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**Technical Reference Manual**

October 2010

**State of Pennsylvania**

**Act 129**

**Energy Efficiency and Conservation Program**

**&**

**Act 213**

**Alternative Energy Portfolio Standards**

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# Introduction[[1]](#footnote-1)

The Technical Reference Manual (TRM) was developed to measure the resource savings from standard energy efficiency measures. The savings’ algorithms use measured and customer data as input values in industry-accepted algorithms. The data and input values for the algorithms come from Alternative Energy Portfolio Standards (AEPS) application forms, EDC program application forms, industry accepted standard values (e.g. ENERGY STAR standards), or data gathered by Electric Distribution Companies (EDCs). The standard input values are based on the best available measured or industry data.

Some electric input values were derived from a review of literature from various industry organizations, equipment manufacturers, and suppliers. These input values are updated to reflect changes in code, federal standards and recent program evaluations.

## Purpose

The TRM was developed for the purpose of estimating annual electric energy savings and coincident peak demand reductions for a selection of energy efficient technologies and measures. The TRM provides guidance to the Administrator responsible for awarding Alternative Energy Credits (AECs). The revised TRM serves a dual purpose of being used to determine compliance with the AEPS Act, 73 P.S. §§ 1648.1-1648.8, and the energy efficiency and conservation requirements of Act 129 of 2008, 66 Pa.C.S. § 2806.1. The TRM will continue to be updated on an annual basis to reflect the addition of technologies and measures as needed to remain relevant and useful.

Resource savings to be measured include electric energy (kWh) and electric capacity (kW) savings. The algorithms in this document focus on the determination of the per unit savings for the energy efficiency and demand response measures. The algorithms and methodologies set forth in this document must be used to determine EDC Reported Gross Savings and Evaluation Measurement and Verification (EM&V) Verified Savings.

## Definitions

The TRM is designed for use with both the AEPS Act and Act 129; however, it contains words and terms that apply only to the AEPS or only to Act 129. The following definitions are provided to identify words and terms that are specific for implementation of the AEPS:

* Administrator/Program Administrator (PA) – The Credit Administrator of the AEPS program that receives and processes, and approves AEPS Credit applications.
* AEPS application forms – application forms submitted to qualify and register alternative energy facilities for alternative energy credits.
* Application worksheets – part of the AEPS application forms.
* Alternative Energy Credits (AECs) – A tradable instrument used to establish, verify, and measure compliance with the AEPS. One credit is earned for each 1000kWh of electricity generated (or saved from energy efficiency or conservation measures) at a qualified alternative energy facility.
* EDC Estimated Savings – EDC estimated savings for projects and programs of projects which are enrolled in a program, but not yet completed and/or Measured and Verified (M&Ved).  The savings estimates may or may not follow a TRM or CMP method. The savings calculations/estimates may or may not follow algorithms prescribed by the TRM or Custom Measure Protocols (CMP) and are based on non-verified, estimated or stipulated values.
* EDC Reported Gross Savings – Also known as “EDC Claimed Savings”. EDC estimated savings for projects and programs of projects which are completed and/or Measured and Verified (M&Ved).  The estimates follow a TRM or CMP method.  The savings calculations/estimates follow algorithms prescribed by the TRM or CMP and are based non-verified, estimated, stipulated, EDC gathered or measured values of key variables.
* EM&V Verified Savings – Evaluator estimated savings for projects and programs of projects which are completed and for which the impact evaluation and EM&V activities are completed.  The estimates follow a TRM or CMP method.  The savings calculations/estimates follow algorithms prescribed by the TRM or CMP and are based on verified values of stipulated variables, EDC or evaluator gathered data, or measured key variables.
* Natural Equipment Replacement Measure – The replacement of equipment that has failed or is at the end of its service life with a model that is more efficient than required by the codes and standards in effect at the time of replacement, or is more efficient than standard practice if there are no applicable codes or standards.  The baseline used for calculating energy savings for natural equipment replacement measures is the applicable code, standard or standard practice.  The incremental cost for natural equipment replacement measures is the difference between the cost of baseline and more efficient equipment.  Examples of projects which fit in this category include replacement due to existing equipment failure, as well as replacement of equipment which may still be in functional condition, but which is operationally obsolete due to industry advances and is no longer cost effective to keep.
* New Construction Measure – The substitution of efficient equipment for standard baseline equipment which the customer does not yet own.  The baseline used for calculating energy savings is the construction of a new building or installation of new equipment that complies with applicable code, standard and standard practice in place at the time of construction/installation.  The incremental cost for a new construction measure is the difference between the cost of the baseline and more efficient equipment.  Examples of projects which fit in this category include installation of a new production line, construction of a new building, or an addition to an existing facility.
* Realization Rate – The ratio of “EM&V Verified Savings” to “EDC Reported Gross Savings”.
* Retrofit Measure (Early Replacement Measure) – The replacement of existing equipment, which is functioning as intended and is not operationally obsolete, with a more efficient model primarily for purposes of increased efficiency.   Retrofit measures have a dual baseline: for the estimated remaining useful life of the existing equipment the baseline is the existing equipment; afterwards the baseline is the applicable code, standard and standard practice expected to be in place at the time the unit would have been naturally replaced.  If there are no known or expected changes to the baseline standards, the standard in effect at the time of retrofit is to be used.  The incremental cost is the full cost of equipment replacement.  In practice in order to avoid the uncertainty surrounding the determination of “remaining useful life” early replacement measure savings and costs sometimes follow natural equipment replacement baseline and incremental cost definitions.  Examples of projects which fit in this category include upgrade of an existing production line to gain efficiency, upgrade of an existing, but functional lighting or HVAC system that is not part of a renovation/remodeling project, replacement of an operational chiller, or installation of a supplemental measure such as adding a Variable Frequency Drive (VFD) to an existing constant speed motor.
* Substantial Renovation Measure – The substitution of efficient equipment for standard baseline equipment during the course of a major renovation project which removes existing, but operationally functional equipment.  The baseline used for calculating energy savings is the installation of new equipment that complies with applicable code, standard and standard practice in place at the time of the substantial renovation.  The incremental cost for a substantial renovation measure is the difference between the cost of the baseline and more efficient equipment.  Examples include renovation of a plant which replaces an existing production line with a production line for a different product, substantial renovation of an existing building interior, replacement of an existing standard HVAC system with a ground source heat pump system.

For the Act 129 program, EDCs may, as an alternative to using the energy savings’ values for standard measures contained in the TRM, submit documentation of alternative measurement methods to support different energy savings’ values. The alternative measurement methods are subject to review and approval by the Commission to ensure their accuracy.

## General Framework

In general, energy and demand savings will be estimated using measured and customer data as input values in algorithms in the TRM, and information from the AEPS application forms, worksheets and field tools.

Three systems will work together to ensure accurate data on a given measure:

1. The application form that the customer or customer’s agent submits with basic information.
2. Application worksheets and field tools with more detailed, site-specific data, input values and calculations.
3. Algorithms that rely on standard or site-specific input values based on measured data. Parts or all of the algorithms may ultimately be implemented within the tracking system, application forms and worksheets and field tools.

## Algorithms

The algorithms that have been developed to calculate the energy and or demand savings are typically driven by a change in efficiency level between the energy efficient measure and the baseline level of efficiency. The following are the basic algorithms.

ΔkW = kWbase - kWee = Demand Savings

ΔkWpeak = ΔkW X CF = Coincident Peak Demand Savings

ΔkWh = ΔkW X EFLH = Annual Energy Savings

**Where:**

kWbase = Connected load kW of baseline case.

kWee = Connected load kW of energy efficient case.

EFLH = Equivalent Full Load Hours of operation for the installed measure.

CF = Demand Coincidence Factor, percentage of load connected during peak hours.

Other resource savings will be calculated as appropriate.

Specific algorithms for each of the measures may incorporate additional factors to reflect specific conditions associated with a measure. This may include factors to account for coincidence of multiple installations or interaction between different measures.

## Data and Input Values

The input values and algorithms are based on the best available and applicable data. The input values for the algorithms come from the AEPS application forms, EDC data gathering, or from standard values based on measured or industry data.

Many input values, including site-specific data, come directly from the AEPS application forms, EDC data gathering, worksheets and field tools. Site-specific data on the AEPS application forms and EDC data gathering are used for measures with important variations in one or more input values (e.g., delta watts, efficiency level, capacity, etc.).

Standard input values are based on the best available measured or industry data, including metered data, measured data from other state evaluations (applied prospectively), field data, and standards from industry associations. The standard values for most commercial and industrial measures are supported by end-use metering for key parameters for a sample of facilities and circuits. These standard values are based on five years of metered data for most measures[[2]](#footnote-2). Data that were metered over that time period are from measures that were installed over an eight-year period. The original TRM included many input values based on program evaluations of New Jersey’s Clean Energy Programs and other similar programs in the northeast region.

For the standard input assumptions for which metered or measured data were not available, the input values (e.g., delta watts, delta efficiency, equipment capacity, operating hours, coincidence factors) were assumed based on best available industry data or standards. These input values were based on a review of literature from various industry organizations, equipment manufacturers and suppliers.

## Baseline Estimates

For all new construction and replacement of non-working equipment, the ΔkW and ΔkWh values are based on standard efficiency equipment versus new high-efficiency equipment. For early replacement measures, the ΔkW and ΔkWh values are based on existing equipment versus new high-efficiency equipment. This approach encourages residential and business consumers to replace working inefficient equipment and appliances with new high-efficiency products rather than taking no action to upgrade or only replacing them with new standard-efficiency products. The baseline estimates used in the TRM are documented in baseline studies or other market information. Baselines will be updated to reflect changing codes, practices and market transformation effects.

## Resource Savings in Current and Future Program Years

AECs and energy efficiency and demand response reduction savings will apply in equal annual amounts corresponding to either PJM planning years or calendar years beginning with the year deemed appropriate by the Administrator, and lasting for the approved life of the measure for AEPS Credits. Energy efficiency and demand response savings associated with Act 129 can claim savings for up to fifteen years.

## Prospective Application of the TRM

The TRM will be applied prospectively. The input values are from the AEPS application forms, EDC program application forms, EDC data gathering and standard input values (based on measured data including metered data and evaluation results). The TRM will be updated annually based on new information and available data and then applied prospectively for future program years. Updates will not alter the number of AEPS Credits, once awarded, by the Administrator, nor will it alter any energy savings or demand reductions already in service and within measure life.

## Electric Resource Savings

Algorithms have been developed to determine the annual electric energy and electric coincident-peak demand savings.

Annual electric energy savings are calculated and then allocated separately by season (summer and winter) and time of day (on-peak and off-peak). Summer coincident peak demand savings are calculated using a demand savings algorithm for each measure that includes a coincidence factor. Application of this coincidence factor converts the demand savings of the measure, which may not occur at time of system peak, to demand savings that is expected to occur during the top 100 hours. This coincidence factor applies to the top 100 hours as defined in the Implementation Order as long as the EE&C measure class is operable during the summer peak hours.

Table 1‑1: Periods For Energy Savings and Coincident Peak Demand Savings

|  |  |  |
| --- | --- | --- |
| **Period** | **Energy Savings** | **Coincident Peak Demand Savings** |
| Summer | May through September | June through September |
| Winter | October through April | N/A |
| Peak[[3]](#footnote-3) | 8:00 a.m. to 8:00 p.m. Mon.-Fri. | 12:00 p.m. to 8:00 p.m. |
| Off-Peak[[4]](#footnote-4) | 8:00 p.m. to 8:00 a.m. Mon.-Fri.,  12 a.m. to 12p.m. Sat/Sun & holidays | N/A |

The time periods for energy savings and coincident peak demand savings were chosen to best fit the Act 129 requirement, which reflects the seasonal avoided cost patterns for electric energy and capacity that were used for the energy efficiency program cost effectiveness purposes. For energy, the summer period May through September was selected based on the pattern of avoided costs for energy at the PJM level. In order to keep the complexity of the process for calculating energy savings’ benefits to a reasonable level by using two time periods, the knee periods for spring and fall were split approximately evenly between the summer and winter periods.

For capacity, the summer period June through September was selected to match the period of time required to measure the 100 highest hours of demand. This period also correlates with the highest avoided costs’ time period for capacity. The experience in PJM has been that nearly all of the 100 highest hours of an EDC’s peak demand occur during these four months. Coincidence factors are used to determine the impact of energy efficiency measures on peak demand.

## Post-Implementation Review

The Administrator will review AEPS application forms and tracking systems for all measures and conduct field inspections on a sample of installations. For some programs and projects (e.g., custom, large process, large and complex comprehensive design), post-installation review and on-site verification of a sample of AEPS application forms and installations will be used to ensure the reliability of site-specific savings’ estimates.

## Adjustments to Energy and Resource Savings

### Coincidence with Electric System Peak

Coincidence factors are used to reflect the portion of the connected load savings or generation that is coincident with the top 100 hours.

### Measure Retention and Persistence of Savings

The combined effect of measure retention and persistence is the ability of installed measures to maintain the initial level of energy savings or generation over the measure life. Measure retention and persistence effects were accounted for in the metered data that were based on C&I installations over an eight-year period. As a result, some algorithms incorporate retention and persistence effects in the other input values. For other measures, if the measure is subject to a reduction in savings or generation over time, the reduction in retention or persistence is accounted for using factors in the calculation of resource savings (e.g., in-service rates for residential lighting measures).

### Interactive Measure Energy Savings

Interaction of energy savings is accounted for specific measures as appropriate. For all other measures, interaction of energy savings is zero.

For Residential New Construction, the interaction of energy savings is accounted for in the home energy rating tool that compares the efficient building to the baseline or reference building and calculates savings.

For Commercial and Industrial Efficient Construction, the energy savings for lighting is increased by an amount specified in the algorithm to account for HVAC interaction.

For commercial and industrial custom measures, interaction where relevant is accounted for in the site-specific analysis.

## Calculation of the Value of Resource Savings

The calculation of the value of the resources saved is not part of the TRM. The TRM is limited to the determination of the per unit resource savings in physical terms at the customer meter.

In order to calculate the value of the energy savings for reporting cost-benefit analyses and other purposes, the energy savings are determined at the customer level and then increased by the amount of the transmission and distribution losses to reflect the energy savings at the system level. The energy savings at the system level are then multiplied by the appropriate avoided costs to calculate the value of the benefits.

System Savings = (Savings at Customer) X (T&D Loss Factor)

Value of Resource Savings = (System Savings) X (System Avoided Costs ) + (Value of Other Resource Savings)

The value of the benefits for a particular measure will also include other resource savings where appropriate. Maintenance savings will be estimated in annual dollars levelized over the life of the measure. The details of this methodology are subject to change by the TRC Working Group.

## Transmission and Distribution System Losses

The TRM calculates the energy savings at the customer meter level. These savings need to be increased by the amount of transmission and distribution system losses in order to determine the energy savings at the system level, which is required for value of resource calculations. The electric loss factor multiplied by the savings calculated from the algorithms will result in savings at the system level.

The electric loss factor applied to savings at the customer meter is 1.11 for both energy and demand. The electric system loss factor was developed to be applicable to statewide programs. Therefore, average system losses at the margin based on PJM data were utilized. This reflects a mix of different losses that occur related to delivery at different voltage levels. The 1.11 factor used for both energy and capacity is a weighted average loss factor. These electric loss factors reflect losses at the margin.

## Measure Lives

Measure lives are provided in Appendix A for informational purposes and for use in other applications such as reporting lifetime savings or in benefit cost studies that span more than one year. For the purpose of calculating the Total Resource Cost Test for Act 129, measures cannot claim savings for more than 15 years.

## Custom Measures[[5]](#footnote-5)

Custom measures are considered too complex or unique to be included in the list of standard measures provided in the TRM. Also included are measures that may involve metered data, but require additional assumptions to arrive at a ‘typical’ level of savings as opposed to an exact measurement. To quantify savings for custom measures, a custom measure protocol must be followed. The qualification for and availability of AEPS Credits and energy efficiency and demand response savings are determined on a case-by-case basis.

