling without Replacement

Target Sector	Residential
Measure Life	**Without Replacement:** Source 1 Refrigerator: 5 years Freezer: 4 years
Vintage	Early Retirement

Eligibility

Refrigerator and freezer recycling programs are designed to save energy through the removal of old-but-operable compact refrigerators and freezers from service. This measure focuses on "mini-fridges" and small freezers, including those regulated as compact refrigerators and freezers (which are defined as having a total volume of 7.5 ft^3 or less), specifically those units with an interior size (total volume) less than 10 cubic feet which are excluded from the Uniform Methods Project-based 2.4.3 Refrigerator / Freezer Recycling of the 2026 TRM.

By offering free pickup, providing incentives, and disseminating information about the operating cost of old compact refrigerators, these programs are designed to encourage consumers to:

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

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. The savings algorithms are based on current and historic federal efficiency standards for refrigerators and freezers. The savings algorithms for this measure can be applied to refrigerator and freezer retirements meeting the following criteria:

1) Existing, working compact refrigerator or freezer less than 10 cubic feet in size (savings does not apply if unit is not working)
2) Unit is a primary, secondary, or abandoned

EDCs can use data gathering to calculate program savings using the federal efficiency standards, and actual program year recycled refrigerator/freezer data.

Algorithms

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

Energy Savings

$$\Delta kWh = UEC \times PART_{USE}$$

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

Unit Energy Consumption (UEC)

Recognizing that determination of appliance characteristics via measurement or make/model lookup may be impractical in some cases, several options for determining the UEC of the existing refrigerator or freezer are permitted, listed below. Option 1 uses the product class average UECs provided in Table 2. The remaining options are more precise than Option 1 and are listed in descending order of precision (Options 2 through 5). EDCs may choose to forego the extra documentation required for the more precise calculation options but note that these options should allow for the capture of more savings.

1) The default class-dependent UEC from Table 2.
2) The official label energy rating for the model such as from an EnergyGuide or historic ENERGY STAR records. Documentation should include the model number and information source.
3) Calculated from class-dependent formula in Table 3 with age verified by nameplate, compressor age, or model and serial number, and adjusted or total volume verified from (1) the nameplate, (2) similar sources as option 2, or (3) measured in the field.
4) Calculated from class-dependent formula in Table 3 with age verified by nameplate, compressor age, or model and serial number, using the age-appropriate default volume from Table 4.
5) Calculated from the "2015 to date" class-dependent formula in Table 3 with total volume verified from nameplate or measured Adjusted volume.

If both fresh and freezer compartment volumes are available, adjusted volume should be calculated as follows:

$$\textit{All Refrigerator}^{10}\ AV = Total\ Volume = Fresh\ Volume + Freezer\ Volume$$

$$Refrigerator\ AV = Fresh\ Volume + 1.63 \times Freezer\ Volume$$

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

Otherwise, the class-dependent average adjusted volume to total volume ratio may be used from Table 4.

Part-Use Factor

When calculating 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 described 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 8, the Commission determined that the average removed standard size 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 2] 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 4.4 of the DOE, Uniform Methods Project protocol.[Source 3]

[10] An all-refrigerator is an appliance in which the freezer compartment—generally the cooling coil as a U shape within the fresh volume—has a volume of 0.5 ft^3 or less.

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.

$$\Delta kW_{summer\ peak} = \Delta kWh \times ETDF_s$$

$$\Delta kW_{winter\ peak} = \Delta kWh \times ETDF_w$$

Definition of Terms

Table 2-93: Terms, Values, and References for Mini-Frig Recycling

Term	Unit	Values	Source
UEC, Unit Energy Consumption	*kWh/yr*	EDC Data Gathering Default in Table 2	Varies
Total Volume, Fresh plus Frozen Volume	ft^3	EDC Data Gathering	
Fresh Volume, volume of refrigerator	ft^3	EDC Data Gathering	
Frozen Volume, volume capable of maintaining 0°F	ft^3	EDC Data Gathering	
AV, Adjusted Volume/calculated as described above	ft^3	EDC Data Gathering, defaults in Table 4	6–8
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%	2
$ETDF_s$, Summer peak Energy to Demand Factor	$\frac{kW}{kWh}$	Refrigerator = 0.0001354 Freezer = 0.0001387	4
$ETDF_w$, Winter peak Energy to Demand Factor	$\frac{kW}{kWh}$	Refrigerator = 0.0001014 Freezer = 0.0000998	4

Table 2-94: Product Class Descriptions and Default UEC

Product Class[11]	Average UEC (kWh/yr)
11 - Compact refrigerator and Refrigerator-Freezer other than All-Refrigerator - manual defrost	288.3
11A - Compact all-refrigerator - manual defrost[12]	242.7
12 - Compact refrigerator-freezer - partial automatic defrost	361.7
13 - Compact refrigerator-freezers - automatic defrost with top-mounted freezer	405.2
13I - Compact refrigerator-freezers - automatic defrost with top-mounted freezer and automatic icemaker	298.2
13A - Compact all-refrigerators - automatic defrost	538.8
14 - Compact refrigerator-freezer - automatic defrost with side-mounted freezer	492.1
14I - Compact refrigerator-freezer - automatic defrost with side-mounted freezer and automatic icemaker	571.5
15 - Compact refrigerator-freezer - automatic defrost with bottom-mounted freezer	413.4
15I - Compact refrigerator-freezer - automatic defrost with bottom-mounted freezer and automatic icemaker	486.3
16 - Compact upright freezers with manual defrost	253.6
17 - Compact upright freezers with automatic defrost	394.5
18 - Compact chest freezers	180.1

[11] This measure uses the federal efficiency standards for compact refrigerators and freezers, which are defined as having a total volume of 7.5 ft^3 or less. However, this measure is also meant to cover equipment with a total volume of 10 ft^3, which are excluded from section 2.4.3 Refrigerator/Freezer Recycling of the 2026 TRM.

[12] An all-refrigerator is an appliance in which the freezer compartment—(generally the exposed cooling coil as a U shape within the fresh volume)—has a volume of 0.5 ft^3 or less.

Table 2-95: Federal Standard-Based UEC by Product Class

Class	1992 or earlier (1/1/1990)	1993 to 2000 (1/1/1993)	2001 to 2014 (1/1/2001)	2015 to date (9/14/2014)
11	16.3 × AV + 316	13.5 × AV + 299	10.70 × AV + 299.0	9.03 × AV + 252.3
11A				7.84 × AV + 219.1
12	21.8 × AV + 429	10.4 × AV + 398	7.00 × AV + 398.0	5.91 × AV + 335.8
13	23.5 × AV + 471	16.0 × AV + 355	12.70 × AV + 355.0	11.80 × AV + 339.2
13I				11.80 × AV + 423.2
13A				9.17 × AV + 259.3
14	27.7 × AV + 488	11.8 × AV + 501	7.60 × AV + 501.0	6.82 × AV + 456.9
14I				6.82 × AV + 540.9
15	27.7 × AV + 488	16.5 × AV + 367	13.10 × AV + 367.0	11.80 × AV + 339.2
15I				11.80 × AV + 423.2
16	10.9 × AV + 422	10.3 × AV + 264	9.78 × AV + 250.8	8.65 × AV + 225.7
17	16.0 × AV + 623	14.9 × AV + 391	11.40 × AV + 391.0	10.17 × AV + 351.9
18	14.8 × AV + 223	11.0 × AV + 160	10.45 × AV + 152.0	9.25 × AV + 136.8

The average adjusted volumes below were calculated by the SWE using a combined database of refrigerators and freezers from Sources 5–8. These were combined into a single data set, and readily identifiable duplicate entries were removed. In addition, low-voltage devices intended for use in cars and RVs were excluded. The number of models in each class is given, as are some historic class prevalence data based on AHAM sales information from 2008.

Table 2-96: Average Adjusted Volume (AV) and AV to Total Volume ratio by Product Class

Class	Compact Products Historic Share[Source 5]	Adjusted Volume[Sources 6 - 8]			
		Sample Size	2014 or earlier	2015 to date	AV ÷ Total Vol.
11	69%	51	3.13	4.3	109%
11A		626		3.0	101%
12	4.9%	369	5.2	5.2	118%
13	0.7%	58	4.4	6.7	121%
13I		1		11.7	119%
13A	6.6%	1,029		4.2	100%
14	0.3%	27	5.5	6.0	116%
14I		24		4.9	110%
15	0.3%	20	7.4	7.9	125%
15I		21		7.0	130%
16	9.1%	84	5.5	5.5	–
17	5.5%	44	6.9	6.9	–
18	3.6%	223	8.2	8.2	–

Measure Life

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

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 Electronic Technical Reference Manual. “Refrigerator or Freezer, Residential”. Accessed December 2023. Weblink

2) Based on a Cadmus survey of 510 PPL participants in PY8.

3) Keeling, J., Bruchs, D. (2017). "Chapter 7: Refrigerator Recycling Evaluation Protocol. The Uniform Methods Project: Methods for Determining Energy-Efficiency Savings for Specific Measures". Section 4.4. National Renewable Energy Laboratory. Weblink

4) Wilson et al. 2021. End-Use Load Profiles for the U.S. Building Stock: Methodology and Results of Model Calibration, Validation, and Uncertainty Quantification. NREL/TP-5500-80889. Weblink

5) Greenblatt, J., Hopkins, A., Letschert, V., and Blasnik, M. (2012, April). "Energy use of US residential refrigerators and freezers: function derivation based on household and climate characteristics". Lawrence Berkeley National Lab. Weblink

6) U.S. Department of Energy Compliance Certification Database. Accessed October 2021. Weblink

7) ENERGY STAR-certified refrigerators. Accessed November 2021. Weblink

8) ENERGY STAR-certified freezers. Accessed November 2011. Weblink

2.4.5 ENERGY STAR Coolers

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

Eligibility

This measure is for the purchase and installation of a new cooler meeting ENERGY STAR or ENERGY STAR Most Efficient criteria. An ENERGY STAR cooler is 10% - 30% more efficient than the minimum federal government standard. Coolers are sometimes called beverage coolers, beverage refrigerators, wine chillers or wine fridges. They typically have glass fronts and operate at higher temperatures than refrigerators. There is currently no ENERGY STAR standard for refrigerator or freezer combination coolers.

Algorithms

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

If the volume and configuration of a cooler is known, the baseline model's annual energy consumption (kWh_{base}) may be determined using
Table 2-98.

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 2-98 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 Cooler

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

$$\Delta kW_{summer\ peak} = \Delta kWh \times ETDF_s$$

$$\Delta kW_{winter\ peak} = \Delta kWh \times ETDF_w$$

Definition of Terms

Table 2-97: 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 2-99	EDC Data Gathering, 2
kWh_{ee}, Annual energy consumption of ENERGY STAR qualified unit	*kWh/yr*	EDC Data Gathering Default = Table 2-99	EDC Data Gathering, 3
$ETDF_s$, Summer peak Energy to Demand Factor	$\frac{kW}{kWh}$	0.0001354	4
$ETDF_w$, Winter peak Energy to Demand Factor	$\frac{kW}{kWh}$	0.0001014	4

Cooler energy consumption is characterized by volume, whether there are refrigerator or freezer compartments, and configuration (built-in, icemaker). If this information is known, annual energy consumption (kWh_{base}) of the "Federal Standard" may be determined using Table 2-98-98. 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 algorithm in Table 2-98 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" in ft^3. For cooler-freezers, Categories beginning with C-9):

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

For all other categories:

$$AV = Cooler\ Volume + Fresh\ Volume$$

Table 2-98: Federal Standard and ENERGY STAR Coolers Maximum Annual Energy Consumption for Known Configuration and Volume[13]

Cooler Configuration Class	Federal Standard Maximum Usage in kWh/yr	ENERGY STAR Maximum Energy Usage in kWh/yr
Standard: 7.75 cubic feet or greater		
2. Built-in	7.88 × AV + 155.8	5.52 × AV + 109.1
4. Freestanding	7.88 × AV + 155.8	7.09 × AV + 140.2
Compact: less than 7.75 cubic feet		
1. Built-in compact	7.88 × AV + 155.8	5.52 × AV + 109.1
3. Freestanding compact	7.88 × AV + 155.8	6.30 × AV + 124.6

[13] Numbering convention (1, C-3A, 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 2-99: Default Savings Values for ENERGY STAR Coolers[14]

Cooler Configuration Class	Assumed Adjusted Volume (cubic feet)Source 5,6	Conventional Unit Energy Usage in kWh/yr	ENERGY STAR Energy Usage in kWh/yr	ΔkWh/yr[15]	$\Delta kW_{summer\ peak}$	$\Delta kW_{winter\ peak}$
Standard: 7.75 cubic feet or greater						
2. Built-in	11.26	244.5	171.3	73	0.0099	0.0074
4. Freestanding	14.63	271.1	243.9	27	0.0037	0.0027
Compact: less than 7.75 cubic feet						
1. Built-in compact	3.97	187.1	131	56	0.0076	0.0057
3. Freestanding compact	3.82	185.9	148.7	37	0.0050	0.0038

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 Electronic Technical Reference Manual. “Refrigerator or Freezer, Residential”. Accessed December 2023. Weblink

2) 10 CFR 430.32(aa) Weblink

3) U.S. EPA. (2014). ENERGY STAR Program Requirements Product Specifications for Consumer Refrigeration Products Version 5.1. Weblink

4) Wilson et al. 2021. End-Use Load Profiles for the U.S. Building Stock: Methodology and Results of Model Calibration, Validation, and Uncertainty Quantification. NREL/TP-5500-80889. Weblink

5) DOE Compliance Certificate Database. Accessed July 2022. Weblink

6) ENERGY STAR-certified refrigerators. Accessed July 2022. Weblink

[14] 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.

[15] kWh/yr. savings may differ from Conventional Usage – ENERGY STAR Usage by 1 kWh/yr. due to rounding.

2.4.6 Cooler Recycling with and without Replacement

Target Sector	Residential
Measure Life	**Without Replacement:** Source 1 5 years **With Replacement:** 9 years
Vintage	Early Retirement, Early Replacement

Eligibility

Coolers are sometimes called beverage coolers, beverage refrigerators, wine chillers or wine fridges. They typically have glass fronts and operate at higher temperatures than refrigerators. This protocol is for the recycling of a cooler manufactured prior to October 2019.

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

- Discontinue the use of secondary refrigeration equipment
- Relinquish units when they are replaced (rather than keeping the old appliance as a secondary unit)
- Prevent the continued use of old refrigeration equipment 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 since consumer-grade cooler usage and energy consumption are assumed to be independent of customer rate class.[16]

This measure may be combined with ENERGY STAR Coolers if the cooler is replaced with qualifying equipment.

Algorithms

The total annual energy savings (kWh/yr) achieved from recycling old-but-operable coolers 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.

[16] 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 cooler usage.

Unit Energy Consumption
Coolers were not federally regulated until October 2019. However, California Energy Commission Title 20 regulations for this product class were introduced in 2002,[Source 3] and remained unchanged and in effect until they were superseded by the federal standards.

Annual energy consumption (UEC) of the decommissioned cooler may be determined using manufacturers' test data for the given model. If test data are not available, annual unit energy consumption is equal to the derated maximum Title 20 annual energy consumption ($\eta \times kWh_{recycled}$).[17] The algorithms in Table 2-101 may be used to determine $kWh_{recycled}$.

Note that if the unit is being recycled without replacement, the kWh_{ee} variable takes on the value of zero. The kWh_{ee} variable only applies to direct install replacement of the recycled cooler.

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", i.e; equipment with not more than 0.5 ft^3 of freezer volume:

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

For all other categories:

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

Part-Use Factor
When calculating default per unit kWh savings for a removed cooler, 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 into an average per-unit deemed savings value. The UEC itself is not equal to the default savings value, because not all coolers would have operated year-round had they not been decommissioned through the program.

EDC's may use either a cooler-specific part-use, or that calculated for refrigerators. In Program Year 8, the Commission determined that the average removed refrigerator was plugged in and used 72.8% of the year.[Source 5] 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 4.4 of the DOE, Uniform Methods Project protocol.[Source 4]

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.

$$\Delta kW_{summer\ peak} = \Delta kWh \times ETDF_s$$

$$\Delta kW_{winter\ peak} = \Delta kWh \times ETDF_w$$

[17] This is results in a conservative savings estimate since equipment sold outside of California could exceed Title 20 levels.

Definition of Terms

Table 2-100: 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	EDC Data Gathering
UEC, Annual energy consumption of the cooler being recycled	*kWh/yr*	EDC Data Gathering, or $\eta \times kWh_{recycled}$	EDC Data Gathering, 2, 3
η, Average fraction of rated usage ÷ Title 20 Annual Energy Consumption. This is a measure of how much more efficient equipment on the market was than what Title 20 permitted.	*%*	89%	2
$kWh_{recycled}$, Maximum annual energy consumption of California Title 20 standard for the recycled unit	*kWh/yr*	Table 2-101	3
kWh_{ee}, Maximum annual energy consumption of ENERGY STAR qualified unit	*kWh/yr*	EDC Data Gathering Table 2-98 Default: Table 2-99	EDC Data Gathering, 7
PART_USE, The portion of the year the average cooler 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%	EDC Data Gathering, 5
$ETDF_s$, Summer peak Energy to Demand Factor	$\frac{kW}{kWh}$	0.0001354	6
$ETDF_w$, Winter peak Energy to Demand Factor	$\frac{kW}{kWh}$	0.0001014	6
AV, Adjusted Volume/calculated as described above	ft^3	EDC Data Gathering Default: Recycled Compact=4.3 Recycled Standard=14.6	EDC Data Gathering, 2

Cooler energy consumption is characterized by volume, whether there are refrigerator or freezer compartments, and configuration (built-in, icemaker). Annual energy consumption may be determined using manufacturer's test data for the given model, or if unavailable and the configuration details are known, using the algorithms in Table 2-101-101. Otherwise, the default values in Table 2-101 may be used.

Table 2-101: Pre-2019 California Title 20 Maximum Annual Energy Consumption[18]

Cooler Configuration	$kWh_{recycled}$	Default
Standard: 7.75 cubic feet or greater		
2. Built-in	13.7 × AV + 267	467
4. Freestanding	13.7 × AV + 267	467
C-3A. Cooler with all-refrigerator - automatic defrost	17.4 × AV + 344	598
C-3A-BI. Built-in cooler with all-refrigerator - automatic defrost	17.4 × AV + 344	598
C-9. Cooler with upright freezers with automatic defrost without an automatic icemaker	17.4 × AV + 344	598
C-9-BI. Built-in cooler with upright freezer with automatic defrost without an automatic icemaker	17.4 × AV + 344	598
C-9I. Cooler with upright freezer with automatic defrost with an automatic icemaker	17.4 × AV + 344	598
C-9I-BI. Built-in cooler with upright freezer with automatic defrost with an automatic icemaker	17.4 × AV + 344	598
Compact: less than 7.75 cubic feet		
1. Built-in compact	13.7 × AV + 267	326
3. Freestanding compact	13.7 × AV + 267	326
C-13A. Compact cooler with all-refrigerator - automatic defrost	17.4 × AV + 344	419
C-13A-BI. Built-in compact cooler with all-refrigerator - automatic defrost	17.4 × AV + 344	419
Unknown Configuration		
Standard	-	467
Compact	-	326
Unknown	-	353

MEASURE LIFE

Since coolers function similarly to refrigerators, the California Electronic Technical Reference Manual refrigerator EUL is used as a proxy. The measure life for refrigerators WITHOUT replacement is 5 years, representing ⅓ of the EUL of a new refrigerator and by extension cooler. The adjusted measure life of coolers recycled WITH replacement is 5 years for federal units and 9 years for ENERGY STAR units.

Adjusted Measure Life with Replacement Rationale:
Consumer refrigeration appliance 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 recycled unit and the replacement

[18] 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.

unit; the RUL can be assumed to be 1/3 of the measure EUL of an ENERGY STAR cooler. For the second period of savings (the remaining EUL of the replacement unit), the energy savings are equal to the difference between a Federal Standard unit and the replacement unit.

