

**TECHNICAL REFERENCE MANUAL**

**Volume 2:**

**Residential Measures**

**April 2019**

**State of Pennsylvania**

**Act 129** Energy Efficiency and Conservation Program

&

**Act 213** Alternative Energy Portfolio Standards

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# Residential Measures

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

## Lighting

### ENERGY STAR Lighting

|  |  |
| --- | --- |
| **Target Sector** | Residential Establishments |
| **Measure Unit** | Light Bulb or Fixture |
| **Measure Life** | LED: 15 years[[1]](#footnote-2) |
| **Vintage** | Replace on Burnout (Upstream) Early Replacement (Direct Install) |

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

Eligibility

Definition of Efficient Equipment

In order for this measure protocol to apply, the high-efficiency equipment must be a screw-in ENERGY STAR LED bulb (general service or specialty bulb) or LED fixture.[[2]](#footnote-3)

Definition of Baseline Equipment

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

Algorithms

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

Total Savings =

Energy and demand savings algorithms include a term to account for cross-sector sales (i.e., lamps that end up in non-residential use). Default values for non-residential terms are based on values in Vol. 3, Sec. 3.1.7 Lighting Improvements for Midstream [[WEBSITE LINK TBD](http://www.puc.pa.gov/)]. 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.

Definition of Terms

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

| **Term** | **Unit** | **Value** | **Sources** |
| --- | --- | --- | --- |
| *Wattsbase*, Wattage of baseline case lamp/fixture | *Watts* | EDC Data Gathering[[3]](#footnote-4) or see Baseline Wattage Values below | 1 |
| *WattsEE*, Wattage of efficient case lamp/fixture | *Watts* | EDC Data Gathering | EDC Data Gathering |
| *HOUres*, Average hours of use per day per unit installed for residential use |  | Table 2‑2 | 2 |
| *HOUnon-res*, Average hours of use per day per unit installed for non-residential use |  | EDC Data Gathering  Default = 2,500 | 5 |
| *IEkWh,res* , HVAC Interactive Effect for LED energy for residential use | *None* | EDC Data Gathering  Default = Table 2‑3  Exterior Fixtures: 0% | 3 |
| *IEkW, res*, HVAC Interactive Effect for LED demand for residential use | *None* | EDC Data Gathering  Default =Table 2‑3  Exterior Fixtures: 0% | 3 |
| *IEkWh,non-res* , HVAC Interactive Effect for LED energy for non-residential use | *None* | EDC Data Gathering  Default = 0% | 5 |
| *IEkW,non- res*, HVAC Interactive Effect for LED demand for non-residential use | *None* | EDC Data Gathering  Default = 19.2% | 5 |
| *ISRres*, In-service rate per incented product for residential use | *%* | EDC Data Gathering[[4]](#footnote-5),  Default = 92%[[5]](#footnote-6) | 4 |
| *ISRnon-res*, In-service rate per incented product for non-residential use | *%* | EDC Data Gathering,  Default = 98% | 5 |
| *CFres*, Demand Coincidence Factor for residential use | *Proportion* | Table 2‑2 | 2 |
| *CFnon-res*, Demand Coincidence Factor for non-residential use | *Proportion* | EDC Data Gathering,  Default = 0.60 | 5 |
| *CSS*, Cross-sector sales. Share of incentivized lamps that go to non-residential uses. | *%* | EDC Data Gathering,  Default = 7.4% | 6 |

Variable Input Values

Baseline Wattage Values

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

,

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

For direct installation programs where the removed bulb is known, and the bulb is in working condition, EDCs may use the wattage of the replaced bulb in lieu of the formula.[[6]](#footnote-7) For bulbs with lumens outside of the lumen bins provided, EDCs should use the manufacturer rated comparable wattage as the Wattsbase.

**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 (HOUres) and coincidence factors (CFres) are below in Table 2‑2. The “all bulbs” HOUres should be used for programs where it is known that the majority (> 90% or entirety) of the home’s sockets are retrofited 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 HOUres and CFres. Specific room-based HOUres and CFres may be used for programs where the room-type of installation is known and recorded, otherwise the whole house or unknown room value should serve as the estimate.

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

| **Room** | **Efficient HOUres** | **Efficient CFres** | **All Bulbs HOUres** | **All bulbs CFres** |
| --- | --- | --- | --- | --- |
| Basement | 1.4 | 0.035 | 1.7 | 0.066 |
| Bathroom | 2.8 | 0.105 | 2.3 | 0.096 |
| Bedroom | 2.3 | 0.073 | 1.8 | 0.064 |
| Closet | 1.2 | 0.038 | 0.6 | 0.029 |
| Dining Room | 3.2 | 0.118 | 2.7 | 0.108 |
| Exterior | 4.4 | 0.274 | 3.9 | 0.265 |
| Hallway | 2.4 | 0.085 | 1.9 | 0.076 |
| Kitchen | 4.4 | 0.150 | 3.9 | 0.142 |
| Living Room | 4.1 | 0.106 | 3.7 | 0.098 |
| Other | 2.1 | 0.070 | 1.7 | 0.061 |
| Overall Household or unknown room | 3.0 | 0.106 | 2.5 | 0.101 |

**Interactive Effects Values**

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

Table 2‑3: Energy and Demand HVAC Interactive Effects by EDC[[7]](#footnote-8)

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

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework[[8]](#footnote-9) provides specific guidelines and requirements for evaluation procedures.

Sources

1. EISA standards require efficacy of 45 lumens/watt. <https://www.energy.gov/sites/prod/files/2017/01/f34/gsl-irl-finalrule_2016-12-29_0.pdf>
2. Statewide Evaluation Team (GDS Associates, Inc, Nexant, Research into Action, Apex Analytics LLC), “2014 Commercial & Residential Light Metering Study”, January 13, 2014. Based on data derived from Tables 1-2 & 1-3 but exclusive of inefficient bulbs
3. GDS Simulation Modeling, September-November 2013. PECO values are based on an analysis of PY4 as performed by Navigant.
4. The ISR is based on an installation rate “trajectory” and includes savings for all program bulbs that are believed to be installed within three years of purchase as established in the DOE Uniform Methods Project (UMP), Chapter 6: Residential Lighting Evaluation Protocol. October 2017. This protocol estimates the three-year ISR based on a researched first year ISR. For the purposes of this TRM, a 79% first year ISR was used based on intercept surveys conducted in the PECO service territory (Navigant Consulting, Inc. “Final Annual Report to the Pennsylvania Public Utility Commission. Prepared for PECO. Program Year 5”. November, 2014.)
5. See Pennsylvania TRM Vol. 3, Sec. 3.1.7 Lighting Improvements for Midstream. [[WEBSITE LINK TBD](http://www.puc.pa.gov/)]
6. Based on a savings-weighted average of EDC-reported cross-sector sales values for PY6-PY9. [[WEBSITE LINK TBD](http://www.puc.pa.gov/)]

### Residential Occupancy Sensors

|  |  |
| --- | --- |
| **Target Sector** | Residential Establishments |
| **Measure Unit** | Occupancy Sensor |
| **Measure Life** | 10 yearsSource 3 |
| **Vintage** | Retrofit |

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

Eligibility

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

Algorithms

ΔkWpeak = 0

Definition of Terms

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

|  |  |  |  |
| --- | --- | --- | --- |
| **Term** | **Unit** | **Value** | **Source** |
| *Wattscontrolled*, Wattage of the fixture(s) being controlled by the occupancy sensor | *W* | EDC Data Gathering  Default = 105.5 W | EDC Data Gathering |
| *RHold*, Daily run hours before installation | *Hours* | 2.5 | 1 |
| *RHnew*, Daily run hours after installation | *Hours* | 1.75 (70% of RHold) | 2 |

Deemed Savings

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

Evaluation Protocols

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

Sources

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

### LED and Electroluminescent Nightlights

|  |  |
| --- | --- |
| **Target Sector** | Residential Establishments |
| **Measure Unit** | Nightlight |
| **Measure Life** | 8 yearsSource 1 |
| **Vintage** | Replace on Burnout |

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

Eligibility

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

Algorithms

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

ΔkWpeak = 0 (assumed)

Definition of Terms

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

| **Term** | **Unit** | **Value** | **Sources** |
| --- | --- | --- | --- |
| , Watts per baseline nightlight | *Watts* | EDC Data Gathering  Default = 7 | 1 |
| , Watts per efficient nightlight | *Watts* | EDC Data Gathering  Default values:  LED = 1  Electroluminescent = 0.03 | 2 |
| , Daily hours of use for baseline nightlight |  | 12 | 1 |
| , Daily hours of use for efficient nightlight |  | LED = 12  Electroluminescent = 24 | 3 |
| *ISRNL*, In-Service Rate per efficient nightlight | *None* | EDC Data Gathering  Default = 0.20 | 4 |

Deemed Energy Savings

LED ΔkWh

Electroluminescent ΔkWh

Evaluation Protocols

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

Sources

1. Southern California Edison Company, “LED, Electroluminescent & Fluorescent Night Lights”, Work Paper WPSCRELG0029 Rev. 1, February 2009, pp. 2–3.
2. Limelite Equipment Specification. Personal Communication, Ralph Ruffin, EL Products, 512-357-2776/ ralph@limelite.com.
3. Electroluminescent nightlights are assumed to operate continuously.
4. Based on ISR rates reported by First Energy for nightlights in kits for PY9. See [[WEBSITE LINK TBD](http://www.puc.pa.gov/)]

### Holiday Lights

|  |  |
| --- | --- |
| Target Sector | Residential Applications |
| Measure Unit | One 25-bulb Strand of Holiday lights |
| Measure Life | 10 yearsSource 1, 2 |
| Vintage | Replace on Burnout |

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

Eligibility

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

Algorithms

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

**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.

Definition of Terms

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

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | **Unit** | **Value** | **Source** |
| *LEDmini*, Wattage of LED mini bulbs | *Watts/Bulb* | 0.08 | 1 |
| *INCmini*, Wattage of incandescent mini bulbs | *Watts/Bulb* | 0.48 | 1 |
| *LEDC7* , Wattage of LED C7 bulbs | *Watts/Bulb* | 0.48 | 1 |
| *INCC7*, Wattage of incandescent C7bulbs | *Watts/Bulb* | 6.0 | 1 |
| *LEDC9*, Wattage of LED C9 bulbs | *Watts/Bulb* | 2.0 | 1 |
| *INCC9*, Wattage of incandescent C9 bulbs | *Watts/Bulb* | 7.0 | 1 |
| *%Mini ,* Percentage of holiday lights that are “mini” | *%* | 50% | 1 |
| *%C7 ,* Percentage of holiday lights that are “C7” | *%* | 25% | 1 |
| *%C9 ,* Percentage of holiday lights that are “C9” | *%* | 25% | 1 |
| *#Bulbs*, Number of bulbs per strand | *Bulbs/strand* | EDC Data Gathering  Default: 50 per strand | 3 |
| *#Strands*, Number of strands of lights per package | *strands/package* | EDC Data Gathering  Default: 1 strand | 3 |
| *HOU* , Annual hours of operation | *Hours/yr* | 150 | 1 |

Deemed Savings

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

Evaluation Protocol

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

Sources

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

## HVAC

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

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

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

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

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

Eligibility

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

Algorithms

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

*ΔkWh*

*ΔkWhcool*

*ΔkWhheat*

*ΔkW*

Baseline: Room Air Conditioner(s)

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

*OFcool*

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 *OFheat* is the ratio of the existing electric capacity to the capacity of the new equipment:

*OFheat*

Qualifying: Ground Source Heat Pump

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

*SEER= EERg* × *GSHPDF* × *GSER*

*EER****=*** *EERg* × *GSPK*

*HSPF****=****COPg* × *GSHPDF* ×3.412

**Qualifying: Package Terminal Heat Pumps, Package Terminal Air Conditioners**

*SEER= EER*

*HSPF = COP* × 3.412

Definition of Terms

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

| **Term** | **Unit** | **Value** | **Sources** |
| --- | --- | --- | --- |
| *CAPYcool* , The cooling capacity of the equipment being installed[[9]](#footnote-10) | *kBTU/hr* | EDC Data Gathering | AEPS Application; EDC Data Gathering |
| *CAPYheat* , The heating capacity of the heat pump being installed[[10]](#footnote-11) | *kBTU/hr* | EDC Data Gathering | AEPS Application; EDC Data Gathering |
| *CAPYRAC* , The cooling capacity of the room AC for the RAC cooling baseline | *kBTU/hr* | EDC Data Gathering | EDC Data Gathering |
| *kWspaceheat* , The heating capacity of the space heaters in kilowatts. | *kW* | EDC Data Gathering | EDC Data Gathering |
| *SEERbase ,* Seasonal Energy Efficiency Ratio of the Baseline Unit |  | EDC Data Gathering, Default see Table 2‑8 | 2; EDC Data Gathering |
| *SEERee ,* Seasonal Energy Efficiency Ratio of the qualifying unit being installed[[11]](#footnote-12) |  | EDC Data Gathering | AEPS Application; EDC Data Gathering |
| *EERbase ,* Energy Efficiency Ratio of the Baseline Unit |  | EDC Data Gathering, Default see Table 2‑8 | 3; EDC Data Gathering |
| *EERee ,* Energy Efficiency Ratio of the unit being installed[[12]](#footnote-13) |  | EDC Data Gathering  Default: | 4; EDC Data Gathering; AEPS Application |
| *EERg ,* Energy Efficiency Ratio of a GSHP, this is measured differently than EER of an air source heat pump and must be converted |  | EDC Data Gathering |  |
| *HSPFbase ,* Heating Seasonal Performance Factor of the Baseline Unit |  | EDC Data Gathering, Default see Table 2‑8 | 2; EDC Data Gathering |
| *HSPFee* , Heating Seasonal Performance Factor of the unit being installed |  | EDC Data Gathering | AEPS Application; EDC Data Gathering |
| *COPee ,* Coefficient of Performance of the unit being installed. This is a measure of the efficiency of a heat pump | *Proportion* | EDC Data Gathering | AEPS Application; EDC Data Gathering |
| *OFcool* , Oversize factor | *None* | EDC Data Gathering, Default see Table 2‑9 | 5 |
| *OFheat* , Oversize factor | *None* | EDC Data Gathering, Default see Table 2‑9 | 6 |
| *GSER* , Factor used to determine the SEER of a GSHP based on its EERg |  | 1.02 | 7 |
| *GSPK* , Factor to convert EERg to the equivalent EER of an air conditioner to enable comparisons to the baseline unit | *Proportion* | 0.8416 | 7 |
| *GSHPDF* , Ground Source Heat Pump De-rate Factor | *Proportion* | 0.885 | 8 |
| *EFLHcool*, Equivalent Full Load Hours of operation during the cooling season for the average unit |  | See *EFLHcool* in Vol. 1, App. A | 9 |
| *EFLHheat* , Equivalent Full Load Hours of operation during the heating season for the average unit |  | See *EFLHheat* in Vol. 1, App. A | 9 |
| *CF* , Demand Coincidence Factor | *Proportion* | See *CF* in Vol. 1, App. A | 9 |

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

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Early Replacement** | | | | **Replace on Burnout / New Construction** | | |
| **Baseline Equip.** | ***SEERbase*** | ***EERbase*** | ***HSPFbase*** | ***SEERbase*** | | ***EERbase*** | ***HSPFbase*** |
| ASHP | 13.5 | 11.4 | 8.2 | 14 | | 12.0 | 8.2 |
| CAC | 12.1 | 10.6a | – | 13 | | 11.3 | 8.2 |
| GSHP | 15.0 | 16.6a | 10.9 | 14 | | 12.0 | 8.2 |
| Elec. Baseboard | – | – | 3.412 | – | | – | – |
| Elec. Furnace[[13]](#footnote-14) | – | – | 3.241 | – | | – | – |
| Space Heaters | – | – | 3.412 | – | | – | – |
| PTAC[[14]](#footnote-15),[[15]](#footnote-16),[[16]](#footnote-17) |  | | – |  | | | – |
| PTHP 15,16,17 |  | |  |  | | |  |
| a. Calculated using the equation from Source 4 | | | | | | | | |

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

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Qualifying** | **Oversize Factor** | **Existing** | | | | | | |
| **ASHP** | **CAC** | **Electric Baseboard** | **Electric Furnace** | **GSHP** | **RAC** | **Space Heaters** |
| CAC | *OFcool* | 1 | 1 | 0 | 0 | 1 | 1 | 0 |
| HP | *OFheat* | 1 | 1 | 1 | 1 | 1 | 0 | 0.6 |
| *OFcool* | 1 | 1 | 0 | 0 | 1 | 1 | 0 |

Evaluation Protocols

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

Sources

1. California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, <http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx> Accessed December 2018
2. For Early Replacement ASHP, CAC: Pennsylvania Act 129 2018 Residential Baseline Study [<http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-Phase3_Res_Baseline_Study_Rpt021219.pdf>] For Early Replacement GSHP: the values represent the minimum efficiency values for GSHP in BEopt v2.8.0. For Replace on Burnout/New Construction ASHP, CAC, GSHP: Federal Code of Regulations 10 CFR 430. <https://www.gpo.gov/fdsys/pkg/CFR-2017-title10-vol3/pdf/CFR-2017-title10-vol3-sec430-32.pdf>. For PTAC and PTHP: standards are based on requirements of ASHRAE 90.1-2016, Energy Standard for Buildings Except Low-Rise Residential Buildings, Table 6.8.1-4, <https://www.ashrae.org/technical-resources/standards-and-guidelines/read-only-versions-of-ashrae-standards>.
3. Average EER for SEER 13 units as calculated by EER = -0.02 × SEER² + 1.12 × SEER based on U.S. DOE Building America House Simulation Protocol, Revised 2010.
4. “Methodology for Calculating Cooling and Heating Energy Input-Ratio (EIR) from the Rated Seasonal Performance Eefficiency (SEER OR HSPF)” (Kim, Baltazar, Haberl). April 2013 Accessed December 2018. <http://oaktrust.library.tamu.edu/bitstream/handle/1969.1/152118/ESL-TR-13-04-01.pdf>
5. Based on REM/Rate modeling using models from the PA 2012 Potential Study. EFLH calculated from kWh consumption for cooling and heating. Models assume 50% over-sizing of air conditioners[[17]](#footnote-18) and 40% oversizing of heat pumps.[[18]](#footnote-19)
6. Assumptions used to calculate a default value for de facto heating system OF: Four (4) 1500W portable electric space heaters in use in the home with capacity of , replaced by DHP with combined heating capacity of 36kBTU.
7. VEIC estimate. Extrapolation of manufacturer data.
8. McQuay Application Guide 31-008, Geothermal Heat Pump Design Manual, 2002. Engineering Estimate - See System Performance of Ground Source Heat Pumps
9. Based on the Phase III SWE team’s analysis of regional HVAC runtime data collected from ecobee’s Donate Your Data research service. <https://www.ecobee.com/donateyourdata/>

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

|  |  |
| --- | --- |
| **Target Sector** | Residential Establishments |
| **Measure Unit** | Ductless Heat Pump Unit |
| **Measure Life** | 15 yearsSource 1 |
| **Vintage** | Early Replacement, Replace on Burnout, New Construction |

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

Eligibility

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

1. Existing electric resistance heating
2. Electric space heaters used as the primary heating source when fossil fuel (other than natural gas) heating systems failed (referred to as de facto heating) [[19]](#footnote-20)
3. A lower-efficiency ductless heat pump system
4. A ducted heat pump
5. Electric furnace
6. A non-electric fuel-based system.

The baseline cooling system can be:

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

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

Midstream HVAC Overview

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

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

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.

*ΔkWh*

*ΔkWhcool*

Note: Be sure to use *EFLHcool* of Room ACs for secondary cooling zones, see Table 2‑11.

*ΔkWhheat*

*ΔkWpeak*

Note: Be sure to use *EFLHheat* of Secondary HP for secondary heating zones, see Table 2‑11.

Baseline: Room Air Conditioner(s)

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

*OFcool*

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 *OFheat* is the ratio of the existing electric capacity to the capacity of the new equipment:

*OFheat*

Definition of Terms

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

| **Term** | **Unit** | **Value** | **Sources** |
| --- | --- | --- | --- |
| *CAPYcool* , The cooling capacity of the central air conditioner or heat pump being installed[[20]](#footnote-21) | *kBTU/hr* | EDC Data Gathering | AEPS Application; EDC Data Gathering |
| *CAPYheat* , The heating capacity of the heat pump being installed[[21]](#footnote-22) | *kBTU/hr* | EDC Data Gathering | AEPS Application; EDC Data Gathering |
| *CAPYRAC* , The cooling capacity of the room AC. Used only for the RAC cooling baseline | *kBTU/hr* | EDC Data Gathering | EDC Data Gathering |
| *kWspaceheat* , The heating capacity of the space heaters in watts. | *kW* | EDC Data Gathering | EDC Data Gathering |
| *SEERbase ,* Seasonal Energy Efficiency Ratio of the Baseline Unit |  | EDC Data Gathering  Default:  Table 2‑12 or Table 2‑8 in Sec. 2.2.1  Midstream: 12.1 | EDC Data Gathering; 2; 10 |
| *SEERee ,* Seasonal Energy Efficiency Ratio of the qualifying unit being installed[[22]](#footnote-23) |  | EDC Data Gathering | AEPS Application; EDC Data Gathering |
| *EERbase ,* Energy Efficiency Ratio of the Baseline Unit |  | EDC Data Gathering  Default:  Table 2‑12 | EDC Data Gathering; 3 |
| *EERee ,* Energy Efficiency Ratio of the unit being installed[[23]](#footnote-24) |  | EDC Data Gathering  Default: | EDC Data Gathering; AEPS Application; 4 |
| *HSPFbase ,* Heating Seasonal Performance Factor of the Baseline Unit |  | EDC Data Gathering  Default:  Table 2‑12 or Table 2‑8 in 2.2.1  Midstream: 6.7 | EDC Data Gathering; 2; 10 |
| *HSPFee* , Heating Seasonal Performance Factor of the unit being installed[[24]](#footnote-25) |  | EDC Data Gathering | AEPS Application; EDC Data Gathering |
| *OFcool* , Oversize factor | None | EDC Data Gathering  Default: Table 2‑9  Midstream: 1.1 | EDC Data Gathering; 5 |
| *OFheat* , Oversize factor | None | EDC Data Gathering  Default: Table 2‑9  Midstream: 1.3 | EDC Data Gathering ;6 |
| *DLF*, “Duct Leakage Factor” accounts for the fact that a % of the energy is lost to duct leakage and conduction for ducted systems, but not ductless ones | None | Depends on baseline & efficient conditions: Table 2‑13  Midstream, cooling: 1.02  Midstream, heating: 1.01 | 7; 10 |
| *zone,* Primary or secondary usage level of a space, this affects *EFLHcool* and *EFLHheat*. For midstream delivery, use provided composite *EFLH* values. | None | See Table 2‑11 |  |
| *nMS zones,* Average number of heating and cooling zones per site. Note: this factor applies to mid-stream delivery only. | None | 1.18 | 10 |
| *EFLHcool*, Equivalent Full Load Hours of operation during the cooling season for the average unit |  | See *EFLHcoo*l in Vol. 1, App. A  Use Room AC hours for secondary zones.  Midstream: Table 2‑18 | 8 |
| *EFLHheat,HP* , Equivalent Full Load Hours of operation during the heating season for the average unit |  | See *EFLHheat* in Vol. 1, App. A  Use Secondary HP for secondary zones.  Midstream: Table 2‑18 | 8 |
| *CF* , Demand Coincidence Factor | *Proportion* | See *CF* in Vol. 1, App. A | 8 |

Table 2‑11: Ductless Heat Pump Usage Zones

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

Table 2‑12: Default Ductless Heat Pump Efficiencies

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Baseline Equip.** | **Early Replacement** | | | **Replace on Burnout/New Construction** | | |
| **SEERbase** | **EERbase** | **HSPFbase** | **SEERbase** | **EERbase** | **HSPFbase** |
| Ductless | 13 | 11.3 | 8.2 | 14 | 12 | 8.2 |

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

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **ASHP** | **CAC** | **Ductless** | **Electric Baseboard** | **Electric Furnace** | **New Construction** | **RAC** | **Space Heaters** |
| *DLF* | 1.15 | 1.15 | 1 | 1 | 1.15 | 1 | 1 | 1 |
| *OFheat* | 1.4 | 0 | 1 | 1.4 | 1.4 | 1 | 0 | 0.6 |
| *OFcoo* | 1.4 | 1.5 | 1 | 0 | 0 | 1 | 1 | 0 |

Midstream Composite baseline Calculations

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

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

|  |  |  |  |
| --- | --- | --- | --- |
| **Cooling Type** | **SEERbase** | **EERbase** | **Split[[25]](#footnote-26)** |
| Central AC | 13.0 | 11.3 | 4% |
| DHP or ASHP | 14.0 | 12.0 | 8% |
| No existing cooling for primary space | 13.0 | 11.3 | 29% |
| No existing cooling for secondary space | 11.3 | 9.8 | 30% |
| Room AC | 11.3 | 9.8 | 30% |
| Composite[[26]](#footnote-27) | 12.1 | 10.5 | 100% |

Table 2‑15: Midstream DHP – HSPF Baseline Splits

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

Table 2‑16: Midstream DHP – DLFcool and OFcool Baseline Splits

|  |  |  |  |
| --- | --- | --- | --- |
| **Cooling Type** | **DLFcool** | **OFcool** | **Split** |
| Central AC | 1.15 | 1.5 | 8% |
| Central ASHP | 1.15 | 1.4 | 5% |
| Ductless Heat Pump | 1.00 | 1.0 | 19% |
| Room AC | 1.00 | 1.0 | 69% |
| Composite | 1.02 | 1.1 | 100% |

Table 2‑17: Midstream DHP – DLFheat and OFheat Baseline Splits

|  |  |  |  |
| --- | --- | --- | --- |
| **Heating Type** | **DLFheat** | **OFheat** | **Split** |
| Central ASHP | 1.15 | 1.4 | 6% |
| De facto Space Heaters | 1.00 | 0.6 | 5% |
| Ductless Heat Pump | 1.00 | 1.0 | 26% |
| Electric Baseboard | 1.00 | 1.4 | 62% |
| Electric Furnace | 1.15 | 1.4 | 1% |
| Composite | 1.01 | 1.3 | 100% |

Table 2‑18: Midstream DHP – Composite EFLH Values

|  |  |  |  |
| --- | --- | --- | --- |
| **Reference City** | **Zone** | **Composite EFLHcool** | **Composite EFLHheat** |
| Allentown | C | 377 | 1040 |
| Binghamton, NY | A | 218 | 1277 |
| Bradford | G | 135 | 1445 |
| Erie | I | 307 | 1213 |
| Harrisburg | E | 479 | 1129 |
| Philadelphia | D | 512 | 906 |
| Pittsburgh | H | 356 | 1073 |
| Scranton | B | 310 | 1143 |
| Williamsport | F | 366 | 1085 |

Evaluation Protocols

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

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

Sources

1. California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, [http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx. Accessed December 2018](http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx.%20Accessed%20December%202018).
2. Federal Code of Regulations 10 CFR 430. <https://www.gpo.gov/fdsys/pkg/CFR-2017-title10-vol3/pdf/CFR-2017-title10-vol3-sec430-32.pdf>
3. Average EER for SEER 13 units as calculated by EER = -0.02 × SEER² + 1.12 × SEER based on U.S. DOE Building America House Simulation Protocol, Revised 2010.
4. “Methodology for Calculating Cooling and Heating Energy Input-Ratio (EIR) from the Rated Seasonal Performance Eefficiency (SEER OR HSPF)” (Kim, Baltazar, Haberl). April 2013 Accessed December 2018. <http://oaktrust.library.tamu.edu/bitstream/handle/1969.1/152118/ESL-TR-13-04-01.pdf>
5. Based on REM/Rate modeling using models from the PA 2012 Potential Study. Models assume 50% over-sizing of air conditioners[[27]](#footnote-28) and 40% oversizing of heat pumps.[[28]](#footnote-29)
6. Assumptions used to calculate a default value for de facto heating system OF: Four (4) 1500W portable electric space heaters in use in the home with capacity of , replaced by DHP with combined heating capacity of 36kBTU.
7. Assumption used in Illinois 2014 TRM, Ductless Heat Pumps Measure, p. 531, footnote 877. Reasonable assumption when compared to [http://www.energystar.gov/index.cfm?‌c=home\_improvement.hm\_improvement\_ducts](http://www.energystar.gov/index.cfm?c=home_improvement.hm_improvement_ducts) and Residential HVAC and Distribution Research Implementation,. Berkeley Labs. May, 2002, p. 6. <http://epb.lbl.gov/publications/pdf/lbnl-47214.pdf>
8. Based on the Phase III SWE team’s analysis of regional HVAC runtime data collected from ecobee’s Donate Your Data research service. <https://www.ecobee.com/donateyourdata/>
9. Assumptions used to calculate a default value for de facto heating system OF: Four (4) 1500 W portable electric space heaters in use in the home with capacity of 1500 × 3.412 × 4 = 20,472 BTU, replaced by DHP with combined heating capacity of 36,000 BTU. OF = 20,472 / 36,000 = 0.6.
10. PECO PY8 to PY9 Program Participation Data and PPL PY8 to PY10Q1 Program Participation Data

### Properly Sized Cooling

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

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

Eligibility

Proper sizing requires Manual J calculations, following of ENERGY STAR HVAC Quality Installation procedures, or similar calculations. This measure may be combined with Section [2.2.1](#_High_Efficiency_Equipment:) or 2.2.2.

Algorithms

ΔkWh =

*ΔkW*=

Definition of Terms

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

| **Term** | **Unit** | **Value** | **Sources** |
| --- | --- | --- | --- |
| *CAPYcool* , The cooling capacity of the air conditioner or heat pump being installed[[29]](#footnote-30) | *kBTU/hr* | EDC Data Gathering | AEPS Application; EDC Data Gathering |
| *SEERee ,* Seasonal Energy Efficiency Ratio of the qualifying unit being installed[[30]](#footnote-31) |  | EDC Data Gathering | AEPS Application; EDC Data Gathering |
| *EERee ,* Energy Efficiency Ratio of the unit being installed[[31]](#footnote-32) |  | EDC Data Gathering  Default: | 2; EDC Data Gathering |
| *PSF* , Proper Sizing Factor or the assumed savings due to proper sizing and proper installation | *Proportion* | 0.05 | 3 |
| *EFLHcool*, Equivalent Full Load Hours of operation during the cooling season for the average unit |  | See *EFLHcool* in Vol. 1, App. A | 4 |
| *CF* , Demand Coincidence Factor | *Proportion* | See *CF* in Vol. 1, App. A | 4 |

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate 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](http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx.%20Accessed%20December%202018).
2. “Methodology for Calculating Cooling and Heating Energy Input-Ratio (EIR) from the Rated Seasonal Performance Eefficiency (SEER OR HSPF)” (Kim, Baltazar, Haberl). April 2013 Accessed December 2018. <http://oaktrust.library.tamu.edu/bitstream/handle/1969.1/152118/ESL-TR-13-04-01.pdf>
3. Northeast Energy Efficiency Partnerships, Inc., “Strategies to Increase Residential HVAC Efficiency in the Northeast”, (February 2006): Appendix C Benefits of HVAC Contractor Training: Field Research Results 03-STAC-01, p. 46.
4. Based on the Phase III SWE team’s analysis of regional HVAC runtime data collected from ecobee’s Donate Your Data research service, <https://www.ecobee.com/donateyourdata/>.

### ECM Circulation Fans

|  |  |
| --- | --- |
| **Target Sector** | Residential Establishments |
| **Measure Unit** | ECM Circulation Fan |
| **Measure Life** | 15 yearsSource 1 |
| **Measure Vintage** | Early Replacement, Replace on Burnout |

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

Eligibility

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

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

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

Efficient conditions are a circulating fan with an ECM.

Algorithms

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

ΔkWhheat =

ΔkWhcool =

ΔkW =

Definition of Terms

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

| **Term** | **Unit** | **Value** | **Sources** |
| --- | --- | --- | --- |
| *ECMkW, Reduced energy demand of the efficient ECM vs. baseline PSC motor.* | *kW* | EDC Data Gathering,  Default: 0.116 | 2, EDC Data Gathering |
| *EFLHcool*, Equivalent Full Load Hours of operation during the cooling season for the average unit |  | See *EFLHcool* in Vol. 1, App. A | 3 |
| *EFLHheat* , Equivalent Full Load Hours of operation during the heating season for the average unit |  | See *EFLHheat* in Vol. 1, App. A | 3 |
| *CF* , Demand Coincidence Factor | *Proportion* | See *CF* in Vol. 1, App. A | 3 |

Evaluation Protocols

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

Sources

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

### GSHP Desuperheaters

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

Eligibility

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

Algorithms

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

ΔkWh

ΔkW

Definition of Terms

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

| **Term** | **Unit** | **Value** | **Sources** |
| --- | --- | --- | --- |
| *EFSH* , Energy Factor per desuperheater | *None* | 0.17 | 1, 2 |
| *HW,* Daily hot water use | *Gallons/Day* | 45.5 | 7 |
| , Hot Water Temperature | *°F* | 119 | 3 |
| ,Cold Water Temperature | *°F* | 52 | 4 |
| *UEFbase*, Energy Factor of Electric Water Heater | *None* | EDC Data Gathering,  Default: 1.02 | EDC Data Gathering,  5 |
| *ETDF* , Energy to Demand Factor | *None* | 0.00008047 | 6 |

Evaluation Protocols

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

Default Savings

Default savings are 451.1 kWh and 0.036 kW demand savings.