An AEPS application must be submitted, containing adequate documentation fully describing the energy efficiency measures installed or proposed and an explanation of how the installed facilities qualify for AECs. The AEPS application must include a proposed evaluation plan by which the Administrator may evaluate the effectiveness of the energy efficiency measures provided by the installed facilities. All assumptions should be identified, explained and supported by documentation, where possible. The applicant may propose incorporating tracking and evaluation measures using existing data streams currently in use provided that they permit the Administrator to evaluate the program using the reported data.

To the extent possible, the energy efficiency measures identified in the AEPS application should be verified by the meter readings submitted to the Administrator.

For further discussion, please see Appendix B.

## Impact of Weather

To account for weather differences within Pennsylvania Equivalent Full Load Hours (ELFH) were taken from the US Department of Energy’s ENERGY STAR Calculator that provides ELFH values for seven Pennsylvania cities: Allentown, Erie, Harrisburg, Philadelphia, Pittsburgh, Scranton, and Williamsport. These cities provide a representative sample of the various climate and utility regions in Pennsylvania.

## Algorithms for Energy Efficient Measures

The following sections present measure-specific algorithms.

# Residential Measures

The method for determining residential high-efficiency cooling and heating equipment energy impact savings is based on algorithms that determine a central air conditioner’s 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 also include the calculation of additional energy and demand savings due to the required proper sizing of high-efficiency units.

The savings will be allocated to summer/winter and on-peak/off-peak time periods based on load shapes from measured data and industry sources. The allocation factors are documented below in the input value table.

The algorithms applicable for this program measure the energy savings directly related to the more efficient hardware installation. Estimates of energy savings due to the proper sizing of the equipment are also included.

The following is an explanation of the algorithms used and the nature and source of all required input data.

## Electric HVAC

### Algorithms

#### Central A/C and Air Source Heat Pump (ASHP) (High Efficiency Equipment Only)

ΔkWh = ΔkWhcool + ΔkWhheat

ΔkWhcool = CAPY/1000 X (1/SEERb – 1/SEERq ) X EFLH

ΔkWhheat (ASHP Only)= CAPY/1000 X (1/HSPFb - 1/HSPFq ) X EFLH

ΔkWpeak = CAPY/1000 X (1/EERb – 1/EERq ) X CF

#### Central A/C and ASHP (Proper Sizing)

ΔkWh = ΔkWhcool

ΔkWhcool = (CAPY/(SEERq X 1000)) X EFLH X PSF

ΔkWpeak = ((CAPY/(EERq X 1000)) X CF) X PSF

#### Central A/C and ASHP (Quality Installation)

ΔkWh = ΔkWhcool

ΔkWhcool = (((CAPY/(1000 X SEERq)) X EFLH) X (1-PSF) X QIF

ΔkWpeak = ((CAPY/(1000 X EERq)) X CF) X (1-PSF) X QIF

#### Central A/C and ASHP (Maintenance)

ΔkWh = ΔkWhcool

ΔkWhcool = ((CAPY/(1000 X SEERm)) X EFLH) X MF

ΔkWpeak = ((CAPY/(1000 X EERm)) X CF) X MF

#### Central A/C and ASHP (Duct Sealing)

ΔkWh = ΔkWhcool

ΔkWhcool = (CAPY/(1000 X SEERq)) X EFLH X DuctSF

ΔkWpeak = ((CAPY/(1000 X EERq)) X CF) X DuctSF

#### Ground Source Heat Pumps (GSHP)

ΔkWh = ΔkWhcool + ΔkWhheat

ΔkWhcool = CAPY/1000 X (1/SEERb – (1/(EERg X GSER))) X EFLH

ΔkWhheat = CAPY/1000 X (1/HSPFb – (1/(COPg X GSOP))) X EFLH

ΔkW = CAPY/1000 X (1/EERb – (1/(EERg X GSPK))) X CF

#### GSHP Desuperheater

ΔkWh = EDSH

ΔkW = PDSH

#### Furnace High Efficiency Fan

ΔkWh = ΔkWhcool + ΔkWhheat

ΔkWhcool = CFS

ΔkWhheat = ((Capyt X EFLHHT)/100,000 BTU/therm) X HFS

### Definition of Terms

CAPY = The cooling capacity (output in Btuh) of the central air conditioner or heat pump being installed. This data is obtained from the AEPS Application Form based on the model number or from EDC data gathering.

SEERb = Seasonal Energy Efficiency Ratio of the Baseline Unit.

SEERq = Seasonal Energy Efficiency Ratio of the qualifying unit being installed. This data is obtained from the AEPS Application Form or EDC’s data gathering based on the model number.

SEERm = Seasonal Energy Efficiency Ratio of the Unit receiving maintenance

EERb = Energy Efficiency Ratio of the Baseline Unit.

EERq = Energy Efficiency Ratio of the unit being installed. This data is obtained from the AEPS Application Form or EDC data gathering based on the model number.

EERg = EER of the ground source heat pump being installed. Note that EERs of GSHPs are measured differently than EERs of air source heat pumps (focusing on entering water temperatures rather than ambient air temperatures). The equivalent SEER of a GSHP can be estimated by multiplying EERg by 1.02.

GSER = The factor to determine the SEER of a GSHP based on its EERg.

EFLH = Equivalent Full Load Hours of operation for the average unit.

ESF = Energy Sizing Factor or the assumed saving due to proper sizing and proper installation.

PSF = Proper Sizing Factor or the assumed savings due to proper sizing of cooling equipment.

QIF = Quality Installation factor or assumed savings due to a verified quality installation of cooling equipment.

MF = Maintenance Factor or assumed savings due to completing recommended maintenance on installed cooling equipment.

DuctSF = Duct Sealing Factor or the assumed savings due to proper sealing of all cooling ducts.

CF = Coincidence Factor. The percentage of the total HVAC connected load that is on during electric system’s peak window.

DSF = Demand Sizing Factor or the assumed peak-demand capacity saved due to proper sizing and proper installation.

HSPFb = Heating Seasonal Performance Factor of the Baseline Unit.

HSPFq = Heating Seasonal Performance Factor of the unit being installed. This data is obtained from the AEPS Application Form or EDC’s data gathering.

COPg = Coefficient of Performance. This is a measure of the efficiency of a heat pump.

GSOP = Factor to determine the HSPF of a GSHP based on its COPg.

GSPK = Factor to convert EERg to the equivalent EER of an air conditioner to enable comparisons to the baseline unit.

EDSH = Assumed savings per desuperheater.[[6]](#footnote-6)

PDSH = Assumed peak-demand savings per desuperheater.

Capyq = Output capacity of the qualifying heating unit in BTUs/hour.

EFLHHT = Equivalent Full Load Hours of operation for the average heating unit.

HFS = Heating fan savings.

CFS = Cooling fan savings.

The 1000 used in the denominator is used to convert watts to kilowatts.

Table 2‑1: Residential Electric HVAC - References

| **Component** | **Type** | **Value** | **Sources** |
| --- | --- | --- | --- |
| CAPY | Variable | EDC Data Gathering | AEPS Application; EDC Data Gathering |
| SEER*b* | Fixed | Baseline = 13 | 1 |
| SEER*q* | Variable | EDC Data Gathering | AEPS Application; EDC Data Gathering |
| SEER*m* | Fixed | 10 | 15 |
| EER*b* | Fixed | Baseline = 11.3 | 2 |
| EER*q* | Fixed | (11.3/13) X SEERq | 2 |
| EER*g* | Variable | EDC Data Gathering | AEPS Application; EDC’s Data Gathering |
| EERm | Fixed | 8.69 | 19 |
| GSER | Fixed | 1.02 | 3 |
| EFLH | Fixed | Allentown Cooling = 784 Hours  Allentown Heating = 2,492 Hours  Erie Cooling = 482 Hours  Erie Heating = 2,901 Hours  Harrisburg Cooling = 929 Hours  Harrisburg Heating = 2,371 Hours  Philadelphia Cooling = 1,032 Hours  Philadelphia Heating = 2,328 Hours  Pittsburgh Cooling = 737 Hours  Pittsburgh Heating = 2,380 Hours  Scranton Cooling = 621 Hours  Scranton Heating = 2,532 Hours  Williamsport Cooling = 659 Hours  Williamsport Heating = 2,502 Hours | 4 |
| ESF | Fixed | 2.9% | 5 |
| PSF | Fixed | 5% | 14 |
| QIF | Fixed | 9.2% | 4 |
| MF | Fixed | 10% | 20 |
| DuctSF | Fixed | 18% | 14 |
| CF | Fixed | 70% | 6 |
| DSF | Fixed | 2.9% | 7 |
| HSPF*b* | Fixed | Baseline = 7.7 | 8 |
| HSPF*q* | Variable | EDC Data Gathering | AEPS Application; EDC’s Data Gathering |
| COP*g* | Variable | EDC Data Gathering | AEPS Application; EDC’s Data Gathering |
| GSOP | Fixed | 3.413 | 9 |
| GSPK | Fixed | 0.8416 | 10 |
| EDSH | Fixed | 1842 kWh | 11 |
| PDSH | Fixed | 0.34 kW | 12 |
| Cooling - CAC  Time Period Allocation Factors | Fixed | Summer/On-Peak 64.9%  Summer/Off-Peak 35.1%  Winter/On-Peak 0%  Winter/Off-Peak 0% | 13 |
| Cooling – ASHP  Time Period Allocation Factors | Fixed | Summer/On-Peak 59.8%  Summer/Off-Peak 40.2%  Winter/On-Peak 0%  Winter/Off-Peak 0% | 13 |
| Cooling – GSHP  Time Period Allocation Factors | Fixed | Summer/On-Peak 51.7%  Summer/Off-Peak 48.3%  Winter/On-Peak 0%  Winter/Off-Peak 0% | 13 |
| Heating – ASHP & GSHP  Time Period Allocation Factors | Fixed | Summer/On-Peak 0.0%  Summer/Off-Peak 0.0%  Winter/On-Peak 47.9%  Winter/Off-Peak 52.1% | 13 |
| GSHP Desuperheater Time Period Allocation Factors | Fixed | Summer/On-Peak 4.5%  Summer/Off-Peak 4.2%  Winter/On-Peak 43.7%  Winter/Off-Peak 47.6% | 13 |
| Capyq | Variable | EDC Data Gathering | AEPS Application; EDC’s Data Gathering |
| EFLHHFS | Fixed | Allentown Heating = 2,492 Hours  Erie Heating = 2,901 Hours  Harrisburg Heating = 2,371 Hours  Philadelphia Heating = 2,328 Hours  Pittsburgh Heating = 2,380 Hours  Scranton Heating = 2,532 Hours  Williamsport Heating = 2,502 | 4 |
| HFS | Fixed | 0.5 kWh | 17 |
| CFS | Fixed | 105 kWh | 18 |

**Sources:**

1. Federal Register, Vol. 66, No. 14, Monday, January 22, 2001/Rules and Regulations, p. 7170-7200.
2. Average EER for SEER 13 units.
3. VEIC estimate. Extrapolation of manufacturer data.
4. US Department of Energy, ENERGY STAR Calculator. Accessed 3/16/2009.
5. Xenergy, “New Jersey Residential HVAC Baseline Study”, (Xenergy, Washington, D.C., November 16, 2001).
6. Based on an analysis of six different utilities by Proctor Engineering.
7. Xenergy, “New Jersey Residential HVAC Baseline Study”, (Xenergy, Washington, D.C., November 16, 2001).
8. Federal Register, Vol. 66, No. 14, Monday, January 22, 2001/Rules and Regulations, p. 7170-7200.
9. Engineering calculation, HSPF/COP=3.413.
10. VEIC Estimate. Extrapolation of manufacturer data.
11. VEIC estimate, based on PEPCo assumptions.
12. VEIC estimate, based on PEPCo assumptions.
13. Time period allocation factors used in cost-effectiveness analysis.
14. 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.
15. Minimum Federal Standard for new Central Air Conditioners between 1990 and 2006.
16. NJ utility analysis of heating customers, annual gas heating usage.
17. Scott Pigg (Energy Center of Wisconsin), “Electricity Use by New Furnaces: A Wisconsin Field Study”, Technical Report 230-1, October 2003.
18. Ibid., p. 34. ARI charts suggest there are about 20% more full load cooling hours in NJ than southern WI. Thus, average cooling savings in NJ are estimated at 95 to 115.
19. The same EER to SEER ratio used for SEER 13 units applied to SEER 10 units. EERm = (11.3/13) \* 10.
20. VEIC estimate. Conservatively assumes less savings than for QIV because of the retrofit context.

## Electric Clothes Dryer with Moisture Sensor

|  |  |
| --- | --- |
| Measure Name | Electric Clothes Dryer with Moisture Sensor |
| Target Sector | Residential Establishments |
| Measure Unit | Clothes Dryer |
| Unit Energy Savings | 136 kWh |
| Unit Peak Demand Reduction | 0.047 kW |
| Measure Life | 11 years |

Clothes dryers with drum moisture sensors and associated moisture-sensing controls achieve energy savings over clothes dryers that do not have moisture sensors.

### Eligibility

This measure requires the purchase of an electric clothes dryer with a drum moisture sensor and associated moisture-sensing controls. ENERGY STAR currently does not rate or certify electric clothes dryers.

The TRM does not provide energy and demand savings for electric clothes dryers. The following sections detail how this measure’s energy and demand savings were determined.

### Algorithms

#### Energy Savings

The annual energy savings of this measure was determined to be **136 kWh**. This value was based on the difference between the annual estimated consumption of a standard unit without a moisture sensor as compared to a standard unit with a moisture sensor. This calculation is shown below:

ΔkWh = 905 - 769 = 136 kWh

The annual consumption of a standard unit without a moisture sensor (905 kWh) was based on 2008 estimates from Natural Resources Canada.[[7]](#footnote-7)

The annual consumption of a standard unit with a moisture sensor (769 kWh) was based on estimates from EPRI[[8]](#footnote-8) and the Consumer Energy Center[[9]](#footnote-9) that units equipped with moisture sensors (and energy efficient motors, EPRI) are about 15% more efficient than units without.

ΔkWh = 905 - (905 \* 0.15) = 769 kWh

#### Demand Savings

The demand savings of this measure was determined to be 0.346 kW. This value was based on the estimated energy savings divided by the estimated of annual hours of use. The estimated of annual hours of use was based on 392[[10]](#footnote-10) loads per year with a 1 hour dry cycle. This calculation is shown below:

ΔkW = 136 / 392 = 0.346 kW

The demand coincidence factor of this measure was determined to be **0.136**. This value was based on the assumption that 5 of 7 loads are run on peak days, 5 of 7 days the peak can occur on, 1.07 loads per day (7.5 per week, Reference #4), 45 minutes loads, and 3 available daily peak hours. This calculation is shown below:

CF = (5/7) \* (5/7) \* (1.07) \* (0.75) \* (1/3) = 0.136

The resulting demand savings based on this coincidence factor was determined to be **0.047 kW**. This calculation is shown below:

ΔkWpeak = 0.346 \* 0.136 = 0.047 kW

The assumptions used to determine this measure’s net demand value are listed below:

On-peak Annual Hours of Operation Assumption =  
66.2% (May 2009 TRM)

Summer Annual Hours of Operation Assumption =  
37.3% (May 2009 TRM)

### Measure Life

We have assumed the measure life to be that of a clothes washer. The Database for Energy Efficiency Resources estimates the measure life of clothes washers at 11 years.[[11]](#footnote-11)

### Evaluation Protocol

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

## Efficient Electric Water Heaters

|  |  |
| --- | --- |
| Measure Name | Efficient Electric Water Heaters |
| Target Sector | Residential Establishments |
| Measure Unit | Water Heater |
| Unit Energy Savings | 133 kWh for 0.93 Energy Factor  175 kWh for 0.94 Energy Factor  217 kWh for 0.95 Energy Factor |
| Unit Peak Demand Reduction | 0.0122 kW for 0.93 Energy Factor  0.0161 kW for 0.94 Energy Factor  0.0199 kW for 0.95 Energy Factor |
| Measure Life | 14 years |

Efficient electric water heaters utilize superior insulation to achieve energy factors of 0.93 or above. Standard electric water heaters have energy factors of 0.9.

