STAR indoor fluorescent fixture, ENERGY STAR outdoor fluorescent fixture, or an ENERGY STAR ceiling fan with a fluorescent light fixture.[31]

Definition of Baseline Equipment

The baseline equipment is assumed to be a socket, fixture, torchiere, or ceiling fan with a standard or specialty incandescent light bulb(s).

An adjustment to the baseline wattage for general service and specialty screw-in CFLs and LEDs is made to account for the Energy Independence and Security Act of 2007 (EISA 2007), which requires that all general service lamps and some specialty lamps between 40W and 100W meet minimum efficiency standards in terms of amount of light delivered per unit of energy consumed. The standard was phased in between January 1, 2012 and January 1, 2014. This adjustment affects any efficient lighting where the baseline condition is assumed to be a general service, standard screw-in incandescent light bulb, or specialty, screw-in incandescent lamp.

For upstream buy-down, retail (time of sale), or efficiency kit programs, baseline wattages can be determined using the tables included in this protocol 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 in lieu of the tables below.

ALGORITHMS

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

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

ENERGY STAR CFL Bulbs (screw-in):

$$\Delta kWh/yr = \frac{Watts_{base} - Watts_{CFL}}{1000\ \frac{kW}{W}} \times HOU_{effbulb} \times (1 + IE_{kWh}) \times 365\frac{days}{yr} \times ISR_{effbulb}$$

$$\Delta kW_{peak} = \frac{Watts_{base} - Watts_{CFL}}{1000\ \frac{W}{kW}} \times CF \times (1 + IE_{kW}) \times ISR_{effbulb}$$

ENERGY STAR LED Bulbs (screw-in):

$$\Delta kWh/yr = \frac{Watts_{base} - Watts_{LED}}{1000\ \frac{W}{kW}} \times HOU_{effbulb} \times (1 + IE_{kWh}) \times 365\frac{days}{yr} \times ISR_{effbulb}$$

$$\Delta kW_{peak} = \frac{Watts_{base} - Watts_{LED}}{1000\ \frac{W}{kW}} \times CF \times (1 + IE_{kW}) \times \cancel{365\frac{days}{yr} \times} ISR_{effbulb}$$

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

Variable Input Values

Baseline Wattage Values – General Service Lamps
Baseline wattage is dependent on lumens, shape of bulb, and EISA qualifications. Commonly used EISA exempt bulbs include 3-way bulbs, globes with ≥5" diameter or ≤749 lumens, and candelabra base bulbs with ≤1049 lumens. See EISA legislation for the full list of exemptions.

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 tables below.[34] For bulbs with lumens outside of the lumen bins provided, EDCs should use the manufacturer rated comparable wattage as the $Watts_{Base}$. For EISA exempt bulbs, EDCs also have the option of using manufacturer rated comparable wattage as the $Watts_{Base}$, rather than the tables below.

To determine the $Watts_{Base}$ for General Service Lamps[35] , follow these steps:

1. Identify the rated lumen output of the energy efficient lighting product
2. Identify if the bulb is EISA exempt[36]
3. In Table 2-2, find the lumen range into which the lamp falls (see columns (a) and (b).
4. Find the baseline wattage ($Watts_{Base}$) in column (c) or column (d). If the bulb is exempt from EISA legislation, use column (c), else, use column (d).

Table 2-1: Baseline Wattage by Lumen Output for General Service Lamps (GSL)[37]

Minimum Lumens (a)	Maximum Lumens (b)	Incandescent Equivalent $Watts_{Base}$ (Exempt Bulbs) (c)	$Watts_{Base}$ (Post-EISA 2007) (d)	$Watts_{base}$ post 2020[38] (e)
2000	2600	150	72	23
1600	1999	100	72	23
1100	1599	75	53	18
800	1099	60	43	15
450	799	40	29	9
310	449	25	25	9~~25~~

[34] 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 estimated using Table 2-2,
Table 2-3, & Table 2-4.

[35] General Service Lamps (GSLs) are omnidirectional bulbs that are A, BT, P, PS, S, or T shape bulbs (as defined by the ANSI Standard Lamp Shapes). GSLs are not globe, bullet, candle, flood, reflector, or decorative shaped (B, BA, C, CA, DC, F, G, R, BR, ER, MR, MRX or PAR shapes). These bulbs do encompass both twist/spiral and a-lamp shaped bulbs.

[36] The EISA 2007 standards apply to general service incandescent lamps. A complete list of the 22 incandescent lamps exempt from EISA 2007 can be found here: http://www.lightingfacts.com/Library/Content/EISA.

[37] Lumen bins and incandescent equivalent wattages from ENERGY STAR labeling requirements, Version 1.1 https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V1%201_Specification.pdf EISA Standards from: United States Department of Energy. *Impact of EISA 2007 on General Service Incandescent Lamps: FACT SHEET.* http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/general_service_incandescent_factsheet.pdf

[38] Example of cost-effectiveness calculation using column (e): If the LED life is 14.7 years, cost-effectiveness models for 2014 would model the first six years using column (d) as the $Watts_{base}$, and the remaining 8.7 years using the $Watts_{base}$,in column (e).

2.1.5 Holiday Lights

Measure Name	Holiday Lights
Target Sector	Residential Applications
Measure Unit	One 25-bulb Strand of Holiday lights
Unit Energy Savings	21.2~~10.6~~ kWh per strand
Unit Peak Demand Reduction	0 kW
Measure Life	10 years[52,53]
Vintage	Replace on Burnout

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

Eligibility

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

Algorithms

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

$$\Delta\, kWh/yr_{C9} = \frac{[(INC_{C9} - LED_{C9}) \times \#Bulbs \times \#Strands \times HR]}{1000\frac{W}{kW}}$$

$$\Delta\, kWh/yr_{C7} = \frac{[(INC_{C7} - LED_{C7}) \times \#Bulbs \times \#Strands \times HR]}{1000\frac{W}{kW}}$$

$$\Delta\, kWh/yr_{mini} = \frac{[(INC_{mini} - LED_{mini}) \times \#Bulbs \times \#Strands \times HR]}{1000\frac{W}{kW}}$$

Key assumptions

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

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

52 http://www.energyideas.org/documents/factsheets/HolidayLighting.pdf

53 The DSMore Michigan Database of Energy Efficiency Measures: Based on spreadsheet calculations using collected data: Franklin Energy Services; "FES-L19 – LED Holiday Lighting Calc Sheet"

Central A/C (Proper Sizing)[52]

This algorithm is specifically intended for new units (Quality installation).

$$\Delta kWh/yr = \frac{CAPY_{cool}}{(SEER_q \times 1000\,\frac{W}{kW})} \times EFLH_{cool} \times PSF$$

$$\Delta kWh_{peak} = \frac{CAPY_{cool}}{(EER_q \times 1000\,\frac{W}{kW})} \times CF \times PSF$$

Central A/C and ASHP (Maintenance)

This algorithm is used for measures providing services to maintain, service or tune-up central A/C and ASHP 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

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

$$\Delta kWh_{cool} = \frac{CAPY_{cool}}{(1000\,\frac{W}{kW} \times SEER_m)} \times EFLH_{cool} \times MF_{cool}$$

$$\Delta kWh_{heat}\,(ASHP\ Only) = \frac{CAPY_{heat}}{(1000\frac{W}{kW} \times HSPF_m)} \times EFLH_{heat} \times MF_{heat}$$

$$\Delta kW_{peak} = \frac{CAPY_{cool}}{(1000\,\frac{W}{kW} \times EER_m)} \times CF \times MF_{cool}$$

Ground Source Heat Pumps (GSHP)

This algorithm is used for the installation of new GSHP units. For GSHP systems over 65,000 $\frac{Btu}{hr}$, see commercial algorithm stated in Section 3.2.3.