Sources

1. “Residential Ground Source Heat Pumps with Integrated Domestic Hot Water Generation: Performance Results from Long-Term Monitoring”, U.S. Department of Energy, November 2012.
2. Desuperheater Study, New England Electric System, 1998 42 U.S.C.A 6295(i) (West Supp. 2011) and 10 C.F.R. 430.32 (x) (2011).
3. Pennsylvania Statewide Residential End-Use and Saturation Study, 2014, <http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-2014_PA_Statewide_Act129_Residential_Baseline_Study.pdf>.
4. Using Rock Spring, PA (Site 2036) as a proxy, the mean of soil temperature at 40 inch depth is 51.861. Calculated using Daily SCAN Standard - Period of Record data from April 1999 to December 2018 from the Natural Resource Conservation Service Database. <https://wcc.sc.egov.usda.gov/nwcc/rgrpt?report=daily_scan_por&state=PA>. Methodology follows Missouri TRM 2017 Volume 2: Commercial and Industrial Measures. p. 78. <https://energy.mo.gov/sites/energy/files/MOTRM2017Volume2.pdf>
5. Pennsylvania Act 129 2018 Residential Baseline Study, <http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-Phase3_Res_Baseline_Study_Rpt021219.pdf>.
6. Straub, Mary and Switzer, Sheldon. "Using Available Information for Efficient Evaluation of Demand Side Management Programs". Study by BG&E. The Electricity Journal, Aug/Sept. 2011. p. 95. <http://www.sciencedirect.com/science/article/pii/S1040619011001941>
7. “Residential End Uses of Water, Version 2.” *Water Research Foundation.* (Apr 2016), p. 5. <https://www.circleofblue.org/wp-content/uploads/2016/04/WRF_REU2016.pdf>

### Air Conditioner & Heat Pump Maintenance

|  |  |
| --- | --- |
| **Target Sector** | Residential Establishments |
| **Measure Unit** | Central A/C, ASHP, Ductless Mini-Split HP, GSHP, PTAC or PTHP Unit |
| **Measure Life** | 3 yearsSource 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

ΔkWh

ΔkWhcool

ΔkWhheat[[32]](#footnote-33)

*ΔkW*

Ground Source Heat Pumps (GSHP)

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

*SEERbase = EERg* × *GSHPDF* × *GSER*

*EERbase* ***=*** *EERg* × *GSPK*

*HSPFbase****=****COPg* × *GSHPDF* ×3.412

**PTAC and PTHP**

*SEERbase  = EERbase*

Definition of Terms

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

| **Term** | **Unit** | **Value** | **Sources** |
| --- | --- | --- | --- |
| *CAPYcool* , The cooling capacity of the central air conditioner or heat pump being installed[[33]](#footnote-34) | *kBTU/hr* | EDC Data Gathering | AEPS Application; EDC Data Gathering |
| *CAPYheat* , The heating capacity of the heat pump being installed[[34]](#footnote-35) | *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 |
| *EFLHcool*, Equivalent Full Load Hours of operation during the cooling season for the average unit |  | See *EFLHcool* in Vol. 1, App. A | 3 |
| *EFLHheat,HP* , Equivalent Full Load Hours of operation during the heating season for the average unit |  | See *EFLHheat* in Vol. 1, App. A | 3 |
| *SEERbase ,* Seasonal Energy Efficiency Ratio of the Baseline Unit |  | EDC Data Gathering, Default: Table 2‑23 | EDC Data Gathering  4 |
| *HSPFbase ,* Heating Seasonal Performance Factor of the Baseline Unit |  | EDC Data Gathering, Default: Table 2‑23 | EDC Data Gathering  4 |
| *EERg ,* Energy Efficiency Ratio of a GSHP, this is measured differently than EER of an air source heat pump and must be converted |  | EDC Data Gathering  Default: 16.6 | 4 |
| *EERbase ,* Energy Efficiency Ratio of the Baseline Unit |  | EDC Data Gathering |  |
| *COPg ,* Coefficient of Performance. This is a measure of the efficiency of a ground source heat pump | *None* | EDC Data Gathering  Default: 3.6 | AEPS Application; EDC Data Gathering |
| *GSER* , Factor used to determine the SEER of a GSHP based on its EERg |  | 1.02 | 5 |
| *GSPK* , Factor to convert EERg to the equivalent EER of an air conditioner to enable comparisons to the baseline unit | *Proportion* | 0.8416 | 5 |
| *GSHPDF* , Ground Source Heat Pump De-rate Factor | *Proportion* | 0.885 | 6 |
| *CF* , Demand Coincidence Factor | *Proportion* | See *CF* in Vol. 1, App. A | 3 |

Table 2‑23: Default Equipment Efficiency

|  |  |  |
| --- | --- | --- |
| **Type** | *SEERbase* | *HSPFbase* |
| Central Air Conditioner | 12.1 | N/A |
| Room Air Conditioner | 11.4 | N/A |
| Air-Source Heat Pump | 13.5 | 8.2 |
| Ground-Source Heat Pump | 15.0 | 10.9 |
| Ductless Mini-Split | 14.9 | 2.6 |
| Electric Resistance | N/A | 3.412 |
| PTAC (EERbase)[[35]](#footnote-36) |  | N/A |
| PTHP (EERbase)34 |  | ) |

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

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

Algorithms

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

**Heating savings with electric furnace (assumes 95% efficiency):[[36]](#footnote-37)**

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

**Heating savings with electric air source heat pump:**

For boilers, the annual pump energy consumption is negligible (<50 kWh per year) and not included in this calculation.[[37]](#footnote-38)

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:

Definition of Terms

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

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

| **Term** | **Units** | **Value** | **Source** |
| --- | --- | --- | --- |
| *CAPYelec* , Total heating capacity of existing electric baseboards or electric furnace |  | EDC Data Gathering | EDC Data Gathering |
| *CAPYHP heat* , Total heating capacity of existing electric ASHP |  | EDC Data Gathering | EDC Data Gathering |
| *EFLHheat,HP* , Equivalent Full Load Heating hours for Air Source Heat Pumps |  | See *EFLHheat,HP* values in Vol. 1, App. A | 3 |
| *EFLHheat,non-HP* , Equivalent Full Load Heating hours for furnaces, boilers, and electric baseboards |  | See *EFLHheat,non-HP* values in Vol. 1, App. A | 3 |
| *HSPF* , Heating Seasonal Performance Factor for existing heat pump |  | EDC Data Gathering or  Default = 8.2 | EDC Data Gathering  4 |
| *AFUEfuel 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 |
| *HPmotor* , Furnace blower motor horsepower | *hp* | EDC Data Gathering or  Default = ½ | EDC Data Gathering  5 |
| *ηmotor* , Efficiency of furnace blower motor | *%* | EDC Data Gathering or  Default = 50% | EDC Data Gathering  Typical efficiency of ½ HP blower motor |

Evaluation Protocols

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

Sources

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

### ENERGY STAR Room Air Conditioners

|  |  |
| --- | --- |
| **Target Sector** | Residential Establishments |
| **Measure Unit** | Room Air Conditioner |
| **Measure Life** | 9 yearsSource 1 |
| **Vintage** | Replace on Burnout |

Eligibility

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

Algorithms

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

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

Definition of Terms

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

|  |  |  |  |
| --- | --- | --- | --- |
| **Term** | **Unit** | **Value** | **Sources** |
| *CAPY*, The cooling capacity of the room air conditioner (RAC) being installed |  | EDC Data Gathering  Default = 7,500 | 5 |
| *CEERbase*, Combined Energy Efficiency ratio of the baseline unit |  | Federal Standard Values in Table 2‑26, Table 2‑27, or Table 2‑28  Default = 11.0 | 2 |
| *CEERee*, Combined Energy efficiency ratio of the RAC being installed |  | EDC Data Gathering  Default = ENERGY STAR values in in Table 2‑26, Table 2‑27, or Table 2‑28 | 3 |
| *EFLHRAC*, Equivalent full load hours of the RAC being installed |  | See *EFLHRAC* in Vol. 1, App. A | 4 |
| *CF*, *Demand coincidence factor* | *Proportion* | See *CF* in Vol. 1, App. A | 4 |

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

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

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

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

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

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

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

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

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

Default Savings

Default energy savings values assume a CAPY=7,500 BTU/hrSource 7, louvered sides, no reverse cycle unit (CEERbase = 11.0, CEERee = 12.1).

Table 2‑29: Deemed EFLH and Default Energy Savings

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

Evaluation Protocols

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

Sources

1. California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, <http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx> . Accessed December 2018.
2. Federal standards: U.S. Department of Energy. Code of Federal Regulations. 10 CFR, part 430.32(b). Effective June 1, 2014. <http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/41>
3. ENERGY STAR Program Requirements Product Specification for Room Air Conditioners, Eligibility Criteria Version 4.1. October 26, 2015. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%204.1%20Room%20Air%20Conditioners%20Specification\_0.pdf
4. Based on the Phase III SWE team’s analysis of regional HVAC runtime data collected from ecobee’s Donate Your Data research service, <https://www.ecobee.com/donateyourdata/>.
5. Statewide average for all housing types from Pennsylvania Act 129 2018 Residential Baseline Study, <http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-Phase3_Res_Baseline_Study_Rpt021219.pdf>.

### Room AC (RAC) Retirement

|  |  |
| --- | --- |
| **Target Sector** | Residential Establishments |
| **Measure Unit** | Room A/C |
| **Measure Life** | 3 yearsSource 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*.

Replacement and Recycling

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

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

**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 calculation.

Definition of Terms

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

|  |  |  |  |
| --- | --- | --- | --- |
| **Term** | **Unit** | **Value** | **Sources** |
| *EFLHRAC* , 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.). |  | See *EFLHRAC* in Vol. 1, App. A | 1 |
| *CAPY* , Rated cooling capacity (size) of the RAC unit. |  | EDC Data Gathering  Default: 7,500 | 3 |
| *EERRetRAC* , The Energy Efficiency Ratio of the unit being retired-recycled.[[38]](#footnote-39) |  | EDC Data Gathering  Default: 9.8 | 4 |
| *EERee* , The Energy Efficiency Ratio for an ENERGY STAR RAC |  | 12.1 | 6 |
| *CEERbase* ,  (for a 8,000 BTU/h unit), The Combined Energy Efficiency Ratio of a RAC that meets the minimum federal appliance standard efficiency. |  | 11.0 | 5 |
| *CEERee* , (for a 8,000 BTU/h unit), The Combined Energy Efficiency Ratio for an ENERGY STAR RAC. |  | EDC Data Gathering  Default=12.1 | 5 |
| *CF*, Demand Coincidence Factor | *Proportion* | See *CF* in Vol. 1, App. A | 2 |

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

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

Evaluation Protocols

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

Sources

1. California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, <http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx> . Accessed December 2018.
2. Based on the Phase III SWE team’s analysis of regional HVAC runtime data collected from ecobee’s Donate Your Data research service, <https://www.ecobee.com/donateyourdata/>.
3. Mid Atlantic TRM Version 7.0. May, 2017. Prepared by Vermont Energy Investment Corporation. An adjustment to the ES RAC EFLHs of 31% was used for the “Window A/C” measure. The average ratio of EFLH for Room AC provided in RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008 (<http://www.puc.nh.gov/Electric/Monitoring%20and%20Evaluation%20Reports/>National%20Grid/117\_RLW\_CF %20Res%20RAC.pdf) to FLH for Central Cooling for the same location (provided by AHRI: http://www.energystar.gov/ia/business/bulk\_purchasing/bpsavings\_calc/Calc\_CAC.xls is 31%. This factor was applied to the EFLH for Central Cooling provided for PA cities and averaged to come up with the assumption for EFLH for Room AC.” <https://neep.org/sites/default/files/resources/Mid_Atlantic_TRM_V7_FINAL.pdf>
4. Statewide average capacity of RAC units, Pennsylvania Act 129 2018 Residential Baseline Study, <http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-Phase3_Res_Baseline_Study_Rpt021219.pdf>.
5. Minimum Federal Standard for most common room AC type (8000-14,999 capacity range with louvered sides) per federal standards from 10/1/2000 to 5/31/2014. Note that this value is the EER value, as CEER were introduced later.
6. ENERGY STAR Program Requirements Product Specification for Room Air Conditioners, Eligibility Criteria Version 4.1. October 26, 2015. <https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%204.1%20Room%20Air%20Conditioners%20Specification_0.pdf>

### Duct Sealing & Duct Insulation

|  |  |
| --- | --- |
| **Target Sector** | Residential Establishments |
| **Measure Unit** | Duct Sealing and/or Insulation Project |
| **Measure Life** | 15 yearsSource 1 |
| **Vintage** | Retrofit |

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

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

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

Eligibility

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

Algorithms

***Methodology 1: Evaluation of Distribution Efficiency***

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

***Methodology 2: RESNET Test 803.7***

1. Determine Duct Leakage rate before and after performing duct sealing

Δ*CFM25DB* =

1. Calculate Energy Savings

**Summer Coincident Peak Demand Savings**

Definition of Terms

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

| **Term** | **Unit** | **Value** | **Source** |
| --- | --- | --- | --- |
| *CF* , Demand Coincidence Factor | *Proportion* | See *CF* in Vol. 1, App. A | 4 |
| *CFM25BASE* , 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 |  | EDC Data Gathering | 3 |
| *CFM25DB* , Cubic feet per minute of air leaving the duct system at 25 Pascals |  | EDC Data Gathering | 3 |
| *CFM25EE* , Standard Duct Leakage test result at 25 Pascal pressure differential of the duct system after sealing, calculated from the duct blaster fan flow chart |  | EDC Data Gathering | 3 |
| *CAPYcool* , Capacity of Air Cooling System | *kBTU/hr* | EDC Data Gathering | EDC Data Gathering |
| *CAPYheat*, Capacity of Air Heating System | *kBTU/hr* | EDC Data Gathering | EDC Data Gathering |
| *TCFM* , Conversion from tons of cooling to CFM |  | 400 | 5 |
| *SEER* , Efficiency of cooling equipment |  | EDC Data Gathering  Default = Table 2‑33 | 6 |
| *COP* , Efficiency of Heating Equipment | *None* | EDC Data Gathering  Default = Table 2‑33 | 6 |
| *EFLHcool*, Cooling equivalent full load hours |  | See *EFLHcool* in Vol. 1, App. A | 4 |
| *EFLHheat* , Heating equivalent full load hours |  | See *EFLHheat* in Vol. 1, App. A | 4 |
| *DEpost*, Distribution efficiency after duct sealing and insulation | *None* | Table 2‑34, Table 2‑35  Not to exceed 100% | 2 |
| *DEpre* , Distribution efficiency before duct sealing and insulation | *None* | Table 2‑34, Table 2‑35  Not to exceed 100% | 2 |

Table 2‑33: Default Equipment Efficiencies

|  |  |  |
| --- | --- | --- |
| **Type** | *SEERbase* | *HSPFbase* |
| Central Air Conditioner | 12.1 | N/A |
| Room Air Conditioner | 11.4 | N/A |
| Air-Source Heat Pump | 13.5 | 8.2 |
| Ground-Source Heat Pump | 15.0 | 10.9 |
| Ductless Mini-Split | 14.9 | 2.6 |
| PTAC | 13.0 | N/A |
| PTHP | 13.0 | 7.7 |

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

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Insulation** | **Location** | **Attic** | | | | **Basement** | | | | **Vented Crawl** | | | |
| **HVAC Type** | **Heat** | | **Cool** | | **Heat** | | **Cool** | | **Heat** | | **Cool** | |
| **Leakage \ CZ\*** | **4&5** | **6** | **4&5** | **6** | **4&5** | **6** | **4&5** | **6** | **4&5** | **6** | **4&5** | **6** |
| R-0 | Leaky | 69% | 64% | 61% | 61% | 93% | 92% | 81% | 92% | 74% | 71% | 76% | 90% |
| Average | 73% | 68% | 64% | 66% | 94% | 94% | 87% | 95% | 78% | 74% | 83% | 93% |
| Tight | 77% | 73% | 73% | 74% | 95% | 95% | 94% | 98% | 82% | 78% | 91% | 97% |
| R-2 | Leaky | 76% | 73% | 65% | 67% | 94% | 94% | 83% | 92% | 80% | 78% | 78% | 91% |
| Average | 82% | 79% | 74% | 75% | 96% | 95% | 88% | 95% | 85% | 83% | 85% | 94% |
| Tight | 87% | 85% | 84% | 85% | 97% | 97% | 95% | 98% | 90% | 88% | 93% | 97% |
| R-4+ | Leaky | 79% | 76% | 67% | 70% | 95% | 95% | 83% | 93% | 82% | 80% | 79% | 91% |
| Average | 84% | 82% | 77% | 78% | 96% | 96% | 89% | 95% | 87% | 85% | 86% | 94% |
| Tight | 90% | 89% | 87% | 88% | 98% | 98% | 95% | 98% | 92% | 91% | 94% | 97% |
| R-8+ | Leaky | 80% | 78% | 69% | 71% | 95% | 95% | 83% | 93% | 84% | 82% | 79% | 91% |
| Average | 86% | 84% | 79% | 80% | 97% | 97% | 89% | 95% | 89% | 87% | 87% | 94% |
| Tight | 92% | 91% | 90% | 90% | 98% | 98% | 95% | 98% | 94% | 93% | 94% | 98% |
| \* Climate Regions A and G correspond to IECC Climate Zone 6, the rest of the state is IECC Climate Zone 4 or 5. | | | | | | | | | | | | | | |

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

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Location** | **Attic** | | | | **Basement** | | | | **Vented Crawl** | | | |
| **HVAC Type** | **Heat** | | **Cool** | | **Heat** | | **Cool** | | **Heat** | | **Cool\*** | |
| **Insulation \ Conditioned** | **50%** | **80%** | **50%** | **80%** | **50%** | **80%** | **50%** | **80%** | **50%** | **80%** | **50%** | **80%** |
| R-0 | 6% | 4% | 11% | 9% | 2% | 3% | 2% | 3% | 6% | 3% | 11% | 5% |
| R-2 | 4% | 5% | 6% | 7% | 1% | 1% | 1% | 2% | 3% | 2% | 5% | 3% |
| R-4+ | 3% | 3% | 4% | 5% | 1% | 1% | 1% | 1% | 2% | 1% | 4% | 3% |
| R-8+ | 3% | 2% | 3% | 3% | 1% | 1% | 1% | 1% | 2% | 1% | 2% | 2% |
| \* In Climate Zone 6 (Climate Regions A & G), the cooling adder is fixed at 1% for ductwork in 80% conditioned space. | | | | | | | | | | | | |

Evaluation Protocols

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

Sources

1. California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, <http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx> . Accessed December 2018. Limited to Act 129 maximum of 15 years.
2. Building Performance Institute, Distribution Efficiency Table, <http://www.bpi.org/sites/default/files/Guidance%20on%20Estimating%20Distribution%20Efficiency.pdf>. Reproduced by permission.
3. Resnet Energy Services Network, Standards for Performance Testing. http://www.resnet.us/blog/wp-content/uploads/2016/01/ANSI-RESNET-ICC\_380-2016-posted-on-website-6-15-16.pdf
4. Based on the Phase III SWE team’s analysis of regional HVAC runtime data collected from ecobee’s Donate Your Data research service. <https://www.ecobee.com/donateyourdata/>
5. Heating, Air conditioning & Refrigeration Distributors International <https://energy.mo.gov/sites/energy/files/61-why-400-cfm-per-ton.pdf>
6. Pennsylvania Act 129 2018 Residential Basline Study , <http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-Phase3_Res_Baseline_Study_Rpt021219.pdf>. Due to small sample sizes, GSHP is lowest efficiency value from BEopt v2.8.0, and PTAC and PTHP are minimum federal standard efficiencies.

### Air Handler Filter Whistles

|  |  |
| --- | --- |
| **Target Sector** | Residential Establishments |
| **Measure Unit** | Filter whistle (to promote regular filter change-out) |
| **Measure Life** | 5 yearsSource 6 |
| **Vintage** | Retrofit |

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

Eligibility

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

Algorithms

ΔkWh

ΔkWhheat

ΔkWhcool

ΔkW

Definition of Terms

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

|  |  |  |  |
| --- | --- | --- | --- |
| **Term** | **Unit** | **Value** | **Sources** |
| , Average motor full load electric demand | *kW* | 0.377 | 1 |
| *EFLHheat* , Estimated Full Load Hours (Heating ) |  | See *EFLHheat* in Vol. 1, App. A | 5 |
| *EFLHcool* , Estimated Full Load Hours (Cooling) |  | See *EFLHcool* in Vol. 1, App. A | 5 |
| *EI* , Efficiency Improvement | *%* | 15% | 2, 4 |
| *ISR* , In-service Rate | *%* | EDC Data Gathering  Default = 15% | 3 |
| *CF* , Coincidence Factor | *Proportion* | See *CF* in Vol. 1., App. A | 5 |

Default Savings

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

Table 2‑37: Default Air Handler Filter Whistle Savings

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

Evaluation Protocols

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

Sources

1. Typical blower motor capacity for gas furnace is ¼ to ¾ HP, ½ HP × .
2. US DOE Office of Energy Efficiency and Renewable Energy - "Energy Savers" publication - "Clogged air filters will reduce system efficiency by 30% or more.” Savings estimates assume the 30% quoted is the worst case and typical households will be at the median or 15% that is assumed to be the efficiency improvement when furnace filters are kept clean.
3. The In Service Rate is the average of values reported by First Energy EDCs for kits including an air handler furnace whistle for PY9. See [[WEBSITE LINK TBD](http://www.puc.pa.gov/)]
4. Energy.gov. “Maintaining Your Air Conditioner”. Accessed 7/16/2014. Says that replacing a dirty air filter with a clean one can lower total air conditioner energy consumption by 5-15%. Since the algorithms in this measure only take into account the blower fan energy use, a 15% savings seems reasonable.
5. Based on the Phase III SWE team’s analysis of regional HVAC runtime data collected from ecobee’s Donate Your Data research service, <https://www.ecobee.com/donateyourdata/>.
6. California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, [http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx . Accessed December 2018](http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx%20.%20Accessed%20December%202018).
7. Your Filter Connection, “What is a Furnace Filter Whistle?”. <https://yourfilterconnection.com/blogs/help/what-is-a-furnace-filter-whistle>. Accessed December, 2018.

### ENERGY STAR® Certified Connected Thermostats

|  |  |
| --- | --- |
| **Target Sector** | Residential Homes, including single or multifamily in-unit spaces |
| **Measure Unit** | Residential Thermostat |
| **Measure Life** | 11 yearsSource 5 |
| **Vintage** | Retrofit, Replace on Burnout, or new construction |

ENERGY STAR®-certified connected thermostats (CT) save heating and cooling energy by operating residential HVAC systems more efficiently. CTs that meet the ENERGY STAR® specification8 will have functions that are located in the home and on the Internet (the cloud). Homes must have Wi-Fi to enable full operating capabilities.

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

Eligibility

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

* ENERGY STAR®-certified connected thermostat (CT)

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

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

Table 2‑38: Installation Classification

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

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

Algorithms

**Energy Savings**

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

ΔkWh

*ΔkWhcool*

*ΔkWhheat,HP*

*ΔkWhheat,elecfurrn*

*ΔkWhheat,fuelfurn*

**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.

**Demand Savings**

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

Definition of Terms

Table 2‑39: Residential Electric HVAC Calculation Assumptions

| **Term** | **Unit** | **Value** | **Sources** |
| --- | --- | --- | --- |
| *CAPYcool*, Capacity of air conditioning unit |  | EDC Data Gathering of  Nameplate data | EDC Data Gathering |
| Default = 30,000 / unit | 1 |
| *CAPYHP*, Normal heat capacity of Heat Pump System. |  | EDC Data Gathering of  Nameplate Data | EDC Data Gathering |
| Default = 32,000 / unit | 1 |
| *CAPYelecfurn*, Normal heat capacity of Electric Furnace systems |  | EDC Data Gathering of  Nameplate data | EDC Data Gathering |
| Default = 60,249 / unit | 1 |
| *SEER*, Seasonal Energy Efficiency Ratio |  | EDC Data Gathering of  Nameplate data | EDC Data Gathering |
| Default: CAC = 12.1 Heat Pump = 13.5 | 1 |
| *HSPFheat pump*, Heating Seasonal Performance Factor of Heat Pump |  | EDC Data Gathering of  Nameplate data | EDC Data Gathering |
| Heat Pump Default = 8.2 | 1 |
| *Effduct*, Duct System Efficiency | *None* | 0.8 | 3 |
| *EFLHcool*, Equivalent Full Load Hours for Cooling |  | See *EFLHcool* in Vol. 1, App. A | 4 |
| *EFLHheat,HP*, Equivalent Full Load Hours for ASHP Systems |  | See *EFLHheat,HP* in Vol. 1, App. A | 4 |
| *EFLHheat,non-HP* Equivalent Full Load Hours for Electric or Gas Furnaces |  | See *EFLHheat,non-HP* in Vol. 1, App. A | 4 |
| *HPmotor*, Gas furnace blower motor horsepower | *Hp* | EDC Data Gathering  Default = ½ | Average blower motor capacity for gas furnace (typical range = ¼ hp to ¾ hp) |
| Nameplate | EDC Data Gathering |
| *ηmotor*, Efficiency of furnace blower motor | *%* | EDC Data Gathering  Default = 50% | Typical efficiency of ½ hp blower motor |
| *%Programmable*, % central AC systems with a programmable thermostat | *None* | EDC Data Gathering | EDC Data Gathering |
| Forced Air Default = 58% | 1 |
| *%Manual*, % central AC systems with a manual thermostat | *None* | EDC Data Gathering | EDC Data Gathering |
| Forced Air Default = 42% | 1 |
| *ESFcool*, cooling energy saving factor | *None* | See Table 2‑40 | Composite of multiple sources |
| *ESFheat*, heating energy saving factor | *None* | See Table 2‑41 | Composite of multiple sources |
| *DF*, Derate Factor for Electric Resistance Heating Systems | *None* | 0.85 | Professional Judgement |

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

Table 2‑40: Cooling Energy Savings Factors (ESFcool)

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

*a Source 6*

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

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

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

Table 2‑41: Heating Energy Savings Factors (ESFheat)

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

|  |
| --- |
| *a Average of heating estimates from two studies. Sources: 9, 11*  *b Heating savings are based on average of savings from unknown mix default with customer self-installation and average of professional installation savings from manual and programmable thermostats. In this case, 7.9%=((11.5%×0.42 + 7.9%×0.58) + 6.4% ) / 2*  *c Average of four heating savings estimates from four studies. Sources****:*** *7, 10, 12*  *d The ESF value for a is applied here as an estimate until information becomes available showing different savings incented through a direct install program.* |

Default Savings

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

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

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

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

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

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

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

Evaluation Protocols

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

Sources

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### Furnace Maintenance

|  |  |
| --- | --- |
| **Target Sector** | Residential Establishments |
| **Measure Unit** | Per Furnace |
| **Measure Life** | 2 yearsSource 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.

ΔkWh

Definition of Terms

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

|  |  |  |  |
| --- | --- | --- | --- |
| **Term** | **Unit** | **Values** | **Source** |
| , Average motor full load electric demand | *kW* | 0.377 | 2 |
| , Equivalent full load heating hours | Hours/year | See *EFLHheat,non-HP* in Vol. 1, App. A | 3 |
| , Energy savings factor | None | 2% | 4 |

Default Savings

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

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

Evaluation Protocols

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

Sources

1. Act on Energy Commercial Technical Reference Manual No. 2010-4, 9.2.3 Gas Forced-Air Furnace Tune-up.
2. Average blower motor capacity for gas furnace (typical range = ¼ hp to ¾ hp). Converted to kW with 1 HP = 0.7547 kW.
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## Domestic Hot Water

### Heat Pump Water Heaters

|  |  |
| --- | --- |
| **Target Sector** | Residential Establishments |
| **Measure Unit** | Water Heater |
| **Measure Life** | 10 yearsSource 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:

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 in Table 2‑50 will account for reduced performance due to cooler annual temperatures.
* If installation location is unknown (such as with midstream delivery programs), use the ‘Default’ value for in Table 2‑50 and both interactive effects will equal zero.

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.

ΔkWpeak =

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

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

Definition of Terms

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

|  |  |  |  |
| --- | --- | --- | --- |
| **Term** | **Unit** | **Values** | **Source** |
| , Uniform Energy Factor of baseline water heater | *None* | See Table 2‑49  Default: 0.9207 (50 gal., unknown draw) | 3 |
| , Uniform Energy Factor of proposed efficient water heater | *gallons* | EDC Data Gathering  Default ≤55 Gals: 2.0  Default >55 Gal: 2.2 | 2 |
| *HW* , Hot water used per day in gallons |  | 45.5 | 4 |
| , Temperature of hot water | *°F* | 119 | 5 |
| , Temperature of cold water supply | *°F* | 52 | 6 |
| , COP De-rating factor | *Proportion* | Table 2‑50 | 7, and discussion below |
| , Equivalent Full Load Hours for cooling |  | See *EFLHcool* in Vol. 1, App. A | 8 |
| , Equivalent Full Load Hours for heating |  | See *EFLHheat* in Vol. 1, App. A | 8 |
| *HSPF* , Heating Seasonal Performance Factor of heating equipment |  | EDC Data Gathering  Default see Table 2‑48 | 9 |
| *SEER* , Seasonal Energy Efficiency Ratio of cooling equipment |  | EDC Data Gathering  Default see Table 2‑48 | 9 |
| *ETDF ,* Energy to Demand Factor (defined above) |  | 0.00008047 | 10 |

Table 2‑48: Default Cooling and Heating System Efficiencies

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

Uniform Energy Factors Based on Tank Size

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

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

| **Tank Size (gallons)** | **Draw Pattern** | **UEF Calculation** | **Minimum UEF** |
| --- | --- | --- | --- |
| 40 | Pre-2017 | 0.9600-(0.0003×Vr) | 0.948 |
| Very Small | 0.8808-(0.0008×Vr) | 0.8488 |
| Low | 0.9254-(0.0003×Vr) | 0.9134 |
| Medium | 0.9307-(0.0002×Vr) | 0.9227 |
| Large | 0.9349-(0.0001×Vr) | 0.9309 |
| 50 | Pre-2017 | 0.9600-(0.0003×Vr) | 0.945 |
| Very Small | 0.8808-(0.0008×Vr) | 0.8408 |
| Low | 0.9254-(0.0003×Vr) | 0.9104 |
| Medium | 0.9307-(0.0002×Vr) | 0.9207 |
| Large | 0.9349-(0.0001×Vr) | 0.9299 |
| 65 | Pre-2017 | 2.057-(0.00113×Vr) | 1.984 |
| Very Small | 1.9236-(0.0011×Vr) | 1.8521 |
| Low | 2.0440-(0.0011×Vr) | 1.9725 |
| Medium | 2.1171-(0.0011×Vr) | 2.0456 |
| Large | 2.2418-(0.0011×Vr) | 2.1703 |
| 80 | Pre-2017 | 2.057-(0.00113×Vr) | 1.967 |
| Very Small | 1.9236-(0.0011×Vr) | 1.8356 |
| Low | 2.0440-(0.0011×Vr) | 1.956 |
| Medium | 2.1171-(0.0011×Vr) | 2.0291 |
| Large | 2.2418-(0.0011×Vr) | 2.1538 |
| 120 | Pre-2017 | 2.057-(0.00113×Vr) | 1.921 |
| Very Small | 1.9236-(0.0011×Vr) | 1.7916 |
| Low | 2.0440-(0.0011×Vr) | 1.912 |
| Medium | 2.1171-(0.0011×Vr) | 1.9851 |
| Large | 2.2418-(0.0011×Vr) | 2.1098 |

Heat Pump Water Heater Uniform Energy Factor

The Uniform Energy Factors (UEF) are determined from a DOE testing procedure that is carried out at 67.5°F dry bulb and 56°F wet bulb temperatures. However, the average dry and wet bulb temperatures in PA are in the range of 50-56˚F DB and 45-50 °F WB[[39]](#footnote-40). The heat pump performance is temperature and humidity dependent, therefor the location and type of installation is significant. To account for this, a UEF de-rating factor () has been adapted from a 2013 NEEA HPWH field study.Source 7 The results used are for “Heating Zone 1”, which is comprised of Olympia, WA and Portland, OR and have average dry and wet bulb temperatures (51˚F DB, 47˚F WB and 55˚F DB, 49˚F WB, respectively)[[40]](#footnote-41) comparable to Pennsylvania.

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

|  |  |
| --- | --- |
| **Installation Location** |  |
| Inside Conditioned Space | 0.98 |
| Unconditioned Garage | 0.85 |
| Unconditioned Basement | 0.72 |
| Default[[41]](#footnote-43) | 0.87 |

Default Savings

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

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.

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### Solar Water Heaters

|  |  |
| --- | --- |
| **Target Sector** | Residential Establishments |
| **Measure Unit** | Water Heater |
| **Measure Life** | 15 yearsSource 1 |
| **Vintage** | Retrofit |

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

Eligibility

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

Algorithms

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

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.

ΔkWpeak = ETDF

Where:

ETDF (Energy to Demand Factor) is defined below:

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

Definition of Terms

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

|  |  |  |  |
| --- | --- | --- | --- |
| **Term** | **Unit** | **Values** | **Source** |
| *UEFbase*, Energy Factor of baseline electric water heater | *Proportion* | EDC Data Gathering | EDC Data Gathering |
| Default = 0.90 | 4 |
| *UEFee*, Year-round average Energy Factor of proposed solar water heater | *Proportion* | EDC Data Gathering | EDC Data Gathering |
| Default = 2.62 | 2 |
| *HW*, Hot water used per day in gallons |  | 45.5 | 5 |
| *Tout*, Temperature of hot water |  | 119 | 6 |
| *Tin*, Temperature of cold water supply |  | 52 | 7 |
| *ETDF*, Energy to Demand Factor (defined above) |  | 0.00008047 | 3 |

Default Savings

Default energy and demand savings are as follows:

ΔkWh = 1,974.4 kWh

ΔkW = 0.2420 kW

Evaluation Protocols

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

Sources

1. ENERGY STAR Solar Water Heater Benefits and Savings. Accessed 8/8/2014. <http://www.energystar.gov/index.cfm?c=solar_wheat.pr_savings_benefits>
2. The average energy factor for all solar water heaters with collector areas of 50 ft2 or smaller is from <https://secure.solar-rating.org/Certification/Ratings/RatingsSummaryPage.aspx>
3. Straub, Mary and Switzer, Sheldon. "Using Available Information for Efficient Evaluation of Demand Side Management Programs". Study by BG&E. The Electricity Journal, Aug/Sept. 2011. p. 95. <http://www.sciencedirect.com/science/article/pii/S1040619011001941>
4. Value is mean UEF for standard electric standalone water heaters from Pennsylvania Act 129 2018 Residential Baseline Study, <http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-Phase3_Res_Baseline_Study_Rpt021219.pdf>.
5. Residential Energy Consumption Survey, EIA, 2009.
6. Pennsylvania Statewide Residential End-Use and Saturation Study, 2014, <http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-2014_PA_Statewide_Act129_Residential_Baseline_Study.pdf>.
7. Using Rock Spring, PA (Site 2036) as a proxy, the mean of soil temperature at 40 inch depth is 51.861. Calculated using Daily SCAN Standard - Period of Record data from April 1999 to December 2018 from the Natural Resource Conservation Service Database. <https://wcc.sc.egov.usda.gov/nwcc/rgrpt?report=daily_scan_por&state=PA> . Methodology follows Missouri TRM 2017 Volume 2: Commercial and Industrial Measures. p. 78. <https://energy.mo.gov/sites/energy/files/MOTRM2017Volume2.pdf>

### Fuel Switching: Electric Resistance to Fossil Fuel Water Heater

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

Eligibility

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

The target sector primarily consists of single-family residences.

Algorithms

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

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:

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.

ΔkWpeak =

ETDF (Energy to Demand Factor) is defined below:

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

Definition of Terms

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

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

Energy Factors based on Tank Size

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

Default Savings

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

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

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

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

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

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

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

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

Evaluation Protocols

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

Sources

1. DEER Effective Useful Life values, accessed Oct. 2018. <http://www.deeresources.com/>
2. U.S. Federal Standards for Residential Water Heaters. Effective April 16, 2015. <http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/27>
3. Commission Order requires fuel switching to ENERGY STAR measures, not standard efficiency measures. The Energy Factor has therefore been updated to reflect the Energy Star 3.2 standard for Gas Storage Water Heaters From Residential Water Heaters Key Product Criteria. <https://www.energystar.gov/sites/default/files/Water%20Heaters%20Final%20Version%203.2_Program%20Requirements_1.pdf> Accessed Oct. 2018. For the Commission Order see p. 42 of the TRC Final Test Order.
4. Federal Standards are 0.68 -0.0019 x Rated Storage in Gallons for oil-fired storage water heater. For a 50-gallon tank this 0.585. <http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/27>
5. “Residential End Uses of Water, Version 2.” *Water Research Foundation.* (Apr 2016), p. 5. <https://www.circleofblue.org/wp-content/uploads/2016/04/WRF_REU2016.pdf>
6. Pennsylvania Statewide Residential End-Use and Saturation Study, 2014, <http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-2014_PA_Statewide_Act129_Residential_Baseline_Study.pdf>.
7. Using Rock Spring, PA (Site 2036) as a proxy, the mean of soil temperature at 40 inch depth is 51.861. Calculated using Daily SCAN Standard - Period of Record data from April 1999 to December 2018 from the Natural Resource Conservation Service Database. <https://wcc.sc.egov.usda.gov/nwcc/rgrpt?report=daily_scan_por&state=PA>. Methodology follows Missouri TRM 2017 Volume 2: Commercial and Industrial Measures. p. 78. <https://energy.mo.gov/sites/energy/files/MOTRM2017Volume2.pdf>
8. Straub, Mary and Switzer, Sheldon. "Using Available Information for Efficient Evaluation of Demand Side Management Programs". Study by BG&E. The Electricity Journal. Aug/Sept, 2011. p. 95. <http://www.sciencedirect.com/science/article/pii/S1040619011001941>

### Water Heater Tank Wrap

|  |  |
| --- | --- |
| **Target Sector** | Residential |
| **Measure Unit** | Tank |
| **Measure Life** | 7 yearsSource 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.[[42]](#footnote-44)

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.