### Eligibility

This protocol documents the energy savings attributed to electric water heaters with Energy Factor of 0.93 or greater. The target sector primarily consists of single-family residences.

### Algorithms

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

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 energy usage during noon and 8PM on summer weekdays to the total annual energy usage.

ΔkWpeak = EnergyToDemandFactor×Energy Savings

The Energy to Demand Factor is defined below:

The ratio of the average energy usage during noon and 8 PM on summer weekdays to the total annual energy usage is taken from load shape data collected for a water heater and HVAC demand response study for PJM[[12]](#footnote-12). The factor is constructed as follows:

1) Obtain the average kW, as monitored for 82 water heaters in PJM territory[[13]](#footnote-13), for each hour of the typical day summer, winter, and spring/fall days. Weight the results (91 summer days, 91 winter days, 183 spring/fall days) to obtain annual energy usage.

2) Obtain the average kW during noon to 8 PM on summer days from the same data.

3) The average noon to 8 PM demand is converted to average *weekday* noon to 8 PM demand through comparison of weekday and weekend monitored loads from the same PJM study[[14]](#footnote-14).

4) The ratio of the average weekday noon to 8 PM energy demand to the annual energy usage obtained in step 1. The resulting number, 0.00009172, is the *EnergyToDemandFactor.*

The load shapes (fractions of annual energy usage that occur within each hour) during summer week days are plotted in Figure 2‑1 below.



Figure 2‑1: Load shapes for hot water in residential buildings taken from a PJM study.

### Definition of Terms

The parameters in the above equation are listed in Table 2‑2below.

Table 2‑2: Calculation Assumptions

|  |  |  |  |
| --- | --- | --- | --- |
| Component | Type | Values | Source |
| EFbase , Energy Factor of baseline water heater | Fixed | 0.90 | 1 |
| EFproposed . Energy Factor of proposed efficient water heater | Variable | >=.93 | Program Design |
| HW , Hot water used per day in gallons | Fixed | 64.3 gallon/day | 2 |
| Thot , Temperature of hot water | Fixed | 120 °F | 3 |
| Tcold , Temperature of cold water supply | Fixed | 55 °F | 4 |
| EnergyToDemandFactor | Fixed | 0.00009172 | 1-4 |

**Sources:**

1. Federal Standards are 0.97 -0.00132 x Rated Storage in Gallons. For a 50-gallon tank this is approximately 0.90. “Energy Conservation Program: Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters” US Dept of Energy Docket Number: EE–2006–BT-STD–0129, p. 30
2. Energy Conservation Program for Consumer Products: Test Procedure for Water Heaters”, Federal Register / Vol. 63, No. 90, p. 25996
3. Many states have plumbing codes that limit shower and bathtub water temperature to 120 °F.
4. Mid-Atlantic TRM, footnote #24

### Deemed Savings

The deemed savings for the installation of efficient electric water heaters with various Energy Factors are listed below.

Table 2‑3: Energy Savings and Demand Reductions

|  |  |  |
| --- | --- | --- |
| Energy Factor | Energy Savings (kWh) | Demand Reduction (kW) |
| 0.95 | 217 | 0.0199 |
| 0.94 | 175 | 0.0161 |
| 0.93 | 133 | 0.0122 |

### Measure Life

According to an October 2008 report for the CA Database for Energy Efficiency Resources, an electric water heater’s lifespan is **14 years**[[15]](#footnote-15)

### Evaluation Protocols

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

## Electroluminescent Nightlight

Savings from installation of plug-in 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 “installation” 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.

### Algorithms

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

ΔkWh = ((Winc \* hinc) – (WNL \* hNL)) \* 365 / 1000 \* ISRNL

ΔkWpeak = 0 (assumed)

Deemed Energy Savings = ((7\*12)–(0.03\*24))\*365/1000\*0.84 = 25.53 kWh

(Rounded to 26 kWh)

### Definition of Terms

WNL = Watts per electroluminescent nightlight

Winc = Watts per incandescent nightlight

hNL = Average hours of use per day per electroluminescent nightlight

hinc = Average hours of use per day per incandescent nightlight

ISRNL = In-service rate per electroluminescent nightlight, to be revised through surveys

Table 2‑4: Electroluminescent Nightlight - References

|  |  |  |  |
| --- | --- | --- | --- |
| Component | Type | Value | Sources |
| WNL | Fixed | 0.03 | 1 |
| Winc | Fixed | 7 | 2 |
| hNL | Fixed | 24 | 3 |
| hinc | Fixed | 12 | 2 |
| ISRNL | Variable | 0.84 | PA CFL ISR value |
| Measure Life (EUL) | Fixed | 8 | 4 |

**Sources:**

1. Limelite Equipment Specification. Personal Communication, Ralph Ruffin, EI Products, 512-357-2776/ ralph@limelite.com.
2. Southern California Edison Company, “LED, Electroluminescent & Fluorescent Night Lights”, Work Paper WPSCRELG0029 Rev. 1, February 2009, p. 2 & p. 3.
3. As these nightlights are plugged in without a switch, the assumption is they will operate 24 hours per day.
4. Southern California Edison Company, “LED, Electroluminescent & Fluorescent Night Lights”, Work Paper WPSCRELG0029 Rev. 1, February 2009, p. 2 & p. 3.

## Furnace Whistle

|  |  |
| --- | --- |
| Measure Name | Furnace Whistle |
| Target Sector | Residential Establishments |
| Measure Unit | Furnace whistle (promote regular filter change-out) |
| Unit Energy Savings | Varies |
| Unit Peak Demand Reduction | 0 |
| Measure Life | 15 |

Savings estimates are based on reduced furnace blower fan motor power requirements for winter and summer use of the blower fan motor. This furnace whistle measure applies to central forced-air furnaces, central AC and heat pump systems. Each table in this protocol (2 through 6) presents the annual kWh savings for each major urban center in Pennsylvania based on their respective estimated full load hours (EFLH). Where homes do not have A/C or heat pump systems for cooling, only the annual heating savings will apply.

### Algorithms

ΔkWh = MkW X EFLH X EI X ISR

ΔkWpeak = 0

### Definition of Terms

MkW = Average motor full load electric demand (kW)

EFLH = Estimated Full Load Hours (Heating and Cooling) for the EDC region.

EI – Efficiency Improvement

ISR = In-service Rate

Table 2‑5: Furnace Whistle - References

|  |  |  |  |
| --- | --- | --- | --- |
| Component | Type | Value | Sources |
| MkW | Fixed | 0.5 kW | 1, 2 |
| EFLH | Fixed | 3117 | TRM Table 2-1 |
| EI | Fixed | 15% | 3 |
| ISR | Fixed | .474 | 4 |
| Measure EUL | Fixed | 15 | 15 |

**Sources:**

1. The Sheltair Group HIGH EFFICIENCY FURNACE BLOWER MOTORS MARKET BASELINE ASSESSMENT provided BC Hydro cites Wisconsin Department of Energy [2003] analysis of electricity use from furnaces (see Blower Motor Furnace Study). The attached Blower Motor Study Table 17 (page 38) shows 505 Watts for PSC motors in space heat mode; last sentence of the second paragraph on page 38 states: " . . . multi-speed and single speed furnaces motors drew between 400 and 800 Watts, with 500 being the average value."Submitted to: Fred Liebich BC Hydro Tel. 604 453-6558 Email: fred.liebich@bchydro.com, March 31, 2004.   
     
   500 watts (.5 kW) times Pittsburgh heating and cooling FLH of 3117 = 1,558.5 kWh (we would expect Pittsburgh to have greater heating loads than the US generally, as referred to by the ACEEE through the Appliance Standards Awareness Project "Furnace fan systems blow warmed air through a home, using approximately 1,000 kilowatt hours of electricity per year . . . An estimated 95% of all residential air handlers use relatively inefficient permanent split capacitor (PSC) fan motors."
2. FSEC, “Furnace Blower Electricity: National and Regional Savings Potential”, page 98 - Figure 1 (assumptions provided in Table 2, page 97) for a blower motor applied in prototypical 3-Ton HVAC for both PSC and BPM motors, at external static pressure of 0.8 in. w.g., blower motor Watt requirement is 452 Watts.
3. 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.
4. The In Service Rate is taken from an SCE Evaluation of 2000-2001 Schools Programs, by Ridge & Associates 8-31-2001, Table 5-19 Installation rates, Air Filter Alarm 47.4%.

Table 2‑6: EFLH for various cities in Pennsylvania (TRM Data)

|  |  |  |  |
| --- | --- | --- | --- |
| **City** | **Cooling load hours** | **Heating load hours** | **Total load hours** |
| Pittsburgh | 737 | 2380 | 3117 |
| Philadelphia | 1032 | 2328 | 3360 |
| Allentown | 784 | 2492 | 3276 |
| Erie | 482 | 2901 | 3383 |
| Scranton | 621 | 2532 | 3153 |
| Harrisburg | 929 | 2371 | 3300 |
| Williamsport | 659 | 2502 | 3161 |

The deemed savings are calculated assuming that an average furnace motor is 500 watts (.5 kW), using the Pittsburgh region as an example, furnace operating hours for Pittsburgh is 2380 hrs/year and cooling system operation is 737 hours/year. A 15% decrease in efficiency is attributed to the dirty furnace filters. The EFLH will depend on the EDC region in which the measure is installed.

Without including correction for in-service rates, the 15% estimated blower fan annual savings of 178.5 kWh is 2.2% of average customer annual energy consumption of 8,221 kWh. The following table presents the assumptions and the results of the deemed savings calculations for each EDC.

Table 2‑7: Assumptions and Results of Deemed Savings Calculations (Pittsburgh, PA)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Blower Motor kW** | **Pittsburgh EFLH** | **Clean Annual kWh** | **Dirty Annual kWh** | **Furnace Whistle Savings** | **ISR** | **Estimated Savings (kWh)** |
| Heating | 0.5 | 2380 | 1190 | 1368.5 | 178.5 | 0.474 | 85 |
| Cooling | 0.5 | 737 | 369 | 424 | 55 | 0.474 | 26 |
| Total |  | 3117 | 1559 | 1792 | 234 |  | 111 |

Table 2‑8: Assumptions and Results of Deemed Savings Calculations (Philadelphia, PA)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Blower Motor kW** | **Philadelphia EFLH** | **Clean Annual kWh** | **Dirty Annual kWh** | **Furnace Whistle Savings** | **ISR** | **Estimated Savings (kWh)** |
| Heating | 0.5 | 2328 | 1164 | 1339 | 175 | 0.474 | 83 |
| Cooling | 0.5 | 1032 | 516 | 593 | 77 | 0.474 | 37 |
| Total |  | 3360 | 1680 | 1932 | 252 |  | 119 |

Table 2‑9: Assumptions and Results of Deemed Savings Calculations (Harrisburg, PA)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Blower Motor kW** | **Harrisburg EFLH** | **Clean Annual kWh** | **Dirty Annual kWh** | **Furnace Whistle Savings** | **ISR** | **Estimated Savings (kWh)** |
| Heating | 0.5 | 2371 | 1185.5 | 1363 | 178 | 0.474 | 84 |
| Cooling | 0.5 | 929 | 465 | 534 | 70 | 0.474 | 33 |
| Total |  | 3300 | 1650 | 1898 | 248 |  | 117 |

Table 2‑10: Assumptions and Results of Deemed Savings Calculations (Erie, PA)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Blower Motor kW** | **Erie EFLH** | **Clean Annual kWh** | **Dirty Annual kWh** | **Furnace Whistle Savings** | **ISR** | **Estimated Savings (kWh)** |
| Heating | 0.5 | 2901 | 1450.5 | 1668 | 217.5 | 0.474 | 103 |
| Cooling | 0.5 | 482 | 241 | 277 | 36 | 0.474 | 17 |
| Total |  | 3383 | 1692 | 1945 | 254 |  | 120 |

Table 2‑11: Assumptions and Results of Deemed Savings Calculations (Allentown, PA)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Blower Motor kW** | **Allentown EFLH** | **Clean Annual kWh** | **Dirty Annual kWh** | **Furnace Whistle Savings** | **ISR** | **Estimated Savings (kWh)** |
| Heating | 0.5 | 2492 | 1246 | 1433 | 187 | 0.474 | 89 |
| Cooling | 0.5 | 784 | 392 | 451 | 59 | 0.474 | 28 |
| Total |  | 3276 | 1638 | 1884 | 246 |  | 116 |

## Heat Pump Water Heaters

|  |  |
| --- | --- |
| Measure Name | Heat Pump Water Heaters |
| Target Sector | Residential Establishments |
| Measure Unit | Water Heater |
| Unit Energy Savings | 2,202, 1,914 kWh for 2.3, 2.0 Energy Factor |
| Unit Peak Demand Reduction | 0.202, 0.175 kW for 2.3,2.0 Energy Factor |
| Measure Life | 14 years |

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 fuels) burners or electric resistance heating coils to heat the water.

### Eligibility

This protocol documents the energy savings attributed to heat pump water heaters with Energy Factors of 2.0 to 2/3. 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 energy savings are obtained through the following formula:

ΔkWh =((EFBase­)-1 - (EFProposed × FDerate)-1 )×HW×365×8.3×(Thot –Tcold)×3413-1

For heat pump water heaters, demand savings result primarily from a reduced connected load. The demand reduction is taken as the annual energy savings multiplied by the ratio of the average energy usage during noon and 8PM on summer weekdays to the total annual energy usage.

ΔkWpeak =EnergyToDemandFactor×Energy Savings

The Energy to Demand Factor is defined below:

The ratio of the average energy usage during noon and 8 PM on summer weekdays to the total annual energy usage is taken from load shape data collected for a water heater and HVAC demand response study for PJM[[16]](#footnote-16). The factor is constructed as follows:

1. Obtain the average kW, as monitored for 82 water heaters in PJM territory[[17]](#footnote-17), for each hour of the typical day summer, winter, and spring/fall days. Weight the results (91 summer days, 91 winter days, 183 spring/fall days) to obtain annual energy usage.
2. Obtain the average kW during noon to 8 PM on summer days from the same data.
3. The average noon to 8 PM demand is converted to average *weekday* noon to 8 PM demand through comparison of weekday and weekend monitored loads from the same PJM study[[18]](#footnote-18).
4. The ratio of the average weekday noon to 8 PM energy demand to the annual energy usage obtained in step 1. The resulting number, 0.00009172, is the *EnergyToDemandFactor.*

The load shapes (fractions of annual energy usage that occur within each hour) during summer week days are plotted for three business types in Figure 2‑2 below.



Figure 2‑2: Load shapes for hot water in residential buildings taken from a PJM study.