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

$$COP_{sys} = COP_g \times GSHPDF$$

$$EER_{sys} = EER_g \times GSHPDF$$

$$\Delta kWh_{cool} = \frac{CAPY_{cool}}{1000\,\frac{W}{kW}} \times \left(\frac{1}{SEER_b} - \frac{1}{EER_{sys} \times GSER}\right) \times EFLH_{cool}$$

$$\Delta kWh_{heat} = \frac{CAPY_{heat}}{1000\,\frac{W}{kW}} \times \left(\frac{1}{HSPF_b} - \frac{1}{COP_{sys} \times GSOP}\right) \times EFLH_{heat}$$

$$\Delta kW = \frac{CAPY_{cool}}{1000\,\frac{W}{kW}} \times \left(\frac{1}{EER_b} - \frac{1}{EER_{sys} \times GSPK}\right) \times CF$$

GSHP Desuperheater

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

$$\Delta kWh = \frac{EFDSH \times \frac{1}{EF_{Base}} \times HW \times 365\,\frac{days}{yr} \times 8.3\,\frac{lb}{gal} \times 1\,\frac{Btu}{lb \cdot °F} \times (T_{hot} - T_{cold})}{3412\,\frac{Btu}{kWh}}$$

= 534~~567~~ kWh

$$\Delta kW = EDSH \times ETDF$$

52 Proper sizing requires Manual J calculations, following of ENERGY STAR QI procedures, or similar calculations.

Furnace High Efficiency Fan

This algorithm is used for the installation of new high efficiency furnace fans.

ΔkWh_{heat} = *HFS*

ΔkWh_{cool} = *CFS*

ΔkW_{peak} = *PDFS*

Definition of Terms

Table 2-1: Residential Electric HVAC - References

Component	Unit	Value	Sources
$CAPY_{cool}$, The cooling capacity of the central air conditioner or heat pump being installed[1]	*Btu/hr*	EDC Data Gathering	AEPS Application; EDC Data Gathering
$CAPY_{heat}$, The heating capacity of the central air conditioner or heat pump being installed[2]	*Btu/hr*	EDC Data Gathering	AEPS Application; EDC Data Gathering
$SEER_b$, Seasonal Energy Efficiency Ratio of the Baseline Unit (split or package units)	$\frac{Btu}{W \cdot h}$	Replace on Burnout: 13 SEER (Central A/C) or 14 SEER (ASHP)	1
	$\frac{Btu}{W \cdot h}$	Early Retirement EDC Data Gathering Default = 11 (Central A/C) or 12 (ASHP)	13; EDC Data Gathering
$SEER_e$, Seasonal Energy Efficiency Ratio of the qualifying unit being installed[3]	$\frac{Btu}{W \cdot h}$	EDC Data Gathering	AEPS Application; EDC Data Gathering
$SEER_m$, Seasonal Energy Efficiency Ratio of the Unit receiving maintenance	$\frac{Btu}{W \cdot h}$	EDC Data Gathering Default= 11 (Central A/C) or 12 (ASHP)	13; EDC Data Gathering
EER_b , Energy Efficiency Ratio of the Baseline Unit	$\frac{Btu}{W \cdot h}$	Replace on Burnout: 11.3 (Central A/C) or 12 (ASHP)	2
	$\frac{Btu}{W \cdot h}$	Early Retirement: EDC Data Gathering Default= 8.69	14; EDC Data Gathering
EER_e , Energy Efficiency Ratio of the unit being installed[4]	$\frac{Btu}{W \cdot h}$	For Central A/C: $\frac{11.3}{13} \times SEER$ Or for ASHP: $\frac{12}{14} \times SEER$	2

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

[2] Ibid.

[3] Ibid.

[4] Ibid.

Component	Unit	Value	Sources
PSF , Proper Sizing Factor or the assumed savings due to proper sizing and proper installation	*None*	0.05	5
MF_{cool} , Maintenance Factor or assumed savings due to completing recommended maintenance on installed cooling equipment	*None*	0.05	15
MF_{heat} , Maintenance Factor or assumed savings due to completing recommended maintenance on installed heating equipment	*None*	0.05	15
CF , Demand Coincidence Factor (See Section 1.5)	*Decimal*	0.647	6
$HSPF_b$, Heating Seasonal Performance Factor of the Baseline Unit	$\frac{Btu}{W \cdot h}$	Replace on Burnout: 8.2	7
	$\frac{Btu}{W \cdot h}$	Early Replacement: EDC Data Gathering Default = 6.9	20
$HSPF_e$, Heating Seasonal Performance Factor of the unit being installed[1]	$\frac{Btu}{W \cdot h}$	EDC Data Gathering	AEPS Application; EDC's Data Gathering
$HSPF_m$, Heating Seasonal Performance Factor of the unit receiving maintenance	$\frac{Btu}{W \cdot h}$	6.9	20
COP_g , Coefficient of Performance. This is a measure of the efficiency of a heat pump	*None*	EDC Data Gathering	AEPS Application; EDC's Data Gathering
GSHPDF , Ground Source Heat Pump De-rate Factor	*None*	0.885	19 (Engineering Estimate - See System Performance of Ground Source Heat Pumps)
COP_{sys} , Ground Source Heat Pump effective system COP	Variable	Calculated	Calculated
GSOP , Factor to determine the HSPF of a GSHP based on its COPg	*None*	3.412~~3~~	8
GSPK , Factor to convert EERg to the equivalent EER of an air conditioner to enable comparisons to the baseline unit	*None*	0.8416	9
EFDSH , Energy Factor per desuperheater	*None*	0.17	10, 11

[1] This data is obtained from the AEPS Application Form or EDC's data gathering.

7. Federal Code of Regulations 10 CFR 430. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/75
8. Engineering calculation, HSPF/COP=3.412~~3~~.
9. VEIC Estimate. Extrapolation of manufacturer data.
10. "Residential Ground Source Heat Pumps with Integrated Domestic Hot Water Generation: Performance Results from Long-Term Monitoring", U.S. Department of Energy, November 2012.
11. 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).
12. Northeast Energy Efficiency Partnerships, Inc., "Benefits of HVAC Contractor Training", (February 2006): Appendix C Benefits of HVAC Contractor Training: Field Research Results 03-STAC-01.
13. 2014 Pennsylvania Residential Baseline Study. The Act 129 2014 Residential Baseline Study may be found at http://www.puc.pa.gov/Electric/pdf/Act129/SWE-2014_PA_Statewide_Act129_Residential_Baseline_Study.pdf
14. The same EER to SEER ratio used for SEER 13 units applied to SEER 10 units. EERm = (11.3/13) * 10.
15. 2013 Illinois Statewide TRM (Central Air Conditioning in Wisconsin, Energy Center of Wisconsin, May 2008)
16. Scott Pigg (Energy Center of Wisconsin), "Electricity Use by New Furnaces: A Wisconsin Field Study", Technical Report 230-1, October 2003, page 20. The average heating-mode savings of 400 kWh multiplied by the ratio of average heating degree days in PA compared to Madison, WI (5568/7172).
17. Ibid, page 34. The average cooling-mode savings of 88 kWh multiplied by the ratio of average EFLH in PA compared to Madison, WI (749/487).
18. Ibid, page 34. The average kW savings of 0.1625 multiplied by the coincidence factor from Table 2-11.
19. McQuay Application Guide 31-008, Geothermal Heat Pump Design Manual, 2002.
20. Based on building energy model simulations and residential baseline characteristics determined from the 2014 Residential End-use Study and applied to an HSPF listing for 12 SEER Air Source Heat Pumps at https://www.ahridirectory.org on July 28th, 2014.