ΔkWpeak

Definition of Terms

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

| **Term** | **Unit** | **Value** | **Source** |
| --- | --- | --- | --- |
| *Rbase*, R-value is a measure of resistance to heat flow prior to adding tank wrap |  | Default: 12 or EDC Data Gathering | 1 |
| *Rinsul*, R-value is a measure of resistance to heat flow after addition of tank wrap |  | Default: 20 or EDC Data Gathering | 2 |
| *Abase*, Surface area of storage tank prior to adding tank wrap |  | See Table 2‑56 |  |
| *Ainsul* , Surface area of storage tank after addition of tank wrap |  | See Table 2‑56 |  |
| *ηElec*, Thermal efficiency of electric heater element | *Proportion* | 0.98 | 3 |
| *Tsetpoint*, Temperature of hot water in tank | *˚F* | 119 | 4 |
| *Tambient*, Temperature of ambient air | *˚F* | 70 | 4 |
| *HOU* , Annual hours of use for water heater tank | *Hours/yr* | 8,760 |  |
| *CF* , Demand Coincidence Factor | *Proportion* | 1.0 |  |

Table 2‑56: Deemed savings by water heater capacity

| **Capacity (gal)** | **Rbase** | **Rinsul** | **Abase (ft2)[[43]](#footnote-45)** | **Ainsul (ft2)[[44]](#footnote-46)** | **ΔkWh** | **ΔkW** |
| --- | --- | --- | --- | --- | --- | --- |
| 30 | 8 | 16 | 19.16 | 20.94 | 139.4 | 0.0159 |
| 30 | 10 | 18 | 19.16 | 20.94 | 96.6 | 0.0110 |
| 30 | 12 | 20 | 19.16 | 20.94 | 70.6 | 0.0081 |
| 30 | 8 | 18 | 19.16 | 20.94 | 158.1 | 0.0180 |
| 30 | 10 | 20 | 19.16 | 20.94 | 111.6 | 0.0127 |
| 30 | 12 | 22 | 19.16 | 20.94 | 82.8 | 0.0094 |
| 40 | 8 | 16 | 23.18 | 25.31 | 168.9 | 0.0193 |
| 40 | 10 | 18 | 23.18 | 25.31 | 117.1 | 0.0134 |
| 40 | 12 | 20 | 23.18 | 25.31 | 85.5 | 0.0098 |
| 40 | 8 | 18 | 23.18 | 25.31 | 191.5 | 0.0219 |
| 40 | 10 | 20 | 23.18 | 25.31 | 135.1 | 0.0154 |
| 40 | 12 | 22 | 23.18 | 25.31 | 100.3 | 0.0114 |
| 50 | 8 | 16 | 24.99 | 27.06 | 183.9 | 0.0210 |
| 50 | 10 | 18 | 24.99 | 27.06 | 127.8 | 0.0146 |
| 50 | 12 | 20 | 24.99 | 27.06 | 93.6 | 0.0107 |
| 50 | 8 | 18 | 24.99 | 27.06 | 208.0 | 0.0237 |
| 50 | 10 | 20 | 24.99 | 27.06 | 147.1 | 0.0168 |
| 50 | 12 | 22 | 24.99 | 27.06 | 109.4 | 0.0125 |
| 80 | 8 | 16 | 31.84 | 34.14 | 237.0 | 0.0271 |
| 80 | 10 | 18 | 31.84 | 34.14 | 165.3 | 0.0189 |
| 80 | 12 | 20 | 31.84 | 34.14 | 121.5 | 0.0139 |
| 80 | 8 | 18 | 31.84 | 34.14 | 267.4 | 0.0305 |
| 80 | 10 | 20 | 31.84 | 34.14 | 189.6 | 0.0216 |
| 80 | 12 | 22 | 31.84 | 34.14 | 141.4 | 0.0161 |

Evaluation Protocols

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

Sources

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

### Water Heater Temperature Setback

|  |  |
| --- | --- |
| **Target Sector** | Residential Establishments |
| **Measure Unit** | Water Heater Temperature |
| **Measure Life** | 2 yearsSource 10 |
| **Vintage** | Retrofit |

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

Eligibility

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

Algorithms

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

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.

ΔkWpeak =

ETDF (Energy to Demand Factor) is defined below:

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

Definition of Terms

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

|  |  |  |  |
| --- | --- | --- | --- |
| **Term** | **Unit** | **Values** | **Source** |
| , Energy Factor of water heater | *Proportion* | EDC data collection  Default:  Electric Storage= 0.904  HPWH= 2.0 | 1 |
| , R value of water heater tank |  | EDC Data Gathering  Default: 12 | 9 |
| , Surface Area of water heater tank |  | EDC Data Gathering  Default: 24.99 | 50 gal. value in Table 2‑58 |
| , Thermal efficiency of electric heater element (equiv. to COP for HPWH) | *Proportion* | Electric Storage: 0.98  HPWH: 2.1 | 2, 3 |
| , Volume of hot water used per cycle by clothes washer | *gallons/day* | 7 | 4 |
| *Cycleswash* , Number of clothes washer cycles per year |  | Clothes washer present:  251  No clothes washer: 0 | 5 |
| *Thot\_i*, Temperature setpoint of water heater initially | *°F* | EDC Data Gathering  Default: 130 | 6 |
| *Thot\_f*, Temperature setpoint of water heater after setback | *°F* | EDC data collection  Default: 119 | 7 |
| *ETDF* , Energy To Demand Factor (defined above) |  | 0.00008047 | 8 |

Default Savings

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

Table 2‑58 below.

Table 2‑58: Default Energy Savings and Demand Reductions

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Type** | **Cycleswash** |  |  | **Energy Savings ()** | **Demand Reduction ()** |
| Electric Storage | 0 | 0.98 | 0.904 | 60.0 | 0.0048 |
| Electric Storage | 260 | 0.98 | 0.904 | 113.9 | 0.0092 |
| HPWH | 0 | 2.1 | 2.0 | 28.0 | 0.0023 |
| HPWH | 260 | 2.1 | 2.0 | 52.4 | 0.0042 |

Evaluation Protocols

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

Sources

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

### Water Heater Pipe Insulation

|  |  |
| --- | --- |
| **Target Sector** | Residential Establishments |
| **Measure Unit** | Water Heater |
| **Measure Life** | 13 yearsSource 3 |
| **Vintage** | Retrofit |

This measure relates to the installation of ¾” thick foam insulation on exposed pipe in unconditioned space. The baseline for this measure is a standard efficiency 50 gallon electric water heater (UEF=0.9207) with an annual energy usage of 2,939 kWh. [[45]](#footnote-47)

Eligibility

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

Algorithms

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

ΔkWh = 8.82 kWh/yr per foot of installed insulation

The summer coincident peak kW savings are calculated as follows:

ΔkWpeak =

Definition of Terms

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

| **Term** | **Unit** | **Value** | **Source** |
| --- | --- | --- | --- |
| *ΔkWh*, annual energy savings per foot of installed pipe insulation |  | 8.82 | 1 |
| *ETDF*, Energy to Demand Factor |  | 0.00008047 | 2 |
| *ΔkWpeak*, Summer peak kW savings per foot of installed pipe insulation |  | 0.00071 | - |

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:

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

Evaluation Protocols

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

Sources

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

### Low Flow Faucet Aerators

|  |  |
| --- | --- |
| **Target Sector** | Residential Establishments |
| **Measure Unit** | Aerator |
| **Measure Life** | 10 yearsSource 1 |
| **Vintage** | Retrofit |

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

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

Eligibility

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

Algorithms

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

**Where:**

Given:

The ratio of the average energy usage during 2 PM and 6 PM on summer weekdays to the total annual energy usage is taken from average daily load shape data collected for faucets from an Aquacraft, Inc study.Source 2 The average daily load shapes (percentages of daily energy usage that occur within each hour) are plotted in Figure 2‑1 below (symbol FAU represents faucets).

Figure 2‑1: Daily Load Shapes for Hot Water MeasuresSource 2



Definition of Terms

Table 2‑60: Low Flow Faucet Aerator Calculation Assumptions

| **Term** | **Unit** | **Value** | **Source** |
| --- | --- | --- | --- |
| *GPMbase* , Average baseline flow rate of aerator (GPM) |  | Default =2.2  Or EDC Data Gathering | 3 |
| *GPMlow* , Average post measure flow rate of aerator (GPM) |  | Default = 1.5  Or EDC Data Gathering | 3 |
| *Tperson-day* , Average time of hot water usage per person per day (minutes) |  | Kitchen=4.5  Bathroom=1.6  Unknown=6.1 | 4 |
| *Npersons* , Average number of persons per household |  | Default SF=2.5  Default MF=1.7  Default Unknown=2.5  Or EDC Data Gathering | 11 |
| *Tout* , Average mixed water temperature flowing from the faucet (ºF) | *˚F* | Kitchen=93  Bathroom=86  Unknown= 87.8 | 6 |
| *Tin* , Average temperature of water entering the house (ºF) | *˚F* | 52 | 7 |
| *RE* , Recovery efficiency of electric water heater | *Proportion* | Default: 0.98  HPWH: 2.1 | 8, 10 |
| ETDF, Energy To Demand Factor |  | 0.000134 | 2 |
| , Average number of faucets in the home |  | EDC Data Gathering,  Default see Table 2‑61 | 5 |
| *DF* , Percentage of water flowing down drain | *%* | Kitchen=75%  Bathroom=90%  Unknown=79.5% | 9 |
| *ISR* , In Service Rate | *%* | EDC Data Gathering,  Kit Delivery Default: 28%  Direct Install Default: 100% | EDC Data Gathering, 12 |
| *ELEC* , Percentage of homes with electric water heat | *%* | Default: Unknown=35%  Or EDC Data Gathering:  Electric = 100%  Fossil Fuel = 0.0% | 5 |
| , percentage of daily faucet use during PJM peak period | *%* | 19.5% | 2 |

Table 2‑61: Average Number of Faucets per Home

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

Default Savings

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

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

Evaluation Protocols

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

Sources

1. California’s Database of Energy Efficiency Resources (DEER), updated 2/5/2014. <http://www.deeresources.com/files/DEER2013codeUpdate/download/DEER2014-EUL-table-update_2014-02-05.xlsx>
2. Aquacraft, Inc., Water Engineering and Management. The end use of hot water in single family homes from flow trace analysis. 2001. <http://s3.amazonaws.com/zanran_storage/www.aquacraft.com/ContentPages/47768067.pdf>. The statewide values were used for inputs in the ETDF. algorithm components. The CF for faucets is found to be 0.00413: [% faucet use during peak × (TPerson-Day× NPerson) /(Nfaucets-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 *FED* is calculated to be 0.000134: CF / Hours = 0.00413 / 30.9 =0.000134.
3. Cadmus and Opinion Dynamics Evaluation Team. Showerhead and Faucet Aerator Meter Study. For Michigan Evaluation Working Group. June 2013. Baseline GPM of replaced aerators is set to the federal minimum GPM of 2.2. The GPM of new aerators is set to the typical rated GPM value of 1.5 GPM. Discounted GPM flow rates were not applied because the “throttle factor” adjustment was found to have been already accounted for in the mixed water temperature variable. Additionally, the GPMBase was set to a default value of 2.2 due to the inability to verify what the GPM flow rate was of the replaced faucet.
4. Cadmus and Opinion Dynamics Evaluation Team. Showerhead and Faucet Aerator Meter Study. For Michigan Evaluation Working Group. June 2013. If aerator location is known, use the corresponding kitchen/bathroom value. If unknown, use 6.1 min/person/day as the average length of use value, which is the total for the household: kitchen (4.5 min/person/day) + bathroom (1.6 min/person/day) = 6.1 min/person/day.
5. Pennsylvania Act 129 2018 Residential Baseline Study, <http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-Phase3_Res_Baseline_Study_Rpt021219.pdf>.
6. Table 7. Cadmus and Opinion Dynamics Evaluation Team. Showerhead and Faucet Aerator Meter Study. For Michigan Evaluation Working Group. June 2013. The study finds that the average mixed water temperature flowing from the kitchen and bathroom faucets is 93ºF and 86ºF, respectively. If the faucet location is unknown, 87.8ºF is the corresponding value to be used, which was calculated by taking a weighted average of faucet type (using the statewide values): (1×93+3×86)/(1+3) = 87.8.
7. Using Rock Spring, PA (Site 2036) as a proxy, the mean of soil temperature at 40 inch depth is 51.861. Calculated using Daily SCAN Standard - Period of Record data from April 1999 to December 2018 from the Natural Resource Conservation Service Database. <https://wcc.sc.egov.usda.gov/nwcc/rgrpt?report=daily_scan_por&state=PA>. Methodology follows Missouri TRM 2017 Volume 2: Commercial and Industrial Measures. p. 78. <https://energy.mo.gov/sites/energy/files/MOTRM2017Volume2.pdf>
8. AHRI Directory. All electric storage water heaters have a recovery efficiency of .98. <https://www.ahridirectory.org/Search/SearchForm?programId=24&searchTypeId=2>
9. Illinois TRM Effective June 1, 2013. Faucet usages are at times dictated by volume, only “directly down the drain” usage will provide savings. Due to the lack of a metering study that has determined this specific factor, the Illinois Technical Advisory Group has deemed these values to be 75% for the kitchen and 90% for the bathroom. If the aerator location is unknown an average of 79.5% should be used which is based on the assumption that 70% of household water runs through the kitchen faucet and 30% through the bathroom 0.7×0.75 + 0.3×0.) = 0.795.
10. NEEA Heat Pump Water Heater Field Study Report. Prepared by Fluid Market Strategies. October 22, 2013. <https://neea.org/img/uploads/heat-pump-water-heater-field-study-report.pdf>.
11. American Community Survey 5-Year (2013-2017) Estimates for 2017. <http://factfinder.census.gov>.
12. Average of PY9 values for kit delivery for First Energy EDCs. [[WEBSITE LINK TBD](http://www.puc.pa.gov/)]

### Low Flow Showerheads

|  |  |
| --- | --- |
| **Target Sector** | Residential Establishments |
| **Measure Unit** | Water Heater |
| **Measure Life** | 9 yearsSource 1 |
| **Vintage** | Retrofit |

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

Eligibility

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

Algorithms

The annual energy savings are obtained through the following formula:

**Where:**

Given:

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

Figure 2‑2: Daily Load Shapes for Hot Water MeasuresSource 2



Definition of Terms

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

| **Term** | **Unit** | **Value** | **Source** |
| --- | --- | --- | --- |
| *GPMbase* , Gallons per minute of baseline showerhead |  | Default value = 2.5 | 3 |
| *GPMlow* , Gallons per minute of low flow showerhead |  | EDC Data Gathering |  |
| , Average time of shower usage per person (minutes) |  | 7.8 | 5 |
| *Npersons* , Average number of persons per household |  | EDC Data Gathering or  Default SF=2.5  Default MF=1.7  Default unknown=2.5 | 6 |
| , Average number of showers per person per day |  | 0.6 | 7 |
| , Average number of showers in the home |  | EDC Data Gathering or  Default SF=1.6  Default MF=1.1  Default unknown = 1.5 | 8 |
| *Tout* , Assumed temperature of water used by showerhead | *° F* | 101 | 9 |
| *Tin* , Assumed temperature of water entering house | *° F* | 52 | 10 |
| *RE* , Recovery efficiency of electric water heater | *Proportion* | Default: 0.98  HPWH: 2.1 | 11, 13 |
| *ETDF* , Energy To Demand Factor |  | 0.00008014 | 12 |
| *ISR* , In Service Rate | *%* | EDC Data Gathering,  Kit Default = 35%  Direct Install Default = 100% | EDC Data Gathering,  14 |
| *ELEC* , Percentage of homes with electric water heat | *%* | EDC Data Gathering or  Default: Unknown=35%  Electric = 100%  Fossil Fuel = 0.0% | 8 |
| , percentage of daily shower use during PJM peak period | *%* | 11.7% | 12 |

Default Savings

Table 2‑64: Default Savings for Low Flow Showerheads

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

Evaluation Protocols

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

Sources

1. Efficiency Vermont, Technical Reference User Manual: Measure Savings Algorithms and Cost Assumptions, TRM User Manual No. 2008-53, 07/18/08, <http://www.veic.org/docs/ResourceLibrary/TRM-User-Manual-Excerpts.pdf>
2. Aquacraft, Inc., Water Engineering and Management. The end use of hot water in single family homes from flow trace analysis. 2001. <http://s3.amazonaws.com/zanran_storage/www.aquacraft.com/ContentPages/47768067.pdf>
3. Cadmus and Opinion Dynamics Evaluation Team. Showerhead and Faucet Aerator Meter Study. For Michigan Evaluation Working Group. June 2013. Uses the federal minimum GPM allowed as the baseline for the replaced showerheads, corresponding to 2.5 GPM.
4. Illinois TRM Effective June 1, 2013. Allows for varying flow rate of the low-flow showerhead, most notably values of 2.0 GPM, 1.75 GPM and 1.5 GPM. Custom or actual values are also allowed for.
5. Table 6. Cadmus and Opinion Dynamics Evaluation Team. Showerhead and Faucet Aerator Meter Study. For Michigan Evaluation Working Group. June 2013. The study compared shower length by single-family and multifamily populations, finding no statistical difference in showering times. For the energy-saving analysis, the study used the combined single-family and multifamily average shower length of 7.8 minutes.
6. American Community Survey 5-Year (2013-2017) Estimates for 2017. <http://factfinder.census.gov>.
7. Table 8. Cadmus and Opinion Dynamics Evaluation Team. Showerhead and Faucet Aerator Meter Study. For Michigan Evaluation Working Group. June 2013. For each shower fixture metered, the evaluation team knew the total number of showers taken, duration of time meters remained in each home, and total occupants reported to live in the home. From these values average showers taken per day, per person was calculated. The study compared showers per day, per person by single-family and multifamily populations, finding no statistical difference in the values. For the energy-saving analysis, the study used the combined single-family and multifamily average showers per day, per person of 0.6.
8. Pennsylvania Act 129 2018 Residential Baseline Study, <http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-Phase3_Res_Baseline_Study_Rpt021219.pdf>.
9. Cadmus and Opinion Dynamics Evaluation Team. Showerhead and Faucet Aerator Meter Study. For Michigan Evaluation Working Group. June 2013. Temperature sensors provided the mixed water temperature readings resulting in an average of 101ºF.
10. Using Rock Spring, PA (Site 2036) as a proxy, the mean of soil temperature at 40 inch depth is 51.861. Calculated using Daily SCAN Standard - Period of Record data from April 1999 to December 2018 from the Natural Resource Conservation Service Database. <https://wcc.sc.egov.usda.gov/nwcc/rgrpt?report=daily_scan_por&state=PA>. Methodology follows Missouri TRM 2017 Volume 2: Commercial and Industrial Measures. p. 78. <https://energy.mo.gov/sites/energy/files/MOTRM2017Volume2.pdf>
11. AHRI Directory. All electric storage water heaters have a recovery efficiency of .98. <https://www.ahridirectory.org/Search/SearchForm?programId=24&searchTypeId=2>
12. Aquacraft, Inc., Water Engineering and Management. The end use of hot water in single family homes from flow trace analysis. 2001. <http://s3.amazonaws.com/zanran_storage/www.aquacraft.com/ContentPages/47768067.pdf>. The statewide values were used for inputs in the ETDF algorithm components. The CF for showerheads is found to be 0.00380: [% showerhead use during peak × (TPerson-Day × NPerson × Nshowers-day) /( Nshowerheads-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: (TPerson-Day× NPersons× 365) /( Nshowerheads-home) / 60 = (7.8 x 2.5 x 0.6 x 365) / 1.5 / 60 = 47.5. The resulting ETDF is calculated to be 0.00008014: CF / Hours = 0.00380 / 47.5 = 0.00008014.
13. NEEA Heat Pump Water Heater Field Study Report. Prepared by Fluid Market Strategies. October 22, 2013. <https://neea.org/img/uploads/heat-pump-water-heater-field-study-report.pdf>
14. Average of PY9 values for kit delivery for First Energy EDCs. [[WEBSITE LINK TBD](http://www.puc.pa.gov/)]

### Thermostatic Shower Restriction Valves

|  |  |
| --- | --- |
| **Target Sector** | Residential Establishments |
| **Measure Unit** | Water Heater |
| **Measure Life** | 15 yearsSource 1 |
| **Vintage** | Retrofit |

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

Eligibility

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

Algorithms

The annual energy savings are obtained through the following formula:

ΔkWpeak =

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

Figure 2‑3: Daily Load Shapes for Hot Water MeasuresSource 2



Definition of Terms

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

| **Parameter** | **Unit** | **Value** | **Source** |
| --- | --- | --- | --- |
| *GPMBase*, Gallons per minute of baseline showerhead |  | EDC Data Gathering or  Default:  Standard shower head=2.5  Low Flow Shower Head=1.5 | 3 |
| *Npersons*, Average number of persons per household |  | EDC Data Gathering or  Default:  SF=2.5  MF=1.7  Unknown=2.5 | 4 |
| *NShowers-Day*, Average number of showers per person per day |  | 0.6 | 5 |
| , Average number of showerhead fixtures in the home | *None* | EDC Data Gathering or  Default:  SF=1.6  MF=1.1  Unknown = 1.5 | 6 |
| *Tout*, Assumed temperature of water used by showerhead | *° F* | EDC Data Gathering or  Default: 104 | 7 |
| *Tin*, 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 |  | 0.00008014 | 10 |
| *ISR*, In Service Rate | *%* | EDC Data Gathering  Default: 100% | EDC Data Gathering |
| *ELEC*, Percentage of homes with electric water heat | *%* | EDC Data Gathering or  Default:  Electric = 100%  Fossil Fuel = 0.0%  Unknown=35% | 6 |
| *BehavioralWasteSeconds*, Time | *sec* | EDC Data Gathering or  Default = 59 | 7 |

Default Savings

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

Table 2‑66: Default Savings for Thermostatic Restriction Valve

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

Evaluation Protocols

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

Sources

1. Uniform Plumbing Code (UPC) certification under the International Association of Plumbing and Mechanical Officials standard IGC 244-2007a stipulates device must meet 10,000 cycles without failure. Measure life: [10,000 cycles / (Npersons x Nshowers-day x 365)] = [10,000 / (2.5 x 0.6 x 365)] = 18 years. Note that measure life is calculated to be 18 years; however, PA Act 129 savings can be claimed for no more than 15 years.
2. Aquacraft, Inc., Water Engineering and Management. The end use of hot water in single family homes from flow trace analysis. 2001. <http://s3.amazonaws.com/zanran_storage/www.aquacraft.com/ContentPages/47768067.pdf>.
3. Cadmus and Opinion Dynamics Evaluation Team. Showerhead and Faucet Aerator Meter Study. For Michigan Evaluation Working Group. June 2013. Uses the federal minimum GPM allowed as the baseline for the replaced showerheads, corresponding to 2.5 GPM.
4. American Community Survey 5-Year (2013-2017) Estimates for 2017. <http://factfinder.census.gov>.
5. Table 8. Cadmus and Opinion Dynamics Evaluation Team. Showerhead and Faucet Aerator Meter Study. For Michigan Evaluation Working Group. June 2013. For each shower fixture metered, the evaluation team knew the total number of showers taken, duration of time meters remained in each home, and total occupants reported to live in the home. From these values average showers taken per day, per person was calculated. The study compared showers per day, per person by single-family and multifamily populations, finding no statistical difference in the values. For the energy-saving analysis, the study used the combined single-family and multifamily average showers per day, per person of 0.6.
6. Pennsylvania Act 129 2018 Residential Baseline Study, <http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-Phase3_Res_Baseline_Study_Rpt021219.pdf>.
7. PPL Electric 2014 ShowerStart Pilot Study. Cadmus memo to PPL Electric in November 2014. The previous Tout value was based on the average water temperature of the entire shower, whereas this pilot study Tout 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 Tout value is more accurate than the previous value because it excludes the warmup phase of the shower and thus reflects the temperature of the water saved by the ShowerStart device during the behavioral waste period more accurately. The BehavioralWasteSeconds value represents the average time the ShowerStart device is engaged during a shower. The BehavioralWasteSeconds value includes instances when the user did not engage the ShowerStart device (instances when BehavioralWasteSeconds = 0s).
8. Using Rock Spring, PA (Site 2036) as a proxy, the mean of soil temperature at 40 inch depth is 51.861. Calculated using Daily SCAN Standard - Period of Record data from April 1999 to December 2018 from the Natural Resource Conservation Service Database. <https://wcc.sc.egov.usda.gov/nwcc/rgrpt?report=daily_scan_por&state=PA>. Methodology follows Missouri TRM 2017 Volume 2: Commercial and Industrial Measures. p. 78. <https://energy.mo.gov/sites/energy/files/MOTRM2017Volume2.pdf>
9. AHRI Directory. All electric storage water heaters have a recovery efficiency of .98. <https://www.ahridirectory.org/Search/SearchForm?programId=24&searchTypeId=2>
10. Aquacraft, Inc., Water Engineering and Management. The end use of hot water in single family homes from flow trace analysis. 2001. <http://s3.amazonaws.com/zanran_storage/www.aquacraft.com/ContentPages/47768067.pdf>. The statewide values were used for inputs in the ETDF algorithm components. The CF for showerheads is found to be 0.00380: [% showerhead use during peak × (TPerson-Day × NPerson × Nshowers-day) /( Nshowerheads-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: (TPerson-Day× NPersons× 365) /( Nshowerheads-home) / 60 = (7.8 x 2.5 x 0.6 x 365) / 1.5 / 60 = 47.5. The resulting ETDF is calculated to be 0.00008014: CF / Hours = 0.00380 / 47.5 = 0.00008014.
11. NEEA Heat Pump Water Heater Field Study Report. Prepared by Fluid Market Strategies. October 22, 2013. <https://neea.org/img/uploads/heat-pump-water-heater-field-study-report.pdf>

## Appliances

### ENERGY STAR Refrigerators

|  |  |
| --- | --- |
| **Target Sector** | Residential Establishments |
| **Measure Unit** | Refrigerator |
| **Measure Life** | 14 yearsSource 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 (kWhbase) may be determined using Table 2‑68.

The efficient model’s annual energy consumption (*kWhee* or *kWhme*) may be determined using manufacturers’ test data for the given model. Where test data is not available the algorithms in Table 2‑68 and Table 2‑70 for “ENERGY STAR and ENERGY STAR Most Efficient maximum energy usage in kWh/year” may be used to determine the efficient energy consumption for a conservative savings estimate.

**ENERGY STAR Refrigerator**

*ΔkWh*

*ΔkWpeak*

**ENERGY STAR Most Efficient Refrigerator**

*ΔkWh*

*ΔkWpeak*

Definition of Terms

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

|  |  |  |  |
| --- | --- | --- | --- |
| **Term** | **Unit** | **Value** | **Source** |
| *kWhbase* , Annual energy consumption of baseline unit | *kWh/yr* | EDC Data Gathering  Default = Table 2‑68 | 2 |
| *kWhee ,* Annual energy consumption of ENERGY STAR qualified unit | *kWh/yr* | EDC Data Gathering  Default = Table 2‑68 | 3 |
| *kWhme ,* 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 |  | 0.0001614 | 5 |

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

The term “AV” in the equations refers to “Adjusted Volume” in ft3. For Category 1 and 1A “All-refrigerators”:

*AV*

For all other categories:

*AV*

Table 2‑68: Federal Standard and ENERGY STAR Refrigerators Maximum Annual Energy Consumption if Configuration and Volume Known[[46]](#footnote-48)

| **Refrigerator Category** | **Federal Standard Maximum Usage in kWh/yr** | **ENERGY STAR Maximum Energy Usage in kWh/yr** |
| --- | --- | --- |
| **Standard Size Models: 7.75 cubic feet or greater** | | |
| 1. Refrigerator-freezers and refrigerators other than all-refrigerators with manual defrost. | 7.99 × AV + 225.0 | 7.19 × AV + 202.5 |
| 1A. All-refrigerators—manual defrost. | 6.79 × AV + 193.6 | 6.11 × AV + 174.2 |
| 2. Refrigerator-freezers—partial automatic defrost | 7.99 × AV + 225.0 | 7.19 × AV + 202.5 |
| 3. Refrigerator-freezers—automatic defrost with top-mounted freezer without an automatic icemaker. | 8.07 × AV + 233.7 | 7.26 × AV + 210.3 |
| 3-BI. Built-in refrigerator-freezer—automatic defrost with top-mounted freezer without an automatic icemaker. | 9.15 × AV + 264.9 | 8.24 × AV + 238.4 |
| 3I. Refrigerator-freezers—automatic defrost with top-mounted freezer with an automatic icemaker without through-the-door ice service. | 8.07 × AV + 317.7 | 7.26 × AV + 294.3 |
| 3I-BI. Built-in refrigerator-freezers—automatic defrost with top-mounted freezer with an automatic icemaker without through-the-door ice service. | 9.15 × AV + 348.9 | 8.24 × AV + 322.4 |
| 3A. All-refrigerators—automatic defrost. | 7.07 × AV + 201.6 | 6.36 × AV + 181.4 |
| 3A-BI. Built-in All-refrigerators—automatic defrost. | 8.02 × AV + 228.5 | 7.22 × AV + 205.7 |
| 4. Refrigerator-freezers—automatic defrost with side-mounted freezer without an automatic icemaker. | 8.51 × AV + 297.8 | 7.66 × AV + 268.0 |
| 4-BI. Built-In Refrigerator-freezers—automatic defrost with side-mounted freezer without an automatic icemaker. | 10.22 × AV + 357.4 | 9.20 × AV + 321.7 |
| 4I. Refrigerator-freezers—automatic defrost with side-mounted freezer with an automatic icemaker without through-the-door ice service. | 8.51 × AV + 381.8 | 7.66 × AV + 352.0 |
| 4I-BI. Built-In Refrigerator-freezers—automatic defrost with side-mounted freezer with an automatic icemaker without through-the-door ice service. | 10.22 × AV + 441.4 | 9.20 × AV + 405.7 |
| 5. Refrigerator-freezers—automatic defrost with bottom-mounted freezer without an automatic icemaker. | 8.85 × AV + 317.0 | 7.97 × AV + 285.3 |
| 5-BI. Built-In Refrigerator-freezers—automatic defrost with bottom-mounted freezer without an automatic icemaker. | 9.40 × AV + 336.9 | 8.46 × AV + 303.2 |
| 5I. Refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker without through-the-door ice service. | 8.85 × AV + 401.0 | 7.97 × AV + 369.3 |
| 5I-BI. Built-In Refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker without through-the-door ice service. | 9.40 × AV + 420.9 | 8.46 × AV + 387.2 |
| 5A. Refrigerator-freezer—automatic defrost with bottom-mounted freezer with through-the-door ice service. | 9.25 × AV + 475.4 | 8.33 × AV + 436.3 |
| 5A-BI. Built-in refrigerator-freezer—automatic defrost with bottom-mounted freezer with through-the-door ice service. | 9.83 × AV + 499.9 | 8.85 × AV + 458.3 |
| 6. Refrigerator-freezers—automatic defrost with top-mounted freezer with through-the-door ice service. | 8.40 × AV + 385.4 | 7.56 × AV + 355.3 |
| 7. Refrigerator-freezers—automatic defrost with side-mounted freezer with through-the-door ice service. | 8.54 × AV + 432.8 | 7.69 × AV + 397.9 |
| 7-BI. Built-In Refrigerator-freezers—automatic defrost with side-mounted freezer with through-the-door ice service. | 10.25 × AV + 502.6 | 9.23 × AV + 460.7 |
| **Compact Size Models: Less than 7.75 cubic feet and 36 inches or less in height** | | |
| 11. Compact refrigerator-freezers and refrigerators other than all-refrigerators with manual defrost. | 9.03 × AV + 252.3 | 8.13 × AV + 227.1 |
| 11A.Compact all-refrigerators—manual defrost. | 7.84 × AV + 219.1 | 7.06 × AV + 197.2 |
| 12. Compact refrigerator-freezers—partial automatic defrost | 5.91 × AV + 335.8 | 5.32 × AV + 302.2 |
| 13. Compact refrigerator-freezers—automatic defrost with top-mounted freezer. | 11.80 × AV + 339.2 | 10.62 × AV + 305.3 |
| 13I. Compact refrigerator-freezers—automatic defrost with top-mounted freezer with an automatic icemaker. | 11.80 × AV + 423.2 | 10.62 × AV + 389.3 |
| 13A. Compact all-refrigerators—automatic defrost. | 9.17 × AV + 259.3 | 8.25 × AV + 233.4 |
| 14. Compact refrigerator-freezers—automatic defrost with side-mounted freezer. | 6.82 × AV + 456.9 | 6.14 × AV + 411.2 |
| 14I. Compact refrigerator-freezers—automatic defrost with side-mounted freezer with an automatic icemaker. | 6.82 × AV + 540.9 | 6.14 × AV + 495.2 |
| 15. Compact refrigerator-freezers—automatic defrost with bottom-mounted freezer. | 11.80 × AV + 339.2 | 10.62 × AV + 305.3 |
| 15I. Compact refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker. | 11.80 × AV + 423.2 | 10.62 × AV + 389.3 |

Table 2‑69: Default Savings Values for ENERGY STAR Refrigerators[[47]](#footnote-49)

| **Refrigerator Category** | **Assumed Volume of Unit (cubic feet)** Source 6 | **Conventional Unit Energy Usage in kWh/yr** | **ENERGY STAR Energy Usage in kWh/yr** | **ΔkWh/yr** | **ΔkWpeak** |
| --- | --- | --- | --- | --- | --- |
| 1A. All-refrigerators—manual defrost. | 12.2 | 276 | 249 | 28 | 0.0045 |
| 2. Refrigerator-freezers—partial automatic defrost | 12.2 | 322 | 290 | 32 | 0.0052 |
| 3I. Refrigerator-freezers—automatic defrost with top-mounted freezer with an automatic icemaker without through-the-door ice service. | 17.9 | 462 | 424 | 38 | 0.0061 |
| 4I. Refrigerator-freezers—automatic defrost with side-mounted freezer with an automatic icemaker without through-the-door ice service. | 22.7 | 575 | 526 | 49 | 0.0079 |
| 5I. Refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker without through-the-door ice service. | 20.0 | 578 | 529 | 49 | 0.0079 |
| 7. Refrigerator-freezers—automatic defrost with side-mounted freezer with through-the-door ice service. | 24.6 | 643 | 587 | 56 | 0.0090 |
| 5A. Refrigerator-freezer—automatic defrost with bottom-mounted freezer with through-the-door ice service. | 25.4 | 710 | 648 | 62 | 0.0100 |
| 3A. All-refrigerators—automatic defrost. | 12.2 | 288 | 259 | 29 | 0.0047 |
| **Compact Size Models: Less than 7.75 cubic feet and 36 inches or less in height** | | | | | |
| 11A.Compact all-refrigerators—manual defrost. | 3.3 | 245 | 220 | 24 | 0.0038 |
| 12. Compact refrigerator-freezers—partial automatic defrost | 3.3 | 355 | 320 | 36 | 0.0058 |
| 13. Compact refrigerator-freezers—automatic defrost with top-mounted freezer. | 4.5 | 392 | 353 | 39 | 0.0063 |
| 15. Compact refrigerator-freezers—automatic defrost with bottom-mounted freezer. | 5.1 | 399 | 359 | 40 | 0.0065 |

ENERGY STAR Most Efficient annual energy consumption (kWhme) 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 (kWhbase) of the federal standard model may be determined using Table 2‑68. *Eann* stands for Maximum Annual Energy Usage.

