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TECHNICAL REFERENCE MANUAL

Volume 2: Residential Measures

State of Pennsylvania

Act 129 Energy Efficiency and Conservation Program

&

Act 213 Alternative Energy Portfolio Standards

Issued August 2019

Revised February 2021

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2 RESIDENTIAL MEASURES

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

2.1 LIGHTING

2 ENERGY STARRESIDENTIAL MEASURES

2.1 LIGHTING

2.1.1 RESIDENTIAL LED LIGHTING

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

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

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

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

Efficient LED Lighting Product	Lumen Range	Program Delivery	Eligibility
		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 is assumed to be a bulb or fixture with an efficacy equal to 45 lumens per watt. For upstream buy-down, retail (time of sale), or efficiency kit programs, baseline wattages can be determined using the methods described below. Forvaries 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 may be used as. 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 ENERGY STAR or other high-efficiencyresidential LED lighting energy savings algorithm is:

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

Energy and demand savings algorithms include a term to account for cross-sector sales (i.e., lamps that end up in non-residential use). Default values for non-residential terms are based on values in Vol. 3, Sec. 3.1.7 Lighting Improvements for Midstream (http://www.puc.pa.gov/filing_resources/issues_laws_regulations/act_129_information/technical_reference_manual.aspx). For direct install programs or other programs where it is known that all lamps will be in residential end uses, there are no non-residential energy or demand savings.

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

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

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

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

Definition of Terms

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

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

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

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 ENERGY STARResidential LED Lighting

Term	Unit	Value	Sources
$Watts_{base}$, Wattage of baseline case lamp/fixture	*Watts*	Direct install: EDC Data Gathering[3] GSLs outside of EISA lumen range or see Baseline Wattage Values belowexempt bulb type: Manufacturer rated comparable wattage Linear LED fixture: EDC Data Gathering ($Lumens_{ee}$) and Table 2-3 ($Efficacy_{base}$)	1EDC data gathering, 3 and 4
$Watts_{EE}$, Wattage of efficient case lamp/fixture	*Watts*	EDC Data Gathering	EDC Data Gathering
HOU_{res}HOU, Average hours of use per day per unit installed for residential use	$\frac{hours}{day}$	Table 2-4	27
$HOU_{non-res}$, Average hours of use per day per unit installed for non-residential use*L*, Factor to adjust interactive effect factors to account for proportion of LEDs installed in interior locations	$\frac{hours}{day}$%	EDC Data Gathering Default = 6.85Interior: 100% Exterior: 0% Unknown: 90.3%	510

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[3] EDCs may use the wattage of the replaced bulb for directly installed program bulbs

Term	Unit	Value	Sources
$IE_{kWh,res}$, HVAC Interactive Effect for LED energy for residential use	*None*	EDC Data Gathering Default = Table 2-5 Exterior Fixtures: 0%	36
$IE_{kW,res}$, HVAC $_s$, Summer Interactive Effect for LED demand for Demand Factor – applies to residential uselighting in conditioned residential spaces.	*None*	EDC Data Gathering Default =Table 2-3 Table 2-5Exterior Fixtures: 0%	36
$IE_{kWh,non\text{-}res}$, HVAC Interactive Effect for LED energy for non-residential use	*None*	EDC Data Gathering Default = 0%	5
$IE_{kW,non\text{-}res}$, HVAC $_w$, Winter Interactive Effect for LED demand for non-Demand Factor – applies to residential uselighting in conditioned residential spaces.	*None*	EDC Data Gathering Default = 19.2%Default =Table 2-5	56
*ISRres*ISR, In-service rate per incented product for residential use	%	Direct Install: 100% All other program delivery: EDC Data Gathering[4], Default = 92%[5]	EDC Data Gathering4
$ISR_{non\text{-}res}$, In-service rate per incented product for non-residential use	%	EDC Data Gathering, Default = 98%	5
CF_{res}, DemandCF_s, Summer Coincidence Factor for residential use	*None*Proportion	Table 2-20.101	25
$CF_{non\text{-}res}$, Demand Coincidence Factor for non-residential useCF_w, Winter coincidence factor	*None*Proportion	EDC Data Gathering, Default = 0.60121	5
CSS, Cross-sector sales. Share$Lumens_{ee}$, Lumen rating of the incentivized lamps that go to non-residential uses.lighting product	%*Lumens*	EDC Data Gathering, Default = 7.4%	EDC Data Gathering6
$Efficacy_{base}$, Efficacy of the baseline fixture type for linear fluorescents	*Lumens/watt*	Table 2-3	8, 9

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VARIABLE INPUT VALUES

Baseline Wattage Values, Linear LEDs

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

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

where *Lumen Output* is the rated light output of the the least-efficient bulb, commercially-available, commonly-installed technology available in lumens.

[4] For EDC Data Gathering, EDCs must use the method established in the DOE Uniform Methods Project, October 2017. (https://www.nrel.gov/docs/fy17osti/68562.pdf)

[5] For direct install, giveaway, and energy kit program bulbs, EDCs have the option to use an evaluated ISR when verified through PA program primary research.

For direct installation programs where the removed bulb is known, and the bulb is in working condition, EDCs may use thethe market. Linear LED baseline wattage of the replaced bulb in lieu of the formula.[6](Watts$_{base}$) is calculated by dividing Lumens$_{ee}$ by Efficacy$_{base}$ (Table 2-3).

Hours of Use and Peak Coincidence Factor Values

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

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

Table 2-3: Bulb and Fixture Hours of Use and Peak Coincidence Factor Values, by Room: Baseline Wattage, Linear Lamps & Fixtures

Room	Efficient HOUres Lamp or Fixture	Efficient CFres Efficacy base (Lumens/watt)	ΔBulbsHOUres	ΔbulbsCFres
Basement Linear Lamps, Fixtures, and Retrofit Kits, 2 ft		167.4	0.035	1.7 / 0.066
Bathroom	2.8	0.105	2.3 Linear Lamps, Fixtures, and Retrofit Kits, 3 ft	0.0967 2.5
Linear Lamps, Fixtures, and Retrofit Kits, 4 ft Bedroom	2.3	0.073	175.8	0.064
Closet	1.2	0.038	0.6	0.029

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Room	Efficient HOUres Lamp or Fixture	Efficient CFres Efficacy base (Lumens/watt)	All Bulbs HOUres	All bulbs CFres
Dining Room	3.2	0.118	2.7	0.108
ExteriorLinear Lamps, Fixtures, and Retrofit Kits, 5 ft	480 4	0.274	3.9	0.265
Hallway	2.4	0.085	1.9	0.076

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Room	Efficient HOU res Lamp or Fixture	Efficient CF res Efficacy base (Lumens/watt)	All Bulbs HOU res	All bulbs CF res
KitchenLinear Lamps, Fixtures, and Retrofit Kits, 8 ft	4.4	0.150	82.3.9	0.142
Living Room	4.1	0.106	3.7	0.098
Other	2.1	0.070	1.7	0.061
Overall Household or unknown room	3.0	0.106	2.5	0.101

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Interactive Effects Values

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

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.

Table 2-4: EnergyBulb and Demand HVAC Interactive EffectsFixture Hours of Use by EDC[7]Room

EDCRoom	$IE_{kWh,res}$HOU	$IE_{kW,res}$
DuquesneBasement	8%1.7	13%
FE (Met-Ed)Bathroom	-8%2.3	13%
BedroomFE (Penelec)	1%.8	10%
FE (Penn Power)Closet	0%.6	20%
FE (WPP)Dining Room	-2%.7	30%
ExteriorPPL	-6%3.9	12%
PECOHallway	1%.9	23%
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

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

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verification of open variables. The Pennsylvania Evaluation Framework[8] provides specific guidelines and requirements for evaluation procedures.

Sources

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

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 2023 PA residential baseline study 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.

2)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", January 13, 2014. Based on data derived from Tables 1-2 &. Pg 4, table 1-3 but exclusive of inefficient bulbs1. Weblink

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

8) The ISR is based on an installation rate "trajectory" and includes savings for all program bulbs that are believed to be installed within three years of purchase as established in the DOE Uniform Methods Project (UMP), Chapter 6: Residential Lighting Evaluation Protocol. October 2017. This protocol estimates the three-year ISR based on a researched first year ISR. For the purposes of this TRM, a 79% first year ISR was used based on intercept surveys conducted in the PECO service territory (Grainger Lighting Product Web Pages: Weblink1, Weblink2

9) PA 2026 TRM Appendix C. Weblink

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

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

4) ~~Navigant Consulting, Inc. "Final Annual Report to the Pennsylvania Public Utility Commission. Prepared for PECO. Program Year 5". November, 2014.)~~

5) ~~See Pennsylvania TRM Vol. 3, Sec. 3.1.7 Lighting Improvements for Midstream. http://www.puc.pa.gov/filing_resources/issues_laws_regulations/act_129_information/technical_reference_manual.aspx~~

6) ~~Based on a savings-weighted average of EDC-reported cross-sector sales values for PY6-PY9. http://www.puc.pa.gov/filing_resources/issues_laws_regulations/act_129_information/electric_distribution_company_act_129_reporting_requirements.aspx~~

2.1.2 Residential Occupancy Sensors

Target Sector	Residential ~~Establishments~~
Measure Unit	Occupancy Sensor
Measure Life	~~10~~8 years Source 3
Vintage	Retrofit

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

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Eligibility

~~Eligibility~~

This protocol is for the installation of ~~occupancy sensors and/or~~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 ~~residential~~ homes. Occupancy sensors installed outdoors or in multifamily common areas~~.~~ are not eligible under this protocol.

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Algorithms

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~~Algorithms~~

$$\Delta kWh = \frac{Watts_{controlled}}{1000\frac{W}{kW}} \times (RH_{old} - RH_{new}) \frac{Watts_{controlled}}{1{,}000} \times (1 + IE_{kWh}) \times (RH_{old} - RH_{new}) \times 365 \frac{days}{yr} \times ISR$$

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

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~~Definition of Terms~~

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

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

Definition of Terms

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

Residential Occupancy Sensors

Term	Unit	Value	Source
Term	Unit	Value	Source
$Watts_{controlled}$, Wattage of the fixture(s) being controlled by the occupancy sensor	W	EDC Data Gathering Default = 105.5 W	EDC Data Gathering
$Watts_{controlled}$, 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	1.75 (70% of RH_{old})	2

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Deemed Savings

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

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”, January 13, 2014. . Weblink

2) Lighting control savings fractions consistent with current programs offered by National Grid, Northeast Utilities, Long Island Power Authority, NYSERDA, and Energy Efficient Vermont

3) GDS Associates, Inc. (2007). Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures. Prepared for The New England State Program Working Group.

4) Statewide Evaluation Team (GDS Associates, Inc, Nexant, Research into Action, Apex Analytics LLC), “2015 Energy Efficiency Potential Study for Pennsylvania”, February 27, 2015. http://www.puc.pa.gov/pcdocs/1345079.pdf

2) 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. Pg 19, table 7. Weblink.

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 2023 PA 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 2023 PA 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”. Pg 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

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2.1.32.1.1 LED and Electroluminescent Nightlights

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

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

Algorithms

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

$$\Delta kWh = \frac{(W_{base} \times HOU_{base} - W_{ee} \times HOU_{ee})}{1000\frac{W}{kW}} \times \frac{(W_{base} \times HOU_{base} - W_{ee} \times HOU_{ee})}{1{,}000} \times ISR_{NL} \times 365\frac{days}{yr}$$

ΔkW_{peak} = 0 (assumed)

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

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

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 = 0.2014	4

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~~Deemed~~Default Energy Savings

LED ΔkWh $= \cancel{\frac{(7 \times 12 - 1 \times 12)}{1000\frac{W}{kW}}} \cancel{\times} \frac{(7 \times 12 - 1 \times 12)}{1{,}000} \times 0.\cancel{2}14 \times 365\frac{days}{yr} = \cancel{5.}3.7\ kWh$

Electroluminescent ΔkWh $= \cancel{\frac{(7 \times 12 - 0.03 \times 24)}{1000\frac{W}{kW}}} \cancel{\times} \frac{(7 \times 12 - 0.03 \times 24)}{1{,}000} \times 0.\cancel{2}14 \times 365\frac{days}{yr} = \cancel{6.1}4.3\ kWh$

~~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~~

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, ~~February 2009, pp~~pg. 2–3.
2) Limelite Equipment Specification. Personal Communication, Ralph Ruffin, EL Products, 512-357-2776/ ralph@limelite.com.
3) Electroluminescent nightlights are assumed to operate continuously.
4) ~~Based on ISR rates reported by FirstEnergy for nightlights in kits for PY9. See http://www.puc.pa.gov/filing_resources/issues_laws_regulations/act_129_information/electric_distribution_company_act_129_reporting_requirements.aspx~~
4) Weighted average of ISRs from surveys of FirstEnergy customers that received nightlights in kits in PY13 and PY14.

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2.1.4 Holiday Lights

Target Sector	Residential ~~Applications~~
Measure Unit	One ~~50-bulb~~ Strand of Holiday lights
Measure Life	10 ~~years[Source 1]~~ 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

~~Eligibility~~

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

Algorithms

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

$$\Delta kWh_{C9} = \frac{[(INC_{C9} - LED_{C9}) \times \#Bulbs \times \#Strands \times HOU]}{1000\frac{W}{kW}} \frac{[(INC_{C9} - LED_{C9}) \times \#Bulbs \times \#Strands \times HOU]}{1{,}000}$$

$$\Delta kWh_{C7} = \frac{[(INC_{C7} - LED_{C7}) \times \#Bulbs \times \#Strands \times HOU]}{1000\frac{W}{kW}} \frac{[(INC_{C7} - LED_{C7}) \times \#Bulbs \times \#Strands \times HOU]}{1{,}000}$$

$$\Delta kWh_{mini} = \frac{[(INC_{mini} - LED_{mini}) \times \#Bulbs \times \#Strands \times HOU]}{1000\frac{W}{kW}} \frac{[(INC_{mini} - LED_{mini}) \times \#Bulbs \times \#Strands \times HOU]}{1{,}000}$$

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

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

Key assumptions

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

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

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.~~48~~35	1
LED_{C7} , Wattage of LED C7 bulbs	*Watts/Bulb*	0.~~48~~08	1
INC_{C7} , Wattage of incandescent C7bulbs	*Watts/Bulb*	~~6.0~~5.25	1
LED_{C9} , Wattage of LED C9 bulbs	*Watts/Bulb*	~~2.~~0.28	1
INC_{C9} , Wattage of incandescent C9 bulbs	*Watts/Bulb*	7.0	1
$\%_{Mini}$, Percentage of holiday lights that are "mini"	*%*	50%	~~1~~2
$\%_{C7}$, Percentage of holiday lights that are "C7"	*%*	25%	~~1~~2
$\%_{C9}$, Percentage of holiday lights that are "C9"	*%*	25%	~~1~~2
$\#_{Bulbs}$, Number of bulbs per strand	*Bulbs/strand*	EDC Data Gathering Default~~: 50 per strand~~ Mini: 100 Default C7: 25 Default C9: 25	~~3~~1
$\#_{Strands}$, Number of strands of lights per package	*~~strands~~Strands/package*	EDC Data Gathering Default: 1 strand	~~3~~1
HOU , Annual hours of operation	*Hours/yr*	150	~~1~~2

~~Deemed~~Default Savings

The ~~deemed~~default savings for installation of LED C9, C7, and mini lights is ~~37.5~~25.2 kWh, ~~41~~19.4 kWh, and ~~3~~4.1 kWh, respectively. The weighted average savings are ~~21~~13.2 kWh per strand. ~~There are no demand savings as holiday lights only operate at night. Since the lights do not operate in the summer, the coincidence factor for this measure is 0.0.~~

Evaluation Protocol

The most appropriate evaluation protocol for this measure is verification of installation coupled with assignment of stipulated energy savings. As these lights are used on a seasonal basis, verification

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must occur in the winter holiday season. Given the relatively small amount of impact evaluation risk that this measure represents, and given that the savings hinge as heavily on the actual wattage of the supplanted lights than the usage of the efficient LED lights, customer interviews should be considered as an appropriate channel for verification.

Sources

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

1)2) Michigan Database of Energy Efficiency Measures: Based on spreadsheet calculations using collected data Database. Accessed January 2024. Weblink

2) http://www.energyideas.org/documents/factsheets/HolidayLighting.pdf

3) Typical values of lights per strand and strands per package at Home Depot and other stores.

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2.2 HVAC

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

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

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.

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

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 dealt withaddressed 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 establishmentsbuildings with properly sized baseline equipment are excluded from claiming savings from proper sizing.

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Algorithms

This algorithm is used for the installation of new high efficiency air conditioners or heat pumps.ASHP and CAC measures:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$\Delta kW = \Delta kW_{cool} + \Delta kW_{PSF}$$

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

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

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

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

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

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

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:

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

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:

$SEER = EER_g \times GSHPDF \times GSER$

$EER = EER_g \times GSPK$

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

Qualifying: Package Terminal Heat Pumps, Package Terminal Air Conditioners

$SEER = EER$

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

Definition of Terms

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

$COP = COP_g$

Qualifying: Package Terminal Heat Pumps, Package Terminal Air Conditioners

$SEER = EER$

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

Definition of Terms

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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[9]	$kBTU/hr$	EDC Data Gathering	AEPS Application; EDC Data Gathering
$CAPY_{heat}$, The heating capacity of the heat pump being installed[10] (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, Default see Table 2-8	2; EDC Data Gathering
		Default: see Table 2-10	2
$SEER2_{ee}$, $SEER_{ee}$, Seasonal Energy Efficiency Ratio of the qualifying unit being installed[11]	$\frac{BTU}{W \cdot h}$	EDC Data Gathering	AEPS Application; EDC Data Gathering
$EER2_{base}$, EER_{base} , Energy Efficiency Ratio of the Baseline Unit	$\frac{BTU}{W \cdot h}$	EDC Data Gathering, Default see Table 2-8	3; EDC Data Gathering
		Default: see Table 2-10	2
$EER2_{ee}$, EER_{ee} , Energy Efficiency Ratio of the unit being installed[12]	$\frac{BTU}{W \cdot h}$	EDC Data Gathering Default: $-0.0228 \times SEER^2 + 1.1522 \times SEER$	4; EDC Data Gathering; AEPS Application
		Default: EERee: $-0.02 \times SEER^2 + 1.12 \times SEER$	3,4
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
$HSPF2_{base}$, $HSPF_{base}$, Heating Seasonal Performance Factor of the Baseline Unit	$\frac{BTU}{W \cdot h}$	EDC Data Gathering, Default see Table 2-8	2; EDC Data Gathering
		Default: see Table 2-10	2
$HSPF2_{ee}$, $HSPF_{ee}$, 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	10 5

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

[10] Ibid. This refers to the capacity of the heat pump and not any auxiliary electric resistance heat.

[11] Ibid.

[12] Ibid.

Term	Unit	Value	Sources
COP_{base} , 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
COP_{ee} , Coefficient of Performance of the unit being installed. This is a measure of the efficiency of a heat pump	*Proportion*	EDC Data Gathering	AEPS Application; EDC Data Gathering
OF_{cool} , Oversize factor	*None*	EDC Data Gathering~~, Default see Table 2-9~~	~~5~~EDC Data Gathering
		Default: see Table 2-12	6
OF_{heat} , Oversize factor	*None*	EDC Data Gathering~~, Default see Table 2-9~~	~~6~~EDC Data Gathering
		Default: see Table 2-12	7
GSER , Factor ~~used~~ to ~~determine~~convert EER_g to the ~~SEER~~equivalent HSPF of ~~a GSHP based on its EER_g~~an air-source unit to enable comparisons to the baseline unit	$\frac{BTU}{W \cdot h}$	~~1.02~~See Table 2-13	~~7~~8
~~*GSPK*~~*GSOP* , Factor to convert ~~EER_g~~COP_g to the equivalent ~~EER~~COP of an air ~~conditioner~~-source unit to enable comparisons to the baseline unit	*Proportion*	~~0.8416~~See Table 2-13	~~7~~8
~~*GSHPDF* , Ground Source Heat Pump Derate Factor~~	~~*Proportion*~~	~~0.885~~	~~8~~
$EFLH_{cool}$, Equivalent Full Load Hours of operation during the cooling season for the average unit	$\frac{hours}{yr}$	See $EFLH_{cool}$ in Vol. 1, App. A	9
$EFLH_{heat}$, Equivalent Full Load Hours of operation during the heating season for the average unit	$\frac{hours}{yr}$	See $EFLH_{heat}$ in Vol. 1, App. A	9
~~CF~~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[illegible]

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Baseline Equip.	Early Replacement				Replace on Burnout / New Construction			
Baseline Equip.	$SEER_{base}$	EER_{base}	$HSPF_{base}$	COP_{base}	$SEER_{base}$	EER_{base}	$HSPF_{base}$	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
ASHP (Single-Package)	14.1[a]	11.7[b]	7.2	2.5[c]	13.4	11.2[b]	6.7	2.3
CAC (Split systems and Single-package)	13.2	11.1[b]	–	–	13.4	11.2[b]	–	–
ASHP	13.5	11.4	8.2		14	12.0	8.2	
CAC	12.1	10.6[a]	–		13	11.3	8.2	
GSHP	15.0	16.6[a]	10.9		14	12.0	8.2	
Elec. Baseboard	–	–	3.4124[d]	1.0	–	–	–	–
Elec. Furnace[13]	–	–	3.2412[d]	0.95	–	–	–	–
Space Heaters	–	–	3.4124[d]	1.0	–	–	–	–
PTAC[14,15,16] GSHP: $EER_{base} = 10.9 - (0.213 \times CAPY_{cool})$ Water-to-air, ground water	18.5[e]	$EER_{base} = 14.0 - (0.3 \times CAPY_{cool})$ 18.0[f]	10.8[g]		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				3.7[f]	PTHP 15.2[h]	$EER_{base} = 10.8 - (0.213 \times CAPY_{cool})$ 16.3	$3.412 \frac{Btu}{W \cdot h} \times (2.9 - 0.026 \times CAPY_{cool})$ 8.9[i]	$EER_{base} = 14.0 - (0.3 \times CAPY_{cool})$ 3.1 / $3.412 \frac{Btu}{W \cdot h} \times (... 0.052 \times CAPY ...)$
a Calculated using GSHP: Brine-to-water, ground loop					11.6[h]	12.1	7.6[i]	2.5

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

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

[15] "Early Replacement" is for nonstandard size packaged terminal air conditioners and heat pumps with existing sleeves having an external wall opening of less than 16 in. high or less than 42 in. wide and having a cross-sectional area less than 670 sq. in. Shall be factory labeled as follows: "Manufactured for nonstandard size applications only: not to be installed in new construction projects."

[16] "New Construction" is intended for applications with new, standard size exterior wall openings.

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PTAC[i]	13.8 - (0.3 x $CAPY_{cool}$)	=	=	13.8 - (0.3 x $CAPY_{cool}$)	=	=
PTHP[i]	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 2023 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 2023 Pennsylvania Statewide Act 129 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.

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

1) For 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.

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

https://www.gpo.gov/fdsys/pkg/CFR-2017-title10-vol3/pdf/CFR-2017-title10-vol3-sec430-32.pdf. For PTAC and PTHP: standards are based on requirements of ASHRAE 90.1-2016, Energy Standard for Buildings Except Low-Rise Residential Buildings, Table 6.8.1-4, https://www.ashrae.org/technical-resources/standards-and-guidelines/read-only-versions-of-ashrae-standards.

3) Average EER for SEER 13 units as calculated by EER = -0.02 × SEER² + 1.12 × SEER based on 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. https://www.nrel.gov/docs/fy11osti/49246.pdfWeblink

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. http://oaktrust.library.tamu.edu/bitstream/handle/1969.1/152118/ESL-TR-13-04-01.pdfWeblink

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, p. 4.

5)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[17] and 40% oversizing of heat pumps.[18] and 40% oversizing of heat pumps. Thus assuming for most baseline overisize 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, emended December 15, 2010. Weblink
ACCA, "Verifying ACCA Manual S Procedures," Weblink

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

7) VEIC estimate. Extrapolation of manufacturer data.

8) McQuay Application Guide 31-008, Geothermal Heat Pump Design Manual, 2002. Engineering Estimate - See System Performance of Ground Source Heat Pumps

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. https://www.ecobee.com/donateyourdata/

10)9) (Weblink) and updated based on the latest CDD and HDD values from NOAA's 15-year annual climate Normals (Northeast Energy Efficiency Partnerships, Inc., "Strategies to Increase Residential HVAC Efficiency in the Northeast", (February 2006): Appendix C Benefits of HVAC Contractor Training: Field Research Results 03-STAC-01, p. 4. –2020) (Weblink)

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

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

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2.2.2 High Efficiency Equipment: Ductless Heat Pumps with for Midstream Delivery Option: ASHP, CAC, PTAC, PTHP

Target Sector	Residential Establishments
Measure Unit	CAC, ASHP, PTAC or PTHP Unit
Measure Life	15 Source 1
Vintage	Replace on Burnout, New Construction
Measure Unit	Ductless Heat Pump Unit
Measure Life	15 years Source 1
Vintage	Early Replacement, 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:

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

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

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

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

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

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

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

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

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

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

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

Qualifying: Package Terminal Heat Pumps, Package Terminal Air Conditioners

$$SEER = EER$$

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

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	3, EDC Data Gathering

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Term	Unit	Value	Sources
		at 230V if dual voltage	
$CAPY_{heat}$, 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 × 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

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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

5.0ENERGY 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

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 5.0 requirements. The baseline heating system could be:

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

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

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1) A standard efficiency heat pump system

2) A central air conditioning system

3) A room air conditioner

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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.

~~The baseline cooling system can be:~~

~~1) A standard efficiency heat pump system~~

~~2)1)A central air conditioning system~~

~~3)1)A room air conditioner~~

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~~For new construction or addition applications, the baseline assumption is a standard-efficiency ductless unit (Table 2-12). DHP systems may be installed as the primary heating or cooling system for the house or as a secondary heating or cooling system for a single room. Cooling savings claimed from proper sizing requires Manual J calculations, following of ENERGY STAR HVAC Quality Installation procedures, or similar calculations.~~ Residential ~~establishments~~buildings with properly sized baseline equipment are excluded from claiming savings from proper sizing.

MIDSTREAM HVAC OVERVIEW

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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.

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

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

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

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

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

$$\Delta kW = \Delta kW_{cool} + \Delta kW_{PSF}$$

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

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

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

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

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

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

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

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[20]	$kBTU/hr$	EDC Data Gathering	AEPS Application; EDC Data Gathering
$CAPY_{heat}$, The heating capacity of the heat pump being installed[21]	$kBTU/hr$	EDC Data Gathering	AEPS Application; EDC Data Gathering

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

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Term	Unit	Value	Sources
$CAPY_{RAC}$, 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
~~$SEER_{base}$~~ $SEER2_{base}$, 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: ~~12.1~~13.6	EDC Data Gathering; ~~2;~~3, 10
~~$SEER_{ee}$~~ $SEER2_{ee}$, Seasonal Energy Efficiency Ratio of the qualifying unit being installed~~[22]~~	$\frac{BTU}{W \cdot h}$	EDC Data Gathering	AEPS Application; EDC Data Gathering
~~EER_{base}~~ $EER2_{base}$, 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 ~~Table 2-12~~ Midstream: 11.4	EDC Data Gathering; 3, 4, 5
~~EER_{ee}~~ $EER2_{ee}$, Energy Efficiency Ratio of the unit being installed~~[23]~~	$\frac{BTU}{W \cdot h}$	EDC Data Gathering Default EER_{ee}: $-0.022802 \times SEER_{ee}^2 + 1.152212 \times SEER_{ee}$	EDC Data Gathering; AEPS Application; 4, 5
~~$HSPF_{base}$~~ $HSPF2_{base}$, 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.~~7~~0	EDC Data Gathering; ~~2;~~3, 10
~~$HSPF_{ee}$~~ $HSPF2_{ee}$, Heating Seasonal Performance Factor of the unit being installed~~[24]~~	$\frac{BTU}{W \cdot h}$	EDC Data Gathering	AEPS Application; EDC Data Gathering
PSF , Proper Sizing Factor or the assumed savings due to proper sizing and proper installation	*Proportion*	Midstream Delivery, properly size baseline equipment, or not properly sized: 0 Properly sized: 0.05	11

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

Term	Unit	Value	Sources
OF_{cool} , Oversize factor	None	EDC Data Gathering Default: Table 2-19 Midstream: 1.~~1~~0	EDC Data Gathering; ~~5~~6
OF_{heat} , Oversize factor	None	EDC Data Gathering Default: Table 2-19 Midstream: 1.~~3~~0	EDC Data Gathering ;~~6~~ 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.~~01~~02	~~7;~~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 2-18~~Table 2-24	~~8~~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	~~8~~9
~~CF~~CF_{summer} , Demand Coincidence Factor during the summer months	*Proportion*	See *CF* in Vol. 1, App. A	~~8~~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

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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		
	$SEER_{base}$ $SEER2_{base}$	EER_{base} $EER2_{base}$	$HSPF_{base}$ $HSPF2_{base}$	$SEER_{base}$ $SEER2_{base}$	EER_{base} $EER2_{base}$	$HSPF_{base}$ $HSPF2_{base}$
Ductless	1314.3	11.3	8.27.5	14.3	1211.7	8.27.5

Note: Early replacement defaults, though stemming from the 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}	1.4	0	1	1.4	1.4	1	0	0.6
OF_{cool}	1.4	1.5	1	0	0	1	1	0

Midstream Composite Baseline Calculations

The Midstream Delivery ProgramThis measure, estimates the baseline system using composite values calculated from historical participant data. The composite

SEER2, EER2, and HSPF2 values of the baseline inputs (SEER, EER, OF, DLF, and HSPF) are based on the PA TRM values Table 2-8 new construction/replace on burnout vintages and baseline heating and cooling system splits from historical PECO PY8 to PY9 and PPL PY8 to PY10Q1 data. the 2023 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 2-14 through Table 2-18

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

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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 make the assumption 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 – SEERSEER2 and EEREER2 Baseline Splits

Cooling Type	$SEER_{base}SEER2_{base}$	$EER_{base}EER2_{base}$	Split[25]
Central AC	13.04	11.32	4%
DHP or ASHP	14.03	12.011.8	8%
No existing cooling for primary space	13.04	11.32	29%
No existing cooling for secondary space	11.313.4	9.811.2	30%
Room AC	11.313.4	9.811.2	30%
Composite[26]	12.113.6	10.511.4	100%

Table 2-21: Midstream DHP – HSPFHSPF2 Baseline Splits

Heating Type	$HSPF_{base}HSPF2_{base}$	Split
ASHP	8.27.5	3%
Electric furnace	3.2.7	1%
Electric resistance or de facto space heaters	3.42.9	32%
No existing or non-electric heating	8.27.5	57%
Standard DHP	8.27.5	8%
Composite	6.70	100%

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

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

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

Cooling Type	DLF_{cool}	OF_{cool}	Split
Central AC	1.15	1.50	8%
Central ASHP	1.15	1.40	5%
Ductless Heat Pump	1.00	1.0	19%
Room AC	1.00	1.0	69%
Composite	1.02	1.10	100%

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

Heating Type	DLF_{heat}	OF_{heat}	Split
Central ASHP	1.15	1.40	6%
De facto Space Heaters	1.00	0.6	5%
Ductless Heat Pump	1.00	1.0	26%
Electric Baseboard	1.00	1.40	62%
Electric Furnace	1.15	1.40	1%
Composite	1.0102	1.30	100%

Table 2-24: Midstream DHP – Composite EFLH Values

Reference City	ZoneClimate Region	Composite $EFLH_{cool}$	Composite $EFLH_{heat}$
Allentown	C	377497	10401,008
Binghamton, NY	A	218253	12771,305
Bradford	G	135201	14451,325
Erie	I	307410	12131,131
Harrisburg	E	479562	1129959
Philadelphia	D	512637	906850
Pittsburgh	H	356439	10731,069
Scranton	B	310427	11431,089
Williamsport	F	366433	10851,083

Evaluation Protocols

Evaluation Protocols

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

Sources

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

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

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

3) Average EER for SEER 13 units as calculated by EER = -0.02 × SEER² + 1.12 × SEER based on 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. https://www.nrel.gov/docs/fy11osti/49246.pdf

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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. (Year, Month). 2023 Pennsylvania Statewide Act 129 Residential Baseline Study. Section/Chapter, pages, table reference. 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

4)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. http://oaktrust.library.tamu.edu/bitstream/handle/1969.1/152118/ESL-TR-13-04-01.pdfWeblink

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5)6) Based on REM/Rate modeling using models from the PA 2012 Potential Study.. Models assume 50% over-sizing of air conditioners[27] and 40% oversizing of heat pumps.[28]

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, emended December 15, 2010. Weblink
ACCA, "Verifying ACCA Manual S Procedures," Weblink

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

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7)8) Assumption used in Illinois 2014 TRM, Ductless Heat Pumps Measure, p. 531, footnote 877. ReasonableEngineering judgement: Conservative assumption when comparedfor duct leakage to http://www.energystar.gov/index.cfm?c=home_improvement.hm_improvement_ducts andbe around 15%. ENERGY STAR. "Duct Sealing". Accessed March 2024. CIEE/PG&E. (2002, May). Residential HVAC and

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

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

Distribution Research Implementation,. Berkeley Labs. May, 2002, p.. Page 6. http://epb.lbl.gov/publications/pdf/lbnl-47214.pdfWeblink

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

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

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2.2.32.2.4 ECM Circulation Fans

Target Sector	Residential Establishments
Measure Unit	ECM Circulation Fan
Measure Life	155 years[Source 1]
Measure Vintage	Early Replacement, Replace on Burnout

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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.

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

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

$\Delta kWkW_{summer\ peak} = ECM_{kW} \times CFCF_{summer}$

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

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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
$CFCF_{summer}$, 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

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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.

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Sources

Evaluation Protocols

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

Sources

1) "Energy Savings from Efficient Furnace Fan Air Handlers in Massachusetts," ACEEE, Sachs and Smith, 2003. For the purpose of calculating the total Resource Cost Test for Act 129, measure cannot claim savings for more than fifteen years.

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", November 2014, Table 3 Description of Variables for Furnaces with ECM. https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdfWeblink

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

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

2.2.42.2.5 GSHP DESUPERHEATERS

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

ELIGIBILITY

Measure Life	15 years
Vintage	Retrofit

ELIGIBILITY

Installation of a desuperheater on ana 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.

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

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

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

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

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	1, 2, 3
HW, Daily hot water use	*Gallons/Day*	45.5	7
T_{hot}, Hot Water Temperature	°F	119	34
T_{cold}, Cold Water Temperature	°F	52	45
UEF_{base}, Uniform Energy Factor of Electric Water Heater	*None*	EDC Data Gathering, Default: 1.030.92	EDC Data Gathering, 56

Term	Unit	Value	Sources
~~$ETDF$~~, $ETDF_{summer}$, Energy to Demand Factor	kW/kWh/year ~~None~~	~~0.00008047~~Table 2-27	~~6~~8

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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

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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.

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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..

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. p. 78. 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.

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Default Savings

Default savings are 446.7 kWh and 0.036 kW demand savings.

Sources

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

2)1)Desuperheater Study, New England Electric System, 1998 42 U.S.C.A 6295(i) (West Supp. 2011) and 10 C.F.R. 430.32 (x) (2011).

3)1)Pennsylvania Statewide Residential End-Use and Saturation Study, 2014, http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-2014_PA_Statewide_Act129_Residential_Baseline_Study.pdf.

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

5) The default value of 1.030.92 UEF includes both standard and heat pumpfor electric water heaters.heater is from NMR Group for the Pennsylvania Act 129 2018 Residential Baseline Study, http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-Phase3_Res_Baseline_Study_Rpt021219.pdf.

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

7)6)"Public Utility Commission. (Year, Month). 2023 Pennsylvania Statewide Act 129 Residential End Uses of Water, Version 2." Baseline Study. Section/Chapter, pages, table reference. WeblinkWater Research Foundation. (Apr 2016), p. 5. https://www.circleofblue.org/wp-content/uploads/2016/04/WRF_REU2016.pdf

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

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2.2.52.2.6 Air Conditioner & Heat Pump Maintenance

Target Sector	Residential Establishments
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:

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

$$\Delta kWh_{cool} = \frac{CAPY_{cool}}{SEER_{base}} \times = \frac{CAPY_{cool}}{SEER2_{base}} \times MF \times EFLH_{cool}$$

$$\Delta kWh_{heat}[29] = \frac{CAPY_{heat}}{HSPF\ \ _{base}} \times MF \times EFLH_{heat,HP}$$

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

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

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

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

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

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

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

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[29] Does not apply for CAC or PTAC.