The EUL of a new ENERGY STAR refrigerator or cooler is 14 years. 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 8]

To simplify the calculation of savings and remove the need to calculate different savings for each population, adjusted measure life values for the state can be used with the savings difference between the recycled baseline unit and the replacement unit over the adjusted measure life. These are provided in Table 2-102 below. The duration of each period (5.2 and 10.4) are based on weighting the aforementioned EULs of 14 and 18 years by the proportion of Pennsylvania's low-income population (40% at or below 150% of federal poverty level).[Source 10]

Table 2-102: Adjusted Measure Life

Replacement	RUL Savings	+ EUL Remainder Savings	= Total Savings	Equivalent Years (Total ÷ RUL)
ENERGY STAR	⅓ × 5.2 × (314-148)	⅔× 10.4 × (203-148)	1,437	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 Electronic Technical Reference Manual. "Refrigerator Recycling". Accessed December 2023. Weblink
2) SWE analysis of 143 wine chiller models in historic records (dated 2002–2013) of the California Energy Commission's Modernized Appliance Efficiency Database System, including 116 compact models and 27 standard models. Weblink
3) California Energy Commission 2015 Appliance Efficiency Regulations, Effective 2002. Accessed 7/7/2022. Weblink
4) Keeling, J., Bruchs, D. (2017). "Chapter 7: Refrigerator Recycling Evaluation Protocol. The Uniform Methods Project: Methods for Determining Energy-Efficiency Savings for Specific Measures". Section 4.4. National Renewable Energy Laboratory. Weblink
5) Based on a Cadmus survey of 510 PPL participants in PY8.
6) Wilson et al. 2021. End-Use Load Profiles for the U.S. Building Stock: Methodology and Results of Model Calibration, Validation, and Uncertainty Quantification. NREL/TP-5500-80889. Weblink
7) 10 CFR 430.32(aa) Weblink
8) Seiden, K., Bruchs, D., Peters, J., Moran, D., Burdick, M. (2006, July). "2004–2005 Final Report: A Measurement and Evaluation Study of the 2004-2005 Limited Income Refrigerator Replacement & Lighting Program". Weblink

9) SWE analysis of 591 cooler models from EPA and DOE records, including 482 compact models (82% class 3, 9% class C-13A, 6% class 1) and 109 standard models (80% class 4, 17% class 2).

   a. DOE Compliance Certificate Database. Accessed July 2022. Weblink

   b. ENERGY STAR-certified refrigerators. Accessed July 2022. Weblink

10) U.S. Census Bureau, 2017-2021 American Community Survey 5-Year Estimates. Weblink

2.4.7 Residential Induction Cooktop

Target Sector	Residential
Measure Unit	Induction Cooktop
Measure Life	15 years[Source 1]
Vintage	Retrofit, Replace on Burnout, or New Construction

Eligibility

Electric induction cooktops are either a freestanding cooktop that heats cooking vessels using electrical induction or a range with an electric resistance oven and an electric induction cooktop. Electric induction cooktops save energy by heating the cookware directly as opposed to the surface of the range as seen in traditional electric resistance cooktops.

Electric induction cooktops may replace electric ovens with electric resistance cooktops or freestanding electric resistance cooktops.

Algorithms

Total savings are calculated based on the increased cooking efficiency of an electric induction cooktop over an existing electric resistance cooktop. Cooking efficiency is defined as the ratio of energy absorbed by the object being heated (food, water, etc.) and the energy consumed by the appliance.

$$\Delta kWh = (AEC_{base} - AEC_{ee}) \times \%_{elec}$$

$$AEC_{base} = AEC_{ee} \times \left(\frac{Eff_{ee}}{Eff_{base}}\right)$$

$$\Delta kW_{summer\ peak} = \Delta kWh \times ETDF_s$$

$$\Delta kW_{winter\ peak} = \Delta kWh \times ETDF_w$$

Definition of Terms

Table 2-103: Terms, Values, and References for Electric Induction Cooktops

Term	Unit	Value	Sources
AEC_{base}, Annual Energy Consumption of a baseline electric cooktop	$\frac{kWh}{yr}$	EDC Data Gathering of Nameplate data	EDC Data Gathering
		Default = 209	Calculated
AEC_{ee}, Annual Energy Consumption of efficient induction cooktop	$\frac{kWh}{yr}$	EDC Data Gathering of Nameplate Data	EDC Data Gathering
		Default = 189	2
Eff_{ee}, Efficiency of electric induction cooktop	%	EDC Data Gathering of Nameplate data	EDC Data Gathering
		Default = 85%	3
Eff_{base}, Efficiency of baseline electric resistance cooktop	%	EDC Data Gathering of Nameplate data	EDC Data Gathering
		Default = 77%	3

Term	Unit	Value	Sources
$ETDF_s$, summer peak energy to demand factor	$\frac{kW}{kWh}$	EDC Data Gathering	EDC Data Gathering
		Default = 0.0002153	4
$ETDF_w$, winter peak energy to demand factor	$\frac{kW}{kWh}$	EDC Data Gathering	EDC Data Gathering
		Default = 0.0002237	4
$\%_{elec}$, electric cooktop penetration	%	EDC Data Gathering	EDC Data Gathering
		61%	5

Default Savings

Default savings for this measure are based on the default energy consumption and efficiencies for the efficient induction and baseline electric resistance measure.

$$\Delta kWh_{default} = (AEC_{base,default} - AEC_{ee,default}) \times \%_{elec}$$
$$= (209 - 189) \times 61\%$$
$$= 12.2\ kWh/yr$$

$$AEC_{base,\ default} = AEC_{ee,default} \times \left(\frac{Eff_{ee,default}}{Eff_{base,default}}\right)$$
$$= 189 \times \left(\frac{85}{77}\right)$$
$$= 209\ kWh/yr$$

$$AEC_{ee,\ default} = 189\ kWh/yr$$

$$\Delta kW_{summer\ peak} = \Delta kWh_{default} \times ETDF_s$$
$$= 12.2 \times 0.0002153$$
$$= 0.0026\ kW$$

$$\Delta kW_{winter\ peak} = \Delta kWh_{default} \times ETDF_w$$
$$= 12.2 \times 0.0002237$$
$$= 0.0027\ kW$$

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. Evaluation contractors may choose 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

14) Federal Register 10 CFR Parts 429 and 430. Vol. 81, No. 171. (2016, September). Measure life capped at 15 years per PA Act 129. Weblink

15) Assigned value for ENERGY STAR-certified Residential Induction Cooktops. QPL accessed 11/21/2023. Weblink

16) Livchak, D., Hedrick R., and Young, R. (2019, July). "Residential Cooktop Performance and Energy Comparison Study". Frontier Energy Report # 501318071-R0. Weblink

17) Wilson et al. 2021. End-Use Load Profiles for the U.S. Building Stock: Methodology and Results of Model Calibration, Validation, and Uncertainty Quantification. NREL/TP-5500-80889. Weblink

18) NMR Group for the Pennsylvania Public Utility Commission. (2024, March). 2023 Pennsylvania Statewide Act 129 Residential Baseline Study. Page 145, Table 130. Weblink

2.4.8 ENERGY STAR Clothes Washers

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

This measure is for the purchase and installation of an ENERGY STAR clothes washer. 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 that exceeds federal minimum efficiency standards.

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:

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

$$\Delta kW_{summer\ peak} = \Delta kWh \times ETDF_s$$

$$\Delta kW_{winter\ peak} = \Delta kWh \times ETDF_w$$

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 2-104: Terms, Values, and References for ENERGY STAR Clothes Washers

Term	Unit	Value	Source
CAPY, Clothes washer capacity	ft^3	EDC Data Gathering Default: Table 2-105	EDC Data Gathering, 2
$IMEF_{base}$, Integrated Modified Energy Factor of baseline clothes washer	$\frac{ft^3}{(kWh/cycle)}$	Table 2-105	7, 10
$IMEF_{ee}$, Integrated Modified Energy Factor of ENERGY STAR clothes washer	$\frac{ft^3}{(kWh/cycle)}$	EDC Data Gathering Default: Table 2-105	EDC Data Gathering, 3
Cycles, Number of clothes washer cycles per year	$\frac{cycles}{yr}$	178	6
CW_{base}, % of total energy consumption for baseline clothes washer mechanical operation	%	8.2%	5
CW_{ee}, % of total energy consumption for ENERGY STAR clothes washer mechanical operation	%	7.6%	5
DHW_{base}, % of total energy consumption attributed to baseline clothes washer water heating	%	10.8%	5
DHW_{ee}, % of total energy consumption attributed to ENERGY STAR clothes washer water heating	%	10.8%	5
$\%_{ElecDHW}$, % of water heaters that are electric	%	EDC Data Gathering Default: 47%	EDC Data Gathering, 4
$Dryer_{base}$, % of total energy consumption for baseline clothes washer dryer operation	%	81.0%	5

Term	Unit	Value	Source
Dryer$_{ee}$, % of total energy consumption for ENERGY STAR clothes washer dryer operation	%	81.6%	5
$\%_{ElecDryer}$, Percentage of dryers that are electric	%	EDC Data Gathering Default: 82%	EDC Data Gathering, 4
$\%_{\frac{dry}{wash}}$, Percentage of homes with a dryer that use the dryer every time clothes are washed	%	Default= 99% Or EDC data gathering	6
$ETDF_S$, Summer energy to Demand Factor	$\frac{kW}{kWh}$	0.0001475	8
$ETDF_W$, Winter energy to Demand Factor	$\frac{kW}{kWh}$	0.0001490	8

Federal standards for clothes washers through 2/29/28 are based on IMEF (ft^3/kWh/cycle). Starting 3/1/28 the federal standards will be based on energy efficiency ratio (EER, lb/kWh/cycle).[Source 9] Table 2-105 converts the 3/1/28 federal minimum EERs to IMEFs for use in the savings algorithm.

Table 2-105: Federal Standards and ENERGY STAR Specifications for Clothes Washers through 2/29/28

Configuration[19]	CAPY	IMEF$_{base}$ through 2/29/28	IMEF$_{base}$ as of 3/1/28	IMEF$_{ee}$
Top-loading, > 2.5 ft^3	5.0	1.57	2.06	2.06
Front-loading, 1.6 ft^3 ≤ 2.5 ft^3	2.2	1.84	2.76	2.07
Front-loading, > 2.5 ft^3	4.5	1.84	2.76	2.76

DEFAULT SAVINGS

Table 2-106 displays default savings from clothes washers through 2/29/28. There are no default savings as of 3/1/28 when federal minimum efficiency standards meet or exceed ENERGY STAR Version 8.1 minimums. However, EDCs can still calculate savings using EDC-gathered data for ENERGY STAR clothes washers that exceed federal minimum efficiency standards.

Table 2-106: Default Clothes Washer Savings through 2/29/28

Fuel Mix	Washer Type	ΔkWh	$\Delta kW_{summer\ peak}$	$\Delta kW_{winter\ peak}$
Electric DHW/Electric Dryer	Top-loading, > 2.5 ft3	133.8	0.0197	0.0199
	Front-loading, 1.6 ft3 ≤ 2.5 ft3	23.5	0.0035	0.0035
	Front-loading, > 2.5 ft3	144.0	0.0212	0.0214

[19] If configuration is front-loading and capacity is unknown, assume capacity > 2.5 ft^3.

Electric DHW/Gas Dryer	Top-loading, > 2.5 ft3	28.2	0.0042	0.0042
	Front-loading, 1.6 ft3 ≤ 2.5 ft3	5.6	0.0008	0.0008
	Front-loading, > 2.5 ft3	29.3	0.0043	0.0044
Gas DHW/Electric Dryer	Top-loading, > 2.5 ft3	119.2	0.0176	0.0178
	Front-loading, 1.6 ft3 ≤ 2.5 ft3	20.9	0.0031	0.0031
	Front-loading, > 2.5 ft3	128.3	0.0189	0.0191
Gas DHW/Gas Dryer	Top-loading, > 2.5 ft3	13.6	0.0020	0.0020
	Front-loading, 1.6 ft3 ≤ 2.5 ft3	3.1	0.0005	0.0005
	Front-loading, > 2.5 ft3	13.6	0.0020	0.0020
Default (47% Electric DHW, 82% Electric Dryer)	Top-loading, > 2.5 ft3	107.1	0.0158	0.0159
	Front-loading, 1.6 ft3 ≤ 2.5 ft3	18.9	0.0028	0.0028
	Front-loading, > 2.5 ft3	115.0	0.0170	0.0171

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) DOE (2021). Residential Clothes Washers Life-Cycle Cost Analysis (LCC) Spreadsheets. Weblink

2) Median capacity of ENERGY STAR-certified models by configuration. Accessed December 2023. Weblink

3) U.S. EPA. (2021). ENERGY STAR Program Requirements Product Specification for Clothes Washers, Eligibility Criteria Version 8.1. Weblink

4) NMR Group for the Pennsylvania Public Utility Commission. (2024, March). 2023 Pennsylvania Statewide Act 129 Residential Baseline Study. Page 122, Table 105 ($\%_{ElecDHW}$). Page 158, Table 149 ($\%_{ElecDryer}$). Weblink

5) The percentage of total energy consumption that is used for the machine, heating the hot water, or by the dryer varies depending on the efficiency of the unit. Values are based on a weighted average of top-loading and front-loading units by consumption data from Source 1. Distribution of baseline top- and front-loading units from NMR Group for the Pennsylvania Public Utility Commission. (2024, March). 2023 Pennsylvania Statewide Act 129 Residential Baseline Study. Page 151, Table 139. Weblink. Distribution of ENERGY STAR top- and front-loading units from ENERGY STAR-certified models. Accessed December 2023. Weblink

6) Calculated using “Frequency of clothes washer use” and “Frequency of dryer use” data for Pennsylvania from U.S. Department of Energy, 2020 Residential Energy Consumption Survey. Weblink

7) 10 CFR 430.32(g)(4) Weblink

8) Wilson et al. 2021. End-Use Load Profiles for the U.S. Building Stock: Methodology and Results of Model Calibration, Validation, and Uncertainty Quantification. NREL/TP-5500-80889. Weblink

9) U.S. DOE. (2024, March 15). Direct final rule. Federal Register, 89 (52), pages 19,026-19,126. Weblink

10) U.S. DOE (2024). Life-Cycle Cost (LCC) Analysis RCW ECS Direct Final Rule Spreadsheet. Weblink

2.4.9 ENERGY STAR Clothes Dryers

Target Sector	Residential
Measure Unit	Clothes Dryer
Measure Life	14 years[Source 3]
Vintage	Replace on Burnout, New Construction

ENERGY STAR clothes dryers have a higher CEF (combined energy factor) than standard dryers. They save energy by using lower temperatures than standard dryers and incorporating a moisture sensor to reduce excessive drying of clothes and prolonged drying cycles.

ENERGY STAR clothes dryers that use heat pump technology have the highest CEFs. Whereas 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 purchasing an electric dryer that meets ENERGY STAR criteria. Different default $\mathrm{CEF_{ee}}$'s are provided for dryers that use heat pump technology (including hybrid heat pump dryers) and those that do not.

Algorithms

The energy savings are obtained through the following formulas:

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

$$\Delta kW_{summer\ peak} = \Delta kWh \times ETDF_s$$

$$\Delta kW_{winter\ peak} = \Delta kWh \times ETDF_w$$

Definition of Terms

Table 2-107: Terms, Values, and References for ENERGY STAR Clothes Dryers

Term	Unit	Values	Source
$Cycles_{wash}$, Number of washing machine cycles per year	*cycles/yr*	178	5
$Load_{avg}$, Weight of average dryer load, in pounds per load	*lbs/load*	Standard: 8.45 Compact: 3.00	6
$\%_{\frac{dry}{wash}}$, Percentage of homes with a dryer that use the dryer for every load	*%*	99% Or EDC data gathering	5, EDC data gathering

CEF_{base}, Combined Energy Factor of baseline dryer, in lbs/kWh	*lbs/kWh*	Table 2-108 or EDC Data Gathering	2, 7, EDC data gathering
CEF_{ee}, Combined Energy Factor of ENERGY STAR dryer, in lbs/kWh	*lbs/kWh*	Table 2-108 or EDC Data Gathering	1, EDC data gathering
$ETDF_s$, Summer energy to Demand Factor	$\frac{kW}{kWh}$	0.0001346	4
$ETDF_w$, Winter energy to Demand Factor	$\frac{kW}{kWh}$	0.0001350	4

Table 2-108: Combined Energy Factor for Federal Minimum Standard and ENERGY STAR Dryers

Product Type	CEF_{base} through 2/29/28	CEF_{base} starting 3/1/28	CEF_{ee}
Vented Electric, Standard (4.4 ft³ or greater capacity)	3.73	3.93	No heat pump: 3.93 Hybrid: 4.50
Ventless Electric, Standard (4.4 ft³ or greater capacity)	3.73	3.93	No heat pump: 3.93 Hybrid: 5.20 Heat pump: 9.75
Vented or Ventless Electric, Compact (120V) (less than 4.4 ft³ capacity)	3.61	4.33	No heat pump: 3.80 Heat pump: 6.37
Vented Electric, Compact (240V) (less than 4.4 ft³ capacity)	3.27	3.57	No heat pump: 3.45
Ventless Electric, Compact (240V) (less than 4.4 ft³ capacity)	2.55	2.68	No heat pump: 2.68 Heat pump: 5.60

Default Savings

Table 2-109 displays default energy savings for ENERGY STAR clothes dryers through 2/29/28. Table 2-110 displays default energy savings for ENERGY STAR clothes dryers starting 3/1/28 when new federal minimum CEFs go into effect, at which point only clothes dryers with heat pump technology will be efficient enough to generate energy savings.

Table 2-109: Default Energy Savings and Demand Reductions for ENERGY STAR Clothes Dryers through 2/29/28

Product Type	ΔkWh	$\Delta kW_{summer\ peak}$	$\Delta kW_{winter\ peak}$
Vented Electric, Standard Capacity	20.3	0.0027345	0.0027435
Vented Electric, Standard Capacity, Hybrid	68.3	0.0091945	0.0092247
Ventless Electric, Standard Capacity	20.3	0.0027345	0.0027435
Ventless Electric, Standard Capacity, Hybrid	112.9	0.0151902	0.0152402
Ventless Electric, Standard Capacity, Heat Pump	246.5	0.0331772	0.0332864
Vented or Ventless Electric, Compact Capacity, 120V, Heat Pump	63.5	0.0085405	0.0085686
Vented Electric, Compact Capacity, 240V	8.4	0.0011353	0.0011391
Ventless Electric, Compact Capacity, 240V	10.1	0.0013536	0.0013581
Ventless Electric, Compact Capacity, 240V, Heat Pump	112.9	0.0151982	0.0152483

Table 2-110: Default Energy Savings and Demand Reductions for ENERGY STAR Clothes Dryers as of 3/1/28

Product Type	ΔkWh	$\Delta kW_{summer\ peak}$	$\Delta kW_{winter\ peak}$
Vented Electric, Standard Capacity, Hybrid	48.0	0.0064599	0.0064812
Ventless Electric, Standard Capacity, Hybrid	92.5	0.0124556	0.0124966
Ventless Electric, Standard Capacity, Heat Pump	226.2	0.0304427	0.0305429
Vented or Ventless Electric, Compact Capacity, 120V, Heat Pump	39.1	0.0052629	0.0052802
Ventless Electric, Compact Capacity, 240V, Heat Pump	102.9	0.0138446	0.0138902

Evaluation Protocols

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

Sources

1) U.S. EPA. (2015). ENERGY STAR Program Requirements Product Specification for Clothes Dryers Version 1.1. Weblink

2) 10 CFR 430.32(h) Weblink

3) Energy Efficiency and Renewable Energy Office (2021). National Impact Preliminary Analysis Spreadsheets. U.S DOE. Weblink

4) Wilson et al. 2021. End-Use Load Profiles for the U.S. Building Stock: Methodology and Results of Model Calibration, Validation, and Uncertainty Quantification. NREL/TP-5500-80889. Weblink

5) Calculated using "Frequency of clothes washer use" and "Frequency of dryer use" data for Pennsylvania from U.S. Department of Energy, 2020 Residential Energy Consumption Survey. Weblink

6) 10 CFR Appendix-D1-to-Subpart-B-of-Part-430 2.7.1 Weblink

7) U.S. DOE. (2024, March 12). Direct final rule. Federal Register, 89 (49), pages 18,164-18,243. Weblink

2.4.10 ENERGY STAR DISHWASHERS

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

ELIGIBILITY

This measure is for the purchase and installation of an ENERGY STAR dishwasher. 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. EDC data gathering is permitted for $\mathrm{kWh_{ee}}$ provided that it is gathered from the ENERGY STAR qualified product list.

Per unit energy and demand savings algorithms for dishwashers utilizing electrically heated hot water:

$$\Delta kWh = (kWh_{base} - kWh_{ee}) \times (\%kWh_{OP} + \%kWh_{heat} \times \%Elec_{DHW})$$

$$\Delta kW_{summer\ peak} = \Delta kWh \times ETDF_s$$

$$\Delta kW_{winter\ peak} = \Delta kWh \times ETDF_w$$

DEFINITION OF TERMS

Table 2-111: Terms, Values, and References for ENERGY STAR Dishwashers

Term	Unit	Value	Source
kWh_{base}, Annual energy consumption of baseline dishwasher	kWh/yr	Standard: 307 Compact: 222	1, 3
kWh_{ee}, Annual energy consumption of ENERGY STAR qualified unit	kWh/yr	EDC data gathering Defaults: Standard: 240 Compact :155	EDC data gathering, 4
$\%kWh_{op}$, Percentage of unit dishwasher energy consumption used for operation	%	44%	1

Term	Unit	Value	Source
$\%kWh_{heat}$, Percentage of dishwasher unit energy consumption used for water heating	%	56%	1
$\%Elec_{DHW}$, Percentage of water heaters that are electric	%	EDC Data Gathering Default = 47%	EDC data gathering, 3
$ETDF_s$, Summer energy to Demand Factor	$\frac{kW}{kWh}$	0.0001699	5
$ETDF_w$, Winter energy to Demand Factor	$\frac{kW}{kWh}$	0.0002640	5

ENERGY STAR qualified dishwashers must use less than or equal to the water and energy consumption values in Table 2-112 and Table 2-113. A standard sized dishwasher is defined as any dishwasher that can hold 8 or more place settings and at least six serving pieces while compact size dishwashers have a capacity less than eight place settings plus six serving pieces.[Source 6]

Table 2-112: Federal Standard and ENERGY STAR v 7.0 Residential Dishwasher Standard

Product Type	Federal Standard[Source 2]		ENERGY STAR v 7.0[Source 4]	
	Water (gallons per cycle)	Energy (kWh per year)	Water (gallons per cycle)	Energy (kWh per year)
Standard	≤ 5.0	≤ 307	≤ 3.2	≤ 240
Compact	≤ 3.5	≤ 222	≤ 2.0	≤ 155

The default savings values for electric and non-electric water heating and the default fuel mix from Table 2-113. Note that default savings for standard and compact dishwashers are the same because the difference in consumption between the baseline and efficient models $(kWh_{base} - kWh_{ee})$ is the same (67 kwh).