Table 2‑70: ENERGY STAR Most Efficient Annual Energy Usage if Configuration and Volume KnownSource 4

| **Refrigerator Category** | **ENERGY STAR Most Efficient Maximum Annual Energy Usage in kWh/yr** |
| --- | --- |
| 1. Refrigerator-freezers and refrigerators other than all-refrigerators with manual defrost. | AV ≤ 65.6, Eann ≤ 6.79 × AV + 191.3  AV > 65.6, Eann ≤ 637 |
| 2. Refrigerator-freezers—partial automatic defrost | AV ≤ 65.6, Eann ≤ 6.79 × AV + 191.3  AV > 65.6, Eann ≤ 637 |
| 3. Refrigerator-freezers—automatic defrost with top-mounted freezer without an automatic icemaker. | <637 kWh/yr |
| 3-BI. Built-in refrigerator-freezer—automatic defrost with top-mounted freezer without an automatic icemaker. | <637 kWh/yr |
| 3I. Refrigerator-freezers—automatic defrost with top-mounted freezer with an automatic icemaker without through-the-door ice service. | <637 kWh/yr |
| 3I-BI. Built-in refrigerator-freezers—automatic defrost with top-mounted freezer with an automatic icemaker without through-the-door ice service. | AV ≤ 51.6, Eann ≤ 6.86 × AV + 282.6  AV > 51.6, Eann ≤ 637 |
| 4. Refrigerator-freezers—automatic defrost with side-mounted freezer without an automatic icemaker. | AV ≤ 53.0, Eann ≤ 7.23 × AV + 253.1  AV > 53.0, Eann ≤ 637 |
| 4-BI. Built-In Refrigerator-freezers—automatic defrost with side-mounted freezer without an automatic icemaker. | AV ≤ 53.0, Eann ≤ 7.23 × AV + 253.1  AV > 53.0, Eann ≤ 637 |
| 4I. Refrigerator-freezers—automatic defrost with side-mounted freezer with an automatic icemaker without through-the-door ice service. | AV ≤ 41.4, Eann ≤ 7.23 × AV + 337.1  AV > 41.4, Eann ≤ 637 |
| 4I-BI. Built-In Refrigerator-freezers—automatic defrost with side-mounted freezer with an automatic icemaker without through-the-door ice service. | AV ≤ 41.4, Eann ≤ 7.23 × AV + 337.1  AV > 41.4, Eann ≤ 637 |
| 5. Refrigerator-freezers—automatic defrost with bottom-mounted freezer without an automatic icemaker. | AV ≤ 48.8, Eann ≤ 7.52 × AV + 269.5  AV > 48.8, Eann ≤ 637 |
| 5-BI. Built-In Refrigerator-freezers—automatic defrost with bottom-mounted freezer without an automatic icemaker. | AV ≤ 48.8, Eann ≤ 7.52 × AV + 269.5  AV > 48.8, Eann ≤ 637 |
| 5I. Refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker without through-the-door ice service. | AV ≤ 37.7, Eann ≤ 7.52 × AV + 353.5  AV > 37.7, Eann ≤ 637 |
| 5I-BI. Built-In Refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker without through-the-door ice service. | AV ≤ 37.7, Eann ≤ 7.52 × AV + 353.5  AV > 37.7, Eann ≤ 637 |
| 5A. Refrigerator-freezer—automatic defrost with bottom-mounted freezer with through-the-door ice service. | AV ≤ 28.0, Eann ≤ 7.86 × AV + 416.7  AV > 28.0, Eann ≤ 637 |
| 5A-BI. Built-in refrigerator-freezer—automatic defrost with bottom-mounted freezer with through-the-door ice service. | AV ≤ 28.0, Eann ≤ 7.86 × AV + 416.7  AV > 28.0, Eann ≤ 637 |
| 956. Refrigerator-freezers—automatic defrost with top-mounted freezer with through-the-door ice service. | AV < 41.5, Eann ≤ 7.14 × AV + 340.2  AV > 41.5, Eann ≤ 637 |
| 7. Refrigerator-freezers—automatic defrost with side-mounted freezer with through-the-door ice service. | AV ≤ 35.3, Eann ≤ 7.26 × AV + 380.5  AV > 35.3, Eann ≤ 637 |
| 7-BI. Built-In Refrigerator-freezers—automatic defrost with side-mounted freezer with through-the-door ice service. | AV ≤ 35.3, Eann ≤ 7.26 × AV + 380.5  AV > 35.3, Eann ≤ 637 |

Default Savings

Table 2‑71: Default Savings Values for ENERGY STAR Most Efficient RefrigeratorsSource 4

| **Refrigerator Category** | **Assumed Volume of Unit (ft3)** Source 7 | **Conventional Unit Energy Usage in kWh/yr[[48]](#footnote-50)** | **ENERGY STAR Most Efficient Consumption in kWh/yr** Source 4 | **ΔkWh** | **ΔkWpeak** |
| --- | --- | --- | --- | --- | --- |
| 3. Refrigerator-freezers—automatic defrost with top-mounted freezer without an automatic icemaker. | 17.1 | 372 | 333 | 39 | 0.0063 |
| 3I. Refrigerator-freezers—automatic defrost with top-mounted freezer with an automatic icemaker without through-the-door ice service. | 21.4 | 490 | 448 | 42 | 0.0068 |
| 5-BI. Built-In Refrigerator-freezers—automatic defrost with bottom-mounted freezer without an automatic icemaker. | 10.9 | 439 | 336 | 103 | 0.0167 |
| 5. Refrigerator-freezers—automatic defrost with bottom-mounted freezer without an automatic icemaker. | 14.9 | 449 | 367 | 82 | 0.0132 |
| 5I. Refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker without through-the-door ice service. | 22.1 | 597 | 511 | 86 | 0.0138 |
| 5A. Refrigerator-freezer—automatic defrost with bottom-mounted freezer with through-the-door ice service. | 30.2 | 755 | 621 | 134 | 0.0216 |
| 5I-BI. Built-In Refrigerator-freezers—automatic defrost with bottom-mounted freezer without an automatic icemaker. | 25.50 | 631 | 519 | 112 | 0.0181 |
| 7. Refrigerator-freezers—automatic defrost with side-mounted freezer with through-the-door ice service. | 27.5 | 668 | 525 | 143 | 0.0231 |

Evaluation Protocols

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

Sources

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

### ENERGY STAR Freezers

|  |  |
| --- | --- |
| **Target Sector** | Residential Establishments |
| **Measure Unit** | Freezer |
| **Measure Life** | 11 yearsSource 4 |
| **Vintage** | Replace on Burnout |

Eligibility

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

Algorithms

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

If the volume and configuration of the freezer is known, the baseline model’s annual energy consumption (kWhbase) may be are determined using Table 2‑72. The efficient model’s annual energy consumption (kWhee) may be determined using manufacturer’s test data for the given model. Where test data is not available the algorithms in Table 2‑73 for “ENERGY STAR Maximum Energy Usage in kWh/year” may be used to determine the efficient energy consumption for a conservative savings estimate

**ENERGY STAR Freezer**

*ΔkWh*

*ΔkWpeak*

Definition of Terms

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

| **Term** | **Unit** | **Value** | **Source** |
| --- | --- | --- | --- |
| *kWhbase* , Annual energy consumption of baseline unit | *kWh/yr* | EDC Data Gathering  Default = Table 2‑73 | 1 |
| *kWhee ,* Annual energy consumption of ENERGY STAR qualified unit | *kWh/yr* | EDC Data Gathering  Default = Table 2‑73 | 2 |
| *ETDF* , Energy to Demand Factor |  | 0.0001614 | 3 |

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

Table 2‑73: Federal Standard and ENERGY STAR Freezers Maximum Annual Energy Consumption if Configuration and Volume Known[[49]](#footnote-51)

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

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

Default Savings

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

| **Freezer Category** | **Average Unit Adj. Volume (ft3)** | **[[50]](#footnote-52)Conventional UsageSource 5 (kWh/yr)** | **[[51]](#footnote-53)ENERGY STAR Usage Source 5 (kWh/yr)** | **ΔkWh** | **ΔkWpeak** |
| --- | --- | --- | --- | --- | --- |
| 8. Upright freezers with manual defrost. | 12.6 | 264 | 237 | 27 | 0.0043 |
| 9. Upright freezers with automatic defrost without an automatic icemaker. | 24.7 | 441 | 397 | 44 | 0.0071 |
| 10. Chest freezers and all other freezers except compact freezers. | 18.5 | 243 | 218 | 25 | 0.0039 |
| 16. Compact upright freezers with manual defrost. | 3.7 | 257 | 231 | 26 | 0.0042 |
| 17. Compact upright freezers with automatic defrost. | 7.7 | 430 | 387 | 43 | 0.0070 |
| 18. Compact chest freezers. | 8.9 | 219 | 197 | 22 | 0.0035 |

Evaluation Protocols

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

Sources

1. Federal Standards for Residential Refrigerators and Freezers, Effective 9/14/2014. <http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/43>
2. ENERGY STAR Program Requirements Product Specifications for Residential Refrigerators and Freezers Version 5.0. Effective 9/15/2014. <http://www.energystar.gov/products/specs/system/files/ENERGY%20STAR%20Final%20Version%205.0%20Residential%20Refrigerators%20and%20Freezers%20Program%20Requirements.pdf>
3. Consistent with the conversion factors in the Mid-Atlantic, Illinois, and Wisconsin TRMs. Derived from: (Temperature Adjustment Factor × Load Shape Adjustment Factor)/8760 hours. The temperature adjustment factor is 1.23 and is based on Blasnik, Michael, "Measurement and Verification of Residential Refrigerator Energy Use, Final Report, 2003-2004 Metering Study", July 29, 2004 (p. 47) and assuming 78% of refrigerators are in cooled space (based on BGE Energy Use Survey, Report of Findings, December 2005; Mathew Greenwald & Associates) and 22% in un-cooled space. The load shape adjustment factor is 1.15, based on the same report.
4. California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, <http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx>. Accessed December 2018.
5. ENERGY STAR Qualified Refrigerators and Freezers. Accessed October 2018. <https://data.energystar.gov/Active-Specifications/ENERGY-STAR-Certified-Residential-Freezers/8t9c-g3tn/data>

### 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.[[52]](#footnote-54) The savings algorithms are based on regression analysis of metered data on kWh consumption from other States. The savings algorithms for this measure can be applied to refrigerator and freezer retirements or early replacements meeting the following criteria:

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

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

Algorithms

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

**Energy Savings**

*ΔkWh* =

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

**Unit Energy Consumption**Source 2

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

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

The kWhee of the efficient freezers may be determined using manufacturers’ test data for the given model. If test data are not available, the algorithms in Table 2‑73 may be used to determine the efficient unit’s energy consumption.

Note that if the unit is being recycled without replacement, the *REPLACEMENTUEC* variable takes on the value of zero.

**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*

For all other categories:

*AV*

**Part-Use Factor**

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

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

**Peak Demand Savings**

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

*ΔkWpeak*

Definition of Terms

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

|  |  |  |  |
| --- | --- | --- | --- |
| **Term** | **Unit** | **Values** | **Source** |
| *N* , The number of refrigerators recycled through the program | *None* | EDC Data Gathering |  |
| *PART\_USE ,* The portion of the year the average refrigerator or freezer would likely have operated if not recycled through the program | *%* | EDC Data Gathering According to Section 4.4 of UMP Protocol  Default:  Refrigerator= 72.8%  Freezer= 84.5% | 4 |
| *ETDF* , Energy to Demand Factor |  | 0.0001119 | 5 |
| *AGE*, age of appliance | *years* | EDC Data Gathering |  |
| *PRE1990*, Fraction of appliances manufactured before 1990 | *%* | EDC Data Gathering |  |
| *AV*, Adjusted Volume/calculated as described above | *ft3* | EDC Data Gathering |  |
| *CONFIGsingle-door*, Fraction of refrigerators with single-door configuration | *%* | EDC Data Gathering |  |
| *CONFIGside-by-side*, Fraction of refrigeraors with side-by-side configuration | *%* | EDC Data Gathering |  |
| *CONFIGchest*, Fraction of freezers with chest configuration | *%* | EDC Data Gathering |  |
| *PRIMARY*, Fraction of appliances in primary use (in absence of program) | *%* | EDC Data Gathering |  |
| *UNCONDITIONED*, Fraction of appliances located in Unconditioned space | *%* | EDC Data Gathering  Default: Refrigerator=8%  Freezer=45% | 9 |
| *CDD*, Cooling degree days | °F-day/year | See CDD in Vol. 1, App. A | 10 |
| *HDD*, Heating degree days | °F-day/year | See HDD in Vol. 1, App. A | 10 |
| *kWhee ,* Annual energy consumption of ENERGY STAR qualified unit | *kWh/yr* | EDC Data Gathering  Refrigerator Default: See Table 2‑68 or Table 2‑70 in Sec. 2.4.1 ENERGY STAR Refrigerators  Freezer Default: See Table 2‑73 in Sec. 2.4.2 ENERGY STAR Freezers | 7, 8 |

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

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

Measure Life

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

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

**Adjusted Measure Life Rationale:**

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

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

To simplify the calculation of savings and remove the need to calculate two different savings, an adjusted value for measure life of 6 years for both low-income specific and non-low-income specific programs can be used with the savings difference between the existing baseline unit and the ENERGY STAR unit over the adjusted measure life. The 6-year adjusted measure life is derived by averaging the lifetime savings of a non-low-income replacement with a 12-year measure life and a low-income replacement with an 18-year measure life.

The derivation of the 6-year adjusted measure life can be demonstrated with an example of a typical refrigerator replacement with an ENERGY STAR unit. Assuming a refrigerator of type 5l in section 2.4.1, ENERGY STAR Refrigerators with an adjusted volume of 20 ft3, annual savings would be 578 kWh for the RUL of the existing baseline unit and annual savings of 49 kWh for the remaining EUL.[[53]](#footnote-55)

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

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

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

Evaluation Protocols

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

Sources

1. California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, <http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx> Accessed December 2018.
2. US DOE Uniform Method Project, Savings Protocol for Refrigerator Retirement, April 2017. <https://www.nrel.gov/docs/fy17osti/68563.pdf>
3. U.S. Department of Energy, Uniform Methods Project protocol titled “Refrigerator Recycling Evaluation Protocol”, prepared by Doug Bruchs and Josh Keeling of the Cadmus Group, September 2013. <https://www.nrel.gov/docs/fy17osti/68563.pdf>
4. Based on a Cadmus survey of 510 PPL participants in PY8.
5. Assessment of Energy and Capacity Savings Potential In Iowa. Quantec in collaboration with Summit Blue Consulting, Nexant, Inc., A-TEC Energy Corporation, and Britt/Makela Group, prepared for the Iowa utility Association, February 2008. <http://plainsjustice.org/files/EEP-08-1/Quantec/QuantecReportVol1.pdf>
6. 2004–2005 Final Report: A Measurement and Evaluation Study of the 2004-2005 Limited Income Refrigerator Replacement & Lighting Program, Prepared for: San Diego Gas & Electric, July 31, 2006
7. Federal Standards for Residential Refrigerators and Freezers, Effective 9/14/2014. <http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/43>
8. ENERGY STAR Program Requirements Product Specifications for Residential Refrigerators and Freezers Version 5.0. Effective 9/15/2014. <https://www.energystar.gov/ia/partners/product_specs/program_reqs/Refrigerators_and_Freezers_Program_Requirements_V5.0.pdf>.
9. Statewide average for all housing types from Pennsylvania Act 129 2018 Residential Baseline Study, <http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-Phase3_Res_Baseline_Study_Rpt021219.pdf>.
10. PA SWE Team Calculations with data from the National Solar Radiation Database. 1991–2005 Update: Typical Meteorological Year 3. NREL. <http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html>.

### ENERGY STAR Clothes Washers

|  |  |
| --- | --- |
| **Target Sector** | Residential Establishments |
| **Measure Unit** | Clothes Washer |
| **Measure Life** | 11 yearsSource 1 |
| **Vintage** | Replace on Burnout |

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

Eligibility

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

Algorithms

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

Total Savings

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:

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

Definition of Terms

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

| **Term** | **Unit** | **Value** | **Source** |
| --- | --- | --- | --- |
| *CAPYbase*, Capacity of baseline clothes washer | *ft3* | EDC Data Gathering  Default: 3.5 | EDC Data Gathering  1 |
| *CAPYEE*, Capacity of ENERGY STAR clothes washer | *ft3* | EDC Data Gathering  Default: 3.5 | EDC Data Gathering  1 |
| *IMEFbase*, Integrated Modified Energy Factor of baseline clothes washer |  | Table 2‑77 | 8 |
| *IMEFEE*, Integrated Modified Energy Factor of ENERGY STAR clothes washer |  | EDC Data Gathering  Default: Table 2‑77 | EDC Data Gathering  2 |
| *Cycles* , Number of clothes washer cycles per year |  | 251 | 5 |
| *CWbase* , % of total energy consumption for baseline clothes washer mechanical operation | *%* | 8.1% | 4 |
| *CWEE*, % of total energy consumption for ENERGY STAR clothes washer mechanical operation | *%* | 5.8% | 4 |
| *DHWbase* , % of total energy consumption attributed to baseline clothes washer water heating | *%* | 26.5% | 4 |
| *DHWEE*, % of total energy consumption attributed to ENERGY STAR clothes washer water heating | *%* | 31.2% | 4 |
| , % of water heaters that are electric | *%* | EDC Data Gathering  Default: 35% | EDC Data Gathering  3 |
| *Dryerbase* , % of total energy consumption for baseline clothes washerdryer operation | *%* | 65.4% | 4 |
| *DryerEE*, % of total energy consumption for ENERGY STAR clothes washer dryer operation | *%* | 63.0% | 4 |
| , Percentage of dryers that are electric | *%* | EDC Data Gathering  Default: 74% | EDC Data Gathering  3 |
| , Percentage of homes with a dryer that use the dryer every time clothes are washed | *%* | Default= 96%  Or EDC data gathering | 5 |
| , average duration of a clothes washer cycle | *hours* | 1.04 | 6 |
| *CF* , Demand Coincidence Factor. The coincidence of average clothes washer demand to summer system peak | *Proportion* | 0.029 | 7 |

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

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

Table 2‑77: Federal Standards and ENERGY STAR Specifications for Clothes WashersSource 2, 8

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

Default Savings

Table 2‑78: Default Clothes Washer Savings

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

Evaluation Protocols

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

Sources

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

### ENERGY STAR Clothes Dryers

|  |  |
| --- | --- |
| **Target Sector** | Residential |
| **Measure Unit** | Clothes Dryer |
| **Measure Life** | 12 yearsSource 4 |
| **Vintage** | Replace on Burnout |

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

Eligibility

This protocol documents the energy savings attributed to purchasing an electric ENERGY STAR Dryer that meets or exceeds the requirement in Table 2‑80 instead of a standard dryer. If a customer submits a rebate for a product that has applied for ENERGY STAR Certification but has not yet been certified, the savings will be counted for that product contingent upon its eventual certification as an ENERGY STAR measure. If at any point the product is rejected by ENERGY STAR, the product is then ineligible for the program and savings will not be counted.[[54]](#footnote-56) The target sector is residential.

Algorithms

The energy savings are obtained through the following formulas:

Definition of Terms

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

|  |  |  |  |
| --- | --- | --- | --- |
| **Term** | **Unit** | **Values** | **Source** |
| , Number of washing machine cycles per year | *cycles/yr* | 251 cycles/year | 1 |
| , Weight of average dryer load, in pounds per load | *lbs/load* | Standard: 8.45 lbs/load  Compact: 3.00 lbs/load | 2 |
| , Percentage of homes with a dryer that use the dryer for every load | *%* | 96%  Or EDC data gathering | 1 |
| , Combined Energy Factor of baseline dryer, in lbs/kWh | *lbs/kWh* | Table 2‑80 or EDC Data Gathering | 3 |
| , Combined Energy Factor of ENERGY STAR dryer, in lbs/kWh | *lbs/kWh* | Table 2‑80 or EDC Data Gathering | 2 |
| , Duration of baseline dryer drying cycle | Hours/ cycle | EDC Data Gathering  Default = 1.0 | Assumption |
| , Duration of efficient dryer drying cycle | Hours/ cycle | EDC Data Gathering  Default = 1.0 | Assumption |
| , Coincidence Factor | *Proportion* | 0.029 | Based on CF assumption for Clothes Washers |

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

|  |  |  |
| --- | --- | --- |
| **Product Type** | **(lbs/kWh)** | **(lbs/kWh)** |
| Vented Electric, Standard  (4.4 ft³ or greater capacity) | 3.73 | 3.93 |
| Vented Electric, Compact (120V)  (less than 4.4 ft³ capacity) | 3.61 | 3.80 |
| Vented Electric, Compact (240V)  (less than 4.4 ft³ capacity) | 3.27 | 3.45 |

Default Savings

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

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

Evaluation Protocols

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

Sources

1. Calculated using “Frequency of clothes washer use” and “Frequency of dryer use” data for the Mid-Atlantic region from U.S. Department of Energy. 2015 Residential Energy Consumption Survey (2015). <https://www.eia.gov/consumption/residential/data/2015/index.php?view=microdata>
2. Energy Star. “Clothes Dryers Key Product Criteria. “ ENERGY STAR Specification for Clothes Dryers Version 1.0, Effective January 1, 2015. <https://www.energystar.gov/products/appliances/clothes_dryers/key_product_criteria>
3. Federal Code of Regulations 10 CFR 430. <https://www.gpo.gov/fdsys/pkg/CFR-2017-title10-vol3/pdf/CFR-2017-title10-vol3-sec430-32.pdf>
4. California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, [http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx. Accessed December 2018](http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx.%20Accessed%20December%202018).

### Heat Pump Clothes Dryers

|  |  |
| --- | --- |
| **Target Sector** | Residential Establishments |
| **Measure Unit** | Per Clothes Dryer |
| **Measure Life** | 13 yearsSource 1 |
| **Vintage** | Replace on Burnout, New Construction |

Heat pump clothes dryers are more energy-efficient than standard dryers. A conventional dryer heats air, passes it through the clothing drum, and exhausts the hot air. A heat pump dryer works by circulating hot air through the clothing drum, extracting moisture from the clothing that becomes condensation after passing over an evaporator coil, then reheating the air before it passes through the drum again. The heat pump dryer saves energy by recirculating the warm air, requiring less heat to reach the desired temperature, and because the process requires a lower air temperature overall to dry clothes.

Eligibility

This protocol documents the energy savings attributed to installing a heat pump clothes dryer that meets or exceeds the default requirements in Table 2‑82. The target sector is residential.

Algorithms

The following algorithms shall be used to calculate the annual energy savings and coincident peak demand savings for this measure:

|  |  |
| --- | --- |
|  |  |
|  |  |

Definition of Terms

Table 2‑82: Terms, Values, and References for Heat Pump Clothes Dryers

|  |  |  |  |
| --- | --- | --- | --- |
| **Term** | **Unit** | **Values** | **Source** |
| , Annual Energy Savings | *kWh/yr* | Table 2‑83 | - |
| , Peak Demand Savings | *kW* | Table 2‑83 | - |
| , Number of washing machine cycles per year | *cycles/yr* | EDC Data Gathering  Default = 251 | 2 |
| , Weight of average dryer load | *lbs/cycle* | Standard = 8.45  Compact = 3.00 | 3 |
| , Percentage of washed loads that get dried | *%* | Default = 96% | 2 |
| , Combined Energy Factor of baseline dryer, in lbs/kWh | *lbs/kWh* | EDC Data Gathering  See *CEFbase* of Table 2‑80 in Sec. 0 | 4 |
| , 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 |
| , Duration of baseline dryer drying cycle | *Hours/ cycle* | EDC Data Gathering  Default = 1.0 | Assumption |
| , Duration of efficient dryer drying cycle | *Hours/ cycle* | EDC Data Gathering  Heat Pump = 1.2 | 6 |
| , Coincidence Factor | *None* | EDC Data Gathering  Default = 0.029 | Based on CF assumption for Clothes Washers |

Default Savings

Table 2‑83: Default Savings for Heat Pump Clothes Dryers

|  |  |  |
| --- | --- | --- |
| **Heat Pump Type** | **Energy Savings (kWh/yr)** | **Peak Demand Reduction (kW)** |
| 4.4 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 PennsylvaniaI Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1. ENERGY STAR, ENERGY STAR Market & Industry Scoping Report - Residential Clothes Dryers, November 2011. [https://www.energystar.gov/sites/default/files/asset/document/‌ENERGY\_STAR\_Scoping\_Report\_Residential\_Clothes\_Dryers.pdf](https://www.energystar.gov/sites/default/files/asset/document/ENERGY_STAR_Scoping_Report_Residential_Clothes_Dryers.pdf)
2. Calculated using “Frequency of clothes washer use” and “Frequency of dryer use” data for the Mid-Atlantic region from U.S. Department of Energy. 2015 Residential Energy Consumption Survey (2015). <https://www.eia.gov/consumption/residential/data/2015/index.php?view=microdata>
3. Energy Star. “Clothes Dryers Key Product Criteria. “ ENERGY STAR Specification for Clothes Dryers Version 1.0, Effective January 1, 2015. <https://www.energystar.gov/products/appliances/clothes_dryers/key_product_criteria>
4. U.S. Code of Federal Regulations, Part 430, Subpart C, *Energy and Water Conservation Standards*. <http://www.ecfr.gov/cgi-bin/text-idx?rgn=div8&node=10:3.0.1.4.18.3.9.2>
5. ENERGY STAR, *Certified Clothes Dryers*. <https://www.energystar.gov/productfinder/product/certified-clothes-dryers/results>  
   (Examined the “ventless” dryers and removed dryers that were condensing and not heat pump. Then took the average CEF of the two different capacity bins.)
6. CLASP, SEDI and Ecova, Analysis of Potential Energy Savings from Heat Pump Clothes Dryers in North America, March 2013. <http://www.ecosresearch.com/wp-content/uploads/2015/12/2013_Analysis-of-Potential-Energy-Savings-from-Heat-Pump-Clothes-Dryers-in-North-America.pdf>

### Fuel Switching: Electric Clothes Dryer to Gas Clothes Dryer

|  |  |
| --- | --- |
| **Target Sector** | Residential Establishments |
| **Measure Unit** | Fuel Switch: Electric Clothes Dryer to Gas Clothes Dryer |
| **Measure Life** | 12 yearsSource 1 |
| **Vintage** | Replace on Burnout |

This protocol outlines the savings associated to purchasing an ENERGY STAR gas clothes dryers to replace an electric dryer. The measure characterization and savings estimates are based on average usage per person and average number of people per household. Therefore, this is a deemed measure with identical savings applied to all installation instances, applicable across all housing types.

Eligibility

This measure is targeted to residential customers that purchase an ENERGY STAR gas clothes dryer rather than an electric dryer.

Algorithms

|  |  |
| --- | --- |
|  |  |
|  | = |
|  |  |

Definition of Terms

Table 2‑84: Terms, Values, and References for Fuel Switching: Electric Clothes Dryer to Gas Clothes Dryer

| **Term** | **Unit** | **Values** | **Source** |
| --- | --- | --- | --- |
| , Baseline annual electricity consumption of electric dryer, deemed |  | 577 | 2, 3 |
| , Annual electricity consumption of gas dryer, deemed |  | 30 | 4 |
| , Weighted average gas fuel savings (negative indicates increase in consumption) | *MMBTU* | -1.99 | 5 |
| , Number of washing machine cycles per year | cycles/yr | 251 | 6 |
| , Percentage of homes with a dryer that use the dryer every time clothes are washed | % | 96% | 6 |
| , Duration of average drying cycle in hours | hours | 1 | Assumption |
| CF, Coincidence Factor | *Proportion* | 0.029 | Based on CF assumption for Clothes Washers |

Default Savings

Savings estimates for this measure are fully deemed and may be claimed using the algorithms above and the deemed variable inputs.

*ΔkWh* = 547 kWh

*ΔkW* = 0.066

Evaluation Protocols

The appropriate evaluation protocol is to verify installation and proper selection of deemed values.

Sources

1. California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx. Accessed December 2018.
2. Statewide average for all housing types from Pennsylvania Act 129 2018 Residential Baseline Study, 2018,[[55]](#footnote-57) <http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-Phase3_Res_Baseline_Study_Rpt021219.pdf>.
3. 2011-04 Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment. Residential Clothes Dryers and Room Air Conditioners, Chapter 7. Table 7.3.4: Electric Standard and Gas Clothes Dryer: Average Annual Energy Consumption Levels by Efficiency <https://www.regulations.gov/document?D=EERE-2007-BT-STD-0010-0053> [[56]](#footnote-58)
4. *Ibid.* Median annual electricity consumption of gas dryers
5. Negative gas fuel savings indicate increase in fuel consumption. Average annual consumption for ENERGY STAR qualified gas units as of 6/22/2015: 685.3kWh/yr. Scaling from 283 cycles/yr (national 2005 RECS) to 251×96%=241 cycles/yr (Mid-Atlantic 2015 RECS): 583.5 kWh/yr. Converting to MMBTU: 583.5×0.003412 = 1.99 MMBTU/yr.
6. Calculated using “Frequency of clothes washer use” and “Frequency of dryer use” data for the Mid-Atlantic region from U.S. Department of Energy. 2015 Residential Energy Consumption Survey (2015). <https://www.eia.gov/consumption/residential/data/2015/index.php?view=microdata>

### ENERGY STAR Dishwashers

|  |  |
| --- | --- |
| **Target Sector** | Residential Establishments |
| **Measure Unit** | Dishwasher |
| **Measure Life** | 10 yearsSource 1 |
| **Vintage** | Replace on Burnout |

Eligibility

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

Algorithms

The general form of the measure savings equation for ENERGY STAR Dishwashers is:

Total Savings

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

Per unit energy and demand savings algorithms for dishwashers utilizing electrically heated hot water:

Definition of Terms

Table 2‑85: Terms, Values, and References for ENERGY STAR Dishwashers

| **Term** | **Unit** | **Value** | **Source** |
| --- | --- | --- | --- |
| *kWhbase*, *Annual energy consumption of baseline dishwasher* | *kWh/yr* | 307 | 1, 6 |
| *kWhee*, *Annual energy consumption of ENERGY STAR qualified unit* | *kWh/yr* | 270 | 1, 7 |
| *%kWhop* , *Percentage of unit dishwasher energy consumption used for operation* | *%* | 44% | 1 |
| *%kWhheat* , *Percentage of dishwasher unit energy consumption used for water heating* | *%* | 56% | 1 |
| *%ElectricDW*, *Percentage of dishwashers assumed to utilize electrically heated hot water* | *%* | EDC Data Gathering  Default = 31.7% | 2 |
| *HOU* , Hours of use per year | *hours/yr* | 234 | 3 |
| *CF, Demand Coincidence Factor. The coincidence of average dishwasher demand to summer system peak* | *Proportion* | 0.026 | 4, 5 |

ENERGY STAR qualified dishwashers must use less than or equal to the water and energy consumption values given in Table 2‑86. Note, as of May 30, 2013, ENERGY STAR compact dishwashers have the same maximum water and energy consumption requirements as the federal standard and therefore are not included in the TRM since there is not energy savings to be calculated for installation of an ENERGY STAR compact dishwasher. A standard sized dishwasher is defined as any dishwasher that can hold 8 or more place settings and at least six serving pieces.Source 6

Table 2‑86: Federal Standard and ENERGY STAR v 6.0 Residential Dishwasher Standard

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Product Type** | **Federal StandardSource 6** | | **ENERGY STAR v 6.0Source 7** | |
| **Water**  **(gallons per cycle)** | **Energy**  **(kWh per year)** | **Water**  **(gallons per cycle)** | **Energy**  **(kWh per year)** |
| Standard | ≤ 5.0 | ≤ 307 | ≤ 3.5 | ≤ 270 |

The default savings values for electric and non-electric water heating and the default fuel mix from Table 2‑87.

Table 2‑87: Default Dishwasher Energy Savings

|  |  |  |
| --- | --- | --- |
| **Water Heating** |  |  |
| Electric (%ElectricDHW = 100%) | 37.0 | 0.00411 |
| Non-Electric (%ElectricDHW = 0%) | 16.3 | 0.00181 |
| Default Fuel Mix (%ElectricDHW = 43%) | 22.8 | 0.00254 |

Evaluation Protocols

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

Sources

1. ENERGY STAR Appliances Calculator. Accessed July 2018. Energy Star Calculator, EPA research on available models. Accessed August 2018. <https://www.energystar.gov/sites/default/files/asset/document/appliance_calculator.xlsx>
2. Statewide average for all housing types from Pennsylvania Statewide Residential Baseline Study, 2018.
3. 2014 Pennsylvania Residential Baseline Study, <http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-2014_PA_Statewide_Act129_Residential_Baseline_Study.pdf>. HOU=(3 loads/week)×(52 weeks/yr)×(1.5 hours/load). 3 load/week comes from 2014 Baseline study. 1.5 hours/load is assumption used by Efficiency Vermont and Illinois Statewide TRMs
4. Calculated from Itron eShapes, 8760 hourly data by end use for Missouri, as provided by Ameren. This is the CF value for ENERGY STAR Dishwashers from Illinois Statewide TRM Version 7.0, June 2018.
5. Illinois Statewide Technical reference Manual for Energy Efficiency Version 7.0. Effective January 1, 2019. <http://www.ilsag.info/technical-reference-manual.html>
6. US Department of ENERGY Website. Appliance and Equipment Standards. Accessed Aug. 2018. <https://www.ecfr.gov/cgi-bin/text-idx?SID=86e70cbc87e5af18caca2e5c205bd107&mc=true&node=se10.3.430_132&rgn=div8>
7. Dishwashers Key product Criteria. Accessed Aug. 2018. <https://www.energystar.gov/products/appliances/dishwashers/key_product_criteria>

### ENERGY STAR Dehumidifiers

|  |  |
| --- | --- |
| **Target Sector** | Residential Establishments |
| **Measure Unit** | Dehumidifier |
| **Measure Life** | 12 yearsSource 1 |
| **Vintage** | Replace on Burnout |

ENERGY STAR qualified dehumidifiers are 15 percent more efficient than non-qualified models due to more efficient refrigeration coils, compressors and fans. ENERGY STAR Most Efficient dehumidifiers are 23 percent more efficient than standard products.Source 6

Eligibility

This protocol documents the energy and demand savings attributed to purchasing an ENERGY STAR or ENERGY STAR Most Efficient dehumidifier instead of a standard one. Dehumidifiers must meet ENERGY STAR Version 4.0 Product Specifications to qualify. The target sector is residential.