Table 2-1: Residential Electric HVAC Calculation Assumptions

Component	Unit	Value	Sources
$CAPY_{COOL}$, Capacity of air conditioning unit	$\frac{Btu}{hr}$	EDC Data Gathering of Nameplate data	EDC Data Gathering
		Default= 32,000	1
$CAPY_{HEAT}$, Normal heat capacity of Electric Furnace	$\frac{Btu}{hr}$	EDC Data Gathering of Nameplate Data	EDC Data Gathering
		Default= 32,000	1
SEER , Seasonal Energy Efficiency Ratio	$\frac{Btu}{W \cdot h}$	EDC Data Gathering of Nameplate data	EDC Data Gathering
		Default= 11.9	1
HSPF , Heating Seasonal Performance Factor of heat pump	$\frac{Btu}{W \cdot h}$	EDC Data Gathering of Nameplate data	EDC Data Gathering
		Default= 3.412~~3~~ (equivalent to electric furnace COP of 1)	2
Eff_{duct} , Duct System Efficiency	*None*	0.8	3
ESF_{COOL} , Energy Saving Factor for Cooling	*None*	0.02	4
ESF_{HEAT} , Energy Saving Factor for Heating	*None*	0.036	5
$EFLH_{COOL}$, Equivalent Full Load hour for Cooling	$\frac{hours}{day}$	Allentown Cooling = 487 Hours Erie Cooling = 389 Hours Harrisburg Cooling = 551 Hours Philadelphia Cooling = 591 Hours Pittsburgh Cooling = 432 Hours Scranton Cooling = 417 Hours Williamsport Cooling = 422 Hours	6
	Optional	Can use the more EDC-specific values in Table 2-11	Alternate EFLH Table 2-11
	Optional	An EDC can estimate it's own EFLH based on customer billing data analysis.	EDC Data Gathering
$EFLH_{HEAT}$, Full Load Hours for Heating	$\frac{hours}{day}$	Allentown Heating = 1,193 Hours Erie Heating = 1,349 Hours Harrisburg Heating = 1,103 Hours Philadelphia Heating = 1,060 Hours Pittsburgh Heating = 1,209 Hours Scranton Heating = 1,296 Hours Williamsport Heating = 1,251 Hours	6
	Optional	An EDC can use the Alternate EFLH values in Table 2-12	Alternate EFLH Table 2-12
	Optional	An EDC can estimate it's own EFLH based on customer billing data analysis.	EDC Data Gathering

2.3.3 Solar Water Heaters

Measure Name	Solar Water Heaters
Target Sector	Residential Establishments
Measure Unit	Water Heater
Default Unit Energy Savings	1,598.8~~1,698~~ kWh
Default Unit Peak Demand Reduction	0.2529~~0.277~~ kW
Measure Life	15 years[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 primarily consists of single-family residences.

Algorithms

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

$$\Delta kWh/yr = \frac{\left(\frac{1}{EF_{base}} - \frac{1}{EF_{ee}}\right) \times HW \times 365\frac{days}{yr} \times 8.3\frac{lbs}{gal} \times 1\frac{Btu}{lbs\cdot{}^{\circ}\mathrm{F}} \times (T_{hot} - T_{cold})}{3412\frac{Btu}{kWh}}$$

The energy factor used in the above equation represents an average energy factor of market available solar water heaters[2].

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.

[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] We have taken the average energy factor for all solar water heaters with collector areas of 50 ft2 or smaller from https://secure.solar-rating.org/Certification/Ratings/RatingsSummaryPage.aspx. As a cross check, we have calculated that the total available solar energy in PA for the same set of solar collectors is about twice as much as the savings claimed herein – that is, there is sufficient solar capacity to actualize an average energy factor of 1.84.

$$\Delta kW_{peak} = ETDF \times kWh/yr_{base}$$

$$Where: \quad kWh/yr_{base} = \frac{\left(\frac{1}{EF_{base}}\right) \times HW \times 365\frac{days}{yr} \times 8.3\frac{lbs}{gal} \times 1\frac{Btu}{lbs\cdot°F} \times (T_{hot} - T_{cold})}{3412\cancel{3}\frac{Btu}{kWh}}$$

ETDF (Energy to Demand Factor) is defined below:

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

The ratio of the average demand between 2 PM and 6 PM on summer weekdays to the total annual energy usage is taken from an electric water heater metering study performed by BG&E (pg 95 of Source 2).

DEFINITION OF TERMS

The parameters in the above equation are listed in Table 2-48.

Table 2-1: Solar Water Heater Calculation Assumptions

Component	Unit	Values	Source
EF_{base} , Energy Factor of baseline electric water heater	*Fraction*	See Table 2-49	3
		Default= 0.904 (50 gallon)	3
EF_{ee} , Year-round average Energy Factor of proposed solar water heater	*Fraction*	EDC Data Gathering	EDC Data Gathering
		Default=1.84	1
HW , Hot water used per day in gallons	$\frac{gallons}{day}$	50	4
T_{hot} , Temperature of hot water	$°F$	119	5
T_{cold} , Temperature of cold water supply	$°F$	55	6
Default Baseline Energy Usage for an electric water heater without a solar water heater (kWh)	Calculated	3,338	
$ETDF$, Energy to Demand Factor (defined above)	$\frac{kW}{kWh/yr}$	0.00008047	2

ENERGY FACTORS BASED ON TANK SIZE

Federal standards for Energy Factors (EF) are equal to 0.97 – (.00132 x Rated Storage in Gallons). The following table shows the baseline Energy Factors for various tank sizes:

2.3.4 FUEL SWITCHING: ELECTRIC RESISTANCE TO FOSSIL FUEL WATER HEATER

Measure Name	Fuel Switching: Electric Resistance to Fossile Fuel Water Heater
Target Sector	Residential
Measure Unit	Water Heater
Unit Energy Savings	3,143~~3,338~~ kWh/yr
Unit Peak Demand Reduction	0.2529~~0.2687~~ kW
Gas, Fossil Fuel Consumption Increase	Gas: 14.47~~15.38~~ MMBtu Propane: 14.47~~15.38~~ MMBtu Oil: 18.86~~20.04~~ MMBtu
Measure Life	Gas:13 years[1] Propane: 13 years[2] Oil: 8 years[3]
Vintage	Replace on Burnout

Natural gas, propane and oil water heaters generally offer the customer lower costs compared to standard electric water heaters. Additionally, they typically see an overall energy savings when looking at the source energy of the electric unit versus the fossil fuel-fired unit. Federal standard electric water heaters have energy factors of 0.904 for a 50 gal unit and an ENERGY STAR gas and propane-fired water heater have an energy factor of 0.67 for a 40gal unit and 0.514 for an oil-fired 40 gal unit.

ELIGIBILITY

This protocol documents the energy savings attributed to converting from a standard electric water heater to an ENERGY STAR natural gas or propane water heater with Energy Factor of 0.67 or greater and 0.514 for oil water heater. If a customer submits a rebate for a product that has applied for ENERGY STAR Certification but has not yet been certified, the savings will be counted for that product contingent upon its eventual certification as an ENERGY STAR measure. If at any point the product is rejected by ENERGY STAR, the product is then ineligible for the program and savings will not be counted.
The target sector primarily consists of single-family residences.

ALGORITHMS

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

$$\Delta kWh/yr = \frac{\left\{\left(\frac{1}{EF_{Elec,bl}}\right)\times\left(HW\times 365\frac{days}{yr}\times 1\frac{BTU}{lb\cdot{}^{\circ}F}\times 8.3\frac{lb}{gal}\times(T_{hot}-T_{cold})\right)\right\}}{3412\frac{Btu}{kWh}}$$

---

[1] RECS 2009 data indicate that the most common size is 31 to 49 gal. An average of 40 gal unit is considered for this protocol. http://www.eia.gov/consumption/residential/data/2009/).