Table 2-113: Default Dishwasher Energy Savings (Standard and Compact)

Water Heating	$\Delta kWh/yr$	$\Delta kW_{summer\ peak}$	$\Delta kW_{winter\ peak}$
Electric ($\%Electric_{DHW}$ = 100%)	67.0	0.01138	0.01769
Non-Electric ($\%Electric_{DHW}$ = 0%)	29.5	0.00501	0.00778
Default Fuel Mix ($\%Electric_{DHW}$ = 47%)	47.1	0.00800	0.01244

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 (2016). Savings Calculator for ENERGY STAR Qualified Appliances. U.S. EPA. Weblink
2) 10 CFR 430.32(f) Weblink
3) NMR Group for the Pennsylvania Public Utility Commission. (2024, March). 2023 Pennsylvania Statewide Act 129 Residential Baseline Study. Page 122, Table 105. Weblink
4) U.S. EPA. (2023). ENERGY STAR Program Requirements Product Specification for Residential Dishwashers Eligibility Criteria Version 7.0. Weblink
5) Wilson et al. 2021. End-Use Load Profiles for the U.S. Building Stock: Methodology and Results of Model Calibration, Validation, and Uncertainty Quantification. NREL/TP-5500-80889. Weblink

2.4.11 ENERGY STAR DEHUMIDIFIERS

Target Sector	Residential
Measure Unit	Dehumidifier
Measure Life	12 years[Source 1]
Vintage	Replace on Burnout

ENERGY STAR qualified dehumidifiers are 13% more efficient than non-qualified models due to more efficient refrigeration coils, compressors, and fans.[Source 2] ENERGY STAR Most Efficient portable dehumidifiers are over 20% more efficient than federal minimum standards.[Source 7]

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 5.0 Product Specifications to qualify.[Source 3] 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 summer peak demand savings algorithms:

$$\Delta kWh = \left(\frac{CAPY \times 0.473\,\frac{\text{liters}}{\text{pint}}}{24\,\frac{\text{hours}}{\text{day}}}\right) \times HOU \times \left(\frac{1}{IEF_{base}} - \frac{1}{IEF_{ee}}\right)$$

$$\Delta kW_{summer\ peak} = \frac{\Delta\, kWh/yr}{HOU} \times CF$$

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

Definition of Terms

Table 2-114: 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	$\frac{hours}{yr}$	2,160	1
IEF_{base}, Baseline unit liters of condensate per kWh consumed	$\frac{liters}{kWh}$	Table 2-115	4
IEF_{ee}, ENERGY STAR qualified unit liters of condensate per kWh consumed	$\frac{liters}{kWh}$	EDC Data Gathering Default: Table 2-115	EDC data gathering, 3, 6
CF, Summer demand coincidence factor	*Proportion*	0.405	5

Table 2-115 shows the federal standard minimum efficiency standards. Federal standards are effective as of June 13, 2019. Table 2-116 shows ENERGY STAR 5.0 standards effective as of October 31, 2019. Table 2-117 shows ENERGY STAR Most Efficient 2024 criteria, effective January 2024.[Source 6] Federal standards and ENERGY STAR Most Efficient 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 2-115: Dehumidifier Efficiency Standards

Type	Capacity (pints/day)	Federal Standard (IEF_{base})	ENERGY STAR (IEF_{ee})	ENERGY STAR Most Efficient (IEF_{ee})
Portable dehumidifier	≤ 25	≥ 1.30	≥ 1.57	≥ 1.75
	> 25 to ≤ 50	≥ 1.60	≥ 1.80	≥ 2.01
	> 50	≥ 2.80	≥ 3.30	≥ 3.40
Whole-home dehumidifier	**Product Case Volume (ft^3)**	**Federal Standard (IEF_{base})**	**ENERGY STAR (IEF_{ee})**	**ENERGY STAR Most Efficient (IEF_{ee})**
	≤ 8	≥ 1.77	≥ 2.09	≥ 2.22
	> 8	≥ 2.41	≥ 3.30	≥ 3.81

Default Savings

The annual energy usage and savings of an ENERGY STAR unit over the federal minimum standard are presented in Table 2-116 for each capacity range.

Table 2-116: Dehumidifier Default Energy Savings

	Product[a]	Capacity Range (pints/day or ft^3)	Default Capacity (pints/day)	Federal Standard (IEF)	Efficient (IEF)	$\Delta kWh/yr$	$\Delta kW_{summer\ peak}$	$\Delta kW_{winter\ peak}$
ENERGY STAR	Portable	≤ 25 pints/day	25	1.30	1.57	141	0.0160	0.0206
	Portable	> 25 to ≤ 50 pints/day	50	1.60	1.80	148	0.0168	0.0216
	Whole house	≤8 ft^3	84[b]	1.77	2.09	309	0.0351	0.0453
ENERGY STAR Most Efficient	Portable	≤ 25 pints/day	25	1.30	1.75	211	0.0239	0.0308
	Portable	> 25 to ≤ 50 pints/day	50	1.60	2.01	271	0.0308	0.0397
	Whole house	≤8 ft^3	84[b]	1.77	2.22	410	0.0465	0.0599

[a] There are no default values for portable humidifiers >50 pints/day or whole house dehumidifiers >8ft^3 because there were no ENERGY STAR qualified dehumidifiers with these capacities as of August 15, 2023.
[b] Default capacity is based on the average capacity of ENERGY STAR whole home models as listed on August 15, 2023.

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) Mattison, Lauren et al. (2012). "Dehumidifiers: A Major Consumer of Residential Electricity". Pages 9-208. The Cadmus Group. Weblink
2) U.S. EPA. (2019). ENERGY STAR Dehumidifiers Version 5.0 Cover letter. Weblink
3) U.S. EPA. (2019). ENERGY STAR Program Requirements Product Specification for Dehumidifiers Eligibility Criteria Version 5.0. Weblink
4) 10 CFR 430.32(v) Weblink
5) Dehumidifier Metering in PA and Ohio by ADM from 7/17/2013 to 9/22/2013. Thirty-one 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.
6) U.S. EPA. (2024). ENERGY STAR Most Efficient 2024 Dehumidifiers Recognition Criteria. Weblink
7) U.S. EPA. (2023). ENERGY STAR Most Efficient 2024 Final Criteria Recognition Letter. Weblink

2.4.12 Dehumidifier Retirement

Target Sector	Residential
Measure Unit	Dehumidifier
Measure Life	4 years[Source 7]
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:

$$THI_{PJM} = DB - 0.55 \times (1 - RH) \times (DB - 58) \quad \text{for DB} \geq 58°F$$
$$= DB \quad \text{for DB} < 58°F$$

Similarly, summer peak demand was modeled with the following capacity-dependent linear regression:[Source 2]

$$\Delta kW_{summer\ peak} = 1.3 \cdot 10^{-3} \times CAPY + 1.07 \cdot 10^{-1}$$

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

Definition of Terms

Table 2-117: 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	$°F$	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. For capacity values not listed in the table, it is acceptable to calculate a value by linear interpolation of the savings values for the adjacent capacities.

Table 2-118: 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 summer 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 2-119: 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 2-120: 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 2-121: Default Dehumidifier Retirement Summer Peak Demand Reduction (kW)

Capacity	Default
$\Delta kW_{summer\ peak}$	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) NMR Group for the Pennsylvania Public Utility Commission. (2024, March). 2023 Pennsylvania Statewide Act 129 Residential Baseline Study. Page 164, Table 156. Weblink

4) Resource Adequacy Planning for PJM. (2017, December). PJM Manual 19: Load Forecasting and Analysis Revision: 32. Page 14. Accessed January 2019. Weblink

5) National Solar Radiation Database. 1991–2005 Update: Typical Meteorological Year 3. NREL. Weblink

6) Wilson et al. 2021. End-Use Load Profiles for the U.S. Building Stock: Methodology and Results of Model Calibration, Validation, and Uncertainty Quantification. NREL/TP-5500-80889. Weblink

7) 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.

2.4.13 ENERGY STAR Ceiling Fans

Target Sector	Residential
Measure Unit	Ceiling Fan Unit
Measure Life	10 years[Source 1]
Vintage	Replace on Burnout

ENERGY STAR ceiling fans require a more efficient CFM/Watt rating than standard ceiling fans.

Eligibility

This protocol documents the energy savings attributed to installing an ENERGY STAR ceiling fan[Source 2] in lieu of a ceiling fan meeting federal efficiency requirements.[Source 3]

Algorithms

The energy and peak demand savings are obtained through the following formulas. These algorithms do not seek to estimate the behavioral change attributable to the use of a ceiling fan versus a lower AC setting.

$$\Delta kWh = \Delta W_{fan} \times \frac{1}{1{,}000} \times HOU_{fan} \times 365$$

$$\Delta kW_{summer\ peak} = \Delta kWh \times ETDF_s$$

$$\Delta kW_{winter\ peak} = \Delta kWh \times ETDF_w$$

Definition of Terms

Table 2-122: 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 2-123	4
HOU_{fan}, fan daily hours of use	$\frac{hours}{day}$	EDC Data Gathering Default: 3	EDC data gathering, 1
$ETDF_s$, Summer energy to Demand Factor	$\frac{kW}{kWh}$	SF Only: 0.0001114	5
$ETDF_w$, Winter energy to Demand Factor	$\frac{kW}{kWh}$	SF Only: 0.0001788	5

Table 2-123: 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[20]	36 < D < 78	33

Default Savings

Table 2-124: Energy Savings and Peak Demand Reductions for ENERGY STAR Ceiling Fans

Product Type (Fan Only)	Diameter, D (inches)	ΔkWh	$\Delta kW_{summer\ peak}$	$\Delta kW_{winter\ peak}$
Standard and Low-Mount High Speed Small Diameter (HSSD) Ceiling Fans	D ≤ 36	0.0	0.0000	0.0000
	36 < D < 78	25.2	0.0028	0.0045
	D ≥ 78	33.9	0.0038	0.0061
Hugger Ceiling Fan	36 < D < 78	36.1	0.0040	0.0065

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) ENERGY STAR (2013). Savings Calculator for ENERGY STAR Qualified Light Fixtures & Ceiling Fans U.S. EPA. Weblink

[20] The ENERGY STAR 4.1 specifications allow for hugger ceiling fans with blade spans of ≤ 36” and ≥ 78”, however, as of November 2023, there are no ENERGY STAR qualified products meeting those criteria. They were therefore omitted from this characterization.

2) U.S. EPA. (2018). ENERGY STAR Program Requirements Product Specification for Residential Ceiling Fans Eligibility Criteria Version 4.1. Weblink

3) 10 CFR 430.32(s) Weblink

4) SWE analysis of ENERGY STAR-Certified Ceiling Fans. Accessed 12/5/18. Weblink

5) Wilson et al. 2021. End-Use Load Profiles for the U.S. Building Stock: Methodology and Results of Model Calibration, Validation, and Uncertainty Quantification. NREL/TP-5500-80889. Weblink

2.4.14 ENERGY STAR Air Purifiers

Target Sector	Residential
Measure Unit	Air Purifier
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 an ENERGY STAR unit that is more energy-efficient than a non-ENERGY STAR unit.

Eligibility

In order to qualify, installed air purifiers must be ENERGY STAR-certified and exceed federal minimum integrated energy factor (IEF) standards.

Algorithms

The following algorithms shall be used to calculate the annual energy savings and coincident peak demand savings for this measure:

$$\Delta kWh = \frac{CADR \times Hours \times \left(\frac{1}{CADR/W_{base}} - \frac{1}{CADR/W_{eff}}\right) + \left(POW_{base} - POW_{eff}\right) \times POHours}{1000}$$

$$\Delta kW_{summer\ peak} = \Delta kWh \times ETDF_s$$

$$\Delta kW_{winter\ peak} = \Delta kWh \times ETDF_w$$

Definition of Terms

Table 2-125: Terms, Values, and References for ENERGY STAR Air Purifier

Term	Unit	Values	Source
$CADR$, Clean Air Delivery Rate	*CFM*	EDC Data Gathering	EDC data gathering
$Hours$, Average hours of use per year	*Hours/year*	EDC Data Gathering Default = 5,840	EDC data gathering, 1
$CADR/W_{base}$, Clean Air Delivery Rate per watt for baseline unit	*CFM/W*	EDC Data Gathering Default = Table 2-126	2
$CADR/W_{eff}$, Clean Air Delivery Rate per watt for efficient unit	*CFM/W*	EDC Data Gathering	EDC data gathering
POW_{base}, Partial on mode power of baseline unit	*watts*	1.0	1
POW_{eff}, Partial on mode power of efficient unit	*watts*	EDC Data Gathering	EDC data gathering

$POHours$, Partial on mode hours per year	*Hours/year*	EDC Data Gathering Default = 2,920	EDC data gathering, 3
$ETDF_s$, Summer energy to Demand Factor	$\frac{kW}{kWh}$	0.0001136	4
$ETDF_w$, Winter energy to Demand Factor	$\frac{kW}{kWh}$	0.0001463	4

Table 2-126 shows the federal minimum integrated energy factors.

Table 2-126: Air Purifier Federal Efficiency Standards

Product Capacity (CADR)	Integrated Energy Factor ($PM_{2.5}$ CADR/W)
10 ≤$PM_{2.5}$ CADR <100	1.9
100 ≤$PM_{2.5}$ CADR <150	2.4
$PM_{2.5}$ CADR ≥150	2.9

Sources

1) 16 hours per day * 365 days per year. ENERGY STAR (2016). Savings Calculator for ENERGY STAR Qualified Appliances. U.S. EPA. Weblink
2) 10 CFR 430.32(ee) Weblink
3) (24 hours per day * 365 days per year) – 5,840 run hours per year
4) Wilson et al. 2021. End-Use Load Profiles for the U.S. Building Stock: Methodology and Results of Model Calibration, Validation, and Uncertainty Quantification. NREL/TP-5500-80889. Weblink

2.5 Consumer Electronics

2.5.1 Advanced Power Strips

Target Sector	Residential
Measure Unit	Per Advanced Power Strip
Measure Life	5 years [Source 1]
Vintage	Retrofit

Advanced Power Strips (APS) are surge protectors that contain a number of power-saver sockets. This measure develops equipment savings for both Tier 1 and Tier 2 APS installed for residential home entertainment centers (HEC) or home office applications.

Tier 1 APS have a master control socket arrangement and will shut off the items plugged into the controlled power-saver sockets when they identify 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. 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 remote 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 APS. The most likely area of application is in residential spaces, i.e. single-family and multifamily homes. However, commercial applications are also appropriate for Advanced Power Strips (see Volume 3, Section 3.9.1 Advanced Power Strip Plug Outlets). The protocol considers usage of Advanced Power Strips for HEC and home offices.

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 HEC and home office use for Tier 1 strips. When possible, identify the equipment connected to the APS and apply the associated energy reduction percentage (ERP). If the intended use for a Tier 1 APS is not identified, or if multiple power strips are purchased, the algorithm for “unspecified use” should be applied. Values for “unspecified use” are based on 69% HEC and 31% home office use.[2] Tier 2 APS savings are only identified for HEC as this is where they are typically installed for residential use.

Tier 1 Advanced Power Strip:

$$\Delta kWh = Annual\_Usage \ x \ ERP_{T1} \ x \ ISR \ x \ RR$$

$$\Delta kW_{summer\ peak} = \Delta kWh \ x \ ETDF_{summer}$$

$$\Delta kW_{winter\ peak} = \Delta kWh \ x \ ETDF_{winter}$$

Tier 2 Advanced Power Strips:

$$\Delta kWh = Annual\_Usage \ x \ ERP_{T2} \ x \ ISR \ x \ RR$$

$$\Delta kW_{summer\ peak} = \Delta kWh \ x \ ETDF_{summer}$$

$$\Delta kW_{winter\ peak} = \Delta kWh \ x \ ETDF_{winter}$$

Definition of Terms

Table 2-127: Terms, Values, and References for Advanced Power Strips

Parameter	Unit	Value	Source
Annual_Usage	*kWh*	See Table 2-128	3
ISR, In-service Rate	%	EDC Data Collection Default = 72%	4
RR, Realization Rate	%	92%	3
ERP, energy reduction percentage	%	See Table 2-129	3
$ETDF_s$, Summer energy to demand factor	$\frac{kW}{kWh}$	0.0001136	5
$ETDF_w$, Winter energy to demand factor	$\frac{kW}{kWh}$	0.0001463	5

The following table shows the Energy Reduction Percentage (ERP) for each strip type and end use.

Table 2-128: Annual Usage by End-use

End-Use	Annual Usage (kWh)
Home Entertainment Center	471
Home Office	399
Unspecified	449

Table 2-129: Impact Factors for Advanced Power Strip Types

Strip Type	End-Use	ERP
Tier 1	Home Entertainment Center	27%
Tier 1	Home Office	21%
Tier 1	Unspecified	25%
Tier 2	Home Entertainment Center	44%

Default Savings

Table 2-130: Default Savings for Advanced Power Strips

APS Type	End Use	Energy Savings (ΔkWh)	Summer Peak Demand Reduction ($\Delta kW_{summer\ peak}$)	Winter Peak Demand Reduction ($\Delta kW_{winter\ peak}$)
Tier 1	Home Entertainment Center (HEC)	84.2	0.010	0.012
Tier 1	Home Office	55.5	0.006	0.008
Tier 1	Unspecified use or multiple purchased	74.4	0.008	0.011
Tier 2	Home Entertainment Center (HEC)	137.3	0.016	0.020

Evaluation Protocols

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

Sources

1) California Electronic Technical Reference Manual. "Smart Connected Power Strip". SWAP010-10. Accessed January 2024. Weblink
2) NMR Group for Massachusetts Program Administrators and EEAC. (2018, October). "RLPNC 17-4 and 17-5: Products Impact Evaluation of In-service and Short-Term Retention Rates Study". Weblink
3) NMR Group for Massachusetts Program Administrators and EEAC. (2019, March). "RLPNC 17-3: Advanced Power Strip Metering Study," page 3, Table 1. Weblink
4) Survey and on-site analysis of 17,718 APS installed in Pennsylvania PY13 and PY14 kit and direct install programs.
5) Wilson et al. 2021. End-Use Load Profiles for the U.S. Building Stock: Methodology and Results of Model Calibration, Validation, and Uncertainty Quantification. NREL/TP-5500-80889. Residential, plug-loads Weblink

2.6 BUILDING SHELL

2.6.1 RESIDENTIAL AIR SEALING

Target Sector	Residential, limited to single family detached houses
Measure Unit	Residential Air Sealing
Measure Life	15 years[Source 1]
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

This measure is applicable to single family detached (including manufactured and mobile homes) houses only.

The baseline for this measure is the existing air leakage as determined through approved and appropriate blower door testing methods. 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 of each measure. 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.

In addition, **savings are capped at 40% of the building's heating/cooling load**.[Source 2]

$$\Delta kWh_{cool} \leq 40\% \times CAPY_{cool} \times EFLH_{cool} \times \eta_{base}$$

$$\Delta kWh_{heat} \leq 40\% \times CAPY_{heat} \times EFLH_{heat} \times \eta_{base}$$

Furthermore, if:

$$CFM50_{ee} < \frac{3\ ACH50 \times CondVol}{60\ {}^{min}/_{hr}}$$

additional testing and intervention is necessary to ensure adequate ventilation for occupants and combustion equipment.[Source 3] Lower rates can increase savings but may require the introduction of new mechanical ventilation. The operating energy of this new equipment, as well as the energy loss from the induced ventilation should be deducted from the savings of this measure. In other words, $CFM50_{ee}$ has an effective minimum equivalent to 3 ACH50 unless energy recovery ventilation is employed.

Finally, to ensure that the alterations do not result in a backdraft, post air-sealing combustion appliance zone (CAZ) testing should be considered for any homes with Category I (gravity-draft) exhaust equipment that undergo a significant reduction in infiltration.

ALGORITHMS

To calculate ΔkWh add together the cooling and heating savings calculated using the appropriate coefficients from Table 2-132 and Table 2-133 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 $\frac{Duct_{proto}}{Duct_{base}}$. Values for $Duct_{base}$ may be generated through measurement or by selecting an appropriate value from Table 2-40 in Sec. 2.2.10.