Ground Source Heat Pumps (GSHP)

GSHP efficiencies are typically calculated differently than air-source units and

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

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:

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

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

$HSPF_{base} = HSPF = COP_g \times GSHPDF \times 3.412\frac{BTU}{W \cdot h} \times GSOP$

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PTAC and PTHP

$COP = COP_g$

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[30]	$kBTU/hr$	EDC Data Gathering	AEPS Application; EDC Data Gathering
$CAPY_{heat}$, The heating capacity of the heat pump being installed[31]	$kBTU/hr$	EDC Data Gathering	AEPS Application; EDC Data Gathering
MF, Maintenance Factor or assumed savings due to completing recommended maintenance on installed cooling equipment	Proportion	0.05	2
$EFLH_{cool}$, Equivalent Full Load Hours of operation during the cooling season for the average unit	$\frac{hours}{yr}$	See $EFLH_{cool}$ in Vol. 1, App. A	3
$EFLH_{heat,HP}$, Equivalent Full Load Hours of operation during the heating season for the average unit	$\frac{hours}{yr}$	See $EFLH_{heat}$ in Vol. 1, App. A	3
$SEER_{base}$, Seasonal Energy Efficiency Ratio of the Baseline Unit	$\frac{BTU}{W \cdot h}$	EDC Data Gathering Default: See Early Replacement values in Table 2-8 in Sec. 2.2.1	EDC Data Gathering 4
		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 Default: See Early Replacement values in Table 2-8 in Sec. 2.2.1	EDC Data Gathering 4
		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 Default: 16.6	4EDC Data Gathering
		Default: 16.6	4
EER_{base} , Energy Efficiency Ratio of the Baseline Unit	$\frac{BTU}{W \cdot h}$	EDC Data Gathering Default: See Early Replacement values in Table 2-8 in Sec. 2.2.1	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 Default: 3.6	AEPS Application; EDC Data Gathering
		Default: 3.6	4

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

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Term	Unit	Value	Sources
GSER , Factor used to determine the SEER of a GSHP based on its EER_g	$\frac{BTU}{W \cdot h}$	1.02See Table 2-13	5
GSPKGSOP , Factor to convert $EER_g$$COP_g$ to the equivalent EERCOP of an air conditioner source unit to enable comparisons to the baseline unit	*Proportion*	0.8416See Table 2-13	5
GSHPDF , Ground Source Heat Pump De-rate FactorCF_{summer} , Demand Coincidence Factor during the summer months	*Proportion*	0.885See *CF* in Vol. 1, App. A	63
CFCF_{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

Evaluation Protocols

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Sources

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

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", May 2008.". 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. https://www.ecobee.com/donateyourdata/ (Weblink) and updated based on the latest CDD and HDD values from NOAA's 15-year annual climate Normals (2006–2020) (Weblink)

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4) Pennsylvania NMR Group for the Pennsylvania Public Utility Commission. (2023, March). 2023 Pennsylvania Statewide Act 129 2018 Residential Baseline Study, http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-Phase3_Res_Baseline_Study_Rpt021219.pdf. Weblink. Due to small sample size for GSHP in Pennsylvania Act 129 20182023 Residential Baseline Study this value is lowest efficiency value from BEopt v2.8v3.0. PTAC and PTHP standards1.0.

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

5) VEIC estimate. Extrapolation of manufacturer data.

6) McQuay Application Guide 31-008, Geothermal derived from the conversion algorithms depicted in the Heat Pump Design Manual, 2002. Engineering Estimate - See System Performance of – Water-to-air Ground Source Heat Pumps

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

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

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

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

Eligibility

The target sector primarily consists of single-family residences.

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

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

(GSHP) Measure of

Algorithms

The energy savings are the full energy consumption of the electric heating source minus the energy consumptionVersion 11 of the fossil fuel furnace blower motor. EDCs may use billing analysis using program participant data to claim measure savings, in lieu of the defaults provided in this measure protocol. The energy savings are obtained through the following formulas:

Heating savings with electric furnace (assumes 95% efficiency):[32]

$$\Delta kWh = EFLH_{heat,non-HP} \times \frac{CAPY_{elec}}{3.241\frac{BTU}{W\cdot h}}$$

[32] 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.

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

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

Heating savings with electric air source heat pump:

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

For boilers, the annual pump energy consumption is negligible (<50 kWh per year) and not included in this calculation.[33]

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

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

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

Definition of Terms

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

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Table 2-22: Terms, Values, and References for Fuel Switching: Electric Heat to Gas Heat

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

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

Term	Units	Value	Source
			5
η_{motor} , Efficiency of furnace blower motor	%	EDC Data Gathering or Default = 50%	EDC Data Gathering Typical efficiency of ½ HP blower motor

Evaluation Protocols

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Sources

1) ENERGY STAR Program Requirements: Product Specification for Boilers, v3.0. https://www.energystar.gov/sites/default/files/specs//private/Boilers%20Program%20Requirements%20Version%203%200.pdf

2)5) ENERGY STAR Program Requirements: Product Specification for Furnaces, v4.1.NY TRM https://www.energystar.gov/sites/default/files/Furnaces%20Version%204.1_Program%20Requirements_0.pdfWeblink

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

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

5) Average blower motor capacity for gas furnace, typical range = ¼ to ¾ HP.

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2.2.7 Room Air Conditioners

Target Sector	Residential Establishments
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 meeting ENERGY STAR Version 4.1exceeding efficiency criteria. prescribed by federal standards.

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Algorithms

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

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

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

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

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

Definition of Terms

Definition of Terms

Table 2-29: Terms, Values, and References for ENERGY STAR Room AC

Term	Unit	Value	Sources
CAPY, The cooling capacity of the room air conditioner (RAC) being installed	$\frac{kBTU}{h}$	EDC Data Gathering Default = 7.5	5EDC Data Gathering
		Default = 7.2	2
CEER$_{base}$, Combined Energy Efficiency ratio of the baseline unit	$\frac{BTU}{W \cdot h}$	Federal Standard Values in Table 2-24, Table 2-25, or Table 2-26 Federal Standard Values Table 2-30: RAC (without reverse cycle) Federal Minimum CEER StandardsTable 2-30.	23

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		Table 2-31, or Table 2-32Table 2-32 Default = 1116.0	
CEER$CEER_{ee}$, Combined Energy efficiency ratio of the RAC being installed	$\frac{BTU}{W \cdot h}$	EDC Data Gathering Default = ENERGY STAR values in in Table 2-24, Table 2-25, or Table 2-26	3EDC 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, Demand coincidence factor CF_{summer}, Demand Coincidence Factor during the summer months	*Proportion*	See *CF* in Vol. 1, App. A	4

Table 2-24Table 2-30: RAC (without reverse cycle) Federal Minimum CEER StandardsTable 2-30 lists the minimum federal efficiency standards as of October 2018 and minimum ENERGY STAR efficiency standardsMay 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. Note that the new federal standards are based on the Combined Energy Efficiency Ratio metric (CEER), which is a metric that incorporates energy use in all modes, including standby and off modes.

Table 2-30: RAC (without reverse cycle) Federal Minimum Efficiency and ENERGY STAR Version 4.1CEER Standards

Capacity (kBTU/h)	Federal StandardMinimum CEER, with louvered sides With Louvered Sides	ENERGY STAR CEER, with louvered sides Without Louvered Sides	Federal Standard CEER, without louvered sides	ENERGY STAR CEER, without louvered sides
<6	11.013.1	12.18	10.0	11.0
6<8	13.7			
8<11 10.9	1216.0	9.614.1	10.6	
11<14		13.9.5	10.5	
14<20		1013.7	11.8	9.3 10.2
20<28	9.413.8	10.313.8	9.4	10.3
≥28	9.013.2	9.9	9.4	10.3

Table 2-25Table 2-31 lists the minimum federal efficiency standards and minimum ENERGY STAR efficiency standards for casement-only and casement-slider RAC units. Casement-only refers to a RAC designed for mounting in a casement window with an encased assembly with a width of 14.8 inches or less and a height of 11.2 inches or less. Casement-slider refers to a RAC with an encased assembly designed for mounting in a sliding or casement window with a width of 15.5 inches or less.

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Table 2-31: Casement-Only and Casement-Slider RAC Federal Minimum ~~Efficiency and ENERGY STAR Version 4.1~~CEER Standards

Casement	Federal ~~Standard~~Minimum CEER	~~ENERGY STAR CEER~~
Casement-only	13.9~~.5~~	~~10.5~~
Casement-slider	~~10.4~~15.3	~~11.4~~

~~Table 2-26~~Table 2-32Table 2-32 lists the minimum federal efficiency standards ~~and minimum ENERGY STAR efficiency standards~~ for reverse-cycle RAC units.

Table 2-32: Reverse-Cycle RAC Federal Minimum ~~Efficiency~~CEER Standards ~~and ENERGY STAR Version 4.1 Standards~~

Capacity (kBTU/h)	Federal ~~Standard~~Minimum CEER~~, with louvered sides~~	~~ENERGY STAR CEER, with louvered sides~~	~~Federal Standard CEER, without louvered sides~~	~~ENERGY STAR CEER, without louvered sides~~	
	With Louvered Sides		Without Louvered Sides		
< 14	n/a		~~n/a~~13.7	~~9.3~~	~~10.2~~
≥ 14			12.8~~.7~~	~~9.6~~	
< 20	~~9.8~~14.4	~~10.8~~	n/a	~~n/a~~	
≥ 20	~~9.3~~13.7		~~10.2~~		

Evaluation Protocols

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Sources

~~Default Savings~~

~~Default energy savings values assume a CAPY=7.5 kBTU/hr Source 5, louvered sides, no reverse cycle unit ($CEER_{base}$ = 11.0, $CEER_{ee}$ = 12.1).~~

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Table 2-27: Deemed EFLH and Default Energy Savings

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

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

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Evaluation Protocols

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Sources

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1) California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx . Accessed December 2018.
2) Federal standards: U.S. Department of Energy. Code of Federal Regulations. 10 CFR, part 430.32(b). Effective June 1, 2014. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/41
3) ENERGY STAR Program Requirements Product Specification for Room Air Conditioners, Eligibility Criteria Version 4.1. October 26, 2015. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%204.1%20Room%20Air%20Conditioners%20Specification_0.pdf
4) Based on the Phase III SWE team's analysis of regional HVAC runtime data collected from ecobee's Donate Your Data research service, https://www.ecobee.com/donateyourdata/.
5)4) Statewide average for all housing types (Weblink) and updated based on the latest CDD and HDD values from Pennsylvania Act 129 2018 Residential Baseline Study, http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-Phase3_Res_Baseline_Study_Rpt021219.pdf. NOAA's 15-year annual climate Normals (2006–2020) (Weblink)

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2.2.8 Room AC (RAC) Retirement

2.2.82.1.1 Room AC (RAC) Retirement

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

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

Eligibility

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

Algorithms

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

Retirement-Only

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

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

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

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

Replacement and Recycling

For this approach, the ENERGY STARefficient 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.

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

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

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

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

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.

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

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

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

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

Term	Unit	Value	Sources
$EFLH_{RAC}$, Equivalent Full Load Hours of operation for the installed measure. In actuality, the number of hours and time of operation can vary drastically depending on the RAC location (living room, bedroom, home office, etc.).	$\frac{hours}{yr}$	See $EFLH_{RAC}$ in Vol. 1, App. A	1
$CAPY$, Rated cooling capacity (size) of the RAC unit.	$\frac{kBTU}{h}$	EDC Data Gathering Default: 7.5	3
EER_{RetRAC}, The Energy Efficiency Ratio of the unit being retired-recycled.[34]	$\frac{BTU}{W \cdot h}$	EDC Data Gathering Default: 9.8	4
EER_{ee}, The Energy Efficiency Ratio for an ENERGY STAR RAC	$\frac{BTU}{W \cdot h}$	12.1	6
$CEER_{base}$, (for a 8,000 BTU/h unit), The Combined Energy Efficiency Ratio of a RAC that meets the minimum federal appliance standard efficiency.	$\frac{BTU}{W \cdot h}$	11.0	5
$CEER_{ee}$, (for a 8,000 BTU/h unit), The Combined Energy Efficiency Ratio for an ENERGY STAR RAC.	$\frac{BTU}{W \cdot h}$	EDC Data Gathering Default=12.1	5
CF, Demand Coincidence Factor	*Proportion*	See *CF* in Vol. 1, App. A	2

Table 2-29: RAC Retirement-Only EFLH and Energy Savings by City

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

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Evaluation Protocols

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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

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

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 StandardsTable 2-30, Table 2-31, or Table 2-32Table 2-32 Default = 16.0	4
$CEER_{ee}$, Combined Energy efficiency ratio of the RAC being installed	$\frac{BTU}{W \cdot h}$	EDC Data Gathering	EDC Data Gathering

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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.

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Sources

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

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

2)3) Based on the Phase III SWE team's analysis of regional HVAC runtime data collected from ecobee's Donate Your Data research service, https://www.ecobee.com/donateyourdata/Weblink.. and updated based on the latest CDD and HDD values from NOAA's 15-year annual climate Normals (2006–2020) (Weblink)

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

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

4) Minimum Federal Standard for most common room AC type (8000-14,999 capacity range with louvered sides) per federal standards from 10/1/2000 to 5/31/2014. Note that this value is the EER value, as CEER were introduced later. Federal code of regulation. Room air conditioners. 10 C.F.R. § 430.32 (b)(2). Weblink

2.2.9 Window Heat Pump

5)

6) ENERGY STAR Program Requirements Product Specification for Room Air Conditioners, Eligibility Criteria Version 4.1. October 26, 2015. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%204.1%20Room%20Air%20Conditioners%20Specification_0.pdf

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~~2.2.9 Duct Sealing & Duct Insulation~~

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

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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.

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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

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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.

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

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

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

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

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

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 installation, 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 2-31Table 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).[Source7Source6]
    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 2-31Table 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%.

Field Code Changed

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

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

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

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

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

Summer Coincident Peak Demand Savings

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

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

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DEFINITION OF TERMS

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

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Term	Unit	Value	Source
~~CF~~ 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

Term	Unit	Value	Source
CFM_{25EE} , Standard Duct Leakage test result at 25 Pascal pressure differential of the duct system after sealing, calculated from the duct blaster fan flow chart	$\frac{ft^3}{min}$	EDC Data Gathering	3
$CAPY_{cool}$, Capacity of Air Cooling System	*kBTU/hr*	EDC Data Gathering	EDC Data Gathering
$CAPY_{heat}$, Capacity of Air Heating System	*kBTU/hr*	EDC Data Gathering	EDC Data Gathering
TCFM , Conversion from tons of cooling to CFM	$\frac{CFM}{ton}$	400	5Conversion 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	65
HSPF2, HSPF , Efficiency of Heating Equipment	*None*	EDC Data Gathering Default: See Early Replacement values in Table 2-10 in Sec. 2.2.1	65
$EFLH_{cool}$, 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 2-31, Table 2-32 Table 2-40, Table 2-41 Not to exceed 100%	2
DE_{pre} , Distribution efficiency before duct sealing and insulation	*None*	Table 2-31, Table 2-32 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%	~~4~~11%	~~11~~4%	9%	2%	~~3~~2%	~~2~~3%	3%	6%	~~3~~11%	~~11~~3%	5%
R-2	4%	~~5~~6%	~~6~~5%	7%	1%	1%	1%	2%	3%	~~2~~5%	~~5~~2%	3%
R-4+	3%	~~3~~4%	~~4~~3%	5%	1%	1%	1%	1%	2%	~~1~~4%	~~4~~1%	3%
R-8+	3%	~~2~~3%	~~3~~2%	3%	1%	1%	1%	1%	2%	~~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.

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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.

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SOURCES

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

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~~,~~. ~~http://www.bpi.org/sites/default/files/Guidance%20on%20Estimating%20Distribution%20Efficiency.pdf~~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, http://www.resnet.us/blog/wp-content/uploads/2016/01/ANSI-RESNET-ICC_380-2016-posted-Weblink

3)4) Based on website 6- 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 15-16.pdfyear annual climate Normals (2006–2020). 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. https://www.ecobee.com/donateyourdata/

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

6)5) Pennsylvania Act 129 2018 Residential Basline Study , http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-Phase3_Res_Baseline_Study_Rpt021219.pdf. 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.)

7)6) Communication with Building Performance Institute.

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2.2.102.2.11 Air Handler Filter Whistles

Target Sector	Residential Establishments
Measure Unit	Filter whistle (to promote regular filter change-out)
Measure Life	5 years[Source 61]
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 72]

Eligibility

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

Algorithms

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

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

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

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

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

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	13
$EFLH_{heat}$, Estimated Full Load Hours (Heating)	$\frac{hours}{yr}$	See $EFLH_{heat}$ in Vol. 1, App. A	54
$EFLH_{cool}$, Estimated Full Load Hours (Cooling)	$\frac{hours}{yr}$	See $EFLH_{cool}$ in Vol. 1, App. A	54
EI , Efficiency Improvement	%	15%	2, 45, 6
ISR , In-service Rate	%	EDC Data Gathering Default = 157%	37
CF , CF_{summer} , Demand Coincidence Factor during the summer months	Proportion	See *CF* in Vol. 1, , App. A	54
CF_{winter} , Demand Coincidence Factor during the winter months	Proportion	See *CF* in Vol. 1, App. A	4

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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	ASHP kWh Winter kW	kWh	Summer kW
C	Allentown 7.7 10.5	4.975	3.27	0.003001 4	3.01	0.0017
A	Binghamton, NY	9.86.00	12.74.6 3	2.80. 0018	1.53	0.0020 010
G	Bradford	6.12	11.4.71	0.00 1814 .2	1.721	0.0020 009
I	Erie	8.95.27	12.13.7 4	4.0.0 015	2.48	0.0020 012
E	Harrisburg	8.54.53	11.23.1 0	6.20. 0013	3.40	0.0040 017
D	Philadelphia	6.54.07	9.2.70	6.60. 0011	3.85	0.0040 019
H	Pittsburgh	8.05.00	10.83.5 1	4.60. 0014	2.65	0.0030 015
B	Scranton	8.5.09	11.43.5 9	4.0.0 015	2.58	0.0030 014
F	Williamsport	7.95.06	10.93.6 0	4.70. 0015	2.62	0.0030 016

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?". Weblink. Accessed December, 2018.

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

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

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Sources

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

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)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.

3) The In Service Rate is the average of values reported by FirstEnergy EDCs for kits including an air handler furnace whistle for PY9. See http://www.puc.pa.gov/filing_resources/issues_laws_regulations/act_129_information/electric_distribution_company_act_129_reporting_requirements.aspx

4)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.

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

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

7) Your Filter Connection, "What is a Furnace Filter Whistle?". https://yourfilterconnection.com/blogs/help/what-is-a-furnace-filter-whistle. Accessed December, 2018surveys of FirstEnergy customers that received air handler filter whistles in kits in PY13 and PY14.

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~~2.2.11~~2.2.12 ENERGY STAR® CERTIFIED CONNECTED THERMOSTATS

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Target Sector	Residential Homes, including single or multifamily in-unit spaces
Measure Unit	Residential Thermostat
Measure Life	~~11~~9 years Source ~~5~~1
Vintage	Retrofit, Replace on Burnout, or ~~new construction~~New Construction

ENERGY STAR®-certified connected thermostats (CT) save heating and cooling energy by operating residential HVAC systems more efficiently. CTs that meet the ENERGY STAR® ~~specification[8]~~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

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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} ~~assumption~~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.

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

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

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

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

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

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} ~~value~~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.

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

(Deleted: $\Delta kW_{peak} = \frac{CAPY_{cool}}{EER \times Eff_{duct}} \times ESF_{cool} \times PDSF \times CF$)

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 = ~~30~~31.9 / unit	~~1~~3
$CAPY_{HP}$, Normal heat capacity of Heat Pump System.	$\frac{kBTU}{h}$	EDC Data Gathering of Nameplate Data	EDC Data Gathering
		Default = ~~32~~31.9 / unit	~~1~~3
$CAPY_{elecfurn}$, Normal heat capacity of Electric Furnace systems	$\frac{kBTU}{h}$	EDC Data Gathering of Nameplate data	EDC Data Gathering
		Default ~~= 60.249~~78.1 / unit	~~1~~3
~~SEER~~SEER2, Seasonal Energy Efficiency Ratio	$\frac{BTU}{W \cdot h}$	EDC Data Gathering of Nameplate data	EDC Data Gathering

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Term	Unit	Value	Sources
		Default: ~~CAC = 12.1 Heat Pump = 13.5~~see Table 2-10	~~1~~3
~~EER~~*EER2*, Energy Efficiency Ratio	$\frac{BTU}{W \cdot h}$	EDC Data Gathering of Nameplate data	EDC Data Gathering
		Default: ~~CAC = 10.6 Heat Pump = 11.4~~see Table 2-10	~~1~~3
~~*HSPFheat pump*~~*HSPF2, HSPF*, Heating Seasonal Performance Factor ~~of Heat Pump~~	$\frac{BTU}{W \cdot h}$	EDC Data Gathering of Nameplate data	EDC Data Gathering
		~~Heat Pump~~ Default = ~~8.2~~see Table 2-10	~~1~~3
Eff_{duct}, Duct System Efficiency	*None*	0.~~8~~83	~~3~~4
$EFLH_{cool}$, Equivalent Full Load Hours for Cooling	$\frac{hours}{yr}$	See $EFLH_{cool}$ in Vol. 1, App. A	~~4~~5
$EFLH_{heat,HP}$, Equivalent Full Load Hours for ASHP Systems	$\frac{hours}{yr}$	See $EFLH_{heat,HP}$ in Vol. 1, App. A	~~4~~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	~~4~~5
HP_{motor}, Gas furnace blower motor horsepower	~~*Hp*~~*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 = ~~58~~68%	~~1~~3
$\%_{Manual}$, % central AC systems with a manual thermostat	*None*	EDC Data Gathering	EDC Data Gathering
		Forced Air Default = ~~42~~32%	~~1~~3
ESF_{cool}, cooling energy saving factor	*None*	~~See Table 2-37~~See Table 2-46	Composite of multiple sources
ESF_{heat}, heating energy saving factor	*None*	~~See Table 2-38~~See Table 2-47	Composite of multiple sources
PDSF, peak demand savings factor relative to ESF_{cool}	*None*	EDC Data Gathering Default = 50%	~~13~~6

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Term	Unit	Value	Sources
CF CF_{summer}, Demand Coincidence Factor during the summer months	*Proportion*	See *CF* in Vol. 1, App. A	144
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

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Table 2-37 and Table 2-38Note: 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)

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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	7.54%[b]	7.54%[b]
Professional Installation	Manual	11.3%[c]	11.3%[c]
	Conventional Programmable	9.3%[d]	9.3%[d]

[a] *Source 67*

[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, 7.54%=((11.3%×0.4232 + 9.3%×0.5868) + 4.8%) / 2*

[c] *Average of cooling savings estimates from multiple studies. Sources: 2, 78, 9, 12,10, 11*

[d] *The ESF value is applied here subtracts the assumed savings value fromvalues are for programmable thermostats in the 2016 Pennsylvania TRM (2.0%) from the manual thermostat baseline ESFbased of DEER 2005's cooling savings for climate zone 16.*

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

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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	7.97%[b]	7.97%[b]
Professional Installation	Manual	11.5%[c]	11.5%[c]
	Conventional programmable	7.9%[d]	7.9%[d]

[a] *Average of heating estimates from two studies. Sources: 9, 1110, 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, 7.97%=((11.5%×0.4232 + 7.9%×0.5868) + 6.4%) / 2*

[c] *Average of four heating savings estimates from fourmultiple studies. Sources: 7, 10, 129, 11, 13*

[d] *The ESF value are for a is applied here as an estimate until information becomes available showing differentprogrammable thermostats based of DEER 2005's cooling savings incented through a direct install programfor climate zone 16.*

DEFAULT SAVINGS

Table 2-39 through Table 2-41Table 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 2-42Table 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 2-43~~Table 2-52 provides default HVAC system type shares, by EDC, from the ~~2018~~2023 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	~~69~~86	~~77~~92
Customer Self-Installation with Education	Unknown Mix Default	~~108~~132	~~120~~141
Professional Installation	Manual	~~163~~202	~~182~~215
	Conventional programmable	~~134~~166	~~150~~177

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

Program Type	Baseline	ASHP ~~with Electric Auxiliary Heating~~	Electric Furnace	Fossil Fuel Furnace (Fan Only)
Upstream buy-down (Customer Self-Installation)	Unknown Mix Default	~~420~~440	1,~~213~~476	~~48~~44
Customer Self-Installation with Education	Unknown Mix Default	~~519~~529	1,~~499~~775	~~60~~53
Professional Installation	Manual	~~756~~791	2,~~180~~651	~~87~~79
	Conventional programmable	~~519~~543	1,~~498~~821	~~60~~54

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

Program Type	Baseline	ASHP ~~with Electric Aux~~	CAC w/ Electric Furnace	CAC w/ Gas (Fan)
Upstream buy-down (Customer Self-Installation)	Unknown Mix Default	~~490~~526	1,~~290~~567	~~125~~136
Customer Self-Installation with Education	Unknown Mix Default	~~627~~661	1,~~619~~916	~~180~~194
Professional Installation	Manual	~~918~~992	2,~~362~~867	~~268~~295

	Conventional programmable	~~653~~709	1,~~647~~999	~~209~~232

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

Program Type	Baseline	ASHP ~~Cooling~~		CAC ~~Coolingw/~~ 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.~~0269~~028	0.~~0289~~064	0.030	0.301	0.030	0.009
Customer Self-Installation with Education	Unknown Mix Default	0.~~0418~~044	0.~~0450~~077	0.046	0.362	0.046	0.011
Professional Installation	Manual	0.~~0633~~067	0.~~0680~~116	0.070	0.541	0.070	0.016
	Conventional programmable	0.~~0521~~055	0.~~0560~~079	0.058	0.372	0.058	0.011

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

EDC	ASHP ~~with Electric Aux~~	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

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2.2.122.2.13 FURNACE MAINTENANCE

Target Sector	Residential Establishments
Measure Unit	Per Furnace
Measure Life	23 years Source 1
Vintage	Retrofit

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

ELIGIBILITY

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

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

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

ALGORITHMS

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

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

DEFINITION OF TERMS

Table 2-53: 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

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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	6.822
A	Binghamton, NY	8.782
G	Bradford	10.28.98
I	Erie	7.913
E	Harrisburg	7.5.90
D	Philadelphia	5.714
H	Pittsburgh	7.16.68
B	Scranton	7.56.84
F	Williamsport	7.06.85

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) Act on Energy Commercial Technical Reference Manual No. 2010-4, 9.2.3 Gas Forced-Air Furnace Tune-up.

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, https://www.ecobee.com/donateyourdata/. (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. http://mn.gov/commerce-stat/pdfs/mn-trm-v2.0-041616.pdfWeblink

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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.[35] 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

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Algorithms

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

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

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

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

[35] 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

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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.

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Sources

1) Estimate 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

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2.32.1 Domestic Hot Water

2.3.12.1.1 Heat Pump Water Heaters

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

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

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

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 2-48Table 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 'Default''Unknown' value for F_{derate} in Table 2-62 and both interactive effects will equal zero.

$$\Delta kWh_{ie,cool} = \frac{HW \times \frac{8.3\ Btu}{gal \cdot °F} \times (T_{out} - T_{in}) \times EFLH_{cool}}{24\frac{hrs}{day} \times SEER \times 1000\frac{W}{kW}} \frac{HW \times 8.3 \times (T_{out} - T_{in}) \times EFLH_{cool}}{24 \times SEER2 \times 1000}$$

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$$\Delta kWh_{ie,heat} = \frac{HW \times \frac{8.3\ \text{Btu}}{\text{gal}\cdot°\text{F}} \times (T_{out} - T_{in}) \times EFLH_{heat}}{24\frac{\text{hrs}}{\text{day}} \times HSPF \times 1000\frac{\text{W}}{\text{kW}}} \frac{HW \times 8.3 \times (T_{out} - T_{in}) \times EFLH_{heat}}{24 \times HSPF2 \times 1000}$$

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

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

ETDF (Energy to Demand Factor) is defined below:

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

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

Definition of Terms

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

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

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Definition of Terms

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

Term	Unit	Values	Source

Heat Pump Water Heater

Term	Unit	Values	Source
UEF_{base}, Uniform Energy Factor of baseline water heater	*None*	See Table 2-47 Default: 0.92 (50 gal., medium draw)	3
UEF_{ee}, Uniform Energy Factor of proposed efficient water heater	*None*	EDC Data Gathering Default ≤55 Gals: 2.00 Default >55 Gal: 2.20	2
HW, Hot water used per day in gallons	$\frac{gallons}{day}$	45.5	4
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	57
T_{in}, Temperature of cold water supply	°F	5253	68
F_{derate}, COP De-rating factor $EFLH_{cool}$, Equivalent Full Load Hours for cooling	$\frac{hours}{yr}$ Proportion	Table 2-48See $EFLH_{cool}$ in Vol. 1, App. A	7, and discussion below10
$EFLH_{cool}$ $EFLH_{heat}$, Equivalent Full Load Hours for coolingheating	$\frac{hours}{yr}$	See $EFLH_{cool}$ $EFLH_{heat}$ in Vol. 1, App. A	810
$EFLH_{heat}$, Equivalent Full Load Hours for heating $HSPF2$, Heating Seasonal Performance Factor of heating equipment	$\frac{BTU}{W \cdot h}$ $\frac{hours}{yr}$	See $EFLH_{heat}$ in Vol. 1, App. AEDC Data Gathering Default see Table 2-60	86
$HSPF$, Heating $SEER2$, Seasonal Performance FactorEnergy Efficiency Ratio of heatingcooling equipment	$\frac{BTU}{W \cdot h}$	EDC Data Gathering Default see Table 2-45Table 2-60	96
$SEER$, Seasonal Energy Efficiency Ratio of cooling equipment $ETDF_s$, Summer Energy to Demand Factor	$\frac{kW}{kWh}$ $\frac{BTU}{W \cdot h}$	EDC Data Gathering Default see Table 2-450.0001057	911
$ETDF$, $ETDF_w$, Winter Energy to Demand Factor (defined above)	$\frac{kW}{kWh/yr}$ $\frac{kW}{kWh}$	0.000080470001761	1011

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Table 2-60: Default Cooling and Heating System Efficiencies

Type	SEERSEER2	HSPFHSPF2
Central Air Conditioner	12.113.2	N/A
Room Air Conditioner Room Air Conditioner	10.6[a]11.4	N/A

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Air-Source Heat Pump	13.514.1	87.2
Ground-Source Heat Pump	15.018.5	10.98
Ductless Mini-Split	14.917.6	8.96
Electric Resistance	N/A	3.412

[a]CEER

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

The current Federal Standards for electric water heater Uniform Energy Factors (UEF) vary based on rated storage volume and draw pattern. This standard, which went into effect at the end of 2016, replaces the old federal standard equal to 0.96-(0.0003×Rated Storage in Gallons) for tanks equal to or smaller than 55 gallons and 2.057 – (0.00113×Rated Storage) for tanks larger than 55 gallons. Table 2-47 shows the formulas to calculate the minimum UEF for various tanks sizes using both the new standard with draw patterns, and the pre-draw pattern standard, which will likely be more common in replacements through 2021. Pre-calculated UEF values are provided for common tank sizes. Draw patterns are defined in the Federal Standard test procedures for water heaters as illustrated in Table 2-46.Source 12

Table 2-48: Draw Pattern Definitions

TypeRated Storage Volume (gallons)	Draw Pattern	Max. Daily Hot Water Draw (gallons)UEF Calculation	First Hour Rating (FHR) (gallons)
Storage>=20 gal and <=55 gal	Very Small 10	0 <= FHR < 180.8808-(0.0008×V_r)	
	Low	380.9254-(0.0003×V_r)	18 <= FHR < 51
	Medium	550.9307-(0.0002×V_r)	51 <= FHR < 75
	High	840.9349-(0.0001×V_r)	FHR >= 75
>55 gal and <=120 gal	Very Small	1.9236-(0.0011×V_r)	
	Low	2.0440-(0.0011×V_r)	
	Medium	2.1171-(0.0011×V_r)	
	High	2.2418-(0.0011×V_r)	

Table 2-49: Minimum Baseline Uniform Energy Factors Based on Rated Storage Volume and Draw Pattern

Rated Storage Volume (gallons)	Draw Pattern	UEF Calculation	Minimum UEF
>=20 gal and <=55 gal	Pre-2017	0.9600-(0.0003×V_r)	
	Very Small	0.8808-(0.0008×V_r)	
	Low	0.9254-(0.0003×V_r)	

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~~Rated Storage Volume (gallons)~~	~~Draw Pattern~~	~~UEF Calculation~~	~~Minimum UEF~~
	~~Medium~~	~~0.9307-(0.0002×V_r)~~	
	~~High~~	~~0.9349-(0.0001×V_r)~~	
~~>55 gal and <=120 gal~~	~~Pre-2017~~	~~0.9600-(0.0003×V_r)~~	
	~~Very Small~~	~~0.8808-(0.0008×V_r)~~	
	~~Low~~	~~0.9254-(0.0003×V_r)~~	
	~~Medium~~	~~0.9307-(0.0002×V_r)~~	
	~~High~~	~~0.9349-(0.0001×V_r)~~	
~~40~~	~~Pre-2017~~	~~0.9600-(0.0003×V_r)~~	~~0.95~~
	~~Very Small~~	~~0.8808-(0.0008×V_r)~~	~~0.85~~
	~~Low~~	~~0.9254-(0.0003×V_r)~~	~~0.91~~
	~~Medium~~	~~0.9307-(0.0002×V_r)~~	~~0.92~~
	~~High~~	~~0.9349-(0.0001×V_r)~~	~~0.93~~
~~50~~	~~Pre-2017~~	~~0.9600-(0.0003×V_r)~~	~~0.95~~
	~~Very Small~~	~~0.8808-(0.0008×V_r)~~	~~0.84~~
	~~Low~~	~~0.9254-(0.0003×V_r)~~	~~0.91~~
	~~Medium~~	~~0.9307-(0.0002×V_r)~~	~~0.92~~
	~~High~~	~~0.9349-(0.0001×V_r)~~	~~0.93~~
~~65~~	~~Pre-2017~~	~~2.057-(0.00113×V_r)~~	~~1.98~~
	~~Very Small~~	~~1.9236-(0.0011×V_r)~~	~~1.85~~
	~~Low~~	~~2.0440-(0.0011×V_r)~~	~~1.97~~
	~~Medium~~	~~2.1171-(0.0011×V_r)~~	~~2.05~~
	~~High~~	~~2.2418-(0.0011×V_r)~~	~~2.17~~
~~80~~	~~Pre-2017~~	~~2.057-(0.00113×V_r)~~	~~1.97~~
	~~Very Small~~	~~1.9236-(0.0011×V_r)~~	~~1.84~~
	~~Low~~	~~2.0440-(0.0011×V_r)~~	~~1.96~~
	~~Medium~~	~~2.1171-(0.0011×V_r)~~	~~2.03~~
	~~High~~	~~2.2418-(0.0011×V_r)~~	~~2.15~~
~~120~~	~~Pre-2017~~	~~2.057-(0.00113×V_r)~~	~~1.92~~
	~~Very Small~~	~~1.9236-(0.0011×V_r)~~	~~1.79~~
	~~Low~~	~~2.0440-(0.0011×V_r)~~	~~1.91~~
	~~Medium~~	~~2.1171-(0.0011×V_r)~~	~~1.99~~
	~~High~~	~~2.2418-(0.0011×V_r)~~	~~2.11~~

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[36]. The heat pump performance is temperature and humidity dependent, therefortherefore 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 74] 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)[37] 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}[38]
Inside Conditioned Space	0.98
Unconditioned Garage	0.85
Unconditioned Basement	0.72
Default[39]Unknown [Source 4]	0.87

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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 calculated using the formulasprovided below.

$$\Delta kWh = \left(\frac{1}{UEF_{base}} - \frac{1}{UEF_{ee} \times F_{derate}}\right) \times 2706.75 \frac{kWh}{yr}$$

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

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

[37] Ibid

[38] 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).

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

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

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. https://www.energystar.gov/sites/default/files/Water%20Heaters%20Final%20Version%203.2_Program%20Requirements.pdf

3)2) Version 5.0. U.S. Federal Standards for Residential Water Heaters. Effective April 16, 2015. https://www.ecfr.gov/cgi-bin/retrieveECFR?n=sp10.3.430.c&r=SUBPART EPA. Weblink

3) "Residential End Uses of Water, Version 2." *Water Research Foundation.* (Apr 2016), p. 5. 10 CFR 430.32(d). Weblink.

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

4) Water Research Foundation. (https://www.circleofblue.org/wp-content/uploads/2016/04/WRF_REU2016.pdf

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

5) 2016). Residential End Uses of Water, Version 2. Pg 5. Weblink

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6) NMR Group for the Pennsylvania Public Utility Commission. (2024, March). 2023 Pennsylvania Statewide Act 129 Residential Baseline Study. Pg 115, table 97, pg. 120, table 103. Weblink . Air source heat pump and ductless mini-split efficiencies calculated using 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, pg 60, Table 4-64. Weblink

6)8) Using Rock Spring, PA (Site 2036) as a proxy, the mean of soil temperature at 40 - inch depth is 51.86152.502. Calculated using Daily SCAN Standard - Period of Record data from April 1999December 2003 to December 20182023 from the Natural Resource Conservation Service Database. https://wcc.sc.egov.usda.gov/nwcc/rgrpt?report=daily_scan_por&state=PAWeblink. Methodology follows Missouri TRM 2017 Volume 2: Commercial and Industrial Measures. p.(2017, March). "2.6.1 Water Heater". Pg 78. https://energy.mo.gov/sites/energy/files/MOTRM2017Volume2.pdfWeblink

7)9) NEEA Heat Pump Water Heater Field Study Report. Prepared by Fluid Market Strategies, 2013. https://rpsc.energy.gov/tech-solutions/sites/default/files/attachments/NEEA_HPWH_Field-Study-Report_October-2013.pdfFluid 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.)

8)10) Based on the Phase III SWE team's analysis of regional HVAC runtime data collected from ecobee's Donate Your Data research service. Based on the Phase III SWE team's analysis of regional HVAC runtime data collected from ecobee's Donate Your Data research service. https://www.ecobee.com/donateyourdata/Weblink

9) Pennsylvania Act 129 2018 Residential Baseline Study, http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-Phase3_Res_Baseline_Study_Rpt021219.pdf. Due to small sample size for GSHP in Pennsylvania Act 129 2018 Residential Baseline Study this value is lowest efficiency value from BEopt v2.8.0.

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

11) ENERGY STAR Product Specifications for Residential Water Heaters Version 3.0. Effective April 15, 2016. http://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Water%20Heaters%20Version%203%200%20Program%20Requirements_0.pdf

12) U.S. Federal Standard Uniform Test Method for Measuring the Energy Consumption of Water Heaters. Effective December 15, 2015. https://www.ecfr.gov/cgi-bin/text-idx?SID=80dfa785ea350ebeee184bb0ae03e7f0&mc=true&node=ap10.3.430_127.e&rgn=div9

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 Establishments
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 eletricelectric water heater.

Algorithms

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

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

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.

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

Where:

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

ETDF (Energy to Demand Factor) is defined below:

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

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

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

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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 = 0.9092	43
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	54
T_{out}, Temperature of hot water	$°F$	119	65
T_{in}, Temperature of cold water supply	$°F$	5253	76
ETDF, $ETDF_s$, Summer Energy to Demand Factor (defined above)	$\frac{kW}{kWh/yr}$ $\frac{kW}{kWh}$	0.000080470001057	37
$ETDF_w$, Winter Energy to Demand Factor	$\frac{kW}{kWh}$	0.0001761	7

Default Savings

Default energy and demand savings are as follows:

ΔkWh = 1,974.41880.5 kWh

ΔkW $\Delta kW_{summer\ peak}$ = 0.24201988 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

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.