[2] DEER Effective Useful Life values, updated October 10, 2008.

[3] ibid.

Table 2-1: Fuel Consumption for Fuel Switching, Domestic Hot Water Electric to Fossil Fuel

Fuel Type	Energy Factor	Fossil Fuel Consumption (MMBtu)
Gas	0.67	14.47~~15.37~~
Propane	0.67	14.47~~15.37~~
Oil	0.514	18.86~~20.04~~

Note: 1 MMBtu of propane is equivalent to 10.87 gals of propane, and 1 MMBtu of oil is equivalent to 7.19 gals of oil[104].

Evaluation Protocols

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

Sources

1. Federal Standards 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
2. Commission Order[105] requires fuel switching to ENERGY STAR measures, not standard efficiency measures. The Energy Factor has therefore been updated to reflect the EnergyStar standard for Gas Storage Water Heaters beginning September 1, 2010. From Residential Water Heaters Key Product Criteria. http://www.energystar.gov/index.cfm?c=water_heat.pr_crit_water_heaters Accessed June 2013
3. Federal Standards are 0.67 -0.0019 x Rated Storage in Gallons for oil-fired storage water heater. For a 40-gallon tank this 0.514. "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. 307. "Energy Conservation Program for Consumer Products: Test Procedure for Water Heaters", Federal Register / Vol. 63, No. 90, p. 26005-26006.
4. "Energy Conservation Program for Consumer Products: Test Procedure for Water Heaters", Federal Register / Vol. 63, No. 90, p. 26005-26006.
5. Pennsylvania Statewide Residential End-Use and Saturation Study, 2014.
6. Mid-Atlantic TRM Version 3.0, March 2013, footnote #314
7. Straub, Mary and Switzer, Sheldon. "Using Available Information for Efficient Evaluation of Demand Side Management Programs". Study by BG&E. The Electricity Journal. Aug/Sept, 2011. http://www.sciencedirect.com/science/article/pii/S1040619011001941

[104] http://www.energystar.gov/ia/business/industry/industry_challenge/QuickConverter.xls

[105] See page 42 of the 2013 TRC Test Final Order

2.3.5 Fuel Switching: Heat Pump Water Heater to Fossil Fuel Water Heater

Measure Name	Fuel Switching: Heat Pump Water Heater to Fossil Fuel Heater
Target Sector	Residential
Measure Unit	Water Heater
Unit Energy Savings	1,632.9~~1,734.5~~ kWh (for EF = 2.0)
Unit Peak Demand Reduction	0.1314 ~~0.140~~kW
Gas, Fossil Fuel Consumption Increase	Gas: 14.47~~15.38~~ MMBtu Propane: 14.47~~15.38~~ MMBtu Oil: 18.86~~20.04~~ MMBtu
Measure Life	Gas:13 years[1] Propane: 13 years[2] Oil: 8 years[3]
Vintage	Replace on Burnout

Natural gas, propane and oil water heaters reduce electric energy and demand compared to heat pump water heaters. Standard heat pump water heaters have energy factors of 2.0 and ENERGY STAR gas and propane water heaters have an energy factor of 0.67 for a 40 gal unit and 0.514 for an oil-fired 40 gal unit.

Eligibility

This protocol documents the energy savings attributed to converting from a standard heat pump water heater with Energy Factor of 2.0 or greater to an ENERGY STAR natural gas or propane water heater with Energy Factor of 0.67 or greater and 0.514 for an oil 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 heat pump water heaters 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 heat pump water heater. The energy savings are obtained through the following formula:

$$\Delta kWh/yr = \frac{\left\{\left(\frac{1}{EF_{HP,bl} \times F_{Derate}}\right) \times \left(HW \times 365\,\frac{days}{yr} \times 1\,\frac{BTU}{lb \cdot {}^{\circ}F} \times 8.3\,\frac{lb}{gal} \times (T_{hot} - T_{cold})\right)\right\}}{3412\,\frac{Btu}{kWh}} + \Delta kWh/yr_{ie,cool} + \Delta kWh/yr_{ie,heat}$$

[1] DEER Effective Useful Life values, updated October 10, 2008.
[2] ibid.
[3] ibid.

Table 2-1: Gas, Oil, Propane Consumption for Heat Pump Water Heater to Fossil Fuel Water Heater

Fuel Type	Energy Factor	Gas Consumption (MMBtu)
Gas	0.67	14.47~~15.37~~
Propane	0.67	14.47~~15.37~~
OIl	0.514	18.86~~20.04~~

Evaluation Protocols

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

Sources

1. Heat pump water heater efficiencies have not been set in a Federal Standard. However, the Federal Standard for water heaters does refer to a baseline efficiency for heat pump water heaters as EF = 2.0 “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.
2. Commission Order[1] requires fuel switching to ENERGY STAR measures, not standard efficiency measures. The Energy Factor has therefore been updated to reflect the EnergyStar standard for Gas Storage Water Heaters beginning September 1, 2010. From Residential Water Heaters Key Product Criteria. http://www.energystar.gov/index.cfm?c=water_heat.pr_crit_water_heaters Accessed June 2013 Federal Standards are 0.67 -0.0019 x Rated Storage in Gallons. Federal Standards are 0.67 -0.0019 x Rated Storage in Gallons. For a 40-gallon tank this is 0.594. “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
3. Federal Standards are 0.67 -0.0019 x Rated Storage in Gallons for oil-fired storage water heater. For a 40-gallon tank this 0.514. “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. 307. “Energy Conservation Program for Consumer Products: Test Procedure for Water Heaters”, Federal Register / Vol. 63, No. 90, p. 26005-26006.
4. “Energy Conservation Program for Consumer Products: Test Procedure for Water Heaters”, Federal Register / Vol. 63, No. 90, p. 26005-26006.
5. Pennsylvania Statewide Residential End-Use and Saturation Study, 2014.
6. Mid-Atlantic TRM Version 3.0, March 2013, footnote #314
7. NEEA Heat Pump Water Heater Field Study Report. Prepared by Fluid Market Strategies, 2013. http://neea.org/docs/default-source/reports/heat-pump-water-heater-field-study-report.pdf?sfvrsn=5 (Note: when this source discusses “ducted” vs “non-ducted” systems it refers to the water heater’s heat pump exhaust, not to the HVAC ducts.)

2.3.8 WATER HEATER PIPE INSULATION

Measure Name	Electric Water Heater Pipe Insulation
Target Sector	Residential Establishments
Measure Unit	Water Heater
Unit Energy Savings	~~Default: 10~~9.43 kWh per foot of installed insulation
Unit Peak Demand Reduction	~~0.00083~~ 0.000759 kW per foot of installed insulation
Measure Life	13 years[122]
Vintage	Retrofit

This measure relates to the installation of foam insulation on 10 feet of exposed pipe in unconditioned space, ¾" thick. The baseline for this measure is a standard efficiency electric water heater (EF=0.904) with an annual energy usage of 31433~~.338~~ kWh. [123]

ELIGIBILITY

This protocol documents the energy savings for an electric water heater attributable to insulating 10 feet of 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 (31433~~,338~~ kWh), or ~~100.14~~94.29 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 9.43~~10~~ kWh.

ΔkWh/yr = *9.43~~10~~ kWh/yr per foot of installed insulation*

The summer coincident peak kW savings are calculated as follows:

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

DEFINITION OF TERMS

Term	Unit	Value	Source
ΔkWh/yr , annual energy savings per foot of installed pipe insulation	$\frac{kWh/yr}{ft}$	9.43~~10~~	1
ETDF, Energy to Demand Factor	$\frac{kW}{kWh/yr}$	0.00008047	2

[122] 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.