The prototype variables in the savings equations for this measure do not refer to the baseline or efficient conditions of the home undergoing improvement. Instead, expressions of the form $\frac{proto}{base}$ are used to scale the savings of the home being improved ($base$) to those of the prototype home which was based on statewide averages from the Act 129 2023 Pennsylvania Residential Baseline Study and used to derive the regressions below. This scaling accounts for differences in energy consumption resulting in deviations in HVAC equipment and distribution system efficiencies from those of the Baseline.

$$\Delta kWh_{cool} = \frac{\eta_{proto}}{\eta_{base}} \times \frac{Duct_{proto}}{Duct_{base}} \times \left(\frac{a_{cool}}{100{,}000} \times \left(CFM50_{base}{}^2 - CFM50_{ee}{}^2\right) + b_{cool} \times \left(CFM50_{base} - CFM50_{ee}\right)\right)$$

$$\Delta kWh_{hea} = \frac{\eta_{proto}}{\eta_{base}} \times \frac{Duct_{proto}}{Duct_{base}} \times \left(\frac{a_{hea}}{100{,}000} \times \left(CFM50_{base}{}^2 - CFM50_{ee}{}^2\right) + b_{heat} \times \left(CFM50_{base} - CFM50_{ee}\right)\right)$$

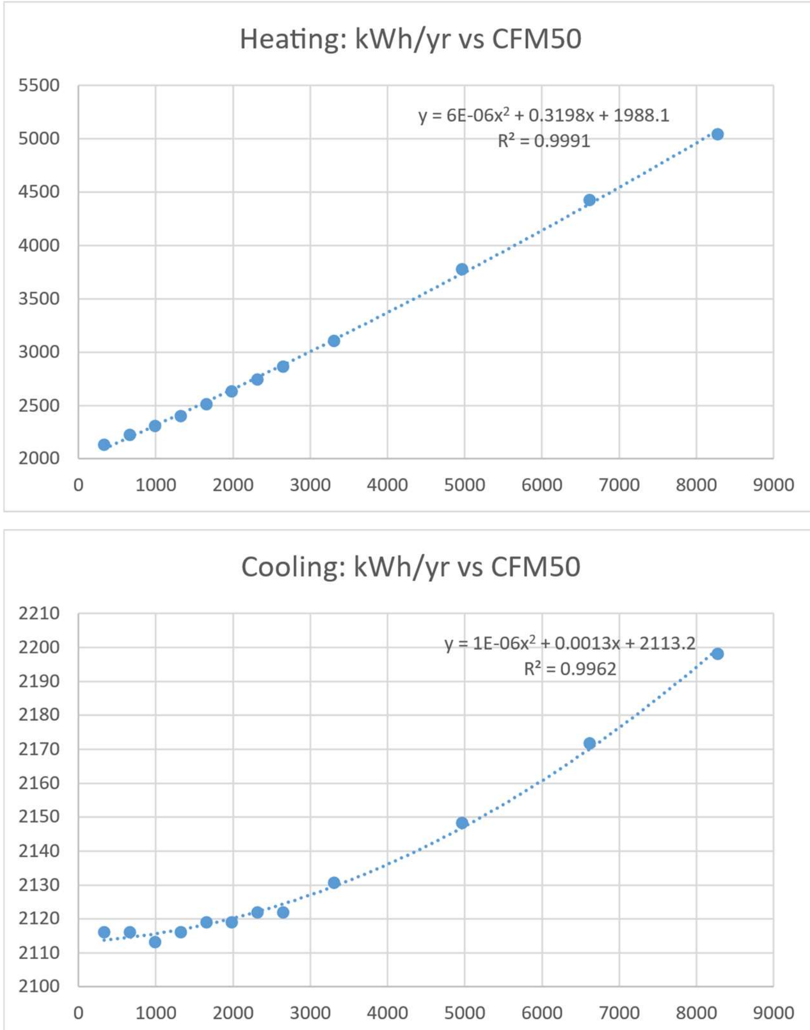
$$\Delta kWh = \Delta kWh_{cool} + \Delta kWh_{heat}$$

$$\Delta kW_{summer\ peak} = \Delta kWh_{cool} \div EFLH_{cool} \times CF_{cool}$$

$$\Delta kW_{winter\ peak} = \Delta kWh_{heat} \div EFLH_{heat} \times CF_{heat}$$

Note: The savings equations above are based on *quadratic* regressions because the change in energy savings for the same reduction in infiltration varies with the initial condition, as well as climate and HVAC technology. In general, there is a larger benefit for an equivalent reduction of CFM50 in a home when tightening very loose building shells compared to homes with a lower initial infiltration rate. For example, when starting from 6600 CFM50 in Figure 2-1, a 1650 CFM50 reduction yields 24 kWh/yr savings whereas starting from 2300 CFM50 results in 9 kWh/yr savings. Since the coefficients of the squared infiltration reduction term are so small, they are multiplied by 10^5 to simplify Table 2-132 and Table 2-133. This scaling is later reversed in the savings calculations.

Figure 2-1: Example Regressions for Ductless Mini-splits in Climate Region D



DEFINITION OF TERMS

Table 2-131: 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
CondVol, Conditioned volume of the home	*ft³*	Measured, EDC Data Gathering	EDC Data Gathering
$Duct_{base}$, Baseline duct efficiency	*None*	EDC Data Gathering: measured value, or appropriate value selected from Table 2-40 in Sec. 2.2.10	EDC Data Gathering

$Duct_{proto}$, Prototype duct efficiency	*None*	Default: See Table 2-40 in Sec. 2.2.10 for "R-2 Average Basement + 50% Conditioned"	4
η_{base}, Baseline equipment efficiency	*varies*	Measured, EDC Data Gathering Default: η_{proto}	EDC Data Gathering
η_{proto}, Prototype equipment efficiency	*varies*	See Table 2-151 in 2.6.5	5
a_{system}, Unit Energy Savings per $CFM50^2$ of air leakage reduction	$\frac{kWh/yr}{CFM_{50}{}^2}$	See Table 2-132	6
b_{system}, Unit Energy Savings per CFM50 of air leakage reduction	$\frac{kWh/yr}{CFM_{50}}$	See Table 2-133	6
$EFLH_{cool}$, 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	7
$EFLH_{heat}$, 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	7
$CF_{summer\ peak}$, Summer demand Coincidence Factor	*Proportion*	See *Summer CF* in Vol. 1, App. A	7
$CF_{winter\ peak}$, Winter demand Coincidence Factor	*Proportion*	See *Winter CF* in Vol. 1, App. A	7
$CAPY_{cool}$, The cooling capacity of the equipment being installed	$kBTU/hr$	EDC Data Gathering	AEPS Application; EDC Data Gathering
$CAPY_{heat}$, The heating capacity of the heat pump being installed	$kBTU/hr$	EDC Data Gathering	AEPS Application; EDC Data Gathering

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 2-132: Default Unit Energy Savings per Reduced CFM50[2] for Air Sealing

Climate Region Reference City		a_{cool}				a_{heat}				
		ASHP	Central AC	GSHP	Mini-split	ASHP	Base-board	Electric Furnace	GSHP	Mini-split
C	Allentown	-0.062	-0.021	0.028	0.097	-1.445	-1.790	-3.317	-1.396	-0.909
A	Binghamton	0.000	0.086	0.061	-1.648	-1.159	0.103	-0.287	-0.789	-1.232
G	Bradford	-2.255	-2.660	-1.547	-4.326	-1.828	-5.151	-4.540	-1.831	-0.709
I	Erie	-0.062	-0.067	0.021	0.059	-0.952	-1.803	-1.467	-0.706	-1.314
E	Harrisburg	-0.067	-1.906	0.013	-0.641	-1.722	-3.238	-4.584	-2.131	-1.141
D	Philadelphia	-0.148	-0.162	-0.202	0.111	0.830	3.626	2.806	0.647	0.649
H	Pittsburgh	0.000	0.026	0.075	0.068	-1.264	-2.548	-2.277	-0.940	-1.405
B	Scranton	-0.031	-0.023	0.049	0.068	-1.42	-2.354	-2.606	-0.990	-1.316
F	Williamsport	-0.03	-0.020	0.070	0.067	-1.921	-4.028	-4.553	-1.740	-1.662

Table 2-133: Default Unit Energy Savings per Reduced CFM50 for Air Sealing

Climate Region Reference City		b_{cool}				b_{heat}				
		ASHP	Central AC	GSHP	Mini-split	ASHP	Base-board	Electric Furnace	GSHP	Mini-split
C	Allentown	0.021	0.020	-0.007	-0.014	0.833	1.943	2.179	0.684	0.553
A	Binghamton	0.000	-0.010	-0.014	0.222	1.141	2.527	2.702	0.875	0.795
G	Bradford	0.321	0.380	0.240	0.478	1.241	3.137	3.233	1.166	0.777
I	Erie	0.001	0.004	-0.017	-0.021	0.977	2.431	2.518	0.749	0.712
E	Harrisburg	0.033	0.228	0.002	0.126	0.827	2.010	2.226	0.713	0.565
D	Philadelphia	0.064	0.071	0.071	0.001	0.487	1.130	1.305	0.466	0.320
H	Pittsburgh	0.000	0.001	-0.017	-0.018	0.917	2.271	2.340	0.711	0.664
B	Scranton	0.004	0.005	-0.016	-0.019	0.899	2.161	2.273	0.691	0.627
F	Williamsport	0.008	0.009	-0.015	-0.017	0.929	2.278	2.410	0.750	0.657

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 requires 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) GDS Associates, Inc. (2007). Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures. Table 1 – Residential Measures. Weblink

2) Lawrence Berkley National Laboratory (1999). Residential Heating and Cooling Loads Component Analysis. Weblink

3) Estimate by Statewide Evaluator informed by the following construction standards:

a. 3 ACH50 maximum. International Code Council. (2017). 2018 International Energy Conservation Code. Weblink

b. 0.93 ACH50 maximum. Passive House Institute US. (2003). Phius 2021: Passive Building Standard Certification Guidebook. Retrieved January 3, 2024 from Weblink

c. 3.6 ACH50 maximum. ASHRAE (2023). Standards Actions (Vol. 13, Issue 17). Retrieved January 5, 2024. Weblink

4) NMR Group for the Pennsylvania Public Utility Commission. (2024, March). 2023 Pennsylvania Statewide Act 129 Residential Baseline Study. Weblink

5) Equipment efficiencies were chosen based on weighted single-family detached results from the 2023 Pennsylvania Residential Baseline, standardized equipment library entries (ASHP), and expertise (GSHP).

6) 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 average characteristics determined through the Pennsylvania Act 129 2023 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 used to calculate energy savings.

7) Based on the Phase III SWE team's analysis of regional HVAC runtime data collected from ecobee's Donate Your Data research service. Weblink

2.6.2 Weather Stripping, Caulking, and Outlet Gaskets

Target Sector	Residential
Measure Unit	Per Project
Measure Life	15 years[Source 1]
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 400 kWh of savings**. Projects with 400 kWh or more of savings should follow the Residential Air Sealing section.

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:

$$\Delta kWh_{cool} \quad \frac{1.08 \times \Delta CFM_{50} \times CDD \times 24 \times ISR}{N \times SEER2 \times 1{,}000} \times LM \times DUA \times F_{RAC} \times \%_{elec}$$

$$\Delta kWh_{heat} = \frac{1.08 \times \Delta CFM_{50} \times HDD \times 24 \times ISR}{N \times HSPF2 \times 1{,}000} \times \%_{elec}$$

$$\Delta kWh = (\Delta kWh_{cool} + \Delta kWh_{heat}) < 400\ kWh$$ If > 400 kWh use Sec. 2.6.1

$$\Delta kW_{summer\ peak} = \Delta kWh_{cool} \times ETDF_{summer}$$

$$\Delta kW_{winter\ peak} = \Delta kWh_{heat} \times ETDF_{winter}$$

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:

$$SEER = EER_g \times GSHPDF$$

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

PTAC and PTHP

$SEER = EER$

DEFINITION OF TERMS

Table 2-134: Terms, Values, and References for Weather Stripping

Term	Unit	Values	Source
ΔkWh_{cool}, Annual cooling energy savings	*kWh/year*	Calculated	-
ΔkWh_{heat}, Annual heating energy savings	*kWh/year*	Calculated	-
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 2-137	2, 3
CDD, Cooling degree-days	*°F-day/year*	See CDD values in Vol. 1, App. A	4
HDD, Heating degree-days	*°F-day/year*	See HDD values in Vol. 1, App. A	4
ISR, In-service rate	*None*	EDC Data Gathering Default: Direct install = 1 Kit delivery = 0.16	5
LM, Latent multiplier to convert the calculated sensible load to the total (sensible and latent) load	*None*	See Table 2-136	6
DUA, Discretionary use adjustment to account for uncertainty in predicting cooling system usage patterns of occupants	*None*	0.75	7
F_{RAC}, Adjustment factor to relate sealed area to area served by room air conditioners	*None*	If Room AC = 0.24 If non-Room AC = 1.0	8
$\%_{cool}$, percent of homes with comfort cooling.	*None*	EDC Data Gathering Default = 67%	9
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 2-135 Default = 16.7	10
$SEER, SEER2$, Cooling system seasonal efficiency	$\frac{Btu}{W \cdot h}$	EDC Data GatheringDefault:13.9, or See Early Replacement values in Table 2-10 of Sec. 2.2.1	11, 15

$\%_{elec}$, percent of homes with electric primary heating fuel	*None*	EDC Data Gathering Default = 36%	9
$HSPF, HSPF2$, Heating system seasonal efficiency	$\frac{Btu}{W \cdot h}$	EDC Data Gathering Default: 7.75, or See Early Replacement values in Table 2-10 in Sec. 2.2.1	11, 15
$ETDF_{summer}$, Summer energy to demand factor	*kW/kWh*	0.0005272	12
$ETDF_{winter}$, Winter energy to demand factor	*kW/kWh*	0.0003398	12
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 = 17.1	13
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	13
GSHPDF, Ground Source Heat Pump De-rate Factor	*Proportion*	0.885	14

Table 2-135: Correlation Factor[Source 10]

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 2-136: Latent Multiplier Values by Climate Reference City[Source 6]

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 2-137: Typical Reductions in Leakage[Sources 2,3]

Technology	Application	ΔCFM50[Source 5]
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 13.9 SEER CAC and electric heating HSPF of 7.75.[Source 15]

Table 2-138, Table 2-139, Table 2-140 present default savings for direct install measures. These savings assume an ISR of 1.0. Cooling savings assume the home has comfort cooling and heating savings assume the home has electric heating.

Table 2-141, Table 2-142, and Table 2-143 present default savings for measures delivered via kit. These savings assume an ISR of 0.16, $\%_{cool}$ of 0.67 and $\%_{elec}$ of 0.36.[Source 5, Source 9]

Table 2-138: Default Annual Energy Savings – Direct Installation

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	8.618	5.250	5.132	11.199	6.822	6.669
A	Binghamton, NY	2.471	1.505	1.471	15.300	9.321	9.111
G	Bradford	4.148	2.527	2.470	15.667	9.544	9.330
I	Erie	9.529	5.805	5.675	12.596	7.673	7.501
E	Harrisburg	6.349	3.868	3.781	10.666	6.497	6.352
D	Philadelphia	10.324	6.289	6.148	9.489	5.781	5.651
H	Pittsburgh	5.731	3.491	3.413	11.869	7.230	7.068
B	Scranton	7.190	4.380	4.282	12.166	7.411	7.245
F	Williamsport	7.519	4.580	4.477	12.176	7.418	7.251

Table 2-139: Default Summer Peak Demand Savings – Direct Installation

Climate Region	Reference City	Caulked Penetrations (ΔkW/ pen.)	Weather Stripping, Caulking and Sealing (ΔkW/10 lf)	Outlet Gaskets (ΔkW/gasket)
C	Allentown	0.0045676	0.0027824	0.0027200
A	Binghamton, NY	0.0013095	0.0007977	0.0007798
G	Bradford	0.0021984	0.0013392	0.0013092
I	Erie	0.0050504	0.0030766	0.0030075
E	Harrisburg	0.0033649	0.0020498	0.0020038
D	Philadelphia	0.0054718	0.0033333	0.0032585
H	Pittsburgh	0.0030373	0.0018502	0.0018087
B	Scranton	0.0038110	0.0023215	0.0022694
F	Williamsport	0.0039848	0.0024275	0.0023730

Table 2-140: Default Winter Peak Demand Savings – Direct Installation

Climate Region	Reference City	Caulked Penetrations (ΔkW/ pen.)	Weather Stripping, Caulking and Sealing (ΔkW/10 lf)	Outlet Gaskets (ΔkW/gasket)
C	Allentown	0.0038075	0.0023194	0.0022674
A	Binghamton, NY	0.0052021	0.0031690	0.0030979
G	Bradford	0.0053268	0.0032449	0.0031721
I	Erie	0.0042825	0.0026088	0.0025503
E	Harrisburg	0.0036264	0.0022091	0.0021595
D	Philadelphia	0.0032264	0.0019654	0.0019213
H	Pittsburgh	0.0040354	0.0024582	0.0024031
B	Scranton	0.0041363	0.0025197	0.0024632
F	Williamsport	0.0041400	0.0025220	0.0024654

Table 2-141: Default Annual Energy Savings – Kit Delivery

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	0.924	0.563	0.550	0.645	0.393	0.384
A	Binghamton, NY	0.265	0.161	0.158	0.881	0.537	0.525
G	Bradford	0.445	0.271	0.265	0.902	0.550	0.537
I	Erie	1.022	0.622	0.608	0.726	0.442	0.432
E	Harrisburg	0.681	0.415	0.405	0.614	0.374	0.366
D	Philadelphia	1.107	0.674	0.659	0.547	0.333	0.325
H	Pittsburgh	0.614	0.374	0.366	0.684	0.416	0.407
B	Scranton	0.771	0.470	0.459	0.701	0.427	0.417
F	Williamsport	0.806	0.491	0.480	0.701	0.427	0.418

Table 2-142: Default Summer Peak Demand Savings – Kit Delivery

Climate Region	Reference City	Caulked Penetrations (ΔkW/ pen.)	Weather Stripping, Caulking and Sealing (ΔkW/10 lf)	Outlet Gaskets (ΔkW/gasket)
C	Allentown	0.0004896	0.0002983	0.0002916
A	Binghamton, NY	0.0001404	0.0000855	0.0000836
G	Bradford	0.0002357	0.0001436	0.0001403
I	Erie	0.0005414	0.0003298	0.0003224
E	Harrisburg	0.0003607	0.0002197	0.0002148
D	Philadelphia	0.0005866	0.0003573	0.0003493
H	Pittsburgh	0.0003256	0.0001983	0.0001939
B	Scranton	0.0004085	0.0002489	0.0002433
F	Williamsport	0.0004272	0.0002602	0.0002544

Table 2-143: Default Winter Peak Demand Savings – Kit Delivery

Climate Region	Reference City	Caulked Penetrations (ΔkW/ pen.)	Weather Stripping, Caulking and Sealing (ΔkW/10 lf)	Outlet Gaskets (ΔkW/gasket)
C	Allentown	0.0002193	0.0001336	0.0001306
A	Binghamton, NY	0.0002996	0.0001825	0.0001784
G	Bradford	0.0003068	0.0001869	0.0001827
I	Erie	0.0002467	0.0001503	0.0001469
E	Harrisburg	0.0002089	0.0001272	0.0001244
D	Philadelphia	0.0001858	0.0001132	0.0001107
H	Pittsburgh	0.0002324	0.0001416	0.0001384
B	Scranton	0.0002383	0.0001451	0.0001419
F	Williamsport	0.0002385	0.0001453	0.0001420

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) GDS Associates, Inc. (2007). Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures. Table 1 – Residential Measures. Weblink
2) ASHRAE. (2001) AHSRAE Handbook – Fundamentals, Chapter 26: Ventilation and Infiltration, Table 1.

3) ΔCFM50 is estimated by dividing the ELA by 0.055. The Energy Conservatory. (2012, August). Minneapolis Blower Door Operation Manual. Page 83. Weblink

4) Based on the Phase III SWE team's analysis of regional HVAC runtime data collected from ecobee's Donate Your Data research service (Weblink) and updated based on the latest CDD and HDD values from NOAA's 15-year annual climate Normals (2006–2020) (Weblink)

5) Weighted average of ISRs from surveys of FirstEnergy customers that received outlet gaskets in kits in PY13 and PY14.

6) LM values calculated as total load (sensible + latent) divided by sensible load, from sensible and latent values in Harriman et al. (1997, November). ASHRAE Journal "Dehumidification and Cooling Loads from Ventilation Air." Weblink

7) Energy Center of Wisconsin. (2008, May). Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research. Weblink

8) NMR Group for the Pennsylvania Public Utility Commission. (2024, March). 2023 Pennsylvania Statewide Act 129 Residential Baseline Study. Weblink. Average home conditioned floor area = 2,019 ft^2; average number of room AC units per home = 1.74; average Room AC capacity = 7,161 BTU/hr. Per ENERGY STAR Room AC sizing chart (Weblink), 7,161 BTU/hr of cooling serves approximately 283 ft^2. F_{RAC} = (283 ft^2 × 1.74)/(2,019 ft^2) = 0.24.

9) NMR Group for the Pennsylvania Public Utility Commission. (2024, March). 2023 Pennsylvania Statewide Act 129 Residential Baseline Study. Page 111, Table 93. Weblink.