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Sources

1) ENERGY STAR Solar Water Heater Benefits and Savings. Accessed 8/8/2014. http://www.energystar.gov/index.cfm?c=solar_wheat.pr_savings_benefits
2) The average energy factor for all solar water heaters with collector areas of 50 ft^2 or smaller is from https://secure.solar-rating.org/Certification/Ratings/RatingsSummaryPage.aspxWeblink
3) Straub, Mary and Switzer, Sheldon. "Using Available Information for Efficient Evaluation of Demand Side Management Programs". Study by BG&E. The Electricity Journal, Aug/Sept. 2011. p. 95. http://www.sciencedirect.com/science/article/pii/S1040619011001941
4)3) Value is mean UEF for standard electric standalone water heaters from Pennsylvania Act 129 20182023 Residential Baseline Study, http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-Phase3_Res_Baseline_Study_Rpt021219.pdfWeblink.
5) Residential Energy Consumption Survey, EIA, 2009.
6) Pennsylvania Statewide Residential End-Use and Saturation Study, 2014, http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-2014_PA_Statewide_Act129_Residential_Baseline_Study.pdf.
4) Water Research Foundation. (2016). Residential End Uses of Water, Version 2. Pg 5. Weblink
5) Pennsylvania Act 129 2014 Residential Baseline Study. Section 4.6.1, pg 60, table 4-64. Weblink
7) Using Rock Spring, PA (Site 2036) as a proxy, the mean of soil temperature at 40--inch depth is 51.86152.502. Calculated using Daily SCAN Standard - Period of Record data from April 1999December 2003 to December 20182023 from the Natural Resource Conservation Service Database. https://wcc.sc.egov.usda.gov/nwcc/rgrpt?report=daily_scan_por&state=PAWeblink-.. Methodology follows Missouri TRM 2017 Volume 2: Commercial and Industrial Measures. p. 78. https://energy.mo.gov/sites/energy/files/MOTRM2017Volume2.pdf

2.3.3 6) Fuel Switching: Electric Resistance to Fossil Fuel (2017, March). "2.6.1 Water Heater". Pg 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

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2.3.3 Water Heater Tank Wrap

Target Sector	Residential
Measure Unit	Water HeaterTank
Measure Life	Gas:117 years Source 1 Propane: 11 years Source 16
Vintage	Replace on Burnout

Eligibility

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

The target sector primarily consists of single-family residences.

Algorithms

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

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

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

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

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

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

ETDF (Energy to Demand Factor) is defined below:

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

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The ratio of the average energy usage between 2 PM and 6 PM on summer weekdays to the total annual energy usage is taken from an electric water heater metering study performed by BG&E.[Source 7]

Definition of Terms

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

Term	Unit	Values	Source
$UEF_{base,elec}$, Uniform Energy Factor of baseline water heater	*Proportion*	EDC Data Gathering Default: Table 2-47 in the Heat Pump Water Heaters section	2
$UEF_{installed,\ NG}$, Uniform Energy Factor of installed natural gas water heater	*Proportion*	EDC Data Gathering Default: ≤55 Gallons= 0.67 >55 Gallons= 0.77	3
$UEF_{installed,Propane}$, Uniform Energy Factor of installed propane water heater	*Proportion*	EDC Data Gathering Default: ≤55 Gallons= 0.67 >55 Gallons= 0.77	3
$UEF_{installed,Tankless\ Water\ Heater}$, Uniform Energy Factor of installed tankless water heater	*Proportion*	EDC Data Gathering Default: 0.90	3
HW, Hot water used per day in gallons	$\frac{gallons}{day}$	45.5	4
T_{out}, Temperature of hot water	°F	119	5
T_{in}, Temperature of cold water supply	°F	52	6
ETDF, Energy to Demand Factor (defined above)	$\frac{kW}{kWh/yr}$	0.00008047	7

Uniform Energy Factors based on Rated Storage Volume and Draw Pattern

The current Federal Standards for electric water heater Uniform Energy Factors (UEF) vary based on rated storage volume and draw pattern. This standard, which went into effect at the end of 2016, replaces the old federal standard equal to 0.96-(0.0003×Rated Storage in Gallons) for tanks equal to or smaller than 55 gallons and 2.057 – (0.00113×Rated Storage) for tanks larger than 55 gallons. Table 2-47 in the Heat Pump Water Heaters section shows the UEF for various tanks sizes using both the new standard with draw patterns, and the pre-draw pattern standard, which will likely be more common in replacements through 2021.

Default Savings

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

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

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

The default savings for the installation of a 50 gallon natural gas/propane water heater in place of a standard electric water heater are listed in Table 2-51, below.

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

Electric unit UEF	Energy Savings (kWh/yr)	Demand Reduction (kW)
0.92	2,938.9	0.2365

The default fossil fuel consumption for the installation of a standard efficiency natural gas/propane water heater in place of a standard electric water heater is listed in Table 2-52 below.

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

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

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

Evaluation Protocols

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

Sources

1) DEER Effective Useful Life values, accessed Oct. 2018. http://www.deeresources.com/
2) U.S. Federal Standards for Residential Water Heaters. Effective April 16, 2015. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/27
3) Commission Order requires fuel switching to ENERGY STAR measures, not standard efficiency measures. The Energy Factor has therefore been updated to reflect the Energy Star 3.2 standard for Gas Storage Water Heaters From Residential Water Heaters Key Product Criteria. https://www.energystar.gov/sites/default/files/Water%20Heaters%20Final%20Version%203.2_Program%20Requirements_1.pdf Accessed Oct. 2018. For the Commission Order see p. 42 of the TRC Final Test Order.
4) “Residential End Uses of Water, Version 2.” *Water Research Foundation.* (Apr 2016), p. 5. https://www.circleofblue.org/wp-content/uploads/2016/04/WRF_REU2016.pdf
5) Pennsylvania Statewide Residential End-Use and Saturation Study, 2014, http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-2014_PA_Statewide_Act129_Residential_Baseline_Study.pdf.
6) Using Rock Spring, PA (Site 2036) as a proxy, the mean of soil temperature at 40 inch depth is 51.861. Calculated using Daily SCAN Standard - Period of Record data from April 1999 to

December 2018 from the Natural Resource Conservation Service Database. https://wcc.sc.egov.usda.gov/nwcc/rgrpt?report=daily_scan_por&state=PA. Methodology follows Missouri TRM 2017 Volume 2: Commercial and Industrial Measures. p. 78. https://energy.mo.gov/sites/energy/files/MOTRM2017Volume2.pdf

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

2.3.4 Water Heater Tank Wrap

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

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

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

Eligibility

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

The U.S. Department of Energy recommends adding a water heater wrap of at least R-8 to any water heater with an existing R-value less than R-24. Source 67

Algorithms

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

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

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

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

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

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	-

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Term	Unit	Value	Source
A_{insul} , Surface area of storage tank after addition of tank wrap	ft^2	See Table 2-66	-
~~η_{Elec} , Thermal efficiency of electric heater element~~	~~*Proportion*~~	~~0.98~~	~~3~~
$T_{setpoint}$, Temperature of hot water in tank	°*F*	119	4
$T_{ambient}$, Temperature of ambient air	°*F*	70	~~4~~5
~~*HOU* , Annual hours of use for water heater tank~~ $ETDF_S$, Summer Energy to Demand Factor	~~*Hours/yr*~~ $\frac{kW}{kWh}$	~~8,760~~0.0001046	8
~~*CF* ,~~ $ETDF_W$, Winter Energy to Demand ~~Coincidence~~ Factor	~~*Proportion*~~ $\frac{kW}{kWh}$	~~1.~~0.0001755	8

Table 2-66: ~~Deemed savings~~Default Savings by ~~water heater capacity~~Water Heater Capacity

Capacity (gal)	R_{base}	R_{insul}	A_{base} (ft²)[40]	A_{insul} (ft²)[41]	ΔkWh	~~ΔkW~~ $\Delta kW_{summer\ peak}$	$\Delta kW_{winter\ peak}$
30	8	16	19.16	20.94	139.4	0.~~0159~~0145	0.0244
30	10	18	19.16	20.94	96.6	0.~~0110~~0101	0.0170
30	12	20	19.16	20.94	70.6	0.~~0081~~0074	0.0124
30	8	18	19.16	20.94	158.1	0.~~0180~~0165	0.0277
30	10	20	19.16	20.94	111.6	0.~~0127~~0117	0.0196
30	12	22	19.16	20.94	82.8	0.~~0094~~0087	0.0145
40	8	16	23.18	25.31	168.9	0.~~0193~~0177	0.0296
40	10	18	23.18	25.31	117.1	0.~~0134~~0122	0.0205
40	12	20	23.18	25.31	85.5	0.~~0098~~0089	0.0150
40	8	18	23.18	25.31	191.5	0.~~0219~~0200	0.0336
40	10	20	23.18	25.31	135.1	0.~~0154~~0141	0.0237
40	12	22	23.18	25.31	100.3	0.~~0114~~0105	0.0176
50	8	16	24.99	27.06	183.9	0.~~0210~~0192	0.0323
50	10	18	24.99	27.06	127.8	0.~~0146~~0134	0.0224
50	12	20	24.99	27.06	93.6	0.~~0107~~0098	0.0164
50	8	18	24.99	27.06	208.0	0.~~0237~~0218	0.0365
50	10	20	24.99	27.06	147.1	0.~~0168~~0154	0.0258
50	12	22	24.99	27.06	109.4	0.~~0125~~0114	0.0192
80	8	16	31.84	34.14	237.0	0.~~0271~~0248	0.0416
80	10	18	31.84	34.14	165.3	0.~~0189~~0173	0.0290
80	12	20	31.84	34.14	121.5	0.~~0139~~0127	0.0213

~~[40] 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.~~
~~[41] A_{insul} was calculated by assuming that the water heater wrap is a 2" thick fiberglass material.~~

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Capacity (gal)	R_{base}	R_{insul}	A_{base} (ft²)[40]	A_{insul} (ft²)[41]	ΔkWh	ΔkW $ΔkW_{summer\ peak}$	$ΔkW_{winter\ peak}$
80	8	18	31.84	34.14	267.4	0.03050280	0.0469
80	10	20	31.84	34.14	189.6	0.02160198	0.0333
80	12	22	31.84	34.14	141.4	0.01610148	0.0248

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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. https://nextgen.ahridirectory.org/Search/QuickSearch?category=8&searchTypeId=3&producttype=15Weblink
4) Pennsylvania Act 129 2014 Residential Baseline Study. Section 4.6.1, pg 60, Table 4-64. Weblink
5) Pennsylvania Act 129 2014 Residential Baseline Study. Section 5.4.4, pg 104. Weblink
6) California Electronic Technical Reference Manual. "Water Heater Tank Wrap". Accessed December 2023. Weblink
4) U.S. Department of Energy. Pennsylvania Statewide Residential End-Use and Saturation Study, 2014, http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-2014_PA_Statewide_Act129_Residential_Baseline_Study.pdf.
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6) "Energy Savers", U.S. Department of Energy, accessed June, 2018 https://www.energy.gov/energysaver/services/do-it-yourself-energy-savings-projects/savings-project-insulate-your-water
7) (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

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~~2.3.5~~2.3.4 WATER HEATER TEMPERATURE SETBACK

Target Sector	Residential ~~Establishments~~
Measure Unit	Water Heater Temperature
Measure Life	2 years Source ~~10~~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.

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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.

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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:

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

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

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

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

~~ETDF (Energy to Demand Factor) is defined below:~~

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

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

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

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

Definition of Terms

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

Term	Unit	Values	Source
UEF_{WH}, Uniform Energy Factor $T_{hot,i}$, Temperature setpoint of water heater initially	Proportion°F	EDC data collectionData Gathering Default: Electric Storage= 0.90 HPWH= 2.00 130	15
R_{tank}, R value $T_{hot,f}$, Temperature setpoint of water heater tankafter setback	$\frac{hr \cdot °F \cdot ft^2}{BTU}$ °F	EDC Data Gatheringdata collection Default: 12119	910
A_{tank}, Surface Area of water heater tank	ft^2	EDC Data Gathering Default: 24.99	50 gal. value in Table 2-54Table 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: 2.103.11	1, 2, 3
V_{HW}, Volume of hot water used per cycle by clothes washer	$\frac{gallons}{cycle}$	7	4
$Cycles_{wash}$, Number of clothes washer cycles per year	$\frac{cycles}{yr}$	Clothes washer present: 251 178 No clothes washer: 0	54
$T_{hot,i}$, Temperature setpoint V_{HW}, Volume of hot water heater initiallyused per cycle by clothes washer	°F $\frac{gallons}{cycle}$	EDC Data Gathering Default: 13025	63
$T_{hot,f}$, Temperature setpoint UEF_{WH}, Uniform Energy Factor of water heater after setback	Proportion°F	EDC data collection Default: 119 Electric Storage= 0.92 HPWH= 3.20	76
$ETDF$, $ETDF_S$, Summer Energy To Demand Factor (defined above)	$\frac{kW}{kWh/yr}$ $\frac{kW}{kWh}$	0.000080470001057	87
$ETDF_W$, Winter Energy To Demand Factor	$\frac{kW}{kWh}$	0.0001761	7

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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}	ΔkWhEnergy Savings (ΔkWh)	Demand Reduction (ΔkW$_{peak}$)ΔkW$_{summer\ peak}$	ΔkW$_{winter\ peak}$
Electric Storage	0	0.98	0.901.03	60.0	0.00480063	0.0106
Electric Storage w/Clothes Washer	251200	0.98	1.03	189.9	0.900199 112.0	0.0090033
HPWH	0	2.13.11	2.0080	18.9	28.0.0020	0.00230033
HPWH w/Clothes Washer	251	2.13.11	2.0080	51.567.0	0.00410070	0.0117

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Evaluation Protocols

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

Sources

1) Previous Federal Standards from 2004-2015 are 0.97 -0.00132 x Rated Storage in Gallons. For a 50-gallon tank this is 0.90. "Energy Conservation Program: Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters" US Dept of Energy Docket Number: EE–2006–BT-STD–0129, p. 30. The previous, long-standing requirements are used since this is a Retrofit measure applied to existing equipment, not new equipment.

2)1)AHRI Directory. All electric storage water heaters have a recovery efficiency of 0.98. https://www.ahridirectory.org/Search/QuickSearch?category=8&searchTypeId=3&producttype=15Weblink

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

3) U.S. Department of Energy. NEEA Heat Pump Water Heater Field Study Report. Prepared by Fluid Market Strategies. October 22, 2013. http://neea.org/docs/default-source/reports/heat-pump-water-heater-field-study-report.pdf?sfvrsn=5

4) Federal Energy Management Program Energy Cost Calculator, March 2010 (visited October 23, 2018) https://www.energy.gov/node/789966

5)4)(2023). 2020 Residential Energy Consumption Survey. Weblink Calculated using "Frequency of clothes washer use" and "Frequency of dryer use" data for the Mid-Atlantic region from U.S. Department of Energy. 2015 Residential Energy Consumption SurveyPennsylvania. (2015). https://www.eia.gov/consumption/residential/data/2015/index.php?view=microdata

6)5)Engineering assumption

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

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

9)1)Conservative estimate of R-12

6) Pennsylvania Act 129 2023 Residential Baseline Study. Section 8.3.5, pg 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 referenceReference Manual for Energy Efficiency Version 7. (2023, version 11.0. Effective January). "5.4.6 Water Heater Temperature Setback". Weblink

10) Pennsylvania Act 129 2014 Residential Baseline Study. Section 4.6.1, 2019.pg 60, Table 4-64. http://www.ilsag.info/technical-reference-manual.htmlWeblink

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2.3.62.3.5 WATER HEATER PIPE INSULATION

Target Sector	Residential Establishments
Target Sector	Residential
Measure Unit	Water Heater
Measure Life	13 years Source 3
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=0.920792) with an annual energy usage of 2,939 kWh. [42]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. The target sector primarily consists of residential establishments.

ALGORITHMS

The annual energy savings are assumed to be 3% of the annual energy use of an electric water heater (2,939 kWh), or 88.2 kWh based on 10 feet of ¾" thick insulation (equal to R-3 on a ½" pipe). This estimate is based on a recent report prepared by the ACEEE for the State of Pennsylvania (Source 1). On a per foot basis, this is equivalent to 8.82 kWh.

ΔkWh = 8.82 kWh/yr per foot of installed insulation

The summer coincident peak kW savings are calculated as follows:

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

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

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

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

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

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

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

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	-
ΔkWh, annual energy savings per foot of installed pipe insulation C_{inside}, Inside circumference of pipe	$\frac{kWh/yr}{ft}$ ft	8.82EDC Data Gathering	17, 8
$L_{horizontal}$, 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, $ETDF_S$, Summer Energy toTo Demand Factor	$\frac{kW}{kWh/yr}$ $\frac{kW}{kWh}$	0.000080470001046	25
ΔkW_{peak}, Summer peak kW savings per foot of installed pipe insulation $ETDF_W$, Winter Energy To Demand Factor	$\frac{kW}{ft}$ $\frac{kW}{kWh}$	0.000710001755	-5

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

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

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

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

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Evaluation Protocols

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

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Sources

1) American Council for an Energy-Efficient Economy, Summit Blue Consulting, Vermont Energy Investment Corporation, ICF International, and Synapse Energy Economics, Potential for Energy Efficiency, Demand Response, and Onsite Solar Energy in Pennsylvania, Report Number E093, April 2009, p. 117.

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

3) California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx. Accessed November 13, 2018

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, pg 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, pg I-6, Table I-5. Weblink

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

~~2.3.7~~2.3.6 Low-~~-~~Flow Faucet Aerators

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

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

~~The low-flow kitchen and bathroom aerators will save on the electric energy usage due to the reduced demand of hot water.~~

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Eligibility

This protocol documents the energy savings attributable to ~~efficient~~ 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.

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Algorithms

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

$$\Delta kWh = \frac{(GPM_{base} - GPM_{low}) \times 8.3\frac{BTU}{gal\text{-}°F} \times (T_{out} - T_{in})}{3412\frac{BTU}{kWh} \times RE} \quad \frac{(GPM_{base} - GPM_{low}) \times 8.3 \times (T_{out} - T_{in})}{3412 \times RE}$$

$$\times \frac{DF \times T_{person-day} \times N_{persons} \times 365 \quad \frac{DF \times T_{person-day} \times N_{persons} \times 365\frac{days}{yr}}{N_{faucets-home}}}{N_{faucets-hom}} \times ISR \times ELEC$$

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

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~~Where:~~

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

~~Given:~~

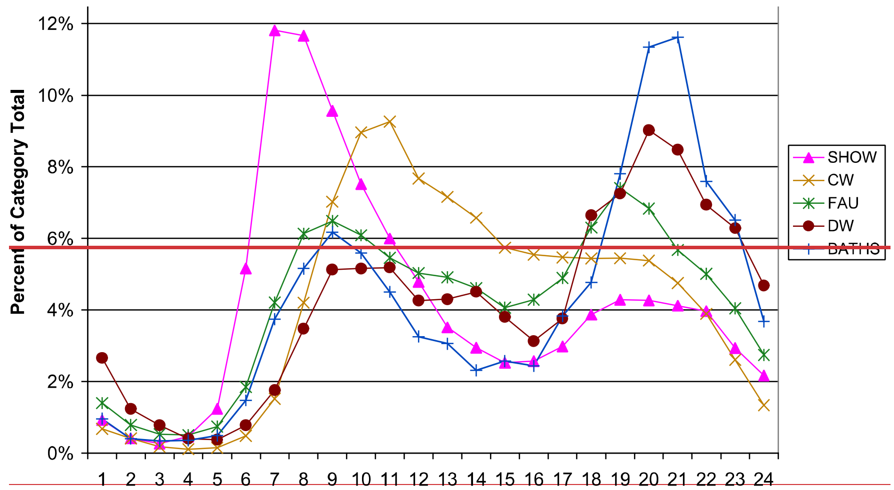
$$CF = \frac{\%_{faucet\ use,peak} \times T_{person-day} \times N_{persons}}{N_{faucets-home} \times 240\frac{minutes}{daily\ peak}}$$

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

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

~~Aquacraft, Inc study.[Source 2] The average daily load shapes (percentages of daily energy usage that occur within each hour) are plotted in Figure 2-1 below (symbol FAU represents faucets).[43]~~

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



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

DEFINITION OF TERMS

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

Term	Unit	Value	Source
GPM_{base}, Average baseline aerator flow rate ~~of aerator~~ (GPM)	$\frac{gallons}{minute}$	EDC Data Gathering or Default = 2.2	~~3~~2
GPM_{low}, Average ~~post measure~~ efficient aerator flow rate ~~of aerator~~ (GPM)	$\frac{gallons}{minute}$	EDC Data Gathering ~~or Default = 1.5~~	~~3~~
~~$T_{person\text{-}day}$~~ T_{out}, Average ~~time of hot~~mixed water ~~usage per person per day (minutes~~temperature flowing from the faucet (°F)	~~$\frac{minutes}{person\text{-}day}$~~ °F	Kitchen=~~4.5~~93.0 Bathroom=~~1.6~~86.0 Unknown=~~6.1~~ 87.8	~~4~~5
~~$N_{persons}$~~ T_{in}, Average ~~number~~temperature of ~~persons per household~~water entering the house (°F)	~~$\frac{persons}{house}$~~ °F	~~Default SF=2.5~~ 53~~Default MF=1.7~~ ~~Default Unknown=2.5~~ ~~Or EDC Data Gathering~~	~~11~~6
~~T_{out}, Average mixed water temperature flowing from the faucet (°F)~~ RE, Recovery efficiency of electric water heater	Proportion ~~°F~~	~~Kitchen=~~Default: Standard: 0.98 HPWH: 3.93 ~~Bathroom=86~~	~~6~~7

[43] ~~SHOW = showers, CW = clothes washers, FAU = Faucets, DW = dishwashers, BATHS = baths. FAU is the relevant curve for this measure.~~

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Term	Unit	Value	Source
		Unknown~~= 87.8~~: 1.22	
~~T_{in}, Average temperature~~ DF, Percentage of water ~~entering the house (ºF)~~flowing down drain	~~ºF~~%	~~52~~Kitchen=75% Bathroom=90% Unknown=79.5%	~~7~~8
~~RE, Recovery efficiency~~ $T_{person\text{-}day}$, Average time of ~~electric~~hot water ~~heater~~usage per person per day (minutes)	$\frac{minutes}{person\text{-}day}$ ~~Proportion~~	~~Default:~~ ~~Standard: 0.98~~ ~~HPWH:~~ Kitchen=4.5 Bathroom=1.6 Unknown=2.~~1~~7	~~8, 10~~3
~~ETDF, Energy To Demand Factor~~ $N_{persons}$, Average number of persons per household	~~$\frac{kW}{kWh/yr}$~~ $\frac{pers}{house}$	Default SF=2.6 Default MF=1.7 Default Unknown=2.4 Or EDC Data Gathering~~0.000134~~	~~2~~9
$N_{faucets-home}$, Average number of faucets in the home	~~$\frac{faucets}{house}$~~ $\frac{fauc}{hom}$	EDC Data Gathering, Default see ~~Table 2-59~~Table 2-72	~~5~~4
~~DF, Percentage of water flowing down drain~~ ISR, In-Service Rate	%	~~Kitchen=75%~~ ~~Bathroom=90%~~ ~~Unknown=79.5%~~EDC Data Gathering, Kit Delivery Default: 26% Direct Install Default: 100%	~~9~~10
$ELEC$, Percentage of homes with electric water heat~~ISR, In Service Rate~~	%	Default: Unknown=47% Or EDC Data Gathering~~,~~: ~~Kit Delivery Default: 28%~~ ~~Direct Install Default:~~Electric = 100% Fossil Fuel = 0%	~~EDC Data Gathering, 12~~4
$ETDF_S$, Summer Energy to Demand Factor~~$ELEC$, Percentage of homes with electric water heat~~	~~%~~ $\frac{kW}{kWh}$	~~Default:~~ SF: 0.0001057 MF: 0.0001006 Unknown~~=35%~~: 0.0001046 ~~Or EDC Data Gathering:~~ ~~Electric = 100%~~ ~~Fossil Fuel = 0.0%~~	~~5~~11
~~$\%_{faucet\text{-}use,peak}$, percentage of daily faucet use during PJM peak period~~ $ETDF_W$, Winter Energy to Demand Factor	~~%~~ $\frac{kW}{kWh}$	~~19.5%~~SF: 0.0001761 MF: 0.0001733 Unknown: 0.0001755	~~2~~11

Table 2-72: Average Number of Faucets per Home

Faucet Type	Single-Family	Multifamily	Unknown
Kitchen	1.~~1~~2	1.~~0~~1	1.~~0~~2

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Bathroom	2.26	1.24	2.0
Unknown	3.31.9	21.2	3.01.7

Default Savings

Default savings assume an electric resistance storage water heater with RE = 0.98.

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

Housing Type	Faucet Location	Water Heater Fuel (% electric)	Kit Delivery: Unit Energy Savings (kWh)	Kit Delivery: Unit Demand Savings (kW)	Direct Install: Unit Energy Savings (kWh)	Direct Install: Unit Demand Savings (kW)
Single Family	Kitchen	Unknown (35%)	19.5	0.0026	69.8	0.0094
	Bathroom	Unknown (35%)	3.5	0.0005	12.3	0.0017
	Unknown	Unknown (35%)	8.2	0.0011	29.2	0.0039
Multifamily	Kitchen	Unknown (35%)	14.6	0.0020	52.2	0.0070
	Bathroom	Unknown (35%)	4.3	0.0006	15.4	0.0021
	Unknown	Unknown (35%)	8.3	0.0011	29.8	0.0040
Statewide (Unknown Housing Type)	Kitchen	Unknown (35%)	21.5	0.0029	76.8	0.0103
	Bathroom	Unknown (35%)	3.8	0.0005	13.6	0.0018
	Unknown	Unknown (35%)	9.0	0.0012	32.1	0.0043
Single Family	Kitchen	Electric (100%)	55.8	0.0075	199.5	0.0267
	Bathroom	Electric (100%)	9.9	0.0013	35.3	0.0047
	Unknown	Electric (100%)	23.4	0.0031	83.4	0.0112
Multifamily	Kitchen	Electric (100%)	41.8	0.0056	149.2	0.0200
	Bathroom	Electric (100%)	12.3	0.0017	44.0	0.0059
	Unknown	Electric (100%)	23.8	0.0032	85.1	0.0114
Statewide (Unknown Housing Type)	Kitchen	Electric (100%)	61.4	0.0082	219.4	0.0294
	Bathroom	Electric (100%)	10.9	0.0015	38.8	0.0052
	Unknown	Electric (100%)	25.7	0.0034	91.8	0.0123

Evaluation Protocols

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

Sources

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

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

faucets is found to be 30.9: (TPerson-Day× NPersons× 365) / (Nfaucets-home) / 60 = (6.1 x 2.5 x 365) / 3.0 / 60 = 30.9. The resulting F_{ED} is calculated to be 0.000134: CF / Hours = 0.00413 / 30.9 =0.000134.

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

4)3) Cadmus and Opinion Dynamics Evaluation Team.). Showerhead and Faucet Aerator Meter Study. For Michigan Evaluation Working Group. June 2013. If2.7 min/person/day for unknown aerator location is known, use the corresponding kitchen/bathroom value. If unknown, use 6.1 min/person/day calculated as theweighted average length of use value, which is the total for the household: kitchen (4.5and bathroom, min/person/day) + bathroom (1.6 min/person/day) = 6.1 min/person/day. by average kitchens and bathrooms per home from the 2023 PA residential baseline study.

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

4) Table 7. NMR Group for the Pennsylvania Public Utility Commission. (2024, March). 2023 Pennsylvania Statewide Act 129 Residential Baseline Study. Pg 122, table 105 (ELEC). Pg 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 2023 Pennsylvania residential baseline study data.

6)5) Cadmus and Opinion Dynamics Evaluation Team. for Michigan Evaluation Working Group. (2013, June). Showerhead and Faucet Aerator Meter Study. For Michigan Evaluation Working Group. June 2013.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.

7)6) Using Rock Spring, PA (Site 2036) as a proxy, the mean of soil temperature at 40 -inch depth is 51.86152.502. Calculated using Daily SCAN Standard - Period of Record data from April 1999December 2003 to December 20182023 from the Natural Resource Conservation Service Database. https://wcc.sc.egov.usda.gov/nwcc/rgrpt?report=daily_scan_por&state=PAWeblink. Methodology follows Missouri TRM 2017 Volume 2: Commercial and Industrial Measures. p.(2017, March). "2.6.1 Water Heater". Pg 78. https://energy.mo.gov/sites/energy/files/MOTRM2017Volume2.pdfWeblink

8)7) AHRI Directory. All electric storage water heaters have a recovery efficiency of 0.98. https://www.ahridirectory.org/Search/SearchForm?programId=24&searchTypeId=2Average 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 2023 PA residential baseline study.

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9)8) Illinois TRM Effective June 1, 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 is based on the assumption 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.

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

11)9) U.S. Census Bureau, 2017-2021 American Community Survey 5-Year (2013-2017) Estimates for 2017. http://data.census.gov.. Weblink

12) Average of PY9 values for kit delivery for FirstEnergy EDCs. http://www.puc.pa.gov/filing_resources/issues_laws_regulations/act_129_information/electric_distribution_company_act_129_reporting_requirements.aspx

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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

~~2.3.8~~2.3.7 LOW-~~-~~FLOW SHOWERHEADS

Target Sector	Residential ~~Establishments~~
Measure Unit	~~Water Heater~~Showerhead
Measure Life	~~9~~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~~. The target sector primarily consists of residential establishments~~.

ALGORITHMS

The annual energy savings are obtained through the following formula:

$$\Delta kWh = \frac{(GPM_{base} - GPM_{low}) \times 8.3\frac{BTU}{gal\cdot°F} \times (T_{out} - T_{in})}{3412\frac{BTU}{kWh} \times RE} \quad \frac{(GPM_{base} - GPM_{low}) \times 8.3 \times (T_{out} - T_{in})}{3412 \times RE}$$

$$\times \frac{T_{person-day} \times N_{persons} \times N_{showers-day} \times 365 \frac{T_{perso-day} \times N_{persons} \times N_{showers-day} \times 365\frac{days}{yr}}{N_{showerheads-home}}}{N_{showerheads-h}}$$

$$\times ISR \times ELEC$$

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

~~Where:~~

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

~~Given:~~

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

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

~~The ratio of the average energy usage during 2 PM and 6 PM on summer weekdays to the total annual energy usage is taken from average daily load shape data collected for showerheads from an Aquacraft, Inc study. Source 2 The average daily load shapes (percentages of daily energy usage that occur within each hour) during are plotted in Figure 2-2 below (symbol SHOW represents showerheads).[44]~~

~~[44] SHOW = showers, CW = clothes washers, FAU = Faucets, DW = dishwashers, BATHS = baths. SHOW is the relevant curve for this measure.~~

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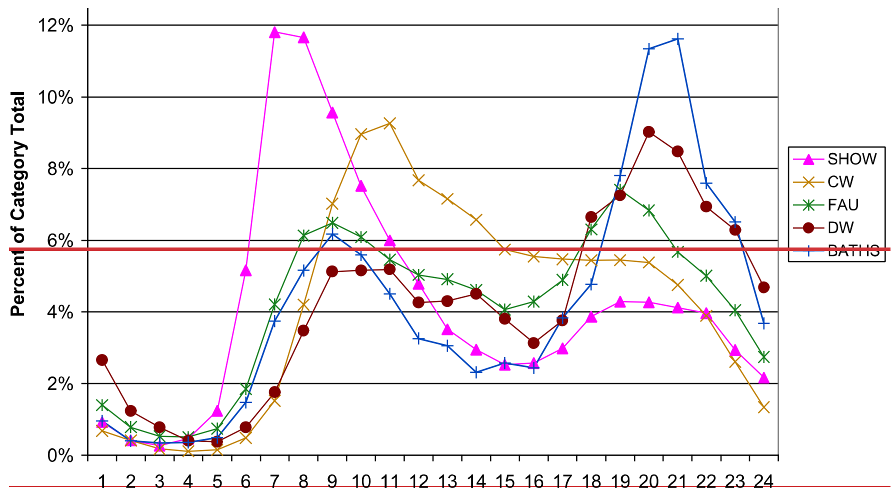
Figure 2-2: Daily Load Shapes for Hot Water Measures Source 2



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

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	32
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 $T_{person-day}$, Average time of shower usage per person (minutes)	$\frac{minutes}{day}$ °F	7.8101	57
T_{in}, Assumed temperature of water entering house $N_{persons}$, Average number of persons per household	$\frac{persons}{hou}$ °F	EDC Data Gathering or Default SF=2.5 Default MF=1.7 Default unknown=2.553	68
$N_{showers-day}$, Average number of showers per person per day RE, Recovery efficiency of electric water heater	$\frac{showers}{person \cdot day}$ Proportion	0.6Default: Electric resistance: 0.98 HPWH: 3.93 Unknown: 1.22	79
$N_{showerheads-home}$ $T_{person-day}$, Average numbertime of showers in the homeshower usage per person (minutes)	$\frac{showers}{house}$ $\frac{minutes}{day}$	EDC Data Gathering or Default SF=1.6 Default MF=1.1 Default unknown = 1.57.8	83

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Term	Unit	Value	Source
$N_{persons}$, Average number of persons per household T_{out} , Assumed temperature of water used by showerhead	°F $\frac{persons}{household}$	EDC Data Gathering or Default SF=2.6 Default MF=1.7 Default unknown=2.1014	94
$N_{showers-day}$, Average number of showers per person per day T_{in} , Assumed temperature of water entering house	°F $\frac{showers}{person \cdot day}$	520.6	105
RE , Recovery efficiency of electric water heater $N_{showerheads-home}$, Average number of showers in the home	$\frac{showers}{home}$ Proportion	EDC Data Gathering or Default: SF=1.9 Standard: 0.98 HPWH: 2.1Default MF=1.2 Default unknown = 1.7	11, 136
$ETDF$, Energy To Demand Factor ISR , In-Service Rate	$\frac{kW}{kWh/yr}$ %	0.00008014EDC Data Gathering, Kit Default = 21% Direct Install Default = 100%	12EDC Data Gathering, 10
$ELEC$, Percentage of homes with electric water heat ISR , In Service Rate	%	EDC Data Gathering, or Kit Default = 35; Unknown=47% Direct Install DefaultElectric = 100% Fossil Fuel = 0%	EDC Data Gathering, 146
$ETDF_S$, Summer Energy to Demand Factor $ELEC$, Percentage of homes with electric water heat	% $\frac{kW}{kWh}$	EDC Data Gathering or Default: SF: 0.0001057 MF: 0.0001006 Unknown=35% Electric = 100% Fossil Fuel = 0.0%0001046	811
$\%_{shower-use,peak}$, percentage of daily shower use during PJM peak period $ETDF_W$, Winter Energy to Demand Factor	% $\frac{kW}{kWh}$	11.7%SF: 0.0001761 MF: 0.0001733 Unknown: 0.0001755	1211

Default Savings

Default savings assume an electric resistance storage water heater with RE = 0.98.

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Table 2-64: Default Savings for Low Flow Showerheads

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

Evaluation Protocols

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

Sources

1) Efficiency Vermont, Technical Reference User Manual: Measure Savings California Electronic Technical Reference Manual. "Low-Flow Showerheads". Accessed December 2023. Weblink

2) 10 CFR 430.32(p). Weblink

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

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

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

4) Illinois TRM Effective June 1, 2013. Allows for varying flow rate of the low-flow showerhead, most notably values of 2.0 GPM, Table 61.75 GPM and 1.5 GPM. Custom or actual values are also allowed for.

5)3)Table 6. Cadmus and Opinion Dynamics Evaluation Team. Showerhead and Faucet Aerator Meter Study. For Michigan Evaluation Working Group. June 2013. The study compared shower length by single-family and multifamily populations, finding no statistical difference in showering times. For the energy-saving analysis, the study used the combined single-family and multifamily average shower length of 7.8 minutes.

4) U.S. Census Bureau, 2017-2021 American Community Survey 5-Year (2013-2017) 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)1)2017. http://factfinder.census.gov.

7)1)Table 8. Cadmus and Opinion Dynamics Evaluation Team. Showerhead and Faucet Aerator Meter Study. For Michigan Evaluation Working Group. June 2013. For each shower fixture metered, the evaluation team knew the total number of showers taken, duration of time meters remained in each home, and total occupants reported to live in the home. From these values average showers taken per day, per person was calculated. The study compared showers per day, per person by single-family and multifamily populations, finding no statistical difference in the values. For the energy-saving analysis, the study used the combined single-family and multifamily average showers per day, per person of 0.6.

8)6)NMR Group for the Pennsylvania Public Utility Commission. (2024, March). 2023 Pennsylvania Statewide Act 129 2018 Residential Baseline Study. Pg 122, table 105 (ELEC). Pg 130 table, 112 ($N_{faucets-home}$). http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-Phase3_Res_Baseline_Study_Rpt021219.pdf.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.

9)1)*Using Rock Spring, PA (Site 2036) as a proxy, the mean* For Michigan Evaluation Working Group. June 2013. Temperature sensors provided the mixed water temperature readings resulting in an average of 101ºF.