[123] See "Efficient Electric Water Heater" sectionfor assumptions used to calculate annual energy usage.

Term	Unit	Value	Source
ΔkW_{peak} , Summer peak kW savings per foot of installed pipe insulation	$\frac{kW}{ft}$	0.000759~~0.0008047~~	

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

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

The ratio of the average energy usage between 2 PM to 6 PM on summer weekdays to the total annual energy usage is taken from an electric water heater metering study performed by BG&E (pg 95 of 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.

Refrigerator Category	Federal Standard Maximum Usage in kWh/yr	ENERGY STAR Maximum Energy Usage in kWh/yr
7. Refrigerator-freezers—automatic defrost with side-mounted freezer with through-the-door ice service.	8.54AV + 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.	10.25AV + 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.	9.03AV + 252.3	8.13 * AV + 227.1
11A.Compact all-refrigerators—manual defrost.	7.84AV + 219.1	7.06 * AV + 197.2
12. Compact refrigerator-freezers—partial automatic defrost	5.91AV + 335.8	5.32 * AV + 302.2
13. Compact refrigerator-freezers—automatic defrost with top-mounted freezer.	11.80AV + 339.2	10.62 * AV + 305.3
13I. Compact refrigerator-freezers—automatic defrost with top-mounted freezer with an automatic icemaker.	11.80AV + 423.2	10.62 * AV + 389.3
13A. Compact all-refrigerators—automatic defrost.	9.17AV + 259.3	8.25 * AV + 233.4
14. Compact refrigerator-freezers—automatic defrost with side-mounted freezer.	6.82AV + 456.9	6.14 * AV + 411.2
14I. Compact refrigerator-freezers—automatic defrost with side-mounted freezer with an automatic icemaker.	6.82AV + 540.9	6.14 * AV + 495.2
15. Compact refrigerator-freezers—automatic defrost with bottom-mounted freezer.	11.80AV + 339.2	10.62 * AV + 305.3
15I. Compact refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker.	11.80AV + 423.2	10.62 * AV + 389.3

The default values for each configuration are given in Table 2-70.

Table 2-1: Default Savings Values for ENERGY STAR Refrigerators[132]

Refrigerator Category	Assumed Volume of Unit (cubic feet)[133]	Conventional Unit Energy Usage in kWh/yr	ENERGY STAR Energy Usage in kWh/yr	ΔkWh/yr	ΔkW_{peak}
1A. All-refrigerators—manual defrost.	12.2	276	249	28	0.0031
2. Refrigerator-freezers—partial automatic defrost	12.2	322	290	32	0.0036

132 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.

133 ENERGY STAR Appliances Calculator. Accessed November 2013.

Table 2-1: Calculation Assumptions and Definitions for Refrigerator and Freezer Recycling

Component	Unit	Values	Source
EXISTING_UEC , The average annual unit energy consumption of participating refrigerators and freezers for Program year 5. Table 2-76 and Table 2-77 below provide the equation inputs needed to calculate the UEC for removed refrigerators and freezers respectively as well as the calculation of the default Unit Energy Consumption value for refrigerators or freezers for each EDC.	*kWh/yr*	EDC Data Gathering Or Default = Table 2-76 and Table 2-77	1, 2
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 4.3 of UMP Protocol Default: Refrigerator= 96.9% Freezer= 98.5%	7
N , The number of refrigerators recycled through the program	*None*	EDC Data Gathering	
NET_FR_SMI_kWh , Average per-unit energy savings net of naturally occurring removal from grid and secondary market impacts	*kWh/yr*	EDC Data Gathering according to section 5.1 of UMP Protocol (Discussion Below)	1
INDUCED_kWh , Average per-unit energy consumption caused by the program inducing participants to acquire refrigerators they would not have independent of program participation	*kWh/yr*	EDC Data Gathering according to section 5.2 of UMP Protocol (Discussion Below)	1
ETDF , Energy to Demand Factor	$\frac{kW}{kWh/yr}$	0.0001119	8

UEC Equations and Default Values

For removed refrigerators, the annual Unit Energy Consumption (UEC) is based upon regression analyses of data from refrigerators metered and recycled through five utilities. The UEC for removed refrigerators was calculated specifically for each utility using data collected from each utility's Program Year Five (PY5) Appliance Removal programs. Therefore, each UEC represents the average ages, sizes, etc of the fleet of refrigerators removed in Program Year Five~~Four~~.

$$\begin{aligned} Existing\ UEC_{Refrigerator} &= 365.25 * (0.582 + 0.027 * (average\ age\ of\ appliance) + 1.055 \\ &* (\%\ of\ appliances\ manufactured\ before\ 1990) + 0.067 \\ &* (number\ of\ \ cubic\ feet) - 1.977 * (\%\ of\ single\ door\ units) + 1.071 \\ &* (\%\ of\ side-by-side) + 0.605 * (\%\ of\ primary\ usage) + 0.02 \\ &* (unconditioned\ space\ CDDs) - 0.045 * (unconditioned\ HDDs)) = kWh \end{aligned}$$

Source for refrigerator UEC equation: *US DOE Uniform Method Project, Savings Protocol for Refrigerator Retirement, April 2013.*

Refrigerator UEC (Unit Energy Consumption) Equation

2.4.6 Fuel Switching: Electric Clothes Dryer to Gas Clothes Dryer

Measure Name	Fuel Switch: Electric Clothes Dryer to Gas Clothes Dryer
Target Sector	Residential Establishments
Measure Unit	Fuel Switch: Electric Clothes Dryer to Gas Clothes Dryer
Unit Energy Savings	875 kWh -2.99 MMBtu (increase in gas consumption)
Unit Peak Demand Reduction	0.149 kW
Measure Life	14 years[1]

This protocol outlines the savings associated to purchasing a 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 a gas clothes dryer rather than an electric dryer.

Algorithms

$$\Delta kWh/yr = kWh_{base} - kWh_{gas} = 905 - 30 = 875$$

$$\Delta MMBtu = -\Delta kWh \times 0.003412\cancel{3} = -2.99$$

$$\Delta kW_{peak} = \frac{\Delta\, kWh/yr}{Cycles_{wash} \times \%_{wash/dry} \times time_{cycle}} \times CF = 0.149\ kW$$

Definition of Terms

Table 2-1 Electric Clothes Dryer to Gas Clothes Dryer – Values and Resources

Term	Unit	Values	Source
ΔkWh, Annual electricity savings, deemed	$\frac{kWh}{yr}$	EDC Data Gathering Default = 875	Calculated
kWh_{base}, Baseline annual electricity consumption of electric dryer, deemed	$\frac{kWh}{yr}$	EDC Data Gathering Default = 905	1
kWh_{gas} , Annual electricity consumption of gas dryer, deemed	$\frac{kWh}{yr}$	EDC Data Gathering Default = 30	2

[1] DOE life-cycle cost and payback period Excel-based calculator. http://www1.eere.energy.gov/buildings/appliance_standards/residential/docs/rcw_dfr_lcc_standard.xlsm

Term	Unit	Values	Source
$\Delta\mathrm{MMBtu}$, Weighted average gas fuel increase	MMBtu	EDC Data Gathering Default = -2.99	Calculated, 3
0.003412~~3~~, Conversion factor	$\frac{MMBtu}{kWh}$	EDC Data Gathering Default = 0.003412~~3~~	None
$Cycles_{wash}$, Number of washing machine cycles per year	cycles/yr	260	4
$\%_{\mathrm{dry/wash}}$, Percentage of homes with a dryer that use the dryer every time clothes are washed	%	95%	5
$time_{cycle}$, Duration of average drying cycle in hours	hours	EDC Data Gathering Default= 1	Assumption
CF, Coincidence Factor	*Fraction*	EDC Data Gathering Default = 0.042	6