Algorithms

The general form of the equation for the ENERGY STAR Dehumidifier savings algorithm is:

Total Savings

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

Per unit energy and demand savings algorithms:

Definition of Terms

Table 2‑88: Terms, Values, and References for ENERGY STAR Dehumidifier

|  |  |  |  |
| --- | --- | --- | --- |
| **Term** | **Unit** | **Value** | **Sources** |
| *CAPY* , *Average capacity of the unit* |  | EDC Data Gathering | EDC Data Gathering |
| *HOU* , *Annual hours of operation* |  | 1,632 | 1 |
| , *Baseline unit liters of water per kWh consumed* |  | Table 2‑89 | 2 |
| , *ENERGY STAR qualified unit liters of water per kWh consumed* |  | EDC Data Gathering  Default: Table 2‑90 or Table 2‑91 | 3, 5 |
| *CF* , *Demand Coincidence Factor* | *Proportion* | 0.405 | 4 |

Table 2‑89 shows the federal standard minimum efficiency standards. Federal standards are effective as of June 13, 2019. Table 2‑90 shows ENERGY STAR 4.0 standards effective as of October 25, 2016. Table 2‑91 shows ENERGY STAR Most Efficient 2018 criteria, effective January 2018. Federal standards and ENERGY STAR Most Effiecient criteria distinguish between portable dehumidifiers (designed to dehumidify a confined living space and plugged into an electrical outlet) and whole-home dehumidifiers (incorporated into the home’s HVAC system and designed to dehumidify all conditioned spaces).

Table 2‑89: Dehumidifier Minimum Federal Efficiency Standards

|  |  |  |
| --- | --- | --- |
| **Type** | **Capacity (pints/day)** | **Federal Standard ()** |
| Portable dehumidifier | ≤ 25 | ≥ 1.30 |
| > 25 to ≤ 50 | ≥ 1.60 |
| > 50 | ≥ 2.80 |
| Whole-home dehumidifier | **Product Case Volume (ft3)** | **Federal Standard ()** |
| ≤ 8 | ≥ 1.77 |
| > 8 | ≥ 2.41 |

Table 2‑90: Dehumidifier ENERGY STAR Standards

|  |  |
| --- | --- |
| **Capacity (pints/day)** | **ENERGY STAR ()** |
| < 75 | ≥ 2.00 |
| 75 to ≤ 185 | ≥ 2.80 |

Table 2‑91: Dehumidifier ENERGY STAR Most Efficient Criteria

|  |  |  |
| --- | --- | --- |
| **Type** | **Capacity (pints/day)** | **ENERGY STAR ()** |
| Portable | < 75 | ≥ 2.20 |
| Whole House | < 75 | ≥ 2.30 |

Default Savings

The annual energy usage and savings of an ENERGY STAR unit over the federal minimum standard are presented in Table 2‑92 for each capacity range.

Table 2‑92: Dehumidifier Default Energy Savings

| **Efficient Product**[[57]](#footnote-59) | **Capacity Range (pints/day)** | **Default Capacity (pints/day)** | **Federal Standard (kWh/yr)** | **Efficient Standard**  **(kWh/yr)** | **ΔkWh/yr** | **ΔkWpeak** |
| --- | --- | --- | --- | --- | --- | --- |
| ENERGY STAR | ≤ 25 | 25 | 1.3 | 2.0 | 216 | 0.05372 |
| > 25 to ≤ 50 | 50 | 1.6 | 2.0 | 201 | 0.04989 |
| ENERGY STAR Most Efficient - Portable | ≤ 25 | 25 | 1.3 | 2.2 | 253 | 0.06279 |
| > 25 to ≤ 50 | 50 | 1.6 | 2.2 | 274 | 0.06803 |
| ENERGY STAR Most Efficient – Whole House with product case volume ≤ 8 ft3 | < 75 | 63[[58]](#footnote-60) | 1.77 | 2.3 | 264 | 0.06547 |

Evaluation Protocols

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

Sources

1. ENERGY STAR Appliance Savings Calculator. Accessedd August, 2018. <https://www.energystar.gov/sites/default/files/asset/document/appliance_calculator.xlsx>
2. US Department of ENERGY Website. Appliance and Equipment Standards. Accessed June 2014. <http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/55>
3. ENERGY STAR Program Requirements Product Specification for Dehumidifiers, Eligibility Criteria Version 4.0. Accessed November 2, 2018. https://www.energystar.gov/products/appliances/dehumidifiers/key\_efficiency\_criteria
4. Dehumidifier Metering in PA and Ohio by ADM from 7/17/2013 to 9/22/2013. 31 Units metered. Assumes all non-coincident peaks occur within window and that the average load during this window is representative of the June PJM days as well.
5. ENERGY STAR Most Efficient 2018 Recognition Criteria: Dehumidifiers. Accessed November 2, 2018. <https://www.energystar.gov/ia/partners/downloads/most_efficient/2018/Dehumidifiers%20ENERGY%20STAR%20Most%20Efficient%202018%20Final%20Criteria.pdf?cddb-3642>
6. ENERGY STAR Most Efficient 2019 memo. Accessed November 2, 2018. <https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Most%20Efficient%202019%20Memo_0.pdf>

### Dehumidifier Retirement

|  |  |
| --- | --- |
| **Target Sector** | Residential Establishments |
| **Measure Unit** | Dehumidifier |
| **Measure Life** | 4 years[[59]](#footnote-61) |
| **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* =

where:

*THIPJM* = for DB ≥ 58°F

= *DB* for DB < 58°F

Similarly, demand was modeled with the following capacity-dependent linear regression:Source 2

*kW* =

Definition of Terms

Table 2‑93: Terms, Values, and References for Dehumidifier Retirement

|  |  |  |  |
| --- | --- | --- | --- |
| **Term** | **Unit** | **Value** | **Sources** |
| *CAPY* , *Average capacity of the unit* |  | EDC Data Gathering  Default: 51 pt/day | EDC Data Gathering  3 |
| *THI , Temperature Humidity Index* | - | Calculated | 4 |
| *DB , Dry bulb temperature* | *℉* | See Source | 5 |
| *RH , Relative humidity* | *%* | See Source | 5 |

The results of the kWh calculation for typical dehumidifier capacities in each of the Climate Regions are presented in the following table:

Table 2‑94: Dehumidifier Retirement Annual Energy Savings (kWh)

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Annual kWh Savings by Climate Region** | | | | | | | | | | | |
| **Climate Region** | **Reference City** | **Capacity (pints per day)** | | | | | | | | | |
| **25** | **30** | **35** | **40** | **45** | **50** | **60** | **65** | **70** | **110** |
| **C** | **Allentown** | 628 | 656 | 684 | 712 | 740 | 768 | 824 | 852 | 881 | 1105 |
| **A** | **Bradford** | 386 | 404 | 422 | 440 | 458 | 476 | 512 | 530 | 547 | 691 |
| **G** | **Binghamton** | 470 | 492 | 513 | 534 | 556 | 577 | 620 | 641 | 663 | 834 |
| **I** | **Erie** | 557 | 582 | 607 | 632 | 656 | 681 | 731 | 756 | 781 | 979 |
| **E** | **Harrisburg** | 656 | 686 | 715 | 745 | 774 | 804 | 863 | 892 | 922 | 1158 |
| **D** | **Philadelphia** | 726 | 758 | 791 | 823 | 856 | 888 | 954 | 986 | 1019 | 1280 |
| **H** | **Pittsburgh** | 605 | 632 | 659 | 686 | 713 | 740 | 795 | 822 | 849 | 1066 |
| **B** | **Scranton** | 577 | 603 | 628 | 654 | 680 | 706 | 758 | 784 | 810 | 1016 |
| **F** | **Williamsport** | 651 | 680 | 709 | 738 | 767 | 797 | 855 | 884 | 913 | 1146 |

The peak kW reduction for recycling a dehumidifier was taken to be equal to the peak demand of the existing unit. These results are presented in the following table:

Table 2‑95: Dehumidifier Retirement Peak Demand Reduction (kW)

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Capacity** | **25** | **30** | **35** | **40** | **45** | **50** | **60** | **65** | **70** | **110** |
| **kW** | 0.1393 | 0.1458 | 0.1523 | 0.1588 | 0.1653 | 0.1718 | 0.1848 | 0.1913 | 0.1979 | 0.2499 |

Default Savings

For programs that do not track capacity, an “unknown” category has been provided based on the weighted average capacity of dehumidifier sales data:

Table 2‑96: Default Dehumidifier Retirement Annual Energy Savings (kWh)

|  |  |  |
| --- | --- | --- |
| **Annual kWh Savings by Climate Region** | | |
| **Region** | **Reference City** | **Default** |
| **C** | Allentown | 774 |
| **A** | Bradford | 479 |
| **G** | Binghamton, NY | 581 |
| **I** | Erie | 686 |
| **E** | Harrisburg | 810 |
| **D** | Philadelphia | 895 |
| **H** | Pittsburgh | 746 |
| **B** | Scranton | 711 |
| **F** | Williamsport | 802 |

Table 2‑97: Default Dehumidifier Retirement Peak Demand Reduction (kW)

|  |  |
| --- | --- |
| **Capacity** | **Default** |
| **kW** | 0.1731 |

Evaluation Protocols

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

Sources

1. Dehumidifier Metering in PA and Ohio by ADM from 7/17/2013 to 9/22/2013. 31 Units metered; five-minute interval power data was recorded. 58% of the units were Energy Star rated.
2. Ibid., by Act 129 Peak Demand window
3. Statewide average for all housing types from Pennsylvania Act 129 2018 Residential Baseline Study, 2018, <http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-Phase3_Res_Baseline_Study_Rpt021219.pdf>.
4. “PJM Manual 19: Load Forecasting and Analysis Revision: 32”. p. 14. <https://www.pjm.com/~/media/documents/manuals/m19.ashx> . Accessed January 2019.
5. National Solar Radiation Database. 1991–2005 Update: Typical Meteorological Year 3. NREL. <http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html>.

### ENERGY STAR Ceiling Fans

|  |  |
| --- | --- |
| **Target Sector** | Residential Establishments |
| **Measure Unit** | Ceiling Fan Unit |
| **Measure Life** | 15 years for fan,Source 1 See 2.1.1 for lighting |
| **Vintage** | Replace on Burnout |

ENERGY STAR ceiling fans require a more efficient CFM/Watt rating than standard ceiling fans as well as ENERGY STAR qualified lighting for those with light kits included. Both of these features save energy compared to standard ceiling fans.

Eligibility

This protocol documents the energy savings attributed to installing an ENERGY STAR Version 4.0 ceiling fan (with or without a lighting kit) in lieu of a standard efficiency ceiling fan meeting the January 21, 2020 federal efficiency requirements.Source 2 If a customer submits a rebate for a product that has applied for ENERGY STAR Certification but has not yet been certified, the savings will be counted for that product contingent upon its eventual certification as an ENERGY STAR measure. If at any point the product is rejected by ENERGY STAR, the product is then ineligible for the program and savings will not be counted.[[60]](#footnote-62) The target sector primarily consists of single-family residences.

Algorithms

The total energy savings is equal to the savings contribution of the fan plus the savings contribution of the lighting, if applicable. If the ENERGY STAR fan does not include a lighting kit, then. These algorithms do not seek to estimate the behavioral change attributable to the use of a ceiling fan vs. a lower AC setting.

The energy savings are obtained through the following formula:

from Section 2.1.1: ENERGY STAR Lighting

Demand savings result from the lower connected load of the ENERGY STAR fan and ENERGY STAR lighting. Peak demand savings are estimated using a Coincidence Factor (CF).

from Section 2.1.1: ENERGY STAR Lighting

Definition of Terms

Table 2‑98: Terms, Values, and References for ENERGY STAR Ceiling Fans

|  |  |  |  |
| --- | --- | --- | --- |
| **Component** | **Unit** | **Values** | **Source** |
| , Weighted average wattage reduction from ENERGY STAR ceiling fan | *Watts* | Default: See Table 2‑99 | 2, 3, 5, 6 |
| , fan daily hours of use |  | EDC Data Gathering  Default: 3.0 hours/day[[61]](#footnote-63) | 4 |
| , Demand Coincidence Factor | *Proportion* | EDC Data Gathering  Default: 0.091[[62]](#footnote-64) | 7 |
| , Demand Coincidence Factor | *Proportion* | See Section 2.1 | 7 |

Table 2‑99: Assumed Wattage of ENERGY STAR Ceiling Fans on High Setting

|  |  |  |
| --- | --- | --- |
| Ceiling Fan Type | **Diameter, D (inches)** | **(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[[63]](#footnote-65) | 36 < D < 78 | 33 |

Default Savings

Table 2‑100: Energy Savings and Demand Reductions for ENERGY STAR Ceiling Fans

|  |  |  |  |
| --- | --- | --- | --- |
| **Product Type (Fan Only)** | **Diameter, D (inches)** | **Energy Savings (kWh)** | **Demand Reduction (kW)** |
| Standard and Low-Mount High Speed Small Diameter (HSSD) Ceiling Fans | D ≤ 36 | 0 | 0.000 |
| 36 < D < 78 | 25 | 0.002 |
| D ≥ 78 | 34 | 0.002 |
| Hugger Ceiling Fan | 36 < D < 78 | 36 | 0.003 |

Evaluation Protocols

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

Sources

1. Residential and C&I Lighting and HVAC Report Prepared for SPWG, 2007. p. C-2.
2. Energy and water conservation standards and their compliance dates.10 C.F.R. § 430.32.
3. See ENERGY STAR Ceiling Fans Work Paper 2018.12.5.xlsx for calculations and description of methodology.
4. ENERGY STAR Lighting Fixture and Ceiling Fan Calculator. Updated September 2013.
5. ENERGY STAR® Program Requirements Product Specification for Residential Ceiling Fans and Ceiling Fan Light Kits Eligibility Criteria Version 4.0
6. ENERGY STAR Certified Ceiling Fans | EPA ENERGY STAR. <https://www.energystar.gov/productfinder/product/certified-ceiling-fans/results>. Accessed 12/5/2018.
7. EmPOWER Maryland 2012 Final Evaluation Report: Residential Lighting Program, Prepared by Navigant Consulting and the Cadmus Group, Inc., March 2013, Table 50.

### ENERGY STAR Air Purifiers

|  |  |
| --- | --- |
| **Target Sector** | Residential Establishments |
| **Measure Unit** | Number of Air Purifiers installed |
| **Measure Life** | 9 yearsSource 1 |
| **Vintage** | Replace on Burnout, Early Replacement, Retrofit, New Construction |

An air purifier (cleaner) is a portable electric appliance that removes dust and fine particles from indoor air. This measure characterizes the purchase and installation of a unit meeting the efficiency specifications of ENERGY STAR in place of or instead of a baseline model.

Eligibility

This measure targets residential customers who purchase and install an air purifier that meets ENERGY STAR specifications rather than installing a non-ENERGY STAR unit. In order to qualify, installed air purifiers must meet the following efficiency specifications of ENERGY STAR:

* Must produce a minimum 50 Clean Air Delivery Rate (CADR) for Dust to be considered under this specification.
* Minimum Performance Requirement: = 2.0 CADR/Watt (Dust)
* Standby Power Requirement: = 2.0 Watts or less. Qualifying models that perform secondary consumer functions (e.g. clock, remote control) must meet the standby power requirement.
* UL Safety Requirement: Models that emit ozone as a byproduct of air cleaning must meet UL Standard 867 (ozone production must not exceed 50ppb)

Algorithms

The following algorithms shall be used to calculate the annual energy savings and coincident peak demand savings for this measure:

|  |  |
| --- | --- |
|  |  |
|  |  |

Definition of Terms

Table 2‑101: Terms, Values, and References for ENERGY STAR Air Purifier

|  |  |  |  |
| --- | --- | --- | --- |
| **Term** | **Unit** | **Values** | **Source** |
| *kWhBase,* Baseline kWh consumption per year | kWh/year | EDC Data Gathering  Default = See Table 2‑102 | 1 |
| *kWhEStar*, ENERGY STAR kWh consumption per year | kWh/year | EDC Data Gathering  Default = See Table 2‑102 | 1 |
| *HOURS,* Average hours of use per year | Hours/year | EDC Data Gathering  Default = 5,840 | 1 |
| *CF,* Summer Peak Coincidence Factor | None | EDC Data Gathering  Default = 0.67 | 1, 2 |

Default Savings

Table 2‑102: Energy Savings Calculation Default Values

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Clean Air Delivery Rate (CADR)** | **CADR Used in Calculation** | **Baseline Unit Energy Consumption (kWh/yr)** | **ENERGY STAR Unit Energy Consumption (kWh/yr)** | **∆kWh** |
| **CADR 51-100** | 75 | 441 | 148 | 293 |
| **CADR 101-150** | 125 | 733 | 245 | 488 |
| **CADR 151-200** | 175 | 1,025 | 342 | 683 |
| **CADR 201-250** | 225 | 1,317 | 440 | 877 |
| **CADR Over 250** | 275 | 1,609 | 537 | 1,072 |

Table 2‑103: Demand Savings Calculation Default Values

|  |  |  |
| --- | --- | --- |
| **Clean Air Delivery Rate (CADR)** | **CADR Used in Calculation** | **ΔkWpeak** |
| **CADR 51-100** | 75 | 0.0336 |
| **CADR 101-150** | 125 | 0.0560 |
| **CADR 151-200** | 175 | 0.0784 |
| **CADR 201-250** | 225 | 0.1006 |
| **CADR Over 250** | 275 | 0.1230 |

Evaluation Protocols

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

Sources

1. ENERGY STAR, ENERGY STAR Appliance Calculator, last updated October 2016. <https://www.energystar.gov/sites/default/files/asset/document/appliance_calculator.xlsx>
2. Assumes appliance use is equally likely at any hour of the day or night.

## Consumer Electronics

### ENERGY STAR Office Equipment

|  |  |
| --- | --- |
| **Target Sector** | Residential Establishments |
| **Measure Unit** | Office Equipment Device |
| **Measure LifeSource 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

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**

ΔkWh = ESavCOM

ΔkWpeak = DSavCOM

**ENERGY STAR Fax Machine**

ΔkWh = ESavFAX

ΔkWpeak = DSavFAX

**ENERGY STAR Copier**

ΔkWh = ESavCOP

ΔkWpeak = DSavCOP

**ENERGY STAR Printer**

ΔkWh = ESavPRI

ΔkWpeak = DSavPRI

**ENERGY STAR Multifunction Device**

ΔkWh = ESavMUL

ΔkWpeak = DSavMUL

**ENERGY STAR Monitor**

ΔkWh = ESavMON

ΔkWpeak = DSavMON

Definition of Terms

Table 2‑104: Terms, Values, and References for ENERGY STAR Office Equipment

| **Term** | **Unit** | **Value** | **Sources** |
| --- | --- | --- | --- |
| *ESavCOM*, Electricity savings per purchased ENERGY STAR computer.  *ESavFAX*, Electricity savings per purchased ENERGY STAR Fax Machine  *ESavCOP*, Electricity savings per purchased ENERGY STAR Copier  *ESavPRI*, Electricity savings per purchased ENERGY STAR Printer  *ESavMUL*, Electricity savings per purchased ENERGY STAR Multifunction Device  *ESavMON* , Electricity savings per purchased ENERGY STAR Monitor | *kWh/yr* | See Table 2‑105 | 1 |
| *DSavCOM*, Summer demand savings per purchased ENERGY STAR computer.  *DSavFAX*, Summer demand savings per purchased ENERGY STAR Fax Machine  *DSavCOP*, Summer demand savings per purchased ENERGY STAR Copier  *DSavPRI*, Summer demand savings per purchased ENERGY STAR Printer  *DSavMUL*, Summer demand savings per purchased ENERGY STAR Multifunction Device  *DSavMON*, Monitor | *kW/yr* | See Table 2‑105 | 1 |

Default Savings

Table 2‑105: ENERGY STAR Office Equipment Energy and Demand Savings Values

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Measure** | | **Energy Savings (ESav, kWh)** | **Demand Savings (DSav, kW)** | **Source** |
| **Computer (Desktop)** | | 119 | 0.0161 | 1 |
| **Computer (Laptop)** | | 22 | 0.0030 | 1 |
| **Fax Machine (laser)** | | 16 | 0.0022 | 1 |
| **Copier (monochrome)** | ≤ 5images/min | 37 | 0.0050 | 1 |
| 5 < images/min ≤ 15 | 26 | 0.0035 |
| 15 < images/min ≤ 20 | 10 | 0.0011 |
| 20 < images/min ≤ 30 | 42 | 0.0057 |
| 30 < images/min ≤ 40 | 50 | 0.0068 |
| 40 < images/min ≤ 65 | 181 | 0.0244 |
| 65 < images/min ≤ 82 | 372 | 0.0502 |
| 82 < images/min ≤ 90 | 469 | 0.0633 |
| > 90 images/min | 686 | 0.0926 |
| **Printer (laser, monochrome)** | ≤ 5 images/min | 37 | 0.0050 | 1 |
| 5 < images/min ≤ 15 | 26 | 0.0035 |
| 15 < images/min ≤ 20 | 24 | 0.0031 |
| 20 < images/min ≤ 30 | 42 | 0.0057 |
| 30 < images/min ≤ 40 | 50 | 0.0068 |
| 40 < images/min ≤ 65 | 181 | 0.0244 |
| 65 < images/min ≤ 82 | 372 | 0.0502 |
| 82 < images/min ≤ 90 | 542 | 0.0732 |
| > 90 images/min | 686 | 0.0926 |
| **Printer (Ink Jet)** | | 6 | 0.0008 | 1 |
| **Multifunction Device (laser, monochrome)** | ≤ 5 images/min | 57 | 0.0077 | 1 |
| 5 < images/min ≤ 10 | 48 | 0.0065 |
| 10 < images/min ≤ 26 | 52 | 0.0070 |
| 26 < images/min ≤ 30 | 93 | 0.0126 |
| 30 < images/min ≤ 50 | 248 | 0.0335 |
| 50 < images/min ≤ 68 | 420 | 0.0567 |
| 68 < images/min ≤ 80 | 597 | 0.0806 |
| > 80 images/min | 764 | 0.1031 |
| **Multifunction Device (Ink Jet)** | | 6 | 0.0008 | 1 |
| **Monitor** | | 24 | 0.0032 | 1 |

Evaluation Protocols

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

Sources

1. **ENERGY STAR Office Equipment Calculator** <http://www.energystar.gov/sites/default/files/asset/document/Office%20Equipment%20Calculator.xlsx>(Referenced latest version released in October 2016). Default values were used. Using a commercial office equipment load shape, the percentage of total savings that occur during the PJM peak demand period was calculated and multiplied by the energy savings. As of December 1, 2018, the published ENERGY STAR Office Equipment Calculator does not reflect the current specification for computers (ENERGY STAR® Program Requirements Product Specification for Computers Eligibility Criteria Version 7.1). V7.1 introduced modest improvements to both desktop and laptop computer efficiency. As a result, the savings values for computers presented in this measure entry reflect savings for V6-compliant models. This characterization should be updated when an updated ENERGY STAR Office Equipment Calculator becomes available.

### Advanced Power Strips

|  |  |
| --- | --- |
| **Target Sector** | Residential Establishments |
| **Measure Unit** | Per Advanced Power Strip |
| **Measure Life** | 5 yearsSource 4 |
| **Vintage** | Retrofit |

Advanced Power Strips (APS) are power strips that contain a number of power-saver sockets. There are two types of APS: Tier 1 and Tier 2.

Tier 1 APS have a master control socket arrangement and will shut off the items plugged into the controlled power-saver sockets when they sense that the appliance plugged into the master socket has been turned off. Conversely, the appliance plugged into the master control socket has to be turned on and left on for the devices plugged into the power-saver sockets to function.

Tier 2 APS deliver additional functionality beyond that of a Tier 1 unit, as Tier 2 units manage both standby and active power consumption. The Tier 2 APS manage standby power consumption by turning off devices from a control event; this could be a TV or other item powering off, which then powers off the controlled outlets to save energy. Active power consumption is managed by the Tier 2 unit by monitoring a user’s engagement or presence in a room by either or both infrared remote signals sensing or motion sensing. If after a period of user absence or inactivity, The Tier 2 unit will shut off all items plugged into the controlled outlets, thus saving energy. There are two types of Tier 2 APS available on the market. Tier 2 Infrared (IR) detect signals sent by remote controls to identify activity, while Tier 2 Infrared-Occupancy Sensing (IR-OS) use infrared signals as well as an occupancy sensing component to detect activity and sense for times to shut down. Due to uncertainty surrounding the differences in savings for each technology, the Tier 2 savings are blended into a single number.

Eligibility

This protocol documents the energy savings attributed to the installation of smart strip plugs. The most likely area of application is in residential spaces, i.e. single-family and multifamily homes. However, commercial applications are also appropriate for smart strips (see Volume 3, Section 3.9.3 Advanced Power Strip Plug Outlets [[WEBSITE LINK TBD](http://www.puc.pa.gov/)]). The protocol considers usage of smart strips with home office systems and home entertainment systems.

Algorithms

The energy savings and demand reduction for Tier 1 and Tier 2 APS outlets are obtained from several recently conducted field studies, with the savings estimates applied to measured in-service rates (ISR) and realization rates (RR) to determine final savings.

The energy savings and demand reduction are calculated for both home office and home entertainment use for Tier 1 strips, and only for home entertainment use for Tier 2 strips.[[64]](#footnote-66) For Tier 1 strips, if the intended use of the power strip is not specified, or if multiple power strips are purchased, the algorithm for “unspecified use” should be applied. If it is known that the power strip is intended to be used for an entertainment center, the “entertainment center” algorithm should be applied, while the “home office” algorithm should be applied if it is being used in a home office setting. For Tier 2 strips, the end use is assumed to be a home entertainment center and the savings vary based on the type of Tier 2 strip, IR, IR-OS, or unspecified.

**Tier 1** **Smart Strip:**

*ΔkWht1\_unspecified = Annual\_Usageunspecified x ERPt1\_­unspecified × ISR x RR*

*ΔkWh t1\_entertainment = Annual\_Usageentertainment x ERPt1\_entertainment × ISR x RR*

*ΔkWh t1\_office = Annual\_Usageoffice x ERPt1\_office × ISR x RR*

*ΔkWpeak, t1\_unspecified = Loadunspecified x ERPpeak, t1\_unspecified x ISR*

*ΔkWpeak, t1\_entertainment = Loadentertainment x ERPpeak, t1\_entertainment x ISR*

*ΔkWpeak, t1\_home office = Loadoffice x ERPpeak, t1\_office x ISR*

**Tier 2 Smart Strip:**

*ΔkWht2 = Annual\_Usageentertainment x ERP t2 × ISR x RR*

*ΔkWpeak, t2 = Loadentertainment x ERPpeak, t2 x ISR*

Definition of Terms

Table 2‑106: Terms, Values, and References for Advanced Power Strips

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | **Unit** | **Value** | **Source** |
| *Annual\_Usageentertainment*, Annual usage of home entertainment system | *kWh* | 471 | 1 |
| *Annual\_Usageoffice*, Annual usage of home office system | *kWh* | 399 | 1 |
| *Annual\_Usageunspecified*, Annual usage of unspecified end-use[[65]](#footnote-67) | *kWh* | 449 | 1, 2 |
| *Loadentertainment*, Demand of home enertainment system | *kW* | 0.058 | 3 |
| *Loadoffice*, Demand of home office system | *kW* | 0.044 | 3 |
| *Loadunspecified*, Demand of unspecified end-use | *kW* | 0.052 | 3 |
| *ERP*, energy reduction percentage | *%* | See Table 2‑107 | 1 |
| *ERPpeak,* energy reduction percentage during peak period | *%* | See Table 2‑107 | 1 |
| *ISR*, In-service Rate | *%* | EDC Data Collection or see Table 2‑107 | 2 |
| *RR,* Realization Rate | *kWh* | 0.92 | 2 |

The following table shows the Energy Reduction Percentage (ERP) and In-Service Rate (ISR) for each strip type and end use.

Table 2‑107: Impact Factors for APS Strip Types

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Strip Type** | **End-Use** | **ERP** | **ERPpeak** | **ISR** |
| Tier 1 | Home Entertainment Center | 27% | 20% | 86% |
| Tier 1 | Home Office | 21% | 18% | 86% |
| Tier 1 | Unspecified | 25% | 19% | 86% |
| Tier 2 | Home Entertainment Center | 44% | 41% | 74% |

Default Savings

Table 2‑108: Default Savings for Advanced Power Strips

|  |  |  |  |
| --- | --- | --- | --- |
| **APS Type** | **End Use** | **Energy Savings (kWh)** | **Peak Demand Reduction (kW)** |
| Tier 1 | Home Entertainment Center | 100.6 | 0.010 |
| Tier 1 | Home Office | 66.3 | 0.007 |
| Tier 1 | Unspecified use or multiple purchased | 88.8 | 0.009 |
| Tier 2 | Home Entertainment Center | 141.1 | 0.018 |

Evaluation Protocols

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

Sources

1. “RLPNC 17-3: Advanced Power Strip Metering Study,” *Massachusetts Programs Administrators and EEAC,* (Oct. 2018), <http://ma-eeac.org/wordpress/wp-content/uploads/RLPNC_173_APSMeteringReport_5OCT2018_Finalv2.pdf>
2. “RLPNC 17-4 and 17-5: Products Impact Evaluation of In-service and Short-Term Retention Rates Study,” *Massachusetts Programs Administrators and EEAC,* (Oct. 2018), <http://ma-eeac.org/wordpress/wp-content/uploads/RLPNC_1745_APSProductsSurveys_5Oct2018_Final.pdf>
3. As reported in correspondence with authors of Source 1 and Source 2.
4. California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx. Accessed December 2018.

## 

## Building Shell

### Residential Air Sealing

|  |  |
| --- | --- |
| **Target Sector** | Residential Establishments, limited to single family detached houses |
| **Measure Unit** | Residential Air Sealing |
| **Measure Life** | 15 years Source 5 |
| **Vintage** | Retrofit |

Thermal shell air leaks are sealed through strategic use and installation of air-tight materials. Leaks are detected and leakage rates measured with the assistance of a blower-door test. This measure applies to the sealing of thermal shell air leaks in existing residential homes with a primary electric heating and/or cooling source.

Eligibility

The baseline for this measure is the existing air leakage as determined through approved and appropriate test methods using a blower door. The baseline condition of a building upon first inspection significantly impacts the opportunity for cost-effective energy savings through air-sealing.

Air sealing materials and diagnostic testing should meet all qualification criteria for program eligibility. The initial and final tested leakage rates should be performed in such a manner that the identified reductions can be properly discerned, particularly in situations where multiple building envelope measures may be implemented simultaneously.

For example, if air sealing, duct sealing and insulation are all installed as a whole home retrofit, efforts should be made to isolate the CFM reductions from each measure individually. This may require performance of a blower door test between each measure installation. Alternatively, the baseline blower door test may be performed after the duct sealing is completed, then air sealing measures installed and the retrofit blower door test completed prior to installation of the new insulation.

This measure is applicable to single family detached houses only.

Algorithms

To calculate add together the cooling and heating savings calculated using the appropriate coefficients from

Table 2‑111 and Table 2‑112 for the matching equipment type and climate region in the algorithm below. For example, if a residence has gas heat with Central AC, there is no heating component to the savings calculations. If a residence has Electric Resistance heating and no AC, calculate the savings for “Baseboard” heating. Ductless installations such as baseboards and mini-split heat pumps should substitute 100% for .

Note: The savings equations above are based on *quadratic* regressions because cooling savings fall off quickly with changes in infiltration in heating dominated climates, whereas some heating technologies exhibit escalating savings as in the example plot below. This results in small coefficients for the squared term, which are therefore multiplied by 105 to simplify Table 2‑111 and Table 2‑112.

Figure 2‑4: Example Regressions for Ductless Mini-splits in Climate Region A





Definition of Terms

Table 2‑109: Terms, Values, and References for Residential Air Sealing

|  |  |  |  |
| --- | --- | --- | --- |
| **Term** | **Unit** | **Values** | **Source** |
| , Baseline infiltration at 50 Pa |  | Measured, EDC Data Gathering | EDC Data Gathering |
| , Infiltration at 50 Pa post air sealing |  | Measured, EDC Data Gathering | EDC Data Gathering |
| , Baseline duct efficiency | None | Measured, EDC Data Gathering | EDC Data Gathering |
| , Prototype duct efficiency | None | Default: See Table 2‑34 in Sec. 2.2.10 for “R-2 Average Basement + 50% Conditioned” | 1 |
| , Baseline equipment efficiency | varies | Measured, EDC Data Gathering  Default: | EDC Data Gathering |
| , Prototype equipment efficiency | varies | See Table 2‑110 | 2 |
| , Unit Energy Savings per CFM502 of air leakage reduction |  | See  Table 2‑111 | 3 |
| , Unit Energy Savings per CFM50 of air leakage reduction |  | See Table 2‑112 | 3 |
| , Equivalent Full Load Cooling hours |  | See *EFLHcool* in Vol.1, App. A | 4 |
| *CF,* Demand Coincidence Factor | Proportion | See *CF* in Vol.1, App. A | 4 |

Default Unit Energy Savings Coefficient & Equipment Efficiency Tables

Savings may be claimed using the algorithms above and the algorithm’s input default values below, in conjunction with customer-specific blower door test data. Site specific data from blower door testing is required to be used in conjunction with these default energy savings values, as outlined in the algorithms.