### Definition of Terms

The parameters in the above equation are listed in Table 2‑12

Table 2‑12: Calculation Assumptions

|  |  |  |  |
| --- | --- | --- | --- |
| **Component** | **Type** | **Values** | **Source** |
| EFbase , Energy Factor of baseline water heater | Fixed | 0.90 | 4 |
| EFproposed . Energy Factor of proposed efficient water heater | Variable | >=2.0 | Program Design |
| HW , Hot water used per day in gallons | Fixed | 64.3 gallon/day | 5 |
| Thot , Temperature of hot water | Fixed | 120 °F | 6 |
| Tcold , Temperature of cold water supply | Fixed | 55 °F | 7 |
| FDerate, COP De-rating factor | Fixed | 0.84 | 8, and discussion below |
| EnergyToDemandFactor | Fixed | 0.00009172 | 1-4 |

*Source:*

1. Deemed Savings Estimates for Legacy Air Conditioning and Water Heating Direct Load Control Programs in PJM Region. The report can be accessed online: http://www.pjm.com/~/media/committees-groups/working-groups/lrwg/20070301/20070301-pjm-deemed-savings-report.ashx ,
2. The average is over all 82 water heaters and over all summer, spring/fall, or winter days. The load shapes are taken from the fourth columns, labeled “Mean”, in tables 14,15, and 16 in pages 5-31 and 5-32
3. The 5th column, labeled “Mean” of Table 18 in page 5-34 is used to derive an adjustment factor that scales average summer usage to summer weekday usage. The conversion factor is 0.925844. A number smaller than one indicates that for residential homes, the hot water usage from noon to 8 PM is slightly higher is the weekends than on weekdays.
4. Federal Standards are 0.97 -0.00132 x Rated Storage in Gallons. For a 50-gallon tank this is approximately 0.90. “Energy Conservation Program: Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters” US Dept of Energy Docket Number: EE–2006–BT-STD–0129, p. 30
5. “Energy Conservation Program for Consumer Products: Test Procedure for Water Heaters”, Federal Register / Vol. 63, No. 90, p. 25996 The temperatures are at 67.5 °F drybulb and 50% RH, which is °F 67.5 wetbulb.
6. Many states have plumbing codes that limit shower and bathtub water temperature to 120 °F.
7. Mid-Atlantic TRM, footnote #24
8. The performance curve is adapted from Table 1 in http://wescorhvac.com/HPWH%20design%20details.htm#Single-stage%20HPWHs

The performance curve depends on other factors, such as hot water set point. Our adjustment factor of 0.84 is a first order approximation based on the information available in literature.

### Heat Pump Water Heater Energy Factor

The Energy Factors are determined from a DOE testing procedure that is carried out at 56 °F wetbulb temperature. However, the average wetbulb temperature in PA is closer to 45 °F[[19]](#footnote-19). The heat pump performance is temperature dependent. The plot below shows relative coefficient of performance (COP) compared to the COP at rated conditions[[20]](#footnote-20). According to the linear regression shown on the plot, the COP of a heat pump water heater at 45 °F is 0.84 of the COP at nominal rating conditions. As such, a de-rating factor of 0.84 is applied to the nominal Energy Factor of the Heat Pump water heaters.



Figure 2‑3: Dependence of COP on outdoor wetbulb temperature.

### Deemed Savings

The deemed savings for the installation of heat pump electric water heaters with various Energy Factors are listed below.

Table 2‑13: Energy Savings and Demand Reductions

|  |  |  |
| --- | --- | --- |
| **Energy Factor** | **Energy Savings (kWh)** | **Demand Reduction (kW)** |
| 2.3 | 2202 | 0.202 |
| 2.0 | 1914 | 0.175 |

### Measure Life

According to an October 2008 report for the CA Database for Energy Efficiency Resources, an electric water heater’s lifespan is **14 years**[[21]](#footnote-21).

### Evaluation Protocols

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

## Home Audit Conservation Kits

|  |  |
| --- | --- |
| Measure Name | Home Audit Conservation Kits |
| Target Sector | Residential Establishments |
| Measure Unit | One Energy Conservation Kit |
| Unit Energy Savings | Variable based on ISR |
| Unit Peak Demand Reduction | Variable based on ISR |
| Measure Life | 8.1 years |

Energy Conservation kits consisting of four CFLs, four faucet aerators, two smart power strips and two LED night lights are sent to participants of the Home Energy Audit programs. This document quantifies the energy savings associated with the energy conservation kits.

### Eligibility

The conservation kits are sent to residential customers only.

### Algorithms

The following algorithms are adopted from the Pennsylvania Public Utilities Commission’s Technical Reference Manual (TRM). The demand term has been modified to include the installation rate, which was inadvertently omitted in the TRM.

ΔkWh = NCFL × ((CFLwatts × (CFLhours × 365))/1000) × ISRCFL+ NAerator × SavingsAerator  × ISRAerator+ NSmartStrip × SavingsSmartStrip  × ISRSmartStrip+ NNiteLites × SavingsNiteLite  × ISRNiteLite

ΔkWpeak = NCFL × (CFLwatts/1000) × CF× ISRCFL  
+ NAerator × DemandReductionAerator  × ISRAerator    
+ NSmartStrip × DemandReductionSmartStrip  × ISRSmartStrip    
+ NNiteLite × DemandReductionNiteLite  × ISRNiteLite

### Definition of Terms

The parameters in the above equations are listed in Table 2‑14.

Table 2‑14: Calculation Assumptions

| **Component** | **Value** | **Source** |
| --- | --- | --- |
| NCFL: Number of CFLs per kit | 4 | Program design[[22]](#footnote-22) |
| CFLWatts, Difference between supplanted and efficient luminaire wattage (W) | 47 | Program Design |
| ISR , In Service Rate or Percentage of units rebated that actually get used | variable | EDC Data Gathering |
| CFLhours, hours of operation per day | 1.9 | 1 |
| CF , CFL Summer Demand Coincidence Factor | 0.05 | PA TRM Table 4-3 |
| NAerator: Number of faucet aerators per kit | 4 | Program design |
| NSmartStrip: Number of Smart Strips per kit | 2 | Program design |
| SavingsAerator (kWh) | 61 | FE Interim TRM |
| DemandReductionAerator (kW) | .006 | FE Interim TRM |
| ISRAerator | variable | EDC Data Gathering[[23]](#footnote-23) |
| SavingsSmartStrip (kWh) | 184 | FE Interim TRM |
| DemandReductionSmartStrip (kW) | .013 | FE Interim TRM |
| ISRSmartStrip | variable | EDC Data Gathering |
| SavingsNiteLite (kWh) | 26.3 | PA Interim TRM[[24]](#footnote-24) |
| DemandReductionNiteLite (kW) | 0 | PA Interim TRM |
| ISRNiteLite | variable | EDC Data Gathering |
| NNiteLite | 2 | Program Design |

**Sources:**

1. United States Department of Energy, *Energy Star CFL Market Profile: Data Trends and Market Insights*. Prebared by D&R International, Ltd.: September 2010; pg. 24.

### Partially Deemed Savings

The deemed energy and demand savings per kit are dependent on the measured ISRs for the individual kit components.

### Measure Life

The measure life for CFLs is **6.4 years** according to ENERGY STAR[[25]](#footnote-25). The measure life of the Smart Strips are **5 years,** and the measure life of the faucet aerators are **12 years.** The weighted (by energy savings) average life of the energy conservation kit is **8.1 years**.

### Evaluation Protocols

The most appropriate evaluation protocol for this measure is verification of installation coupled with assignment of stipulated energy savings. The fraction of cases where a given measure has supplanted the baseline equipment constitutes the ISR for the measure.

## LED Nightlight

|  |  |
| --- | --- |
| Measure Name | LED Nightlight |
| Target Sector | Residential Establishments |
| Measure Unit | LED Nightlight |
| Unit Energy Savings | 22kWh |
| Unit Peak Demand Reduction | 0kW |
| Measure Life | 8 years |

### Algorithms

Assumes a 1 Watt LED nightlight replaces a 7 Watt incandescent nightlight. The nightlight is assumed to operate 12 hours per day, 365 days per year; estimated useful life is 8 years (manufacturer cites 11 years 100,000 hours). Savings are calculated using the following algorithm:

ΔkWh = ((NLwatts X (NLhours X 365))/1000) x ISR

ΔkWpeak = 0 (assumed)

### Definition of Terms

NLwatts = Average delta watts per LED Nightlight

NLhours = Average hours of use per day per Nightlight

ISR = In-service rate

(The EDC EM&V contractors will reconcile the ISR through survey activities)

Table 2‑15: LED Nightlight - References

|  |  |  |  |
| --- | --- | --- | --- |
| **Component** | **Type** | **Value** | **Sources** |
| NLwatts | Fixed | 6 Watts | Data Gathering |
| NLhours | Fixed | 12 | 1 |
| ISR | Fixed | 0.84 | PA CFL ISR value |
| EUL | Fixed | 8 years | 1 |

**Sources:**

1. Southern California Edison Company, “LED, Electroluminescent & Fluorescent Night Lights”, Work Paper WPSCRELG0029 Rev. 1, February 2009, p. 2 & p. 3.

### Deemed Savings

ΔkWh = ((6 X (12 X 365))/1000) X 0.84 = 22.07 kWh (rounded to 22kWh)

## Low Flow Faucet Aerators

|  |  |
| --- | --- |
| Measure Name | Low Flow Faucet Aerators |
| Target Sector | Residential |
| Measure Unit | Aerator |
| Unit Energy Savings | 61 kWh |
| Unit Peak Demand Reduction | 0.056 kW |
| Measure Life | 12 years |

### Introduction

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.

### Measure Description

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

### Measure Applicability

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.

### Savings Calculations

The energy savings and demand reduction obtain through the following calculations:

ΔkWh = ISR × [(FB­ – FP) ×TPerson-Day×NPersons×365×ΔTL×UH×UE×Eff-1] / (F/home)

ΔkWpeak  = ISR ×Energy Impact × FED

The Energy to Demand Factor, FED, is defined below:

EnergyToDemandFactor = AverageUsageSummerWDNoon-8PM  / AnnualEnergyUsage

The ratio of the average energy usage during noon and 8 PM on summer weekdays to the total annual energy usage is taken from load shape data collected for a water heater and HVAC demand response study for PJM[[26]](#footnote-26). The load shapes (fractions of annual energy usage that occur within each hour) during summer week days are plotted for three business types in Figure 2‑4 below.



Figure 2‑4: Load shapes for hot water in residential buildings taken from a PJM study.

### Definition of Terms

The parameters in the above equation are defined in Table 2‑16.

Table 2‑16: Calculation Assumptions

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Parameter** | **Description** | **Type** | **Value** | **Source** |
| **FB** | Average Baseline Flow Rate of aerator (GPM) | Fixed | 2.2 | 2 |
| **FP** | Average Post Measure Flow Rate of Sprayer (GPM) | Fixed | 1.5 | 2 |
| **TPerson-Day** | Average time of hot water usage per person per day (minutes) | Fixed | 4.95 | 3 |
| **NPer** | Average number of persons per household | Fixed | 2.48 | 4 |
| **ΔT** | Average temperature differential between hot and cold water (ºF) | Fixed | 25 | 5 |
| **UH** | Unit Conversion: 8.33BTU/(Gallons-°F) | Fixed | 8.33 | Convention |
| **UE** | Unit Conversion: 1 kWh/3413 BTU | Fixed | 1/3413 | Convention |
| **Eff** | Efficiency of Electric Water Heater | Fixed | 0.90 | 2 |
| **FED** | Energy To Demand Factor | Fixed | 0.00009172 | 1 |
| **F/home** | Average number of faucets in the home | Fixed | 3.5 | 6 |
| **ISR** | In Service Rate | Variable | Variable | EDC Data Gathering |

**Sources:**

1. Deemed Savings Estimates for Legacy Air Conditioning and Water Heating Direct Load Control Programs in PJM Region. The report can be accessed online: http://www.pjm.com/~/media/committees-groups/working-groups/lrwg/20070301/20070301-pjm-deemed-savings-report.ashx The summer load shapes are taken from tables 14,15, and 16 in pages 5-31 and 5-32, and table 18 in page 5-34 is used to derive an adjustment factor that scales average summer usage to summer weekday usage. The factor is constructed as follows: 1) Obtain the average kW, as monitored for 82 water heaters in PJM territory , for each hour of the typical day summer, winter, and spring/fall days. Weight the results (91 summer days, 91 winter days, 183 spring/fall days) to obtain annual energy usage. 2) Obtain the average kW during noon to 8 PM on summer days from the same data. 3) The average noon to 8 PM demand is converted to average weekday noon to 8 PM demand through comparison of weekday and weekend monitored loads from the same PJM study. 4) The ratio of the average weekday noon to 8 PM energy demand to the annual energy usage obtained in step 1. The resulting number, 0.00009172, is the *EnergyToDemandFactor*.
2. Public Service Commission of Wisonsin Focus on Energy Evaluation Default Deemed Savings Review, June 2008. http://www.focusonenergy.com/files/Document\_Management\_System/Evaluation/acesdeemedsavingsreview\_evaluationreport.pdf
3. EPA, Water-Efficient Single-Family New Home Specification, May 14, 2008.
4. Pennsylvania Census of Population 2000: http://censtats.census.gov/data/PA/04042.pdf
5. Vermont TRM No. 2008-53, pp. 273-274, 337, 367-368, 429-431.
6. East Bay Municipal Utility District; "Water Conservation Market Penetration Study" http://www.ebmud.com/sites/default/files/pdfs/market\_penetration\_study\_0.pdf

### Deemed Savings

The deemed energy savings for the installation of a low flow aerator compared to a standard aerator is **ISR ×** **61 kWh/year** with a demand reduction of **ISR ×** **0.056 kW,** with ISR determined through data collection.

### Measure Life

The measure life is 12 years, according to California’s Database of Energy Efficiency Resources (DEER).

### Evaluation Protocols

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

## Low Flow Showerheads

|  |  |
| --- | --- |
| Measure Name | Low Flow Showerheads |
| Target Sector | Residential Establishments |
| Measure Unit | Water Heater |
| Unit Energy Savings | Partially Deemed  461 kWh for 1.5 GPM showerhead |
| Unit Peak Demand Reduction | Partially Deemed  0.042 kW for 1.5 GPM showerhead |
| Measure Life | 9 years |

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 residences.

### Algorithms

The annual energy savings are obtained through the following formula:

ΔkWh = ((((GPMbase - GPMlow) / GPMbase) \* people \* gals/day \* days/year) / showers) \* lbs/gal \* (TEMPft - TEMPin) / 1,000,000) / EF / 0.003412

ΔkWpeak = ΔkWh \* EnergyToDemandFactor

### Definition of Terms

GPMbase =Gallons per minute of baseline showerhead = 2.5 GPM[[27]](#footnote-27)

GPMlow =Gallons per minute of low flow showerhead

people =Average number of people per household = 2.48[[28]](#footnote-28)

gals/day =Average gallons of hot water used by shower per day = 11.6[[29]](#footnote-29)

days/year =Number of days per year = 365

showers =Average number of showers in the home = 1.6[[30]](#footnote-30)

lbs/gal =Pounds per gallon = 8.3

TEMPft =Assumed temperature of water used by faucet = 120° F[[31]](#footnote-31)

TEMPin =Assumed temperature of water entering house = 55° F[[32]](#footnote-32)

EF =Recovery efficiency of electric hot water heater = 0.90[[33]](#footnote-33)

0.003412 =Constant to converts MMBtu to kWh

EnergyToDemandFactor=Summer peak coincidence factor for measure = 0.00009172[[34]](#footnote-34)

ΔkWh =Annual kWh savings = 461kWh per fixture installed, for low flow showerhead with 1.5 GPM

ΔkW =Summer peak kW savings =0.042 kW.

The demand reduction is taken as the annual energy savings multiplied by the ratio of the average energy usage during noon and 8PM on summer weekdays to the total annual energy usage. The Energy to Demand Factor is defined as:

The ratio of the average energy usage during noon and 8 PM on summer weekdays to the total annual energy usage is taken from load shape data collected for a water heater and HVAC demand response study for PJM[[35]](#footnote-35). The factor is constructed as follows:

1. Obtain the average kW, as monitored for 82 water heaters in PJM territory, for each hour of the typical day summer, winter, and spring/fall days. Weight the results (91 summer days, 91 winter days, 183 spring/fall days) to obtain annual energy usage.
2. Obtain the average kW during noon to 8 PM on summer days from the same data.
3. The average noon to 8 PM demand is converted to average *weekday* noon to 8 PM demand through comparison of weekday and weekend monitored loads from the same PJM study,
4. The ratio of the average weekday noon to 8 PM energy demand to the annual energy usage obtained in step 1. The resulting number, 0.00009172, is the Energy to Demand Factor, or Coincidence Factor.