Default Savings

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

Evaluation Protocols

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

Sources

1. Average annual dryer kWh without moisture sensor per 2014 PA TRM protocol 2.2 *Electric Clothes Dryer with Moisture Sensor*.
2. 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. Median annual electricity consumption of gas dryers from Table 7.3.4: Electric Standard and Gas Clothes Dryer: Average Annual Energy Consumption Levels by Efficiency http://www.regulations.gov/#!documentDetail;D=EERE-2007-BT-STD-0010-0053
3. Negative gas fuel savings indicate increase in fuel consumption. It is assumed that gas and electric dryers have similar efficiencies. All heated air passes through the clothes and contributes to drying.
4. Statewide average for all housing types from Pennsylvania Statewide Residential End-Use and Saturation Study, 2014.
5. 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. Clothes Dryer Frequency from Table 7.3.3 for Electric Standard. http://www.regulations.gov/contentStreamer?objectId=0900006480c8ee11&disposition=attachment&contentType=pdf

2.4.8 ENERGY STAR DEHUMIDIFIERS

Measure Name	Dehumidifiers
Target Sector	Residential Establishments
Measure Unit	Dehumidifier
Unit Energy Savings	Varies based on capacity
Unit Peak Demand Reduction	Varies based on capacity ~~0.0098 kW~~
Measure Life	12 years[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.

ELIGIBILITY

This protocol documents the energy and demand savings attributed to purchasing an ENERGY STAR dehumidifier instead of a standard one. Dehumidifiers must meet ENERGY STAR Version 3.0 Product Specifications to qualify. The target sector is residential.

ALGORITHMS

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

Total Savings $= Number\ of\ Dehumidifiers \times Savings\ per\ Dehumidifier$

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

Per unit energy and demand savings algorithms:

$$\Delta\, kWh/yr = \left(\frac{CAPY \times 0.437\frac{liters}{pint}}{24\frac{hours}{day}}\right) \times HOU \times \left(\frac{1}{L/kWh_{base}} - \frac{1}{L/kWh_{ee}}\right)$$

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

[1] EnergyS tar Calculator Accessed July 2013 using ENERGY STAR Appliances. February 2008. U.S. Environmental Protection Agency and U.S. Department of Enegy. ENERGY STAR. http://www.energystar.gov/.

2.4.9 ENERGY STAR Water Coolers

Measure Name	ENERGY STAR Water Coolers
Target Sector	Residential Establishments
Measure Unit	Water Cooler
Unit Energy Savings	Cold ~~Water~~ Only: 47.5 kWh ~~Hot/Cold Water: 361 kWh~~Hot & Cold Storage: 481.8 kWh Hot & Cold On-Demand: 733.65 kWh
Unit Peak Demand Reduction	~~0.0232 kW~~ Cold Only: 0.00532 kW Hot & Cold Storage: 0.0539 kW Hot & Cold On-Demand: 0.0821 kW
Measure Life	10 years[1]
Vintage	Replace on Burnout

This protocol estimates savings for installing ENERGY STAR Water Coolers 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.

Eligibility

In order for this measure protocol to apply, the high-efficiency equipment must meet the ENERGY STAR 2.0 efficiency criteria: Cold Only or Cook & Cold Units ≤0.16 kWh /day, Hot & Cold Storage Units ≤0.87 kWh/day, and Hot & Cold On-Demand ≤0.18 kWh/day.

Algorithms

The general form of the equation for the ENERGY STAR Water Coolers measure savings algorithms is:

Total Savings $= Number\ of\ Water\ Coolers\ \times\ Savings\ per\ Water\ Cooler$

To determine resource savings, the per unit estimates in the algorithms will be multiplied by the number of water coolers. Per unit savings are primarily derived from the May 2012 release of the ENERGY STAR calculator for water coolers.

Per unit energy and demand savings algorithms:

$$\Delta kWh = (kWh_{base} - kWh_{ee}) \times 365 \frac{days}{year}$$

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

[1] ENERGY STAR Water Coolers Savings Calculator (Calculator updated: May 2012)

Term	Unit	Value	Source
		Heat Pump = 16.2	
		Nameplate	EDC Gathering
GSER , Factor to determine the SEER of a GSHP based on its EER	*None*	1.02	6
COP_{GSHP} , Coefficient of Performance for existing home ground source heat pump	*None*	Default for Ground Source Heat Pump = 3.1 Default for Groundwater Source Heat Pump = 3.6	5
		Nameplate	EDC Gathering
GSOP , Factor to determine the HSPF of a GSHP based on its COP	$\frac{Btu}{W \cdot hr}$	3.412~~3~~	7
GSHPDF , Ground Source Heat Pump De-rate Factor	*None*	0.885	(Engineering Estimate - See 2.2.1)
CF_{CAC} , Demand Coincidence Factor for central AC systems	*Fraction*	0.647	8
CF_{RAC} , Demand Coincidence Factor for Room AC systems	*Fraction*	0.647	9
CF_{ASHP} , Demand Coincidence Factor for ASHP systems	*Fraction*	0.647	8
CF_{GSHP} , Demand Coincidence Factor for GSHP systems	*Fraction*	0.647	8
$F_{Room,AC}$, Adjustment factor to relate insulated area to area served by Room AC units	*None*	0.38	Calculated[1]
CDD , Cooling Degree Days	$°F \cdot Days$	Table 2-103	10
HDD , Heating Degree Days	$°F \cdot Days$	Table 2-103	10
$EFLH_{cool}$, Equivalent Full Load Cooling hours for Room AC	$\frac{hours}{year}$	Table 2-103	11
$EFLH_{cool\ RAC}$, Equivalent Full Load Cooling hours for Central AC and ASHP	$\frac{hours}{year}$	Table 2-103	12

[1] From PECO baseline study, average home size = 2323 ft^2, average number of room AC units per home = 2.1. Average Room AC capacity = 10,000 Btu/hr per ENERGY STAR Room AC Calculator, which serves 425 ft^2 (average between 400 and 450 ft^2 for 10,000 Btu/hr unit per ENERGY STAR Room AC sizing chart). $F_{Room,AC} = (425\ ft^2 * 2.1)/(2323\ ft^2) = 0.38$

3. NOAA Climatic Data for Pennsylvania cities- Cloudiness (mean number of days Sunny, Partly Cloudy, and Cloudy), http://ols.nndc.noaa.gov/plolstore/plsql/olstore.prodspecific?prodnum=C00095-PUB-A0001.
4. US DOE Federal Standards for Central Air Conditioners and Heat Pumps. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/75
5. Minimum efficiency standards for Ground and Groundwater Source Heat Pumps. IECC 2009.
6. VEIC estimate. Extrapolation of manufacturer data.
7. Engineering calculation, HSPF/COP=3.412~~3~~
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. http://www.sciencedirect.com/science/article/pii/S1040619011001941
9. Consistent with CFs found in RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008.[1]
10. Climatography of the United States No. 81. Monthly Station Normals of Temperature, Precipitation, and Heating and Cooling Degree Days 1971-2000, 36 Pennsylvania. NOAA. http://cdo.ncdc.noaa.gov/climatenormals/clim81/PAnorm.pdf
11. Based on REM/Rate modeling using models from the PA 2012 Potential Study. EFLH calculated from kWh consumption for cooling and heating. Models assume 50% over-sizing of air conditioners and 40% oversizing of heat pumps.[2]
12. 2014 PA TRM Section 2.2.4 Room AC Retirement.