Table 2‑110: Default Residential Equipment Efficiency

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Cooling** | | | | **Heating** | | | | |
|  | **ASHP** | **Central AC** | **Mini-split** | **GSHP** | **ASHP** | **Base-board** | **Electric Furnace** | **Mini-split** | **GSHP** |
| Efficiency | 15 | 12.1 | 14.9 | 16.6 | 8.5 | 1 | 1 | 8.9 | 3.6 |
| Units | SEER | SEER | SEER | EER | HSPF | COP | COP | HSPF | COP |

Table 2‑111: Default Unit Energy Savings per Reduced CFM502 for Air Sealing

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Climate Region**  **Reference City** | |  | | | |  | | | | | |
| **ASHP** | **Central AC** | **Mini-split** | **GSHP** | **ASHP** | **Base-board** | **Electric Furnace** | **Mini-split** | **GSHP** |
| **C** | Allentown | -0.042 | -0.076 | 0.09 | 0.023 | 5.064 | 1.166 | 3.485 | 0.944 | 0.413 |
| **A** | Binghamton | 0.028 | 0.018 | 0.087 | 0.046 | 3.335 | 1.271 | 4.653 | 0.986 | 0.293 |
| **G** | Bradford | 0.043 | 0.02 | 0.067 | 0.06 | 0.112 | 1.515 | 4.545 | 1.173 | 0.283 |
| **I** | Erie | 0.022 | 0.004 | 0.058 | 0.027 | 5.67 | 1.318 | 4.309 | 1.066 | 0.367 |
| **E** | Harrisburg | -0.079 | -0.125 | 0.126 | -0.066 | 4.488 | 1.242 | 3.488 | 0.886 | 0.112 |
| **D** | Philadelphia | -0.08 | -0.121 | 0.096 | 0.002 | 3.078 | 1.004 | 2.208 | 0.792 | 0.286 |
| **H** | Pittsburgh | -0.014 | -0.053 | 0.075 | 0.079 | 4.657 | 1.185 | 2.778 | 0.93 | 0.497 |
| **B** | Scranton | 0.004 | -0.029 | 0.086 | 0.058 | 4.845 | 1.21 | 4.073 | 0.958 | 0.411 |
| **F** | Williamsport | -0.037 | -0.032 | 0.104 | 0.052 | 5.175 | 1.181 | 3.477 | 0.925 | 0.392 |

Table 2‑112: Default Unit Energy Savings per Reduced CFM50 for Air Sealing

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Climate Region**  **Reference City** | |  | | | |  | | | | | |
| **ASHP** | **Central AC** | **Mini-split** | **GSHP** | **ASHP** | **Base-board** | **Mini-split** | **Electric Furnace** | **GSHP** |
| **C** | Allentown | 0.025 | 0.033 | 0.004 | 0.007 | 0.951 | 1.966 | 0.864 | 2.138 | 0.616 |
| **A** | Binghamton | -0.001 | 0.001 | -0.002 | -0.007 | 1.948 | 2.393 | 1.448 | 2.599 | 0.788 |
| **G** | Bradford | -0.007 | -0.005 | -0.007 | -0.011 | 2.703 | 2.803 | 2.001 | 3.032 | 0.951 |
| **I** | Erie | 0.004 | 0.001 | -0.003 | -0.004 | 1.279 | 2.238 | 1.098 | 2.423 | 0.726 |
| **E** | Harrisburg | 0.055 | 0.066 | 0.025 | 0.033 | 1.092 | 2.194 | 1.032 | 2.378 | 0.709 |
| **D** | Philadelphia | 0.05 | 0.061 | 0.017 | 0.023 | 0.589 | 1.604 | 0.573 | 1.752 | 0.498 |
| **H** | Pittsburgh | 0.019 | 0.026 | 0.005 | -0.002 | 1.051 | 1.958 | 0.99 | 2.125 | 0.612 |
| **B** | Scranton | 0.009 | 0.013 | -0.002 | -0.004 | 1.25 | 2.056 | 1.004 | 2.24 | 0.659 |
| **F** | Williamsport | 0.02 | 0.023 | 0.001 | -0.001 | 1.048 | 1.981 | 0.932 | 2.158 | 0.627 |

Evaluation Protocols

The appropriate evaluation protocol for this measure is desk audit verification that the pre and post blower door tests were performed in accordance with industry standards. Verification through desk audits require confirmation of the proper application of the TRM protocol using default unit energy and demand savings values in coordination with blower door test results. Field verification of each test or re-test is not required.

Sources

1. Pennsylvania Act 129 2018 Residential Baseline, <http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-Phase3_Res_Baseline_Study_Rpt021219.pdf>.
2. Equipment efficiencies were chosen based on weighted single-family detached results from the 2017 Pennsylvania Residental Baseline, standardized equipment library entries (ASHP), and expertise (GSHP).
3. Based on modelling using BEopt v2.8.0 performed by NMR Group, Inc. Unit energy savings were calculated by modeling a prototypical Pennsylvania single family detached house with statewide average characteristics determined through the Pennsylvania Act 129 2018 Residential Baseline. Simulations for each equipment-climate region combination were performed at multiple levels of air leakage (1, 2, 3, 4, 5, 6, 7, 8, 10, 15, 20, and 25 ACH50). The heating or cooling loads for each system combination were then fitted with separate quadratic regressions, the coefficients of which are the UES values. Supporing files can be found at [[WEBSITE LINK TBD](http://www.puc.pa.gov/)].
4. Based on the Phase III SWE team’s analysis of regional HVAC runtime data collected from ecobee’s Donate Your Data research service, <https://www.ecobee.com/donateyourdata/>.
5. Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, 2007

### Weather Stripping, Caulking, and Outlet Gaskets

|  |  |
| --- | --- |
| **Target Sector** | Residential Establishments |
| **Measure Unit** | Per Project |
| **Measure Life** | 15 years |
| **Vintage** | Retrofit |

Residential structures can lose significant amounts of heat through the infiltration of unconditioned outside air into the conditioned space. Infiltration enters conditioned spaces in a variety of ways: building joints, gaps in door and window frames, basement and attic penetrations (electrical and plumbing) and recessed light fixtures. Air sealing measures like adding weather stripping, caulking and installing outlet gaskets can reduce the amount of infiltration and the related heating and cooling for a building.

Eligibility

To be eligible:

* Weather stripping must be installed on doors, windows, or attic hatches/doors.
* Caulking and/or spray foam sealant must be applied to window frames, door frames or plumbing/electrical penetrations.
* Gaskets must be installed on electrical outlets.

In addition, **this measure is limited to projects with less than than 400 kWh of savings**. Projects with 400 kWh or more of savings should follow [Section 2.6.1 – Residential Air Sealing](#_Residential_Air_Sealing).

Algorithms

There are two approaches that can be utilized to estimate savings due to air sealing, one using algorithms requiring EDC data gathering, and a default savings method when data are unavailable. The annual energy and peak demand savings are obtained through the following formulas:

|  |  |
| --- | --- |
|  |  |
|  |  |
|  | If > 400 kWh use Sec. 2.6.1 |
|  |  |

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= EERg × GSHPDF × GSER*

*HSPF****=****COPg* × *GSHPDF* ×3.412

**PTAC and PTHP**

*= EER*

Definition of Terms

Table 2‑113: Terms, Values, and References for Weather Stripping

|  |  |  |  |
| --- | --- | --- | --- |
| **Term** | **Unit** | **Values** | **Source** |
| , Conversion factor that converts CFM air (at 70°F) to BTU/hr-°F |  | 1.08 | - |
| , Reduction in air leakage at a test pressure of 50 Pascals | *CFM* | See Table 2‑117 | 1, 4 |
| Cooling degree-days | *°F-day/year* | See CDD values in Vol. 1, App. A | 10 |
| Heating degree-days | *°F-day/year* | See HDD values in Vol. 1, App. A | 10 |
| In-service rate | None | Kit delivery: EDC Data Gathering  Direct install = 1 | EDC Data Gathering |
| , Latent multiplier to convert the calculated sensible load to the total (sensible and latent) load | None | See Table 2‑115 | 5 |
| Discretionary use adjustment to account for uncertainty in predicting cooling system usage patterns of occupants | None | 0.75 | 3 |
| Correlation factor. This factor accounts for four environmental characteristics that may influence infiltration, which include climate, building height, wind shielding and building leakiness | None | See Table 2‑114  Default = 16.7 | 2 |
| Cooling system seasonal efficiency |  | EDC Data Gathering  Default: See Table 2‑116 | 7 |
| Heating system seasonal efficiency |  | EDC Data Gathering  Default: See Table 2‑116 | 7 |
| *EER,* Energy Efficiency Ratio of a GSHP, this is measured differently than EER of an air source heat pump and must be converted |  | EDC Data Gathering | - |
| *COP,* Coefficient of Performance. This is a measure of the efficiency of a heat pump | *None* | EDC Data Gathering | - |
| *GSER* , Factor used to determine the SEER of a GSHP based on its EERg |  | 1.02 | 8 |
| *GSPK* , Factor to convert EERg to the equivalent EER of an air conditioner to enable comparisons to the baseline unit | *Proportion* | 0.8416 | 8 |
| *GSHPDF* , Ground Source Heat Pump De-rate Factor | *Proportion* | 0.885 | 9 |
| Peak demand savings conversion factor | *kW/kWh* | 0.000017 ( | 6 |

Table 2‑114: Correlation Factor Source 2

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Shielding/Stories** | **1** | **1.5** | **2** | **3** |
| Well-shielded | 22.2 | 20.0 | 17.8 | 15.5 |
| Normal | 18.5 | 16.7 | 14.8 | 13.0 |
| Exposed | 16.7 | 15.0 | 13.3 | 11.7 |

Table 2‑115: Latent Multiplier Values by Climate Reference City

|  |  |  |
| --- | --- | --- |
| **Climate Region** | **Reference City** | **LM** |
| **C** | Allentown | 9.0 |
| **A** | Binghamton, NY | 6.75 |
| **G** | Bradford | 16.0 |
| **I** | Erie | 13.0 |
| **E** | Harrisburg | 5.6 |
| **D** | Philadelphia | 7.8 |
| **H** | Pittsburgh | 7.3 |
| **B** | Scranton | 9.3 |
| **F** | Williamsport | 9.5 |

Table 2‑116: Default Cooling and Heating System Efficiencies

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

Table 2‑117: Typical Reductions in Leakage Source 1

|  |  |  |
| --- | --- | --- |
| **Technology** | **Application** | **ΔCFM50** Source 4 |
| Weather Stripping | Single Door | 25.5 CFM/door |
| Double Door | 0.73 CFM/ft2 |
| 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/ft2 |
| Window Framing, Wood | 0.382 CFM/ft2 |
| Door Frame, Masonry | 1.018 CFM/ft2 |
| Door Frame, Wood | 0.364 CFM/ft2 |
| Average Window/Door Caulking | 0.689 CFM/lf of crack |
| *Average Window/Door Caulking and Weather Stripping* | | *0.664 CFM/lf of crack* |
| Gasket | Electrical Outlets | 6.491 CFM each |

Default Savings

If the information needed to utilize the algorithms is unavailable, the default savings listed below may be used. The default savings are based on a home with a 12.1 SEER CAC and electric resistance heat (COP=1). The default savings assume direct install of measures. To use default savings for kit delivery measures, EDCs must determine an ISR multiplier through independent research.

Table 2‑118: Default Annual Energy Savings

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Climate Region** | **Reference City** | **Cooling Savings (kWh)** | | | | **Heating Savings (kWh)** | | |
| **Caulked Penetrations**  **(per pen.)** | **Weather Stripping, Caulking and Sealing (per 10 lf)** | **Outlet Gaskets**  **(per gasket)** | **Caulked Penetrations**  **(per pen.)** | | **Weather Stripping, Caulking and Sealing (per 10 lf)** | **Outlet Gaskets**  **(per outlet)** |
| **C** | Allentown | 7.317 | 4.457 | 4.357 | 28.178 | | 17.165 | 16.780 |
| **A** | Binghamton, NY | 2.875 | 1.752 | 1.712 | 34.997 | | 21.319 | 20.841 |
| **G** | Bradford | 3.433 | 2.091 | 2.044 | 40.930 | | 24.933 | 24.374 |
| **I** | Erie | 7.917 | 4.823 | 4.714 | 32.207 | | 19.619 | 19.179 |
| **E** | Harrisburg | 6.603 | 4.022 | 3.932 | 30.466 | | 18.559 | 18.143 |
| **D** | Philadelphia | 9.426 | 5.742 | 5.613 | 23.971 | | 14.602 | 14.275 |
| **H** | Pittsburgh | 5.666 | 3.452 | 3.374 | 29.014 | | 17.674 | 17.278 |
| **B** | Scranton | 5.928 | 3.611 | 3.530 | 30.556 | | 18.614 | 18.196 |
| **F** | Williamsport | 7.284 | 4.437 | 4.338 | 28.581 | | 17.411 | 17.020 |

Table 2‑119: Default Summer Peak Demand Savings

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Climate Region** | **Reference City** | **Caulked Penetrations (ΔkW/ pen.)** | **Weather Stripping, Caulking and Sealing (ΔkW/10 lf)** | **Outlet Gaskets**  **(ΔkW/gasket)** |
| **C** | Allentown | 0.0001244 | 0.0000758 | 0.0000741 |
| **A** | Binghamton, NY | 0.0000489 | 0.0000298 | 0.0000291 |
| **G** | Bradford | 0.0000584 | 0.0000356 | 0.0000348 |
| **I** | Erie | 0.0001346 | 0.0000820 | 0.0000801 |
| **E** | Harrisburg | 0.0001122 | 0.0000684 | 0.0000668 |
| **D** | Philadelphia | 0.0001602 | 0.0000976 | 0.0000954 |
| **H** | Pittsburgh | 0.0000963 | 0.0000587 | 0.0000574 |
| **B** | Scranton | 0.0001008 | 0.0000614 | 0.0000600 |
| **F** | Williamsport | 0.0001238 | 0.0000754 | 0.0000737 |

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables. The Pennsylvania Evaluation Framework provides specific guidelines and requirements for evaluation procedures. For kit delivery, EDCs should estimate in-service rate through customer surveys.

Sources

1. ASHRAE, 2001 AHSRAE Handbook – Fundamentals, Table 1.
2. ENERGY STAR Home Sealing Specification, Version 1.0. October 2001. <https://www.energystar.gov/ia/home_improvement/home_sealing/ES_HS_Spec_v1_0b.pdf>
3. Energy Center of Wisconsin, “Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research,” May 2008. <https://focusonenergy.com/sites/default/files/centralairconditioning_report.pdf>
4. ΔCFM50 is estimated by dividing the ELA by 0.055. See p. 83, The Energy Conservatory, Minneapolis Blower Door Operation Manual, <http://energyconservatory.com/wp-content/uploads/2014/07/Blower-Door-model-3-and-4.pdf>
5. LM values calculated as total load (sensible + latent) divided by sensible load, from sensible and latent values in Harriman et al. "Dehumidification and Cooling Loads from Ventilation Air." ASHRAE Journal. November 1997. https://energy.mo.gov/sites/energy/files/harriman-dehumidification-and-cooling-loads-from-ventilation-air.pdf
6. KEMA, Evaluation of the Weatherization Residential Assistance Partnership (WRAP) and Helps Programs, September 2010. <http://www.energizect.com/sites/default/files/Final%20WRAP%20%20Helps%20Report.pdf>
7. For all systems excluding ground source heat pumps: Pennsylvania Act 129 2018 Residential Baseline Study, <http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-Phase3_Res_Baseline_Study_Rpt021219.pdf>. Due to small sample size in residential baseline, the lowest efficiency options available in BEopt were chosen as defaults for ground source heat pumps.
8. VEIC estimate. Extrapolation of manufacturer data.
9. McQuay Application Guide 31-008, Geothermal Heat Pump Design Manual, 2002. Engineering Estimate - See System Performance of Ground Source Heat Pumps
10. PA SWE Team Calculations with data from the National Solar Radiation Database. 1991–2005 Update: Typical Meteorological Year 3. NREL. <http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html>

### Ceiling/Attic, Wall, Floor and Rim Joist Insulation

|  |  |
| --- | --- |
| **Target Sector** | Residential Establishments |
| **Measure Unit** | Per Project |
| **Measure Life** | 15 years Sources 1, 2 |
| **Vintage** | Retrofit |

This protocol covers the calculation of energy and demand savings associated with insulating ceilings/attics, walls, floors above vented crawlspaces, and rim joists in residential buildings.

Eligibility

**Ceiling/Attic or Wall Insulation**

This measure applies to installation/retrofit of new or additional insulation in a ceiling/attic, or walls of existing residential homes or apartment units in multifamily complexes with a primary electric heating and/or cooling source. The installation must achieve a finished ceiling/attic insulation rating of R-49 or higher, and/or must add wall insulation of at least an R-6 or greater rating.Source 12

**Floor Insulation**

This measure requires the installation of new insulation to the floors of existing residential buildings with vented (unconditioned) crawlspaces and a primary electric heating and/or cooling source. The installation must achieve a finished floor insulation R-value of R-30 or higher, except for homes in IECC Climate Zone 4, where R-19 is permissable.Source 12

**Rim Joist Insulation**

This measure protocol applies to the installation of insulation in the rim joists of residential homes. This includes the rim joists of unvented crawlspaces and the rim joists between the first and second floor of a residence. The insulation should have either a minimum R-10 continuous insulated sheathing on the interior or exterior of the home, or R-13 cavity insulation at the interior of the rim joist.Because of the difficulty of a proper air-sealed installation, using fiberglass batts between the joists is not usually recommended. The insulation should be sprayed foam or rigid foam.Source 3

Algorithms

The annual energy and peak demand savings are obtained through the following formulas. Note that these equations are applied separately for each ceiling / attic, wall, floor, and rim joist component upgraded.

|  |  |
| --- | --- |
|  |  |
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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= EERg* × *GSHPDF* × *GSER*

*HSPF****=****COPg* × *GSHPDF* ×3.412

**PTAC and PTHP**

*= EER*

Definition of Terms

Table 2‑120: Terms, Values, and References for Basement Wall Insulation

| **Term** | **Unit** | **Values** | **Source** |
| --- | --- | --- | --- |
| , Annual cooling energy savings | *kWh/year* | Calculated | - |
| , Annual heating energy savings | *kWh/year* | Calculated | - |
| R-value of existing insulation | *°F.ft2.hr/BTU* | EDC Data Gathering  Default:  Table 2‑122 | 9, 10 |
| R-value of insulation added | *°F.ft2.hr/BTU* | EDC Data Gathering  Default:  Table 2‑122 | 9, 10 |
| Area of component being insulated | *Ft2* | EDC Data Gathering | - |
| 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 |
| Annual cooling degree-days, base 65°F | *°F-day/year* | See *CDD* in Vol 1., App. A | 15 |
| Annual heating degree-days, base 65°F | *°F-day/year* | See *HDD* in Vol 1., App. A | 15 |
| Equivalent full load cooling hours | *Hours/year* | See *EFLHcool* in Vol 1., App. A | 14 |
| Discretionary use adjustment to account for uncertainty in predicting cooling system usage patterns of occupants | None | 0.75 | 5 |
| Cooling system seasonal efficiency |  | EDC Data Gathering  Default: See Table 2‑121 | 6 |
| Heating system seasonal efficiency |  | EDC Data Gathering  Default: See Table 2‑121 | 6 |
| Adjustment factor to relate insulated area to area served by room air conditioners | None | If Room AC = 0.38  If non-Room AC = 1.0 | 7 |
| *COP,* Coefficient of Performance. This is a measure of the efficiency of a heat pump | *None* | EDC Data Gathering | - |
| *EERg ,* Energy Efficiency Ratio of a GSHP, this is measured differently than EER of an air source heat pump and must be converted |  | EDC Data Gathering  Default = 16.6 | - |
| *GSER* , Factor used to determine the SEER of a GSHP based on its EERg |  | 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 |
| Coincidence factor | None | See *CF* in Vol. 1, App. A | 14 |
| *AHF*, Adjustment for cooling savings to account for inaccuracies in engineering algorithms. | *None* | 1.21 if adding attic ins., 1.0 if not | 8 |

Table 2‑121: Default Cooling and Heating System Efficiencies

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

Table 2‑122: Default Base and Energy Efficient (Insulated) R Values

|  |  |  |
| --- | --- | --- |
| **Component** | **Existing Condition** | **Value** (**)** |
| *Rceil,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 |
| *Rceil,ee,* Assembly R-value of ceiling/attic after retrofit | Retrofit to R-49 total attic insulation | 49 |
| *Rwall,base*, Assembly R-value of wall before retrofit | Assumes existing, un-insulated wall with 2x4 studs @ 16” o.c., w/ wood/vinyl siding | 5 |
| *Rwall,ee*, Assembly R-value of wall after retrofit | Assumes adding R-6 per DOE recommendations | 11 |
| *Rfloor,base,* R-value of floor before retrofit | Thermal resistance of existing floor insulation above crawlspace | 3.96 |
| *Rfloor,ee,* R-value of floor after retrofit | Thermal resistance of insulation added to floor above crawlspace | EDC Data Gathering |
| , R-value of rim joist before retrofit | Baseline R-value of rim joist | 2.5 |
| , R-value of rim joist after retrofit | R-value of installed spray foam or rigid foam insulation applied to rim joist | EDC Data Gathering |

Default Savings

There are no default savings for this measure.

Evaluation Protocols

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

Sources

1. GDS Associates, Inc., Measure Life Report, *Residential and Commercial/Industrial Lighting and HVAC Measures*, 2007. <https://library.cee1.org/system/files/library/8842/CEE_Eval_MeasureLifeStudyLights%2526HVACGDS_1Jun2007.pdf>
2. State of Ohio Energy Efficiency Technical Reference Manual, prepared for the Public Utilities Commission of Ohio by Vermont Energy Investment Corporation. August 6, 2010.
3. Minnesota Department of Commerce, Home Envelope, An Energy Guide to Help You Keep the Outside Out and the Inside In. <http://mn.gov/commerce/energy/topics/resources/Consumer-Guides/home-envelope/basement.jsp>
4. CEC 2001A. “Characterization of Framing Factors for Low-Rise Residential Building Envelopes in California” - Public Interest Energy Research Program: Final Report, Publication Number: 500-02-002, Dec 2001. <http://www.energy.ca.gov/reports/2002-09-06_500-02-002.PDF> .
5. Energy Center of Wisconsin, “Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research,” <https://focusonenergy.com/sites/default/files/centralairconditioning_report.pdf>
6. For all systems excluding ground source heat pumps: Pennsylvania Act 129 2018 Residential Baseline Study, <http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-Phase3_Res_Baseline_Study_Rpt021219.pdf>. Due to small sample size in residential baseline, the lowest efficiency options available in BEopt were chosen as defaults for ground source heat pumps.
7. From PECO baseline study, average home size = 2,323 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). FRAC = (425 ft2 × 2.1)/(2,323 ft2) = 0.38.
8. Illinois Statewide Technical Reference Manual, Version 7.0. September 28, 2018. <http://www.ilsag.info/technical-reference-manual.html> .
9. Used eQuest 3.64 to derive roof assembly R-values. When insulation is added between the joists as in most insulation up to R-30 (10”), the assembly R-value is based on a parallel heat transfer calculation of the insulation and joists, rather than a series heat transfer.
10. 2009 ASHRAE Fundamentals, Chapter 25 and 26. Method from “Total Thermal Resistance of a Flat Building Assembly” in Chapter 25. Values from Chapter 26: interior air film = 0.68, 1.5" wooden rim joist = 1.65, exterior air film = 0.17. Total= 2.50 *°F-ft2-h/BTU*
11. 2015 International Energy Conservation Code, Table R402.1.2: Insulation and Fenestration Requirements by Component. <https://codes.iccsafe.org/content/IECC2015/chapter-4-re-residential-energy-efficiency>
12. VEIC estimate. Extrapolation of manufacturer data.
13. McQuay Application Guide 31-008, Geothermal Heat Pump Design Manual, 2002. Engineering Estimate - See System Performance of Ground Source Heat Pumps
14. Based on the Phase III SWE team’s analysis of regional HVAC runtime data collected from ecobee’s Donate Your Data research service. <https://www.ecobee.com/donateyourdata/>
15. PA SWE Team Calculations with data from the National Solar Radiation Database. 1991–2005 Update: Typical Meteorological Year 3. NREL. <http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html>

### Basement Wall Insulation

|  |  |
| --- | --- |
| **Target Sector** | Residential Establishments |
| **Measure Unit** | Per Project |
| **Measure Life** | 15 years Source 1 |
| **Vintage** | Retrofit |

This protocol covers the calculation of energy and demand savings associated with insulating walls in conditioned and semi-conditioned (i.e. unfinished) basements. Cooling savings are only produced from insulation improvements to above-grade portions of the wall, since the below-grade portions are expected to be cooler than the temperature set point of the building. Heating savings will be produced from the entire insulation improvement, though in varying quantities depending on whether above or below grade.

Eligibility

This measure requires the installation of new insulation to the basement walls of existing residential buildings. The installation must achieve a finished wall insulation value of R-10 (if continuous insulation) or R-13 (if cavity insulation such as batts between studs) in IECC Climate Zone 4 or R-15 (if continuous insulation) or R-19 (if cavity insulation such as batts between studs) in IECC Climate Zones 5 and 6.Source 9

Algorithms

The annual energy and peak demand savings are obtained through the following formulas:

|  |  |
| --- | --- |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |

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= EERg* × *GSHPDF* × *GSER*

*HSPF****=****COPg* × *GSHPDF* ×3.412

**PTAC and PTHP**

*= EER*

Definition of Terms

Table 2‑123: Terms, Values, and References for Basement Wall Insulation

| **Term** | **Unit** | **Values** | **Source** |
| --- | --- | --- | --- |
| , Annual cooling energy savings | *kWh/year* | Calculated | - |
| , Annual heating energy savings | *kWh/year* | Calculated | - |
| Thermal resistance of existing wall insulation. | *°F.ft2.hr/BTU* | EDC Data Gathering  Default = existing nominal R-value + 1; Minimum = 1. (An uninsulated wall is assumed to be R-1.) | 2 |
| Thermal resistance of existing wall below grade. Assumes R-1 for concrete wall. | *°F.ft2.hr/BTU* | EDC Data Gathering  See Table 2‑124 | 3 |
| Thermal resistance of insulation added to wall | *°F.ft2.hr/BTU* | EDC Data Gathering | - |
| Height of insulated basement wall above ground | *Feet* | EDC Data Gathering | - |
| Height of insulated basement wall below ground | *Feet* | EDC Data Gathering |  |
| Length of basement wall around insulated perimeter | *Feet* | EDC Data Gathering | - |
| Frame factor, designed to account for space that is occupied framing | None | If externally applied = 0%  If studs and cavity = 25% | 4 |
| Annual cooling degree-days | *°F-day/year* | See CDD in Vol 1., App. A | 12 |
| Annual heating degree-days | *°F-day/year* | See HDD in Vol 1., App. A | 12 |
| Discretionary use adjustment to account for uncertainty in predicting cooling system usage patterns of occupants | None | 0.75 | 5 |
| Cooling system seasonal efficiency |  | EDC Data Gathering  Default: See Table 2‑125 | 6 |
| Heating system seasonal efficiency |  | EDC Data Gathering  Default: See Table 2‑125 | 6 |
| Adjustment factor to relate insulated area to area served by room air conditioners | None | If Room AC = 0.38  If non-Room AC = 1.0 | 7 |
| *COP,* Coefficient of Performance. This is a measure of the efficiency of a heat pump | None | EDC Data Gathering | - |
| *EERg ,* Energy Efficiency Ratio of a GSHP, this is measured differently than EER of an air source heat pump and must be converted |  | EDC Data Gathering  Default = 16.6 | - |
| *GSER* , Factor used to determine the SEER of a GSHP based on its EERg |  | 1.02 | 9 |
| *GSPK* , Factor to convert EERg to the equivalent EER of an air conditioner to enable comparisons to the baseline unit | *Proportion* | 0.8416 | 9 |
| *GSHPDF* , Ground Source Heat Pump De-rate Factor | *Proportion* | 0.885 | 10 |
| Equivalent full load cooling hours | *Hours/year* | See *EFLHcool* in Vol 1., App. A | 11 |
| Coincidence factor | None | See *CF* in Vol 1., App. A | 11 |

Table 2‑124: Below Grade Thermal Resistance Values

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Thermal Resistance (°F-ft2-h/BTU)** | | | | | | | | | |
| **Depth Below Grade (ft)** | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Total below grade, average (including R-1 for concrete wall) | 3.44 | 4.47 | 5.41 | 6.41 | 7.42 | 8.46 | 9.46 | 10.53 | 11.69 |

Table 2‑125: Default Cooling and Heating System Efficiencies

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

Default Savings

There are no default savings for this measure.

Evaluation Protocols

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

Sources

1. GDS Associates, Inc., Measure Life Report, *Residential and Commercial/Industrial Lighting and HVAC Measures*, 2007. Reduced to 15 years maximum as required by Act 129. <https://library.cee1.org/system/files/library/8842/CEE_Eval_MeasureLifeStudyLights%2526HVACGDS_1Jun2007.pdf>
2. ORNL Builders Foundation Handbook, crawl space data from Table 5-5: Initial Effective R-values for Uninsulated Foundation System and Adjacent Soil, 1991, <http://smartenergy.illinois.edu/pdf/Archive/FoundationHandbookforBuilders.pdf>
3. Illinois Statewide Technical Reference Manual, Version 7.0. September 28, 2018. <http://www.ilsag.info/technical-reference-manual.html>
4. CEC 2001A. “Characterization of Framing Factors for Low Rise Residential Building Envelopes in California” - Public Interest Energy Research Program: Final Report, Publication Number: 500-02-002, Dec 2001. <http://www.energy.ca.gov/reports/2002-09-06_500-02-002.PDF>
5. Energy Center of Wisconsin, “Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research,” <https://focusonenergy.com/sites/default/files/centralairconditioning_report.pdf>
6. For all systems excluding ground source heat pumps: Pennsylvania Act 129 2018 Residential Baseline Study, <http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-Phase3_Res_Baseline_Study_Rpt021219.pdf>. Due to small sample size in residential baseline, the lowest efficiency options available in BEopt were chosen as defaults for ground source heat pumps.
7. From PECO baseline study, average home size = 2,323 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). *FRAC* = (425 ft2 × 2.1)/(2,323 ft2) = 0.38.
8. 2015 International Energy Conservation Code, Table R402.1.2: Insulation and Fenestration Requirements by Component. <https://codes.iccsafe.org/content/IECC2015/chapter-4-re-residential-energy-efficiency>
9. VEIC estimate. Extrapolation of manufacturer data.
10. McQuay Application Guide 31-008, Geothermal Heat Pump Design Manual, 2002. Engineering Estimate - See System Performance of Ground Source Heat Pumps
11. Based on the Phase III SWE team’s analysis of regional HVAC runtime data collected from ecobee’s Donate Your Data research service. <https://www.ecobee.com/donateyourdata/>
12. PA SWE Team Calculations with data from the National Solar Radiation Database. 1991–2005 Update: Typical Meteorological Year 3. NREL. <http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html>

### Crawl Space Wall Insulation

|  |  |
| --- | --- |
| **Target Sector** | Residential Establishments |
| **Measure Unit** | Insulation Addition |
| **Measure Life** | 15 years Source 1 |
| **Vintage** | Retrofit |

A residential crawl space is a structural foundation that is tall enough for a person to crawl within the space to perform any necessary maintenance. This measure protocol applies to the installation of insulation in the crawl space walls of residential homes. The baseline is a crawl space that has no insulation.

Eligibility

This measure protocol applies to the installation of insulation in the unvented crawl space walls of residential homes with ductwork. Research has shown that vented crawlspaces that are sealed and insulated operate similarly to basements in providing benefits such as energy savings, comfort, moisture control, long-term durability, and healthier air quality.Source 2 Sealing the crawl space must follow the required PA building codes, including covering the earth with a Class I vapor retarder and providing ventilation of at least 1cfm per 50 ft2 of crawlspace. In addition, sealing of the crawlspace must not block access to the space. The insulation should have either a minimum R-10 continuous insulated sheathing on the interior or exterior of the home, or R-13 cavity insulation at the interior of the crawl space wall in IECC Climate Zone 4, and R-15 continuous or R-19 cavity insulation in zones 5 or 6.Source 3

Algorithms

Savings are due to a reduction in cooling and heating requirements due to insulation.

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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= EERg* × *GSHPDF* × *GSER*

*HSPF****=****COPg* × *GSHPDF* ×3.412

**PTAC and PTHP**

*= EER*

Definition of Terms

Table 2‑126: Terms, Values, and References for Residential Crawl Space Insulation

| **Term** | **Unit** | **Values** | **Source** |
| --- | --- | --- | --- |
| , baseline R-value of foundation wall | *°F-ft2-h/BTU* | EDC Data Gathering  Default = 1.73 | 4 |
| , average R-value for the thermal resistance of the Earth at the height of insulated crawlspace wall below grade (*Hbg*) | *°F-ft2-h/BTU* | Table 2‑127 | 5 |
| , R-value of installed spray foam, rigid foam, or cavity insulation applied to crawlspace wall | *°F-ft2-h/BTU* | EDC Data Gathering | EDC Data Gathering |
| *L*, length of crawlspace wall around the entire insulated perimeter | *ft* | EDC Data Gathering | EDC Data Gathering |
| , height of insulated crawlspace wall above grade | *ft* | EDC Data Gathering | EDC Data Gathering |
| , height of insulated crawlspace wall below grade | *ft* | EDC Data Gathering | EDC Data Gathering |
| *FF*, framing factor, adjustment to account for area of framing when cavity insulation is used | *Proportion* | External foam: 0.0  Spray foam : 0.0  Other cavity ins.: 0.25 | 6 |
| *CDD,* cooling degree days matched to crawlspace condition. Insulation in unconditioned spaces (standard crawlspace) is modeled by reducing the degree days to reflect the smaller but non-zero contribution to heating and cooling load. | *°F-day* | See CDD in Vol. 1 App. A | 13 |
| *HDD*, heating degree days matched to crawlspace condition | *°F-day* | See HDD in Vol. 1 App. A | 13 |
| *DUA*, Discretionary Use Adjustment, adjustment for times when AC is not operating even though conditions may call for it | *Proportion* | 0.75 | 7 |
| , Cooling system seasonal efficiency |  | EDC Data Gathering  Default: Table 2‑128 | 8 |
| , Heating system seasonal efficiency | *Proportion* | EDC Data Gathering  Default: Table 2‑128 | 8 |
| *AF*, adjustment factor, accounts for prescriptive engineering algorithms overestimating savings | *Proportion* | 0.88 | 9 |
| *COP,* Coefficient of Performance. This is a measure of the efficiency of a heat pump | None | EDC Data Gathering | - |
| *EER,* Energy Efficiency Ratio of a GSHP, this is measured differently than EER of an air source heat pump and must be converted |  | EDC Data Gathering | - |
| *GSER* , Factor used to determine the SEER of a GSHP based on its EERg |  | 1.02 | 11 |
| *GSPK* , Factor to convert EERg to the equivalent EER of an air conditioner to enable comparisons to the baseline unit | *Proportion* | 0.8416 | 11 |
| *GSHPDF* , Ground Source Heat Pump De-rate Factor | *Proportion* | 0.885 | 12 |
| , equivalent full-load hours of air conditioning | *hours* | EDC Data Gathering or  See *EFLHcool* in Vol. 1 App. A | EDC Data Gathering  10 |
| *CF*, coincidence factor | *Proportion* | See *CF* in Vol. 1 App. A | 10 |

Table 2‑127 should be used to determine the average thermal resistance of the Earth (*REarth)* at the height of crawlspace wall below grade (*Hbg*). Use a crawlspace wall that is 5ft in height as an example of proper use of the table. If the crawlspace wall is 5 ft in height and 1ft is above grade (*Hag* = 1ft), then the remaining 4ft are below grade (*Hbg* = 4ft). To determine the *REarth* for that below-grade wall height, look for the column for *Hbg* = 4ft in Table 2‑127. *REarth* in this example is therefore 6.42 °F-ft2-h/BTU.

Table 2‑127: Below-grade R-values

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| *Hbg* (ft) | **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** |
| *REarth* **(°F-ft2-h/BTU)** | 2.44 | 3.47 | 4.41 | 5.41 | 6.42 | 7.46 | 8.46 | 9.53 | 10.69 |

Table 2‑128: Default Cooling and Heating System Efficiencies

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

Default Savings

There are no default savings for this measure.