The load shapes (fractions of annual energy usage that occur within each hour) during summer week days are plotted in below.



Figure 2‑5: Load shapes for hot water in residential buildings taken from a PJM study.

### Deemed Savings

ΔkWh = 461 kWh (assuming 1.5 GPM showerhead)

ΔkW = 0.042 kW (assuming 1.5 GPM showerhead)

### Measure Life

According to the Efficiency Vermont Technical Reference User Manual (TRM), the expected measure life is **9 years[[36]](#footnote-36)**.

### Evaluation Protocols

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

## Programmable Setback Thermostat

|  |  |
| --- | --- |
| Measure Name | Programmable Setback Thermostat |
| Target Sector | Residential Establishments |
| Measure Unit | Programmable Setback Thermostat |
| Unit Energy Savings | *Varies* |
| Unit Peak Demand Reduction | *Varies* |
| Measure Life | 11 |

Programmable thermostats are used to control heating and/or cooling loads in residential buildings by setting back the temperature during specified unoccupied and nighttime hours. These units are expected to replace a manual thermostat and the savings assume an existing ducted HVAC system; however, the option exists to input higher efficiency levels if coupled with a newer unit. The EDCs will strive to educate the customers to use manufacturer default setback and setup settings.

### Algorithms

ΔkWh = (CAPCOOL X (12/(EERCOOL x Effduct) X EFLH X ESFCOOL)   
+ (CAPHEAT X (1/(EERHEAT X 3.41 X Effduct)) X EFLH X ESFHEAT)

ΔkWpeak = 0

### Definition of Terms

CAPCOOL = capacity of the air conditioning unit in tons, based on nameplate capacity

EERCOOL,HEAT = Seasonally averaged efficiency rating of the baseline unit . For units > 65,000

BTUh, refer to Commercial application.

Effduct = duct system efficiency

ESFCOOL,HEAT = energy savings factor for cooling and heating, respectively

CAPHEAT = nominal rating of the heating capacity of the electric furnace (kBtu/hr)

EFLH = equivalent full load hours

Table 2‑17: Residential Electric HVAC - References

|  |  |  |  |
| --- | --- | --- | --- |
| **Component** | **Type** | **Value** | **Sources** |
| CAPCOOL | Variable | Nameplate data | EDC Data Gathering |
| Default: 3 tons | 1 |
| EERCOOL, HEAT | Variable | Nameplate data | EDC Data Gathering |
| Default: Cooling = 10 SEER  Default: Heating = 1.0 (electric furnace COP) | 2 |
| Effduct | Fixed | 0.8 | 3 |
| ESFCOOL | Fixed | 2% | 4 |
| ESFHEAT | Fixed | 3.6% | 5 |
| CAPHEAT | Variable | Nameplate Data | EDC Data Gathering |
| Default: 36 kBTU/hr | 1 |
| EFLH | Fixed | Allentown Cooling = 784 Hours  Allentown Heating = 2,492 Hours  Erie Cooling = 482 Hours  Erie Heating = 2,901 Hours  Harrisburg Cooling = 929 Hours  Harrisburg Heating = 2,371 Hours  Philadelphia Cooling = 1,032 Hours  Philadelphia Heating = 2,328 Hours  Pittsburgh Cooling = 737 Hours  Pittsburgh Heating = 2,380 Hours  Scranton Cooling = 621 Hours  Scranton Heating = 2,532 Hours  Williamsport Cooling = 659 Hours  Williamsport Heating = 2,502 Hours | 6 |
| Measure Life (EUL) | Fixed | 11 | 7 |

**Sources:**

1. Average size of residential air conditioner or furnace.
2. Minimum Federal Standard for new Central Air Conditioners/Heat Pumps between 1990 and 2006.
3. New York Standard Approach for Estimating Energy Savings from Energy Efficiency Measures in Commercial and Industrial Programs, September 1, 2009.
4. DEER 2005 cooling savings for climate zone 16, assumes a variety of thermostat usage patterns.
5. “Programmable Thermostats. Report to KeySpan Energy Delivery on Energy Savings and Cost Effectiveness”, GDS Associates, Marietta, GA. 2002. 3.6% factor includes 56% realization rate.
6. US Department of Energy, ENERGY STAR Calculator. Accessed 3/16/2009.
7. New York Standard Approach for Estimating Energy Savings from Energy Efficiency Measures in Commercial and Industrial Programs, September 1, 2009, based on DEER.

## Room AC (RAC) Retirement

|  |  |
| --- | --- |
| Measure Name | Room A/C Retirement |
| Target Sector | Residential Establishments |
| Measure Unit | Room A/C |
| Unit Energy Savings | *Varies* |
| Unit Peak Demand Reduction | *Varies* |
| Measure Life | 4 |

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. Furthermore, 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). The hypothetical nature of this measure implies a significant amount of risk and uncertainty in the energy and demand impact estimates.

### Algorithms

The energy and demand impacts are based on corrected ENERGY STAR calculator EFLH values for the ES Room AC measure as shown in , and an assumed RAC size of 10,000 Btuh. 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*.

ΔkWh = EFLHRAC \* (CAPY/1000) \* (1/EERRetRAC)

ΔkWpeak  = (CAPY/1000) \* (1/EERRetRAC) \* CFRAC

#### Replacement and Recycling

It is not apparent that any EDCs are currently implementing the program in this manner, but the algorithms are included here for completeness. 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.

ΔkWh = EFLHRAC \* (CAPY/1000) \* (1/EERRetRAC – 1/EERES)

ΔkWpeak  = (CAPY/1000) \* (1/EERRetRAC – 1/EERES) \* CFRAC

**After the RUL for (EUL-RUL) years:** The baseline EER would revert to the minimum Federal appliance standard EER.

ΔkWh = EFLHRAC \* (CAPY/1000) \* (1/EERb – 1/EERES)

ΔkWpeak  = (CAPY/1000) \* (1/EERb – 1/EERES) \* CFRAC

### Definition of Terms

EFLHRAC = The 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.).

Correction of ES RAC EFLH Values:

An additional step is required to determine EFLHRAC values. Normally, the EFLH values from the ENERGY STAR Room AC Calculator would be used directly. However, the current (July 2010) ES Room AC calculator EFLHs are too high because they are the same as those used for the Central AC calculator, whereas RAC full load hours should be much lower than for a CAC system. As such, the ES EFLH values were corrected as follows:

EFLHRAC = EFLHES-RAC \* AF

Where:

EFLH ES-RAC = Full load hours from the ENERGY STAR Room AC Calculator

AF = Adjustment factor for correcting current ES Room AC calculator EFLHs.

Note that when the ENERGY STAR RAC calculator values are eventually corrected in the ES calculator, the corrected EFLHES-RAC values can be used directly and this adjustment step can be ignored and/or deleted.

CAPY = Rated cooling capacity (size) of the RAC in Btuh.

EERRetRAC = The Energy Efficiency Ratio of the unit being retired-recycled expressed as kBtuh/kW.

EERb = The Energy Efficiency Ratio of a RAC that just meets the minimum federal appliance standard efficiency expressed as kBtuh/kW.

EERES = The Energy Efficiency Ratio for an ENERGY STAR RAC expressed as kBtuh/kW.

CFRAC = Demand Coincidence Factor which is 0.58 from the 2010 PA TRM for the “ENERGY STAR Room Air Conditioner” measure.

1000 = Conversion factor, convert capacity from Btuh to kBtuh (1000 Btuh/kBtuh)

### Savings Assumptions & References

Table 2‑18: Room AC Retirement - References

|  |  |  |  |
| --- | --- | --- | --- |
| Component | Type | Value | Sources |
| EFLHRAC | Varies | , “Corrected Hours” | ---- |
| EFLHES-RAC | Varies | , “Original Hours” | 1 |
| AF | Fixed | 0.31 | 2 |
| CAPY (RAC capacity, Btuh) | Fixed | 10,000 | 3 |
| EERRetRAC | Fixed | 9.07 | 4 |
| EERb  (for a 10,000 Btuh unit) | Fixed | 9.8 | 5 |
| EERES (for a 10,000 Btuh unit) | Fixed | 10.8 | 5 |
| CFRAC | Fixed | 0.58 | 6 |
| RAC Time Period Allocation Factors | Fixed | 65.1%, 34.9%, 0.0%, 0.0% | 6 |
| Measure Life (EUL) | Fixed | 4 | See source notes |

Table 2‑19: RAC Retirement-Only EFLH and Energy Savings by City

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **City** | **Original**  **Hours (EFLHES-RAC)** | **Corrected**  **Hours (EFLHRAC)** | **Energy**  **Impact (kWh)** | **Demand Impact (kW)** |
| Allentown | 784 | 243 | 268 | 0.6395 |
| Erie *(Lowest EFLH)* | 482 | 149 | 164 |
| Harrisburg | 929 | 288 | 318 |
| Philadelphia *(Highest EFLH)* | 1032 | 320 | 353 |
| Pittsburgh | 737 | 228 | 251 |
| Scranton | 621 | 193 | 213 |
| Williamsport | 659 | 204 | 225 |

NOTE: Table 2‑19 should be used with a master “mapping table” that maps the zip codes for all PA cities to one of the representative cities above. This mapping table would also be used for the TRM ENERGY STAR Room Air Conditioning measure.

### Sources:

1. Full load hours for Pennsylvania cities from the ENERGY STAR Room AC Calculator[[37]](#footnote-37) spreadsheet, Assumptions tab. Note that the EFLH values currently used in the ES Room AC calculator are incorrect and too high because they are the same as those used for the Central AC calculator, but should be much less.
   1. For reference, EIA-RECS for the Northeast, Middle Atlantic region shows the per-household energy use for an RAC = 577 kWh and an average of 2.04 units per home, so the adjusted RAC use = 283 kWh per unit. This more closely aligns with the energy consumption for room AC using the adjusted EFLH values than without adjustment.
2. Mid Atlantic TRM Version 1.0. April 28, 2010 Draft. Prepared by Vermont Energy Investment Corporation. An adjustment to the ES RAC EFLHs of 31% was used for the “Window A/C” measure.
3. 10,000 Btuh is the typical size assumption for the ENERGY STAR Room AC Savings calculator. It is also used as the basis for PA TRM ENERGY STAR Room AC measure savings calculations, even though not explicitly stated in the TRM. For example:
   1. Energy savings for Allentown = 74 kWh and EFLH = 784 hrs:

784 \* (10,000/1000) \* (1/9.8 – 1/10.8) = 74 kWh.

* 1. CPUC 2006-2008 EM&V, “Residential Retrofit High Impact Measure Evaluation Report”, prepared for the CPUC Energy Division, February 8, 2010, page 165, Table 147 show average sizes of 9,729 and 10,091 Btuh.

1. Massachusetts TRM, Version 1.0, October 23, 2009, “Room AC Retirement” measure, Page 52-54. Assumes an existing/recycled unit EER=9.07, reference is to weighted 1999 AHAM shipment data. This value should be evaluated and based on the actual distribution of recycled units in PA and revised in later TRMs if necessary. Other references include:
   1. ENERGY STAR website materials on Turn-In programs, if reverse-engineered indicate an EER=9.16 is used for savings calculations for a 10 year old RAC. Another statement indicates that units that are at least 10 years old use 20% more energy than a new ES unit which equates to: 10.8 EER/1.2 = 9 EER <http://www.energystar.gov/ia/products/recycle/documents/RoomAirConditionerTurn-InAndRecyclingPrograms.pdf>
   2. “Out With the Old, in With the New: Why Refrigerator and Room Air Conditioner Programs Should Target Replacement to Maximize Energy Savings.” National Resources Defense Council, November 2001. Page 3, Cites a 7.5 EER as typical for a room air conditioner in use in 1990s. However, page 21 indicates an 8.0 EER was typical for a NYSERDA program.
2. ENERGY STAR and Federal Appliance Standard minimum EERs for a 10,000 Btuh unit with louvered sides.<http://www.energystar.gov/index.cfm?c=roomac.pr_crit_room_ac>
3. PA TRM June 2010, coincident demand factor and Time Period Allocation Factors for ENERGY STAR Room AC.

### Expected Life of Savings

This value would be added to the TRM Appendix A:

Room Air Conditioner Retirement = 4 years

From the PA TRM, the EUL for an ENERGY STAR Room Air Conditioner is 10 years, but the TRM does not provide an RUL for RACs. However, as shown in , the results from a recent evaluation of ComEd’s appliance recycling program[[38]](#footnote-38) found a median age of 21 to 25 years for recycled ACs. For a unit this old, the expected life of the savings is likely to be short, so 4 years was chosen as a reasonable assumption based on these references:

1. DEER database, presents several values for EUL/RUL for room AC recycling: <http://www.deeresources.com/deer2008exante/downloads/EUL_Summary_10-1-08.xls>
   1. DEER 0607 recommendation: EUL=9, RUL=1/3 of EUL = 3 years. The 1/3 was defined as a “reasonable estimate”, but no basis given.
   2. 2005 DEER: EUL=15, did not have recycling RUL
   3. Appliance Magazine and EnergyStar calculator: EUL=9 years
   4. CA IOUs: EUL=15, RUL=5 to 7
2. “Out With the Old, in With the New: Why Refrigerator and Room Air Conditioner Programs Should Target Replacement to Maximize Energy Savings,” National Resources Defense Council, November 2001, page 21, 5 years stated as a credible estimate.
3. From the PA TRM June 2010, if the ratio of refrigerator recycling measure life to ENERGY STAR measure life is applied: (8/13) \* 10 years (for RAC) = 6 years for RAC recycling.

Table 2‑20: Preliminary Results from ComEd RAC Recycling Evaluation

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Appliance Type** | **Age in Years** | | | | | | | | | **N** |
| 0 to 5 | 6 to 10 | 11 to 15 | 16 to 20 | 21 to 25 | 26 to 30 | 31 to 35 | 36 to 40 | Over 40 |
| Room Air Conditioners | 0% | 5% | 7% | 18% | 37% | 18% | 5% | 6% | 5% | — |

**Sources:**

1. Navigant Consulting evaluation of ComEd appliance recycling program.

## Smart Strip Plug Outlets

|  |  |
| --- | --- |
| Measure Name | Smart Strip Plug Outlets |
| Target Sector | Residential |
| Measure Unit | Per Smart Strip |
| Unit Energy Savings | 184 kWh |
| Unit Peak Demand Reduction | 0.013 kW |
| Measure Life | 5 years |

Smart Strips are power strips that contain a number of controlled sockets with at least one uncontrolled socket. When the appliance that is plugged into the uncontrolled socket is turned off, the power strips then shuts off the items plugged into the controlled sockets. Qualified power strip must automatically turn off when equipment is unused / unoccupied.

### Eligibility

This protocol documents the energy savings attributed to the installation of smart strip plugs. The most likely area of application is within residential spaces, i.e. single family and multifamily homes. The two areas of usage considered are home computer systems and home entertainment systems. It is expected that approximately four items will be plugged into each power strip.

### Algorithms

The DSMore Michigan Database of Energy Efficiency Measures performed engineering calculations using standard standby equipment wattages for typical computer and TV systems and idle times. The energy savings and demand reduction were obtained through the following calculations:

### Definition of Terms

The parameters in the above equation are listed in Table 2‑21.

Table 2‑21: Calculation Assumptions

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Parameter** | **Component** | **Type** | **Value** | **Source** |
| kWcomp | Idle kW of computer system | Fixed | 0.0201 | 1 |
| Hrcomp | Daily hours of computer idle time | Fixed | 20 | 1 |
| kWTV | Idle kW of TV system | Fixed | 0.0320 | 1 |
| HrTV | Daily hours of TV idle time | Fixed | 19 | 1 |
| CF | Coincidence Factor | Fixed | 0.50 | 1 |

**Sources:**

1. DSMore MI DB

### Deemed Savings

ΔkWh = 184 kWh

ΔkWpeak  = 0.013 kW

### Measure Life

To ensure consistency with the annual savings calculation procedure used in the DSMore MI database, the measure of **5 years** is taken from DSMore.