10) The N factor methodology was developed by Lawrence Berkeley Lab to convert air flow measurements taken at 50 pascal pressure (from blower door tests) to natural air changes. The N factors presented here are taken from Krigger, J. and Dorsi, C. (2004), "Residential Energy: Cost Savings and Comfort for Existing Buildings", page 284.

11) NMR Group for the Pennsylvania Public Utility Commission. (2024, March). 2023 Pennsylvania Statewide Act 129 Residential Baseline Study. Page 115, Table 97, page 120, Table 103. Weblink. Air source heat pump efficiencies calculated using 2023 Pennsylvania Residential Baseline Study data. Federal minimum efficiencies for GSHP due to small sample size for GSHP in baseline study.

12) Wilson et al. 2021. End-Use Load Profiles for the U.S. Building Stock: Methodology and Results of Model Calibration, Validation, and Uncertainty Quantification. NREL/TP-5500-80889. Weblink

13) Federal minimum efficiency standards, based on ASHRAE 90.1-2019. Weblink

14) McQuay. (2002). Application Guide 31-008, Geothermal Heat Pump Design Manual. Engineering Estimate - See System Performance of Ground Source Heat Pumps

15) NMR Group for the Pennsylvania Public Utility Commission. (2024, March). 2023 Pennsylvania Statewide Act 129 Residential Baseline Study. Weblink. 7.75 HSPF value is an average performance efficiency of all electric heating systems, including both resistance and heat pump technologies.

2.6.3 Ceiling/Attic, Wall, Floor and Rim Joist Insulation

Target Sector	Residential
Measure Unit	Per Project
Measure Life	15 years Source 1
Vintage	Retrofit, New Construction

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 with a primary electric heating and/or cooling source.

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.

Floor Insulation
This measure applies to the installation of new insulation to the floors of existing residential buildings with vented (unconditioned) crawlspaces.

Rim Joist Insulation
This measure applies to the installation of new 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.

Required R-values

For retrofit applications, the new insulation must achieve R-values that meet or exceed ENERGY STAR recommendations. Source 2 ENERGY STAR guidance is based on the 2021 IECC. Source 3

For new construction applications, the insulation must achieve R-values exceeding the 2021 IECC.

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.

$$\Delta kWh_{cool} = \left(\frac{1}{R_{base}} - \frac{1}{R_{ee}}\right) \times A \times (1 - FF) \times \frac{24 \times CDD \times DUA}{SEER \times 1{,}000} \times F_{RAC}$$

$$\Delta kWh_{heat} = \left(\frac{1}{R_{base}} - \frac{1}{R_{ee}}\right) \times A \times (1 - FF) \times \frac{24 \times HDD}{HSPF \times 1{,}000}$$

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

$$\Delta kW_{summer\ peak} = \Delta kWh_{cool} \times ETDF_{summer}$$

$$\Delta kW_{winter\ peak} = \Delta kWh_{heat} \times ETDF_{winter}$$

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:

$$SEER = EER_g \times GSHPDF$$

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

PTAC and PTHP

$$SEER = EER$$

Definition of Terms

Table 2-144: 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	$\frac{°F \cdot ft^3 \cdot hr}{BTU}$	Retrofit: EDC Data Gathering or Default: Table 12	EDC Data Gathering, Various
		New Construction: Table 2-146	3
R_{ee}, R-value after adding new insulation	$\frac{°F \cdot ft^3 \cdot hr}{BTU}$	Retrofit: EDC Data Gathering or Default: Table 2-145	EDC Data Gathering, 2
		New Construction: EDC Data Gathering	
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 continuous = 0% If stud-cavity = 25%	11
CDD, Annual cooling degree-days, base 65°F	*°F-day/year*	See *CDD* in Vol 1., App. A	12
HDD, Annual heating degree-days, base 65°F	*°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	13
$SEER$, Cooling system seasonal efficiency	$\frac{BTU}{W \cdot h}$	EDC Data Gathering Default: See Early Replacement or New Construction values (as appropriate) in Table 2-10 in Sec. 2.2.1	14
$HSPF$, Heating system seasonal efficiency	$\frac{BTU}{W \cdot h}$	EDC Data Gathering Default: See Early Replacement or New Construction values (as	14

Term	Unit	Values	Source
		appropriate) in Table 2-10 in Sec. 2.2.1	
F_{RAC}, Adjustment factor to relate insulated area to area served by room air conditioners	*None*	If Room AC = 0.24 If non-Room AC = 1.0	15
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	16
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 = 17.1	16
$GSHPDF$, Ground Source Heat Pump De-rate Factor	*Proportion*	0.885	17
$ETDF_{summer}$, Summer energy to demand factor	*kW/kWh*	0.0005272	18
$ETDF_{winter}$, Winter energy to demand factor	*kW/kWh*	0.0003398	18

Table 2-145: Retrofit Default Base and Energy Efficient R-Values

Component	Description	Value $(\frac{°F \cdot ft^2 \cdot hr}{Btu})$	Source
$R_{ceil,base}$, Assembly R-value of ceiling/attic before retrofit	Un-insulated attic	5	4, 5
	4.5” (R-13) of existing attic insulation	16	4, 5
	6” (R-19) of existing attic insulation	22	4, 5
	10” (R-30) of existing attic insulation	30	4, 5
	Vaulted ceiling insulation, primarily consisting of fiberglass batts	22.9	6
	Default unknown: flat ceiling insulation, typically consisting of fiberglass batts	27.3	7
$R_{ceil,ee}$, Assembly R-value of ceiling/attic after retrofit	Retrofit to R-60 total attic insulation	60	2
$R_{wall,base}$, Assembly R-value of wall before retrofit	Un-insulated wall with 2x4 studs @ 16” o.c., w/ wood/vinyl siding	5	4, 5
	Default unknown: primarily batt insulated 2x4 stud cavity	13	8
$R_{wall,ee}$, Assembly R-value of wall after retrofit	Add R10 insulative wall sheathing beneath the new siding	15	2
$R_{floor,base}$, R-value of floor before retrofit	Thermal resistance of existing floor above crawlspace	4	4, 5
	Default unknown: primarily uninsulated floors with some homes having fiberglass batts installed	6.9	9
$R_{floor,ee}$, R-value of floor after retrofit	IECC climate zone 4	19	2
	IECC climate zone 5	30	

$R_{rimjoist,base}$, R-value of rim joist before retrofit	Thermal resistance of existing rim joist	2.5	4, 5
	Default unknown: mix of uninsulated and insulated homes. Insulation primarily fiberglass batt type.	7.4	10
$R_{rim\ joist,ee}$, R-value of rim joist after retrofit	IECC climate zone 4: Add R10 insulative wall sheathing or R13 batt	12.5	2
	IECC climate zone 5: Add R15 insulative wall sheathing or R19 batt	17.5	

Table 2-146: New Construction Baseline R-Values (2021 IECC)

IECC Climate Zone	Ceiling R-Value	Wood Frame Wall R-Value	Floor R-Value	Rim Joist R-Value
4	60	30 or 20&5ci or 13&10ci or 0&20ci	19	10ci or 13
5			30	15ci or 19 or 13&5ci

Notes on reading values in Table 2-146:

- **Wood Frame Wall R-value:** The first value is cavity insulation; the second value is continuous insulation. Therefore, as an example, "20 & 5ci" means R-20 cavity insulation plus R-5 continuous insulation.
- **Rim Joist R-Value, Climate Zone 4**: "10ci or 13" means R-10 continuous insulation on the interior or exterior surface of the wall or R-13 cavity insulation on the interior side of the wall.
- **Rim Joist R-Value, Climate Zone 5**: "15ci or 19 or 13 13&5ci" means R-15 continuous insulation on the interior or exterior surface of the wall; or R-19 cavity insulation on the interior side of the wall; or R-13 cavity insulation on the interior of the wall in addition to R-5 continuous insulation on the interior or exterior surface of the wall.

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. (2007). Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures. Weblink. 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) ENERGY STAR Recommended Home Insulation R-Values. Accessed February 2023. Weblink

3) 2021 International Energy Conservation Code, Table R402.1.3: Insulation Minimum R-values and Fenestration Requirements by Component. Weblink

4) 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.

5) ASHRAE. (2009). Fundamentals. Chapter 25 and 26. Method from “Total Thermal Resistance of a Flat Building Assembly” in Chapter 25. Thermal resistance values from Chapter 26.

6) NMR Group for the Pennsylvania Public Utility Commission. (2024, March). 2023 Pennsylvania Statewide Act 129 Residential Baseline Study. Section 6.3.6: Vaulted Ceiling R-value. Weblink

7) NMR Group for the Pennsylvania Public Utility Commission. (2024, March). 2023 Pennsylvania Statewide Act 129 Residential Baseline Study. Section 6.3.3: Flat Ceiling R-value. Weblink

8) NMR Group for the Pennsylvania Public Utility Commission. (2024, March). 2023 Pennsylvania Statewide Act 129 Residential Baseline Study. Section 6.2.3: Conditioned to Ambient Walls Average R-value. Weblink

9) NMR Group for the Pennsylvania Public Utility Commission. (2024, March). 2023 Pennsylvania Statewide Act 129 Residential Baseline Study. Section 6.4.3: Frame Floor R-value. Weblink

10) NMR Group for the Pennsylvania Public Utility Commission. (2024, March). 2023 Pennsylvania Statewide Act 129 Residential Baseline Study. Section 6.5.3: Foundation Wall R-value. Weblink. Results in the referenced study are presented for foundation walls, which are applied in this TRM as the best proxy for rim joist insulation.

11) ASHRAE. (2021). Fundamentals. Chapter 27, Page 27.3.

12) Based on the Phase III SWE team’s analysis of regional HVAC runtime data collected from ecobee’s Donate Your Data research service (Weblink) and updated based on the latest CDD and HDD values from NOAA’s 15-year annual climate Normals (2006–2020) (Weblink)

13) Energy Center of Wisconsin, (2008, May). “Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research.” Page 31. Weblink

14) NMR Group for the Pennsylvania Public Utility Commission. (2024, March). 2023 Pennsylvania Statewide Act 129 Residential Baseline Study. Weblink. Air source heat pump efficiencies calculated using 2023 Pennsylvania Residential Baseline Study data. Federal minimum efficiencies for GSHP due to small sample size for GSHP in baseline study.

15) NMR Group for the Pennsylvania Public Utility Commission. (2024, March). 2023 Pennsylvania Statewide Act 129 Residential Baseline Study. Weblink. Average home conditioned floor area = 2,019 ft^2; average number of room AC units per home = 1.74; average Room AC capacity = 7,161 BTU/hr. Per ENERGY STAR Room AC sizing chart (Weblink), 7,161 BTU/hr of cooling serves approximately 283 ft^2. F_{RAC} = (283 ft^2 × 1.74)/(2,019 ft^2) = 0.24.

16) Federal minimum efficiency standards, based on ASHRAE 90.1-2019. Weblink

17) McQuay Application Guide 31-008, Geothermal Heat Pump Design Manual, 2002. Engineering Estimate - See System Performance of Ground Source Heat Pumps

18) Wilson et al. 2021. End-Use Load Profiles for the U.S. Building Stock: Methodology and Results of Model Calibration, Validation, and Uncertainty Quantification. NREL/TP-5500-80889. Weblink

2.6.4 Basement or Crawl Space Wall Insulation

Target Sector	Residential
Measure Unit	Insulation Addition
Measure Life	15 years[Source 1]
Vintage	Retrofit, New Construction

This protocol covers the calculation of energy and demand savings associated with insulating foundation walls in basements and crawl spaces in residential homes. 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 protocol applies to the installation of insulation to the walls of basements or unvented crawl space walls in existing residential buildings.

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.

In 2021 IECC Climate Zone 4, basement or crawl space insulation should have either a minimum R-10 continuous insulation on the interior or exterior of the home, or R-13 cavity insulation on the interior of the home. In IECC Climate Zone 5, basement or crawl space insulation should have either a minimum of R-15 continuous insulation on the interior or exterior of the home, or R-19 cavity insulation on the interior of the home, or R-13 cavity insulation on the interior of the home and R-5 continuous insulation.[Source 3]

Algorithms

Savings are due to a reduction in cooling and heating requirements due to insulation.

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

$$\Delta kWh_{cool} = \left(\frac{1}{R_{base,ag}} - \frac{1}{R_{base,ag} + R_{ee}}\right) \times \frac{L \times H_{ag} \times (1 - FF) \times CDD \times 24}{\text{SEER} \times 1{,}000} \times DUA \times F_{RAC}$$

$$\Delta kWh_{heat} = \left\{\left(\frac{1}{R_{base,ag}} - \frac{1}{R_{base,ag} + R_{ee}}\right) \times H_{ag} + \left(\frac{1}{R_{base,bg}} - \frac{1}{R_{base,bg} + R_{ee}}\right) \times H_{bg}\right\} \times \frac{L \times (1 - FF) \times HDD \times 24}{\text{HSPF} \times 1{,}000}$$

$$\Delta kW_{summer\ peak} = \Delta kWh_{cool} \times ETDF_{summer}$$

$$\Delta kW_{winter\ peak} = \Delta kWh_{heat} \times ETDF_{winter}$$

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:

$$SEER = EER_g \times GSHPDF$$

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

PTAC and PTHP

$$SEER = EER$$

Definition of Terms

Table 2-147: Terms, Values, and References for Basement or Crawl Space Insulation

Term	Unit	Values		Source
ΔkWh_{cool}, Annual cooling energy savings	*kWh/year*	Calculated		-
ΔkWh_{heat}, Annual heating energy savings	*kWh/year*	Calculated		-
$R_{base,ag}$, baseline R-value of foundation wall above grade	$\frac{°F \cdot ft^2 \cdot h}{BTU}$	Retrofit:	EDC Data Gathering	EDC Data Gathering
			Uninsulated: R-1.47	4
			Default/unknown: R-8.9	14
		New Construction:	IECC climate zone 4: 10ci or 13	3
			IECC climate zone 5: 15ci or 19 or 13&5ci	
$R_{base,bg}$, the combined average R-value for the wall and Earth at the height of foundation wall below grade (H_{bg})	$\frac{°F \cdot ft^2 \cdot h}{BTU}$	Table 2-148		3, 4
R_{ee}, R-value of installed spray foam, rigid foam, or cavity insulation applied to foundation wall	$\frac{°F \cdot ft^2 \cdot h}{BTU}$	EDC Data Gathering		EDC Data Gathering
L, total length of all perimeter foundation walls receiving new insulation	*ft*	EDC Data Gathering		EDC Data Gathering
H_{ag}, height of insulated foundation wall above grade	*ft*	EDC Data Gathering		EDC Data Gathering
H_{bg}, height of insulated foundation 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*	If continued = 0% If stud-baycavity = 25%		5
CDD, cooling degree days matched to basement or crawlspace condition (conditioned/unconditioned). Insulation in unconditioned spaces 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		6

Term	Unit	Values	Source
HDD, heating degree days matched to basement or crawlspace condition (conditioned/unconditioned). Insulation in unconditioned spaces is modeled by reducing the degree days to reflect the smaller but non-zero contribution to heating and cooling load.	*°F-day*	See HDD in Vol. 1 App. A	6
DUA, Discretionary Use Adjustment, adjustment for times when AC is not operating even though conditions may call for it	*Proportion*	0.75	7
F_{RAC}, Adjustment factor to relate insulated area to area served by room air conditioners	*None*	If Room AC = 0.24 If non-Room AC = 1.0	8
$SEER$, Cooling system seasonal efficiency	$\frac{BTU}{W \cdot h}$	EDC Data Gathering Default: See Early Replacement or New Construction values (as appropriate) in Table 2-10 in Sec. 2.2.1	9
$HSPF$, Heating system seasonal efficiency	*Proportion*	EDC Data Gathering Default: See Early Replacement or New Construction values (as appropriate) in Table 2-10 in Sec. 2.2.1	9
COP_g, Coefficient of Performance. This is a measure of the efficiency of a ground source heat pump	None	EDC Data Gathering Default = 13.6	10
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 = 17.1	10
$GSHPDF$, Ground Source Heat Pump De-rate Factor	*Proportion*	0.885	11
$ETDF_{summer}$, Summer energy to demand factor	*kW/kWh*	0.0005272	12
$ETDF_{winter}$, Winter energy to demand factor	*kW/kWh*	0.0003398	12

Table 2-148 should be used to determine the average thermal resistance of the combined wall and Earth ($R_{base,bg}$) at the height of foundation wall below grade (H_{bg}). Use a crawl space wall that is 5 ft in height as an example of proper use of the table. If the crawl space wall is 5 ft in height and 1 ft is above grade (H_{ag} = 1 ft), then the remaining 4 ft are below grade (H_{bg} = 4 ft). To determine the $R_{base,bg}$ for that below-grade wall height, look for the column for H_{bg} = 4ft in Table 2-148. $R_{base,bg}$ in this example is therefore 4.26 °F-ft^2-h/BTU.

Table 2-148: Below-grade R-values (°F-ft²-h/BTU) for combined Earth and basement wall

	Retrofit		New Construction[Source 13]	
H_{bg} (ft)	No Existing Insulation[Source 4]	Unknown Existing Insulation[Source 15]	IECC Climate Zone 4	IECC Climate Zone 5
1	2.31	9.71	12.31	17.31
2.6	3.02	10.42	13.02	18.02
3	3.66	11.06	13.66	18.66
4	4.26	11.66	14.26	19.26
5	4.81	12.21	14.81	19.81
6	5.35	12.75	15.35	20.35
7	5.88	13.28	15.88	20.88
8	6.37	13.77	16.37	21.37

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) GDS Associates, Inc. (2007). Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures. Table 1 – Residential Measures. Weblink. 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. Weblink
3) 2021 International Energy Conservation Code, Table R402.1.3: Insulation Minimum R-values and Fenestration Requirements by Component. Weblink. 20ci or 13” means R-10 continuous insulation (ci) on the interior or exterior surface of the wall or R-13 cavity insulation on the interior side of the wall. “15ci or 19 or 13&5ci” means R-15 continuous insulation (ci) on the interior or exterior surface of the wall; or R-19 cavity insulation on the interior side of the wall; or R-13 cavity insulation on the interior of the wall in addition to R-5 continuous insulation on the interior or exterior surface of the wall.
4) ASHRAE. (2021). Fundamentals, Chapter 18, page 18.44. ASHRAE assumes an uninsulated concrete wall has an R-value of 1.47. R_{bg} values are calculated from $U_{avg,bw}$ values in Table 22 on page 18.44.
5) ASHRAE. (2021). Fundamentals. Chapter 27, page 27.3.
6) Based on the Phase III SWE team’s analysis of regional HVAC runtime data collected from ecobee’s Donate Your Data research service (Weblink) and updated based on the latest CDD and HDD values from NOAA’s 15-year annual climate Normals (2006–2020) (Weblink)
7) Energy Center of Wisconsin, (2008, May). “Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research.” Page 31. Weblink
8) NMR Group for the Pennsylvania Public Utility Commission. (2024, March). 2023 Pennsylvania Statewide Act 129 Residential Baseline Study. Weblink. Average home conditioned floor area = 2,019 ft²; average number of room AC units per home = 1.74; average Room AC capacity = 7,161 BTU/hr. Per ENERGY STAR Room AC sizing chart (Weblink), 7,161 BTU/hr of cooling serves approximately 283 ft². F_{RAC} = (283 ft² × 1.74)/(2,019 ft²) = 0.24.

9) NMR Group for the Pennsylvania Public Utility Commission. (2024, March). 2023 Pennsylvania Statewide Act 129 Residential Baseline Study. Page 115, Table 97, page 120, Table 103. Weblink. Air source heat pump efficiencies calculated using 2023 Pennsylvania Residential Baseline Study data. Federal minimum efficiencies for GSHP due to small sample size for GSHP in baseline study.

10) Federal minimum efficiency standards, based on ASHRAE 90.1-2019. Weblink.

11) McQuay. (2002). Application Guide 31-008, Geothermal Heat Pump Design Manual. Engineering Estimate - See System Performance of Ground Source Heat Pumps

12) Wilson et al. 2021. End-Use Load Profiles for the U.S. Building Stock: Methodology and Results of Model Calibration, Validation, and Uncertainty Quantification. NREL/TP-5500-80889. Weblink

13) Default new construction below grade R-values are the sum of the uninsulated wall assembly in the retrofit case and the code minimum continuous insulation R-value.

14) NMR Group for the Pennsylvania Public Utility Commission. (2024, March). 2023 Pennsylvania Statewide Act 129 Residential Baseline Study. Section 6.5.3: Foundation Wall R-value. Weblink. The R-8.9 value is the sum of the wall materials (R-1.47) and average added insulation (R-7.4).

15) NMR Group for the Pennsylvania Public Utility Commission. (2024, March). 2023 Pennsylvania Statewide Act 129 Residential Baseline Study. Section 6.5.3: Foundation Wall R-value. Weblink. In retrofit cases where it is unknown whether there is existing insulation present on the basement wall, add R-7.4 to the below-grade uninsulated retrofit R-value.