Evaluation Protocols

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

Sources

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2. USDOE, Guide to Closing and Conditioning Ventilated Crawlspaces, <http://www.nrel.gov/docs/fy13osti/54859.pdf>
3. 2015 International Energy Conservation Code, Table R402.1.2: Insulation and Fenestration Requirements by Component. <https://codes.iccsafe.org/content/IECC2015/chapter-4-re-residential-energy-efficiency>
4. 2009 ASHRAE Fundamentals, Chapter 25 and 26. Method from “Total Thermal Resistance of a Flat Building Assembly” in Chapter 25. Values from Chapter 26: interior air film = 0.68, 7" concrete or CMU wall = 0.88, exterior air film = 0.17. Total= 1.73 *°F-ft2-h/BTU*
5. ASHRAE Fundamentals Handbook, 1977. Adapted from Table 1, p. 24.4
6. ASHRAE Fundamentals Handbook, 2009. Adapted from Chapter 27, p. 27.4
7. Energy Center of Wisconsin, May 2008 metering study; “Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research”, p31. <http://cleanefficientenergy.org/resource/central-air-conditioning-wisconsin-compilation-recent-field-research>
8. For all systems excluding ground source heat pumps: Pennsylvania Act 129 2018 Residential Baseline Study, <http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-Phase3_Res_Baseline_Study_Rpt021219.pdf>. Due to small sample size in residential baseline, the lowest efficiency options available in BEopt were chosen as defaults for ground source heat pumps.
9. “Home Energy Services Impact Evaluation”, August 2012. Based on comparing algorithm derived savings estimate and evaluated bill analysis estimate. <http://ma-eeac.org/wordpress/wp-content/uploads/Home-Energy-Services-Impact-Evaluation-Report_Part-of-the-Massachusetts-2011-Residential-Retrofit-and-Low-Income-Program-Area-Evaluation.pdf>
10. Based on the Phase III SWE team’s analysis of regional HVAC runtime data collected from ecobee’s Donate Your Data research service. <https://www.ecobee.com/donateyourdata/>
11. VEIC estimate. Extrapolation of manufacturer data.
12. McQuay Application Guide 31-008, Geothermal Heat Pump Design Manual, 2002. Engineering Estimate - See System Performance of Ground Source Heat Pumps
13. PA SWE Team Calculations with data from the National Solar Radiation Database. 1991–2005 Update: Typical Meteorological Year 3. NREL. <http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html>

### ENERGY STAR Windows

|  |  |
| --- | --- |
| **Target Sector** | Residential Establishments |
| **Measure Unit** | Window Area |
| **Measure Life** | (15 max, but 20 for TRC) yearsSource 1 |
| **Vintage** | Retrofit |

Eligibility

This protocol documents the energy savings for replacing existing windows in a residence with ENERGY STAR certified windows.

Algorithms

ΔkWh

ΔkWhcool

ΔkWhheat

ΔkW

Definition of Terms

Table 2‑129: Terms, Values, and References for ENERGY STAR Windows

| **Term** | **Unit** | **Value** | **Sources** |
| --- | --- | --- | --- |
| , Climate region dependent electricity savings for efficient glazing |  | See Table 2‑130 | 2 |
| , Baseline equipment efficiency | varies | Measured, EDC Data Gathering  Default: |  |
| , Prototype equipment efficiency | varies | See Table 2‑8 in Sec. 2.2 | 3 |
| , Equivalent Full Load Cooling hours |  | See *EFLHcool* in Vol. 1, App. A | 4 |
| *CF,* Demand Coincidence Factor | *Proportion* | See *CF* in Vol. 1, App. A | 4 |

Table 2‑130: Default , kWh per Square Foot of Replaced Window

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Reference City** | **Cooling** | | | | **Heating** | | | | |
| **ASHP** | **Central AC** | **Mini-split** | **GSHP** | **ASHP** | **Electric Furnace** | **Base-board** | **Mini-split** | **GSHP** |
| Allentown | 0.66 | 1.50 | 0.59 | 0.57 | 2.86 | 3.40 | 3.12 | 2.10 | 0.95 |
| Binghamton | 0.46 | 0.65 | 0.47 | 0.36 | 4.50 | 4.60 | 4.28 | 3.56 | 1.27 |
| Bradford | 0.35 | 1.10 | 0.34 | 0.25 | 5.57 | 5.51 | 7.86 | 4.63 | 1.58 |
| Erie | 0.51 | 0.51 | 0.46 | 0.41 | 4.07 | 4.81 | 4.07 | 3.12 | 1.35 |
| Harrisburg | 0.75 | 0.82 | 0.73 | 0.66 | 2.84 | 3.91 | 3.17 | 2.40 | 1.06 |
| Philadelphia | 0.86 | 0.83 | 0.76 | 0.86 | 1.68 | 2.53 | 5.85 | 1.31 | 0.68 |
| Pittsburgh | 0.66 | 0.66 | 0.64 | 0.60 | 3.06 | 3.82 | 3.06 | 2.28 | 1.07 |
| Scranton | 0.59 | 0.68 | 0.57 | 0.50 | 3.36 | 3.83 | 3.55 | 2.58 | 1.06 |
| Williamsport | 0.65 | 0.46 | 0.61 | 0.58 | 2.99 | 3.47 | 5.08 | 2.19 | 0.96 |

Evaluation Protocols

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

Sources

1. California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, <http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx>. Accessed December 2018.
2. Based on modelling using BEopt v2.8.0 performed by NMR Group, Inc. Unit energy savings were calculated by modeling a prototypical Pennsylvania single family detached house with statewide average characteristics determined through the Pennsylvania Act 129 2018 Residential Baseline Study. Simulations for each equipment-climate region combination were performed for plain double-plane (0.49 U, 0.56 SHGC) and triple-pane ENERGY STAR (0.27 U, 0.26 SHGC) windows. The difference in heating and cooling loads were then apportioned evenly among the 322 square feet of windows in the prototype home yielding the UES values.
3. Pennsylvania Act 129 2018 Residential Baseline, <http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-Phase3_Res_Baseline_Study_Rpt021219.pdf>.
4. Based on the Phase III SWE team’s analysis of regional HVAC runtime data collected from ecobee’s Donate Your Data research service. <https://www.ecobee.com/donateyourdata/>

### Residential Window Repair

|  |  |
| --- | --- |
| **Target Sector** | Residential Establishments |
| **Measure Unit** | Per window repaired |
| **Measure Life** | 15 years Source 1 |
| **Vintage** | Retrofit |

Most residential windows lose some heat to air leakage, which is typically measured in infiltration per window area (CFM/ft2). In 2004, the National Fenestration Rating Council (NFRC) listed a range of typical air leakage rates from 0.06 CFM/ft2 to 1.0 CFM/ft2, though actual air leakage will vary based on the condition of individual windows. Windows with compression seals (e.g. casement and awning windows) can achieve lower infiltration rates than sliding windows with felt seals.Source 2 Currently, the NFRC states that most windows now range between 0.1 and 0.3 CFM/ft2. Source 3

Repairs to wooden windows are recommended to include the following as part of the repair:Source 4

* Remove the sashes by removing the interior stops and parting bead of the window frame.
* Clean the frames and sashes of any flaking paint or other coatings that may impede the proper installation of gaskets and seals.
* Caulk and seal the corners and joints in the window frame. This includes all joints between the sill and jambs as well as between the casings and frames.
* Cut grooves into the sashes where new gaskets will be installed.
* Prime and paint the window frames and sashes.
* Install new gaskets around the perimeter of the sashes. V-groove type gaskets will likely work the best at the jambs and meeting rails, while bubble gaskets work well at the head and sill interface.
* Reinstall the sashes, meeting rails, and interior stops.
* As part of the work, if the weight pockets are retained, clean and lubricate pulleys, replace the sash cords or chains, and balance the weights as part of the work.
* The weight and balance system could also be abandoned and replaces with a spring-loaded tape balance. The weight pockets can then be insulated and sealed, improving the overall thermal performance of the window frame-to-rough opening interface.

Eligibility

To be eligible, the window’s weatherstripping must be repaired or replaced in addition to an assessment—and possible repair—of the condition of the window sash.

Algorithms

The annual energy savings are obtained through the following formula. Any cooling savings resulting from this measure are considered negligible. Since the estimated savings are based on heating, there is no anticipated impact on demand during the peak period (June through August, 2 p.m. to 6 p.m.).

|  |  |
| --- | --- |
|  |  |

Definition of Terms

Table 2‑131: Terms, Values, and References for Residential Window Repair

|  |  |  |  |
| --- | --- | --- | --- |
| **Term** | **Unit** | **Values** | **Source** |
| , Number of windows | Windows | EDC Data Gathering | - |
| , Conversion factor that converts CFM air (at 70°F) to BTU/hr-°F |  | 1.08 | - |
| , Infiltration of existing window | *CFM* | See Table 2‑132 | 5, 7\* |
| , Infiltration reduction factor | None | 60% | 6 |
| , Orientation factor, relating the prevailing wind direction to building façade orientation | None | 25% | 5\* |
| , Heating degree-days | *°F-day* | See HDD in Vol. 1, App F. | - |
| , Heating system efficiency |  | EDC Data Gathering  Default: see Table 2‑133 | 1 |

\* Assumes a typical window size of 24 inches by 48 inches (8 ft2), that a repaired window has a 1 in 4 chance of being on the windward face of a building at a given time, and based on “Only windows on windward elevations exhibit air infiltration at any one time.”Source 6 The infiltration rates are provided in Source 6. The infiltration rates in Source 6 reflect infiltration at 1.56 lb/ft2 (25 mph winds), which is higher than 10 mph average wind speed for Pennsylvania’s heating season (estimated at October through March). According to Ensewiler’s Formula (see below), at wind speeds of 10 mph the pressure difference across a window is 0.26 lb/ft2. Using the the fact that 0.1 CFM/ft2 at 6.24 lb/ft2 is equivalent to 0.04 CFM/ft2 at 1.56 lb/ft2 (Source 6), and the relationship between flow rate and pressure from Source 7 the infiltration rates were extrapolated to the values tabulated above.

Where,

P = Pressure difference across window, lb/ft2

V = Wind velocity, mph

Source 8 establishes the relationship between flow rate and pressure:

Where,

q = Flow rate per unit area, CFM/ft2

C = flow coefficient, CFM/ft2 × (lb/ft2)n

ΔP = pressure difference across window

n = flow exponent

Table 2‑132: Existing Infiltration Assumptions

|  |  |
| --- | --- |
| **Window Type** | **Infiltration Rate (CFM/ft2)** |
| Non-weatherstripped hung or sliding window | 6.0 |
| Weatherstrippied hung or sliding window OR non-weatherstripped awning or casement windows | 2.4 |
| Weatherstripped awning or casement windows | 1.2 |

Table 2‑133: Default Heating System Efficiency

|  |  |
| --- | --- |
| **Type** | **HSPF** |
| Air-Source Heat Pump | 8.2 |
| Ground-Source Heat Pump | 12.28 |
| Ductless Mini-Split | 8.9 |
| Electric Resistance | 3.412 |

Default Savings

There are no default savings for this measure.

Evaluation Protocols

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

Sources

1. Pennsylvania Act 129 2018 Residential Baseline Study, <http://www.puc.state.pa.us/Electric/pdf/Act129/SWE-Phase3_Res_Baseline_Study_Rpt021219.pdf>.
2. Krigger, John and Dorsi, Chris. *Residential Energy*, 4th Edition. 2004.
3. The National Fenestration Rating Council, “The NFRC Label,” <http://www.nfrc.org/WindowRatings/The-NFRC-Label.html>
4. Baker, P. *Measure Guideline: Wood Window Repair, Rehabilitation and Replacement.* December 2012. <http://www.nrel.gov/docs/fy13osti/55219.pdf>
5. Wausau Window and Wall Systems, “Air Infiltration Energy Usage,” <http://www.wausauwindow.com/index.cfm?pid=51&pageTitle=Air-Infiltration-Energy-Usage>
6. James, Shapiro, Flanders and Hemenway, Testing the Energy Performance of Wood Windows in Cold Climates, August 30, 1996. <http://ohp.parks.ca.gov/pages/1054/files/testing%20windows%20in%20cold%20climates.pdf>
7. Shaw, C.Y. and Jones, L. Air Tightness and Air Infiltration of School Buildings, 1979. <http://web.mit.edu/parmstr/Public/NRCan/nrcc18030.pdf>

## Whole Home

### Residential New Construction

|  |  |
| --- | --- |
| **Target Sector** | Residential Establishments |
| **Measure Unit** | Multiple |
| **Measure Life** | Varies |
| **Vintage** | New Construction |

Eligibility

This protocol documents the energy savings attributed to improvements to the construction of residential homes above the baseline home as calculated by the appropriate energy modeling software or as determined by deemed savings values.

Algorithms

**Insulation Up-Grades, Efficient Windows, Air Sealing, Efficient HVAC Equipment and Duct Sealing (Weather-Sensitive Measures):**

Energy and peak demand savings due to improvements in the above mentioned measures in Multifamily New Construction programs will be an output of an energy modeling package that compares the as-designed building to a minimally code-compliant baseline building. The baseline building thermal envelope and/or system characteristics shall be based on the current state adopted International Energy Conservation Code (IECC) 2015.[[66]](#footnote-68)

Modeled energy and peak demand savings shall be produced by a RESNET accredited software program[[67]](#footnote-69) or by other models approved by the PA SWE. The latter include the Passive House accreditation software packages (Passive House Planning Package[[68]](#footnote-70) and WUFI Passive[[69]](#footnote-71)), though both tools require the user to separately model the code baseline reference design to calculate energy and demand savings.

The energy savings for weather-sensitive measures will be calculated from the software output using the following algorithm:

*Energy savings of the qualified home (kWh)*

The system peak electric demand savings for weather-sensitive measures will be calculated from the software output with the following algorithm, which is based on compliance and certification of the energy efficient home to the EPA’s ENERGY STAR for New Homes’ program standard:

Peak demand of the baseline home

Peak demand of the qualifying home

Coincident system peak electric demand savings

**Hot Water, Lighting, and Appliances (Non-Weather-Sensitive Measures):**

Quantification of additional energy and peak demand savings due to the installation of high-efficiency electric water heaters, lighting and other appliances may be done using the chosen modeling software or using the TRM algorithms presented for these measures elsewhere in this volume of the Manual.

When using the TRM algorithms, and where the TRM algorithms involve deemed savings, e.g. lighting, the savings in the baseline and qualifying homes should be compared to determine the actual savings of the qualifying home above the baseline.

In instances where model parameters or inputs do not match TRM algorithm inputs, additional data collection is necessary to use the TRM algorithms. One such example is lighting, where some models require an input of percent of lighting fixtures that are energy efficient whereas the TRM requires exact fixture counts and wattages.

It is also possible to have increases in consumption or coincident peak demand instead of savings for some non-weather sensitive measures. For example, if the amount of efficient lighting in a new home is less than the amount assumed in the baseline, the home will have higher energy consumption and coincident peak demand for lighting, even though it still qualifies for the program.

Definition of Terms

A summary of the input values and their data sources follows:

Table 2‑134: Terms, Values, and References for Residential New Construction

|  |  |  |  |
| --- | --- | --- | --- |
| **Term** | **Unit** | **Value** | **Sources** |
| *Heating kWhbase* , Annual heating energy consumption of the baseline home, from software. | *kWh* | Software Calculated | 1 |
| *Heating kWhee* , Annual heating energy consumption of the qualifying home, from software. | *kWh* | Software Calculated | 2 |
| *Cooling kWhbase* , Annual cooling energy consumption of the baseline home, from software. | *kWh* | Software Calculated | 1 |
| *Cooling kWhee* , Annual cooling energy consumption of the qualifying home, from software. | *kWh* | Software Calculated | 2 |
| *PLbase* , Estimated peak cooling load of the baseline home, from software. | *kBTU/hr* | Software Calculated | 3 |
| *EERbase ,* Energy Efficiency Ratio of the baseline unit. |  | EDC Data Gathering  Default: | 4 |
| *EERee* , Energy Efficiency Ratio of the qualifying unit. |  | EDC Data Gathering  Default: | 4 |
| *SEERbase ,* Seasonal Energy Efficiency Ratio of the baseline unit. |  | 13  14 (ASHP) | 8 |
| *SEERee ,* SEER associated with the HVAC system in the qualifying home. |  | EDC Data Gathering | 6 |
| *PLq ,* Estimated peak cooling load for the qualifying home constructed, from software. | *kBTU/hr* | Software Calculated | 5 |

The following table lists the building envelope characteristics of the baseline reference home based on 2015 IECC for the three climate zones in Pennsylvania.

Table 2‑135: Baseline Insulation and Fenestration Requirements by Component (Equivalent U-Factors)Source 12

| **IECC Climate Zone** | **Fenestration U-Factor** | **Skylight U-Factor** | **Ceiling U-Factor** | **Frame Wall U-Factor** | **Mass Wall U-Factor** | **Floor**  **U-Factor** | **Basement Wall U*-*Factor** | **Slab**  **R-Value & Depth** | **Crawl Space Wall U-Factor** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 4A | 0.35 | 0.55 | 0.026 | 0.060 | 0.098 | 0.047 | 0.059 | 10, 2 ft | 0.065 |
| 5A | 0.32 | 0.55 | 0.026 | 0.060 | 0.082 | 0.033 | 0.050 | 10, 2 ft | 0.055 |
| 6A | 0.32 | 0.55 | 0.026 | 0.060 | 0.060 | 0.033 | 0.050 | 10, 4 ft | 0.055 |
| Climate Region D and York County are CZ4, Climate Region A and G are CZ6, everything else is CZ5. | | | | | | | | | |

Table 2‑136: Energy Star Homes - User Defined Reference Home

| **Data Point** | **Value** | **Source** |
| --- | --- | --- |
| Air Infiltration Rate | 3 ACH50 for the whole house | 7 |
| Duct Leakage | 4 CFM25 (4 cubic feet per minute per 100 square feet of conditioned space when tested at 25 pascals) | 7 |
| Duct Insulation | Supply and return ducts in attics shall be insulated to a minimum of R-8 where ≥3” in diameter and a minimum of R-6 where <3” in diameter. All other ducts not located completely inside the building thermal envelope shall be insulated to a minimum of R-6 where ≥3” in diameter and a minimum of R-4.2 where <3” in diameter. | 7 |
| Duct Location | 50% in conditioned space, 50% unconditioned space | Program Design |
| Mechanical Ventilation | A continuous whole-house ventilation system with efficiency of 2.8 CFM/Watt and airflow defined by Table M1507.3.3(1) of 2015 IRC | 11 |
| Appliances | Use Default |  |
| Thermostat Setback | Maintain zone temperature down to 55 oF (13 oC) or up to 85 oF (29 oC) | 7 |
| Temperature Set Points | Heating: 70°F  Cooling: 78°F | 7 |
| **Heating Efficiency** |  |  |
| Furnace | 80% AFUE | 8 |
| Gas Fired Steam Boiler | 82% AFUE | 8 |
| Gas Fired Hot Water Boiler | 84% AFUE | 8 |
| Oil Fired Steam Boiler | 85% AFUE | 8 |
| Oil Fired Hot Water Boiler | 86% AFUE | 8 |
| Combo Water Heater | 76% AFUE (recovery efficiency) | 8 |
| Air Source or Geothermal Heat Pump | 8.2 HSPF | 7 |
| PTAC / PTHP | Use value for air source heat pump | 7 |
| **Cooling Efficiency** |  |  |
| Central Air Conditioning | 13.0 SEER | 7 |
| Air Source Heat Pump | 14.0 SEER | 7 |
| Geothermal Heat Pump | 14 SEER (12.2 EER) | 7 |
| PTAC / PTHP | Use value for central AC | 7 |
| Window Air Conditioners | Use value for central AC | 7 |
| **Domestic WH Efficiency** |  |  |
| Electric | ≥20 gal and ≤55 gal: EF = 0.9307 - 0.0002×(Vs)  >55 gal and ≤120 gal: EF = 2.1171 - 0.0011×(Vs) | 9 |
| Natural Gas | ≥20 gal and ≤55 gal: EF = 0.6483 – (0.0017×Vs)  >55 gal and ≤100 gal: EF = 0.7897 – (0.0004× Vs)  Vs: Rated Storage Volume – the water storage capacity of a water heater (in gallons) | 7 |
| Additional Water Heater Tank Insulation | None |  |

Evaluation Protocols

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

Sources

1. Calculation of annual energy consumption of a baseline home from the home energy rating tool based on the reference home energy characteristics.
2. Calculation of annual energy consumption of an energy efficient home from the home energy rating tool based on the qualifying home energy characteristics
3. Calculation of peak load of baseline home from the home energy rating tool based on the reference home energy characteristics.
4. “Methodology for Calculating Cooling and Heating Energy Input-Ratio (EIR) from the Rated Seasonal Performance Eefficiency (SEER OR HSPF)” (Kim, Baltazar, Haberl). April 2013 Accessed December 2018. <http://oaktrust.library.tamu.edu/bitstream/handle/1969.1/152118/ESL-TR-13-04-01.pdf>
5. Calculation of peak load of energy efficient home from the home energy rating tool based on the qualifying home energy characteristics.
6. SEER of HVAC unit in energy efficient qualifying home.
7. 2015 International Energy Conservation Code §R401-R404. <https://codes.iccsafe.org/content/IECC2015/chapter-4-re-residential-energy-efficiency>
8. Electronic Code of Federal Regulations, 10 CFR Part 430, Subpart C, §430.32, “Energy Conservation Program for Consumer Products: Energy and Water Conservation Standards.” <https://www.ecfr.gov/cgi-bin/retrieveECFR?&n=pt10.3.430#se10.3.430_132>. Current as of November 13, 2018.
9. US Federal Standards for Residential Water Heaters. Effective April 16, 2015. <http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/27>
10. 2015 International Energy Conservation Code Table R402.1.4 Equivalent U-Factors presents the R-Value requirements of Table R402.1.2 in an equivalent U-Factor format. Users may choose to follow Table R402.1.2 instead. 2015 IECC supersedes this table in case of discrepancy. Additional requirements per §R402 of 2015 IECC must be followed even if not listed here. <https://codes.iccsafe.org/content/IECC2015/chapter-4-re-residential-energy-efficiency>
11. 2015 International Residential Code, Table M1507.3.3(1): Continuous Whole-House Mechanical Ventilation System Airflow Rate Requirements. <https://codes.iccsafe.org/content/IRC2015/chapter-15-exhaust-systems>

### Home Performance with ENERGY STAR

|  |  |
| --- | --- |
| **Target Sector** | Residential Establishments |
| **Measure Unit** | Multiple |
| **Measure Life** | Years |
| **Vintage** | Retrofit |

In order to implement Home Performance with ENERGY STAR, there are various standards an Implementation Conservation Service Provider must adhere to in order to deliver the program. These standards, along with operational guidelines on how to navigate through the HPwES program can be found on the ENERGY STAR website. Minimum requirements, Sponsor requirements, reporting requirements, and descriptions of the performance and prescriptive based options can be found in the v. 1.5 Reference Manual.[[70]](#footnote-72) The program implementer must use software that meets a national standard for savings calculations from whole-house approaches such as home performance. The software program implementer must adhere to at least one of the following standards:

* A software tool whose performance has passed testing according to the National Renewable Energy Laboratory’s HERS BESTEST software energy simulation testing protocol.[[71]](#footnote-73)
* Software approved by the US Department of Energy’s Weatherization Assistance Program.[[72]](#footnote-74)
* RESNET approved rating software.[[73]](#footnote-75)

There are numerous software packages that comply with these standards. Some examples of the software packages are REM/Rate, EnergyGauge, TREAT, and HomeCheck. These examples are not meant to be an exhaustive list of software approved by the bodies mentioned above.

Eligibility

The efficient condition is the performance of the residential home as modeled in the approved software after home performance improvements have been made. The baseline condition is the same home modeled prior to any energy efficiency improvements.

Algorithms

There are no algorithms associated with this measure as the energy savings are shown through modeling software. For modeling software that provides 8760 energy consumption data, the following algorithm may be used as guidance to determine demand savings:

Definition of Terms

Table 2‑137: Terms, Values, and References for Home Performance with ENERGY STAR

|  |  |  |  |
| --- | --- | --- | --- |
| **Term** | **Unit** | **Values** | **Source** |
| , Average demand during the PJM Peak Period | *kW* | EDC Data Gathering | 1 |

Evaluation Protocols

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

Sources

1. The coincident summer peak period is defined as the period between the hour ending 15:00 Eastern Prevailing Time[[74]](#footnote-76) (EPT) and the hour ending 18:00 EPT during all days from June 1 through August 31, inclusive, that is not a weekend or federal holiday[[75]](#footnote-77).

### Low-Rise Multifamily New Construction

|  |  |
| --- | --- |
| **Target Sector** | Residential Low-Rise Multifamily Buildings |
| **Measure Unit** | Multiple |
| **Measure Life** | Varies |
| **Vintage** | New Construction |

Eligibility

This protocol documents the energy savings attributed to improvements to the construction of low-rise multifamily residential buildings (≥3 dwelling units and <4 stories) above the baseline building as calculated by the appropriate energy modeling software or as determined by deemed savings values.

Algorithms

**Insulation Up-Grades, Efficient Windows, Air Sealing, Efficient HVAC Equipment and Duct Sealing (Weather-Sensitive Measures):**

Energy and peak demand savings due to improvements in the above mentioned measures in Multifamily New Construction programs will be an output of an energy modeling package that compares the as-designed building to a minimally code-compliant baseline building. The baseline building thermal envelope and/or system characteristics shall be based on the current state adopted International Energy Conservation Code (IECC) 2015.[[76]](#footnote-78)

Modeled energy and peak demand savings shall be produced by a RESNET accredited software program[[77]](#footnote-79) or by other models approved by the PA SWE. The latter include the Passive House accreditation software packages (Passive House Planning Package[[78]](#footnote-80) and WUFI Passive[[79]](#footnote-81)), though both tools require the user to separately model the code baseline reference design to calculate energy and demand savings.

The energy savings for weather-sensitive measures will be calculated from the software output using the following algorithm:

*Energy savings of the qualified building (kWh)*

The system peak electric demand savings for weather-sensitive measures will be calculated from the software output with the following algorithm, which is based on compliance and certification of the energy efficient home to the EPA’s ENERGY STAR for New Homes’ program standard:

Peak demand of the baseline multifamily building

Peak demand of the as-designed multifamily building

Coincident system peak electric demand savings

**Hot Water, Lighting, and Appliances (Non-Weather-Sensitive Measures):**

Quantification of additional energy and peak demand savings due to the installation of high-efficiency electric water heaters, lighting and other appliances may be done using the chosen modeling software or using the TRM algorithms presented for these measures elsewhere in this volume or Volume 3: Commercial and Industrial Measures, as applicable, of the Manual. As a rule of thumb, in-unit measures are generally considered residential, and common areas and central systems (e.g., commercial-grade hot water) are generally considered commercial.

When using the TRM algorithms, and where the TRM algorithms involve deemed savings, e.g. lighting, the savings in the baseline and qualifying homes should be compared to determine the actual savings of the qualifying home above the baseline.

In instances where model parameters or inputs do not match TRM algorithm inputs, additional data collection is necessary to use the TRM algorithms. One such example is lighting, where some models require an input of percent of lighting fixtures that are energy efficient whereas the TRM requires exact fixture counts and wattages.

It is also possible to have increases in consumption or coincident peak demand instead of savings for some non-weather sensitive measures. For example, if the amount of efficient lighting in a new home is less than the amount assumed in the baseline, the home will have higher energy consumption and coincident peak demand for lighting, even though it still qualifies for the program.

Definition of Terms

Table 2‑138: Terms, Values, and References for Low-Rise Multifamily New Construction

|  |  |  |  |
| --- | --- | --- | --- |
| **Term** | **Unit** | **Value** | **Sources** |
| *Heating kWhbase* , Annual heating energy consumption of the baseline building, from software. | *kWh* | Software Calculated | 1 |
| *Heating kWhq* , Annual heating energy consumption of the as-designed building, from software. | *kWh* | Software Calculated | 2 |
| *Cooling kWhbase* , Annual cooling energy consumption of the baseline building, from software. | *kWh* | Software Calculated | 1 |
| *Cooling kWhq* , Annual cooling energy consumption of the as-designed building, from software. | *kWh* | Software Calculated | 2 |
| *PLbase* , Estimated peak cooling load of the baseline building, from software. | *kBTU/hr* | Software Calculated | 3 |
| *EERbase ,* Energy Efficiency Ratio of the baseline equipment. |  | EDC Data Gathering  Default: | 4 |
| *EERq* , Energy Efficiency Ratio of the qualifying equipment. |  | EDC Data Gathering  Default: | 4 |
| *SEERbase ,* Seasonal Energy Efficiency Ratio of the baseline equipment. |  | 13  14 (ASHP) | 5 |
| *SEERq ,* SEER associated with the HVAC system in the as-designed building. |  | EDC Data Gathering | 7 |
| *PLq ,* Estimated peak cooling load for the as-designed building constructed, from software. | *kBTU/hr* | Software Calculated | 6 |

Evaluation Protocols

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

Sources

1. Calculation of annual energy consumption of a baseline building from the building energy model based on the reference building energy characteristics.
2. Calculation of annual energy consumption of an energy efficient building from the building energy model based on the as-designed building energy characteristics.
3. Calculation of peak load of baseline building from the building energy model based on the reference building energy characteristics.
4. “Methodology for Calculating Cooling and Heating Energy Input-Ratio (EIR) from the Rated Seasonal Performance Eefficiency (SEER OR HSPF)” (Kim, Baltazar, Haberl). April 2013 Accessed December 2018. <http://oaktrust.library.tamu.edu/bitstream/handle/1969.1/152118/ESL-TR-13-04-01.pdf>
5. Electronic Code of Federal Regulations, 10 CFR Part 430, Subpart C, §430.32, “Energy Conservation Program for Consumer Products: Energy and Water Conservation Standards.” <https://www.ecfr.gov/cgi-bin/retrieveECFR?&n=pt10.3.430#se10.3.430_132>. Current as of November 13, 2018.
6. Calculation of peak load of energy efficient building from the building energy model based on the as-designed building energy characteristics.
7. SEER of HVAC unit in energy efficient as-designed building.

### ENERGY STAR Manufactured Homes

|  |  |
| --- | --- |
| **Target Sector** | Manufactured homes |
| **Measure Unit** | Variable |
| **Measure Life** | 15 YearsSource 14 |
| **Vintage** | New Construction |

Eligibility

This measure applies to ENERGY STAR Manufactured Homes.

Algorithms

**Insulation Upgrades, Efficient Windows, Air Sealing, Efficient HVAC Equipment and Duct Sealing (Weather-Sensitive Measures):**

Energy and peak demand savings due to improvements in the above measures in ENERGY STAR Manufactured Homes programs will be a direct output of accredited Home Energy Ratings (HERS) software that meets the applicable Mortgage Industry National Home Energy Rating System Standards. REM/Rate[[80]](#footnote-82) is cited here as an example of an accredited software which can be used to estimate savings for this program. REM/Rate has a module that compares the energy characteristics of the energy efficient home to the baseline/reference home and calculates savings. For ENERGY STAR Manufactured Homes, the baseline building thermal envelope and/or system characteristics shall be based on the current Manufactured Homes Construction and Safety Standards (HUD Code). For this measure a manufactured home “means a structure, transportable in one or more sections, which in the traveling mode, is eight body feet or more in width or forty body feet or more in length, or, when erected on site, is three hundred twenty or more square feet, and which is built on a permanent chassis and designed to be used as a dwelling with or without a permanent foundation when connected to the required utilities, and includes the plumbing, heating, air conditioning, and electrical systems contained therein.”Source 14

The energy savings for weather-sensitive measures will be calculated from the software output using the following algorithm:

*Energy savings of the qualified home (kWh/yr)*

ΔkWh =

The system peak electric demand savings for weather-sensitive measures will be calculated from the software output with the following algorithm, which is based on compliance and certification of the energy efficient home to the EPA’s ENERGY STAR Manufactured Home’ program standard:

Peak demand of the baseline home  
=

Peak demand of the qualifying home  
=

Coincident system peak electric demand savings (kW)

ΔkWpeak =

**Hot Water, Lighting, and Appliances (Non-Weather-Sensitive Measures):**

Quantification of additional energy and peak demand savings due to the installation of high-efficiency electric water heaters, lighting and other appliances may be based either on direct output of accredited Home Energy Ratings (HERS) software that meets the applicable Mortgage Industry National Home Energy Rating System Standards or on the algorithms presented for these measures in Volume 2 (Residential Measures) of this Manual. Where the TRM algorithms involve deemed savings, e.g. lighting, the savings in the baseline and qualifying homes should be compared to determine the actual savings of the qualifying home above the baseline.

In instances where REM/Rate calculated parameters or model inputs do not match TRM algorithm inputs, additional data collection is necessary to use the TRM algorithms. One such example is lighting. REM/Rate requires an input of percent of lighting fixtures that are energy efficient whereas the TRM requires an exact fixture count. Another example is refrigerators, where REM/Rate requires projected kWh consumed and the TRM deems savings based on the type of refrigerator.

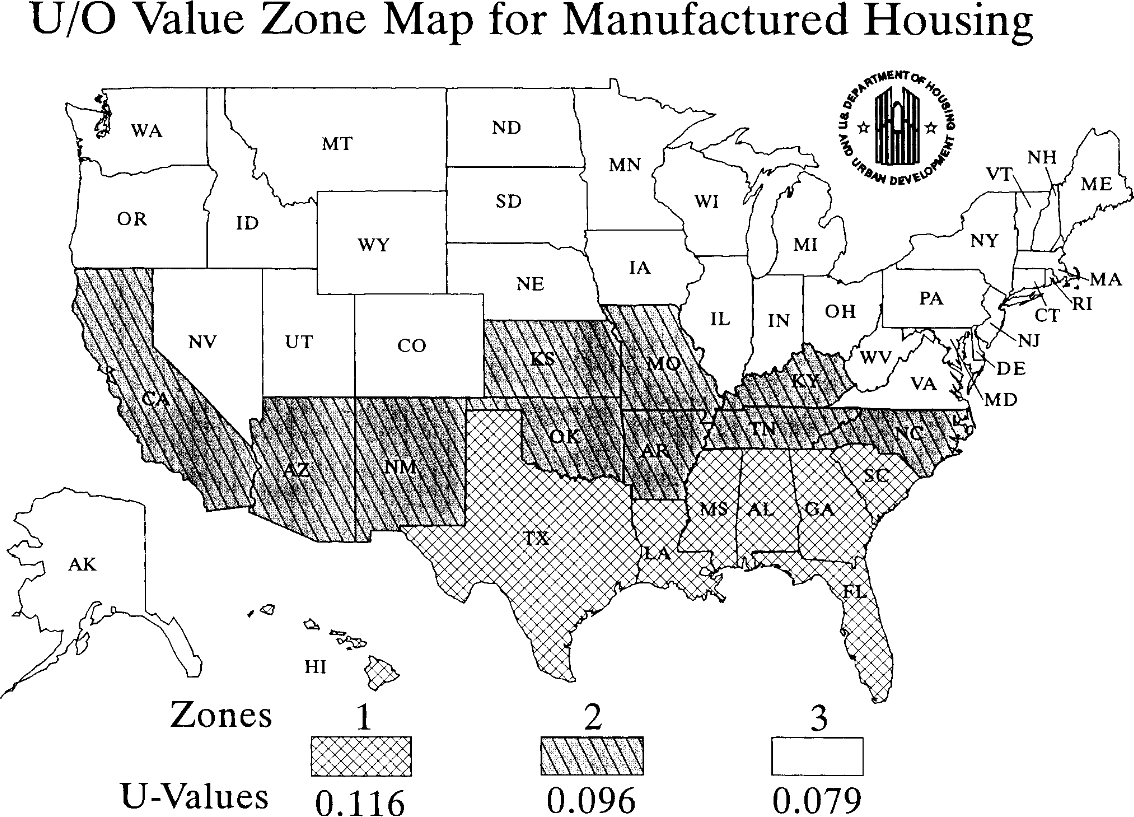
Definition of Terms

Table 2‑139: ENERGY STAR Manufactured Homes– References

|  |  |  |  |
| --- | --- | --- | --- |
| **Term** | **Unit** | **Value** | **Sources** |
| *Heating kWhbase*, Annual heating energy consumption of the baseline home | *kWh* | Software Calculated | 1 |
| *Heating kWhee*, Annual heating energy consumption of the qualifying home | *kWh* | Software Calculated | 1 |
| *Cooling kWhbase*, Annual cooling energy consumption of the baseline home | *kWh* | Software Calculated | 1 |
| *Cooling kWhee*, Annual cooling energy consumption of the qualifying home | *kWh* | Software Calculated | 1 |
| *PLb*, Estimated peak cooling load of the baseline home | *kBTU/h* | Software Calculated | 1 |
| *EERb*, Energy Efficiency Ratio of the baseline unit. |  | EDC Data Gathering  Default: | 2 |
| *EERq*, Energy Efficiency Ratio of the qualifying unit. |  | EDC Data Gathering  Default: | 2 |
| *SEERb*, Seasonal Energy Efficiency Ratio of the baseline unit. |  | 13  14 (ASHP) | 3 |
| *SEERq*, SEER associated with the HVAC system in the qualifying home. |  | EDC Data Gathering | 4 |
| *PLq*, Estimated peak cooling load for the qualifying home constructed, in kBTU/hr, from software. | *kBTU/h* | Software Calculated | 1 |

The HUD Code defines required insulation levels as an average envelope U0 factor per zone. In Pennsylvania zone 3 requirements apply with a required U0-factor of 0.079. This value cannot be directly used to define a baseline envelope R-values because the U0-factor is dependent on both the size of the manufactured homes and insulating levels together. However because manufactured homes are typically built to standard dimensions baseline U-factors can be estimated with reasonable accuracy.