10)8) Using Rock Spring, PA (Site 2036) as a proxy, the mean of soil temperature at 40-inch depth is 51.86152.502. Calculated using Daily SCAN Standard - Period of Record data from April 1999December 2003 to December 20182023 from the Natural Resource Conservation Service Database. https://wcc.sc.egov.usda.gov/nwcc/rgrpt?report=daily_scan_por&state=PAWeblink. Methodology follows Missouri TRM 2017 Volume 2: Commercial and Industrial Measures. p.(2017, March). "2.6.1 Water Heater". Pg 78. https://energy.mo.gov/sites/energy/files/MOTRM2017Volume2.pdfWeblink

11) 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. https://www.ahridirectory.org/NewSearch?programId=24&searchTypeId=Weblink3

12)9) Aquacraft, Inc., Water Engineering 1.22 for unknown type calculated as the weighted average of electric resistance and Management. The end useHPWH recover efficiencies by

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Formatted: Font color: Custom Color(RGB(55,65,81)) the relative proportions of hot water in single family homeselectric resistance and HPWHs from flow trace analysis. 2001. http://s3.amazonaws.com/zanran_storage/www.aquacraft.com/ContentPages/47768067.pdf. The statewide values were used for inputs in the ETDF algorithm components. The CF for showerheads is found to be 0.00380: [% showerhead use during peak × ($T_{person\text{-}day}$ × N_{person} × $N_{showers\text{-}day}$) / ($N_{showerheads\text{-}home}$)] / 240 (minutes in peak period) = [11.7% × (7.8 x 2.5 x 0.6 / 1.5)] / 240 = 0.00371. The Hours for showerheads is found to be 47.5: ($T_{person\text{-}day}$ × $N_{persons}$ × 365) /($N_{showerheads\text{-}home}$) / 60 = (7.8 x 2.5 x 0.6 x 365) / 1.5 / 60 = 47.5. The resulting ETDF is calculated to be 0.00008014: CF / $Hours$ = 0.00380 / 47.5 = 0.00008014the 2023 PA residential baseline study.

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

14) Average of PY9 values for kit delivery for FirstEnergy EDCs. http://www.puc.pa.gov/filing_resources/issues_laws_regulations/act_129_information/electric_distribution_company_act_129_reporting_requirements.aspx

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

2.3.9 2.3.8 THERMOSTATIC SHOWER RESTRICTION VALVES

Target Sector	Residential Establishments
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. The target sector primarily consists of residences.

ALGORITHMS

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ALGORITHMS

The annual energy savings are obtained through the following formula:

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

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

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

DEFINITION OF TERMS

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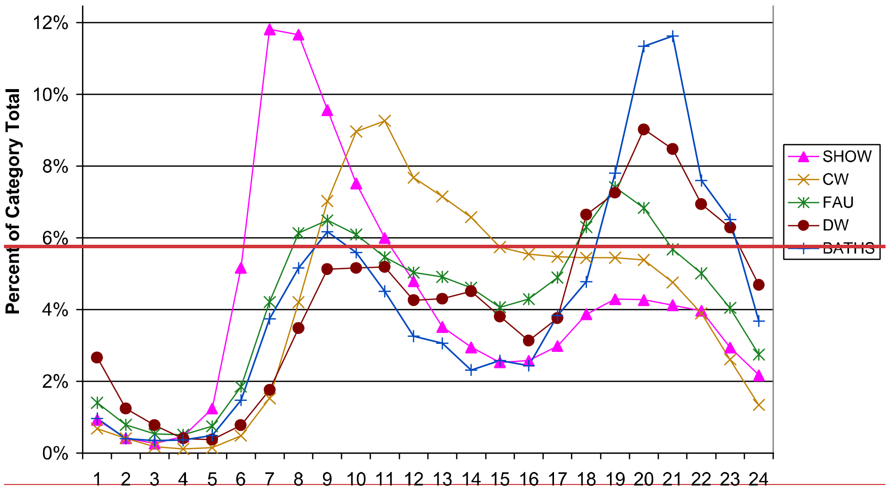
$$\Delta kWh = ISR \times ELEC \times \frac{GPM_{base} \times 8.3 \frac{BTU}{gal \cdot °F} \times (T_{out} - T_{in})}{3412 \frac{BTU}{kW} \times RE} \times \frac{BehavioralWasteSeconds \times (N_{persons} \times N_{showers-day}) \times 365 \frac{days}{yr}}{60 \frac{sec}{min} \times N_{showerheads-home}}$$

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

The ratio of the average energy usage during 2 PM and 6 PM on summer weekdays to the total annual energy usage is taken from average daily load shape data collected for showerheads from an Aquacraft, Inc study. Source 2 The average daily load shapes (percentages of daily energy usage that occur within each hour) during are plotted in Figure 2-3: Daily Load Shapes for Hot Water Measures below (symbol SHOW represents showerheads).[45]

A default in-service rate (ISR) of 100% is permissible for direct-install programs, but EDC data-gathering is required for kit delivery.

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



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Definition of Terms

Default savings assume an electric resistance storage water heater with RE = 0.98.

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: Standard shower head= 2.5 Low Flow Shower Head=1.50	35
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

[45] SHOW = showers, CW = clothes washers, FAU = Faucets, DW = dishwashers, BATHS = baths. SHOW is the relevant curve for this measure.

Parameter	Unit	Value	Source
$N_{persons}$, Average number of persons per household	$\frac{persons}{household}$	EDC Data Gathering or Default: SF=2.56 MF=1.7 Unknown=2.54	43
$N_{Showers\text{-}Day}$, Average number of showers per person per day	$\frac{showers}{person \cdot day}$	0.6	54
$N_{showerheads-home}$, Average number of showerhead fixtures in the home	Noneunits	EDC Data Gathering or Default: SF=1.69 MF=1.12 Unknown = 1.57	65
T_{out}, Assumed temperature of water used by showerhead	$°F$	EDC Data Gathering or Default: 104	7
T_{in}, Assumed temperature of water entering house	$°F$	52	8
RE, Recovery efficiency of electric water heater	Proportion	Default: 0.98 HPWH: 2.1	9, 11
$ETDF$, Energy To Demand Factor	$\frac{kW}{kWh/yr}$	0.00008014	10
ISR, In--Service Rate	%	EDC Data Gathering Default, 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=3547%	65
$BehavioralWasteSeconds$, Time$ETDF_S$, Summer Energy to Demand Factor	sec $\frac{kW}{kWh}$	EDC Data Gathering or Default = 59SF: 0.0001057 MF: 0.0001006 Unknown: 0.0001046	79
$ETDF_W$, Winter Energy to Demand Factor	$\frac{kW}{kWh}$	SF: 0.0001761 MF: 0.0001733 Unknown: 0.0001755	9

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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

ApplicationHousing Type	Baseline Flowrate (GPM)	Water Heater Fuel (% electric)	Energy Savings (kWh/yr)Water Heater Type	Peak Demand Reduction (kW)ΔkWh	$\Delta kW_{summer\ peak}$	$\Delta kW_{winter\ peak}$
Single Family		2.5100%	Unknown (35%)Electric Resistance	74.6	38.0.0079	0.00300131
	2	Unknown (35%)	30.4	0.0024		
	1.5	Unknown (35%)	22.8	0.0018		

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Multifamily	2.5100%	Unknown (35%)HPWH	3718.6	0.00300020	0.0033
	2100%	Unknown (35%)	30.159.9	0.00240063	0.0106
	1.5	Unknown (35%)	22.6	0.0018	
Unknown / Default Housing Type	2.547%	Unknown (35%)	40.528.2	0.00320030	0.0050
	2	Unknown (35%)	32.4	0.0026	
	1.5	Unknown (35%)	24.3	0.0019	
Single Family	2.5	Electric (100%)	108.6	0.0087	
	2	Electric (100%)	86.9	0.0070	
	1.5	Electric (100%)	65.1	0.0052	
Multifamily	2.5100%	Electric (100%)Resistance	107.477.2	0.00860078	0.0134
2	Electric (100%)%	85.9HPWH	19.3	0.00690019	0.0033
1.5	Electric (100%)%	64.4Unknown	62.0	0.00520062	0.0108
	47%	Unknown	29.2	0.0029	0.0051
Unknown / Default Housing Type	2.547%	Electric (100%)Unknown	115.829.1	0.00930030	0.0051
	2	Electric (100%)	92.7	0.0074	
	1.5	Electric (100%)	69.5	0.0056	

Evaluation Protocols

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

Sources

1) Uniform Plumbing Code (UPC) certification under the International Association of Plumbing and Mechanical Officials standard IGC 244-2007a stipulates device must meet 10,000 cycles without failure. Measure life: $[10{,}000 \text{ cycles} / (N_{persons} \times N_{showers\text{-}day} \times 365)] = [10{,}000 / (2.5 \times 0.6 \times 365)] = 18 \text{ years}$. 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) Aquacraft, Inc., Water Engineering and Management. The end use of hot water in single family homes from flow trace analysis. 2001. http://s3.amazonaws.com/zanran_storage/www.aquacraft.com/ContentPages/47768067.pdf.

3)2) Cadmus and Opinion Dynamics Evaluation Team. Showerhead and Faucet Aerator Meter Study. For Michigan Evaluation Working Group. June 2013. Uses the federal minimum GPM allowed as the baseline for the replaced showerheads, corresponding to 2.5 GPM.

3) U.S. Census Bureau, 2017-2021 American Community Survey 5-Year (2013-2017) Estimates. Weblink

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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.

4) for 2017. http://factfinder.census.gov.

5)1)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.

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6)5)NMR Group for the Pennsylvania Public Utility Commission. (2024, March). 2023 Pennsylvania Statewide Act 129 2018 Residential Baseline Study, http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-Phase3_Res_Baseline_Study_Rpt021219.pdf. . Pg 122, table 105 (ELEC). Pg 130 table, 115 (GPM_{base}, $N_{showerheads-home}$). Weblink

7)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).

8)7)Using Rock Spring, PA (Site 2036) as a proxy, the mean of soil temperature at 40--inch depth is 51.86152.502. Calculated using Daily SCAN Standard - Period of Record data from April 1999December 2003 to December 20182023 from the Natural Resource Conservation Service Database. https://wcc.sc.egov.usda.gov/nwcc/rgrpt?report=daily_scan_por&state=PAWeblink. Methodology follows Missouri TRM 2017 Volume 2: Commercial and Industrial Measures. p.(2017, March). “2.6.1 Water Heater”. Pg 78. https://energy.mo.gov/sites/energy/files/MOTRM2017Volume2.pdfWeblink

9) AHRI Directory. All electric storage water heaters have a recovery efficiency of 0.98. https://www.ahridirectory.org/Search/SearchForm?programId=24&searchTypeId=2

10) Aquacraft, Inc., Water Engineering and Management. The end use of hotAverage recovery efficiency for heat pump water in single family homes from flow trace analysis. 2001. http://s3.amazonaws.com/zanran_storage/www.aquacraft.com/ContentPages/47768067.pdf. The statewide values were used for inputs in the ETDF algorithm components. The CF for showerheadsheaters is found to be 0.00380: [% showerhead use during peak × ($T_{Person-Day}$ × N_{Person} × $N_{showers-day}$) /($N_{showerheads-home}$)] / 240 (minutes in peak period) = [11.7% × (7.8 x 2.5 x 0.6 /3.93. Accessed December 2023. Weblink 1.5)] / 240 = 0.00380. The Hours for showerheads is found to be 47.5: ($T_{Person-Day}$× $N_{Persons}$× 365) /($N_{showerheads-home}$) / 60 = (7.8 x 2.5 x 0.6 x 365) / 1.5 / 60 = 47.5. The resulting ETDF is22 for unknown type calculated to be 0.00008014: CF / Hours = 0.00380 / 47.5 = 0.00008014.

8) NEEA Heat Pump Water Heater Field Study Report. Preparedas the weighted average of electric resistance and HPWH recover efficiencies by Fluid Market Strategies. October 22, 2013. https://neea.org/img/uploads/heat-pump-water-heater-field-study-report.pdfthe relative proportions of electric resistance and HPWHs from the 2023 PA 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

2.3.102.3.9 Drain Water Heat Recovery Units

Target Sector	Residential Establishments
Measure Unit	Drain Water Heat Recovery Unit
Measure Life	15 years Source 121
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 shower greydrain water and use it to preheat cold water that is delivered to the showerfixture's mixing valve, the water heater, or both. Savings are calculated per drain water heat recovery unit. A term is included to accommodate multifamily buildings with multiple units' drains connected to a single drain water heat recovery unit.

Eligibility

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Eligibility

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

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Algorithms

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Algorithms

The algorithms for annual energy savings and peak demand savings are obtained through the following formulashown below:

$$\Delta kWh = \frac{(T_{out} - T_{in}) \times 8.3\frac{BTU}{gal \cdot °F} \times GPM \times T_{person-day} \times N_{persons} \times N_{showers-day} \times N_{units} \times 365\frac{days}{yr} \times SF}{3412\frac{BTU}{kW} \times RE}$$

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

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

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

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Definition of Terms

Where:

$$ETDF = \frac{CF}{HOU}$$

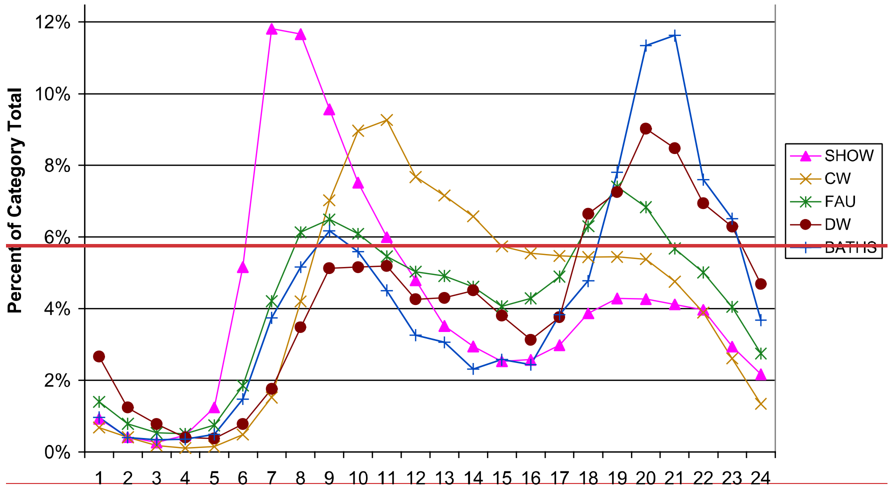
Given:

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

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

The ratio of the average energy usage during 2 PM and 6 PM on summer weekdays to the total annual energy usage is taken from average daily load shape data collected for showerheads from an Aquacraft, Inc study.Source 8 The average daily load shapes (percentages of daily energy usage that occur within each hour) during are plotted in Figure 2-2 below (symbol SHOW represents showerheads).[46]

Figure 2-4: Daily Load Shapes for Hot Water Measures Source 2



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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	52
T_{in}, Assumed temperature of water entering house	°F	5253	63
GPM, Gallons per minute of showerhead	$\frac{gallons}{minute}$	Default standard = 2.5 Low-flow = EDC Data Gathering[47]	1
$T_{person-day}$, Average time of shower usage per person (minutes)	$\frac{minutes}{day}$	7.8	2

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[46] SHOW = showers, CW = clothes washers, FAU = Faucets, DW = dishwashers, BATHS = baths. SHOW is the relevant curve for this measure.

[47] The low-flow showerhead GPM should be used where both a low-flow showerhead and a drain water heat recovery unit are installed in the same home.

Term	Unit	Value	Source
$N_{persons}$, Average number of persons per household	$\frac{persons}{house}$	EDC Data Gathering or Default SF=2.5 Default MF=1.7 Default unknown=2.5	3
$N_{showers-day}$, Average number $GPHD$, Gallons of showershot water use per personhousehold per day	$\frac{showers}{person \cdot day}$ $\frac{gallon}{day}$	0.6Shower only: 17.8 Whole house: 45.5	4
N_{units}, Number of units in a multifamily building with drains connected to the drain water heat recovery unit.	Units	SF: 1 MF: 1 or EDC Data Gathering	-
SF, Water heating energy savings factor	%	30%	10, 115
RE, Recovery efficiency of electric water heater	Proportion	Default: Resistance: 0.98 HPWH: 2.3.93 Unknown: 1.22	7, 96
ETDF , $ETDF_S$, Summer Energy Toto Demand Factor	$\frac{kW}{kWh/yr}$ $\frac{kW}{kWh}$	SF: 0.000080130001057 MF: 0.0001006 Unknown: 0.0001046	87
$\%_{shower-use,peak}$, percentage of daily shower use during PJM peak period $ETDF_W$, Winter Energy to Demand Factor	$\%\frac{kW}{kWh}$	11.7%SF: 0.0001761 MF: 0.0001733 Unknown: 0.0001755	87

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Default Savings

Default Savings

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

Housing Type	Flow Rate (gpm)	Energy Savings per Unit (kWh)		Demand Savings per Unit (kW)	
		Electric Resistance	HPWH	Electric Resistance	HPWH
Single Family/ Unknown	2.5	365.7	170.7	0.0293	0.0137
	2.0	292.6	136.5	0.0234	0.0109
	1.75	256.0	119.5	0.0205	0.0096
	1.5	219.4	102.4	0.0176	0.0082
Multifamily	2.5	248.7	116.1	0.0199	0.0093
	2.0	198.9	92.8	0.0159	0.0074
	1.75	174.1	81.2	0.0139	0.0065
	1.5	149.2	69.6	0.0120	0.0056

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

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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". Pg 69. ACEEE. Weblink. Note that measure life is defined as 30 years; however, PA Act 129 Legislation caps measure life at 15 years.

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

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

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

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

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

6)3)Using Rock Spring, PA (Site 2036) as a proxy, the mean of soil temperature at 40 -inch depth is 51.86152.502. Calculated using Daily SCAN Standard - Period of Record data from April 1999 to December 20182003 to December 2023 from the Natural Resource Conservation Service Database. https://wcc.sc.egov.usda.gov/nwcc/rgrpt?report=daily_scan_por&state=PAWeblink. Methodology follows Missouri TRM 2017 Volume 2: Commercial and Industrial Measures. p. 78. https://energy.mo.gov/sites/energy/files/MOTRM2017Volume2.pdf.

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

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

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

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

10)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). https://www.fpl.fs.fed.us/documnts/informationalkits/infokit_0003_DrainwaterFact%20Sheet.pdfWeblink

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 2023 PA 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

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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

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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.

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Definition of Terms

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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

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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, Table 110, pg 128. Weblink

3) Conservative estimate of R-12

11) Zaloum et al., Drain Water Heat Recovery Characterization and Modeling, Sustainable Buildings and Communities, Natural Resources Canada, Ottawa, June 29, 2007. http://gfxtechnology.com/NRCAN-6_29_07.pdf

12)1) Sachs, Talbot, Kaufman, "Emerging Hot Water Technologies and Practices for Energy Efficiency as of 2011," ACEEE, February 2012. Note that measure life is defined as 30 years; however, PA Act 129 Legislation caps measure life at 15 years.

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

4) 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". Weblink

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". Pg. 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

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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.[48]

2.4.1 ENERGY STAR REFRIGERATORS

Target Sector	Residential Establishments
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 percent% more efficient than the minimum federal government standard. The ENERGY STAR Most Efficient is a new certification that identifies the most efficient products among those that qualify for ENERGY STAR. ENERGY STAR Most Efficient refrigerators must be at least 15 percent% more efficient than the minimum federal standard.

ALGORITHMS

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

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

Table 2-81. 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 algorithms in Table 2-68 and Table 2-70 for "ENERGY STAR and ENERGY STAR Most Efficient maximum energy usage in kWh/year" may be used to determine, the efficient model's annual energy consumption for a conservative savings estimate.may be determined using Table 2-81.

ENERGY STAR Refrigerator

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

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

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

ENERGY STAR Most Efficient Refrigerator

[48] 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.

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

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

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

Definition of Terms

Table 2-69: Terms, Values, and References for ENERGY STAR Refrigerators

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

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 2-68. Table 2-81. 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 2-68 and Table 2-69Table 2-82 for "ENERGY STAR and ENERGY STAR Most Efficient maximum energy usage in kWh/year" may be used to determine efficient energy consumption for a conservative savings estimate.

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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 ~~and ENERGY STAR Refrigerators~~ Maximum Annual Energy Consumption ~~if Configuration and Volume Known~~[49]

Refrigerator Category	~~Federal Standard Maximum Usage in kWh/yr~~9/15/14 - 1/30/29	~~ENERGY STAR Maximum Energy Usage in kWh/yr~~1/31/29 - 1/30/30	As of 1/31/30
	~~Standard Size Models: 7.75 cubic feet or greater~~		
1. Refrigerator-freezers and refrigerators other than all-refrigerators with manual defrost.	7.99 × AV + 225.0		~~7.19 ×~~6.79 x AV + ~~202.5~~191.3
1A. All-refrigerators—manual defrost.	6.79 × AV + 193.6		~~6.11 × AV + 174.2~~5.77AV + 164.6
2. Refrigerator-freezers—partial automatic defrost	7.99 × AV + 225.0		~~7.19 ×~~(6.79 x AV + ~~202.5~~191.3) × K2
3. Refrigerator-freezers—automatic defrost with top-mounted freezer without an automatic icemaker.	8.07 × AV + 233.7		~~7.26 ×~~6.86 x AV + ~~210.3~~198.6 + 28I
3-BI. Built-in refrigerator-freezer—automatic defrost with top-mounted freezer without an	9.15 × AV + 264.9	8.24 ~~×~~x AV + 238.4 + 28I	

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

Refrigerator Category	~~Federal Standard Maximum Usage in kWh/yr~~9/15/14 - 1/30/29	~~ENERGY STAR Maximum Energy Usage in kWh/yr~~1/31/29 - 1/30/30	As of 1/31/30
automatic icemaker.			
3I. Refrigerator-freezers—automatic defrost with top-mounted freezer with an automatic icemaker without through-the-door ice service.	8.07 × AV + 317.7	~~7.26 × AV + 294.3~~	
3I-BI. Built-in refrigerator-freezers—automatic defrost with top-mounted freezer with an automatic icemaker without through-the-door ice service.	9.15 × AV + 348.9	~~8.24 × AV + 322.4~~	
3A. All-refrigerators—automatic defrost.	7.07 × AV + 201.6		(6.~~36 ×~~01 x AV + ~~181~~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.~~66 ×~~28 x AV + ~~268.0~~254.9) × K4 + 28I
4-BI. Built-In Refrigerator-freezers—automatic defrost with side-mounted freezer without	10.22 × AV + 357.4	~~9.20 ×~~(8.79 x AV + ~~321.7~~307.4) × K4BI + 28I	

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Refrigerator Category	Federal Standard Maximum Usage in kWh/yr9/15/14 - 1/30/29	ENERGY STAR Maximum Energy Usage in kWh/yr1/31/29 - 1/30/30	As of 1/31/30
an automatic icemaker.			
4I. Refrigerator-freezers—automatic defrost with side-mounted freezer with an automatic icemaker without through-the-door ice service.	8.51 × AV + 381.8	7.66 × AV + 352.0	
4I-BI. Built-In Refrigerator-freezers—automatic defrost with side-mounted freezer with an automatic icemaker without through-the-door ice service.	10.22 × AV + 441.4	9.20 × AV + 405.7	
5. Refrigerator-freezers—automatic defrost with bottom-mounted freezer without an automatic icemaker.	8.85 × AV + 317.0		(7.97 ×61 x AV + 285.3272.6) × K5 + 28I
5-BI. Built-In Refrigerator-freezers—automatic defrost with bottom-mounted freezer without an automatic icemaker.	9.40 × AV + 336.9	(8.46 ×65 x AV + 303.2309.9) × K5BI + 28I	
5I. Refrigerator-freezers—automatic defrost with bottom-mounted freezer	8.85 × AV + 401.0	7.97 × AV + 369.3	

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Refrigerator Category	Federal Standard Maximum Usage in kWh/yr9/15/14 - 1/30/29	ENERGY STAR Maximum Energy Usage in kWh/yr1/31/29 - 1/30/30	As of 1/31/30
with an automatic icemaker without through-the-door ice service.			
5I-BI. Built-In Refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker without through-the-door ice service.	9.40 × AV + 420.9	8.46 × AV + 387.2	
5A. Refrigerator-freezer—automatic defrost with bottom-mounted freezer with through-the-door ice service.	9.25 × AV + 475.4	8.33 ×(7.76 x AV + 436.3351.9) × K5A	
5A-BI. Built-in refrigerator-freezer—automatic defrost with bottom-mounted freezer with through-the-door ice service.	9.83 × AV + 499.9	(8.85 ×21 x AV + 458.3370.7) × K5ABI	
6. Refrigerator-freezers—automatic defrost with top-mounted freezer with through-the-door ice service.	8.40 × AV + 385.4		7.56 ×14 x AV + 355.3280.0
7. Refrigerator-freezers—automatic	8.54 × AV + 432.8		(7.69 ×31 x AV + 397.9322.5) × K7

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Refrigerator Category	Federal Standard Maximum Usage in kWh/yr9/15/14 - 1/30/29	ENERGY STAR Maximum Energy Usage in kWh/yr1/31/29 - 1/30/30	As of 1/31/30
defrost with side-mounted freezer with through-the-door ice service.			
7-BI. Built-In Refrigerator-freezers—automatic defrost with side-mounted freezer with through-the-door ice service.	10.25 × AV + 502.6	9.23 ×(8.82 x AV + 460.7384.1) × K7BI	
Compact Size Models: Less than 7.75 cubic feet and 36 inches or less in height			
11. Compact refrigerator-freezers and refrigerators other than all-refrigerators with manual defrost.	9.03 × AV + 252.3	8.137.68 × AV + 227.1214.5	
11A.Compact all-refrigerators—manual defrost.	7.84 × AV + 219.1	7.066.66 × AV + 197186.2	
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	11.80 × AV + 423.2	10.62 × AV + 389.3	

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Refrigerator Category	Federal Standard Maximum Usage in kWh/yr9/15/14 - 1/30/29	ENERGY STAR Maximum Energy Usage in kWh/yr1/31/29 - 1/30/30	As of 1/31/30
automatic icemaker.			
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 with an automatic icemaker.	6.82 × AV + 540.9	6.14 × AV + 495.2	
15. Compact refrigerator-freezers—automatic defrost with bottom-mounted freezer.	11.80 × AV + 339.2	10.62 × AV + 305.3 + 28I	
15I. Compact refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker.	11.80 × AV + 423.2	10.62 × AV + 389.3	

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Table 2-82: Default Savings Values: Door Coefficients for ENERGY STAR Refrigerators[50]Federal Standard Energy Consumption Algorithms

Refrigerator CategoryDoor Coefficient	Assumed Adjusted Volume of Unit (cubic feet) Source 6Products with a Transparent Door	Conventional Unit Energy Usage in kWh/yrProducts without a Transparent Door with a Door-in-Door			ENERGY STAR Energy Usage in kWh/yrProducts without a Transparent Door or Door-in-Door with Added External Doors	ΔkWh/yr[51]	ΔkWpeak
1A. All-refrigerators—manual defrost.K2	15.1.0	2961.0	267	30	0.00481 + 0.02 x (N_d[52] – 1)		
2. Refrigerator-freezers—partial automatic defrostK3A	151.1	3461.0	311	35	1.0.0056		
3A. All-refrigerators—automatic defrost.K3ABI	151.1	3081.0	278	31	1.0.0050		
3I. Refrigerator-freezers—automatic defrost with top-mounted freezer with an automatic icemaker without through-the-door ice service.K4	22.21.1	4971.06	455	41	1 + 0.006702 x (N_d – 2)		
4I. Refrigerator-freezers—automatic defrost with side-mounted freezer with an automatic icemaker without through-the-door ice service.K4BI	281.1	6211.06	567	54	1 + 0.008702 x (N_d – 2)		
5A. Refrigerator-freezer—automatic defrost with bottom-mounted freezer with	31.51.1	7661.06	698	68	1 + 0.011002 x (N_d – 2)		

[50] 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.
[51] kWh/yr savings may differ from Conventional Usage – ENERGY STAR Usage by 1 kWh/yr due to rounding error.
[52] 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.

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through-the-door ice service.K5					
5I. Refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker without through-the-door ice service.K5BI	24.81.1	6201.06	567	54	1 + 0.008602 x (N_d – 2)
7. Refrigerator-freezers—automatic defrost with side-mounted freezer with through-the-door ice service.K5A	30.51.1	6931.06	632	61	1 + 0.009802 x (N_d – 3)
Compact Size Models: Less than 7.75 cubic feet and 36 inches or less in heightK5ABI	1.1	1.06			1 + 0.02 x (N_d – 3)
11A.Compact all-refrigerators—manual defrost.K7	41 1	2511.06	226	25	1 + 0.004002 x (N_d – 2)
12. Compact refrigerator-freezers—partial automatic defrostK7BI	41 1	3601.06	324	36	1 + 0.005802 x (N_d – 2)
13. Compact refrigerator-freezers—automatic defrost with top-mounted freezer.K12	5.61.0	4051.0	365	40	1 + 0.006502 x (N_d – 1)
15. Compact refrigerator-freezers—automatic defrost with bottom-mounted freezer.K13A	6.31.1	4141.0	372	41	1 0.0067

ENERGY STAR Most Efficient annual energy consumption (kWh_{me}) may be determined using manufacturer's test data for the given model. Where test data is not available, the algorithms in Table 2-70 for "ENERGY STAR Most Efficient maximum energy usage in kWh/year" may be used

~~to determine efficient energy consumption for a conservative savings estimate. Baseline annual energy usage consumption (kWh_{base}) of the federal standard model may be determined using Table 2-68. E_{ann} stands for Maximum Annual Energy Usage.~~

~~Table 2-72: ENERGY STAR Most Efficient Annual Energy Usage if Configuration and Volume Known~~ [Source 4]

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 ~~Annual~~ Energy Usage in kWh/yr
1. Refrigerator-freezers and refrigerators other than all-refrigerators with manual defrost.	7.19 × AV + 202.5	AV ≤ ~~71.~~81.1, AEC_{MAX}[53] ≤ 5~~, E_{ann} ≤ 6.~~39.83 × AV + ~~180.0~~164.3 AV > ~~71.5, E_{ann}~~81.1, AEC_{MAX} ≤ 637
1A. All-refrigerators—manual defrost	6.11 × AV + 174.2	-
2. Refrigerator-freezers—partial automatic defrost	7.19 × AV + 202.5	AV ≤ ~~71.~~81.1, AEC_{MAX} ≤ 5~~, E_{ann} ≤ 6.~~39.83 × AV + ~~180.0~~164.3 AV > ~~71.5, E_{ann}~~81.1, AEC_{MAX} ≤ 637
3. Refrigerator-freezers—automatic defrost with top-mounted freezer without an automatic icemaker.	~~E_{ann} ≤637 kWh/yr~~7.26 × AV + 210.3	
3~~-~~BI. Built-in refrigerator-freezer—automatic defrost with top-mounted freezer without an automatic icemaker.	~~E_{ann} ≤637 kWh/yr~~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~~E_{ann} ≤637 kWh/yr~~	-
3I~~-~~BI. Built-in refrigerator-freezers—automatic defrost with top-mounted freezer with an automatic icemaker	~~E_{ann} ≤637 kWh/yr~~8.24 × AV + 322.4	-

[53] Maximum annual energy consumption.

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Refrigerator Category	ENERGY STAR Maximum Energy Usage in kWh/yr	ENERGY STAR Most Efficient Maximum ~~Annual~~ Energy Usage in kWh/yr
without through-the-door ice service~~.~~		
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 ≤ ~~58~~67.6, ~~E_{ann}~~AEC_{MAX} ≤ 6.~~81~~21 × AV + ~~322.2~~ 217.4 AV > ~~58~~67.6, ~~E_{ann}~~AEC_{MAX} ≤ 637
4~~-~~BI. Built-In Refrigerator-freezers—automatic defrost with side-mounted freezer without an automatic icemaker~~.~~	9.20 × AV + 321.7	AV ≤ ~~58~~67.6, ~~E_{ann}~~AEC_{MAX} ≤ 6.~~81~~21 × AV + ~~322.2~~ 217.4 AV > ~~58~~67.6, ~~E_{ann}~~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 ≤ ~~46.2, E_{ann}~~54.0, AEC_{MAX} ≤ 6.~~81~~21 × AV + ~~322.2~~ 301.4 AV > ~~46.2, E_{ann}~~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 ≤ ~~46.2, E_{ann}~~54.0, AEC_{MAX} ≤ 6.~~81~~21 × AV + ~~322.2~~ 301.4 AV > ~~46.2, E_{ann}~~54.0, AEC_{MAX} ≤ 637
5. Refrigerator-freezers—automatic defrost with bottom-mounted freezer without an automatic icemaker~~.~~	7.97 × AV + 285.3	AV ≤ ~~54.2, E_{ann} ≤ 7.08~~62.8, AEC_{MAX} ≤ 6.46 × AV + ~~253.6~~ 231.4 AV > ~~54.2, E_{ann}~~62.8, AEC_{MAX} ≤ 637

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Refrigerator Category	ENERGY STAR Maximum Energy Usage in kWh/yr	ENERGY STAR Most Efficient Maximum ~~Annual~~ Energy Usage in kWh/yr
5~~-~~BI. Built-In Refrigerator-freezers—automatic defrost with bottom-mounted freezer without an automatic icemaker	8.46 × AV + 303.2	AV ≤ ~~54.2, E_{ann} ≤ 7.08~~62.8, AEC_{MAX} ≤ 6.46 × AV + ~~253.6~~ 231.4 AV > ~~54.2, E_{ann}~~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 ≤ ~~42.3, E_{ann} ≤ 7.08~~49.8, AEC_{MAX} ≤ 6.46 × AV + ~~337.6~~ 315.4 AV > ~~42.3, E_{ann}~~49.8, AEC_{MAX} ≤ 637
5I~~-~~BI. Built-In Refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker without through-the-door ice service	8.46 × AV + 387.2	AV ≤ ~~42.3, E_{ann} ≤ 7.08~~49.8, AEC_{MAX} ≤ 6.46 × AV + ~~337.6~~ 315.4 AV > ~~42.3, E_{ann}~~49.8, AEC_{MAX} ≤ 637
5A. Refrigerator-freezer—automatic defrost with bottom-mounted freezer with through-the-door ice service	8.33 × AV + 436.3	AV ≤ ~~32.4, E_{ann} ≤ 7.40~~39.6, AEC_{MAX} ≤ 6.75 × AV + ~~397.1~~ 369.7 AV > ~~28.0, E_{ann}~~39.6, AEC_{MAX} ≤ 637
5A~~-~~BI. Built-in refrigerator-freezer—automatic defrost with bottom-mounted freezer with through-the-door ice service	8.85 × AV + 458.3	AV ≤ ~~32.4, E_{ann} ≤ 7.40~~39.6, AEC_{MAX} ≤ 6.75 × AV + ~~397.1~~ 369.7 AV > ~~28.0, E_{ann}~~39.6, AEC_{MAX} ≤ 637
6. Refrigerator-freezers—automatic defrost with top-mounted freezer with through-the-door ice service	~~E_{ann} ≤637 kWh/yr~~7.56 × AV + 355.3	
7. Refrigerator-freezers—automatic defrost with side-mounted	7.69 × AV + 397.9	AV ≤ ~~40.1, E_{ann}~~47.9, AEC_{MAX} ≤ 6.~~83~~23 × AV + ~~363.0~~

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Refrigerator Category	ENERGY STAR Maximum Energy Usage in kWh/yr	ENERGY STAR Most Efficient Maximum ~~Annual~~ Energy Usage in kWh/yr
freezer with through-the-door ice service.		338.6 AV > ~~35.3, E_{ann}~~47.9, AEC_{MAX} ≤ 637
7—BI. Built-In Refrigerator-freezers—automatic defrost with side-mounted freezer with through-the-door ice service.	9.23 × AV + 460.7	AV ≤ ~~40.1, E_{ann}~~47.9, AEC_{MAX} ≤ 6.~~83~~23 × AV + ~~363.0~~ 338.6 AV > ~~35.3, E_{ann}~~47.9, AEC_{MAX} ≤ 637
11. Compact refrigerator-freezers and refrigerators other than all-refrigerators with manual defrost	8.13 × AV + 227.1	AEC_{MAX} ≤ 6.32 × AV + 176.6
11A.Compact all-refrigerators—manual defrost	7.06 × AV + 197.2	AEC_{MAX} ≤ 5.49 × AV + 153.4
12. Compact refrigerator-freezers—partial automatic defrost	5.32 × AV + 302.2	AEC_{MAX} ≤ 4.14 × AV + 235.1
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	6.14 × AV + 495.2	AEC_{MAX} ≤ 4.77 × AV + 403.8

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Refrigerator Category	ENERGY STAR Maximum Energy Usage in kWh/yr	ENERGY STAR Most Efficient Maximum Annual Energy Usage in kWh/yr
freezer with an automatic icemaker		
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

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Default Savings

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 Most Efficient Refrigerators Source 4 Refrigerators

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Refrigerator Category	Assumed Adjusted Volume of Unit (ft³) Source 7	Conventional Unit Energy Usage in kWh/yr[54]	ENERGY STAR Most Efficient Consumption in kWh/yr Source 4	ΔkWh	ΔkW_{peak}
1. Refrigerator-freezers and refrigerators other than all-refrigerators with manual defrost.	15.1	296	277	20	0.0032
2. Refrigerator-freezers—partial automatic defrost	15.1	346	277	69	0.0112
3I. Refrigerator-freezers—automatic defrost with top-mounted freezer with an automatic icemaker without through-the-door ice service.	22.2	497	397	99	0.0160
4I. Refrigerator-freezers—automatic defrost with side-mounted freezer	28.1	621	514	107	0.0173

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

Refrigerator Category	Assumed Adjusted Volume of Unit (ft^3) Source 7	Conventional Unit Energy Usage in kWh/yr[54]	ENERGY STAR Most Efficient Consumption in kWh/yr Source 4	ΔkWh	ΔkW_{peak}
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.	31.5	766	630	137	0.0220
5I. Refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker without through-the-door ice service.	24.8	593	513	80	0.0129
7. Refrigerator-freezers—automatic defrost with side-mounted freezer with through-the-door ice service.	30.5	693	571	122	0.0197

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-mounted freezer with an automatic icemaker without through-the-door ice service.	18.6	9/15/14 - 1/30/29	160	0.0216548	0.0162171
		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.

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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

5) Average adjusted volume of ENERGY STAR-certified refrigerators by configuration. Accessed December 2023. 8760 hours. The temperature adjustment factor is 1.23 and is based on Blasnik, Michael, "Measurement and Verification of Residential Refrigerator Energy Use, Final Report, 2003-2004 Metering Study", July 29, 2004 (p. 47) and assuming 78% of refrigerators are in cooled space (based on BGE Energy Use Survey, Report of Findings, December 2005; Mathew Greenwald & Associates) and 22% in un-cooled space. The load shape adjustment factor is 1.15, based on the same report.