2.6.5 ENERGY STAR WINDOWS

Target Sector	Residential
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 version 7 certified windows.[Source 2]

ALGORITHMS

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

$$\Delta kWh_{cool} = Area\ of\ Window\ ft^2 \times \frac{\eta_{proto}}{\eta_{base}} \times a_{cool} \times overlap$$

$$\Delta kWh_{heat} = Area\ of\ Window\ ft^2 \times \frac{\eta_{proto}}{\eta_{base}} \times a_{hea} \times overlap$$

$$\Delta kW_{summer} = \frac{\Delta kWh_{cool}}{EFLH_{cool}} \times CF_{summer}$$

$$\Delta kW_{winter} = \frac{\Delta kW\ \ _{heat}}{EFLH_{heat}} \times CF_{winter}$$

Energy savings depend on three components: a unit energy savings value (UES) coefficient ($\mathbf{a_{cool}}$ or $\mathbf{a_{heat}}$) developed from prototype home energy models, the ratio of the efficiency of the cooling and heating equipment in the home to the values in the prototype home ($\frac{\eta_{proto}}{\eta_{base}}$), and eligible window area. To calculate energy savings, look up the efficiency value for the applicable equipment type in Table 2-151. This is $\boldsymbol{\eta_{proto}}$. For $\boldsymbol{\eta_{base}}$, use the corresponding value for the equipment in the home, or the default value of $\boldsymbol{\eta_{proto}}$ (i.e., a ratio of 1). Calculate the ratio. Then look up the UES (a) for the correct equipment type and climate region in Table 2-150. Multiply these values by the window area to get cooling or heating savings.

Non-centralized cooling systems such as room air conditioners and mini-splits include an additional factor representing the overlap between the fraction of a home's conditioned floor area (CFA) served by these systems that also receive upgraded windows. For instance, if two bedrooms each representing 15% of CFA are cooled with room ACs, but only one of the room's windows are upgraded, then overlap is 15%. If both bedrooms receive new windows, then overlap is 30%. (Upgraded windows in other parts of the home also reduce cooling load however, calculating their contributions is non-trivial. Consequently, these effects are omitted for simplicity and to allow for conservative results when an imprecise overlap is used.)

Definition of Terms

Table 2-149: Terms, Values, and References for ENERGY STAR Windows

Term	Unit	Value	Sources
a_{cool}, Climate region dependent electricity savings for efficient glazing	$\frac{kWh}{ft^2}$	See Default Unit Energy Savings Coefficient & Equipment Efficiency Tables Table 2-150	3
a_{heat}, Climate region dependent heating electricity savings for efficient glazing	$\frac{kWh}{ft^2}$	See Default Unit Energy Savings Coefficient & Equipment Efficiency Tables Table 2-150	3
η_{base}, Baseline heating or cooling equipment efficiency	varies	Measured, EDC Data Gathering Default: η_{proto}	-
η_{proto}, Prototype heating or cooling equipment efficiency	varies	See Table 2-151	4
overlap, Fraction of conditioned floor area served by HVAC with upgraded windows	*Proportion*	Measured, EDC Data Gathering Default: 100% for ASHP, CAC, GSHP, baseboard & electric furnace 0% for Mini-split, Room AC	-
$EFLH_{cool}$, Equivalent Full Load Hours of operation during the cooling season for the average unit	$\frac{hours}{year}$	See *EFLHcool* in Vol. 1, App. A	5
$EFLH_{heat}$, Equivalent Full Load Hours of operation during the heating season for the average unit	$\frac{hours}{yr}$	See *EFLHcool* in Vol. 1, App. A	5
CF_{summer}, Summer demand Coincidence Factor	*Proportion*	See *Summer CF* in Vol. 1, App. A	5
CF_{winter}, Winter demand Coincidence Factor	*Proportion*	See *Winter CF* in Vol. 1, App. A	5

Default Unit Energy Savings Coefficient & Equipment Efficiency Tables

Table 2-150: Default unit energy savings – kWh per Square Foot of Replaced Window

Climate Region	a_{cool}					a_{heat}				
	ASHP	Central AC	GSHP	Mini-split	Room AC	ASHP	Base-board	Electric Furnace	GSHP	Mini-split
A	0.23	0.18	0.12	0.13	0.26	2.52	6.39	6.80	2.00	2.21
B	0.31	0.38	0.20	0.27	0.52	1.93	4.96	5.25	1.43	1.36
C	0.41	0.49	0.30	0.30	0.66	1.75	4.59	4.80	1.29	1.24
D	0.70	0.76	0.60	0.51	1.05	0.83	2.59	2.35	0.76	0.56
E	0.60	0.63	0.38	0.42	0.90	1.00	2.76	2.71	0.68	0.71
F	0.34	0.39	0.24	0.27	0.56	1.89	5.00	5.15	1.39	1.39
G	0.13	0.15	0.08	0.06	0.19	2.64	6.74	7.22	2.51	2.45
H	0.33	0.37	0.22	0.27	0.52	1.97	5.12	5.38	1.49	1.44
I	0.31	0.36	0.19	0.26	0.49	2.15	5.43	5.90	1.61	1.59

Table 2-151: Prototype Residential Equipment Efficiency (η_{proto})

	ASHP	Baseboard	Central AC	Electric Furnace	GSHP	Mini-split	Room AC
Cooling	15 SEER/ 14.3 SEER2	–	13.2 SEER/ 12.9 SEER2	–	23.9 EER	18.9 SEER/ 17.5 SEER2	10.7 EER/ 10.6 CEER
Heating	8.5 HSPF/ 7.3 HSPF2	1.0 COP	–	1.0 COP	4.2 COP	10.0 HSPF/ 8.6 HSPF2	–

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 Electronic Technical Reference Manual. “Effective Useful Life and Remaining Useful Life”. Accessed December 2023. Weblink

2) U.S. EPA. (2022). ENERGY STAR Program Requirements for Residential Windows, Doors, and Skylights Version 7.0 Specification. Weblink

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 average characteristics determined through the Act 129 2023 Pennsylvania Residential Baseline Study; 0.44 U / 0.52 SHGC. Simulations for each equipment-climate region combination were performed for ENERGY STAR version 7 windows using 0.25 U / 0.30 SHGC as representative specifications for climate regions D & E, and 0.21 / 0.32 SHGC for the remaining regions. The difference in heating and cooling consumption was then apportioned evenly among the 305 square feet of windows in the prototype home yielding the UES values.

4) NMR Group for the Pennsylvania Public Utility Commission. (2024, March). 2023 Pennsylvania Statewide Act 129 Residential Baseline Study. Weblink

5) Based on the Phase III SWE team’s analysis of regional HVAC runtime data collected from ecobee’s Donate Your Data research service. Weblink

2.7 WHOLE HOME

2.7.1 RESIDENTIAL NEW CONSTRUCTION

Target Sector	Residential
Measure Unit	Multiple
Measure Life	Varies
Vintage	New Construction

ELIGIBILITY

This protocol documents the energy savings attributed to improvements to the construction of residential buildings compared to the baseline of a minimally code-compliant building, as calculated by the appropriate energy modeling software. This measure may be applied to attached or detached single-family homes and to multifamily residential buildings.

Mixed-use buildings are also eligible where the dwelling units and residential use common space combined exceed 50% of the building's square footage. Parking garage square footage is excluded from this calculation.[Source 1]

Multifamily buildings of 4 stories and higher are subject to the commercial building code and hence have different baseline specifications than buildings subject to residential building code requirements. Savings for multifamily buildings may be claimed only for savings generated in the residential spaces of the building.

ALGORITHMS

Energy and peak demand savings for Residential New Construction measures will be calculated by comparing outputs of energy models of the as-designed unit or building to a minimally code-compliant baseline unit or building. The characteristics of the baseline unit or building thermal envelope and/or system characteristics shall be based on the current state-adopted 2021 International Energy Conservation Code (IECC).[Source 2]

For single-family homes and individual dwelling units, modeled energy savings shall be produced with a RESNET accredited software[Source 3] or the Passive House accredited software packages (Passive House Planning Package[Source 4] and WUFI Passive[Source 5]), though both Passive House tools require the user to separately model the code baseline reference design to calculate energy and demand savings.

For multifamily buildings, modeled energy savings shall be produced at the building level with whole building modeling tools as designated by the ENERGY STAR Multifamily New Construction Program (eQUEST, DOE2.1, Energy Plus, Carrier HAP, Open Studio, and Trane Trace 700).[Source 6] Alternatively, RESNET accredited software[Source 3] or the Passive House accreditation software packages (Passive House Planning Package[Source 4] and WUFI Passive[Source 5]) may be used to model energy savings for each residential dwelling unit archetype, where dwelling archetype can be defined by one or more key metrics such as bedroom/bathroom counts or square footage ranges.

Energy savings will be calculated from the software output using the following algorithm:

Energy savings of the qualified unit/building (kWh/yr)

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

If the modeling software provides building-level outputs of hourly energy consumption (an 8760 load profile), then coincident peak demand savings may be calculated by averaging the hourly energy savings during the TRM defined peak demand time period. The TRM peak demand time period is defined in Volume 1.

If the modeling software does not provide building-level outputs of hourly energy consumption, the system peak electric demand savings for shall be calculated from the software's calculated annual energy savings and the following algorithm:

Coincident system peak electric demand savings (kW)

$\Delta kW_{peak,summer} = \Delta kWh \times ETDF_{summer}$

$\Delta kW_{peak,winter} = \Delta kWh \times ETDF_{winter}$

Definition of Terms

A summary of the input values and their data sources follows:

Table 2-152: Terms, Values, and References for Residential New Construction

Term	Unit	Value	Sources
kWh_{base}, Annual energy consumption of the baseline home/unit/building.	kWh	Software Calculated	7
kWh_{ee}, Annual energy consumption of the qualifying home/unit/building.	kWh	Software Calculated	8
$ETDF_s$, Summer energy to demand factor	kW/kWh	0.0001376	9
$ETDF_w$, Winter energy to demand factor	kW/kWh	0.0001967	9
V_r, Rated storage volume of baseline water heater	*gallons*	EDC Data Gathering	EDC Data Gathering
Model inputs for baseline home	*Varies*	Less than 4 stories: See Table 2-153 and Table 2-154 4 stories and higher: See Table 2-156 and Table 2-157	

The following table lists the building envelope characteristics of the baseline reference home based on 2021 IECC for the two climate zones in Pennsylvania.

Table 2-153: Baseline Insulation and Fenestration Requirements by Component for Buildings Less Than 4 Stories (Equivalent U-Factors) Source 10

IECC Climate Zone	Fenestration U-Factor	Skylight U-Factor	Glazed Fenestration SHGC	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
4	0.30	0.55	0.40	0.024	0.045	0.098	0.047	0.059	10ci, 4 ft	0.065
5	0.30	0.55	0.40	0.024	0.045	0.082	0.033	0.050	10ci, 4 ft	0.055

Table 2-154: Residential New Construction Baseline Building Values for Buildings Less Than 4 Stories

Data Point	Value	Source
Air Infiltration Rate	3.0 ACH_{50} for the whole house	11
Duct Leakage	4 CFM_{25} (4 cubic feet per minute per 100 square feet of conditioned space when tested at 25 pascals)	11
Duct Insulation	Within ceiling insulation: R-8 Other locations not completely inside thermal envelope: R-8 where ≥3” in diameter and R-6 where <3” in diameter	11
Mechanical Ventilation	HRV/ERV/Air handler = 1.2 CFM/Watt In-line supply or exhaust = 3.8 CFM/Watt Other (< 90 CFM) = 2.8 CFM/Watt Other (≥ 90 CFM) = 3.5 CFM/Watt	12
Lighting	Use baseline wattage as defined in the Residential LED Lighting section of the TRM (2.1.1), Table 2-2 for the residential units, and Lighting Improvement section (3.1.1) and New Construction Lighting section (3.1.2) of the TRM for common spaces	
Appliances	Use baseline values as defined in applicable TRM measure for each appliance.	
Thermostat Type	Programmable, with ability to maintain zone temperature down to 55 ºF (13 ºC) or up to 85 ºF (29 ºC)	11
Temperature Set Points	Heating: 70°F Cooling: 78°F	11
Heating Efficiency		
Furnace	80% AFUE	13
Gas Fired Steam Boiler	82% AFUE	13
Gas Fired Hot Water Boiler	84% AFUE	13
Oil Fired Steam Boiler	85% AFUE	13
Oil Fired Hot Water Boiler	86% AFUE	13
ASHP, GSHP, PTHP	For residential units, see New Construction values in Table 2-10 in Sec. 2.2.1. For ductless heat pumps, use value for ASHP. For common areas, see New Construction values in Table 3-24 in Sec. 3.2.1. For ductless heat pumps, use value for ASHP.	
Cooling Efficiency		
All types	For residential units, see New Construction values in Table 2-10 in Sec. 2.2.1. For ductless heat pumps, use value for ASHP. For common areas, see New Construction values in Table 3-24 in Sec. 3.2.1. For ductless heat pumps, use value for ASHP. For Chillers, see values in Table 3-29 in Sec. 3.2.3.	
Domestic WH Efficiency		

Data Point	Value	Source
Electric	See volume and load dependent values in in Table 2-61 in Sec. 2.3.1	
Natural Gas	See volume and load dependent values in Table 2-155	13
Additional Water Heater Tank Insulation	None	

Table 2-155: Minimum Residential Baseline Gas-Fired Uniform Energy Factors Based on Storage Volume and Draw Pattern

V_r: Rated Storage Volume (gallons)	Draw Pattern	Max. Daily Hot Water Draw (gallons)	First Hour Rating (FHR) (gallons)	UEF Calculation
≥20 gal and ≤55 gal	Very Small	10	0 ≤ FHR < 18	$0.3456 -(0.0020\times V_r)$
	Low	38	18 ≤ FHR < 51	$0.5982-(0.0019\times V_r)$
	Medium	55	51 ≤ FHR < 75	$0.6483-(0.0017\times V_r)$
	High	84	FHR ≥ 75	$0.6920-(0.0013\times V_r)$
>55 gal and ≤120 gal	Very Small	10	0 ≤ FHR < 18	$0.6470-(0.0006\times V_r)$
	Low	38	18 ≤ FHR < 51	$0.7689-(0.0005\times V_r)$
	Medium	55	51 ≤ FHR < 75	$0.7897-(0.0004\times V_r)$
	High	84	FHR ≥ 75	$0.8072-(0.0003\times V_r)$
Instantaneous ≤2 gal and >50 kBTU/h	Very Small	10	0 ≤ FHR < 18	0.80
	Low	38	18 ≤ FHR < 51	0.81
	Medium	55	51 ≤ FHR < 75	0.81
	High	84	FHR ≥ 75	0.81

Table 2-156: Baseline Insulation and Fenestration Requirements by Component for Buildings 4 Stories or Higher (Equivalent U-Factors) Source 14

	IECC Climate Zone	
Building Element	**4**	**5**
Fixed Fenestration U-Factor	0.36	0.36
Operable Fenestration U-Factor	0.45	0.45
Skylight U-Factor	0.50	0.50
Roof U-Factor, Insulation entirely above roof deck	0.032	0.032
Roof U-Factor, Metal building	0.035	0.035
Roof U-Factor, Attic and other	0.021	0.021
Above Grade Wall U-Factor, Mass	0.104	0.090
Above Grade Wall U-Factor, Metal building	0.052	0.050
Above Grade Wall U-Factor, Metal framed	0.064	0.055

	IECC Climate Zone	
Building Element	4	5
Above Grade Wall U-Factor, Wood framed and other	0.064	0.051
Below Grade Wall C-Factor	0.119	0.119
Floor U-Factor, Mass	0.057	0.057
Floor U-Factor, Joist/framing	0.033	0.033
Slab-on-grade Floors, F-Factor, Unheated	0.52	0.52
Slab-on-grade Floors, F-Factor, Heated	0.62	0.62

Table 2-157: Residential New Construction Baseline Building Values for Buildings 4 Stories or Higher

Data Point	Value	Source
Air Infiltration Rate	0.3 cfm/ft^2	15
Duct Insulation	Unconditioned spaces = R-6 Outside building = R-8 (zone 4) R-12 (zone 5)	16
Mechanical Ventilation	0.35 ACH but not less than 15 cfm/person	17
Lighting	Use baseline wattage as defined in the Residential LED Lighting section of the TRM (2.1.1), Table 2-2 for the residential units, and Lighting Improvement section (3.1.1) and New Construction Lighting section (3.1.2) of the TRM for common spaces	
Appliances	Use baseline values as defined in applicable TRM measure for each appliance.	
Thermostat Setback	Maintain zone temperature down to 55 ºF (13 ºC) or up to 85 ºF (29 ºC)	11
Temperature Set Points	Heating: 70°F Cooling: 78°F	11
Heating Efficiency		
Warm air furnace, gas fired	81% E_t	18
Warm air furnace, oil fired	82% E_t	18
Boiler, hot water, gas fired	82% AFUE (< 300,000 Btu/h) 80% E_t (≥ 300,000 Btu/h and ≤ 2,500,000 Btu/h) 82% E_c (>2,500,000 Btu/h)	18
Boiler, hot water, oil fired	84% AFUE (< 300,000 Btu/h) 82% E_t (≥ 300,000 Btu/h and ≤ 2,500,000 Btu/h) 84% E_c (>2,500,000 Btu/h)	18
Boiler, steam, gas fired	80% AFUE (< 300,000 Btu/h) 79% E_t (≥ 300,000 Btu/h)	18
Boiler, steam, oil fired	82% AFUE (< 300,000 Btu/h) 81% E_t (≥ 300,000 Btu/h)	18

Data Point	Value	Source
ASHP, GSHP, PTHP	For residential units, see New Construction values in Table 2-10 in Sec. 2.2.1. For ductless heat pumps, use value for ASHP. For common areas, see New Construction values in Table 3-24 in Sec. 3.2.1. For ductless heat pumps, use value for ASHP.	
Cooling Efficiency		
All types	For residential units, see New Construction values in Table 2-10 in Sec. 2.2.1. For ductless heat pumps, use value for ASHP. For common areas, see New Construction values in Table 3-24 in Sec. 3.2.1. For ductless heat pumps, use value for ASHP. For Chillers, see values in Table 3-29 in Sec. 3.2.3.	
Domestic WH Efficiency		
Electric	See volume and load dependent values in in Table 2-61 in Sec. 2.3.1	
Natural Gas	See volume and load dependent values in Table 2-155	19
Additional Water Heater Tank Insulation	None	

E_t = Thermal Efficiency; E_c = Combustion Efficiency

Table 2-158: Minimum Commercial Baseline Gas- and Oil-Fired Uniform Energy Factors Based Fuel Type and Draw Pattern

					UEF Calculation*	
Equipment (specifications)		Draw Pattern	Max. Daily Hot Water Draw (gallons)	First Hour Rating (FHR) (gallons)	Equipment Manufactured Before October 6, 2026	Equipment Manufactured After October 6, 2026
Gas-fired storage (>75 kBtu/h and ≤105 kBtu/h and ≤ 120 gal)		Very Small	10	0 ≤ FHR < 18	$0.2674 - (0.0009 \times V_r)$	$0.5374 - (0.0009 \times Vr)$
		Low	38	18 ≤ FHR < 51	$0.5362 - (0.0012 \times V_r)$	$0.8062 - (0.0012 \times V_r)$
		Medium	55	51 ≤ FHR < 75	$0.6002 - (0.0011 \times V_r)$	$0.8702 - (0.0011 \times V_r)$
		High	84	FHR ≥ 75	$0.6597 - (0.0009 \times V_r)$	$0.9297 - (0.0009 \times V_r)$
Oil-fired storage (>105 kBtu/h and ≤140 kBtu/h and ≤ 120 gal)		Very Small	10	0 ≤ FHR < 18	$0.2932 - (0.0015 \times V_r)$	$0.2932 - (0.0015 \times Vr)$
		Low	38	18 ≤ FHR < 51	$0.5596 - (0.0018 \times V_r)$	$0.5596 - (0.0018 \times Vr)$
		Medium	55	51 ≤ FHR < 75	$0.6194 - (0.0016 \times V_r)$	$0.6194 - (0.0016 \times Vr)$
		High	84	FHR ≥ 75	$0.6470 - (0.0013 \times V_r)$	$0.6470 - (0.0013 \times Vr)$
Electric instantaneous (>12 kW and ≤ 58.6 kW and ≤ 2 gal)		Very Small	10	0 ≤ FHR < 18	0.80	0.80
		Low	38	18 ≤ FHR < 51	0.80	0.80
		Medium	55	51 ≤ FHR < 75	0.80	0.80
		High	84	FHR ≥ 75	0.80	0.80

* Vr is the rated storage volume (in gallons)

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values.

SOURCES

1) ENERGY STAR Multifamily New Construction Program Decision Tree. (2021, May). Weblink

2) International Code Council. (2021). 2021 International Energy Conservation Code, Effective Use of the International Energy Conservation Code, Introduction. Weblink

3) See the RESNET National Registry of Accredited Rating Software Programs for a complete listing: Weblink

4) Passive House Planning Package. Weblink

5) WUFI Passive. Weblink

6) See the ENERGY STAR Multifamily New Construction Simulation Guidelines for guidance on qualifying software: Weblink

7) Calculation of annual energy consumption of a baseline home from the home energy rating tool based on the reference home energy characteristics.

8) Calculation of annual energy consumption of an energy efficient home from the home energy rating tool based on the qualifying home energy characteristics.