Figure 2‑5: Uo Baseline Requirements[[81]](#footnote-83)



The HUD Code required insulation levels can be expressed as a set of estimated envelope parameters to be used in REM/Rate’s user defined reference home function. Using typical manufactured home sizes these values are expressed below along with federal standard baseline parameters below in Table 2‑140.

Table 2‑140: ENERGY STAR Manufactured Homes - User Defined Reference Home

| **Data Point** | **Value**[[82]](#footnote-84) | **Source** |
| --- | --- | --- |
| Walls | U-factor 0.090 | 6, 7 |
| Ceilings | U-factor 0.045 | 6, 7 |
| Floor | U-factor 0.045 | 6, 7 |
| Windows | U-factor 0.59 | 6, 7 |
| Doors | U-factor 0.33 | 6, 7 |
| Air Infiltration Rate | 10 ACH50 | 6 |
| Duct Leakage | RESNET/HERS default | 6 |
| Duct Insulation | RESNET/HERS default | 6 |
| Duct Location | Supply 100% manufactured home belly, Return 100% conditioned space | 8 |
| Mechanical Ventilation | 0.035 CFM/ft2 Exhaust | 7 |
| Lighting Systems | 0% CFL 10% pin based (Default assumption) | 9 |
| Appliances | Use Default | 6 |
| Thermostat Setback | Non-Programmable thermostat | 6 |
| Temperature Set Points | Heating: 70°F  Cooling: 78°F | 10 |
| **Heating Efficiency** |  |  |
| Furnace | 80% AFUE | 3 |
| Gas Fired Steam Boiler | 82% AFUE | 3 |
| Gas Fired Hot Water Boiler | 84% AFUE | 3 |
| Oil Fired Steam Boiler | 85% AFUE | 3 |
| Oil Fired Hot Water Boiler | 86% AFUE | 3 |
| Combo Water Heater | 76% AFUE (recovery efficiency) | 3 |
| Electric Resistance | 3.412 HSPF | 7 |
| **Cooling Efficiency** |  |  |
| Central Air Conditioning | 13.0 SEER | 3 |
| Air Source Heat Pump | 14.0 SEER | 3 |
| Geothermal Heat Pump | 14 SEER (12.2 EER) | 3 |
| PTAC / PTHP | Use value for central AC | 3 |
| Window Air Conditioners | Use value for central AC | 3 |
| **Domestic WH Efficiency** |  |  |
| Electric | ≥20 gal and ≤55 gal: EF = 0.9307 - 0.0002×(Vs)  >55 gal and ≤120 gal: EF = 2.1171 - 0.0011×(Vs) | 11 |
| Natural Gas | ≥20 gal and ≤55 gal: EF = 0.6483 – (0.0017×Vs)  >55 gal and ≤100 gal: EF = 0.7897 – (0.0004× Vs)  Vs: Rated Storage Volume – the water storage capacity of a water heater (in gallons) | 12 |
| Additional Water Heater Tank Insulation | None | 13 |

Evaluation Protocols

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

Sources

* + - 1. Calculation of annual energy and peak load consumption of a baseline home from the home energy rating tool based on the reference home energy characteristics.
      2. “Methodology for Calculating Cooling and Heating Energy Input-Ratio (EIR) from the Rated Seasonal Performance Eefficiency (SEER OR HSPF)” (Kim, Baltazar, Haberl). April 2013 Accessed December 2018. <http://oaktrust.library.tamu.edu/bitstream/handle/1969.1/152118/ESL-TR-13-04-01.pdf>
      3. Electronic Code of Federal Regulations, 10 CFR Part 430, Subpart C, §430.32, “Energy Conservation Program for Consumer Products: Energy and Water Conservation Standards.” <https://www.ecfr.gov/cgi-bin/retrieveECFR?&n=pt10.3.430#se10.3.430_132>. Current as of November 13, 2018.
      4. SEER of HVAC unit in energy efficient qualifying home.
      5. Straub, Mary and Switzer, Sheldon. "Using Available Information for Efficient Evaluation of Demand Side Management Programs". Study by BG&E. The Electricity Journal. Aug/Sept, 2011. p. 95. <http://www.sciencedirect.com/science/article/pii/S1040619011001941>
      6. ENERGY STAR QUALIFIED MANUFACTURED HOMES-Guide for Retailers with instructions for installers and HVAC contractors / June 2007 / (<http://www.research-alliance.org/pages/es_retail.htm>)
      7. Electronic Code of Federal Regulations, 24 CFR Part 3280, Manufactured Home Construction and Safety Standards. <https://www.ecfr.gov/cgi-bin/retrieveECFR?&n=pt24.5.3280> Accessed November 16, 2018.
      8. Standard manufactured home construction
      9. Not a requirement of the HUD Code.
      10. 2015 International Energy Conservation Code §R401-R404.
      11. US Federal Standards for Residential Water Heaters. Effective April 16, 2015. For a 40-gallon tank this is 0.948. <http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/27>
      12. US Federal Standards for Residential Water Heaters. Effective April 16, 2015. For a 40-gallon tank this is 0.615 <http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/27>
      13. No requirement in code or federal regulation.
      14. NREL, Northwest Energy Efficient Manufactured Housing Program Specification Development, T.Huges, B. Peeks February 2013. <http://www.nrel.gov/docs/fy13osti/56761.pdf>

### Home Energy Reports

|  |  |
| --- | --- |
| **Target Sector** | Residential Establishments |
| **Measure Unit** | Household |
| **Measure Life** | Specified in protocol |
| **Vintage** | Retrofit |

Home Energy Report (HER) programs encourage conservation through greater awareness of consumption patterns and engagement with EDC resources to help reduce usage and lower bills. HER program vendors provide participants with account-specific information that allows customers to view various aspects of their energy use over time. Behavioral reports compare energy use of recipient homes with clusters of similar homes and businesses and provide comparisons with other efficient and average homes. This so-called “neighbor” comparison is believed to create cognitive dissonance in participants and spur them to modify their behavior to be more efficient. Reports also include a variety of seasonally appropriate energy-saving tips that are tailored for the home and are often used to promote other EDC program offerings. Historically, HERs have been largely issued on paper via the USPS, but EDCs and their vendors are increasingly moving toward email reports and digital portals to promote increased engagement and conserve resources. This protocol applies to residential HER programs regardless of delivery mode.

A growing list of evaluation studies, including analyses of HER persistence by the Phase II and Phase III Pennsylvania Statewide Evaluation team, have observed energy savings among HER recipient households for two years after HER exposure was discontinued. The persistence of HER savings has implications for calculation of first-year energy savings and cost-effectiveness. This protocol provides guidance to EDCs and their evaluation contractors for calculating first-year incremental savings and lifetime savings from HER programs using a multi-year measure life with “decay” perspective. This multi-year persistence perspective is a departure from prior phases of Act 129, which assumed a 1-year measure life for HER programs.

Because Act 129 goals are based on first-year incremental savings, accounting for persistence will yield reduced first-year compliance savings from EDC programs that continue to expose the same homes to HER messaging year after year. However, the multi-year perspective will improve the cost-effectiveness of new cohorts of HER recipients compared to a 1-year measure life assumption.

The core assumption in this protocol is an annual decay rate of 31.3%. To illustrate the concept of decay consider a hypothetical cohort of 20,000 treatment group homes that have been receiving HERs for two years. Table 2‑141 shows the average kWh savings per treatment group home by year as measured through a billing analysis of the randomized control trial design.

Table 2‑141: Home Energy Report Persistence Example

|  |  |
| --- | --- |
| Year | Avg. kWh Savings per Home |
| 1 | 150 |
| 2 | 200 |

For Year 3, the EDC can choose to either continue issuing HERs to the treatment group homes or stop treating them. If the EDC stops issuing HERs to the treatment group in Year 3, little or no cost will be incurred. If the EDC continues issuing HERs to the treatment group in Year 3, a full year of program delivery costs will be incurred. The key question is “what are the incremental energy savings associated with the decision to mail HERs in Year 3?” Table 2‑142 shows the components of this calculation.

Table 2‑142: Calculation of Avoided Decay and Incremental Annual Compliance Savings

|  |  |  |  |
| --- | --- | --- | --- |
| Year | Avg. kWh Savings per Home | Avg. kWh Savings Absent Year 3 Treatment | Avg. kWh Savings with Year 3 Treatment |
| 1 | 150 |  |  |
| 2 | 200 |  |  |
| 3 |  | 200×(1-0.313/2) = 168.7 | 210 |

In this hypothetical example the incremental first-year savings achieved by the HER program in Year 3 is 41.3 kWh (210 – 168.7). This is the sum of two separate factors.

* **Avoided Decay** = 31.3 kWh. The avoided decay is the difference between the Year 2 savings and the assumed annual rate of decay. Because the decay rate is assumed to be linear the average amount of decay over the year is equal to half of the decay at the end of the year. The 168.7 kWh value in Table 2‑142 is an estimate of what would have happened absent any further program effort. Some kWh savings persist, but at a lower rate than observed in Year 2, when households were actively receiving HER messaging. By continuing to issue HERs in Year 3, the EDC avoids this savings decay.
* **Change in the Average Treatment Effect** = 10 kWh. The “Avg. kWh Savings with Year 3 Treatment” column of Table 2‑142 shows an average kWh savings value of 210 kWh per household. This is an increase of 10 kWh over the Year 2 measurement of 200 kWh per household. Many HER programs show growth in the average rate of savings over time as participants continue to respond to the messaging. This component of the calculation of the calculation could also be negative if the Year 3 savings measurement was smaller than the Year 2 measurement. HER savings can fluctuate based on weather and the measurement is inherently noisy because of the small effect size.

The following algorithms and default assumptions provide guidance on calculating and reporting compliance savings from HER programs in Phase IV of Act 129. Several assumptions that straddle technical and policy considerations are listed below.

1. The change in perspective from a 1-year EUL to a multi-year with decay approach creates an issue of unaccounted for lifetime savings from Phase III HER programs. Specifically, HER cohorts that were active in PY12 will be assumed to have persistent savings in PY13 even though persistent savings were not accounted for in Phase III TRC calculations. This is unavoidable with a change in accounting methods and best handled at the beginning of a Phase IV. It has no bearing on Phase III compliance savings.
2. The assumed annual rate of decay for Act 129 HER programs is based on an analysis of mature programs where treatment group homes received HER messaging for multiple years. Studies have also consistently shown that it takes time for HER savings to mature. For Phase IV of Act 129, new HER cohorts will continue to assume a 1-year EUL during the first year of HER exposure. The persistence and decay assumptions outlined in this protocol will take effect for Year 2 of exposure. Years of exposure are mapped to Act 129 program years. If a cohort begins receiving HER messaging in December (halfway through the program year), that program year is still Year 1, and the following program year is Year 2 with regard to application of persistence assumptions.
3. The Phase IV HER accounting methodology may lead EDCs to modify their historic HER delivery approach of treating the same homes year after year. Doing so would lead to diminished cost-effectiveness in Year 3 and beyond. EDCs may instead organize their EE&C plans to ‘rotate’ through eligible households. Act 129 HER programs should always be delivered as a randomized control trial (RCT), but EDCs have significant flexilbility in designing new HER cohorts. New cohorts can be composed of a mix of past HER recipients and control group homes or non-recipients. Randomization should ensure a balanced mix across the new treatment and control group and the billing analysis will capture the savings associated with exposing the new treatment group to HERs, but not the control group. When a new cohort is created, accounting always begins at Year 1, even if some of the treatment and control group homes have received HER messaging previously.
4. Over time, households close their EDC accounts. The most common reason is because the occupant is moving, but other possibilities exist. This account “churn” happens at a fairly predictable rate for an EDC service territory and can be forecasted with some degree of certainty. Calculating persistent HER savings in future program years requires both an assumption of the savings decay rate and an assumption of the churn rate.

Algorithms

The equations for incremental first-year savings from HER programs are:

Year 1 and 2 of HER Exposure:

If an EDC elects to treat an HER cohort for a 3rd year or beyond the equation for incremental first-year savings is:

Year 3 and Beyond of HER Exposure:

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:

Year 2 and Beyond of HER Exposure:

Definition of Terms

Table 2‑143: Terms, Values, and References for HER Persistence Protocol

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | **Unit** | **Value** | **Source** |
| *,* kWh savingsper home in the program year being evaluated | *Total Incremental Annual kWh Savings of an HER cohort* | EDC Data Gathering | EDC Data Gathering |
| *ATE,* Average Treatment Effect | *kWh/day per household* | EDC Data Gathering | EDC Data Gathering |
| *Treatment Accounts,* number of active homes in the treatment group | *Households (EDC account number)* | EDC Data Gathering | EDC Data Gathering |
| *Days*, average number of post-treatment days in the analysis period per household | *Days* | EDC Data Gathering | EDC Data Gathering |
| *Decay,* Annual rate of decay of the HER effect when exposure is discontinued | *-* | 31.3% | 1 |
| *Churn,* Average annual reduction in participating households due to account closures, move-out etc. | *-* | Default: 6% | 2 |
| EDC Data Gathering |

Evaluation Protocols

This protocol deals with the measure life and persistence aspects of HER programs. Chapter 6.1 of the Pennsylvania Evaluation Framework provides detailed guidance on other aspects of HER evaluation protocols.

Sources

1. Pennsylvania Statewide Evaluation Team. Residential Behavioral Program Persistence Study. <http://www.puc.state.pa.us/Electric/pdf/Act129/SWE_Res_Behavioral_Program-Persistence_Study_Addendum2018.pdf>
2. SWE Analysis of average annual churn rate among Phase III EDC cohorts.

## Miscellaneous

### Variable Speed Pool Pumps

|  |  |
| --- | --- |
| **Target Sector** | Residential Establishments |
| **Measure Unit** | VFD Pool Pumps |
| **Measure Life** | 10 yearsSource 4 |
| **Vintage** | Replace on Burnout |

In this measure a variable speed pool pump must be purchased and installed on a residential pool to replace an existing constant speed pool pump. Residential variable frequency drive pool pumps can be adjusted so that the minimal required flow is achieved for each application. Reducing the flow rate results in significant energy savings because pump power and pump energy usage scale with the cubic and quadratic powers of the flow rate respectively. Additional savings are achieved because the VSD pool pumps typically employ premium efficiency motors.

Eligibility

To qualify for this rebate a variable speed pool pump must be purchased and installed on a residential pool to replace an existing constant speed pool pump.

Algorithms

This protocol documents the energy savings attributed to variable frequency drive pool pumps in various pool sizes. The target sector primarily consists of single-family residences. There are no demand savings for this measure.

ΔkWh

kWhbase

kWhVFD

ΔkW

Definition of Terms

Table 2‑144: Terms, Values, and References for Variable Speed Pool Pumps

| **Term** | **Unit** | **Values** | **Source** |
| --- | --- | --- | --- |
| *HOUSS*, Hours of operation per day for Single Speed Pump. This quantity should be recorded by the applicant. |  | EDC Data Gathering  Default = 11.4 | 2 |
| *HOUVFD,filter* , Hours of operation per day for Variable Frequency Drive Pump on filtration mode. |  | EDC Data Gathering  Default = 10.0 | 2 |
| *HOUVFD,clean* , Hours of operation per day for Variable Frequency Drive Pump on cleaning mode. |  | EDC Data Gathering  Default = 2.0 | 2 |
| *Days* , Pool pump days of operation per year. |  | 122 | 2 |
| *kWSS*, Electric demand of single speed pump at a given flow rate. This quantity should be recorded by the applicant or looked up through the horsepower in Table 2‑145. | *Kilowatts* | EDC Data Gathering  Default =1.364 kW or See Table 2‑145 | 1 or Table 2‑145 |
| *kWVFD, filter*, Electric demand of variable frequency drive pump during filtration mode. | *Kilowatts* | EDC Data Gathering  Default = 0.25 | 2 |
| *kWVFD, clean*, Electric demand of variable frequency drive pump during cleaning mode. | *Kilowatts* | EDC Data Gathering  Default = 0.75 | 2 |
| *CF,* Coincidence factor | None | EDC Data Gathering  Default = 0.31 | 4 |

Average Single Speed Pump Electric Demand

Since this measure involves functional pool pumps, actual measurements of pump demand are encouraged. If this is not possible, then the pool pump power can be inferred from the nameplate horsepower. Table 2‑145 shows the average service factor (over-sizing factor), motor efficiency, and electrical power demand per pump size based on California Energy Commission (CEC) appliance database for single speed pool pump.Source 1 Note that the power to horsepower ratios appear high because many pumps, in particular those under 2 HP, have high ‘service factors’. The true motor capacity is the product of the nameplate horsepower and the service factor.

Table 2‑145: Single Speed Pool Pump Specification[[83]](#footnote-85)

|  |  |  |  |
| --- | --- | --- | --- |
| **Pump Horse Power (HP)** | **Average Pump Service Factor** | **Average Pump Motor Efficiency** | **Average Pump Power (kW)** |
| 0.50 | 1.62 | 0.66 | 0.946 |
| 0.75 | 1.29 | 0.65 | 1.081 |
| 1.00 | 1.28 | 0.70 | 1.306 |
| 1.50 | 1.19 | 0.75 | 1.512 |
| 2.00 | 1.20 | 0.78 | 2.040 |
| 2.50 | 1.11 | 0.77 | 2.182 |
| 3.00 | 1.21 | 0.79 | 2.666 |

Electric Demand and Pump Flow Rate

The electric demand on a pump is related to pump flow rate, pool hydraulic properties, and the pump motor efficiency. For VFD pumps that have premium efficiency (92%) motors, a regression is used to relate electric demand and pump flow rates using the data from Southern California Edison’s Innovative Designs for Energy Efficiency (InDEE) Program. This regression reflects the hydraulic properties of pools that are retrofitted with VSD pool pumps. The regression is:

Demand (W)

Where *f* is the pump flow rate in gallons per minute. This regression can be used if the flow rate is known but the wattage is unknown. However, most VFD pool pumps can display instantaneous flow and power.

Default Savings

Default energy and demand savings are as follows:

ΔkWh = 1,409 kWh

ΔkW = 0.3195 kW

Evaluation Protocol

The most appropriate evaluation protocol for this measure is verification of installation coupled with survey on run time and speed settings. It may be helpful to work with pool service professionals in addition to surveying customers to obtain pump settings, as some customers may not be comfortable operating their pump controls. Working with a pool service professional may enable the evaluator to obtain more data points and more accurate data.

Sources

1. “CEC Appliances Database – Pool Pumps.” *California Energy Commission.* Updated Feb 2008. Accessed March 2008. <http://www.energy.ca.gov/appliances/database/historical_excel_files/2009-03-01_excel_based_files/Pool_Products/Pool_Pumps.zip>
2. ENERGY STAR Pool Pump Calculator. Updated December 2013. kW values are derived from gallons/minute and Energy Factor (gallons/Wh) for each speed. Days of operation are for Pennsylvania (4 months/yr). <https://www.energystar.gov/sites/default/files/asset/document/Pool%20Pump%20Calculator.xlsx>
3. California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, [http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx . Accessed December 2018](http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx%20.%20Accessed%20December%202018).
4. Derived from values for 2pm-6pm for all pool pumps in Pool Pump and Demand Response Potential, DR 07.01 Report, SCE Design and Engineering, Table 16. <https://www.etcc-ca.com/sites/default/files/reports/dr07_01_pool_pump_demand_response_potential_report.pdf>

## Demand Response

The primary focus of this section of the TRM is to provide technical guidance for estimating the load impacts of demand response programs. The methods discussed are aimed at providing accurate estimates of the true load impacts at the program level. EDCs and CSPs may use alternate methods for quarterly reporting of ex ante impacts or to calculate financial settlements with participating customers, but the methods detailed in the TRM should be used to verify achievement of Phase IV demand reduction targets. In some instances, the analysis may be carried out at the individual customer level, however, the outcome of interest is the aggregate load reduction (MW) that is caused by the program.

### Direct Load Control and Behavior-Based Demand Response Programs

|  |  |
| --- | --- |
| **Target Sector** | Residential Establishments |
| **Measure Unit** | N/A |
| **Measure Life** | 10 years |
| **Measure Vintage** | N/A |

The protocols for Act 129 covering Direct Load Control (DLC) and Behavior-Based demand response programs are intended to give guidance to the EDCs when dispatching and evaluating the load impacts of an event over the course of Phase IV. In these programs, residential and small commercial customers either allow EDCs to remotely reduce equipment run time during peak hours (DLC programs) or reduce their loads voluntarily in response to a combination of incentive payments, messaging and/or other behavioral stimuli.

Behavior-based demand response programs are ones that have a goal of reducing electric load during peak load hours. Examples of behavior-based demand response programs include utility programs that request customers to reduce electric loads during peak load hours voluntarily, programs where customers are provided with real-time information on the cost of electricity and can then take action voluntarily to reduce electric loads during high cost hours and other similar information programs. For purposes of the Pennsylvania TRM, behavior-based demand response programs do not include utility information programs that are based on consumer education or marketing and have a goal of reducing electricity use on a year round basis, including non-peak load hours.

For DLC programs, the participants may elect to receive incentive payments for allowing a signaled device to control or limit the power draw of certain HVAC, electric water heating, or swimming pool pump equipment at a participant’s home, contributing to the reduction of peak demand. For measurement purposes, peak demand reductions are defined as the difference between a customer’s actual (measured) electricity demand, and an estimate of the amount of electricity the customer would have demanded in the absence of the program incentive. The estimate of this counterfactual outcome is referred to as the reference load throughout this protocol.

EDCs must use one of the evaluation approaches below when estimating peak period load reductions that result from DLC and behavior-based programs. The approaches are not equivalent in terms of their ability to produce accurate and robust results and are therefore listed in descending order of desirability. Because of these differences in performance, EDCs shall use Option 2 only under circumstances when Option 1 is infeasible and shall similarly use Option 3 only under circumstances where both Option 1 and Option 2 are infeasible. In situations where Option 1 and/or 2 are not utilized, justification(s) must be provided by the EDC. EDCs with interval meter data available should use it to estimate load impacts. For DLC and behavior-based programs where advanced metering infrastructure (AMI) data is not available for all participants, estimates based on a sample of metered homes is permissible at the discretion of the SWE.

1. An analysis based on an experimental design that makes appropriate use of random assignment so that the reference load is estimated using a representative control group of program participants.[[84]](#footnote-86) The most common type of design satisfying this criteria is a randomized control trial (RCT), but other designs may also be used. The specific design used can be selected by the EDC evaluation contractor based on their professional experience. It is important to note that experimental approaches to evaluation generally require the ability to call events at the individual device level. An operations strategy must be determined ahead of time in order to ensure that an appropriate control group is available for the analysis.
2. A comparison group analysis where the loads of a group of non-participating customers that are similar to participating homes with respect to observable characteristics (e.g. electricity consumption) are used to estimate the reference load. A variety of matching techniques are available and the EDC evaluation contractor can choose the technique used to select the comparison group based on their professional judgment. If events are most likely to be called on hot days, hot non-event days should be used for statistical matching and very cool days should be excluded.[[85]](#footnote-87) 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[[86]](#footnote-88) are used to estimate the reference load. This can be accomplished via a regression equation that relates loads to temperature and other variables that influence usage. The regression model should be estimated using hot days that would be similar to an event. Including cooler days in the model can degrade accuracy because it puts more pressure on accurately modeling the relationship between weather and load across a broad temperature spectrum, which is hard because the relationship is not linear. Reducing the estimating sample to relevant days reduces that modeling challenge, or a ‘day-matching’ technique with a day-of or weather adjustment to account for the more extreme conditions in place on event days. The weather conditions in place at the time of the event are always used to claim savings. Weather-normalized or extrapolation of impacts to other weather conditions is not permitted.

**Eligibility**

In order to be eligible for the direct load control program, a customer must have a signaled device used to control the operability of the equipment specified to be called upon during an event. All residential and small commercial customers are eligible to participate in the behavior-based program.

**Algorithms**

The specific algorithms(s) used to estimate the demand impacts caused by DLC and behavior-based programs will depend on the specific method of evaluation used. In general, regression-based estimates are most preferred, due to their ability to produce more precise impact estimates and quantitative measures of uncertainty. Details on specific types of equations that can be used for each evaluation approach are provided in the Pennsylvania Evaluation Framework.

Annual peak demand savings must be estimated using individual customer data (e.g. account, meter, or site as defined by program rules) regardless of which evaluation method is used. Program savings are the sum of the load impacts across all participants. Equations 1 and 2 provide mathematical definitions of the average peak period load impact estimate that would be calculated using an approved method.

|  |  |  |
| --- | --- | --- |
|  |  | (1) |
|  | *=* | (2) |

**Definition of Terms**

**Table 2‑2: Definition of Terms for Estimating DLC and Behavior-based Load Impacts**

|  |  |  |  |
| --- | --- | --- | --- |
| **Term** | **Unit** | **Values** | **Source** |
| *n*, Number of DR hours during a program year for the EDC | *Hours* | EDC Data Gathering | EDC Data Gathering |
| *,* 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 |
| , Estimated customer load absent DR during hour i | *kW* | EDC Data Gathering | EDC Data Gathering |
| , 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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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>. [↑](#footnote-ref-2)
2. The protocol also applies to products that are pending ENERGY STAR qualification. [↑](#footnote-ref-3)
3. EDCs may use the wattage of the replaced bulb for directly installed program bulbs [↑](#footnote-ref-4)
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> ) [↑](#footnote-ref-5)
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. [↑](#footnote-ref-6)
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. [↑](#footnote-ref-7)
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. [↑](#footnote-ref-8)
8. http://www.puc.pa.gov/filing\_resources/issues\_laws\_regulations/act\_129\_information/act\_129\_statewide\_evaluator\_swe\_.aspx [↑](#footnote-ref-9)
9. This data is obtained from the AEPS Application Form or EDC’s data gathering based on the model number. [↑](#footnote-ref-10)
10. Ibid. This refers to the capacity of the heat pump and not any auxiliary electric resistance heat. [↑](#footnote-ref-11)
11. Ibid. [↑](#footnote-ref-12)
12. Ibid. [↑](#footnote-ref-13)
13. 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. [↑](#footnote-ref-14)
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. [↑](#footnote-ref-15)
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.” [↑](#footnote-ref-16)
16. “New Construction” is intended for applications with new, standard size exterior wall openings. [↑](#footnote-ref-17)
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> [↑](#footnote-ref-18)
18. ACCA, “Verifying ACCA Manual S Procedures,” <http://www.acca.org/wp-content/uploads/2014/01/Manual-S-Brochure-Final.pdf> [↑](#footnote-ref-19)
19. This baseline is for participants with broken-beyond-repair oil heating systems who are heating their homes with portable electric space heaters. [↑](#footnote-ref-20)
20. This data is obtained from the AEPS Application Form or EDC’s data gathering based on the model number. [↑](#footnote-ref-21)
21. Ibid. [↑](#footnote-ref-22)
22. Ibid. [↑](#footnote-ref-23)
23. Ibid. [↑](#footnote-ref-24)
24. This data is obtained from the AEPS Application Form or EDC’s data gathering. [↑](#footnote-ref-25)
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. [↑](#footnote-ref-26)
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. [↑](#footnote-ref-27)
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> [↑](#footnote-ref-28)
28. ACCA, “Verifying ACCA Manual S Procedures,” <http://www.acca.org/wp-content/uploads/2014/01/Manual-S-Brochure-Final.pdf> [↑](#footnote-ref-29)
29. This data is obtained from the AEPS Application Form or EDC’s data gathering based on the model number. [↑](#footnote-ref-30)
30. Ibid. [↑](#footnote-ref-31)
31. Ibid. [↑](#footnote-ref-32)
32. Does not apply for CAC or PTAC. [↑](#footnote-ref-33)
33. This data is obtained from the AEPS Application Form or EDC’s data gathering based on the model number. [↑](#footnote-ref-34)
34. Ibid. [↑](#footnote-ref-35)
35. If the unit’s capacity is less than 7 kBTU/hr, use 7 kBTU/hr in the calculation. If the unit’s capacity is greater than 15 kBTU/h, use 15 kBTU/hr in the calculation. [↑](#footnote-ref-36)
36. 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. [↑](#footnote-ref-37)
37. Pump motors are typically 1/25 HP. With 1,000 hour runtime and 80% assumed efficiency, this translates to 37 kWh. [↑](#footnote-ref-38)
38. Note that this value is the EER value, as CEER were introduced later. [↑](#footnote-ref-39)
39. Based on average weather data from weatherbase.com for the climate reference cities referenced elsewhere in this TRM [↑](#footnote-ref-40)
40. Ibid [↑](#footnote-ref-41)
41. 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 [↑](#footnote-ref-43)
42. “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 [↑](#footnote-ref-44)
43. 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. [↑](#footnote-ref-45)
44. Ainsul was calculated by assuming that the water heater wrap is a 2” thick fiberglass material. [↑](#footnote-ref-46)
45. See 2.3.1 Heat Pump Water Heaters section for baseline water heater consumption formula and assumptions. [↑](#footnote-ref-47)
46. 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. [↑](#footnote-ref-48)
47. 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. [↑](#footnote-ref-49)
48. Baseline consumption of unit based on category and assumed volume. [↑](#footnote-ref-50)
49. Lettering convention (8, 9, 9l, 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. [↑](#footnote-ref-51)
50. [↑](#footnote-ref-52)
51. [↑](#footnote-ref-53)
52. 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. [↑](#footnote-ref-54)
53. A refrigerator with automatic defrost with bottom-mounted freezer with an automatic icemaker without through-the-door ice service. [↑](#footnote-ref-55)
54. 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. [↑](#footnote-ref-56)
55. Statewide average of 3.12 EF for electric dryers, comparable to 3.77 CEF; q.v. the federal standard of 3.73 CEF at in Sec. [↑](#footnote-ref-57)
56. 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). [↑](#footnote-ref-58)
57. tandards for portable dehumidiers with capacity of >50 pints/day and for whole home dehumidifiers with product case volume > 8 ft3. [↑](#footnote-ref-59)
58. Average of products listed on ENERGY STAR Most Efficient 2018 – Dehumidifiers. <https://www.energystar.gov/most-efficient/me-certified-dehumidifiers/> Accessed November 16, 2018. [↑](#footnote-ref-60)
59. 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. [↑](#footnote-ref-61)
60. 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. [↑](#footnote-ref-62)
61. 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. [↑](#footnote-ref-63)
62. 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. [↑](#footnote-ref-64)
63. The ENERGY STAR 4.0 specifications allow for hugger ceiling fans with blade spans of ≤ 36” and ≥ 78”, however, as of December 2018, there are no ENERGY STAR qualified products meeting those criteria. They were therefore omitted from this characterization. [↑](#footnote-ref-65)
64. Tier 2 strips are typically installed only in home entertainment center applications. [↑](#footnote-ref-66)
65. Note that this was based on the MA RPLNC 17-4/5 APS Survey that determined Tier 1 APS to be used in home entertainment settings 60% of the time, and 40% in home office environments. [↑](#footnote-ref-67)
66. International Code Council, Inc. (2015). 2015 International Energy Conservation Code. Retrieved from International Code Council: <https://codes.iccsafe.org/content/IECC2015?site_type=public> [↑](#footnote-ref-68)
67. See the RESNET National Registry of Accredited Rating Software Programs for a complete listing:

    http://www.resnet.us/professional/programs/energy\_rating\_software [↑](#footnote-ref-69)
68. http://www.passivehouseacademy.com/index.php/shop-us [↑](#footnote-ref-70)
69. http://www.phius.org/software-resources/wufi-passive-and-other-modeling-tools/wufi-passive-3-0 [↑](#footnote-ref-71)
70. The HPwES Reference Manual may be found at [https://www.energystar.gov/ia/home\_improvement/downloads/HPwES\_Sponsor\_Guide\_v1-5.pdf](https://www.energystar.gov/ia/home_improvement/downloads/HPwES_Sponsor_Guide_v1-5.pdf?07e7-3320) [↑](#footnote-ref-72)
71. A new standard for BESTEST-EX for existing homes is currently being developed - status is found at <http://www.nrel.gov/buildings/bestest_Ex.html>. The existing 1995 standard can be found at <http://www.nrel.gov/docs/legosti/fy96/7332a.pdf> [↑](#footnote-ref-73)
72. A listing of the approved software available at [http://www.waptac.org](http://www.waptac.org/si.asp?id=736) [↑](#footnote-ref-74)
73. A listing of the approved software available at <http://resnet.us> [↑](#footnote-ref-75)
74. This is same as the Daylight Savings Time (DST) [↑](#footnote-ref-76)
75. PJM Manual 18B for Energy Efficiency Measurement & Verification [↑](#footnote-ref-77)
76. International Code Council, Inc. (2015). 2015 International Energy Conservation Code. Retrieved from International Code Council: <https://codes.iccsafe.org/content/IECC2015?site_type=public> [↑](#footnote-ref-78)
77. See the RESNET National Registry of Accredited Rating Software Programs for a complete listing:

    http://www.resnet.us/professional/programs/energy\_rating\_software [↑](#footnote-ref-79)
78. http://www.passivehouseacademy.com/index.php/shop-us [↑](#footnote-ref-80)
79. http://www.phius.org/software-resources/wufi-passive-and-other-modeling-tools/wufi-passive-3-0 [↑](#footnote-ref-81)
80. See the RESNET’s National Registry of Accredited Rating Software Programs for a complete list: <http://www.resnet.us/professional/programs/energy_rating_software>. [↑](#footnote-ref-82)
81. 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>) [↑](#footnote-ref-83)
82. Single and multiple family as noted. [↑](#footnote-ref-84)
83. 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. [↑](#footnote-ref-85)
84. 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. [↑](#footnote-ref-86)
85. 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. [↑](#footnote-ref-87)
86. Either Act 129 or PJM [↑](#footnote-ref-88)