6) ENERGY STAR Appliances Calculator. Accessed July 2018. https://www.energystar.gov/sites/default/files/asset/document/appliance_calculator.xlsx

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Field Code Changed

2.4.2 ENERGY STAR Freezers

Target Sector	Residential Establishments
Measure Unit	Freezer
Measure Life	11 years Source 43
Vintage	Replace on Burnout
Vintage	Replace on Burnout

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Eligibility

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

Algorithms

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

If the volume and configuration of the freezer is known, the baseline model's annual energy consumption (kWh_{base}) may be are determined using Table 2-86Table 2-86. The efficient model's annual energy consumption (kWh_{ee}) may be determined using Table 2-72. The efficient model's annual energy consumption (kWh_{ee}) may be determined using manufacturer's test data for the given model. manufacturer's test data for the given model. Where test data is not available the algorithms in Table 2-73Table 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

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

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

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Definition of Terms

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

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 2-73~~Table 2-89	EDC Data Gathering, 2
~~ETDF~~ , $ETDF_s$, Summer Energy to Demand Factor	~~$\frac{kW}{kWh/yr}$~~ $\frac{kW}{kWh}$	0.~~00016140~~0001387	~~3~~6
$ETDF_w$, Winter Energy to Demand Factor	$\frac{kW}{kWh}$	0.0000998	6

Freezer energy use is characterized by configuration (upright, chest ~~or compact~~), volume, and whether defrost is manual or automatic. If this information is known, annual energy consumption of the federal minimum efficiency standard model may be determined using ~~Table 2-72~~Table 2-86. 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 2-73~~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 $\mathrm{AV} = 1.76 \times \text{Freezer Volume}$.

Table 2-87: Federal Standard ~~and ENERGY STAR Freezers~~ Maximum Annual Energy Consumption ~~if Configuration and Volume Known~~[55]

Freezer Category	~~Federal Standard Maximum Usage (kWh/yr)~~9/15/14 - 1/30/29	~~ENERGY STAR Maximum Energy Usage (kWh/yr)~~1/31/29 - 1/30/30	As of 1/31/30	
8. Upright freezers with manual defrost.	5.57 × AV + 193.7			~~5.01 × AV + 174.3~~
9. Upright freezers with automatic defrost without an automatic icemaker.	8.62 × AV + 228.3		(7.~~76~~33 × AV + ~~205.5~~194.1) × K9 + 28I	

[55] 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.

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Freezer Category	Federal Standard Maximum Usage (kWh/yr)9/15/14 - 1/30/29	ENERGY STAR Maximum Energy Usage (kWh/yr)1/31/29 - 1/30/30	As of 1/31/30
9I. Upright freezers with automatic defrost with an automatic icemaker.	8.62 × AV + 312.3	7.76 × AV + 289.5	
9-BI. Built-In Upright freezers with automatic defrost without an automatic icemaker.	9.86 × AV + 260.9	8.87(9.37 × AV + 234.8247.9) × K9BI + 28I	
9I-BI. Built-in upright freezers with automatic defrost with an automatic icemaker.	9.86 × AV + 344.9	8.87 × AV + 318.8	
9A-BI. NEW PRODUCT CLASS: Upright built-in freezer with auto defrost and through-door-ice		9.86 × AV + 288.9	
10. Chest freezers and all other freezers except compact freezers.	7.29 × AV + 107.8		6.56 × AV + 97.0
10A. Chest freezers with automatic defrost.	10.24 × AV + 148.1		9.22 × AV + 133.3
16. Compact upright freezers with manual defrost.	8.65 × AV + 225.7	7.7935 × AV + 203.1191.8	
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	8.337.86 × AV + 123.1107.8	

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

Default Savings

Table 2-88: Default Savings Values for ENERGY STAR Freezers: Door Coefficients for Federal Standard Energy Consumption Algorithms

Freezer Category	Average Unit Adj. Volume (ft³)	Conventional Usage Source 5 (kWh/yr)	ENERGY STAR Usage Source 5 (kWh/yr)	ΔkWh	ΔkW_{peak}
8. Upright freezers with manual defrost.	12.6	264	237	27	0.0043
Door Coefficient	Products with a Transparent Door	9. Upright freezers with automatic defrost without an automatic icemaker.Products without a Transparent Door with a Door-in-Door	24.7Products without a Transparent Door or Door-in-Door with Added External Doors	441 / 397 / 44	0.0071
10. Chest freezers and all other freezers except compact freezers.K9	18.51.0	2431.0	218 / 25 / 1 + 0.003902 x (N_d – 1)		
16. Compact upright freezers with manual defrost.K9BI	3.71.0	2571.0	231 / 26 / 1 + 0.004202 x (N_d – 1)		
17. Compact upright freezers with automatic defrost.	7.7	430	387	43	0.0070
18. Compact chest freezers.	8.9	219	197	22	0.0035

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

Freezer Category	ENERGY STAR Maximum Energy Usage in kWh/yr	ENERGY STAR Most Efficient Maximum Energy Usage in kWh/yr
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
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

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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

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3)2) Consistent with the conversion factors in the Mid-Atlantic, Illinois, and Wisconsin TRMs. Derived from: (Temperature Adjustment Factor × Load Shape Adjustment Factor)/8760 hours. The temperature adjustment factor is 1.23 and is based on Blasnik, Michael, "Measurement and Verification of Residential Refrigerator Energy Use, Final Report, 2003-2004 Metering Study", July 29, 2004 (p. 47) and assuming 78% of refrigerators are in cooled space (based on BGE Energy Use Survey, Report of Findings, December 2005; Mathew Greenwald & Associates) and 22% in un-cooled space. The load shape adjustment factor is 1.15, based on the same report. Weblink

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2.4.3 Refrigerator / Freezer Recycling with and without Replacement

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

Eligibility

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

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

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

This protocol applies to both residential and non-residential sectors, as refrigerator and freezer usage and energy usage are assumed to be independent of customer rate class.[56] The savings algorithms are based on regression analysis of metered data on kWh consumption from other Statesstates. The savings algorithms for this measure can be applied to refrigerator and freezer retirements or early replacements meeting the following criteria:

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

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

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

ALGORITHMS

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

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.

Unit Energy Consumption[Source 2]

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

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

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The kWh_{ee} of the efficient freezers may be determined using manufacturers' test data for the given model. If test data are not available, the algorithms in Table 2-73Table 2-83 and Table 2-89 may be used to determine the efficient unit'srefrigerator's or freezer's annual energy consumption.

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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.

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

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

Adjusted Volume (AV)

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

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

For all other categories:

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

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Part-Use Factor

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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 38, 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 43] 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 4.34 of the DOE, Uniform Methods Project protocol.[Source 32]

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.

ΔkW_{peak}

Peak Demand Savings

Use the below algorithms to calculate peak demand savings.

$\Delta kW_{summer\_peak} = \Delta kWh \times ETDF\ ETDF_s$

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

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%	~~4~~EDC Data Gathering, 3
~~*ETDF* ,~~$ETDF_s$, Summer Energy to Demand Factor	$\frac{kW}{kWh/yr}$	~~0.0001614~~Refrigerator = 0.0001354 Freezer = 0.0001387	~~5~~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
~~*AV*, Adjusted~~*V*, Total Volume~~/calculated as described above~~ of recycled unit	ft^3	EDC Data Gathering	EDC Data Gathering
$CONFIG_{single-door}$, Fraction of refrigerators with single-door configuration	%	EDC Data Gathering	EDC Data Gathering
$CONFIG_{side-by-side}$, Fraction of ~~refrigeraors~~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=~~8~~12% Freezer=~~45~~52%	~~9~~EDC Data Gathering, 7
CDD, Cooling degree days	*°F-day/year*	See ~~CDD~~CDD65 in Vol. 1, App. A	~~10~~8
HDD, Heating degree days	*°F-day/year*	See ~~HDD~~HDD65 in Vol. 1, App. A	~~10~~8
kWh_{ee} , Annual energy consumption of ENERGY STAR qualified unit	*kWh/yr*	EDC Data Gathering Refrigerator Default: See ~~Table 2-68 or Table 2-70 in~~Table 2-84 In Sec. ~~2.4.1~~2.4.1 ENERGY STAR Refrigerators Freezer Default: See ~~Table 2-73~~Table 2-90 in Sec. ~~2.4.2~~2.4.2 ENERGY STAR Freezers	~~7, 8~~EDC Data Gathering, 6

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

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

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MEASURE LIFE

The measure lives for refrigerators and freezers recycled without replacement are 5 years and 4 years, respectively, from the California DEER EUA table.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 1214 years (see the ENERGY STAR RefrigeratorsENERGY 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 65]

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 1214-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 RefrigeratorsENERGY 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 annual savings of 49 kWh for the remaining EUL.[57]

In the case of a non-low-income program there is an RUL of 45 years for the existing unit (1/3 * 12 = 414= 5) and a remaining EUL of the efficient unit of 89 years (2/3 * 12 = 814 = 9). The lifetime savings are equal to 2,7063,331 kWh (578 kWh/yr * 45 yrs + 49 kWh / yr * 89 yrs), resulting in an adjusted measure life of 56 years: 2,7063,331 kWh / 578 kWh/yr = 56 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

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

4,059056 kWh (578 kWh/yr * 6 yrs + 49 kWh / yr * 12 yrs), resulting in an adjusted measure life of 7 years: 4,059056 kWh / 578 kWh/yr = 7 years.

Averaging the two lifetime savings values results in an adjusted measure life of 6 years (3,383694 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

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1) US DOE Uniform Method Project, Savings Protocol for Refrigerator Retirement, April California Electronic Technical Reference Manual. "Refrigerator or Freezer, Residential". Accessed December 2023. Weblink

2) Keeling, J., Bruchs, D. (2017. https://www.nrel.gov/docs/fy17osti/68563.pdf

3)2)U.S. Department of Energy, Uniform Methods Project protocol titled "). "Chapter 7: Refrigerator Recycling Evaluation Protocol", prepared by Doug Bruchs and Josh Keeling of the Cadmus Group, September 2013. . The Uniform Methods Project: Methods for Determining Energy-Efficiency Savings for Specific Measures". Section 4.4. National Renewable Energy Laboratory. https://www.nrel.gov/docs/fy17osti/68563.pdfWeblink

4)3)Based on a Cadmus survey of 510 PPL participants in PY8.

5) Consistent with the conversion factors in the Mid-Atlantic, Illinois, and Wisconsin TRMs. Derived from: (Temperature Adjustment Factor × Load Shape Adjustment Factor)/8760 hours. The temperature adjustment factor is 1.23 and is based on Blasnik, Michael, "Measurement and Verification of Residential Refrigerator Energy Use, Final Report, 2003-2004 Metering Study", July 29, 2004 (p. 47) and assuming 78% of refrigerators are in cooled space (based on BGE Energy Use Survey, Report of Findings, December 2005; Mathew Greenwald & Associates) and 22% in un-cooled space. The load shape adjustment factor is 1.15, based on the same report.

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

6)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, Prepared for: San Diego Gas & Electric, July 31, 2006". Weblink

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7) U.S. EPA. (2014. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/43

8)6)). ENERGY STAR Program Requirements Product Specifications for Residential Refrigerators and FreezersConsumer Refrigeration Products, Version 5.0. Effective 9/15/2014.1.

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https://www.energystar.gov/ia/partners/product_specs/program_reqs/Refrigerators_and_Freezers_Program_Requirements_V5.0.pdf.Weblink

9)7) Statewide averageProportion of refrigerators and freezers calculated using data gathered for all housing types from 2023 Pennsylvania Act 129 2018 Residential Baseline Study, http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-Phase3_Res_Baseline_Study_Rpt021219.pdf..

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

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2.4.4 ENERGY STAR Clothes Washers

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 Establishments
Measure Unit	Clothes Washer
Measure Life	11 years Source 1 Without Replacement: Source 1 Refrigerator: 5 years Freezer: 4 years
Vintage	Replace on Burnout 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.

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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:

$$All\ Refrigerator^{58}\ AV = Total\ Volume = Fresh\ Volume + Freezer\ Volume$$

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

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

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]

[58] 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.

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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.

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

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Eligibility

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

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Algorithms

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

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

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

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

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

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

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

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

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

Definition of Terms

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

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

Definition of Terms

Table 2-93: Terms, Values, and References for ENERGY STAR Clothes WashersMini-Frig Recycling

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

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

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

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

Term	Unit	Values	Source
UEC, Unit Energy Consumption	*kWh/yr*	EDC Data Gathering Default in Table 2	Varies
Total Volume, Fresh plus Frozen Volume	*ft³*	EDC Data Gathering	
Fresh Volume, volume of refrigerator	*ft³*	EDC Data Gathering	
Frozen Volume, volume capable of maintaining 0°F	*ft³*	EDC Data Gathering	
AV, Adjusted Volume/calculated as described above	*ft³*	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: Federal Standards and ENERGY STAR Specifications for Clothes Washers[Source 2, 8]**: Product Class Descriptions and Default UEC**

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

Default Savings

Product Class[59]	Average UEC (kWh/yr)
11 - Compact refrigerator and Refrigerator-Freezer other than All-Refrigerator - manual defrost	288.3
11A - Compact all-refrigerator - manual defrost[60]	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

[59] 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.

[60] 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: Default Clothes Washer Savings: 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

Fuel Mix	Washer Type	$DkWh$	ΔkW_{peak}
Electric DHW/Electric Dryer	Top-Loading	129.2	0.0144
	Front-Loading	154.7	0.0172
Electric DHW/Gas Dryer	Top-Loading	35.8	0.0040
	Front-Loading	47.4	0.0053
Gas DHW/Electric Dryer	Top-Loading	114.0	0.0127
	Front-Loading	127.5	0.0142
Gas DHW/Gas Dryer	Top-Loading	20.6	0.0023
	Front-Loading	20.2	0.0022
Default (35% Electric DHW, 75% Electric Dryer)	Top-Loading	95.0	0.0106
	Front-Loading	109.1	0.0121

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

7)1).

8) U.S. Department of Energy. 10 CFR Parts 429 and 430. Energy Conservation Program: Energy Conservation Standards for Residential Clothes Washers. Direct Final Rule. https://www.ecfr.gov/cgi-bin/text-idx?SID=86e70cbc87e5af18caca2e5c205bd107&mc=true&node=se10.3.430_132&rgn=div8

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2.4.5 ENERGY STAR Clothes Dryers

Target Sector	Residential
Measure Unit	Clothes DryerCooler
Measure Life	1214 years[Source 41]
Vintage	Replace on Burnout
Vintage	Replace on Burnout

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

Eligibility

This protocol documents the energy savings attributed to purchasing an electric ENERGY STAR Dryer that meets or exceeds the CEF_{ee} requirement in Table 2-80 instead of a standard dryer. If a customer submits a rebate for a product that has applied for ENERGY STAR Certification but has not yet been certifiedEligibility

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

, the To determine resource savings, the per-unit estimates in the algorithms will be countedmultiplied 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 that product contingent upon its eventual certification as an the given model. Where test data is not available the algorithms in Table 2-98 for "ENERGY STAR measure. If at any point the product is rejected by maximum energy usage in kWh/year" may be used to determine the efficient energy consumption for a conservative savings estimate.

ENERGY STAR, the product is then ineligible for the program and savings will not be counted.[61] The target sector is residential. **Cooler**

Algorithms

[61] 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.

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The energy savings are obtained through the following formulas:

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

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

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

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

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

Definition of Terms

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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, ice-maker). If this information is known, annual energy consumption (kWh_{base}) of the "Federal Standard" may be determined using Table 2-98. The efficient model's annual energy consumption (kWh_{ee}) may be determined using manufacturer's test data for the given model. 81: Terms, Values, and References for ENERGY STAR Clothes Dryers

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

$Time_{base}$, Duration of baseline dryer drying cycle	Hours/ cycle	EDC Data Gathering Default = 1.0	Assumption
$Time_{ee}$, Duration of efficient dryer drying cycle	Hours/ cycle	EDC Data Gathering Default = 1.0	Assumption
CF, Coincidence Factor	*Proportion*	0.029	Based on CF assumption for Clothes Washers

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 ft³. 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: Combined Energy Factor for Federal Minimum Standard and ENERGY STAR DryersCoolers Maximum Annual Energy Consumption for Known Configuration and Volume[62]

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

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

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[62] 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

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Table 2-99: Default Energy Savings and Demand Reductions for ENERGY STAR Clothes Dryers

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

VALUES

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EVALUATION PROTOCOLS

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

SOURCES

1) Calculated using "Frequency of clothes washer use" and "Frequency of dryer use" data for the Mid-Atlantic region from ENERGY STAR Coolers[63] U.S. Department of Energy. 2015 Residential Energy Consumption Survey (2015). https://www.eia.gov/consumption/residential/data/2015/index.php?view=microdata

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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[64]	$\Delta kW_{summer\ peak}$	$\Delta kW_{winter\ peak}$
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

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EVALUATION PROTOCOLS

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1) For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. Energy Star. "Clothes Dryers Key Product Criteria." ENERGY STAR Specification for Clothes Dryers Version 1.0, Effective January 1, 2015. https://www.energystar.gov/products/appliances/clothes_dryers/key_product_criteria
2) Federal Code of Regulations 10 CFR 430. https://www.gpo.gov/fdsys/pkg/CFR-2017-title10-vol3/pdf/CFR-2017-title10-vol3-sec430-32.pdf

[63] 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.

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

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

2.4.6 Heat Pump Clothes Dryers

Target Sector	Residential Establishments
Measure Unit	Per Clothes Dryer
Measure Life	12 years Source 1
Vintage	Replace on Burnout, New Construction

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Heat pump clothes dryers are more energy-efficient than standard dryers. A conventional dryer heats air, passes it through the clothing drum, and exhausts the hot air. A heat pump dryer works by circulating hot air through the clothing drum, extracting moisture from the clothing that becomes condensation after passing over an evaporator coil, then reheating the air before it passes through the drum again. The heat pump dryer saves energy by recirculating the warm air, requiring less heat to reach the desired temperature, and because the process requires a lower air temperature overall to dry clothes.

Eligibility

This protocol documents the energy savings attributed to installing a heat pump clothes dryer that meets or exceeds the default CEF_{ee} requirements in Table 2-82. The target sector is residential.

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Algorithms

The following algorithms shall be used to calculate the annual energy savings and coincident peak demand savings for this measure:

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

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

Definition of Terms

Table 2-84: Terms, Values, and References for Heat Pump Clothes Dryers

Term	Unit	Values	Source
ΔkWh , Annual Energy Savings	kWh/yr	Table 2-83	-
ΔkW_{peak} , Peak Demand Savings	kW	Table 2-83	-
$Cycles_{wash}$, Number of washing machine cycles per year	cycles/yr	EDC Data Gathering Default = 251	2
$Load_{avg}$, Weight of average dryer load	lbs/cycle	Standard = 8.45 Compact = 3.00	3
$\%_{\frac{dry}{wash}}$, Percentage of washed loads that get dried	%	Default = 96%	2
CEF_{base} , Combined Energy Factor of baseline dryer, in lbs/kWh	lbs/kWh	EDC Data Gathering See CEF_{base} of Table 2-80 in Sec. 0	4

CEF_{ee} , Combined Energy Factor of heat pump dryer, in lbs/kWh	lbs/kWh	EDC Data Gathering Default: ≥4.4 ft³ (std) = 4.50 <4.4 ft³ (cmpct) = 4.71	5
$Time_{base}$, Duration of baseline dryer drying cycle	Hours/ cycle	EDC Data Gathering Default = 1.0	Assumption
$Time_{ee}$, Duration of efficient dryer drying cycle	Hours/ cycle	EDC Data Gathering Heat Pump = 1.2	6
CF , Coincidence Factor	None	EDC Data Gathering Default = 0.029	Based on CF assumption for Clothes Washers

Default Savings

Table 2-85: Default Savings for Heat Pump Clothes Dryers

Heat Pump Type	Energy Savings (kWh/yr)	Peak Demand Reduction (kW)
4.4 ft³ or greater capacity	93.4	0.0203
Less than 4.4 ft³ capacity, 120 V	46.8	0.0087
Less than 4.4 ft³ capacity, 240 V	67.6	0.0112

Evaluation Protocols

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

Sources

1) California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx
2) Calculated using "Frequency of clothes washer use" and "Frequency of dryer use" data for the Mid-Atlantic region from U.S. Department of Energy. 2015 Residential Energy Consumption Survey (2015). https://www.eia.gov/consumption/residential/data/2015/index.php?view=microdata
3) Energy Star. "Clothes Dryers Key Product Criteria. " ENERGY STAR Specification for Clothes Dryers Version 1.0, Effective January 1, 2015. https://www.energystar.gov/products/appliances/clothes_dryers/key_product_criteria
4) U.S. Code of Federal Regulations, Part 430, Subpart C, *Energy and Water Conservation Standards*. http://www.ecfr.gov/cgi-bin/text-idx?rgn=div8&node=10:3.0.1.4.18.3.9.2
5) ENERGY STAR, *Certified Clothes Dryers*. https://www.energystar.gov/productfinder/product/certified-clothes-dryers/results (Examined the "ventless" dryers and removed dryers that were condensing and not heat pump. Then took the average CEF of the two different capacity bins.)

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6) CLASP, SEDI and Ecova, Analysis of Potential Energy Savings from Heat Pump Clothes Dryers in North America, March 2013. http://www.ecosresearch.com/wp-content/uploads/2015/12/2013_Analysis-of-Potential-Energy-Savings-from-Heat-Pump-Clothes-Dryers-in-North-America.pdf

2.4.7 Fuel Switching: Electric Clothes Dryer to Gas Clothes Dryer

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

2.4.6 Cooler Recycling with and without Replacement

Target Sector	Residential Establishments
Measure UnitLife	Fuel Switch: Electric Clothes Dryer to Gas Clothes Dryer**Without Replacement:** Source 1 5 years **With Replacement:** 9 years
Measure LifeVintage	12 years Source 1 Early Retirement, Early Replacement

Eligibility

Vintage	Replace on Burnout

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 outlinesis 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 associated to purchasing an 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.[65]

This measure may be combined with ENERGY STAR gas clothes dryer to replace an electric dryer. The measure characterization and Coolers if the cooler is replaced with qualifying equipment.

Algorithms

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

Energy Savings

[65] 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.

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

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

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 ($\eta \times kWh_{recycled}$).[66] 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 usage per person and 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 number of people per household. Therefore, this is a deemed measure with identical savings applied to all installation instances, applicable across all housing types. 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

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Eligibility

This measure is targeted to residential customers that purchase an ENERGY STAR gas clothes dryer rather than an electric dryer.

Algorithms

$DkWh = kWh_{base} - kWh_{gas} = 577 - 30 = 547$

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

$$DMMBtu = -1.99$$

$$DkW_{peak} = \frac{\Delta kWh}{Cycles_{wash} \times \%_{\frac{wash}{dry}} \times Time_{cycle}} \times CF = 0.066$$

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 2-100: Terms, Values, and References for Fuel Switching: Electric Clothes Dryer to Gas Clothes DryerRefrigerator 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, ice-maker). Annual energy consumption may be

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Table 2-101: Pre-2019 California Title 20 Maximum Annual Energy Consumption[67]

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

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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.

[67] 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.

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 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

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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

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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.

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

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

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

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

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Definition of Terms

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

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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 kWh_{base}, Baseline annual electricity consumption of electric dryer, deemed	$\frac{kWh}{yr}$	577	2, 3
kWh_{gas}, Annual electricity consumption of gas dryer, deemed	$\frac{kWh}{yr}$	30	4
$DMMBtu$, Weighted average gas fuel savings (negative indicates increase in consumption)	MMBTU	-1.99	5
$Cycles_{wash}$, Number of washing machine cycles per year	cycles/yr	251	6
$\%_{\frac{dry}{wash}}$, Percentage of homes with a dryer that use the dryer every time clothes are washed	%	96%	6
$Time_{cycle}$, Duration of average drying cycle in hours	hours	1	Assumption
CF, Coincidence Factor	Proportion	0.029	Based on CF assumption for Clothes Washers

Default Savings

Savings Estimates

Default savings for this measure are fully deemed and may be claimed using the algorithms above and the deemed variable inputsbased on the default energy consumption and efficiencies for the efficient induction and baseline electric resistance measure.

$$\Delta kWh_{default} = (AEC_{base,default} - AEC_{ee,default}) \times \%_{elec}$$
$$= (209 - 189) \times 61\%$$
$$= 12.2 \; \Delta kWh = 547 \; kWh/yr$$

ΔkW = 0.066

Evaluation Protocols

The appropriate evaluation protocol is to verify installation and proper selection of deemed values.

Sources

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

$= 189 \times \left(\frac{85}{77}\right)$
$= 209\ kWh/yr$

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

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

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

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Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. CaliforniaFor 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

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

2)18) . (2024, March). 2023 Pennsylvania Statewide average for all housing types from Pennsylvania Act 129 2018Act 129 Residential Baseline Study, 2018,[68] http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-Phase3_Res_Baseline_Study_Rpt021219.pdf.. Page 145, Table 130. Weblink

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[68] Statewide average of 3.12 EF for electric dryers, comparable to 3.77 CEF; q.v. the federal standard of 3.73 CEF at Table 73 in the ENERGY STAR Clothes Dryers section.

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2.4.8 ENERGY STAR Clothes Washers

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

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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.

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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[69]	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

[69] 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

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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

3) 2011-04 Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment. Residential Clothes Dryers and Room Air Conditioners, Chapter 7. Table 7.3.4: Electric Standard and Gas Clothes Dryer: Average Annual Energy Consumption Levels by Efficiency https://www.regulations.gov/document?D=EERE-2007-BT-STD-0010-0053 [70]

4) *Ibid.* Median annual electricity consumption of gas dryers

5) Negative gas fuel savings indicate increase in fuel consumption. Average annual consumption for ENERGY STAR qualified gas units as of 6/22/2015: 685.3kWh/yr. Scaling from 283 cycles/yr (national 2005 RECS) to 251×96%=241 cycles/yr (Mid-Atlantic 2015 RECS): 583.5 kWh/yr. Converting to MMBTU: 583.5×0.003412 = 1.99 MMBTU/yr.

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

[70] Average annual electricity consumption of 3.73 and 3.81 CEF dryers scaled from 283 cycles/yr (national 2005 RECS) to 251×96%=241 cycles/yr (Mid-Atlantic 2015 RECS).

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 the Mid-Atlantic regionPennsylvania from U.S. Department of Energy. 2015, 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.

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Eligibility

This protocol documents the energy savings attributed to purchasing an electric dryer that meets ENERGY STAR criteria. Different default 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:

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

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

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

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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

6)1) U.S. EPA. (2015). https://www.eia.gov/consumption/residential/data/2015/index.php?view=microdataENERGY STAR Program Requirements Product Specification for Clothes Dryers Version 1.1. Weblink

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3) Energy Efficiency and Renewable Energy Office (2021). National Impact Preliminary Analysis Spreadsheets. U.S DOE. Weblink

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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

2.4.82.4.10 ENERGY STAR Dishwashers

Target Sector	Residential Establishments
Target Sector	Residential
Measure Unit	Dishwasher
Measure Life	10 years Source 1
Vintage	Replace on Burnout

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Eligibility

Vintage	Replace on Burnout

Eligibility

This measure is for the purchase and installation of aan ENERGY STAR dishwasher meeting ENERGY STAR eligibility criteria.. ENERGY STAR dishwashers use less energy and hot water than non-qualified models.

Algorithms

The general form of the measure savings equation for ENERGY STAR Dishwashers is:

Total Savings $= Number\ of\ Dishwashers \times Savings\ per\ Dishwasher$

To determine resource savings, the per-unit estimates in the algorithms will be multiplied by the number of dishwashers. The number of dishwashers will be determined using market assessments and market tracking. EDC data gathering is permitted for 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:

$$\Delta kWh = (kWh_{base} - kWh_{ee}) \times (\%kWh_{OP} + \%kWh_{heat} \times \%Electric_{DHW})(\%kWh_{OP} + \%kWh_{heat} \times \%Elec_{DHW})$$

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

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

Definition of Terms

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

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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, 63
kWh_{ee}, Annual energy consumption of ENERGY STAR qualified unit	kWh/yr	270EDC data gathering Defaults: Standard: 240 Compact :155	1, 7EDC data gathering, 4
$\%kWh_{op}$, Percentage of unit dishwasher energy consumption used for operation	%	44%	1
$\%kWh_{heat}$, Percentage of dishwasher unit energy consumption used for water heating	%	56%	1
$\%Electric_{DW}Elec_{DHW}$, Percentage of dishwashers assumed to utilize electrically heated hot water heaters that are electric	%	EDC Data Gathering Default = 31.747%	2EDC data gathering, 3
HOU , Hours of use per year$ETDF_S$, Summer energy to Demand Factor	hours/yr$\frac{kW}{kWh}$	2340.0001699	35
CF, Demand Coincidence Factor. The coincidence of average dishwasher demand to summer system peak$ETDF_W$, Winter energy to Demand Factor	Proportion$\frac{kW}{kWh}$	0.0260002640	4, 5

ENERGY STAR qualified dishwashers must use less than or equal to the water and energy consumption values given in Table 2-86. Note, as of May 30, 2013, ENERGY STAR compact dishwashers have the same maximum water and energy consumption requirements as the federal standard and therefore are not included in the TRM since there is not energy savings to be calculated for installation of an ENERGY STAR compact dishwasher. 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. Source 6 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 67.0 Residential Dishwasher Standard

Product Type	Federal Standard Source 62		ENERGY STAR v 67.0 Source 74	
	Water (gallons per cycle)	Energy (kWh per year)	Water (gallons per cycle)	Energy (kWh per year)
Standard	≤ 5.0	≤ 307	≤ 3.52	≤ 270240
Compact	≤ 3.5	≤ 222	≤ 2.0	≤ 155

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The default savings- values for electric and non-electric water heating and the default fuel mix from Table 2-87. 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	$\Delta kWh/yr$	ΔkW_{peak} $\Delta kW_{summer\ peak}$	$\Delta kW_{winter\ peak}$
Electric (%Electric$_{DHW}$ = 100%)	3767.0	0.0041401138	0.01769
Non-Electric (%Electric$_{DHW}$ = 0%)	16.329.5	0.0018100501	0.00778
Default Fuel Mix (%Electric$_{DHW}$ = 4347%)	22.847.1	0.0025400800	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

Evaluation Protocols

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

Sources

1) ENERGY STAR Appliances Calculator. Accessed July 2018. Energy Star Calculator, EPA research on available models. Accessed August 2018. https://www.energystar.gov/sites/default/files/asset/document/appliance_calculator.xlsx

1) Statewide average for all housing types from ENERGY STAR (2016). Savings Calculator for ENERGY STAR Qualified Appliances. U.S. EPA. Weblink

2) 10 CFR 430.32(f) Weblink

2)3) NMR Group for the Pennsylvania StatewidePublic Utility Commission. (2024, March). 2023 Pennsylvania Statewide Act 129 Residential Baseline Study, 2018.. 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

https://www.energystar.gov/products/appliances/dishwashers/key_product_criteria

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3) 2014 Pennsylvania Residential Baseline Study, http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-2014_PA_Statewide_Act129_Residential_Baseline_Study.pdf. HOU=(3 loads/week)×(52 weeks/yr)×(1.5 hours/load). 3 load/week comes from 2014 Baseline study. 1.5 hours/load is assumption used by Efficiency Vermont and Illinois Statewide TRMs

4) Calculated from Itron eShapes, 8760 hourly data by end use for Missouri, as provided by Ameren. This is the CF value for ENERGY STAR Dishwashers from Illinois Statewide TRM Version 7.0, June 2018.

5) Illinois Statewide Technical reference Manual for Energy Efficiency Version 7.0. Effective January 1, 2019. http://www.ilsag.info/technical-reference-manual.html

6) US Department of ENERGY Website. Appliance and Equipment Standards. Accessed Aug. 2018. https://www.ecfr.gov/cgi-bin/text-idx?SID=86e70cbc87e5af18caca2e5c205bd107&mc=true&node=se10.3.430_132&rgn=div8

7) Dishwashers Key product Criteria. Accessed Aug. 2018. https://www.energystar.gov/products/appliances/dishwashers/key_product_criteria

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2.4.92.4.11 ENERGY STAR DEHUMIDIFIERS

Target Sector	Residential Establishments
Target Sector	Residential
Measure Unit	Dehumidifier
Measure Life	12 years[Source 1]
Vintage	Replace on Burnout

Vintage	Replace on Burnout

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ENERGY STAR qualified dehumidifiers are 15 percent13% more efficient than non-qualified models due to more efficient refrigeration coils, compressors and fans.[Source 2] ENERGY STAR Most Efficient portable dehumidifiers are 23 percentover 20% more efficient than standard productsfederal minimum standards.[Source 67]

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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.

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 45.0 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:

$$\Delta kWh = \left(\frac{CAPY \times 0.473 \frac{liters}{pint}}{24 \frac{hours}{day}}\right)\left(\frac{CAPY \times 0.473 \frac{liters}{pint}}{24 \frac{hours}{day}}\right) \times HOU$$

$$\times \left(\frac{1}{L/kWh_{base}} - \frac{1}{L/kWh_{ee}}\right)\left(\frac{1}{IEF_{base}} - \frac{1}{IEF_{ee}}\right)$$

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

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

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	$\frac{hours}{yr}$	~~1,632~~2,160	1
~~L/kWh_{base}~~ IEF_{base}, Baseline unit liters of ~~water~~condensate per kWh consumed	$\frac{liters}{kWh}$	~~Table 2-89~~Table 2-115	~~2~~4
~~L/kWh_{ee}~~ IEF_{ee}, ENERGY STAR qualified unit liters of ~~water~~condensate per kWh consumed	$\frac{liters}{kWh}$	EDC Data Gathering ~~Default: Table 2-90 or Table 2-91~~Default: Table 2-115	EDC data gathering, 3, ~~5~~6
CF , ~~*Demand Coincidence Factor*~~Summer demand coincidence factor	*Proportion*	0.405	~~4~~5

~~Table 2-89~~

Table 2-115 shows the federal standard minimum efficiency standards. Federal standards are effective as of June 13, 2019. ~~Table 2-90~~Table 2-116 shows ENERGY STAR ~~4~~5.0 standards effective as of October ~~25, 2016~~31, 2019. ~~Table 2-91~~Table 2-117 shows ENERGY STAR Most Efficient ~~2018~~2024 criteria, effective January ~~2018.~~2024.Source 6 Federal standards and ENERGY STAR Most ~~Effiecient~~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 ~~Minimum Federal~~ Efficiency Standards

Type	Capacity (pints/day)	Federal Standard (~~L/kWh_{base}~~)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 (~~L/kWh_{base}~~)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 ENERGY STAR StandardsDefault Energy Savings

	Product[a]	Capacity Range (pints/day or ft³)	Default Capacity Capacity (pints/day)	Federal Standard ENERGY STAR (L/kWh_e)(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
< 75	Whole house	≤8 ft³	84[b]	1.77	≥ 2.0009	309	0.0351	0.0453
ENERGY STAR Most Efficient	Portable	≤ 25 pints/day	25	1.30	1.75	211	0.0239	0.0308
	Portable	75> 25 to ≤ 18550 pints/day	50	1.60	≥ 2.8001	271	0.0308	0.0397
	Whole house	≤8 ft³	84[b]	1.77	2.22	410	0.0465	0.0599

Table 2-93: Dehumidifier ENERGY STAR Most Efficient Criteria

Type	Capacity (pints/day)	ENERGY STAR (L/kWh_e)
Portable	< 75	≥ 2.20
Whole House	< 75	≥ 2.30

[a] There are no default values for portable humidifiers >50 pints/day or whole house dehumidifiers >8ft³ because there were no ENERGY STAR qualified dehumidifiers with these capacities as of August 15, 2023.

[b] Default Savings

The annual energy usage and savings of an ENERGY STAR unit over the federal minimum standard are presented in Table 2-92 for each capacity rangeis 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.

Table 2-94: Dehumidifier Default Energy Savings

Efficient Product[71]	Capacity Range (pints/day)	Default Capacity (pints/day)	Federal Standard (kWh/yr)	Efficient Standard (kWh/yr)	ΔkWh/yr	ΔkW_{peak}
ENERGY STAR	≤ 25	25	1.3	2.0	216	0.05372
	> 25 to ≤ 50	50	1.6	2.0	201	0.04989
ENERGY STAR Most Efficient - Portable	≤ 25	25	1.3	2.2	253	0.06279
	> 25 to ≤ 50	50	1.6	2.2	274	0.06803

[71] As of November 16, 2018, Federal standards equal or exceed ENERGY STAR standards for portable dehumidifiers with capacity of >50 pints/day and for whole home dehumidifiers with product case volume > 8 ft³.

Efficient Product[71]	Capacity Range (pints/day)	Default Capacity (pints/day)	Federal Standard (kWh/yr)	Efficient Standard (kWh/yr)	ΔkWh/yr	ΔkW_{peak}
ENERGY STAR Most Efficient – Whole House with product case volume ≤ 8 ft³	≤ 75	63[72]	1.77	2.3	264	0.06547

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Evaluation Protocols

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

Sources

1) ENERGY STAR Appliance Savings Calculator. Accessedd August, 2018. https://www.energystar.gov/sites/default/files/asset/document/appliance_calculator.xlsx
2) US Department of ENERGY Website. Appliance and Equipment Standards. Accessed June 2014. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/55
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2) U.S. EPA. (2019). ENERGY STAR Dehumidifiers Version 5.0 Cover letter. Weblink
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4) 10 CFR 430.32(v) Weblink
4)5) Dehumidifier Metering in PA and Ohio by ADM from 7/17/2013 to 9/22/2013. 31 Units 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.
5) ENERGY STAR Most Efficient 2018 Recognition Criteria: Dehumidifiers. Accessed November 2, 2018. https://www.energystar.gov/ia/partners/downloads/most_efficient/2018/Dehumidifiers%20ENERGY%20STAR%20Most%20Efficient%202018%20Final%20Criteria.pdf?cddb-3642
6) ENERGY STAR Most Efficient 2019 memo. Accessed November 2, 2018. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Most%20Efficient%202019%20Memo_0.pdf
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7) U.S. EPA. (2023). ENERGY STAR Most Efficient 2024 Final Criteria Recognition Letter. Weblink

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[72] Average of products listed on ENERGY STAR Most Efficient 2018 – Dehumidifiers. https://www.energystar.gov/most-efficient/me-certified-dehumidifiers/ Accessed November 16, 2018.