### Evaluation Protocols

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

## Solar Water Heaters

|  |  |
| --- | --- |
| Measure Name | Solar Water Heaters |
| Target Sector | Residential Establishments |
| Measure Unit | Water Heater |
| Unit Energy Savings | 2,106 kWh |
| Unit Peak Demand Reduction | 0.378 kW |
| Measure Life | 14 years |

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:

The energy factor used in the above equation represents an average energy factor of market available solar water heaters[[39]](#footnote-39). The demand reduction is taken as the annual energy *usage* of the baseline water heater multiplied by the ratio of the average energy usage during noon and 8PM 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 (top 100 hours), the water heater is expected to fully supply all domestic hot water needs.

ΔkWpeak  = EnergyToDemandFactor×BaseEnergy Usage

The Energy to Demand Factor is defined below:

The ratio of the average energy usage during noon and 8 PM on summer weekdays to the total annual energy usage is taken from load shape data collected for a water heater and HVAC demand response study for PJM[[40]](#footnote-40). The factor is constructed as follows:

1. Obtain the average kW, as monitored for 82 water heaters in PJM territory[[41]](#footnote-41), for each hour of the typical day summer, winter, and spring/fall days. Weight the results (91 summer days, 91 winter days, 183 spring/fall days) to obtain annual energy usage.
2. Obtain the average kW during noon to 8 PM on summer days from the same data. Noon to 8 PM is used because most of the top 100 hours (over 80%) occur during noon and 8 PM[[42]](#footnote-42).
3. The average noon to 8 PM demand is converted to average *weekday* noon to 8 PM demand through comparison of weekday and weekend monitored loads from the same PJM study[[43]](#footnote-43).
4. The ratio of the average weekday noon to 8 PM energy demand to the annual energy usage obtained in step 1. The resulting number, 0.00009172, is the *EnergyToDemandFactor.*

The load shapes (fractions of annual energy usage that occur within each hour) during summer week days are plotted for three business types in Figure 2‑6



Figure 2‑6: Load shapes for hot water in residential buildings taken from a PJM study.

### Definition of Terms

The parameters in the above equation are listed in Table 2‑22.

Table 2‑22: Calculation Assumptions

|  |  |  |  |
| --- | --- | --- | --- |
| **Component** | **Type** | **Values** | **Source** |
| EFbase , Energy Factor of baseline electric heater | Fixed | 0.9 | 6 |
| EFproposed, Year-round average Energy Factor of proposed solar water heater | Fixed | 1.84 | 1 |
| HW , Hot water used per day in gallons | Fixed | 64.3 gallon/day | 7 |
| Thot , Temperature of hot water | Fixed | 120 F | 8 |
| Tcold , Temperature of cold water supply | Fixed | 55 F | 9 |
| Baseline Energy Usage (kWh) | Calculated | 4,122 |  |
| EnergyToDemandFactor: Ratio of average Noon to 8 PM usage during summer peak to annual energy usage | Fixed | 0.00009172 | 2-5 |

**Source:**

1. We have taken the average energy factor for all solar water heaters with collector areas of 50 ft2 or smaller from http://www.solar-rating.org/ratings/ratings.htm. 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.
2. Deemed Savings Estimates for Legacy Air Conditioning and Water Heating Direct Load Control Programs in PJM Region. The report can be accessed online: http://www.pjm.com/~/media/committees-groups/working-groups/lrwg/20070301/20070301-pjm-deemed-savings-report.ashx ,
3. The average is over all 82 water heaters and over all summer, spring/fall, or winter days. The load shapes are taken from the fourth columns, labeled “Mean”, in tables 14,15, and 16 in pages 5-31 and 5-32
4. On the other hand, the band would have to expanded to at least 12 hours to capture all 100 hours.
5. The 5th column, labeled “Mean” of Table 18 in page 5-34 is used to derive an adjustment factor that scales average summer usage to summer weekday usage. The conversion factor is 0.925844. A number smaller than one indicates that for residential homes, the hot water usage from noon to 8 PM is slightly higher is the weekends than on weekdays.
6. Federal Standards are 0.97 -0.00132 x Rated Storage in Gallons. For a 50-gallon tank this is approximately 0.90. “Energy Conservation Program: Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters” US Dept of Energy Docket Number: EE–2006–BT-STD–0129, p. 30
7. “Energy Conservation Program for Consumer Products: Test Procedure for Water Heaters”, Federal Register / Vol. 63, No. 90, p. 25996
8. Many states have plumbing codes that limit shower and bathtub water temperature to 120 °F.
9. Mid-Atlantic TRM, footnote #24

### Deemed Savings

ΔkWh = 2,106 kWh

ΔkWpeak  = 0.378 kW

### Measure Life

The expected useful life is 20 years, according to ENERGY STAR[[44]](#footnote-44).

### Evaluation Protocols

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

## Water Heater Pipe Insulation

|  |  |
| --- | --- |
| Measure Name | Water Heater Pipe Insulation |
| Target Sector | Residential Establishments |
| Measure Unit | Water Heater |
| Unit Energy Savings | 124 kWh |
| Unit Peak Demand Reduction | 0.011 kW |
| Measure Life | 13 years |

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=0.90) with an annual energy usage of 4,122 kWh.

### 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 residences.

### Algorithms

The annual energy savings are assumed to be 3% of the annual energy use of an electric water heater (4,122 kWh), or 124 kWh. This estimate is based on a recent report prepared by the ACEEE for the State of Pennsylvania.[[45]](#footnote-45)

ΔkWh = 124 kWh

The summer coincident peak kW savings are calculated as follows:

ΔkWpeak = ΔkWh \* EnergyToDemandFactor

### Definition of Terms

ΔkWh = Annual kWh savings = 124kWh per fixture installed

EnergyToDemandFactor= Summer peak coincidence factor for measure = 0.00009172[[46]](#footnote-46)

ΔkWpeak =Summer peak kW savings = 0.011 kW.

The demand reduction is taken as the annual energy savings multiplied by the ratio of the average energy usage during noon and 8PM on summer weekdays to the total annual energy usage. The Energy to Demand Factor is defined as:

The ratio of the average energy usage during noon and 8 PM on summer weekdays to the total annual energy usage is taken from load shape data collected for a water heater and HVAC demand response study for PJM[[47]](#footnote-47). The factor is constructed as follows:

1. Obtain the average kW, as monitored for 82 water heaters in PJM territory, for each hour of the typical day summer, winter, and spring/fall days. Weight the results (91 summer days, 91 winter days, 183 spring/fall days) to obtain annual energy usage.
2. Obtain the average kW during noon to 8 PM on summer days from the same data.
3. The average noon to 8 PM demand is converted to average *weekday* noon to 8 PM demand through comparison of weekday and weekend monitored loads from the same PJM study,
4. The ratio of the average weekday noon to 8 PM energy demand to the annual energy usage obtained in step 1. The resulting number, 0.00009172, is the Energy to Demand Factor, or Coincidence Factor.

The load shapes (fractions of annual energy usage that occur within each hour) during summer week days are plotted in Figure 2‑7



Figure 2‑7: Load shapes for hot water in residential buildings taken from a PJM study.

### Measure Life

According to the Efficiency Vermont Technical Reference User Manual (TRM), the expected measure life is **13 years[[48]](#footnote-48)**.

### Evaluation Protocols

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

## Residential Whole House Fans

This measure applies to the installation of a whole house fan. The use of a whole house fan will offset existing central air conditioning loads. Whole house fans operate when the outside temperature is less than the inside temperature, and serve to cool the house by drawing cool air in through open windows and expelling warmer air through attic vents.

The baseline is taken to be an existing home with central air conditioning (CAC) and without a whole house fan.

The retrofit condition for this measure is the installation of a new whole house fan.

### Algorithms

The energy savings for this measure result from reduced air conditioning operation. While running, whole house fans can consume up to 90% less power than typical residential central air conditioning units.[[49]](#footnote-49) Energy savings for this measure are based on whole house fan energy savings values reported by the energy modeling software, REM/Rate[[50]](#footnote-50).

### Model Assumptions

* The savings are reported on a “per house” basis with a modeled baseline cooling provided by a SEER 10 Split A/C unit.
* Savings derived from a comparison between a naturally ventilated home and a home with a whole-house fan.
* 2181 square-foot single-family detached home built over unconditioned basement.[[51]](#footnote-51)

Table 2‑23: Deemed Energy Savings by PA City

|  |  |
| --- | --- |
| **City** | **Annual Energy Savings (kWh/house)** |
| Allentown | 204 |
| Erie | 200 |
| Harrisburg | 232 |
| Philadelphia | 229 |
| Pittsburgh | 199 |
| Scranton | 187 |
| Williamsport | 191 |

This measure assumes no demand savings as whole house fans are generally only used during milder weather (spring/fall and overnight). Peak 100 hours typically occur during very warm periods when a whole house fan is not likely being used.

### Measure Life

Measure life = 20 years[[52]](#footnote-52) (15 year maximum for PA TRM)

## Ductless Mini-Split Heat Pumps

|  |  |
| --- | --- |
| Measure Name | Ductless Heat Pumps |
| Target Sector | Residential Establishments |
| Measure Unit | Ductless Heat Pumps |
| Unit Energy Savings |  |
| Unit Peak Demand Reduction |  |
| Measure Life | 15 |

ENERGY STAR ductless “mini-split” heat pumps utilize high efficiency SEER/EER and HSPF energy performance factors of 14.5/12 and 8.2, respectively, or above. This technology typically converts an electric resistance home into an efficient single or multi-zonal ductless heat pump system. Homeowners have choice to install an ENERGY STAR qualified model or a standard efficiency model.

### Eligibility

This protocol documents the energy savings attributed to ductless mini-split heat pumps with energy efficiency performance of 14.5/12 SEER/EER and 8.2 HSPF or greater with inverter technology.[[53]](#footnote-53) The baseline heating system could be an existing electric resistance heating, a lower-efficiency ductless heat pump system, a ducted heat pump, or electric furnace. Fuel conversion from a gas heated system is not applicable. In addition, this could be installed in a new construction or addition. These systems could be installed as the primary heating system for the house or as a secondary heating system for a single room.

### Algorithms

The savings depend on three main factors: baseline condition, usage (primary or secondary heating system), and the capacity of the indoor unit. The algorithm is separated into two calculations: single zone and multi-zone ductless heat pumps. The savings algorithm is as follows:

#### Single Zone:

ΔkWh = ΔkWhcool + ΔkWhheat

ΔkWhheat = CAPY/1000 X (1/HSPFb - 1/HSPFe ) X EFLH X LF

ΔkWhcool = CAPY/1000 X (1/SEERb – 1/SEERe ) X EFLH X LF

Note, that if the customer did not have a cooling system installed prior, there may be a negative cooling energy impact.

ΔkWpeak = CAPY/1000 X (1/EERb – 1/EERe ) X CF

#### Multi-Zone

ΔkWh = ΔkWhcool + ΔkWhheat

ΔkWhheat = [CAPY/1000 X (1/HSPFb - 1/HSPFe ) X EFLH X LF]ZONE1 + [CAPY/1000 X (1/HSPFb - 1/HSPFe ) X EFLH X LF]ZONE2 + [CAPY/1000 X (1/HSPFb - 1/HSPFe ) X EFLH X LF]ZONEn

ΔkWhcool = [CAPY/1000 X (1/SEERb – 1/SEERe ) X EFLH X LF]ZONE1 + [CAPY/1000 X (1/SEERb – 1/SEERe ) X EFLH X LF]ZONE2 + [CAPY/1000 X (1/SEERb – 1/SEERe ) X EFLH X LF]ZONEn

Note, that if the customer did not have a cooling system installed prior, there may be a negative cooling energy impact.

ΔkWpeak = [CAPY/1000 X (1/EERb – 1/EERe ) X CF]ZONE1 + [CAPY/1000 X (1/EERb – 1/EERe ) X CF]ZONE2 + [CAPY/1000 X (1/EERb – 1/EERe ) X CF]ZONEn

### Definition of Terms

CAPY = The capacity of the indoor unit is given in BTUH

EFLH = Equivalent Full Load Hours – If the unit is installed as the primary heating system; that is, in a living room or large room of the house, the EFLH will be equivalent to those for a central heating system. If the unit is installed as a secondary heating system, the EFLH will be equivalent to a room unit (ie. for cooling, equivalent to a room AC system).

HSPFb = Heating efficiency of baseline unit

HSPBe = Efficiency of the installed DHP

SEERb = Cooling efficiency of baseline unit

SEERe = Efficiency of the installed DHP

EERb = The Energy Efficiency Ratio of the baseline unit

EERe = The Energy Efficiency Ratio of the efficient unit

LF = Load factor

Table 2‑24: DHP – Values and References

| **Component** | **Type** | **Values** | **Sources** |
| --- | --- | --- | --- |
| CAPY | Variable |  | AEPS Application; EDC Data Gathering |
| EFLH primary | Fixed | Allentown Cooling = 784 Hours  Allentown Heating = 2,492 Hours  Erie Cooling = 482 Hours  Erie Heating = 2,901 Hours  Harrisburg Cooling = 929 Hours  Harrisburg Heating = 2,371 Hours  Philadelphia Cooling = 1,032 Hours  Philadelphia Heating = 2,328 Hours  Pittsburgh Cooling = 737 Hours  Pittsburgh Heating = 2,380 Hours  Scranton Cooling = 621 Hours  Scranton Heating = 2,532 Hours  Williamsport Cooling = 659 Hours  Williamsport Heating = 2,502 Hours | 1 |
| EFLH secondary | Fixed | Allentown Cooling = 243 Hours  Allentown Heating = 774 Hours  Erie Cooling = 149 Hours  Erie Heating = 897 Hours  Harrisburg Cooling = 288 Hours  Harrisburg Heating = 735 Hours  Philadelphia Cooling = 320 Hours  Philadelphia Heating = 722 Hours  Pittsburgh Cooling = 228 Hours  Pittsburgh Heating = 736 Hours  Scranton Cooling = 193 Hours  Scranton Heating = 787 Hours  Williamsport Cooling = 204 Hours  Williamsport Heating = 775 hours | 2, 3 |
| HSPFb | Fixed | Standard DHP: 7.7  Electric resistance: 3.413  ASHP: 7.7  Electric furnace: 3.242 | 4, 6 |
| SEERb | Fixed | DHP or central AC: 13  Room AC: 11  No Cooling: remove 1/SEER*b* | 5, 6, 7 |
| HSPFe | Variable | Based on nameplate information. Should be at least ENERGY STAR. | AEPS Application; EDC Data Gathering |
| SEERe | Variable | Based on nameplate information. Should be at least ENERGY STAR. | AEPS Application; EDC Data Gathering |
| CF | Fixed | 70% | 8 |
| EERb | Fixed | = (11.3/13) X SEERb for DHP or central AC  = 9.8 room AC | 5,9 |
| EERe | Fixed | = (11.3/13) X SEERe | 9 |
| LF | Fixed | 25% | 10 |

**Sources:**

1. US Department of Energy, ENERGY STAR Calculator. Accessed 3/16/2009. From Pennsylvania’s Technical Reference Manual.
2. Secondary cooling load hours based on room air conditioner “corrected” EFLH workpaper that adjusted the central cooling hours to room cooling hours by “Approved Interim PA TRM Protocol for Room AC Recycling”, August 2010.
3. Secondary heating load hours based ratio of central cooling hours to room cooling hours multiplied by the central heating hours. The ratio of time spent heating or cooling in a secondary room versus the whole house is assumed to be the same.
4. COP = 3.413 HSPF for electric resistance heating. Electric furnace efficiency typically varies from 0.95 to 1.00 and thereby assumed a COP 0.95 = 3.242.
5. Federal Register, Vol. 66, No. 14, Monday, January 22, 2001/Rules and Regulations, p. 7170-7200.
6. 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.
7. SEER based on average EER of 9.8 for room AC unit. From Pennsylvania’s Technical Reference Manual.
8. Based on an analysis of six different utilities by Proctor Engineering. From Pennsylvania’s Technical Reference Manual.
9. Average EER for SEER 13 unit. From Pennsylvania’s Technical Reference Manual.
10. Personal communication with Bruce Manclark, Delta-T, Inc. who is working with Northwest Energy Efficiency Alliance (NEEA) on the Northwest DHP Project http://www.nwductless.com/

### Definition of Heating Zone

Definition of primary and secondary heating systems depends primarily on the location where the source heat is provided in the household, and shown in Table 2‑25.