9) Wilson et al. 2021. End-Use Load Profiles for the U.S. Building Stock: Methodology and Results of Model Calibration, Validation, and Uncertainty Quantification. NREL/TP-5500-80889. Weblink

10) 2021 International Energy Conservation Code Table R402.1.2 Maximum Assembly U-Factors and Fenestration Requirements presents the R-Value requirements of Table R402.1.3 in an equivalent U-Factor format. Users may choose to follow Table R402.1.2 instead. 2021 IECC supersedes this table in case of discrepancy. Additional requirements per §R402 of 2021 IECC must be followed even if not listed here.

11) 2021 International Energy Conservation Code §R401-R404. Weblink

12) 2021 International Residential Code, Table N1103.6.2(R403.6.2): Whole-Dwelling Mechanical Ventilation System Fan Efficacy. Weblink

13) Electronic Code of Federal Regulations, 10 CFR Part 430, Subpart C, §430.32, "Energy and water conservation standards and their compliance dates." Weblink.

14) 2021 International Energy Conservation Code Tables C402.4 and C402.1.4. Users may choose to follow Table C402.1.3 instead of Table C402.1.4. 20121 IECC supersedes this table in case of discrepancy. Additional requirements per §C402 of 20121 IECC must be followed even if not listed here. Weblink

15) 2021 International Energy Conservation Code §C402.5.2 Weblink

16) 2021 International Energy Conservation Code §C403.12.1. Weblink

17) 2021 International Mechanical Code, Table 403.3.1.1: Minimum Ventilation Rates. Weblink

18) 2021 International Energy Conservation Code §C403.3.2. Weblink

19) Electronic Code of Federal Regulations, 10 CFR Part 431, Subpart G, §431.110. Weblink

2.7.2 ENERGY STAR Manufactured Homes

Target Sector	Manufactured homes
Measure Unit	Variable
Measure Life	15 Years[Source 1]
Vintage	New Construction

Eligibility

This measure applies to manufactured homes compliant to and certified by EPA's ENERGY STAR Manufactured Homes program standard, Version 3.

Algorithms

Energy and peak demand savings in the ENERGY STAR Manufactured Homes program will be calculated by comparing outputs of energy models of the as-designed home to a minimally code-compliant baseline home.

Modeled energy and peak demand savings shall be produced by a RESNET accredited software program.[Source 2]

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).[Source 3] 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 in the structure."[Source 3]

Energy savings will be calculated from the software output using the following algorithm:

Energy savings of the qualified home (kWh/yr)

$$\Delta \text{kWh} = kWh_{base} - kWh_q$$

If the modeling software provides building-level outputs of hourly energy consumption (an 8760 load profile), then coincident peak demand savings may be calculated by averaging the hourly energy savings during the TRM defined peak demand time period.

If the modeling software does not provide building-level outputs of hourly energy consumption, the system peak electric demand savings for shall be calculated from the software's calculated annual energy savings and the following algorithm:

Coincident system peak electric demand savings (kW)

$$\Delta \text{kW}_{\text{summer peak}} = \Delta \text{kWh} \times ETDF_{summer}$$

$$\Delta \text{kW}_{\text{winter peak}} = \Delta \text{kWh} \times ETDF_{winter}$$

Additional demand savings may be claimed under this measure, but these additional demand savings must be calculated using the algorithms from the applicable measure elsewhere in the

TRM. For example, to claim demand savings from a refrigerator, demand savings for that end use must be calculated using the demand savings algorithms in Sec. 2.4.1 ENERGY STAR Refrigerators. Claiming additional demand savings may require additional EDC data collection than required to generate the energy model.

Definition of Terms

Table 2-159: Terms, Values, and References for Manufactured Homes

Term	Unit	Value	Sources
kWh_{base}, Estimated annual energy consumption of the baseline home	kWh	Software Calculated	
kWh_q, Estimated annual energy consumption of the qualifying home	kWh	Software Calculated	
$ETDF_{summer\ peak}$, Summer energy to demand factor	kW/kWh	0.0001376	4
$ETDF_{winter\ peak}$, Winter energy to demand factor	kW/kWh	0.0001967	4
Model inputs for baseline home	*Varies*	See Table 2-160 and Table 2-161	
Model inputs for ENERGY STAR home	*Varies*	See Table 2-162 and Table 2-163	

Federal energy code for manufactured homes provides both a prescriptive and a performance-based path to meet required insulation levels. Table 2-160 and presents the minimum requirements for manufactured homes that are manufactured on or after July 1, 2025. Additional federal energy code requirements and TRM assumed baseline values are presented in Table 2-161.

Table 2-160: Building Thermal Envelope Requirements for Code-Compliant Baseline Home Source 5

	Single-section home	Multi-section home
Prescriptive Requirements		
Exterior wall insulation R-value	19	21
Exterior ceiling insulation R-value	22	38
Exterior floor insulation R-value	22	30
Window U-factor	0.35	0.30
Skylight U-factor	0.55	0.55
Door U-factor	0.40	0.40
Prescriptive Requirements – Alternatives to R-Value Requirements		
Exterior ceiling U-factor	0.061	0.037
Exterior wall U-factor	0.068	0.063
Exterior floor U-factor	0.049	0.032
OR Performance Requirements		
Overall thermal transmittance (U_o)	0.074	0.055

Table 2-161: Values and References for Code-Compliant Baseline Home

Data Point	Value	Source
Air Infiltration Rate	5 ACH50	6
Mechanical Ventilation	0.035 CFM/ft^2 Exhaust	7
Mechanical Ventilation Fan Efficacy	HRV or ERV = 1.2 CFM/W Inline supply/exhaust: 3.8 CFM/W Other exhaust < 90 CFM = 2.8 CFM/W Other exhaust ≥90 CFM = 3.5 CFM/W Air-handler that is integrated to tested and listed HVAC equipment = 1.2 CFM/W	8
Duct Leakage	4 CFM25 / 100 ft^2 conditioned floor area	8
Lighting	Use baseline wattage as defined in the Residential LED Lighting section of the TRM (2.1.1), Table 2-2.	
Appliances	Use baseline values as defined in applicable TRM measure for each appliance.	
Thermostat Type	Programmable, with ability to maintain zone temperature down to 55 ºF (13 ºC) or up to 85 ºF (29 ºC)	9
Temperature Set Points	Heating: 70°F Cooling: 78°F	9
Heating Efficiency		
Furnace	80% AFUE	10
Gas Fired Steam Boiler	82% AFUE	10
Gas Fired Hot Water Boiler	84% AFUE	10
Oil Fired Steam Boiler	85% AFUE	10
Oil Fired Hot Water Boiler	86% AFUE	10
Combo Water Heater	76% AFUE (recovery efficiency)	10
Electric Resistance	3.412 HSPF	
ASHP, GSHP, PTHP, Ductless heat pump	See New Construction values in Table 2-10 in Sec. 2.2.1	AEPS Application; EDC Data Gathering
Cooling Efficiency		
All types	See New Construction values in Table 2-10 in Sec. 2.2.1	AEPS Application; EDC Data Gathering
Domestic WH Efficiency		
Electric	See volume and load dependent values in Table 2-61 in Sec. 2.3.1	
Natural Gas	See volume and load dependent values in Table 2-155 in Sec. 2.7.1	
Additional Water Heater Tank Insulation	None	

The ENERGY STAR Manufactured Homes program provides a list of requirements for certified homes to meet. Below is a summary of those requirements.Source 11

Table 2-162: Building Thermal Envelope Requirements for ENERGY STAR Manufactured Home Source 11

	Single-section home	Multi-section home
Prescriptive Requirements		
Exterior wall insulation R-value	R-21	
Exterior ceiling insulation R-value	R-38	
Exterior floor insulation R-value	R-33	
Window U-factor	0.30	
Door U-factor	0.30	
OR Performance Requirements		
Single-section overall thermal transmittance (U_o)	0.057	0.054

Additionally, the ENERGY STAR Manufactured Homes program requires that ducts in floor cavities shall be enclosed by floor insulation and that crossover ducts, ducts in unconditioned attics, and other ducts in unconditioned space shall have at least R-8 duct insulation.

For only multi-section manufactured homes, ENERGY STAR requires additional energy efficiency measures to the required measures listed above. These additional measures are each assigned a point value. The points must sum to at least the program minimum total of 10 points. Table 2-163 presents the point values for climate zone 3.

Table 2-163: ENERGY STAR Manufactured Homes Program Optional Measure Point Values for Multi-Section Homes

Energy Efficiency Measure		Point Value
Mandatory requirements		
All requirements in Table 2-162		2.0
Optional Envelope Improvements		
Coefficient of heat transmission (U_o) ≤ 0.049		4.5
Optional Heating and Cooling Equipment		
Heat pump ≥ 7.5 HSPF2 / 14.3 SEER2		17.0
Gas / propane Furnace ≥ 90 AFUE		5.5
Gas / propane Furnace ≥ 95 AFUE		7.5
Gas / propane Furnace ≥ 96 AFUE		8.5
Optional Water Heater Equipment		
Gas / Propane Water Heater ≥ 0.93 UEF		0.5
Heat pump water heater ≥ 2.20 UEF	With electric furnace, electric strip, or electric baseboard primary heating	1.5
Heat pump water heater ≥ 3.30 UEF		1.5
Heat pump water heater ≥ 2.20 UEF	With all other primary space heating systems	7.5
Heat pump water heater ≥ 3.30 UEF		9.0
Optional Lighting, Appliances, and Water Fixtures		
LED lighting installed in all permanently installed fixtures		0.5
Bathroom faucets ≤ 1.5 gallons per minute (gpm) and showerheads ≤ 2.0 gpm		0.5
ENERGY STAR certified refrigerator and dishwasher		0.5
ENERGY STAR certified clothes washer		0.5

Evaluation Protocols

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

Sources

1) Hewes, T. and Peeks, B. (2013, February). "Northwest Energy Efficient Manufactured Housing Program Specification Development". NREL. Weblink. Note: this reference provides measure lives of major home components and not a single home-wide measure life. The ENERGY STAR Manufactured Home program's requirements and optional measures focus on the building's envelope and HVAC system, which have measure lives of 45 years and 20 years, respectively. Therefore, the aggregate life for this measure is considered to be 30 years. Note that PA Act 129 savings can be claimed for no more than 15 years, thus the 15-year measure life.
2) See the RESNET National Registry of Accredited Rating Software Programs for a complete listing: Weblink
3) Electronic Code of Federal Regulations, 24 CFR Part 3280, "Manufactured Home Construction and Safety Standards." Weblink
4) Wilson et al. 2021. End-Use Load Profiles for the U.S. Building Stock: Methodology and Results of Model Calibration, Validation, and Uncertainty Quantification. NREL/TP-5500-80889. Weblink
5) Electronic Code of Federal Regulations, 10 CFR Part 460, §460.102. "Building Thermal envelope requirements." All values shown are applicable to climate zone 3, which includes all of Pennsylvania. Weblink
6) U.S. Department of Energy. Energy Conservation Program. Energy Conservation Standards for Manufactured Housing. Effective August 1, 2022. Weblink
7) Electronic Code of Federal Regulations, 24 CFR Part 3280, Subpart B, §3280.103(b). Weblink
8) 2021 International Residential Code, Table N1103.6.2(R403.6.2): Whole-Dwelling Mechanical Ventilation System Fan Efficacy. Weblink
9) Electronic Code of Federal Regulations, 10 CFR Part 460, §460.202. "Thermostats and controls." Weblink
10) Electronic Code of Federal Regulations, 10 CFR Part 430, Subpart C, §430.32, "Energy Conservation Program for Consumer Products: Energy and Water Conservation Standards." Weblink
11) ENERGY STAR Manufactured New Homes National Program Requirements, Version 3 (Rev. 01). Weblink

2.7.3 HOME ENERGY REPORTS

Target Sector	Residential
Measure Unit	Household
Measure Life	Specified in protocol
Vintage	Retrofit

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 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.

Because Act 129 goals are based on first-year incremental savings, accounting for persistence reduces first-year compliance savings from EDC programs that continue to expose the same homes to HER messaging year after year.

The core assumption in this protocol is an annual decay rate of 31.3%. To illustrate the decay concept, consider a hypothetical cohort of 20,000 treatment group homes that have been receiving HERs for two years. Table 2-164 shows the average kWh savings per treatment group home by year as measured through a billing analysis of the randomized control trial design.

Table 2-164: Home Energy Report Persistence Example

Year	Avg. kWh Savings per Home
1	150
2	250

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 2-165 shows the components of this calculation.

Table 2-165: 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	250		
3		250×(1-0.313/2) = 210.9	260

In this hypothetical example the incremental first-year savings achieved by the HER program in Year 3 is 49.1 kWh (260 – 210.9). This is the sum of two separate factors.

- **Avoided Decay** = 39.1 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 210.9 kWh value in Table 2-165 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 2-165 shows an average kWh savings value of 260 kWh per household. This is an increase of 10 kWh over the Year 2 measurement of 250 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 V of Act 129. Several assumptions that straddle technical and policy considerations are listed below.

1) 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 V 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.
2) Act 129 HER programs should always be delivered as a randomized control trial (RCT), but EDCs have significant flexibility 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.
3) 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.

4) Home Energy Reports are expected to generate summer and winter peak demand savings. The Behavioral Conservation Programs protocol of the Pennsylvania Evaluation Framework provides detailed guidance regarding measurement techniques for peak demand savings. Peak demand (kW) savings are presumed to follow the same persistence logic as energy (kWh) savings with respect to first-year incremental compliance and lifetime impacts.

ALGORITHMS

The equations for incremental first-year savings from HER programs are:

Year 1 and 2 of HER Exposure:

$$\Delta kWh_Y = ATE_y * Treatment\ Accounts_y * Days_y$$

$$FYSATE_y = ATE_y$$

Where ATE_y is the average daily savings determined through a billing regression analysis, minus the average daily uplift (kWh/day). The uplift of the HER program is determined by examining the cumulative difference in other EE program savings between the treated population and the control group since the inception of the HER cohort. In years 1 and 2 of HER exposure the ATE_y and $FYSATE_y$ terms are identical.

If an EDC elects to treat an HER cohort for a third year or beyond the equation for incremental first-year savings is:

Year 3 of HER Exposure:

$$FYSATE_y = ATE_y - \sum_{x=1}^{x=1} FYSATE_{y-x} - FYSATE_{y-x} * Decay * (X - 0.5)$$

$$\Delta kWh_Y = FYSATE_y * Treatment\ Accounts_y * Days_y$$

Year 4 of HER Exposure:

$$FYSATE_y = ATE_y - \sum_{x=1}^{x=2} FYSATE_{y-x} - FYSATE_{y-x} * Decay * (X - 0.5)$$

$$\Delta kWh_Y = FYSATE_y * Treatment\ Accounts_y * Days_y$$

Year 5 and Beyond of HER Exposure:

$$FYSATE_y = ATE_y - \sum_{x=1}^{x=3} FYSATE_{y-x} - FYSATE_{y-x} * Decay * (X - 0.5)$$

$$\Delta kWh_Y = FYSATE_y * Treatment\ Accounts_y * Days_y$$

Where $FYSATE_y$ is the average daily savings attributable to HERs delivered in year Y and $FYSATE_{y\text{-}x}$ is the average daily savings attributable to HERs delivered in year Y-X.

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 (where Y = 1):

$$\Delta kWh_{Y,lifetime} = ATE_Y * Treatment\ Accounts_Y * Days_Y$$

Year 2 and Beyond of HER Exposure (where Y >= 2):

$$\Delta kWh_{Y,lifetime} = \Delta kWh_Y + \sum_{X=1}^{X=3} \left(\left(FYSATE_Y - FYSATE_Y * Decay * (X - 0.5) \right) * (1 - Churn)^X \right) * Days_{Y+X} * Treatment\ Accounts_Y$$

For year two and onwards, the lifetime savings are simply a function of the decay rate and customer churn assumption, accounted for the current year and across the three future years where savings persist. In this case, it may be helpful to consider the sum in the formula above a scalar that adjusts that program year's savings. For example, in a hypothetical program with 200 kWh of total incremental annual savings in its second year of program delivery, the lifetime savings associated with the second year of program year delivery would be 200 * 2.44 = 488 kWh, where the 2.44 factor is the ratio of the lifetime savings to the incremental first-year savings. The 2.44 approximation factor is valid for programs that rely on the default decay and churn assumptions. EDCs that use the 'EDC Data Gathering' option for one or both of these parameters would need to calculate the appropriate lifetime first-year ratio for the parameter values selected.

Definition of Terms

Table 2-166: Terms, Values, and References for HER Persistence Protocol

Parameter	Unit	Value	Source
ΔkWh_Y, First-year compliance kWh savings for the cohort being evaluated in the program year being analyzed	*Total Incremental Annual kWh Savings of an HER cohort*	EDC Data Gathering	EDC Data Gathering
$\Delta kWh_{Y,lifetime}$ Lifetime kWh savings for the cohort being evaluated attributable to the program year being analyzed. Inclusive of ΔkWh_Y	*Total Lifetime kWh Savings of an HER cohort*	EDC Data Gathering	EDC Data Gathering
ATE_Y, Average Treatment Effect determined via regression analysis of billed consumption, net of Daily Uplift	*kWh/day per household*	EDC Data Gathering	EDC Data Gathering
$FYSATE_Y$, First-Year Savings Average Treatment Effect attributable to HERs delivered in year Y	*kWh/day per household*	EDC Data Gathering	EDC Data Gathering
$Treatment\ Accounts_Y$, number of active homes in the treatment group in year Y.	*Households (EDC account number)*	EDC Data Gathering	EDC Data Gathering
$Days_Y$, 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	-	Default: 31.3%	1
		EDC Data Gathering	
Churn, Average annual reduction in participating households due to account closures, move-out etc.	-	Default: 6%	2
		EDC Data Gathering	

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. Weblink
2) SWE Analysis of average annual churn rate among Phase III EDC cohort

2.8 Miscellaneous

2.8.1 ENERGY STAR Pool Pumps

Target Sector	Residential
Measure Unit	Pool Pumps
Measure Life	10 years[Source 1]
Vintage	Replace on Burnout, New Construction

High efficiency pump installations typically employ variable frequency drives and are generally configured to run 24 hours per day at low speed. To achieve adequate filtering the pump must run for longer to compensate for a lower speed/flow. However, this still saves energy since pump power consumption increases with the cube of speed. Consequently, load-shifting of continuous VFD's to reduce demand is not recommended since energy consumption nearly doubles with two turnovers in 20 hours versus 24.

Eligibility

This measure is for the purchase and installation of an ENERGY STAR v3.1 pool pump. The target sector primarily consists of single-family residences.

Algorithms

This protocol documents the energy savings attributed to various configurations of ENERGY STAR pool pumps.

$$\Delta kWh = \frac{Volume \times Turnover \times Days}{1{,}000} \times \left(\frac{1}{WEF_{base}} - \frac{1}{WEF_{ee}}\right)$$

$$\Delta kW_{summer\ peak} = \left(\Delta kWh / (HOU \times Days)\right) \times CF_{summer}$$

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

Definition of Terms

Table 2-167: Terms, Values, and References for Variable Speed Pool Pumps

Term	Unit	Values	Source
Days, Pool pump days of operation per year	$\frac{days}{yr}$	EDC Data Gathering Default: Table 2-169	2
WEF_{base}, Baseline weighted energy factor of pool pump for Curve C flow.	$\frac{gallons}{W \cdot h}$	EDC Data Gathering Default: Table 2-168 or Table 2-169	3
WEF_{ee}, Weighted energy factor of ENERGY STAR pool pump for Curve C flow.	$\frac{gallons}{W \cdot h}$	EDC Data Gathering Default: Table 2-168 or Table 2-169	4
hhp, hydraulic horsepower is a measure of pump output rather than pump input	*745.7 W*	EDC Data Gathering Default: Table 2-168 or Table 2-169	2

Term	Unit	Values	Source
Volume, pool capacity	*Gallons*	EDC Data Gathering Default: Table 2-169	5
Turnover, number of times the full volume of the pool is filtered each day	$\frac{Pool\ volumes}{day}$	EDC Data Gathering Default: Table 2-169	6,9
HOU, Hours of operation per day	$\frac{hours}{day}$	EDC Data Gathering Default=24	2
CF_{summer}, Coincidence factor	*None*	EDC Data Gathering Default: Table 2-169	7

Table 2-168 shows the federal standard minimum efficiency (effective as of July 19, 2021), alongside the ENERGY STAR v3.1 specifications (effective July 19, 2021).

Table 2-168: Pool Pump Weighted Energy Factor Requirements and Specifications

Pump Type	Nameplate Power (hhp)	Federal Minimum (WEF_{base})Source 3	ENERGY STAR (WEF_{ee})Source 4
Self-Priming (In-ground)	≤0.130	5.55	13.40
	0.130–0.711	-1.30×ln(hhp)+2.90	-2.45×ln(hhp)+8.40
	0.712-2.500	-2.30×ln(hhp)+6.59	-2.45×ln(hhp)+8.40
Non-Self-Priming (Above-ground)	≤0.130	4.60	4.92
	>0.130	-0.85×ln(hhp)+2.87	-1.00×ln(hhp)+3.85
Pressure Cleaner Booster	Any	0.42	0.51

Table 2-169: Default Inputs

Pool/ Pump Type	hhp	WEF_{base}	WEF_{ee}	Days	Volume	Turnover	CF
In-ground Pool	0.72 Source 2	7.35 Source 3	9.20 Source 4	122 Source 2	15,750 Source 5	2 Source 6	1 Source 7
Above-ground Pool	0.72 Source 2	3.15 Source 3	4.18 Source 4	122 Source 2	7,540 Source 8	2 Source 9	1 Source 7
Pressure Cleaner Booster	N/A	0.42 Source 3	0.51 Source 4	Same as pool		0.08 Source 10	0.31 Source 11

Default Savings

Default energy and demand savings follow however, many ENERGY STAR pool pumps exceed program specifications; some by as much as 190%. Therefore, EDCs are encouraged to collect records of pool volume, WEF and hhp for installed equipment to calculate the full project savings due. Federal regulations require that equipment ratings be printed on the pump.