2.4.102.4.12 Dehumidifier Retirement

Target Sector	Residential Establishments
Measure Unit	Dehumidifier
Measure Life	4 years[73]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} $= DB - 0.55 \times (1 - RH) \times (DB - 58)$ for DB ≥ 58°F
$= DB$ for DB < 58°F

Similarly, summer peak demand was modeled with the following capacity-dependent linear regression:Source 2

$$kW \quad \Delta kW_{summer\ peak} = 1.3 \cdot 10^{-3} \times CAPY + 1.07 \cdot 10^{-1}$$

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

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[73] CA DEER gives the following rule-of-thumb for remaining useful life: RUL = (1/3) X EUL. As the Energy Star Dehumidifier [replacement] uses an EUL of 12 years, we have a suggested RUL of (1/3) X 12 years = 4 years.

Definition of Terms

Table 2-117: 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

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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

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Table 2-121: Default Dehumidifier Retirement Summer Peak Demand Reduction (kW)

Capacity	Default
~~kW~~ $\Delta kW_{summer\ peak}$	0.1731

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Evaluation Protocols

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

Sources

1) Dehumidifier Metering in PA and Ohio by ADM from 7/17/2013 to 9/22/2013. 31 Units metered; five-minute interval power data was recorded. 58% of the units were Energy Star rated.
2) Ibid., by Act 129 Peak Demand window
3) ~~Statewide average~~NMR Group for ~~all housing types from~~the Pennsylvania Public Utility Commission. (2024, March). 2023 Pennsylvania Statewide Act 129 ~~2018~~ Residential Baseline Study~~, 2018, http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-Phase3_Res_Baseline_Study_Rpt021219.pdf.~~ . Page 164, Table 156. Weblink
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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

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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.

2.4.11 2.4.13 ENERGY STAR CEILING FANS

Target Sector	Residential Establishments
Measure Unit	Ceiling Fan Unit
Measure Life	1510 years for fan,Source 1 See 2.1.1 for lighting
Vintage	Replace on Burnout
Vintage	Replace on Burnout

ENERGY STAR ceiling fans require a more efficient CFM/Watt rating than standard ceiling fans as well as ENERGY STAR qualified lighting for those with light kits included. Both of these features save energy compared to standard ceiling fans..

ELIGIBILITY

ELIGIBILITY

This protocol documents the energy savings attributed to installing an ENERGY STAR Version 4.0 ceiling fan (with or without a lighting kit) Source 2 in lieu of a standard efficiency ceiling fan meeting the January 21, 2020 federal efficiency requirements.Source 2 If a customer submits a rebate for a product that has applied for ENERGY STAR Certification but has not yet been certified, the savings will be counted for that product contingent upon its eventual certification as an ENERGY STAR measure. If at any point the product is rejected by ENERGY STAR, the product is then ineligible for the program and savings will not be counted.[74] The target sector primarily consists of single-family residences.[3]

ALGORITHMS

The total energy savings is equal to the savings contribution of the fan plus the savings contribution of the lighting, if applicable. If the ENERGY STAR fan does not include a lighting kit, then $DkWh_{lighting} = 0$.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 vs.versus a lower AC setting.

The energy savings are obtained through the following formula:

$$DkWh = DkWh_{fan} + DkWh_{lighting}$$

$$DkWh_{fan} = DW_{fan}\Delta kWh = \Delta W_{fan} \times \frac{1\ kW}{1{,}000\ W}\frac{1}{1{,}000} \times HOU_{fan} \times 365\frac{days}{yr}$$

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

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

[74] 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.

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Definition of Terms

$DkWh_{lighting} = DkWh$ from the *ENERGY STAR Lighting* section

Demand savings result from the lower connected load of the ENERGY STAR fan and ENERGY STAR lighting. Peak demand savings are estimated using a Coincidence Factor (CF).

$$\Delta kW_{peak,total} = \Delta kW_{peak,fan} + \Delta kW_{peak,lighting}$$

$$DkW_{peak,fan} = DW_{fan} \times \frac{1\ kW}{1{,}000\ W} \times CF_{fan}$$

$\Delta kW_{peak,lighting} = \Delta kW_{peak}$ from the *ENERGY STAR Lighting* section

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Definition of Terms

Table 2-122: Terms, Values, and References for ENERGY STAR Ceiling Fans

Component	Unit	Values	Source
DW_{fan} ΔW_{fan}, Weighted average wattage reduction from ENERGY STAR ceiling fan	*Watts*	Default: See Table 2-99Table 2-123	2, 3, 5, 64
HOU_{fan}, fan daily hours of use	$\frac{hours}{day}$	EDC Data Gathering Default: 3.0 hours/day[75]	4EDC data gathering, 1
CF_{fan}, $ETDF_s$, Summer energy to Demand Coincidence Factor	$\frac{kW}{kWh}$ Proportion	EDC Data Gathering DefaultSF Only: 0.091[76]0001114	75
$CF_{lighting}$, $ETDF_w$, Winter energy to Demand Coincidence Factor	$\frac{kW}{kWh}$ Proportion	See Section 2.1SF Only: 0.0001788	75

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Table 2-123: Assumed Wattage of ENERGY STAR Ceiling Fans on High Setting

Ceiling Fan Type	Diameter, D (inches)	DW_{fan} 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[77]	36 < D < 78	33

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Default Savings

Table 2-124: Energy Savings and Peak Demand Reductions for ENERGY STAR Ceiling Fans

Product Type (Fan Only)	Diameter, D (inches)	Energy Savings (kWh) ΔkWh	Demand Reduction (kW) $\Delta kW_{summer\ peak}$	$\Delta kW_{winter\ peak}$
Standard and Low-Mount High Speed Small Diameter (HSSD) Ceiling Fans	D ≤ 36	0.0	0.0000000	0.0000
	36 < D < 78	25.2	0.0020028	0.0045
	D ≥ 78	3433.9	0.0020038	0.0061
Hugger Ceiling Fan	36 < D < 78	36.1	0.0030040	0.0065

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Evaluation Protocols

[75] The 3 hour/day for a ceiling fan is assumed here to be the same hours of use as a typical residential lightbulb, in absence of better data. EDCs are allowed to do research on hours of use for ceiling fans in lieu of using the 3 hours/day figure. It is likely that the hours of use for ceiling fans is different than that of residential lighting.

[76] Assumed same usage characteristics as lighting. EDCs are allowed to do research on Coincidence Factor for ceiling fans in lieu of using the 3 hours/day figure. It is likely that the hours of use for ceiling fans is different than that of residential lighting.

[77] The ENERGY STAR 4.01 specifications allow for hugger ceiling fans with blade spans of ≤ 36" and ≥ 78", however, as of December 2018November 2023, there are no ENERGY STAR qualified products meeting those criteria. They were therefore omitted from this characterization.

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

Sources

1) Residential and C&I Lighting and HVAC Report Prepared for SPWG, 2007. p. C-2.
2) Energy and water conservation standards and their compliance dates.10 C.F.R. § 430.32.
3) See ENERGY STAR Ceiling Fans Work Paper 2018.12.5.xlsx for calculations and description of methodology.
4) ENERGY STAR Lighting Fixture and Ceiling Fan Calculator. Updated September 2013.
1) ENERGY STAR (2013). Savings Calculator for ENERGY STAR Qualified Light Fixtures & Ceiling Fans U.S. EPA. Weblink
5)2) U.S. EPA. (2018). ENERGY STAR® Program Requirements Product Specification for Residential Ceiling Fans and Ceiling Fan Light Kits Eligibility Criteria Version 4.01. Weblink
3) 10 CFR 430.32(s) Weblink
6)4) SWE analysis of ENERGY STAR - Certified Ceiling Fans | EPA ENERGY STAR. https://www.energystar.gov/productfinder/product/certified-ceiling-fans/results.. Accessed 12/5/2018.18. Weblink
7) EmPOWER Maryland 2012 Final Evaluation Report: Residential Lighting Program, Prepared by Navigant Consulting and the Cadmus Group, Inc., March 2013, Table 50.
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

2.4.122.4.14 ENERGY STAR Air Purifiers

Target Sector	Residential Establishments
Measure Unit	Number of Air Purifiers installedPurifier
Measure Life	9 years Source 1
Vintage	Replace on Burnout, Early Replacement, Retrofit, New Construction

An air purifier (cleaner) is a portable electric appliance that removes dust and fine particles from indoor air. This measure characterizes the purchase and installation of a unit meeting the efficiency specifications of ENERGY STAR in place of or instead of a baseline modelan ENERGY STAR unit that is more energy-efficient than a non-ENERGY STAR unit.

Eligibility

Eligibility

This measure targets residential customers who purchase and install an air purifier that meets ENERGY STAR specifications rather than installing a non-ENERGY STAR unit. In order to qualify, installed air purifiers must meet the following efficiency specifications ofbe ENERGY STAR:

- Must produce a certified and exceed federal minimum 50 ft³/min Clean Air Delivery Rate (CADR) for Dust to be considered under this specificationintegrated energy factor (IEF) standards.
  - Minimum Performance Requirement: 2.0 CADR/Watt (Dust)
  - Standby Power Requirement: 2.0 Watts or less. Qualifying models that perform secondary consumer functions (e.g. clock, remote control) must meet the standby power requirement.
- UL Safety Requirement: Models that emit ozone as a byproduct of air cleaning must meet UL Standard 867 (ozone production must not exceed 50ppb)[78]

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

$$DkWh = kWh_{Base} - kWh_{Estar}$$

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

Definition of Terms

[78] ENERGY STAR certification is sufficient to establish that an air purifier meets this requirement. No additional UL safety listing certification is required.

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Table 2-125: Terms, Values, and References for ENERGY STAR Air Purifier

Term	Unit	Values	Source
kWh_{Base}, Baseline kWh consumption per year	kWh/year	EDC Data Gathering Default = See Table 2-102	1
kWh_{EStar}, ENERGY STAR kWh consumption per year	kWh/year	EDC Data Gathering Default = See Table 2-102	1
HOURS, Average hours of use per year	Hours/year	EDC Data Gathering Default = 5,840	1
CF, Summer Peak Coincidence Factor	None	EDC Data Gathering Default = 0.67	1, 2

Default Savings

Table 2-104: Energy Savings Calculation Default Values

Clean Air Delivery Rate (CADR) (ft^3/min)	CADR Used in Calculation	Baseline Unit Energy Consumption (kWh/yr)	ENERGY STAR Unit Energy Consumption (kWh/yr)	ΔkWh
CADR 51-100	75	441	148	293
CADR 101-150	125	733	245	488
CADR 151-200	175	1,025	342	683
CADR 201-250	225	1,317	440	877
CADR Over 250	275	1,609	537	1,072

$CADR$, 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

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$POHours$, 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: Demand Savings Calculation Default Values: Air Purifier Federal Efficiency Standards

Clean Air Delivery Rate (CADR) (ft³/min)	CADR Used in Calculation	ΔkW_{peak}
CADR 51-100	75	0.0336
CADR 101-150	125	0.0560
CADR 151-200	175	0.0784
CADR 201-250	225	0.1006
CADR Over 250	275	0.1230

Evaluation Protocols

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

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Sources

1) ENERGY STAR, ENERGY STAR Appliance Calculator, last updated October 2016. https://www.energystar.gov/sites/default/files/asset/document/appliance_calculator.xlsx

2) Assumes appliance use is equally likely at any hour of the day or night.

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 ENERGY STAR OFFICE EQUIPMENT

Target Sector	Residential Establishments
Measure Unit	Office Equipment Device
Measure Life Source 1	Computer: 4 years Monitor: 4 years Fax: 4 years Printer: 5 years Copier: 6 years Multifunction Device: 6 years
Vintage	Replace on Burnout

ELIGIBILITY

This protocol estimates savings for installing ENERGY STAR office equipment compared to standard efficiency equipment in residential applications. The measurement of energy and demand savings is based on a deemed savings value multiplied by the quantity of the measure. The target sector is primarily residential.

ALGORITHMS

The general form of the equation for the ENERGY STAR Office Equipment measure annual savings is:

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

To determine resource savings, the per-unit estimates in the algorithms will be multiplied by the number of units. Per unit savings are primarily derived from the ENERGY STAR calculator for office equipment.

ENERGY STAR Computer

$$\Delta kWh = ESav_{COM}$$
$$\Delta kW_{peak} = DSav_{COM}$$

ENERGY STAR Fax Machine

$$\Delta kWh = ESav_{FAX}$$
$$\Delta kW_{peak} = DSav_{FAX}$$

ENERGY STAR Copier

$$\Delta kWh = ESav_{COP}$$
$$\Delta kW_{peak} = DSav_{COP}$$

ENERGY STAR Printer

$$\Delta kWh = ESav_{PRI}$$
$$\Delta kW_{peak} = DSav_{PRI}$$

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ENERGY STAR Multifunction Device

$\Delta kWh = ESav_{MUL}$

$\Delta kW_{peak} = DSav_{MUL}$

ENERGY STAR Monitor

$\Delta kWh = ESav_{MON}$

$\Delta kW_{peak} = DSav_{MON}$

Definition of Terms

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Table 2-106: Terms, Values, and References for ENERGY STAR Office Equipment

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Term	Unit	Value	Sources
$ESav_{COM}$, Electricity savings per purchased ENERGY STAR computer. $ESav_{FAX}$, Electricity savings per purchased ENERGY STAR Fax Machine $ESav_{COP}$, Electricity savings per purchased ENERGY STAR Copier $ESav_{PRI}$, Electricity savings per purchased ENERGY STAR Printer $ESav_{MUL}$, Electricity savings per purchased ENERGY STAR Multifunction Device $ESav_{MON}$, Electricity savings per purchased ENERGY STAR Monitor	*kWh/yr*	See Table 2-105	1
$DSav_{COM}$, Summer demand savings per purchased ENERGY STAR computer. $DSav_{FAX}$, Summer demand savings per purchased ENERGY STAR Fax Machine $DSav_{COP}$, Summer demand savings per purchased ENERGY STAR Copier $DSav_{PRI}$, Summer demand savings per purchased ENERGY STAR Printer $DSav_{MUL}$, Summer demand savings per purchased ENERGY STAR Multifunction Device $DSav_{MON}$, Monitor	*kW/yr*	See Table 2-105	1

Default Savings

Table 2-107: ENERGY STAR Office Equipment Energy and Demand Savings Values

Measure		Energy Savings (ESav, kWh)	Demand Savings (DSav, kW)	Source
Computer (Desktop)		119	0.0161	1
Computer (Laptop)		22	0.0030	1
Fax Machine (laser)		16	0.0022	1
Copier (monochrome)	≤ 5images/min	37	0.0050	1
	5 < images/min ≤ 15	26	0.0035	
	15 < images/min ≤ 20	10	0.0011	
	20 < images/min ≤ 30	42	0.0057	
	30 < images/min ≤ 40	50	0.0068	
	40 < images/min ≤ 65	181	0.0244	
	65 < images/min ≤ 82	372	0.0502	
	82 < images/min ≤ 90	469	0.0633	
	> 90 images/min	686	0.0926	
Printer (laser, monochrome)	≤ 5 images/min	37	0.0050	1
	5 < images/min ≤ 15	26	0.0035	
	15 < images/min ≤ 20	24	0.0031	
	20 < images/min ≤ 30	42	0.0057	
	30 < images/min ≤ 40	50	0.0068	
	40 < images/min ≤ 65	181	0.0244	
	65 < images/min ≤ 82	372	0.0502	
	82 < images/min ≤ 90	542	0.0732	
	> 90 images/min	686	0.0926	
Printer (Ink Jet)		6	0.0008	1
Multifunction Device (laser, monochrome)	≤ 5 images/min	57	0.0077	1
	5 < images/min ≤ 10	48	0.0065	
	10 < images/min ≤ 26	52	0.0070	
	26 < images/min ≤ 30	93	0.0126	
	30 < images/min ≤ 50	248	0.0335	
	50 < images/min ≤ 68	420	0.0567	
	68 < images/min ≤ 80	597	0.0806	
	> 80 images/min	764	0.1031	
Multifunction Device (Ink Jet)		6	0.0008	1
Monitor		24	0.0032	1

Evaluation Protocols

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

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Sources

1) **ENERGY STAR Office Equipment Calculator** http://www.energystar.gov/sites/default/files/asset/document/Office%20Equipment%20Calculator.xlsx (Referenced latest version released in October 2016). Default values were used. Using a commercial office equipment load shape, the percentage of total savings that occur during the PJM peak demand period was calculated and multiplied by the energy savings. As of December 1, 2018, the published ENERGY STAR Office Equipment Calculator does not reflect the current specification for computers (ENERGY STAR® Program Requirements Product Specification for Computers Eligibility Criteria Version 7.1). V7.1 introduced modest improvements to both desktop and laptop computer efficiency. As a result, the savings values for computers presented in this measure entry reflect savings for V6-compliant models. This characterization should be updated when an updated ENERGY STAR Office Equipment Calculator becomes available.

2.5.22.5.1 Advanced Power Strips

Target Sector	Residential Establishments
Target Sector	Residential
Measure Unit	Per Advanced Power Strip
Measure Life	5 years Source 4
Measure Life	5 years[1]
Vintage	Retrofit

Advanced Power Strips (APS) are surge protectors that contain a number of power-saver sockets. There are two types of APS: Tier 1 and Tier 2This 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 sense thatidentify the appliance plugged into the master socket has been turned off. Conversely, the appliance plugged into the master control socket has to be turned on and left on for the devices plugged into the power-saver sockets to function.

Tier 2 APS deliver additional functionality beyond that of a Tier 1 unit, as Tier 2 units manage both standby and active power consumption. The Tier 2 APS manage standby power consumption by turning off devices from a control event; this could be a TV or other item powering off, which then powers off the controlled outlets to save energy. Active power consumption is managed by the Tier 2 unit by monitoring a user's engagement or presence in a room by either or both infrared remote signals sensing or motion sensing. If afterAfter 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 Advanced Power Strips.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 3.9.31 Advanced Power Strip Plug Outlets- http://www.puc.pa.gov/filing_resources/issues_laws_regulations/act_129_information/technical_reference_manual.aspx.). The protocol considers usage of Advanced Power Strips with home office systemsfor HEC and home entertainment systemsoffices.

Algorithms

The energy savings and demand reduction for Tier 1 and Tier 2 APS outlets are obtained from several recently conducted field studies, with the savings estimates applied to measured in-service rates (ISR) and realization rates (RR) to determine final savings.

The energy savings and demand reduction are calculated for both home officeHEC and home entertainment office use for Tier 1 strips, and only for home entertainment use for Tier 2 strips.[79] For Tier 1 strips, if. When possible, identify the equipment connected to the APS and apply the

[79] Tier 2 strips are typically installed only in home entertainment center applications.

associated energy reduction percentage (ERP). If the intended use of the power stripfor a Tier 1 APS is not specifiedidentified, or if multiple power strips are purchased, the algorithm for "unspecified use" should be applied. If it is known that the power strip is intended to be used for an entertainment center, the "entertainment center" algorithm should be applied, while the "home office" algorithm should be applied if it is being used in a home office setting. For Tier 2 strips, the end use is assumed to be a home entertainment center and the savings varyValues for "unspecified use" are based on the type of Tier 2 strip, IR, IR-OS, or unspecified69% 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:

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$\Delta kWh_{t1\_unspecified} = Annual\_Usage_{unspecified} \times ERP_{t1\_unspecified} \times ISR \times RR$

$\Delta kWh_{t1\_entertainment} = Annual\_Usage_{entertainment} \times ERP_{t1\_entertainment} \times ISR \times RR$

$\Delta kWh_{t1\_office} = Annual\_Usage_{office} \times ERP_{t1\_office} \times ISR \times RR$

$\Delta kW_{peak,\ t1\_unspecified} = Load_{unspecified} \times ERP_{peak,\ t1\_unspecified} \times ISR$

$\Delta kW_{peak,\ t1\_entertainment} = Load_{entertainment} \times ERP_{peak,\ t1\_entertainment} \times ISR$

$\Delta kW_{peak,\ t1\_home\ office} = Load_{office} \times ERP_{peak,\ t1\_office} \times ISR$

$\Delta kWh = Annual\_Usage \times ERP_{T1} \times ISR \times RR$

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

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

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Tier 2 Advanced Power Strips:

$\Delta kWh_{t2} = Annual\_Usage_{entertainment} \times ERP_{t2} \times ISR \times RR$

$\Delta kW_{peak,\ t2} = Load_{entertainment} \times ERP_{peak,\ t2} \times ISR$

Definition of Terms

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$\Delta kWh = Annual\_Usage \times ERP_{T2} \times ISR \times RR$

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

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

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Definition of Terms

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Table 2-127: Terms, Values, and References for Advanced Power Strips

Parameter	Unit	Value	Source
$Annual\_Usage_{entertainment}$, Annual usage of home entertainment system $Annual\_Usage$	kWh	471See Table 2-128	13
$Annual\_Usage_{office}$, Annual usage of home office system	kWh	399	1

$Annual\_Usage_{unspecified}$, Annual usage of unspecified end-use[80]	kWh	449	1
$Load_{entertainment}$, Demand of home enertainment system	kW	0.058	3
$Load_{office}$, Demand of home office system	kW	0.044	3
$Load_{unspecified}$, Demand of unspecified end-use	kW	0.052	3
ERP, energy reduction percentage	%	See Table 2-107	1
ERP_{peak}, energy reduction percentage during peak period	%	See Table 2-107	1
ISR, In-service Rate	%	EDC Data Collection or see Table 2-107 Default = 72%	24
RR, Realization Rate	kWh%	0.92%	23
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) and In-Service Rate (ISR) for each strip type and end use.

Table 2-128: Impact Factors for Advanced Power Strip Types: Annual Usage by End-use

Strip Type	End-Use	ERPAnnual Usage (kWh)	ERP_{peak}	ISR
Tier 1	Home Entertainment Center	27%471	20%	86%
Tier 1	Home Office	21%399	18%	86%
Tier 1	Unspecified	25%449	19%	86%
Tier 2	Home Entertainment Center	44%	41%	74%

Default Savings

Table 2-129: Default SavingsImpact Factors for Advanced Power StripsStrip Types

APSStrip Type	End-Use	Energy Savings (kWh)ERP	Peak Demand Reduction (kW)
Tier 1	Home Entertainment Center	100.627%	0.010
Tier 1	Home Office	66.321%	0.007
Tier 1	Unspecified use or multiple purchased	88.825%	0.009
Tier 2	Home Entertainment Center	141.144%	0.018

Default Savings

[80] Note that this was based on the MA RPLNC 173 APS Metering Study that determined Tier 1 APS to be used in home entertainment settings 69% of the time, and 31% in home office environments.

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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) "RLPNC 17-3: AdvancedCalifornia Electronic Technical Reference Manual. "Smart Connected Power Strip Metering Study,""". SWAP010-10. Accessed January 2024. Weblink

1) NMR Group for Massachusetts ProgramsProgram Administrators and EEAC, (Mar. 2019), http://ma-eeac.org/wordpress/wp-content/uploads/RLPNC_173_APSMeteringReport_Revised_18March2019.pdf

2) . (2018, October). "RLPNC 17-4 and 17-5: Products Impact Evaluation of In-service and Short-Term Retention Rates Study," Massachusetts Programs Administrators and EEAC, (Oct. 2018),". http://ma-eeac.org/wordpress/wp-content/uploads/RLPNC_1745_APSProductsSurveys_5Oct2018_Final.pdfWeblink

3) As reported in correspondence with authors of Source 1 and Source 2.

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

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3) NMR Group for Massachusetts Program Administrators and EEAC. (2019, March). "RLPNC 17-3: Advanced Power Strip Metering Study," pg. 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

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Target Sector	Residential Establishments, limited to single family detached houses
Measure Unit	Residential Air Sealing
Measure Life	15 years Source 51
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 test methods using a 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 fromof each measure individually. This may require performance of a blower door test between each measure installation. Alternatively, the baseline blower door test may be performed after the duct sealing is completed, then air sealing measures installed and the retrofit blower door test completed prior to installation of the new insulation.

In addition, **seasonal savings are capped at 40% of the building's heating/cooling load**.Source 62

$$\Delta kWh_{cool} \leq 40\% \times CAPY_{cool} \times EFLH_{cool} \times \eta_{base}$$

$$\Delta kWh_{heat} \leq 40\% \times CAPY_{heat} \times EFLH_{heat} \times \eta_{base}$$

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 DkWhΔkWh add together the cooling and heating savings calculated using the appropriate coefficients from Table 2-111 and Table 2-112Table 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 2-31Table 2-40 in Sec. 2.2.10.

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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 $proto/base$ $\frac{proto}{base}$ 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 20182022 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.

$$\Delta kWh_{cool} = \frac{\eta_{proto}}{\eta_{base}} \times \frac{Duct_{proto}}{Duct_{base}} \times \left(\frac{a_{cool}}{100{,}000} \times \left({CFM50_{base}}^2 - {CFM50_{ee}}^2 \right) + b_{cool} \times \left(CFM50_{base} - CFM50_{ee} \right) \right)$$

$$\Delta kWh_{heat} = \frac{\eta_{proto}}{\eta_{base}} \times \frac{Duct_{proto}}{Duct_{base}} \times \left(\frac{a_{heat}}{100{,}000} \times \left({CFM50_{base}}^2 - {CFM50_{ee}}^2 \right) + b_{heat} \times \left(CFM50_{base} - CFM50_{ee} \right) \right)$$

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

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

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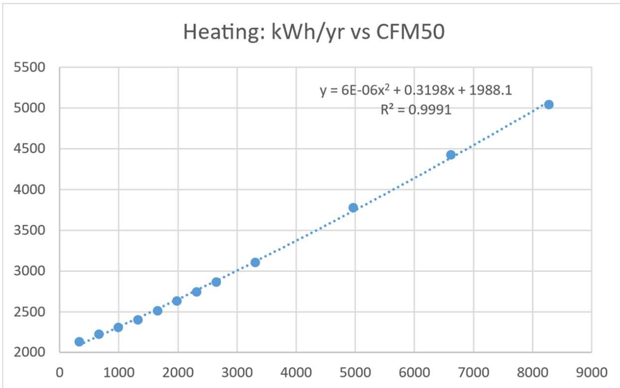
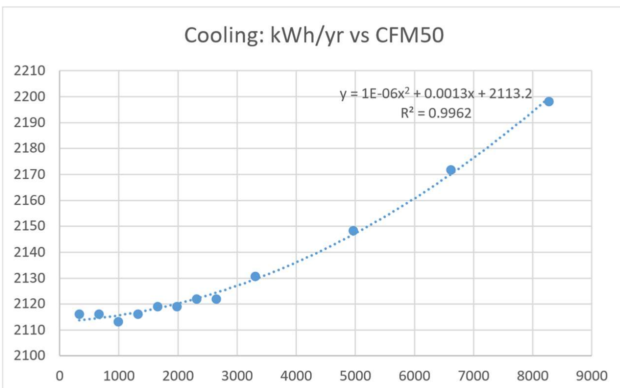
$$\Delta kW_{winter\ peak} = \Delta kWh_{heat} \div EFLH_{heat} \times CF_{heat}$$

Note: The savings equations above are based on *quadratic* regressions because coolingthe change in energy savings fall off quickly with changesfor the same reduction in infiltration in heating dominated climates, whereas some heating technologies exhibit escalating savings varies with the initial condition, as in thewell 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 plot below. This , 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 small9 kWh/yr savings. Since the coefficients forof the squared infiltration reduction term, which are thereforeso small, they are multiplied by 10^5 to simplify Table 2-111 and Table 2-112.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 AD





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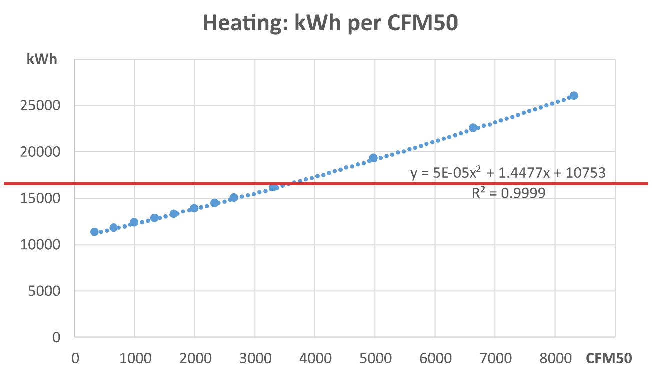

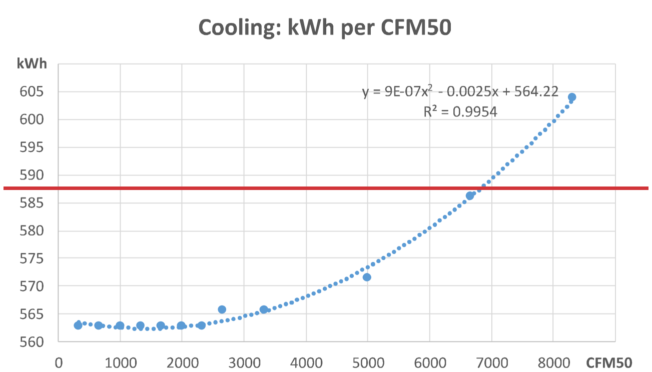

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Table 2-131: Terms, Values, and References for Residential Air Sealing

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	*ft*^{3}	Measured, EDC Data Gathering	EDC Data Gathering
$Duct_{base}$, Baseline duct efficiency	*None*	EDC Data Gathering: measured value, or appropriate value selected from ~~Table~~	EDC Data Gathering

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		~~2-31~~Table 2-40 in Sec. ~~2.2.9~~2.2.10	
$Duct_{proto}$, Prototype duct efficiency	*None*	Default: See ~~Table 2-31~~Table 2-40 in Sec. ~~2.2.9~~2.2.10 for "R-2 Average Basement + 50% Conditioned"	~~1~~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 2-110~~See Table 2-151 in 2.6.5	~~2~~5
a_{system} , Unit Energy Savings per CFM50[2] of air leakage reduction	$\frac{kWh/yr}{{CFM_{50}}^2}$	See Table 2-132	~~3~~6
b_{system} , Unit Energy Savings per CFM50 of air leakage reduction	$\frac{kWh/yr}{CFM_{50}}$	See Table 2-133	~~3~~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	~~4~~7
~~$EFLH_{cool}$~~$EFLH_{heat}$, Equivalent Full Load ~~Cooling hours~~Hours of operation during the heating season for the average unit	~~$\frac{hours}{year}$~~ $\frac{hours}{yr}$	See ~~$EFLH_{cool}$~~$EFLH_{heat}$ in Vol.1, App. A	~~4~~7
~~CF, Demand~~$CF_{summer\ peak}$, Summer demand Coincidence Factor	*Proportion*	See *Summer* *CF* in Vol. 1, App. A	~~4~~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[81]	$kBTU/hr$	EDC Data Gathering	AEPS Application; EDC Data Gathering
$CAPY_{heat}$, The heating capacity of the heat pump being installed[82]	$kBTU/hr$	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

~~[81] This data is obtained from the AEPS Application Form or EDC's data gathering based on the model number.~~
~~[82] Ibid. This refers to the capacity of the heat pump and not any auxiliary electric resistance heat.~~

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testing is required to be used in conjunction with these default energy savings values, as outlined in the algorithms.

Table 2-132: Default Residential Equipment Efficiency

	Cooling				Heating				
	ASHP	Central AC	Mini-split	GSHP	ASHP	Base-board	Electric Furnace	Mini-split	GSHP
Efficiency	15	12.1	14.9	16.6	8.5	1	1	8.9	3.6
Units	SEER	SEER	SEER	EER	HSPF	COP	COP	HSPF	COP

Table 2-113: Default Unit Energy Savings per Reduced CFM50[2] for Air Sealing

Climate Region	Reference City	a_{cool} ASHP	a_{cool} Central AC	a_{cool} GSHP Mini-split	a_{cool} GSHPMini-split	a_{heat} ASHP	a_{heat} Base-board	a_{heat} Electric Furnace	a_{heat} GSHPMini-split	a_{heat} Mini-splitGSHP
C	Allentown	-0.042062	-0.076021	0.09028	0.023097	5.064-1.445	-1.166790	-3.485317	0.944-1.396	-0.413909
A	Binghamton	0.028000	0.018086	0.087061	-1.6480.046	3.335-1.159	1.2710.103	4.653-0.287	-0.986789	0.293-1.232
G	Bradford	0.043-2.255	0.02-2.660	0.067-1.547	0.06-4.326	0.112-1.828	1.515-5.151	-4.545540	-1.173831	-0.283709
I	Erie	-0.022062	-0.004067	0.058021	0.027059	5.67-0.952	-1.318803	4.309-1.467	1.066-0.706	0.367-1.314
E	Harrisburg	-0.079067	-0.1251.906	0.126013	-0.066641	4.488-1.722	1.242-3.238	3.488-4.584	0.886-2.131	0.112-1.141
D	Philadelphia	-0.08148	-0.121162	-0.096202	0.002111	3.0780.830	1.0043.626	2.208806	0.792647	0.286649
H	Pittsburgh	-0.014000	-0.053026	0.075	0.079068	4.657-1.264	1.185-2.548	-2.778277	-0.93940	0.497-1.405
B	Scranton	-0.004031	-0.029023	0.086049	0.058068	4.845-1.42	1.21-2.354	4.073-2.606	-0.958990	0.411-1.316
F	Williamsport	-0.03703	-0.032020	0.104070	0.052067	5.175-1.921	1.181-4.028	3.477-4.553	0.925-1.740	0.392-1.662

Table 2-133: Default Unit Energy Savings per Reduced CFM50 for Air Sealing

Climate Region	Reference City	b_{cool} ASHP	b_{cool} Central AC	b_{cool} GSHPMini-split	b_{cool} Mini-splitGSHP	b_{heat} ASHP	b_{heat} Base-board	b_{heat} Mini-splitElectric Furnace	b_{heat} Electric FurnaceGSHP	b_{heat} Mini-splitGSHP
C	Allentown	0.025021	0.033020	-0.004007	-0.007014	0.951833	1.966943	0.8642.179	2.1380.684	0.616553
A	Binghamton	-0.001000	-0.001010	-0.002014	-0.007222	1.948141	2.393527	1.4482.702	2.5990.875	0.788795

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G	Bradford	-0.007321	-0.005380	-0.007240	-0.011478	2.7031.241	2.8033.137	2.0013.233	3.0321.166	0.951777
I	Erie	0.004001	0.001004	-0.003017	-0.004021	1.2790.977	2.238431	1.0982.518	2.4230.749	0.726712
E	Harrisburg	0.055033	0.066228	0.025002	0.033126	1.0920.827	2.194010	1.0322.226	2.3780.713	0.709565
D	Philadelphia	0.05064	0.061071	0.017071	0.023001	0.589487	1.604130	0.5731.305	1.7520.466	0.498320
H	Pittsburgh	0.019000	0.026001	-0.005017	-0.002018	1.0510.917	1.9582.271	0.992.340	2.1250.711	0.612664
B	Scranton	0.009004	0.013005	-0.002016	-0.004019	1.250.899	2.056161	1.0042.273	2.240.691	0.659627
F	Williamsport	0.02008	0.023009	-0.001015	-0.001017	1.0480.929	1.9812.278	0.9322.410	2.1580.750	0.627657

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 requirerequires 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 from Weblink

1)4) NMR Group for the Pennsylvania Public Utility Commission. (2024, March). 2023 Pennsylvania Statewide Act 129 2018 Residential Baseline, http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-Phase3_Res_Baseline_Study_Rpt021219.pdf. Study. Weblink

2)5) Equipment efficiencies were chosen based on weighted single-family detached results from the 20172023 Pennsylvania Residential Baseline, standardized equipment library entries (ASHP), and expertise (GSHP).

3)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 statewide average characteristics determined through the Pennsylvania Act 129 20182023 Residential Baseline. Simulations for each equipment-climate region combination were performed at multiple levels of air leakage (1, 2, 3, 4, 5, 6, 7, 8, 10, 15, 20, and 25 ACH50).

The heating or cooling loads for each system combination were then fitted with separate quadratic regressions, the coefficients of which are the UES values. Supporting files can be found at http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-Phase3_Res_Baseline_Study_Rpt021219.pdf. 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. Based on the Phase III SWE team's analysis of regional HVAC runtime data collected from ecobee's Donate Your Data research service, https://www.ecobee.com/donateyourdata/Weblink.