Table 2‑25: Heating Zones

|  |  |
| --- | --- |
| Component | Definition |
| Primary Heating Zone | Living room Dining room  House hallway Kitchen areas |
| Secondary Heating Zone | Bedroom  Bathroom  Basement/Recreation Room  Storage Room Office/Study  Add-on room |

### Measure Life

According to an October 2008 report for the CA Database for Energy Efficiency Resources, a heat pump’s lifespan is **15 years.[[54]](#footnote-54)**

### 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.

## Fuel Switching: DHW Electric to Gas

|  |  |
| --- | --- |
| Measure Name | Fuel Switching: DHW Electric to Gas |
| Target Sector | Residential |
| Measure Unit | Water Heater |
| Unit Energy Savings | 4104 kWh |
| Unit Peak Demand Reduction | 0.376 kW |
| Gas Consumption Increase | 21.32 MMBtu |
| Measure Life | 13 years |

Natural gas 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 gas unit. Standard electric water heaters have energy factors of 0.904 and a federal standard efficiency gas water heater has an energy factor of 0.594 for a 40gal unit.

### Eligibility

This protocol documents the energy savings attributed to converting from a standard electric water heater with Energy Factor of 0.904 or greater to a standard natural gas water heater with Energy Factor of 0.594 or greater. The target sector primarily consists of single-family residences.

### Algorithms

The energy savings calculation utilizes average performance data for available residential standard electric and natural gas water heaters and typical water usage for residential homes. Because there is little electric energy associated with a natural gas 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 natural gas energy consumption. While this gas consumption does not count against PA Act 129 energy savings, it is expected to be used in the program TRC test. The increased natural gas energy 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 during noon and 8PM on summer weekdays to the total annual energy usage.

ΔkWpeak  = EnergyToDemandFactor × Energy Savings

The Energy to Demand Factor is defined below:

The ratio of the average energy usage during noon and 8 PM on summer weekdays to the total annual energy usage is taken from load shape data collected for a water heater and HVAC demand response study for PJM[[55]](#footnote-55). The factor is constructed as follows:

1. Obtain the average kW, as monitored for 82 water heaters in PJM territory[[56]](#footnote-56), for each hour of the typical day summer, winter, and spring/fall days. Weight the results (91 summer days, 91 winter days, 183 spring/fall days) to obtain annual energy usage.
2. Obtain the average kW during noon to 8 PM on summer days from the same data.
3. The average noon to 8 PM demand is converted to average *weekday* noon to 8 PM demand through comparison of weekday and weekend monitored loads from the same PJM study[[57]](#footnote-57).
4. The ratio of the average weekday noon to 8 PM energy demand to the annual energy usage obtained in step 1. The resulting number, 0.00009172, is the *EnergyToDemandFactor.*

The load shapes (fractions of annual energy usage that occur within each hour) during summer week days are plotted in Figure 2‑8.



Figure 2‑8: Load shapes for hot water in residential buildings taken from a PJM.

### Definition of Variables

The parameters in the above equation are listed in below.

Table 2‑26: Calculation Assumptions

|  |  |  |  |
| --- | --- | --- | --- |
| Component | Type | Values | Source |
| EFelect,bl, Energy Factor of baseline water heater | Fixed | 0.904 | 4 |
| EFNG,inst, Energy Factor of installed natural gas water heater | Variable | >=.594 | 5 |
| HW, Hot water used per day in gallons | Fixed | 64.3 gallon/day | 6 |
| Thot, Temperature of hot water | Fixed | 120 °F | 7 |
| Tcold, Temperature of cold water supply | Fixed | 55 °F | 8 |
| EnergyToDemandFactor | Fixed | 0.00009172 | 1-3 |

1. Deemed Savings Estimates for Legacy Air Conditioning and Water Heating Direct Load Control Programs in PJM Region. The report can be accessed online: http://www.pjm.com/~/media/committees-groups/working-groups/lrwg/20070301/20070301-pjm-deemed-savings-report.ashx
2. The average is over all 82 water heaters and over all summer, spring/fall, or winter days. The load shapes are taken from the fourth columns, labeled “Mean”, in tables 14,15, and 16 in pages 5-31 and 5-32
3. The 5th column, labeled “Mean” of Table 18 in page 5-34 is used to derive an adjustment factor that scales average summer usage to summer weekday usage. The conversion factor is 0.925844. A number smaller than one indicates that for residential homes, the hot water usage from noon to 8 PM is slightly higher is the weekends than on weekdays.
4. 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
5. 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
6. “Energy Conservation Program for Consumer Products: Test Procedure for Water Heaters”, Federal Register / Vol. 63, No. 90, p. 25996
7. Many states have plumbing codes that limit shower and bathtub water temperature to 120 °F.
8. Mid-Atlantic TRM, footnote #24

### Deemed Savings

The deemed savings for the installation of a natural gas water heater in place of a standard electric water heater are listed in Table 2‑27 below.

Table 2‑27: Energy Savings and Demand Reductions

|  |  |  |
| --- | --- | --- |
| Electric unit Energy Factor | Energy Savings (kWh) | Demand Reduction (kW) |
| 0.904 | 4104 | 0.376 |

The deemed gas consumption for the installation of a standard efficiency natural gas water heater in place of a standard electric water heater is listed in Table 2‑28 below.

Table 2‑28: Gas Consumption

|  |  |
| --- | --- |
| Gas unit Energy Factor | Gas Consumption (MMBtu) |
| 0.594 | 21.32 |

### Measure Life

According to an October 2008 report for the CA Database for Energy Efficiency Resources, a gas water heater’s lifespan is **13 years[[58]](#footnote-58)**.

### Evaluation Protocols

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

## Fuel Switching: DHW Heat Pump to Gas

|  |  |
| --- | --- |
| Measure Name | Fuel Switching: DHW Heat Pump to Gas |
| Target Sector | Residential |
| Measure Unit | Water Heater |
| Unit Energy Savings | 4104 kWh |
| Unit Peak Demand Reduction | 0.376 kW |
| Gas Consumption Increase | 21.32 MMBtu |
| Measure Life | 13 years |

Natural gas 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 a federal standard efficiency gas water heater has an energy factor of 0.594 for a 40gal 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 a standard natural gas water heater with Energy Factor of 0.594 or greater. The target sector primarily consists of single-family residences.

### Algorithms

The energy savings calculation utilizes average performance data for available residential standard heat pump and natural gas water heaters and typical water usage for residential homes. Because there is little electric energy associated with a natural gas 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:

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

Demand savings result from the removal of the connected load of the heat pump water heater. The demand reduction is taken as the annual energy savings multiplied by the ratio of the average energy usage during noon and 8PM on summer weekdays to the total annual energy usage.

The Energy to Demand Factor is defined below:

The ratio of the average energy usage during noon and 8 PM on summer weekdays to the total annual energy usage is taken from load shape data collected for a water heater and HVAC demand response study for PJM[[59]](#footnote-59). The factor is constructed as follows:

1. Obtain the average kW, as monitored for 82 water heaters in PJM territory[[60]](#footnote-60), for each hour of the typical day summer, winter, and spring/fall days. Weight the results (91 summer days, 91 winter days, 183 spring/fall days) to obtain annual energy usage.
2. Obtain the average kW during noon to 8 PM on summer days from the same data.
3. The average noon to 8 PM demand is converted to average *weekday* noon to 8 PM demand through comparison of weekday and weekend monitored loads from the same PJM study[[61]](#footnote-61).
4. The ratio of the average weekday noon to 8 PM energy demand to the annual energy usage obtained in step 1. The resulting number, 0.00009172, is the *EnergyToDemandFactor.*

The load shapes (fractions of annual energy usage that occur within each hour) during summer week days are plotted in Figure 2‑9



Figure 2‑9: Load shapes for hot water in residential buildings taken from a PJM.

### Definition of Terms

The parameters in the above equation are listed in Table 2‑29 below.

Table 2‑29: Calculation Assumptions

|  |  |  |  |
| --- | --- | --- | --- |
| Component | Type | Values | Source |
| EFHP,bl , Energy Factor of baseline heat pump water heater | Fixed | ≥ 2.0 | 4 |
| EFNG,inst . Energy Factor of installed natural gas water heater | Variable | ≥ 0.594 | 5 |
| HW, Hot water used per day in gallons | Fixed | 64.3 gallon/day | 6 |
| Thot, Temperature of hot water | Fixed | 120 °F | 7 |
| Tcold, Temperature of cold water supply | Fixed | 55 °F | 8 |
| FDerate, COP De-rating factor | Fixed | 0.84 | 9, and discussion below |
| EnergyToDemandFactor | Fixed | 0.00009172 | 1-3 |

**Source:**

1. Deemed Savings Estimates for Legacy Air Conditioning and Water Heating Direct Load Control Programs in PJM Region. The report can be accessed online: <http://www.pjm.com/~/media/committees-groups/working-groups/lrwg/20070301/20070301-pjm-deemed-savings-report.ashx>
2. The average is over all 82 water heaters and over all summer, spring/fall, or winter days. The load shapes are taken from the fourth columns, labeled “Mean”, in tables 14,15, and 16 in pages 5-31 and 5-32
3. The 5th column, labeled “Mean” of Table 18 in page 5-34 is used to derive an adjustment factor that scales average summer usage to summer weekday usage. The conversion factor is 0.925844. A number smaller than one indicates that for residential homes, the hot water usage from noon to 8 PM is slightly higher is the weekends than on weekdays.
4. 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**.
5. 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
6. “Energy Conservation Program for Consumer Products: Test Procedure for Water Heaters”, **Federal Register** / Vol. 63, No. 90, p. 25996
7. Many states have plumbing codes that limit shower and bathtub water temperature to 120 °F.
8. Mid-Atlantic TRM, footnote #24
9. Based on TMY2 weather files from DOE2.com for Erie, Harrisburg, Pittsburgh, Wilkes-Barre, And Williamsport, the average annual wetbulb temperature is 45 ± 1.3 °F. The wetbulb temperature in garages or attics, where the heat pumps are likely to be installed, are likely to be two or three degrees higher, but for simplicity, 45 °F is assumed to be the annual average wetbulb temperature.

### Heat Pump Water Heater Energy Factor

The Energy Factors are determined from a DOE testing procedure that is carried out at 56 °F wetbulb temperature. However, the average wetbulb temperature in PA is closer to 45 °F[[62]](#footnote-62). The heat pump performance is temperature dependent. The plot in Figure 2‑10 shows relative coefficient of performance (COP) compared to the COP at rated conditions[[63]](#footnote-63). According to the linear regression shown on the plot, the COP of a heat pump water heater at 45 °F is 0.84 of the COP at nominal rating conditions. As such, a de-rating factor of 0.84 is applied to the nominal Energy Factor of the Heat Pump water heaters.



Figure 2‑10: Dependence of COP on Outdoor Wet-Bulb Temperature

### Deemed Savings

The deemed savings for the installation of a natural gas water heater in place of a standard heat pump water heater are listed in Table 2‑30 below.

Table 2‑30: Energy Savings and Demand Reductions

|  |  |  |
| --- | --- | --- |
| Heat Pump unit Energy Factor | Energy Savings (kWh) | Demand Reduction (kW) |
| 2.0 | 2208 | 0.203 |

The deemed gas consumption for the installation of a standard efficiency natural gas water heater in place of a standard heat pump water heater is listed in Table 2‑31 below.

Table 2‑31: Gas Consumption

|  |  |
| --- | --- |
| Gas unit Energy Factor | Gas Consumption (MMBtu) |
| 0.594 | 21.32 |

### Measure Life

According to an October 2008 report for the CA Database for Energy Efficiency Resources, a gas water heater’s lifespan is **13 years[[64]](#footnote-64)**.

### Evaluation Protocols

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

## Fuel Switching: Electric Heat to Gas Heat

This protocol documents the energy savings attributed to converting from an existing electric heating system to a new natural gas furnace in a residential home. The target sector primarily consists of single-family residences.

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.

The retrofit condition for this measure is the installation of a new standard efficiency natural gas furnace.

### Algorithms

The energy savings are the full energy consumption of the electric heating source minus the energy consumption of the gas furnace blower motor. The energy savings are obtained through the following formulas:

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

Energy Impact:

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

Energy Impact:

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. While this gas consumption does not count against PA Act 129 energy savings, it is expected to be used in the program TRC test. The increased natural gas energy is obtained through the following formulas:

#### Gas consumption with natural gas furnace:

### Definition of Terms

CAPYelec heat = Total heating capacity of existing electric baseboards or electric furnace (BtuH)

CAPYASHP heat = Total heating capacity of existing electric ASHP (BtuH)

CAPYGas heat = Total heating capacity of new natural gas furnace (BtuH)

EFLHheat = Equivalent Full Load Heating hours

HSPFASHP = Heating Seasonal Performance Factor for existing heat pump (Btu/W▪hr)

AFUEGas heat = Annual Fuel Utilization Efficiency for the new gas furnace (%)

HPmotor = Gas furnace blower motor horsepower (hp)

ηmotor = Efficiency of furnace blower motor

The default values for each term are shown in Table 2‑32.

Table 2‑32: Default values for algorithm terms

|  |  |  |  |
| --- | --- | --- | --- |
| Term | Type | Value | Source |
| CAPYelec heat | Variable | Nameplate | EDC Data Gathering |
| CAPYASHP heat | Variable | Nameplate | EDC Data Gathering |
| CAPYGas heat | Variable | Nameplate | EDC Data Gathering |
| EFLHheat | Fixed | Allentown = 2492  Erie = 2901  Harrisburg = 2371  Philadelphia = 2328  Pittsburgh = 2380  Scranton = 2532  Williamsport = 2502 | 2010 PA TRM Table 2-1 |
| HSPFASHP | Variable | Default = 7.7 | 2010 PA TRM Table 2-1 |
| Nameplate | EDC Data Gathering |
| AFUEGas heat | Variable | Default = 78% | IECC 2009 minimum efficiency |
| Nameplate | EDC Data Gathering |
| HPmotor | Variable | Default = ½ hp | Average blower motor capacity for gas furnace (typical range = ¼ hp to ¾ hp) |
| Nameplate | EDC Data Gathering |
| ηmotor | Variable | Default = 0.50 | Typical efficiency of ½ hp blower motor |
| Nameplate | EDC Data Gathering |

### Measure Life

Measure life = 20 years[[65]](#footnote-65)

## Ceiling / Attic and Wall Insulation

This measure applies to installation/retrofit of new or additional insulation in a ceiling/attic, or walls of existing residential homes with a primary electric heating and/or cooling source. The installation must achieve a finished ceiling/attic insulation rating of R-38 or higher, and/or must add wall insulation of at least an R-6 or greater rating.

The baseline for this measure is an existing residential home with a ceiling/attic insulation R-value less than or equal to R-30, and wall insulation R-value less than or equal to R-11, with an electric primary heating source and/or cooling source.

### Algorithms

The savings values are based on the following algorithms.