[1] In the absence of better, Pennsylvania-specific data, this is the same source and value as the Mid-Atlantic and Illinois TRMs.
[2] ACCA, "Verifying ACCA Manual S Procedures," http://www.acca.org/Files/?id=67.

2. Lighting that is integral to:

    Equipment or instrumentation and installed by its manufacturer,

    Refrigerator and freezer cases (both open and glass-enclosed),

    Equipment used for food warming and food preparation,

    Medical equipment, or

    Advertising or directional signage

3. Lighting specifically designed only for use during medical procedures
4. Lighting used for plant growth or maintenance
5. Lighting used in spaces designed specifically for occupants with special lighting needs
6. Lighting in retail display windows that are enclosed by ceiling height partitions.

~~Within a single project, to the extent that there are different control strategies (SVG), hours of use (HOU), coincidence factors (CF) or interactive factors (IF), the ΔkW will be broken out to account for these different factors. This will be accomplished using Appendix E: Lighting Audit and Design Tool for C&I New Construction Projects, a Microsoft Excel inventory form that specifies the lamp and ballast configuration using the Standard Wattage Table and SVG, HOU, CF and IF values for each line entry. The inventory will also specify the location and number of fixtures for reference and validation.~~

Appendix E was developed to automate the calculation of energy and demand impacts for New Construction lighting projects, based on a series of entries by the user defining key characteristics of the retrofit project. The main sheet, "Interior Lighting Form", is a detailed line-by-line inventory incorporating variables required to calculate savings. Each line item represents a specific area with installed fixtures, controls strategy, space cooling, and space usage.

Installed fixture wattages are determined by selecting the appropriate fixture code from the "06 Wattage Table" sheet. The "08 Fixture Code Locator" sheet can be used to find the appropriate code for a particular lamp-ballast combination[1]. Actual wattages of fixtures determined by manufacturer's equipment specification sheets or other independent sources may not be used unless (1) the manufacturer's cut sheet indicates that the difference in delta-watts of fixture wattages (i.e. difference in delta watts of baseline and "actual" installed efficient fixture wattage and delta watts of baseline and nearest matching efficient fixture in standard wattage table of Appendix E is more than 10%[2] or (2) the corresponding fixture code is not listed in the Standard Wattage Table. In these cases, alternate wattages for lamp-ballast combinations can be inputted using the "02 Interior User Input" or the "04 Exterior User Input" sheets of Appendix E: Lighting Audit and Design Tool for C&I New Construction Projects. Documentation supporting the alternate wattages must be provided in the form of manufacturer provided specification sheets or other industry accepted sources (e.g. ENERGY STAR listing, Design Lights Consortium listing). It must cite test data performed under standard ANSI procedures. These exceptions will be used as the basis for periodically updating the Standard Wattage Table to better reflect market conditions and more accurately represent savings.

Some lighting contractors may have developed in-house lighting inventory forms that are used to determine preliminary estimates of projects. In order to ensure standardization of all New

[1] The Locator is intended to assist users locate codes in the Standard Wattage Table. It does not generate new codes or wattages. In a few cases, the fixture code noted in the Standard Wattage Table may not use standard notation. Therefore, these fixtures may not be able to be found using the Locator and a manual search may be necessary to locate the code.

[2] This value was agreed upon by the Technical Working Group convened to discuss updates to the TRM. This value is subject to adjustment based on implementation feedback during PY3 and PY4.

Definition of Terms

Table 3-1: DHP – Values and References

Term	Unit	Values	Source
$CAPY_{cool}$, The cooling capacity of the indoor unit, given in $\frac{Btu}{hr}$ as appropriate for the calculation. This protocol is limited to units < 65,000 $\frac{Btu}{hr}$ (5.4 tons) $CAPY_{heat}$, The heating capacity of the indoor unit, given in $\frac{Btu}{hr}$ as appropriate for the calculation.	$\frac{Btu}{hr}$	Nameplate	EDC Data Gathering
$EFLH_{cool}$, Equivalent Full Load Hours for cooling $EFLH_{heat}$, Equivalent Full Load Hours for heating	$\frac{Hours}{Year}$	Based on Logging, BMS data or Modeling[1] Default: See Table 3-24 and Table 3-26	EDC Data Gathering 1
$HSPF_b$, Heating Seasonal Performance Factor, heating efficiency of the installed DHP	$\frac{Btu/hr}{W}$	Standard DHP: 7.7 Electric resistance: 3.41~~3~~2 ASHP: 7.7 PTHP[2] (Replacements): 2.9 - (0.026 x Cap / 1000) COP PTHP (New Construction): 3.2 - (0.026 x Cap / 1000) COP Electric furnace: 3.241~~2~~ For new space, no heat in an existing space, or non-electric heating in an existing space: use standard DHP: 7.7	2, 4,7
$SEER_b$, Seasonal Energy Efficiency Ratio cooling efficiency of baseline unit	$\frac{Btu/hr}{W}$	DHP, ASHP, or central AC: 13 Room AC: 11.3 PTAC[3] (Replacements): 10.9 - (0.213 x Cap / 1000) EER PTAC (New Construction): 12.5 - (0.213 x Cap / 1000) EER PTHP (Replacements): 10.8 - (0.213 x Cap /	3,4,5,6,7

[1] Ibid

[2] Cap represents the rated cooling capacity of the product in Btu/h. If the unit's capacity is less than 7,000 Btu/h, 7,000 Btu/h is used in the calculation. If the unit's capacity is greater than 15,000 Btu/h, 15,000 Btu/h is used in the calculation. Use HSPF = COP X 3.41~~3~~2.

[3] Cap represents the rated cooling capacity of the product in Btu/h. If the unit's capacity is less than 7,000 Btu/h, 7,000 Btu/h is used in the calculation. If the unit's capacity is greater than 15,000 Btu/h, 15,000 Btu/h is used in the calculation. Use SEER = EER X (13/11.3).

Term	Unit	Values	Source
		1000) EER PTHP (New Construction): 12.3 - (0.213 x Cap / 1000) EER For new space or no cooling in an existing space: use Central AC: 13	
$HSPF_e$, Heating Seasonal Performance Factor, heating efficiency of the installed DHP	$\frac{Btu/hr}{W}$	Based on nameplate information. Should be at least ENERGY STAR.	EDC Data Gathering
$SEER_e$, Seasonal Energy Efficiency Ratio cooling efficiency of the installed DHP	$\frac{Btu/hr}{W}$	Based on nameplate information. Should be at least ENERGY STAR.	EDC Data Gathering
CF, Demand Coincidence Factor	*Decimal*	See Table 3-25	1

Default Savings

There are no default savings for this measure.

Evaluation Protocols

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

Sources

1. Based on Nexant's eQuest modeling analysis 2014.
2. COP = HSPF/3.412~~3~~. HSPF = 3.412~~3~~ for electric resistance heating, HSPF = 7.7 for standard DHP. Electric furnace COP typically varies from 0.95 to 1.00 and thereby assumed a COP 0.95 (HSPF = 3.241~~2~~).
3. Federal Register, Vol. 66, No. 14, Monday, January 22, 2001/Rules and Regulations, p. 7170-7200.
4. Air-Conditioning, Heating, and Refrigeration Institute (AHRI); the directory of the available ductless mini-split heat pumps and corresponding efficiencies (lowest efficiency currently available). Accessed 8/16/2010. https://www.ahridirectory.org/ahridirectory/pages/home.aspx
5. ENERGY STAR and Federal Appliance Standard minimum EERs for a 10,000 Btu/hr unit with louvered sides. http://www.energystar.gov/index.cfm?c=roomac.pr_crit_room_ac

Average EER for SEER 13 units as calculated by EER = -0.02 × SEER² + 1.12 × SEER based on U.S. DOE Building America House Simulation Protocol, Revised 2010. http://www.nrel.gov/docs/fy11osti/49246.pdf

Table 3-1: Default Motor Wattage (WATTSbase and WATTSee) for Circulating Fan

Motor Type	Motor Category		
	1/40 HP (16-23 watts) (Using 19.5 watt as industry average)	**1/20 HP (~37 watts)**	**1/15 HP (~49 watts)**
Motor Output Watts	19.5	37	49
SP	93	142	191
PSC	48	90	120
ECM	30	56	75

Default Savings

Default savings may be claimed using the algorithms above and the variable defaults. EDCs may also claim savings using customer specific data.