4)

5) Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, 2007

6) "Residential Heating and Cooling Loads Component Analysis", Lawrence Berkley National Laboratory Building Technologies Department, 1999, https://simulationresearch.lbl.gov/dirpubs/44636.pdf

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2.6.2 WEATHER STRIPPING, CAULKING, AND OUTLET GASKETS

~~**Target Sector**~~	~~Residential Establishments~~
Target Sector	Residential
Measure Unit	Per Project
~~**Measure Life**~~	~~15 years~~
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 SealingResidential 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:

$$\sout{DkW}\,\Delta kWh_{cool} = \sout{\frac{1.08 \times DCFM_{50} \times CDD \times 24\frac{hr}{day} \times ISR}{N \times SEER \times 1{,}000\frac{W}{kW}} \times LM \times DUA}\ \frac{1.08 \times \Delta CFM_{50} \times CDD \times 24 \times ISR}{N \times SEER2 \times 1{,}000} \times LM \times DUA \times F_{RAC} \times \%_{elec}$$

$$\sout{DkW}\,\Delta kWh_{heat} = \sout{\frac{1.08 \times DCFM_{50} \times HDD \times 24\frac{hr}{day} \times ISR}{N \times HSPF \times 1{,}000\frac{W}{kW}}} = \frac{1.08 \times \Delta CFM_{50} \times HDD \times 24 \times ISR}{N \times HSPF2 \times 1{,}000} \times \%_{elec}$$

$$\sout{DkWh}\,\Delta kWh = \sout{(DkWh_{cool} + DkWh_{heat})}(\Delta kWh_{cool} + \Delta kWh_{heat}) < 400\ kWh$$ If > 400 kWh use Sec. 2.6.1

$$\sout{\Delta kW_{peak}}\,\Delta kW_{summer\ peak} = \sout{DkW} = \Delta kWh_{cool} \times \sout{PCF}\,ETDF_{summer}$$

$$\Delta kW_{winter\ peak} = \Delta kWh_{heat} \times ETDF_{winter}$$

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Ground Source Heat Pumps (GSHP)

GSHP efficiencies are typically calculated differently than air-source units

Ground Source Heat Pumps (GSHP)

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

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

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

PTAC and PTHP

$SEER = EER$

Definition of Terms

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

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	-
DCF ΔCFM_{50}, Reduction in air leakage at a test pressure of 50 Pascals	*CFM*	See Table 2-137	1, 42, 3
CDD, Cooling degree-days	*°F-day/year*	See CDD values in Vol. 1, App. A	104
HDD, Heating degree-days	*°F-day/year*	See HDD values in Vol. 1, App. A	104
ISR, In-service rate	*None*	Kit delivery: EDC Data Gathering Default: Direct install = 1 Kit delivery = 0.16	EDC Data Gathering5
LM, Latent multiplier to convert the calculated sensible load to the total (sensible and latent) load	*None*	See Table 2-136	56
DUA, Discretionary use adjustment to account for uncertainty in predicting cooling system usage patterns of occupants	*None*	0.75	37
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,	*None*	See Table 2-135 Default = 16.7	210

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building height, wind shielding and building leakiness			
$SEER$, $SEER2$, Cooling system seasonal efficiency	$\frac{Btu}{W \cdot h}$	EDC Data Gathering Default: GatheringDefault:13.9, or See Early Replacement values in Table 2-10 inof Sec. 2.2.12.2.1	711, 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. 2.2.12.2.1	711, 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 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 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
$GSER$, Factor used to determine the SEER of a GSHP based on its EERg	$\frac{BTU}{W \cdot h}$	1.02	8
$GSPK$, Factor to convert EERg to the equivalent EER of an air conditioner to enable comparisons to the baseline unit	Proportion	0.8416	8
$GSHPDF$, Ground Source Heat Pump De-rate Factor	Proportion	0.885	914
PCF, Peak demand savings conversion factor	kW/kWh	0.000017 (1.7×10^{-5})	6

Table 2-135: Correlation Factor Source 210

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

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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 Source 1Sources 2,3

Technology	Application	ΔCFM50 Source 45
Weather Stripping	Single Door	25.5 CFM/door
	Double Door	0.73 CFM/ft^2
	Casement Window	0.036 CFM/lf of crack
	Double Horizontal Slider, Wood	0.473 CFM/lf of crack
	Double-Hung	1.618 CFM/lf of crack
	Double-Hung, with Storm Window	0.164 CFM/lf of crack
	Average Weatherstripping	0.639 CFM/lf of crack
Caulking	Piping/Plumbing/Wiring Penetrations	10.9 CFM each
	Window Framing, Masonry	1.364 CFM/ft^2
	Window Framing, Wood	0.382 CFM/ft^2
	Door Frame, Masonry	1.018 CFM/ft^2
	Door Frame, Wood	0.364 CFM/ft^2
	Average Window/Door Caulking	0.689 CFM/lf of crack
Average Window/Door Caulking and Weather Stripping		*0.664 CFM/lf of crack*
Gasket	Electrical Outlets	6.491 CFM each

DEFAULT SAVINGS

If the information needed to utilize the algorithms is unavailable, the default savings listed below may be used. The default savings are based on a home with a 12.113.9 SEER CAC and electric resistance heat (COP=1). The default savings assume direct installheating HSPF of measures. To use default savings for kit delivery measures, EDCs must determine an ISR multiplier through independent research.7.75.Source 15

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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	~~7.317~~0.924	~~4.457~~0.563	~~4.357~~0.550	~~28.178~~0.645	~~17.165~~0.393	~~16.780~~0.384
A	Binghamton, NY	~~2.875~~0.265	~~1.752~~0.161	~~1.712~~0.158	~~34.997~~0.881	~~21.319~~0.537	~~20.841~~0.525
G	Bradford	~~3.433~~0.445	~~2.091~~0.271	~~2.044~~0.265	~~40.930~~0.902	~~24.933~~0.550	~~24.374~~0.537
I	Erie	~~7.917~~1.022	~~4.823~~0.622	~~4.714~~0.608	~~32.207~~0.726	~~19.619~~0.442	~~19.179~~0.432
E	Harrisburg	~~6.603~~0.681	~~4.022~~0.415	~~3.932~~0.405	~~30.466~~0.614	~~18.559~~0.374	~~18.143~~0.366
D	Philadelphia	~~9.426~~1.107	~~5.742~~0.674	~~5.613~~0.659	~~23.971~~0.547	~~14.602~~0.333	~~14.275~~0.325
H	Pittsburgh	~~5.666~~0.614	~~3.452~~0.374	~~3.374~~0.366	~~29.014~~0.684	~~17.674~~0.416	~~17.278~~0.407
B	Scranton	~~5.928~~0.771	~~3.611~~0.470	~~3.530~~0.459	~~30.556~~0.701	~~18.614~~0.427	~~18.196~~0.417
F	Williamsport	~~7.284~~0.806	~~4.437~~0.491	~~4.338~~0.480	~~28.581~~0.701	~~17.411~~0.427	~~17.020~~0.418

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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.~~0001244~~0002193	0.~~0000758~~0001336	0.~~0000741~~0001306
A	Binghamton, NY	0.~~0000489~~0002996	0.~~0000298~~0001825	0.~~0000291~~0001784
G	Bradford	0.~~0000584~~0003068	0.~~0000356~~0001869	0.~~0000348~~0001827
I	Erie	0.~~0001346~~0002467	0.~~0000820~~0001503	0.~~0000801~~0001469
E	Harrisburg	0.~~0001122~~0002089	0.~~0000684~~0001272	0.~~0000668~~0001244
D	Philadelphia	0.~~0001602~~0001858	0.~~0000976~~0001132	0.~~0000954~~0001107
H	Pittsburgh	0.~~0000963~~0002324	0.~~0000587~~0001416	0.~~0000574~~0001384
B	Scranton	0.~~0001008~~0002383	0.~~0000614~~0001451	0.~~0000600~~0001419
F	Williamsport	0.~~0001238~~0002385	0.~~0000754~~0001453	0.~~0000737~~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

~~1)~~ ASHRAE~~, .~~ (2001) AHSRAE Handbook – Fundamentals, ~~Table 1.~~

2) ENERGY STAR Home Sealing Specification, VersionChapter 26: Ventilation and Infiltration, Table 1.0. October 2001. https://www.energystar.gov/ia/home_improvement/home_sealing/ES_HS_Spec_v1_0b.pdf

3) Energy Center of Wisconsin, "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research," May 2008. https://focusonenergy.com/sites/default/files/centralairconditioning_report.pdf

4)3) ΔCFM50 is estimated by dividing the ELA by 0.055. See p. 83, The Energy Conservatory,. (2012, August). Minneapolis Blower Door Operation Manual,. Pg 83. http://energyconservatory.com/wp-content/uploads/2014/07/Blower-Door-model-3-and-4.pdfWeblink

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.

5)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." ASHRAE Journal. November 1997. https://energy.mo.gov/sites/energy/files/harriman-dehumidification-and-cooling-loads-from-ventilation-air.pdfWeblink

6) KEMA, Evaluation of the Weatherization Residential Assistance Partnership (WRAP) and Helps Programs, September 2010. http://www.energizect.com/sites/default/files/Final%20WRAP%20%20Helps%20Report.pdf

7) For all systems excluding ground source heat pumps: 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 2018Residential 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, http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-Phase3_Res_Baseline_Study_Rpt021219.pdf. Due. Pg 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", pg 284.

11) NMR Group for the Pennsylvania Public Utility Commission. (2024, March). 2023 Pennsylvania Statewide Act 129 Residential Baseline Study. Pg 115, table 97, pg. 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 residential baseline, study.

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

13) Federal minimum efficiency options available in BEopt were chosen as defaults for ground sourcestandards, 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

7)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 pumpspump technologies.

8) VEIC estimate. Extrapolation of manufacturer data.

9)1)McQuay Application Guide 31-008, Geothermal Heat Pump Design Manual, 2002. Engineering Estimate - See System Performance of Ground Source Heat Pumps

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

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2.6.3 Ceiling/Attic, Wall, Floor and Rim Joist Insulation

~~**Target Sector**~~	~~Residential Establishments~~
Target Sector	Residential
Measure Unit	Per Project
~~**Measure Life**~~	~~15 years Sources 1, 2~~
~~**Vintage**~~	~~Retrofit~~
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 ~~or apartment units in multifamily complexes with a primary electric heating and/or cooling source. The installation must achieve a finished ceiling/attic insulation rating of R-49 or higher, and/or must add wall insulation of at least an R-6 or greater rating.Source 12~~

Floor Insulation
This measure ~~requires~~applies to the installation of new insulation to the floors of existing residential buildings with vented (unconditioned) crawlspaces ~~and a primary electric heating and/or cooling source. The installation must achieve a finished floor insulation R-value of R-30 or higher, except for homes in IECC Climate Zone 4, where R-19 is permissible.Source 12~~.

Rim Joist Insulation
This measure ~~protocol~~ 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. ~~The insulation should have either a minimum R-10 continuous insulated sheathing on the interior or exterior of the home, or R-13 cavity insulation at the interior of the rim joist. Because of the difficulty of a proper air-sealed installation, using fiberglass batts between the joists is not usually recommended. The insulation should be sprayed foam or rigid foam.Source 3~~

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.

$$\sout{DkWh_{cool,component}}\Delta kWh_{cool} = \left(\frac{1}{R_{base}} - \frac{1}{R_{ee}}\right) \times \sout{A_{component} \times (1-FF)} A \times (1-FF) \times \sout{\frac{24\frac{hr}{day} \times CDD \times DUA}{SEER \times 1{,}000\frac{W}{kW}}} \frac{24 \times CDD \times DUA}{SEER \times 1{,}000} \times F_{RAC}$$

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$$\times F_{RAC} \times AHF$$

$$DkWh_{heat,component}\,\Delta kWh_{heat} = \left(\frac{1}{R_{base}} - \frac{1}{R_{ee}}\right) \times A_{component} \times (1 - FF)\,A \times (1 - FF) \times \frac{24\frac{hr}{day} \times HDD}{HSPF \times 1{,}000\frac{W}{kW}}\,\frac{24 \times HDD}{HSPF \times 1{,}000}$$

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

$$DkWh\,\Delta kW_{summer\ peak} = \sum_{components} DkWh_{cool} + DkWh_{heat} = \Delta kWh_{cool} \times ETDF_{summer}$$

$$\Delta kW_{peak}\,\Delta kW_{winter\ peak} = \frac{\Delta kWh_{cool}}{EFLH_{cool}} \times CF = \Delta kWh_{heat} \times ETDF_{winter}$$

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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:

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

$HSPF \quad = COP_g \times GSHPDF \times 3.412 \frac{BTU}{W \cdot h}$

PTAC and PTHP

PTAC and PTHP

$SEER \quad = EER$

Definition of Terms

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	*°F.ft².hr/BTU*	EDC Data Gathering Default: Table 2-120	9, 10
R_{ee}, R-value of insulation added	*°F.ft².hr/BTU*	EDC Data Gathering Default: Table 2-120	9, 10
A, Area of component being insulated	*Ft²*	EDC Data Gathering	-
FF, Framing factor, designed to account for space that is occupied by framing	None	If externally applied or non-floor component = 0% If studs and cavity = 12%	4
CDD, Annual cooling degree-days, base 65°F	*°F-day/year*	See *CDD* in Vol 1., App. A	15
HDD, Annual heating degree-days, base 65°F	*°F-day/year*	See *HDD* in Vol 1., App. A	15
$EFLH_{cool}$, Equivalent full load cooling hours	*Hours/year*	See *$EFLH_{cool}$* in Vol 1., App. A	14
DUA, Discretionary use adjustment to account for uncertainty in predicting cooling system usage patterns of occupants	None	0.75	5
$SEER$, Cooling system seasonal efficiency	$\frac{Btu}{W \cdot h}$	EDC Data Gathering Default: See Early Replacement values in Table 2-8 in Sec. 2.2.1	6

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Term	Unit	Values	Source
$HSPF$, Heating system seasonal efficiency	$\frac{BTU}{W \cdot h}$	EDC Data Gathering Default: See Early Replacement values in Table 2-8 in Sec. 2.2.1	6
F_{RAC}, Adjustment factor to relate insulated area to area served by room air conditioners	None	If Room AC = 0.38 If non-Room AC = 1.0	7
COP_g, Coefficient of Performance. This is a measure of the efficiency of a heat pump	*None*	EDC Data Gathering	-
EER_g, Energy Efficiency Ratio of a GSHP, this is measured differently than EER of an air source heat pump and must be converted	$\frac{BTU}{W \cdot h}$	EDC Data Gathering Default = 16.6	-
$GSER$, Factor used to determine the SEER of a GSHP based on its *EERg*	$\frac{BTU}{W \cdot h}$	1.02	12
$GSPK$, Factor to convert *EERg* to the equivalent EER of an air conditioner to enable comparisons to the baseline unit	*Proportion*	0.8416	12
$GSHPDF$, Ground Source Heat Pump De-rate Factor	*Proportion*	0.885	13
CF, Coincidence factor	None	See *CF* in Vol. 1, App. A	14
AHF, Adjustment for cooling savings to account for inaccuracies in engineering algorithms.	*None*	1.21 if adding attic ins., 1.0 if not	8

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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	ft^2	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 appropriate) in Table 2-10 in Sec. 2.2.1	14
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 (Insulated) R R-Values

Component	Existing Condition	Value $(\frac{°F \cdot ft^2 \cdot hr}{Btu})$
$R_{ceil,base}$, Assembly R-value of ceiling/attic before retrofit	Un-insulated attic	5
	4.5" (R-13) of existing attic insulation	16
	6" (R-19) of existing attic insulation	22
	10" (R-30) of existing attic insulation	30
$R_{ceil,ee}$, Assembly R-value of ceiling/attic after retrofit	Retrofit to R-49 total attic insulation	49
$R_{wall,base}$, Assembly R-value of wall before retrofit	Assumes existing, un-insulated wall with 2x4 studs @ 16" o.c., w/ wood/vinyl siding	5
$R_{wall,ee}$, Assembly R-value of wall after retrofit	Assumes adding R-6 per DOE recommendations	11
$R_{floor,base}$, R-value of floor before retrofit	Thermal resistance of existing floor insulation above crawlspace	3.96
$R_{floor,ee}$, R-value of floor after retrofit	Thermal resistance of insulation added to floor above crawlspace	EDC Data Gathering
$R_{rimjoist_{base}}$, R-value of rim joist before retrofit	Baseline R-value of rim joist	2.5
$R_{rimjoist_{ee}}$, R-value of rim joist after retrofit	R-value of installed spray foam or rigid foam insulation applied to rim joist	EDC Data Gathering

Default Savings

There are no default savings for this measure.

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, 2007. https://library.cee1.org/system/files/library/8842/CEE_Eval_MeasureLifeStudyLights%2526HVACGDS_1Jun2007.pdfWeblink. 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) State of Ohio Energy Efficiency Technical Reference Manual, prepared for the Public Utilities Commission of Ohio by Vermont Energy Investment Corporation. August 6, 2010.

3) Minnesota Department of Commerce, Home Envelope, An Energy Guide to Help You Keep the Outside Out and the Inside In. http://mn.gov/commerce/energy/topics/resources/Consumer-Guides/home-envelope/basement.jsp

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5) Energy Center of Wisconsin, "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research," https://focusonenergy.com/sites/default/files/centralairconditioning_report.pdf

6) For all systems excluding ground source heat pumps: Pennsylvania Act 129 2018 Residential Baseline Study, http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-Phase3_Res_Baseline_Study_Rpt021219.pdf. Due to small sample size in residential baseline, the lowest efficiency options available in BEopt were chosen as defaults for ground source heat pumps.

7) From PECO baseline study, average home size = 2,323 ft^2, average number of room AC units per home = 2.1. Average Room AC capacity = 10,000 BTU/hr per ENERGY STAR Room AC Calculator, which serves 425 ft^2 (average between 400 and 450 ft^2 for 10,000 BTU/hr unit per ENERGY STAR Room AC sizing chart). F_{RAC} = (425 ft^2 × 2.1)/(2,323 ft^2) = 0.38.

8) Illinois Statewide Technical Reference Manual, Version 7.0. September 28, 2018. http://www.ilsag.info/technical-reference-manual.html .

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

9)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.

10)5) 2009 ASHRAE. (2009). Fundamentals,. Chapter 25 and 26. Method from "Total Thermal Resistance of a Flat Building Assembly" in Chapter 25. Values from Chapter 26: interior air film = 0.68, 1.5" wooden rim joist = 1.65, exterior air film = 0.17. Total= 2.50 *°F-ft²-h/BTU*Thermal resistance values from Chapter 26.

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~~11) 2015 International Energy Conservation Code, Table R402.1.2: Insulation and Fenestration Requirements by Component. https://codes.iccsafe.org/content/IECC2015/chapter-4-re-residential-energy-efficiency~~

~~12) VEIC estimate. Extrapolation of manufacturer data.~~

~~13) McQuay Application Guide 31-008, Geothermal Heat Pump Design Manual, 2002. Engineering Estimate - See System Performance of Ground Source Heat Pumps~~

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

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11) ASHRAE. (2021). Fundamentals. Chapter 27, pg 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." Pg 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

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14) Based on the Phase III SWE team's analysis of regional HVAC runtime data collected from ecobee's Donate Your Data research service. https://www.ecobee.com/donateyourdata/
15) PA SWE Team Calculations with data from the National Solar Radiation Database. 1991–2005 Update: Typical Meteorological Year 3. NREL. http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html

2.6.4 Basement or Crawl Space Wall Insulation

Target Sector	Residential Establishments
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.

BasementIn 2021 IECC Climate Zone 4, basement or crawl space insulation should have either a minimum R-10 continuous insulated sheathing insulation on the interior or exterior of the home, or R-13 cavity insulation aton the interior of the home. In IECC Climate Zone 5, basement or crawl space wall in IECC Climate Zone 4, and R-insulation should have either a minimum of R-15 continuous insulation on the interior or exterior of the home, or R-19 cavity insulation in zones 5 or 6.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.

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

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$$DkWh_{cool}\Delta kWh_{cool} = \left(\frac{1}{R_{base}} - \frac{1}{R_{base} + R_{ee}}\right)\left(\frac{1}{R_{base,ag}} - \frac{1}{R_{base,ag} + R_{ee}}\right) \times \frac{L \times H_{ag} \times (1 - FF) \times CDD \times 24\frac{hr}{day}}{SEER \times 1{,}000\frac{W}{kW}}$$
$$\times \frac{L \times H_{ag} \times (1 - FF) \times CDD \times 24}{SEER \times 1{,}000} \times DUA \times F_{RAC}$$

$$DkWh_{heat}\Delta kWh_{heat} = \left\{\left(\frac{1}{R_{base}} - \frac{1}{R_{base}+R_{ee}}\right)\times H_{ag} + \left(\frac{1}{R_{base}+R_{earth}} - \frac{1}{R_{base}+R_{eart}+R_{ee}}\right)\times H_{bg}\right\} \times \frac{L\times(1-FF)\times HDD\times 24\frac{hr}{day}}{\text{HSPF}\times 1{,}000\frac{W}{kW}}\times AF$$

$$= \left\{\left(\frac{1}{R_{base,ag}} - \frac{1}{R_{base,ag}+R_{ee}}\right)\times H_{ag} + \left(\frac{1}{R_{base,bg}} - \frac{1}{R_{base,bg}+R_{ee}}\right)\times H_{bg}\right\} \times \frac{L\times(1-FF)\times HDD\times 24}{\text{HSPF}\times 1{,}000}$$

$$\Delta kW_{peak}\Delta kW_{summer\ peak} = \frac{DkWh_{cool}}{EFLH_{cool}}\times CF = \Delta kWh_{cool}\times ETDF_{summer}$$

$$\Delta kW_{winter\ peak} = \Delta kWh_{heat}\times ETDF_{winter}$$

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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::

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

$HSPF \quad = COP_g \times GSHPDF \times 3.412 \frac{BTU}{W \cdot h}$

PTAC and PTHP

$SEER \quad = EER$

Definition of Terms

$HSPF \quad = COP_g \times GSHPDF \times 3.412 \frac{BTU}{W \cdot h}$

PTAC and PTHP

$SEER \quad = EER$

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}, $R_{base,ag}$, baseline R-value of foundation wall above grade	$\frac{°F \cdot ft^2 \cdot h}{BTU}$	Retrofit:	EDC Data Gathering Default = existing nominal R-value + 1; Minimum = 1. (An uninsulated wall is assumed to be R-1.)	4EDC 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_{Earth}, $R_{base,bg}$, the combined average R-value for the thermal resistance of thewall and Earth at the height of insulated foundation wall below grade (H_{bg})	$\frac{°F \cdot ft^2 \cdot h}{BTU}$	Table 2-148		53, 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 wall around the entire insulated perimeterwalls 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

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Term	Unit	Values	Source
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 ~~externally applied~~continued = 0% If ~~studs and cavity~~stud-baycavity = 25%	~~6~~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	~~13~~6
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	~~13~~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.~~38~~24 If non-Room AC = 1.0	~~14~~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	~~8~~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	~~8~~9
~~*AF*, adjustment factor, accounts for prescriptive engineering algorithms overestimating savings~~	~~*Proportion*~~	~~0.88~~	~~9~~
~~*COP*~~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*~~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

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Term	Unit	Values	Source
$GSER$, Factor used to determine the SEER of a GSHP based on its EERg	$\frac{BTU}{W \cdot h}$	1.02	11
$GSPK$, Factor to convert EERg to the equivalent EER of an air conditioner to enable comparisons to the baseline unit	Proportion	0.8416	11
$GSHPDF$, Ground Source Heat Pump Derate Factor	Proportion	0.885	1211
$EFLH_{cool}$, equivalent full-load hours of air conditioning $ETDF_{summer}$, Summer energy to demand factor	hourskW/kWh	0.0005272 EDC Data Gathering or See $EFLH_{cool}$ in Vol. 1 App. A	12 EDC Data Gathering 10
CF, coincidence factor $ETDF_{winter}$, Winter energy to demand factor	Proportion kW/kWh	See CF in Vol. 1 App. A 0.0003398	1012

Table 2-122 Table 2-148 should be used to determine the average thermal resistance of the combined wall and Earth (R_{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_{Earth} $R_{base,bg}$ for that below-grade wall height, look for the column for H_{bg} = 4ft in Table 2-122. R_{Earth} Table 2-148. $R_{base,bg}$ in this example is therefore 6.42 4.26 °F-ft²-h/BTU.

Table 2-148: Below-grade R-values (°F-ft²-h/BTU) for combined Earth and basement wall

H_{bg} (ft)		Retrofit				New Construction Source 13			
		0 No Existing Insulation Source 4	2	3	1 Unknown Existing Insulation Source 15	4 IECC Climate Zone 4	5 IECC Climate Zone 5	6 7	8
1		2.31			9.71	12.31	17.31		
R_{Earth} (°F-ft²-h/BTU)	2.446	3.4702	4.41	5.41	610.42	7.4613.02	8.4618.02	9.53	10.69
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		

Default Savings

There are no default savings for this measure.

Evaluation Protocols

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

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verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

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2) USDOE, Guide to Closing and Conditioning Ventilated Crawlspaces,. http://www.nrel.gov/docs/fy13osti/54859.pdfWeblink

3) 20152021 International Energy Conservation Code, Table R402.1.23: Insulation Minimum R-values and Fenestration Requirements by Component. https://codes.iccsafe.org/content/IECC2015/chapter-4-re-residential-energy-efficiencyWeblink. 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.

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7) Energy Center of Wisconsin, May (2008 metering study;, May). "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research", p31. http://cleanefficientenergy.org/resource/central-air-conditioning-wisconsin-compilation-recent-field-research ." Pg 31. Weblink

8) For all systems excluding ground source heat pumps: NMR Group for the Pennsylvania Public Utility Commission. (2024, March). 2023 Pennsylvania Statewide Act 129 2018 Residential Baseline Study, http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-Phase3_Res_Baseline_Study_Rpt021219.pdf. Due. 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. Pg 115, table 97, pg, 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 residential baseline, the lowest study.

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14) From PECO baseline study, average home size = 2,323 ft², average number of room AC units per home = 2.1. Average Room AC capacity = 10,000 BTU/hr per ENERGY STAR Room AC Calculator, which serves 425 ft² (average between 400 and 450 ft² for 10,000 BTU/hr unit per ENERGY STAR Room AC sizing chart). $F_{RAC} = (425\ ft^2 \times 2.1)/(2{,}323\ ft^2) = 0.38$.

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.

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2.6.5 ENERGY STAR WINDOWS

Target Sector	Residential Establishments
Measure Unit	Window Area
Measure Life	(15 max, but 20 for TRC) years Source 1
Vintage	Retrofit

ELIGIBILITY

This protocol documents the energy savings for replacing existing windows in a residence with ENERGY STAR version 7 certified windows. Source 2

ALGORITHMS

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

$$\Delta kWh_{cool} = Area\ of\ Window\ ft^2 \times \frac{\eta_{proto}}{\eta_{base}} \times UES_{region,system}\ a_{cool} \times overlap$$

$$\Delta kWh_{heat} = Area\ of\ Window\ ft^2 \times \frac{\eta_{proto}}{\eta_{base}} \times UES_{region,system}\ a_{heat} \times overlap$$

$$\Delta kW = \frac{DkWh_{cool}}{EFLH_{cool}} \times CF$$

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

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

Energy savings depend on three components: a unit energy savings value (UES) coefficient (a_{cool} or 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 ($\frac{\eta_{proto}}{\eta_{base}}$ $\frac{\eta_{proto}}{\eta_{base}}$), and THE eligible window area. To calculate energy savings, look up the efficiency value for the applicable equipment type in THE EARLY REPLACEMENT VALUES IN TABLE 2-8 IN SEC. 2.2. Table 2-151. This is η_{proto} η_{proto}. For η_{base} η_{base}, use the corresponding value for the equipment in the home, or the default value of η_{proto} η_{proto} (i.e., a ratio of 1). Calculate the ratio. Then look up the VALUE FOR UES IN TABLE 2-124 (a) for the correct equipment type and climate REFERENCE CITY. region in Table 2-150. Multiply these values by the window area to get cooling or heating savings.

DEFINITION OF TERMS

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

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Formatted: Don't keep with next, Don't keep lines together 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
$UES_{region,system}$, Climate region dependent electricity savings for efficient glazing	$\frac{kWh}{ft^2}$	See Table 2-124	2
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 Early Replacement values in Table 2-8 in Sec. 2.2.1	3
$EFLH_{cool}$, Equivalent Full Load Cooling hours	$\frac{hours}{year}$	See $EFLH_{cool}$ in Vol. 1, App. A	4
CF, Demand Coincidence Factor	*Proportion*	See *CF* in Vol. 1, App. A	4

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 *EFLH_{cool}* 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 $EFLH_{cool}$ 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 ~~$UES_{region,system}$~~ unit energy savings – kWh per Square Foot of Replaced Window

Reference City	Cooling ASHP	Cooling Central AC	Cooling Mini-split	Cooling GSHP	Heating ASHP	Heating Electric Furnace	Heating Base-board	Heating Mini-split	Heating GSHP
Allentown	0.66	1.50	0.59	0.57	2.86	3.40	3.12	2.10	0.95
Binghamton	0.46	0.65	0.47	0.36	4.50	4.60	4.28	3.56	1.27
Bradford	0.35	1.10	0.34	0.25	5.57	5.51	7.86	4.63	1.58
Erie	0.51	0.51	0.46	0.41	4.07	4.81	4.07	3.12	1.35
Harrisburg	0.75	0.82	0.73	0.66	2.84	3.91	3.17	2.40	1.06
Philadelphia	0.86	0.83	0.76	0.86	1.68	2.53	5.85	1.31	0.68
Pittsburgh	0.66	0.66	0.64	0.60	3.06	3.82	3.06	2.28	1.07
Scranton	0.59	0.68	0.57	0.50	3.36	3.83	3.55	2.58	1.06
Williamsport	0.65	0.46	0.61	0.58	2.99	3.47	5.08	2.19	0.96

Climate Region	a_{cool} ASHP	a_{cool} Central AC	a_{cool} GSHP	a_{cool} Mini-split	a_{cool} Room AC	a_{heat} ASHP	a_{heat} Base-board	a_{heat} Electric Furnace	a_{heat} GSHP	a_{heat} 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 Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx. Accessed December 2018.~~

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

~~2)~~3) Based on modelling using BEopt v2.8.0 performed by NMR Group, Inc. Unit energy savings were calculated by modeling a prototypical Pennsylvania single family detached house with ~~statewide~~ average characteristics determined through the Pennsylvania Act 129 ~~2018~~2023 Residential Baseline Study~~.~~; 0.44 U / 0.52 SHGC. Simulations for each equipment-climate

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region combination were performed for plain double-plane (0.49 U, 0.56 SHGC) and triple-pane ENERGY STAR (version 7 windows using 0.2725 U, / 0.2630 SHGC) windows. as representative specifications for climate regions D & E, and 0.21 / 0.32 SHGC for the remaining regions. The difference in heating and cooling loads wereconsumption was then apportioned evenly among the 322305 square feet of windows in the prototype home yielding the UES values.

3)4) NMR Group for the Pennsylvania Public Utility Commission. (2024, March). 2023 Pennsylvania Statewide Act 129 2018 Residential Baseline, Study. http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-Phase3_Res_Baseline_Study_Rpt021219.pdf.Weblink

4)5) Based on the Phase III SWE team's analysis of regional HVAC runtime data collected from ecobee's Donate Your Data research service. Based on the Phase III SWE team's analysis of regional HVAC runtime data collected from ecobee's Donate Your Data research service. https://www.ecobee.com/donateyourdata/Weblink

2.7 WHOLE HOME

2.7.1 RESIDENTIAL NEW CONSTRUCTION

Target Sector	Residential Establishments
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 that meet the following requirements:[Source 12].

- All units must be individually metered.
- Each unit must have its own residential-grade heating, cooling, and water heating equipment.
- The building must be under 6 stories.

Dwelling units must comprise at least 80% of the occupiable[83] space of the building.[84]
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 programsmeasures 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) 2015.[85]).[Source 2]

ModeledFor single-family homes and individual dwelling units, modeled energy and peak demand savings shall be produced bywith a RESNET accredited software program[86]software[Source 3] or the Passive House accreditationaccredited software packages (Passive House Planning

[83] Per ASHRAE 62.2-2010, occupiable space is any enclosed space inside the pressure boundary and intended for human activities or continual human occupancy, including, but not limited to, areas for living, sleeping, dining, and cooking, toilets, closets, halls, storage and utility areas, and laundry areas.

[84] For mixed-use buildings, exclude the retail/commercial area when determining the square footage of the building.

[85] International Code Council, Inc. (2015). 2015 International Energy Conservation Code. Retrieved from International Code Council: https://codes.iccsafe.org/content/IECC2015?site_type=public

[86] See the RESNET National Registry of Accredited Rating Software Programs for a complete listing: http://www.resnet.us/professional/programs/energy_rating_software

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Package[87]Package[Source 4] and WUFI Passive[88]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.

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For multifamily buildings, savings may be calculated by modeling the building's individual units using any approved software. Savings may also be calculated for the entire building using Passive House accreditation software, or under RESNET multifamily sampling protocols.[89]
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)

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

Peak demand savings are based on reduction in peak cooling loads. Neither the RESNET accredited software nor Passive House accreditation software allow calculations of peak demand savings for end uses other than cooling equipment, which is assumed to be active during the peak period. 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.

The 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 will beshall be calculated from the software's calculated from the software output withannual energy savings and the following algorithm:

Coincident system peak electric demand savings (kW)

Peak demand of the baseline home/unit

$$= \frac{PL_{base}}{EER_{base}}$$

[87] http://www.passivehouseacademy.com/index.php/shop-us
[88] http://www.phius.org/software-resources/wufi-passive-and-other-modeling-tools/wufi-passive-3-0
[89] At the time of publication, RESNET standards for multifamily inspection and sampling were still under development, though they are expected to be adopted before this TRM takes effect. See http://conference2018.resnet.us/data/energymeetings/presentations/How%20Standards%20are%20Evolving%20to%20Better%20Address%20Multifamily%20Ratings%20.pdf

Peak demand of the qualifying home/unit

$$= \frac{PL_{ee}}{EER_{ee}}$$

Coincident system peak electric demand savings (kW)

$\Delta kW_{peak} = (Peak\ demand\ of\ the\ baseline\ home/unit - Peak\ demand\ of\ the\ qualifying\ home/unit)$

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

$\Delta kW_{peak,winter} = \Delta kWh \times ETDF_{winter}$

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	17
kWh_{ee}, Annual energy consumption of the qualifying home/unit/building.	kWh	Software Calculated	28
PL_{base}, Estimated peak cooling load of the baseline home/unit. $ETDF_s$, Summer energy to demand factor	$kBTU/hr$ kW/kWh	Software Calculated 0.0001376	39
PL_{ee}, Estimated peak cooling load for the qualifying home/unit. $ETDF_w$, Winter energy to demand factor	$kBTU/hr$ kW/kWh	Software Calculated 0.0001967	59
EER_{base}, Energy Efficiency Ratio of the baseline unit.	$\frac{BTU}{W \cdot h}$	EDC Data Gathering Default: $-0.0228 \times SEER_{base}^2 + 1.1522 \times SEER_{base}$	4
EER_{ee}, Energy Efficiency Ratio of the qualifying unit.	$\frac{BTU}{W \cdot h}$	EDC Data Gathering Default: $-0.0228 \times SEER_{ee}^2 + 1.1522 \times SEER_{ee}$	4
$SEER_{base}$, Seasonal Energy Efficiency Ratio of the baseline unit.	$\frac{BTU}{W \cdot h}$	13 14 (ASHP)	8
$SEER_{ee}$, SEER associated with the HVAC system in the qualifying home.	$\frac{BTU}{W \cdot h}$	EDC Data Gathering	6
V_T, 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 2-128Table 2-153 and Table 2-154 4 stories and higher: See Table 2-130Table 2-156 and Table 2-131Table 2-157	

The following table lists the building envelope characteristics of the baseline reference home based on 20152021 IECC for the threetwo 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-
4A4	0.3530	0.55	0.02640	0.060 024	0.045	0.098	0.047	0.059	10, 210 4 f	
5A5	0.3230	0.55	0.02640	0.060 024	0.045	0.082	0.033	0.050	10, 210 4 f	
6A	0.32		0.55	0.026	0.045	0.060	0.033	0.050	10, ft	

Climate Region D and York County are CZ4A, Climate Region A and G are CZ6A, everything else is CZ5

Table 2-154: Residential New Construction Baseline Building Values for Buildings Less Than 4 Stories

Data Point	Value	Source
Air Infiltration Rate	53.0 ACH_{50} for the whole house	711
Duct Leakage	4 CFM_{25} (4 cubic feet per minute per 100 square feet of conditioned space when tested at 25 pascals)	711
Duct Insulation	Supply and return ducts in attics shall be insulated to a minimum ofWithin ceiling insulation: R-8 Other locations not completely inside thermal envelope: R-8 where ≥3" in diameter and a minimum of R-6 where <3" in diameter. All other ducts not located completely inside the building thermal envelope shall be insulated to a minimum of R-6 where ≥3" in diameter and a minimum of R-4.2 where <3" in diameter.	711
Duct Location	50% in conditioned space, 50% unconditioned space	Program Design
Mechanical Ventilation	A continuous whole-house ventilation system with efficiency of 2.8 CFM/Watt and airflow defined by Table M1507.3.3(1) of 2015 IRCHRV/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	1112
Lighting	Use baseline wattage as defined in the ENERGY STAR Lighting section. 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.	