Table 2-170: Default ENERGY STAR Pool Pump Savings

Pump Type	ΔkWh	$\Delta kW_{summer\ peak}$
In-ground Pool	106	0.0361
Above-ground Pool	144	0.0493
Pressure Cleaner Booster, In-ground Pool	67	0.0071
Pressure Cleaner Booster, Above-ground Pool	32	0.0034

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) California Electronic Technical Reference Manual: (2019). "VSD for Pool & Spa Pump". California Technical Forum. Retrieved February 4, 2022. Weblink
2) U.S. EPA. (2020). ENERGY STAR Pool Pump Calculator. Retrieved July 31, 2020. Weblink
3) 10 CFR 431.465(f) Weblink
4) U.S. EPA. (2021). ENERGY STAR Program Requirements for Pool Pumps Version 3.1.Retrieved February 4, 2022. Weblink
5) Engineering judgement. Source 1 Gives 15,700 gallons (15,754 in reference R802), Source 2 gives 22,000 gallons, and Source 8 gives 15,147 gallons.
6) International Swimming Pool and Spa Code. (2015). Section 810.1. Retrieved February 4, 2022. Weblink
7) To maximize energy savings, it is assumed that the pump runs 24 hours per day, which includes 100% of peak.
8) Koeller, J., Hoffman, H.W., *et al.* (2010). "Evaluation of Potential Best Management Practices - Pools, Spas, and Fountains." Retrieved on February 21, 2022. Weblink
9) International Swimming Pool and Spa Code. (2015). Section 704.4. Accessed February 4, 2022. Weblink
10) U.S. EPA. (2013). ENERGY STAR Pool Pump Calculator. Retrieved July 31, 2020. Weblink
11) Southern California Edison. (2008). Pool Pump Demand Response Potential: Demand and Run-time Monitored Data. Page 22, Table 16. Weblink

2.8.2 Single Speed Pool Pump Replacement

Target Sector	Residential
Measure Unit	VFD Pool Pumps
Measure Life	3.3 years[Source 1]
Vintage	Early Replacement

In this measure a variable speed pool pump must be purchased and installed on a residential pool to replace an existing single-speed pool pump. Residential variable frequency drive (VFD) pool pumps can be adjusted to match the minimal flow required for each application. This typically involves running all-day long at the flow rate necessary to achieve the desired number of turnovers per day. Reducing the flow rate results in significant energy savings because even though the run time is extended proportional to the reduction in flow rate, pump power scales with the cube of the flow rate. For example, halving the flow doubles the time required to process the same volume of water, but the flow power consumption is reduced by 87.5%.

If the replacement pump is ENERGY STAR qualified, measure 2.8.1 ENERGY STAR Pool Pumps may also be applied for the same equipment.

Eligibility

To qualify for this rebate a variable speed pool pump must be purchased and installed on a residential pool to replace an existing single speed pool pump. The target sector primarily consists of single-family residences.

Algorithms

This protocol documents the energy savings attributed to variable frequency drive pool pumps in various pool sizes. These pumps are generally configured to run 24 hours per day at low speed because a pump's power requirements increase with the cube of its speed. Most VFD pool pumps can display instantaneous flow and power.

$$\Delta kWh = \frac{Volume \times Turnover \times Days}{1{,}000} \times \left(\frac{1}{EF_{base}} - \frac{1}{WEF_{CFR}}\right)$$

$$\Delta kW_{summer\ peak} = \frac{Volume \times Turnover}{1{,}000} \times \left(\frac{CF_{base}}{EF_{base} \times HOU_{base}} - \frac{CF_{CFR}}{WEF_{CFR} \times HOU_{CFR}}\right)$$

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

$$HOU_{base} = Volume \times Turnover \div \left(Flow_{base} \times 60\,\frac{min}{hr}\right)$$

Definition of Terms

Table 2-171: Terms, Values, and References for Variable Speed Pool Pumps

Term	Unit	Values	Source
Days, Pool pump days of operation per year.	$\frac{days}{yr}$	EDC Data Gathering Default: Table 2-174	2
EF_{base}, Baseline weighted energy factor of single-speed pool pump for Curve C flow.	$\frac{gallons}{W \cdot h}$	EDC Data Gathering Default: Table 2-172	2
WEF_{CFR}, Weighted energy factor of federal minimum compliant variable frequency drive pump for Curve C flow.	$\frac{gallons}{W \cdot h}$	EDC Data Gathering Default: Table 2-173 or Table 2-174	3
hhp, hydraulic horsepower is a measure of pump output rather than pump input.	*745.7 W*	EDC Data Gathering Default: Table 2-173 or Table 2-174	2
Volume, pool capacity	*Gallons*	EDC Data Gathering Default: Table 2-174	4
Turnover, number of times the full volume of the pool is filtered each day	$\frac{Pool\ volumes}{day}$	EDC Data Gathering Default: Table 2-174	5,8
Days, Pool pump days of operation per year.	*Days*	122 (4 months)	1
$Flow_{base}$, Single speed pump flow rate	$\frac{gallons}{minute}$	Table 2-172 Default=78	2
HOU_{base}, Hours of operation per day for base case single-speed frequency drive pool pump	$\frac{hours}{day}$	EDC Data Gathering Default: Table 2-174	2
HOU_{CFR}, Hours of operation per day for variable frequency drive pool pump	$\frac{hours}{day}$	EDC Data Gathering Default: 24	2
CF_{base}, Coincidence factor of existing pool pump	*None*	EDC Data Gathering Default: Table 2-174	9
CF_{CFR}, Coincidence factor of federal minimum compliant variable speed pool pump in continuous use	*None*	EDC Data Gathering Default: Table 2-174	6

Average Single Speed Pump Efficiency

Since this measure involves functional pool pumps, actual measurements of pump flow and wattage are encouraged. If this is not possible, then the pool pump efficiency can be inferred from the nameplate horsepower. Table 2-172 shows the average efficiency factor by pump size. Note that $EF_{base} = (Flow_{base} \times 60\ ^{minutes}/_{hour}) \div (Watts)$.

Table 2-172: Single Speed Pool Pump Efficiency Factors Source 2

Nameplate Power (HP)	0.50	0.75	1.00	1.50	2.00	2.50	3.00
EF_{base} (Gal/Wh)	3.38	3.29	2.51	2.27	2.3	2.18	2.00
Flow (Gal/min)	62.00	65.00	75.50	78.14	89.67	93.09	101.67

Table 2-173: Replacement Pool Pump Weighted Energy Factor[Source 3]

Pump Type	hhp Range	Federal Minimum (WEF_{CFR})
Self-Priming (In-ground)	≤0.130	5.55
	0.130–0.711	-1.30×ln(hhp)+2.90
	0.712-2.500	-2.30×ln(hhp)+6.59
Non-Self-Priming (Above-ground)	≤0.130	4.60
	>0.130	-0.85×ln(hhp)+2.87

Table 2-174: Default Inputs

Pool/ Pump Type	hhp	WEF_{CFR}	Days	Volume	Turn-over	HOU_{base}	CF_{base}	CF_{CFR}
In-ground Pool	0.72 Source 2	7.35 Source 3	122 Source 2	15,750 Source 4	2 Source 5	6.3 Source 2	0.31 Source 9	1 Source 6
Above-ground Pool	0.72 Source 2	3.15 Source 3	122 Source 2	7,540 Source 7	2 Source 8	4.0 Source 2	0.31 Source 9	1 Source 6

Default Savings

Default energy and demand savings for a 0.72 hhp (1–1.4 HP equivalent)[Source 2] motor are shown in Table 2-175, including those for the installation of a default ENERGY STAR pool pump from 2.8.1. However, you are encouraged to complete your own calculations for an ENERGY STAR installation to capture the full savings of higher efficiency pumps. Also note that the savings from 2.8.1 ENERGY STAR Pool Pumps extend for another 6.7 years beyond the life of this measure.

Table 2-175: Default Variable Speed Pool Pump Savings

Pump Type	ΔkWh	$\Delta kW_{summer\ peak}$
Non-ENERGY STAR In-ground Pool	1,170	0.5041
Non-ENERGY STAR Above-ground Pool	226	0.3153
ENERGY STAR In-ground Pool	1,275	0.5402
ENERGY STAR Above-ground Pool	371	0.3646

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) California Electronic Technical Reference Manual: (2019). "VSD for Pool & Spa Pump". California Technical Forum. Retrieved February 4, 2022. Weblink
2) U.S. EPA. (2020). ENERGY STAR Pool Pump Calculator. Retrieved July 31, 2020. Weblink
3) 10 CFR 431.465(f) Weblink
4) Engineering judgement. Source 1 Gives 15,700 gallons (15,754 in reference R802), Source 2 gives 22,000 gallons, and Source 8 gives 15,147 gallons.
5) International Swimming Pool and Spa Code. (2015). Section 810.1. Retrieved February 4, 2022. Weblink
6) To maximize energy savings, it is assumed that the pump runs 24 hours per day, which includes 100% of peak.
7) Koeller, J., Hoffman, H.W., *et al*. (2010). "Evaluation of Potential Best Management Practices - Pools, Spas, and Fountains." Retrieved on February 21, 2022. Weblink
8) International Swimming Pool and Spa Code. (2015). Section 704.4. Accessed February 4, 2022. Weblink
9) Southern California Edison. (2008). Pool Pump Demand Response Potential: Demand and Run-time Monitored Data. Page 22, Table 16. Weblink

2.8.3 Photovoltaic (PV) Solar Generation

Target Sector	Residential
Measure Unit	Photovoltaic (PV) array
Measure Life	15 years[Source 1]
Vintage	Retrofit or New Construction

Eligibility

Photovoltaic (PV) solar systems consist of an array of panels or thin-film substrates that generate direct current (DC) power when exposed to sunlight. These surfaces are tied together into a single circuit to expand generation levels. The DC power output is converted to alternating current (AC) power through inverter(s) that transform the electricity into the type of power used in residential homes. Generated power must be used to offset concurrent building loads and feed onto the local power grid through net metering to meet the needs of other customers. Charging of on-site battery systems is permitted, however peak demand savings as defined by this measure assumes non-tracking arrays without battery backup. This measure covers residential PV systems up to 30 kW DC.

The goals of Pennsylvania Act 129 are to reduce consumption and congestion on the state's power grid. Projects that generate savings for Act 129 programs must offset existing facility loads. Virtual metering of multiple sites, within the guidelines provided by 52 Pa. Code § 75.14.(e)[Source 2], will be permitted to define existing loads. Annual generated AC power from the PV array must not exceed 110% of the annual electric energy load of the customer's utility metered consumption.

Default values for project generation estimates can be developed using the National Renewable Energy Laboratory PV Watts® calculator[Source 3]. Additional details on required inputs for the PV Watts® model are included in the *Algorithms* section below. Demand savings estimated in this measure assume no tracking, panel tilt of 20°, and instantaneous fulfillment of on-site loads or back feeding to the grid.

Algorithms

All energy savings will be determined by the PV Watts® model and installed system specifications. System losses defined below will be the sum of PV Watts® deemed losses (14.08%) and an estimated in-situ loss factor to align model capacity factors with a Pennsylvania statewide analysis of PV system production and expected PV Watts® estimates[Source 4]. If the array contains non-tracking panels at varying azimuths or tilts, a new PV Watts® model must be completed for each array with the results combined to estimate project savings. There are no default savings for this measure.

$$System\ Losses = Default\ Model\ Losses + In\text{-}situ\ Losses$$

$$\Delta kWh = Provided\ by\ PV\ Watts$$

$$\Delta kW_{peak,summer} = \Delta kWh \times ETDF_{summer}$$

$$ETDF_{summer} = ETDF_{summer,ordinal} + (\Delta Azimuth * ETDF_{summer,incremental})$$

$$\Delta Azimuth = Difference\ between\ PV\ array\ azimuth\ and\ closest,\ smaller\ ordinal\ direction\ (90,\ 135,\ 180,\ or\ 225)$$

$$\Delta kW_{peak,winter} = \Delta kWh \times ETDF_{winter}$$

$$ETDF_{winter} = ETDF_{winter,ordinal} + (\Delta Azimuth * ETDF_{winter,incremental})$$

DEFINITION OF TERMS

Table 2-176 Terms, Values, and References for Solar PV

Term	Unit	Value		Sources
Location	*n/a*	EDC Data Gathering		EDC Data Gathering
DC System Size	*kW*	EDC Data Gathering		EDC Data Gathering
Module Type	*n/a*	Standard		Default
Array Type	*n/a*	EDC Data Gathering		EDC Data Gathering
System Losses	*%*	Default Model Losses + In-situ Losses		Calculated
Default Model Losses	*%*	14.08%		PV Watts Model
In-situ Losses	*%*	Up to 30 kW_{DC}	3.7%	4
Array Tilt	*degrees*	EDC Data Gathering		EDC Data Gathering
Array Azimuth	*degrees*	EDC Data Gathering		EDC Data Gathering
∆Aziumth	*degrees*	Calculated		Calculation
Advanced Parameters	*n/a*	As defined by PV Watts		PV Watts Model
DC to AC Size Ratio	*n/a*	1.2		Default
Inverter Efficiency	*%*	96		Default
Ground Coverage Ratio	*n/a*	0.4		Default
Albedo	*n/a*	Varies by location		Default
Bifacial	*n/a*	No		Default
Monthly Irradiance Loss	*%*	0 for all months		Default
$ETDF_{summer,ordinal}$	$\frac{kW}{kWh}$	See Table 2-177		5
$ETDF_{summer,increments}$	$\frac{kW}{kWh}$	See Table 2-178		Calculated
$ETDF_{winter,ordinal}$	$\frac{kW}{kWh}$	See Table 2-179		6
$ETDF_{winter,increments}$	$\frac{kW}{kWh}$	See Table 2-180		Calculated

Table 2-177: Summer Energy to Demand Factor, East to West facing Ordinal Numbers ($ETDF_{summer,ordinal}$)

Climate Region	Reference City	Array Azimuth				
		90°	135°	180°	225°	270°
C	Allentown	0.0624265	0.0651860	0.0817416	0.1044553	0.1245200
A	Binghamton	0.0678131	0.0719111	0.0907818	0.1150982	0.1357120
G	Bradford	0.0699694	0.0740833	0.0928029	0.1162379	0.1357924
I	Erie	0.0788975	0.0851381	0.1067952	0.1320825	0.1520063
E	Harrisburg	0.0647908	0.0680365	0.0857973	0.1096607	0.1307424
D	Philadelphia	0.0600152	0.0620246	0.0772186	0.0988952	0.1185881
H	Pittsburgh	0.0722741	0.0765022	0.0948878	0.1179122	0.1370800
B	Scranton	0.0630191	0.0664687	0.0836893	0.1063465	0.1257134
F	Williamsport	0.0679989	0.0712337	0.0883588	0.1107460	0.1301680

Table 2-178: Summer Energy to Demand Factor Increments, ($ETDF_{summer,increments}$)

Climate Region	Reference City	Array Azimuth Range			
		90 to 135	135 to 180	180 to 225	225 to 270
C	Allentown	0.0000613	0.0003679	0.0005047	0.0004459
A	Binghamton	0.0000911	0.0004193	0.0005404	0.0004581
G	Bradford	0.0000914	0.0004160	0.0005208	0.0004345
I	Erie	0.0001387	0.0004813	0.0005619	0.0004428
E	Harrisburg	0.0000721	0.0003947	0.0005303	0.0004685
D	Philadelphia	0.0000447	0.0003376	0.0004817	0.0004376
H	Pittsburgh	0.0000940	0.0004086	0.0005117	0.0004260
B	Scranton	0.0000767	0.0003827	0.0005035	0.0004304
F	Williamsport	0.0000719	0.0003806	0.0004975	0.0004316

Table 2-179: Winter Energy to Demand Factor Ordinal, East to West facing Ordinal Numbers ($ETDF_{winter,ordinal}$)

Climate Region	Reference City	Array Azimuth				
		90°	135°	180°	225°	270°
C	Allentown	0.0121198	0.0113890	0.0085075	0.0035736	0.0019462
A	Binghamton	0.0099532	0.0092431	0.0070935	0.0033193	0.0022980
G	Bradford	0.0074126	0.0068730	0.0052236	0.0022748	0.0017657
I	Erie	0.0045040	0.0041701	0.0030910	0.0013280	0.0011115
E	Harrisburg	0.0099236	0.0092490	0.0068901	0.0029286	0.0018332
D	Philadelphia	0.0125401	0.0118317	0.0088548	0.0037608	0.0020548
H	Pittsburgh	0.0060367	0.0056171	0.0043588	0.0019083	0.0015966
B	Scranton	0.0106358	0.0100137	0.0076209	0.0034986	0.0021796
F	Williamsport	0.0096529	0.0089461	0.0067885	0.0030166	0.0020645

Table 2-180: Winter Energy to Demand Factor Increments, ($ETDF_{winter,increments}$)

Climate Region	Reference City	Array Azimuth Range			
		90° to 135°	135° to 180°	180° to 225°	225° to 270°
C	Allentown	(0.0000162)	(0.0000640)	(0.0001096)	(0.0000362)
A	Binghamton	(0.0000158)	(0.0000478)	(0.0000839)	(0.0000227)
G	Bradford	(0.0000120)	(0.0000367)	(0.0000655)	(0.0000113)
I	Erie	(0.0000074)	(0.0000240)	(0.0000392)	(0.0000048)
E	Harrisburg	(0.0000150)	(0.0000524)	(0.0000880)	(0.0000243)
D	Philadelphia	(0.0000157)	(0.0000662)	(0.0001132)	(0.0000379)
H	Pittsburgh	(0.0000093)	(0.0000280)	(0.0000545)	(0.0000069)
B	Scranton	(0.0000138)	(0.0000532)	(0.0000916)	(0.0000293)
F	Williamsport	(0.0000157)	(0.0000479)	(0.0000838)	(0.0000212)

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify system specifications (array size, azimuth, tilt, etc.) through document or on-site review and ensure PV Watts® model inputs align with the design parameters used for system generation estimates.

Sources

19) Wisler, R. Bolinger, M. Seel, J. (2020, June). "Benchmarking Utility-Scale PV Operational Expenses and Project Lifetimes: Results from a Survey of U.S. Solar Industry Professionals". Current EUL assumptions are 25-35 years with an average of 32.5 years. Act 129 caps lifetime at 15 years. Weblink

20) 52 Pa. Code § 75.14.(e). Weblink

21) PV Watts® Calculator. National Renewable Energy Lab (NREL). Weblink

22) InClime for PA PUC. (2024, February). "Capacity Factor Analysis EY2014-EY2023". Analysis of Pennsylvania Alternative Energy Portfolio Standards (AEPS) Program and additional losses needed to align PV Watts capacity factor output with AEPS Program DC capacity factor analysis.

23) Calculated through the ratio of PV Array total summer peak demand savings (aligned with PA Ph V peak demand definitions) and the annual electric generation for a given array azimuth installed at 20° tilt. Incremental $ETDF_{summer}$ calculated assuming linear changes between two ordinal values.

24) Calculated through the ratio of PV Array total winter peak demand savings (aligned with PA Ph V peak demand definitions) and the annual electric generation for a given array azimuth installed at 20° tilt. Incremental $ETDF_{winter}$ calculated assuming linear changes between two ordinal values.

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 V 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
Measure Unit	N/A
Measure Life	Direct Load Control: 11 years Behavioral DR: 1 year
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 V. 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 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 act 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. The most common type of design satisfying this criterion 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 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 like 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 summer 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. Similarly, if winter events are most likely to be called on very cold days, cold non-event days should be used for matching and mild days should be excluded. 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 (Act 129 or PJM) 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 or cold days that would be similar to an event. Including mild 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 estimation sample to relevant days reduces that modeling challenge.

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

To be eligible for a 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-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. The following equations provide mathematical definitions of the average peak period load impact estimate that would be calculated using an approved method.

$$\Delta kW_{summer\ peak} = \frac{\sum_{i=1}^{n\_summer} \Delta kW_i}{n\_summer}$$

$$\Delta kW_{winter\ peak} = \frac{\sum_{i=1}^{n\_winter} \Delta kW_i}{n\_winter}$$

$$\Delta kW_i = kW_{Reference_i} - kW_{Metered_i}$$

Definition of Terms

Table 2-181 Definition of Terms for Estimating DLC and Behavior-based Load Impacts

Term	Unit	Values	Source
n_summer, Number of summer DR hours during a program year for the EDC	*Hours*	EDC Data Gathering	EDC Data Gathering
n_winter, Number of winter 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.