Evaluation Protocols

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

Sources

1. Regional Technical Forum (RTF) as part of the Northwest Power & Conservation Council, Deemed Measures List. Grocery Display Case ECM, FY2010, V2. http://rtf.nwcouncil.org/measures/measure.asp?id=107&decisionid=230
2. Regional Technical Forum (RTF) as part of the Northwest Power & Conservation Council, Deemed Measures List. Deemed MeasuresV26 _walkinevapfan.
3. AO Smith New Product Notification. I-motor 9 & 16 Watt. Stock Numbers 9207F2 and 9208F2. Web address: http://www.electricmotorwarehouse.com/PDF/Bulletin%206029B.pdf
4. PSC of Wisconsin, Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0, p. 4-103 to 4-106. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
5. Assuming that the waste heat is within the conditioned air stream, then the energy associated with removing the waste heat during peak times is approximated as the inverse of the COP, or 3.412~~3~~/EER = 0.30 if one uses 11.3 as a default value for cooling system EER.
6. This is an approximation that accounts for the coincidence between cooling and fan operation and corrects with a factor of 11.3/13 to account for seasonal cooling efficiency rather than peak cooling efficiency.
7. Nexant eQuest modeling analysis 2014.

Ceiling/Wall Insulation

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

$$\Delta kWh_{cool} = \left(\frac{CDD \times 24}{Eff \times 1{,}000}\right) \times \left[A_{ceiling}\left(\frac{1}{Ceiling\ R_i} - \frac{1}{Ceiling\ R_f}\right) + A_{wall}\left(\frac{1}{WallR_i} - \frac{1}{Wall\ R_f}\right)\right]$$

$$\Delta kWh_{heat} = \left(\frac{HDD \times 24}{COP \times 3{,}412\cancel{3}}\right) \times \left[A_{ceiling}\left(\frac{1}{Ceiling\ R_i} - \frac{1}{Ceiling\ R_f}\right) + A_{wall}\left(\frac{1}{WallR_i} - \frac{1}{Wall\ R_f}\right)\right]$$

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

DEFINITION OF TERMS

Table 3-1: Non-Residential Insulation – Values and References

Term	Unit	Values	Source
$A_{ceiling}$, Area of the ceiling/attic insulation that was installed	ft^2	EDC Data Gathering	EDC Data Gathering
A_{wall}, Area of the wall insulation that was installed	ft^2	EDC Data Gathering	EDC Data Gathering
HDD, Heating degree days with 65 degree base	$°F \cdot Days$	Allentown = 5318 Erie = 6353 Harrisburg = 4997 Philadelphia = 4709 Pittsburgh = 5429 Scranton = 6176 Williamsport = 5651	1
CDD, Cooling degree days with a 65 degree base	$°F \cdot Days$	Allentown = 787 Erie = 620 Harrisburg = 955 Philadelphia = 1235 Pittsburgh = 726 Scranton = 611 Williamsport = 709	1
24, Hours per day	$\frac{Hours}{Day}$	24	Conversion Factor
1000, Watts per kilowatt	$\frac{W}{kW}$	1000	Conversion Factor
$3{,}412$, Btu per kWh	$\frac{Btu}{kWh}$	3,412	Conversion Factor
$Ceiling\ R_i$, the R-value of the ceiling insulation and support structure before the additional insulation is installed	$\frac{°F \cdot ft^2 \cdot hr}{Btu}$	For new construction buildings and when variable is unknown for existing buildings: See Table 3-144 and Table 3-145 for values by building type	EDC Data Gathering; 2, 4

5 APPENDICES

5.1 Appendix A: Measure Lives

Measure Lives Used in Cost-Effectiveness Screening
August 2014

*For the purpose of calculating the total Resource Cost Test for Act 129, measure cannot claim savings for more than fifteen years.

Measure	Measure Life
RESIDENTIAL SECTOR	
Lighting End-Use	
Electroluminescent Nightlight	8
LED Nightlight	8
Compact Fluorescent Light Bulb	5.2
Recessed Can Fluorescent Fixture	20*
Torchieres	10
Fixtures Other	20*
ENERGY STAR LEDs	15~~14.7~~
Residential Occupancy Sensors	10
Holiday Lights	10
HVAC End-Use	
Central Air Conditioner (CAC)	14
Air Source Heat Pump	12
Central Air Conditioner proper sizing/install	14
Central Air Conditioner Quality Installation Verification	14
Central Air Conditioner Maintenance	7
Central Air Conditioner duct sealing	20
ENERGY STAR Room Air Conditioners	9
Air Source Heat Pump proper sizing/install	12
ENERGY STAR Thermostat (Central Air Conditioner)	15
ENERGY STAR Thermostat (Heat Pump)	15
Ground Source Heat Pump	30*
Room Air Conditioner Retirement	4
Furnace Whistle	14
Programmable Thermostat	11
Room AC (RAC) Retirement	4
Residential Whole House Fans	15
Ductless Mini-Split Heat Pumps	15
Fuel Switching: Electric Heat to Gas Heat	20*
Efficient Ventilation Fans with Timer	10

New Construction (NC): Single Family - gas heat with CAC	20*
NC: Single Family - oil heat with CAC	20*
NC: Single Family - all electric	20*
NC: Multiple Single Family (Townhouse) – oil heat with CAC	20*
NC: Multiple Single Family (Townhouse) - all electric	20*
NC: Multi-Family – gas heat with CAC	20*
NC: Multi-Family - oil heat with CAC	20*
NC: Multi-Family - all electric	20*
Hot Water End-Use	
Efficient Electric Water Heaters	14
Heat Pump Water Heaters	14
Low Flow Faucet Aerators	12
Low Flow Showerheads	9
Solar Water Heaters	15
Electric Water Heater Pipe Insulation	13
Fuel Switching: Domestic Hot Water Electric to Gas or Propane Water Heater	13
Fuel Switching: Domestic Hot Water Electric to Oil Water Heater	8
Fuel Switching: Heat Pump Water Heater to Gas or Propane Water Heater	13
Fuel Switching: Heat Pump Water Heater to Oil Water Heater	8
Water Heater Tank Wrap	7
Appliances End-Use	
ENERGY STAR Clothes Dryer	13
Refrigerator / Freezer Recycling without replacement	8
Refrigerator / Freezer Recycling with replacement	7
ENERGY STAR Refrigerators	12
ENERGY STAR Freezers	12
ENERGY STAR Clothes Washers	11
ENERGY STAR Dishwashers	10
ENERGY STAR Dehumidifers	12
ENERGY STAR Water Coolers	10
ENERGY STAR Ceiling Fans	20*
Consumer Electronics End-Use	
ENERGY STAR Televisions	6
Smart Strip Plug Outlets	10
ENERGY STAR Computer	4
ENERGY STAR Monitor	5
ENERGY STAR Fax	4
ENERGY STAR Multifunction Device	6