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Data Point	Value	Source
Thermostat SetbackType	MaintainProgrammable, with ability to maintain zone temperature down to 55 °F (13 °C) or up to 85 °F (29 °C)	711
Temperature Set Points	Heating: 70°F Cooling: 78°F	711
Heating Efficiency		
Furnace	80% AFUE	813
Gas Fired Steam Boiler	82% AFUE	813
Gas Fired Hot Water Boiler	84% AFUE	813
Oil Fired Steam Boiler	85% AFUE	813
Oil Fired Hot Water Boiler	86% AFUE	813
Combo Water Heater	76% AFUE (recovery efficiency)	8
ASHP, GSHP, PTHP	SeeFor residential units, see New Construction values in Table 2-8Table 2-10 in Sec. 2.2.1.2.2.1. 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	SeeFor residential units, see New Construction values in Table 2-10 in Sec. 2.2.1.2.2.1. 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 Table 2-47in Table 2-61 in Sec. 2.3.12.3.1	9
Natural Gas	See volume and load dependent values in Table 2-132 155	913
Additional Water Heater Tank Insulation	None	

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Table 2-132: Baseline Insulation and Fenestration Requirements by Component for Buildings 4 Stories or Higher (Equivalent U-Factors) Source 13

	IECC Climate Zone		
Building Element	**4A**	**5A**	**6A**
Fixed Fenestration U-Factor	0.38	0.38	0.36
Operable Fenestration U-Factor	0.45	0.45	0.43
Skylight U-Factor	0.50	0.50	0.50
Roof U-Factor, Insulation entirely above roof deck	0.032	0.032	0.032
Roof U-Factor, Metal building	0.035	0.035	0.035
Roof U-Factor, Attic and other	0.027	0.027	0.027
Above Grade Wall U-Factor, Mass	0.090	0.080	0.071
Above Grade Wall U-Factor, Metal building	0.052	0.052	0.052
Above Grade Wall U-Factor, Metal framed	0.064	0.064	0.057
Above Grade Wall U-Factor, Wood framed and other	0.064	0.064	0.051
Below Grade Wall C-Factor	0.119	0.119	0.119
Floor U-Factor, Mass	0.074	0.064	0.057
Floor U-Factor, Joist/framing	0.033	0.033	0.033
Slab-on-grade Floors, F-Factor, Unheated	0.54	0.54	0.52
Slab-on-grade Floors, F-Factor, Heated	0.65	0.65	0.58

Table 2-133: Residential New Construction Baseline Building Values for Buildings 4 Stories or Higher

Data Point	Value	Source
Air Infiltration Rate	0.4 cfm/ft^2	14
Duct Insulation	Supply and return ducts and plenums shall be insulated with a minimum of R-6 insulation where located in unconditioned spaces and where located outside the building with a minimum of R-8 insulation in Climate Zone 4A and a minimum of R-12 insulation in Zones 5A and 6A. Where located within the building envelope assembly, the duct or plenum shall be separated from the building exterior or unconditioned or exempt spaces by a minimum of R-8 insulation in Climate Zone 4A and a minimum of R-12 insulation in Zones 5A and 6A.	15
Mechanical Ventilation	0.35 ACH but not less than 15 cfm/person	16
Lighting	Use baseline wattage as defined in the ENERGY STAR Lighting section.	
Appliances	Use baseline values as defined in applicable TRM measure for each appliance.	
Thermostat Setback	Maintain zone temperature down to 55 °F (13 °C) or up to 85 °F (29 °C)	7

Data Point	Value	Source
Temperature Set Points	Heating: 70°F Cooling: 78°F	7
Heating Efficiency		
Furnace	80% AFUE	8
Gas Fired Steam Boiler	82% AFUE	8
Gas Fired Hot Water Boiler	84% AFUE	8
Oil Fired Steam Boiler	85% AFUE	8
Oil Fired Hot Water Boiler	86% AFUE	8
Combo Water Heater	76% AFUE (recovery efficiency)	8
ASHP, GSHP, PTHP	See New Construction values in Table 2-8 in Sec. 2.2.1. For ductless heat pumps, use value for ASHP.	
Cooling Efficiency		
All types	See New Construction values in Table 2-8 in Sec. 2.2.1. For ductless heat pumps, use value for ASHP.	
Domestic WH Efficiency		
Electric	See volume and load dependent values in Table 2-47 in Sec. 2.3.1	9
Natural Gas	See volume and load dependent values in Table 2-132	9
Additional Water Heater Tank Insulation	None	

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Table 2-134155: 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×V_r)
	Low	38	18 ≤ FHR < 51	0.5982-(0.0019×V_r)
	Medium	55	51 ≤ FHR < 75	0.6483-(0.0017×V_r)
	High	84	FHR ≥ 75	0.6920-(0.0013×V_r)
>55 gal and ≤120 gal	Very Small	10	0 ≤ FHR < 18	0.6470-(0.0006×V_r)
	Low	38	18 ≤ FHR < 51	0.7689-(0.0005×V_r)
	Medium	55	51 ≤ FHR < 75	0.7897-(0.0004×V_r)
	High	84	FHR ≥ 75	0.8072-(0.0003×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

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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
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 °F (13 °C) or up to 85 °F (29 °C)	11
Temperature Set Points	Heating: 70°F Cooling: 78°F	11
Heating Efficiency		

Data Point	Value	Source
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
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 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		Very Small	10	0 ≤ FHR < 18	0.2674 –(0.0009×V_r)	0.5374−(0.0009 × Vr)

					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
(>75 kBtu/h and ≤105 kBtu/h and ≤ 120 gal)		Low	38	18 ≤ FHR < 51	0.5362-(0.0012×V_r)	0.8062−(0.0012 × V_r)
		Medium	55	51 ≤ FHR < 75	0.6002-(0.0011×V_r)	0.8702−(0.0011 × V_r)
		High	84	FHR ≥ 75	0.6597-(0.0009×V_r)	0.9297−(0.0009 × 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×V_r)	0.2932−(0.0015 × Vr)
		Low	38	18 ≤ FHR < 51	0.5596-(0.0018×V_r)	0.5596−(0.0018 × Vr)
		Medium	55	51 ≤ FHR < 75	0.6194-(0.0016×V_r)	0.6194−(0.0016 × Vr)
		High	84	FHR ≥ 75	0.6470-(0.0013×V_r)	0.6470−(0.0013 × 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)

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Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values.

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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

1)7) Calculation of annual energy consumption of a baseline home from the home energy rating tool based on the reference home energy characteristics.

2) Calculation of annual energy consumption of an energy efficient home from the home energy rating tool based on the qualifying home energy characteristics

3) Calculation of peak load of baseline home from the home energy rating tool based on the reference home energy characteristics.

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

5)8)Calculation of peak load of energy efficient home from the home energy rating tool based on the qualifying home energy characteristics.

6) SEER of HVAC unit in energy efficient qualifying home.

9) 2015Wilson 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. Weblink

7)11) 2021 International Energy Conservation Code §R401-R404. https://codes.iccsafe.org/content/IECC2015/chapter-4-re-residential-energy-efficiency 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.

8) 2021 International Energy Conservation Program for Consumer Products: Energy and Water Conservation Standards.” https://www.ecfr.gov/cgi-bin/retrieveECFR?&n=pt10.3.430#se10.3.430_132. Current asCode Tables C402.4 and C402.1.4. Users may choose to follow Table C402.1.3 instead of November 13, 2018.

9) US Federal Standards for Residential Water Heaters. Effective April 16, 2015. https://www.ecfr.gov/cgi-bin/retrieveECFR?n=sp10.3.430.c&r=SUBPART

10)14) 2015 International Energy Conservation Code Table R402.1.4 Equivalent U-Factors presents the R-Value requirements of Table R402.1.2 in an equivalent U-Factor format. Users may choose to follow Table R402C402.1.2 instead. 20154. 20121 IECC supersedes this table in case of discrepancy. Additional requirements per §R402C402 of 201520121 IECC must be followed even if not listed here. https://codes.iccsafe.org/content/IECC2015/chapter-4-re-residential-energy-efficiencyWeblink

11) 2015 International Residential Code, Table M1507.3.3(1): Continuous Whole-House Mechanical Ventilation System Airflow Rate Requirements. https://codes.iccsafe.org/content/IRC2015/chapter-15-exhaust-systems

12) EPA ENERGY STAR Multifamily New Construction Program Decision Tree, Version 1.4. https://www.energystar.gov/sites/default/files/asset/document/MFHR%20Flowchart_v1%204_Mar2020.pdf

13) 2015 International Energy Conservation Code Table C402.1.4 Equivalent U-Factors presents the R-Value requirements of Table C402.1.3 in an equivalent U-Factor format. Users may choose to follow Table C402.1.3 instead. 2015 IECC supersedes this table in case of discrepancy. Additional requirements per §C402 of 2015 IECC must be followed even if not listed here. https://codes.iccsafe.org/content/IECC2015/chapter-4-ce-commercial-energy-efficiency.

14) 2015 International Energy Conservation Code §C403.2.9. https://codes.iccsafe.org/content/IECC2015/chapter-4-ce-commercial-energy-efficiency.

15) 20152021 International Energy Conservation Code §C402.5. https://codes.iccsafe.org/content/IECC2015/chapter-4-ce-commercial-energy-efficiency.2 Weblink

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16) 20152021 International Energy Conservation Code §C403.12.1. Weblink

16)17) 2021 International Mechanical Code, Table 403.3.1.1: Minimum Ventilation Rates. https://codes.iccsafe.org/content/IMC2015/chapter-4-ventilation.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 131]
Vintage	New Construction

ELIGIBILITY

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ELIGIBILITY

This measure applies to manufactured homes compliant to and certified by EPA's ENERGY STAR Manufactured Home'Homes program standard, Version 3.

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ALGORITHMS

Energy and peak demand savings in the ENERGY STAR Manufactured Homes programsprogram 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.[90 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 therein."in the structure." [Source 143]

Energy savings will be calculated from the software output using the following algorithm:

Energy savings of the qualified home (kWh/yr)

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

Peak If the modeling software provides building-level outputs of hourly energy consumption (an 8760 load profile), then coincident peak demand savings are based on reduction in peak cooling loads. The RESNET accreditedmay be calculated by averaging the hourly energy savings during the TRM defined peak demand time period.

If the modeling software does not offer output to allow calculationsprovide building-level outputs of hourly energy consumption, the system peak electric demand savings for end uses other than cooling equipment, which is assumed to be active during the peak period. shall be calculated from the software's calculated annual energy savings and the following algorithm:

[90] See the RESNET National Registry of Accredited Rating Software Programs for a complete listing: http://www.resnet.us/professional/programs/energy_rating_software

Coincident system peak electric demand savings (kW)

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

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

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.2.4.1_ENERGY STAR Refrigerators. Claiming additional demand savings may require additional EDC data collection than required to generate the energy model.

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Definition of Terms

The system peak electric demand savings for will be calculated from the software output with the following algorithm:

Peak demand of the baseline home

$$= \frac{PL_{base}}{EER_{base}}$$

Peak demand of the qualifying home

$$= \frac{PL_q}{EER_q}$$

Coincident system peak electric demand savings (kW)

$\Delta kW_{peak} = (Peak\ demand\ of\ the\ baseline\ home - Peak\ demand\ of\ the\ qualifying\ home)$

Definition of Terms

Table 2-159: ENERGY STAR : Terms, Values, and References for Manufactured Homes– References

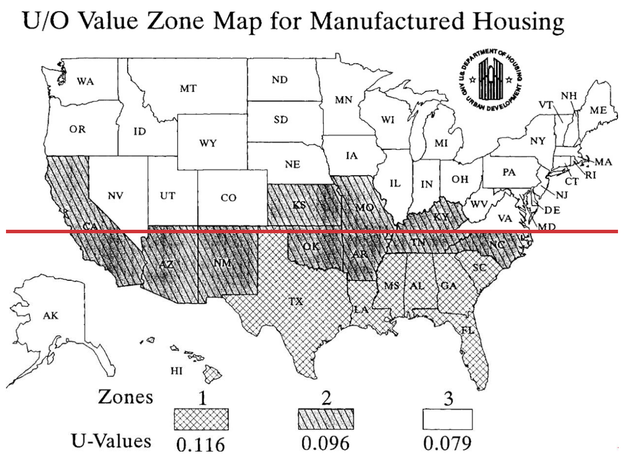
Term	Unit	Value	Sources
kWh_{base}, Estimated annual energy consumption of the baseline home	kWh	Software Calculated	1
kWh_{q}, Estimated annual energy consumption of the qualifying home	kWh	Software Calculated	1
PL_{b}, Estimated peak cooling load of the baseline home	$kBTU/h$	Software Calculated	1
PL_{q}, Estimated peak cooling load for the qualifying home.	$kBTU/h$	Software Calculated	1
EER_{b}, Energy Efficiency Ratio of the baseline unit.	$\frac{BTU}{W \cdot h}$	EDC Data Gathering Default: $-0.0228 \times SEER_{base}^{2} + 1.1522 \times SEER_{base}$	2
EER_{q}, Energy Efficiency Ratio of the qualifying unit.	$\frac{BTU}{W \cdot h}$	EDC Data Gathering Default: $-0.0228 \times SEER_{ee}^{2} + 1.1522 \times SEER_{ee}$	2
$SEER_{b}$, Seasonal Energy Efficiency Ratio of the baseline unit.	$\frac{BTU}{W \cdot h}$	13 14 (ASHP)	3
$SEER_{q}$, SEER associated with the HVAC system in the qualifying home.	$\frac{BTU}{W \cdot h}$	EDC Data Gathering	4
V_{t}, Rated storage volume of baseline water heater	gallons	EDC Data Gathering	EDC Data Gathering
Model inputs for baseline home	$Varies$	See Table 2-134133	

The HUD Code defines required insulation levels as an average envelope U_0 factor per zone. In Pennsylvania zone 3 requirements apply with a required U_0-factor of 0.079. This value cannot be directly used to define a baseline envelope R-values because the U_0-factor is dependent on both the size of the manufactured homes and insulating levels together. However, because manufactured homes are typically built to standard dimensions baseline U-factors can be estimated with reasonable accuracy.

Figure 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	
$ETDF_{peak,summer}$, Summer energy to demand factor	kW/kWh	0.0001376	4
$ETDF_{peak,winter}$, 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 2-6: Uo160: Building Thermal Envelope Requirements for Code-Compliant Baseline Requirements[91]Home[Source 5]



The HUD Code-required insulation levels can be expressed as a set of estimated envelope parameters. Using typical manufactured home sizes, these values are included below along with federal standard baseline parameters below in Table 2-134133.

	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

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[91] 24 CFR Part 3280-MANUFACTURED HOMES CONSTRUCTION AND SAFETY STANDARD (http://www.gpo.gov/fdsys/pkg/CFR-2013-title24-vol5/pdf/CFR-2013-title24-vol5-part3280.pdf)

Table 2-161: ENERGY STAR Manufactured Homes - User Defined Reference: Values and References for Code-Compliant Baseline Home

Data Point	Value[92]	Source
Walls	U-factor 0.090	6, 7
Ceilings	U-factor 0.045	6, 7
Floor	U-factor 0.045	6, 7
Windows	U-factor 0.59	6, 7
Doors	U-factor 0.33	6, 7
Air Infiltration Rate	10 ACH50	6
Duct Leakage	Approved model package default	6
Duct Insulation	Approved model package default	6
Duct Location	Supply 100% manufactured home belly, Return 100% conditioned space	8
Data Point	**Value**	**Source**
Air Infiltration Rate	5 ACH50	6
Mechanical Ventilation	0.035 CFM/ft² Exhaust	7
Lighting	Use baseline wattage as defined in the ENERGY STAR Lighting section.	
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 ft² 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 Setback	Non-Programmable thermostat	6
Temperature Set Points	Heating: 70°F Cooling: 78°F	10
Thermostat Type	Programmable, with ability to maintain zone temperature down to 55 °F (13 °C) or up to 85 °F (29 °C)	9
Temperature Set Points	Heating: 70°F Cooling: 78°F	9
Heating Efficiency		
Furnace	80% AFUE	3
Gas Fired Steam Boiler	82% AFUE	3

[92] Single and multiple family as noted.

Data Point	Value[92]	Source
Gas Fired Hot Water Boiler	84% AFUE	3
Oil Fired Steam Boiler	85% AFUE	3
Oil Fired Hot Water Boiler	86% AFUE	3
Combo Water Heater	76% AFUE (recovery efficiency)	3
Electric Resistance	3.412 HSPF	7
ASHP, GSHP, PTHP, Ductless heat pump	See New Construction values in Table 2-8 in Sec. 2.2.1. For ductless heat pumps, use value for ASHP.	
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 2-8 in Sec. 2.2.1. For ductless heat pumps, use value for ASHP.	
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 2-47Table 2-61 in Sec. 2.3.12.3.1	11
Natural Gas	See volume and load dependent values in Table 2-132 155 in Sec. 2.7.12.7.1	11
Additional Water Heater Tank Insulation	None	12
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

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EVALUATION PROTOCOLS

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

Sources

1) Calculation of annual energy and peak load consumption of a baseline home from the home energy rating tool based on the reference home energy characteristics.

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

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.

3)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." https://www.ecfr.gov/cgi-bin/retrieveECFR?&n=pt10.3.430#se10.3.430_132Weblink. Current as of November 13, 2018..

4) SEER of HVAC unit in energy efficient qualifying home.

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

6) ENERGY STAR QUALIFIED MANUFACTURED HOMES-Guide for Retailers with instructions for installers and HVAC contractors / June 2007 / (http://www.research-alliance.org/pages/es_retail.htm)

7) Electronic Code of Federal Regulations, 24 CFR Part 3280, Manufactured Home Construction and Safety Standards. https://www.ecfr.gov/cgi-bin/retrieveECFR?&n=pt24.5.3280 Accessed November 16, 2018.

8) Standard manufactured home construction

9) Not a requirement of the HUD Code.

10) 2015 International Energy Conservation Code §R401-R404.

11) US Federal Standards for Residential Water Heaters. Effective April 16, 2015. https://www.ecfr.gov/cgi-bin/retrieveECFR?n=sp10.3.430.c&r=SUBPART

12) No requirement in code or federal regulation.

13) NREL, Northwest Energy Efficient Manufactured Housing Program Specification Development, T.Huges, B. Peeks February 2013. http://www.nrel.gov/docs/fy13osti/56761.pdf

11) ENERGY STAR Manufactured New Homes National Program Requirements, Version 3 (Rev. 01). Weblink

2.7.3 Home Energy Reports

Target Sector	Residential Establishments
Measure Unit	Household
Measure Life	Specified in protocol
Vintage	Retrofit

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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. This multi-year persistence perspective is a departure from prior phases of Act 129, which assumed a 1-year measure life for HER programs.

Because Act 129 goals are based on first-year incremental savings, accounting for persistence will yield reducedreduces 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 of decay, consider a hypothetical cohort of 20,000 treatment group homes that have been receiving HERs for two years. Table 2-135134Table 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

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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.

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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 2-136135Table 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 2-136135Table 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 IVV of Act 129. Several assumptions that straddle technical and policy considerations are listed below.

1) The change in perspective from a 1-year EUL to a multi-year with decay approach creates an issue of unaccounted for lifetime savings from Phase III HER programs. Specifically, HER cohorts that were active in PY12 will be assumed to have persistent savings in PY13 even though persistent savings were not accounted for in Phase III TRC calculations. This is unavoidable with a change in accounting methods and best handled at the beginning of a Phase IV. It has no bearing on Phase III compliance savings.

2)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 IVV of Act 129, new HER cohorts will continue to assume a 1-year EUL during the first year of HER exposure. The persistence and decay assumptions outlined in this protocol will take effect for Year 2 of exposure. Years of exposure are mapped to Act 129 program years. If a cohort begins receiving HER messaging in December (halfway through the program year), that program year is still Year 1, and the following program year is Year 2 with regard to application of persistence assumptions.

3)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.

4)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.

5)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:

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$$\Delta kWh_y = ATE_y * Treatment\ Accounts_y * Days_y$$

$$FYSATE_y = ATE_y$$

$$\Delta kWh_y = ATE_y * Treatment\ Accounts_y * Days_y$$

$$FYSATE_y = ATE_y$$

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 3rd third year or beyond the equation for incremental first-year savings is:

Year 3 of HER Exposure:

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$$FYSATE_y = ATE_y - \sum_{x=1}^{x=1} FYSATE_{y-x} - FYSATE_{y-x} * Decay * (X - 0.5)$$

$$\Delta kWh_y = FYSATE_y * Treatment\ Accounts_y * Days_y$$

$$FYSATE_y = ATE_y - \sum_{x=1}^{x=1} FYSATE_{y-x} - FYSATE_{y-x} * Decay * (X - 0.5)$$

$$\Delta kWh_y = FYSATE_y * Treatment\ Accounts_y * Days_y$$

Year 4 of HER Exposure:

$$FYSATE_y = ATE_y - \sum_{x=1}^{x=2} FYSATE_{y-x} - FYSATE_{y-x} * Decay * (X - 0.5)$$

$$\Delta kWh_Y = FYSATE_y * Treatment\ Accounts_y * Days_y$$

$$FYSATE_y = ATE_y - \sum_{x=1}^{x=2} FYSATE_{y-x} - FYSATE_{y-x} * Decay * (X - 0.5)$$

$$\Delta kWh_Y = FYSATE_y * Treatment\ Accounts_y * Days_y$$

Year 5 and Beyond of HER Exposure:

$$FYSATE_y = ATE_y - \sum_{x=1}^{x=3} FYSATE_{y-x} - FYSATE_{y-x} * Decay * (X - 0.5)$$

$$\Delta kWh_Y = FYSATE_y * Treatment\ Accounts_y * Days_y$$

$$FYSATE_y = ATE_y - \sum_{x=1}^{x=3} FYSATE_{y-x} - FYSATE_{y-x} * Decay * (X - 0.5)$$

$$\Delta kWh_Y = FYSATE_y * Treatment\ Accounts_y * Days_y$$

Where $FYSATE_y$ is the average daily savings attributable to HERs delivered in year Y and $FYSATE_{y-x}$ 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):

$$\Delta kWh_{Y,lifetime} = ATE_Y * Treatment\ Accounts_Y * Days_Y$$

$$\Delta kWh_{Y,lifetime} = ATE_Y * Treatment\ Accounts_Y * Days_Y$$

Year 2 and Beyond of HER Exposure (where Y >= 2):

$$\Delta kWh_{Y,lifetime} = \Delta kWh_Y + \sum_{X=1}^{X=3} \left(\left(FYSATE_Y - FYSATE_Y * Decay * (X - 0.5) \right) * (1 - Churn)^X \right) * Days_{Y+X} * Treatment\ Accounts_Y$$

$$\Delta kWh_{Y,lifetime} = \Delta kWh_Y + \sum_{X=1}^{X=3} \left(\left(FYSATE_Y - FYSATE_Y * Decay * (X - 0.5) \right) * (1 - Churn)^X \right) * Days_{Y+X} * Treatment\ Accounts_Y$$

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

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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 = 488kWh488 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	

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Evaluation Protocols

This protocol deals with the measure life and persistence aspects of HER programs. Chapter 6.1 of the Pennsylvania Evaluation Framework provides detailed guidance on other aspects of HER evaluation protocols.

Sources

1) Pennsylvania Statewide Evaluation Team. Residential Behavioral Program Persistence Study. http://www.puc.state.pa.us/Electric/pdf/Act129/SWE_Res_Behavioral_Program-Persistence_Study_Addendum2018.pdfWeblink

2) SWE Analysis of average annual churn rate among Phase III EDC cohorts.

cohort

2.8 MISCELLANEOUS

2.8.1 VARIABLE SPEEDENERGY STAR POOL PUMPS

Target Sector	Residential Establishments
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, EDC's 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.

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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 from https://www.caetrm.com/measure/SWRE002/01/
2) U.S. EPA. (2020). ENERGY STAR Pool Pump Calculator. Retrieved July 31, 2020 from https://www.energystar.gov/productfinder/downloads/Pool_Pump_Calculator_2020.05.05_FINAL.xlsx
3) U.S. DOE. (2017). 10 CFR 431.465(f). Retrieved February 4, 2022 from https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-431/subpart-Y/section-431.465#p-431.465(f)
4) U.S. EPA. (2021). ENERGY STAR Program Requirements for Pool Pumps Version 3.1.Retrieved February 4, 2022 from https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%203.1%20Pool%20Pumps%20Final%20Specification_0.pdf
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 from https://codes.iccsafe.org/content/ISPSC2018/chapter-8-permanent-inground-residential-swimming-pools#ISPSC2018_Ch08_Sec810.1
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 from https://calwep.org/wp-content/uploads/2021/03/Pools-Spas-and-Fountains-PBMP-2010.pdf
9) International Swimming Pool and Spa Code. (2015). Section 704.4. Accessed February 4, 2022. https://codes.iccsafe.org/content/ISPSC2018/chapter-7-onground-storable-residential-swimming-pools#ISPSC2018_Ch07_Sec704.4
10) U.S. EPA. (2013). ENERGY STAR Pool Pump Calculator. Retrieved July 31, 2020 from https://web.archive.org/web/20170427214700/https://www.energystar.gov/sites/default/files/asset/document/Pool%20Pump%20Calculator.xlsx

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11) Southern California Edison. (2008). Pool Pump Demand Response Potential: Demand and Run-time Monitored Data. Retrieved February 4, 2022 from https://www.etcc-ca.com/sites/default/files/reports/dr07_01_pool_pump_demand_response_potential_report.pdf
Average percentage of all pumps operating during peak hours in Table 16.

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2.8.2 Single Speed Pool Pump Replacement

Target Sector	Residential
Measure Unit	VFD Pool Pumps
Measure Life	~~10~~3.3 years Source ~~2~~1
Vintage	Early Replacement
~~Vintage~~	~~Replace on Burnout~~

In this measure a variable speed pool pump must be purchased and installed on a residential pool to replace an existing ~~constant~~ 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 ~~pump power and pump energy usage scale with the cubic and quadratic powers of the flow rate respectively. Additional savings are achieved because VFD pool pumps typically employ premium efficiency motors.~~ 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.

~~Most VFD pool pumps can display instantaneous flow and power.~~

Algorithms

This protocol documents the energy savings attributed to variable frequency drive pool pumps in various pool sizes. ~~The target sector primarily consists of single-family residences. There are no demand savings for this measure~~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.

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

$$kWh_{base} = kW_{ss} \times HOU_{ss} \times Days$$

$$kWh_{VFD} = \frac{Volume \times Turnover}{EF_{VFD,Weighted} \times 1{,}000\frac{W}{kW}} \times Days$$

$$\Delta kWh = \frac{Volume \times Turnover \times Days}{1{,}000} \times \left(\frac{1}{EF_{base}} - \frac{1}{WEF_{CFR}}\right)$$

$$\Delta kW = \left(kW_{ss} - \frac{kWh_{VFD}}{(HOU_{VFD} \times Days)}\right) \times CF$$

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$$HOU_{SS} = Volume \times Turnover \div (Flow_{SS} \times 60\ \frac{min}{hr})$$

VFD pump sizing algorithm to determine $EF_{VFD,Weighted}$ using Table 2-140. Select the pump with the smallest $Flow_{VFD,Low}$ that satisfies calculated flow requirements:

$$Flow_{VFD,Low} = Volume \div \left({HOU_{VFD}}/{Turnover} \times 60\ \frac{min}{hr} \right)$$

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Definition of Terms

Table 2-138: Terms, Values, and References for Variable Speed Pool Pumps

$$\Delta kW_{summer} = \frac{Volume \times Turnover}{1,000} \times \left(\frac{CF_{base}}{EF_{base} \times HOU_{base}} - \frac{CF_{CFR}}{WEF_{CFR} \times HOU_{CFR}}\right)$$

Term	Unit	Values	Source
HOU_{SS} , Hours of operation per day for Single speed pump. This quantity should be recorded by the applicant.	$\frac{hours}{day}$	EDC Data Gathering Default = 9.7 or Calculated	1
kW_{SS} , Electric demand of single speed pump for Curve C flow rate. This quantity should be recorded by the applicant or looked up in Table 2-139 by horsepower.	Kilowatts	EDC Data Gathering Default =1.803 kW or See Table 2-139	1
Days , Pool pump days of operation per year.	$\frac{days}{yr}$	122 (4 months)	1
$EF_{VFD,Weighted}$, Weighted energy factor of variable frequency drive pump for Curve C flow. This quantity should be recorded by the applicant or looked up in Table 2-140 by horsepower.	$\frac{gallons}{W \cdot h}$	EDC Data Gathering or See Table 2-140, selecting smallest pump that meets $Flow_{VFD,Low}$	1
Volume, pool capacity	Gallons	EDC Data Gathering Default = 22,000	1
Turnover, number of times the full volume of the pool is filtered each day	$\frac{Pool\ volumes}{day}$	EDC Data Gathering Default = 2	1
$Flow_{SS}$, Single speed pump flow rate	$\frac{gallons}{minute}$	Table 2-139 Default=78	1
$Flow_{VFD,Low}$, Variable frequency drive pump low flow rate	$\frac{gallons}{minute}$	EDC Data Gathering Default= Calculated	1
HOU_{VFD}, *Hours of operation per day for variable frequency drive pool pump*	$\frac{hours}{day}$	EDC Data Gathering Default=24	1
CF,	None	EDC Data Gathering Default = 0.31	3

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Average Single Speed Pump Electric Demand

Since this measure involves functional pool pumps, actual measurements of pump demand are encouraged. If this is not possible, then the pool pump power can be inferred from the nameplate horsepower. Table 2-1392-139 shows the average electrical power demand per pump size in the Savings Calculator for an ENERGY STAR Certified Inground Pool Pump.[Source 1] Note that kW_{ss} = $Flow_{ss}$ × 60 min/hr ÷ (EF_{ss} × 1,000 W/kWh).

$$HOU_{base} = Volume \times Turnover \div (Flow_{base} \times 60 \frac{min}{hr})$$

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Definition of Terms

Table 2-171: SingleTerms, Values, and References for Variable Speed Curve C Pool Pump Specification[93]Pumps

Nameplate Power (HP)Term	EF_{ss} (Gal/Wh)Unit	$Flow_{ss}$ (GPM)Values	kW_{SS}Source
0.50*Days*, Pool pump days of operation per year.	3.4 $\frac{days}{yr}$	62.00EDC Data Gathering Default: Table 2-174	1.1012
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
0.75*WEF_CFR*, Weighted energy factor of federal minimum compliant variable frequency drive pump for Curve C flow.	3.3 $\frac{gallons}{W \cdot h}$	65.00EDC Data Gathering Default: Table 2-173 or Table 2-174	1.1853
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
1.00*Days*, Pool pump days of operation per year.	2.5*Days*	75.50122 (4 months)	1.803
1.50*Flow_base*, Single speed pump flow rate	2.3 $\frac{gallons}{minute}$	Table 2-172 Default=78.14	2.068
2.00*HOU_base*, Hours of operation per day for base case single-speed frequency drive pool pump	2.3 $\frac{hours}{day}$	89.67EDC Data Gathering Default: Table 2-174	2.314
2.50*HOU_CFR*, Hours of operation per day for variable frequency drive pool pump	2.2 $\frac{hours}{day}$	93.09EDC Data Gathering Default: 24	2.561
3.00*CF_base*, Coincidence factor of existing pool pump	2.0*None*	101.67EDC Data Gathering Default: Table 2-174	3.0529
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

[93] Averaged for all listed single-speed pumps in the last available version of the CEC appliance efficiency database. The powers are for 'CEC Curve A,' which represents hydraulic properties of 2" PVC pipes rather than older, 1.5" copper pipes.

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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: VariableSingle Speed Curve C Pool Pump Specification[94]Efficiency Factors Source 2

Hydraulic Horsepower (Nameplate Power at High Speed)	$Flow_{VFD,Low}$ (GPM)	$Flow_{VFD,High}$ (GPM)	$EF_{VFD,Weighted}$ (Gal/Wh)					
0.72 hhp (1-1.4 HP)	40.33	70.00	8.7					
0.95 hhp (1.65 Nameplate Power (HP)	0.50	410.75	781.00	8.91.50	2.00	2.50	3.00	
1.18 hhp (2 HP)	44.75	89.71	9.3					
EF_{base} (Gal/Wh)	3.38	3.29	1.25 hhp (2.5 HP)51	45.672.27	2.3	2.18	902.00	7.4
1.65 hhp (3 HP)Flow (Gal/min)	5162.00	10265.00	7.175.50	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 1 HP motor are as follows:

ΔkWh = 1,517 kWh

ΔkW = 0.4936 kW

[94] Averaged for all listed single-speed pumps in the last available version of the CEC appliance efficiency database. The powers are for 'CEC Curve A,' which represents hydraulic properties of 2" PVC pipes rather than older, 1.5" copper pipes.

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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.

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Sources

1) California Electronic Technical Reference Manual: (2019). "VSD for Pool & Spa Pump". California Technical Forum. Retrieved February 4, 2022 from https://www.caetrm.com/measure/SWRE002/01/

1)2)U.S. EPA. (2020). ENERGY STAR Pool Pump Calculator. May 5, 2020. *HOU*ss is for a 22,000 gallon pool with a 15 HP pump and 2 turnovers per day.Retrieved July 31, 2020 from https://www.energystar.gov/productfinder/downloads/Pool_Pump_Calculator_2020.05.05_FINAL.xlsx

3) U.S. DOE. (2017). 10 CFR 431.465(f). Retrieved February 4, 2022 from https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-431/subpart-Y/section-431.465#p-431.465(f)

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.

2) International Swimming Pool and Spa Code. (2015). California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx.

3) Derived from values for 2pm-6pm for all pool pumps in Pool Pump and Demand Response Potential, DR 07.01 Report, SCE Design and Engineering, Table 16. https://www.etcc-ca.com/sites/default/files/reports/dr07_01_pool_pump_demand_response_potential_report.pdf

5) Section 810.1. Retrieved February 4, 2022 from https://codes.iccsafe.org/content/ISPSC2018/chapter-8-permanent-inground-residential-swimming-pools#ISPSC2018_Ch08_Sec810.1

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 from https://calwep.org/wp-content/uploads/2021/03/Pools-Spas-and-Fountains-PBMP-2010.pdf

8) International Swimming Pool and Spa Code. (2015). Section 704.4. Accessed February 4, 2022. https://codes.iccsafe.org/content/ISPSC2018/chapter-7-onground-storable-residential-swimming-pools#ISPSC2018_Ch07_Sec704.4

9) Southern California Edison. (2008). Pool Pump Demand Response Potential: Demand and Run-time Monitored Data. Retrieved February 4, 2022 from https://www.etcc-ca.com/sites/default/files/reports/dr07_01_pool_pump_demand_response_potential_report.pdf *Average percentage of all pumps operating during peak hours in Table 16.*

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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.

$$System\ Losses = Default\ Model\ Losses + In\text{-}situ\ Losses$$

$$\Delta kWh = Provided\ by\ PV\ Watts$$

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

$$ETDF_{summer} = ETDF_{summer,ordinal} + (\Delta Azimuth * ETDF_{summer,incremental})$$

$$\Delta Azimuth = Difference\ between\ PV\ array\ azimuth\ and\ closest,\ smaller\ ordinal\ direction\ (90,\ 135,\ 180,\ or\ 225)$$

$$\Delta kW_{peak,winter} = \Delta kWh \times ETDF_{winter}$$

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$$ETDF_{winter} = ETDF_{winter,ordinal} + (\Delta Azimuth * ETDF_{winter,incremental})$$

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}	15%	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

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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

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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

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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.

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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 IVV demand reduction targets. In some instances, the analysis may be carried out at the individual customer level, however, the outcome of interest is the aggregate load reduction (MW) that is caused by the program.

2.9.1 Direct Load Control and Behavior-Based Demand Response Programs

Target Sector	Residential Establishments
Measure Unit	N/A
Measure Life	Direct Load Control: 11 years Behavioral DR: 1 year
Measure Vintage	N/A

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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 IVV. In these programs, residential and small commercial customers either allow EDCs to remotely reduce equipment run time during peak hours (DLC programs) or reduce their loads voluntarily in response to a combination of incentive payments, messaging and/or other behavioral stimuli.

Behavior-based demand response programs are ones that have a goal of reducing electric load during peak load hours. Examples of behavior-based demand response programs include utility programs that request customers to reduce electric loads during peak load hours voluntarily, programs where customers are provided with real-time information on the cost of electricity and can then take action voluntarily to reduce electric loads during high- -cost hours and other similar information programs. For purposes of the Pennsylvania TRM, behavior-based demand response programs do not include utility information programs that are based on consumer education or marketing and have a goal of reducing electricity use on a year- -round basis, including non-peak load hours.

For DLC programs, the participants may elect to receive incentive payments for allowing a signaled device to control or limit the power draw of certain HVAC, electric water heating, or swimming pool pump equipment at a participant's home, contributing to the reduction of peak demand. For measurement purposes, peak demand reductions are defined as the difference between a customer's actual (measured) electricity demand, and an estimate of the amount of electricity the customer would have demanded in the absence of the program incentive. The estimate of this counterfactual outcome is referred to as the reference load throughout this protocol.

EDCs must use one of the evaluation approaches below when estimating peak period load reductions that result from DLC and behavior-based programs. The approaches are not equivalent in terms of their ability to produce accurate and robust results and are therefore listed in descending order of desirability. Because of these differences in performance, EDCs shall use Option 2 only under circumstances when Option 1 is infeasible and shall similarly use Option 3 only under circumstances where both Option 1 and Option 2 are infeasible. In situations where Option 1 and/or

2 are not utilized, justification(s) must be provided by the EDC. EDCs with interval meter data available should use it to estimate load impacts. For DLC and behavior-based programs where advanced metering infrastructure (AMI) data is not available for all participants, estimates based on a sample of metered homes is permissible at the discretion of the SWE.

1) An analysis based on an experimental design that makes appropriate use of random assignment so that the reference load is estimated using a representative control group of program participants.[95] The most common type of design satisfying this criteriacriterion is a randomized control trial (RCT), but other designs may also be used. The specific design used can be selected by the EDC evaluation contractor based on their professional experience. It is important to note that experimental approaches to evaluation generally require the ability to call events at the individual device level. An operations strategy must be determined ahead of time in order to ensure that an appropriate control group is available for the analysis.

2) A comparison group analysis where the loads of a group of non-participating customers that are similar tolike 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.[96] Similarly, if winter events are most likely to be fall 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[97] (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 coolermild 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 estimatingestimation sample to relevant days reduces that modeling challenge, or a 'day-matching' technique with a day-of or weather adjustment to account for the more extreme conditions in place on event days. .

3) 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.

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ELIGIBILITY

In order toTo be eligible for thea 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.

[95] For discussion on the rationale of random assignment, see Shadish, et al. (*Experimental and quasi-experimental designs for generalized causal inference*, 2002), Khandker, et al. (*Handbook on impact evaluation: quantitative methods and practices*. World Bank Publications, 2010) and Todd, et al. (Evaluation, measurement and verification (EM&V) of residential behavior-based energy efficiency programs: issues and recommendations, 2012). More detailed technical discussions of the core evaluation issues and Options 1-3 are provided in the Phase III Evaluation Framework.

[96] Though including some amount of variability in temperatures is necessary for identifying the relationship between temperature and load, including too broad a spectrum of temperatures can reduce modeling accuracy due to the non-linear relationship between the variables. Focusing on hot, event-like days helps to isolate a linear piece of the relationship and enhances the ability of the model to predict accurately.

[97] Either Act 129 or PJM.

All residential and small commercial customers are eligible to participate in the behavior-based program.

ALGORITHMS

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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. ~~Equations 1 and 2~~The following equations provide mathematical definitions of the average peak period load impact estimate that would be calculated using an approved method.

$$\Delta kW_{peak} = \frac{\sum_{i=1}^{n} \Delta kW_i}{n}$$

$$\Delta kW_{summer\ peak} = \frac{\sum_{i=1}^{n\_summer} \Delta kW_i}{n\_summer}$$

~~(1)~~

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$$\Delta kW_{winter\ peak} = \frac{\sum_{i=1}^{n\_winter} \Delta kW_i}{n\_winter}$$

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$$\Delta kW_i = kW_{Reference_i} - kW_{Metered_i}$$

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.

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