#### Cooling savings with central A/C:

#### Cooling savings with room A/C:

#### Cooling savings with electric air-to-air heat pump:

#### Heating savings with electric air-to-air heat pump:

#### Heating savings with electric baseboard or electric furnace heat (assumes 100% efficiency):

### Definition of Terms

CDD = Cooling Degree Days (Degrees F \* Days)

HDD = Heating Degree Days (Degrees F \* Days)

DUA = Discretionary Use Adjustment to account for the fact that people do not always operate their air conditioning system when the outside temperature is greater than 65F.

= Area of the ceiling/attic with upgraded insulation (ft2)

= Area of the wall with upgraded insulation (ft2)

= Assembly R-value of ceiling/attic before retrofit (ft2\*°F\*hr/Btu)

= Assembly R-value of ceiling/attic after retrofit (ft2\*°F\*hr/Btu)

= Assembly R-value of wall before retrofit (ft2\*°F\*hr/Btu)

= Assembly R-value of wall after retrofit (ft2\*°F\*hr/Btu)

SEERCAC = Seasonal Energy Efficiency Ratio of existing home central air conditioner (Btu/W▪hr)

= Average Energy Efficiency Ratio of existing room air conditioner (Btu/W▪hr)

SEERASHP = Seasonal Energy Efficiency Ratio of existing home air source heat pump (Btu/W▪hr)

HSPFASHP = Heating Seasonal Performance Factor for existing home heat pump (Btu/W▪hr)

CFCAC = Summer peak coincidence factor for central AC systems

CFRAC = Summer peak coincidence factor for Room AC systems

CFASHP = Summer peak coincidence factor for ASHP systems

EFLHcool = Equivalent Full Load Cooling hours for Central AC and ASHP

EFLHcool RAC = Equivalent Full Load Cooling hours for Room AC

FRoom AC = Adjustment factor to relate insulated area to area served by Room AC units

The default values for each term are shown in Table 2‑33. The default values for heating and cooling days and hours are given in Table 2‑34.

Table 2‑33: Default values for algorithm terms

| Term | Type | Value | Source |
| --- | --- | --- | --- |
| Aroof | Variable | Varies | EDC Data Gathering |
| Awall | Variable | Varies | EDC Data Gathering |
| DUA | Fixed | 0.75 | OH TRM[[66]](#footnote-66) |
| Rroof,bl[[67]](#footnote-67) | Variable | 5 | Un-insulated attic |
| 16 | 4.5” (R-13) of existing attic insulation |
| 22 | 6” (R-19) of existing attic insulation |
| 30 | 10” (R-30) of existing attic insulation |
| Rroof,ee[[68]](#footnote-68) | Variable | 38 | Retrofit to R-38 total attic insulation |
| 49 | Retrofit to R-49 total attic insulation |
| Rwall,bl[[69]](#footnote-69) | Variable | Default = 3.0 | Assumes existing, un-insulated wall with 2x4 studs @ 16” o.c., w/ wood/vinyl siding |
| Existing Assembly R-value | EDC Data Gathering |
| Rwall,ee[[70]](#footnote-70) | Variable | Default = 9.0 | Assumes adding R-6 per DOE recommendations[[71]](#footnote-71) |
| Retrofit Assembly R-value | EDC Data Gathering |
| SEERCAC | Variable | Default = 13 | 2010 PA TRM Table 2-1 |
| Nameplate | EDC Data Gathering |
|  | Variable | Default = 9.8 | DOE Federal Test Procedure 10 CFR 430, Appendix F (Used in ES Calculator for baseline) |
| Nameplate | EDC Data Gathering |
| SEERASHP | Variable | Default = 13 | 2010 PA TRM Table 2-1 |
| Nameplate | EDC Data Gathering |
| HSPFASHP | Variable | Default = 7.7 | 2010 PA TRM Table 2-1 |
| Nameplate | EDC Data Gathering |
| CFCAC | Fixed | 0.70 | 2010 PA TRM Table 2-1 |
| CFRAC | Fixed | 0.58 | 2010 PA TRM Table 4-1 |
| CFASHP | Fixed | 0.70 | 2010 PA TRM Table 2-1 |
| FRoom,AC | Fixed | 0.38 | Calculated[[72]](#footnote-72) |

Table 2‑34: EFLH, CDD and HDD by City

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **City** | **EFLHcool**  **(Hours)[[73]](#footnote-73)** | **EFLHcool RAC**  **(Hours)[[74]](#footnote-74)** | **CDD (Base 65)[[75]](#footnote-75)** | **HDD (Base 65)[[76]](#footnote-76)** |
| Allentown | 784 | 243 | 787 | 5830 |
| Erie | 482 | 149 | 620 | 6243 |
| Harrisburg | 929 | 288 | 955 | 5201 |
| Philadelphia | 1032 | 320 | 1235 | 4759 |
| Pittsburgh | 737 | 228 | 726 | 5829 |
| Scranton | 621 | 193 | 611 | 6234 |
| Williamsport | 659 | 204 | 709 | 6063 |

### Measure Life

Measure life = 25 years[[77]](#footnote-77).

## Refrigerator / Freezer Recycling and Replacement

|  |  |
| --- | --- |
| Measure Name | Residential Refrigerator/Freezer Recycling and Replacement |
| Target Sector | Residential Establishments |
| Measure Unit | Refrigerator or Freezer |
| Unit Annual Energy Savings | 1205kWh |
| Unit Peak Demand Reduction | 0.1494kW |
| Measure Life | 7 years |

This measure is the recycling and replacement before end of life of an existing 10 year old or older refrigerator or freezer with a new ENERGY STAR refrigerator or freezer.

The deemed savings values for this measure can be applied to refrigerator and freezer 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 10 years old or older regardless of type
3. Unit is a primary or secondary unit
4. Replacement unit is an ENERGY STAR refrigerator or freezer

|  |  |
| --- | --- |
| BASE | Baseline Unit Energy Consumption |
| EE | Energy Efficient Replacement Unit - e.g. Consumption (kWhEE) |
| RefRpl | Refrigerator Replacement - e.g. Energy savings from replacement(ΔkWhRefRepl) |

### Algorithms

The deemed savings values are based on the following algorithms:

Energy Savings:

(ΔkWhRefRepl) = kWhBASE – kWhEE

Coincident peak demand savings

(ΔkWRefRepl) = ΔkWhRefRepl/HOURSRefRepl \* CFRefRepl

### Definition of Terms

The energy and demand savings shall be:

ΔkWhRefRepl = 1659 kWh - 454kWh = 1205 kWh/unit

ΔkWRefRepl = 1205 kWh/5000 hrs \* 0.62 =0.1494 kW/unit

These savings numbers are derived from the following assumptions:

CFRefRepl = Summer Peak Coincidence Factor = 0.620[[78]](#footnote-78)

HOURSRefRepl = Average annual run time = 5000 hrs, [[79]](#footnote-79),[[80]](#footnote-80)

The combined average refrigerator and freezer annual kWh consumption for Pennsylvania is based upon the data contained in the PA EDC appliance recycling contractor (JACO) databases. Because the manufacturer annual kWh consumption data was recorded in less than 50% of appliance collections, it was not used to calculate an average. SWE utilized the recorded year of manufacture in the “JACO Databases” and the annual kWh consumption data by size and age contained in the ENERGY STAR Refrigerator Retirement Calculator.[[81]](#footnote-81)

Table 2‑35: Average Energy Savings for Appliances Collected for Pennsylvania EDCs

|  |  |  |
| --- | --- | --- |
|  | Average annual kWh consumption from Pennsylvania EDC databases[[82]](#footnote-82) | Number of complete appliance collection records provided by Pennsylvania EDCs data) |
| Average of all Fridges and Freezers | 1659 | 18276 |

Table 2‑36: Average Energy Savings

|  |  |  |  |
| --- | --- | --- | --- |
| Source/Reference | Baseline Energy Consumption (kWhBASE) | ENERGY STAR Refrigerator Energy Consumption (kWhEE) | Estimated Energy Savings (ΔkWhRefRepl) |
| Refrigerator | 1659[[83]](#footnote-83) | 454[[84]](#footnote-84) | 1205 |

### Measure Life

Refrigerator/Freezer Replacement programs: Measure Life = 7 yrs

#### Measure Life Rationale

The 2010 PA TRM specifies a Measure Life of 13 years for refrigerator replacement and 8 years for refrigerator retirement (Appendix A). It is assumed that the TRM listed measure life is either an Effective Useful Life (EUL) or Remaining Useful Life (RUL), as appropriate to the measure. Survey results from a study of the low-income program for SDG&E (2006)[[85]](#footnote-85) found that among the program’s target population, refrigerators are likely to be replaced less frequently than among average customers. Southern California Edison uses an EUL of 18 years for its Low-Income Refrigerator Replacement measure which reflects the less frequent replacement cycle among low-income households. The PA TRM limits measure savings to a maximum of 15 yrs.

Due to the nature of a Refrigerator/Freezer Early Replacement Program, measure savings should be calculated over the life of the ENERGY STAR replacement unit. These savings should be calculated over two periods, the RUL of the existing unit, and the remainder of the measure life beyond the RUL. For the RUL of the existing unit, the energy savings would be equal to the full savings difference between the existing baseline unit and the ENERGY STAR unit, and for the remainder of the measure life the savings would be equal to the difference between a Federal Standard unit and the ENERGY STAR unit. The RUL can be assumed to be 1/3 of the measure EUL.

As an example, Low-Income programs use a measure life of 18 years and an RUL of 6 yrs (1/3\*18). The measure savings for the RUL of 6 yrs would be equal to the full savings. The savings for the remainder of 12 years would reflect savings from normal replacement of an ENERGY STAR refrigerator over a Federal Standard baseline, as defined in the TRM.

Example Measure savings over lifetime   
= 1205 kWh/yr \* 6 yrs + 100 kWh/yr (ES side mount freezer w/ door ice) \* 12 yrs = 8430 kWh/measure lifetime

For non-Low-Income specific programs, the measure life would be 13 years and an RUL of 4 yrs (1/3\*15). The measure savings for the RUL of 4 yrs would be equal to the full savings. The savings for the remainder of 9 years would reflect savings from normal replacement of an ENERGY STAR refrigerator over a Federal Standard baseline, as defined in the TRM.

Example Measure savings over lifetime   
= 1205 kWh/yr \* 4 yrs + 100 kWh/yr (ES side mount freezer w/ door ice) \* 9 yrs = 5720 kWh/measure lifetime

To simplify the programs and remove the need to calculate two different savings, a compromise value for measure life of 7 years for both Low-Income specific and non-Low Income specific programs can be used with full savings over this entire period. This provides an equivalent savings as the Low-Income specific dual period methodology for an EUL of 18 yrs and a RUL of 6 yrs.

Example Measure savings over lifetime   
= 1205 kWh/yr \* 7 yrs = 8435 kWh/measure lifetime

## Refrigerator/Freezer Retirement (and Recycling)

|  |  |
| --- | --- |
| Measure Name | Refrigerator/Freezer Retirement (and recycling) |
| Target Sector | Residential Establishments |
| Measure Unit | Refrigerator or Freezer |
| Unit Annual Energy Savings | 1659kWh |
| Unit Peak Demand Reduction | 0.2057kW |
| Measure Life | 8 years[[86]](#footnote-86) |

This measure is the retirement of an existing secondary refrigerator or freezer that is no less than 10 years old, without replacement.

The deemed savings values for this measure can be applied to refrigerator and freezer retirements 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 10 years old or older regardless of type
3. The refrigerator or freezer is a secondary unit that will not be replaced.

### Algorithms

To determine resource savings, per unit estimates in the algorithms will be multiplied by the number of appliance units. The general form of the equation for the Refrigerator/Freezer Retirement savings algorithm is:

Number of Units X Savings per Unit

The deemed savings values are based on the following algorithms or data research:

ΔkWh = kWhRetFridge

ΔkWpeak = kWRetFridge / hours \* CFRetFridge

### Definition of Terms

kWhRetFridge = Gross annual energy savings per unit retired appliance

kWRetFridge = Summer demand savings per retired refrigerator/freezer

CFRetFridge = Summer demand coincidence factor.

**Where:**

kWhRetFridge =1659 kWh

CFRetFridge =0.620

hours =5000

Unit savings are the product of average fridge/freezer consumption (gross annual savings). The combined average refrigerator and freezer annual kWh consumption for Pennsylvania is based upon the data contained in the PA EDC appliance recycling contractor (JACO) databases. Because the manufacturer annual kWh consumption data was recorded in less than 50% of appliance collections, it was not used to calculate an average. SWE utilized the recorded year of manufacture in the “JACO Databases” and the annual kWh consumption data by size, age and refrigerator/freezer type contained in the ENERGY STAR Refrigerator Retirement Calculator. 203 incomplete or erroneous records, from a total 18479 records (1%) were removed from the sample prior to calculating the average annual kWh consumption.[[87]](#footnote-87)

Table 2‑37: Energy and Demand Savings

|  |  |  |
| --- | --- | --- |
|  | Source/Reference | Energy and Demand Savings |
| kWhRetFridge | Combined average refrigerator and freezer annual kWh consumption for Pennsylvania (based on all available PA EDC appliance recycling databases from JACO) | 1659kWh[[88]](#footnote-88) |
| kWRetFridge = | 1659kWh/5000hours \* 0.620 | .2057kW |

## Residential New Construction

### Algorithms

#### Insulation Up-Grades, Efficient Windows, Air Sealing, Efficient HVAC Equipment and Duct Sealing

Energy savings due to improvements in Residential New Construction 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 is cited here as an example of an accredited software which has a module that compares the energy characteristics of the energy efficient home to the baseline/reference home and calculates savings.

The system peak electric demand savings will be calculated from the software output with the following savings’ algorithms, which are 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   
= (PLb X OFb) / (SEERb X BLEER X 1,000).

Peak demand of the qualifying home   
= (PLq X OFq) / (EERq X 1,000).

Coincident system peak electric demand savings   
= (Peak demand of the baseline home – Peak demand of the qualifying home) X CF.

#### Lighting and Appliances

Quantification of additional saving due to the addition of high-efficiency lighting and clothes washers will be based on the algorithms presented for these appliances in the ENERGY STAR Lighting Algorithms and the ENERGY STAR Appliances Algorithms, respectively. These algorithms are found in ENERGY STAR Products.

#### Ventilation Equipment

Additional energy savings of 175 kWh and peak-demand saving of 60 Watts will be added to the output of the home energy rating software to account for the installation of high-efficiency ventilation equipment. These values are based on a baseline fan of 80 Watts and an efficient fan of 20 Watts running for eight-hours per day.

### Definition of Terms

PLb = Peak load of the baseline home in Btuh.

OFb = The over-sizing factor for the HVAC unit in the baseline home.

SEERb = The Seasonal Energy Efficiency Ratio of the baseline unit.

BLEER = Factor to convert baseline SEERb to EERb.

PLq = The actual predicted peak load for the program qualifying home constructed, in Btuh.

OFq = The over-sizing factor for the HVAC unit in the program qualifying home.

EERq = The EER associated with the HVAC system in the qualifying home.

CF = Demand Coincidence Factor – the percentage of the total installed HVAC system’s connected load that is on during electric system’s peak window as defined in Section 1- Electric Resource Savings.

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

Table 2‑38: Residential New Construction – References[[89]](#footnote-89)

|  |  |  |  |
| --- | --- | --- | --- |
| **Component** | **Type** | **Value** | **Sources** |
| PLb | Variable |  | 1 |
| OF*b* | Fixed | 1.6 | 2 |
| SEER*b* | Fixed | 13 | 3 |
| BLEER | Fixed | 0.92 | 4 |
| PL*q* | Variable |  | Software Output |
| OF*q* | Fixed | 1.15 | 5 |
| EER*q* | Variable |  | AEPS Application; EDC’s Data Gathering |
| CF | Fixed | 0.70 | 6 |

*Sources*:

1. Calculation of peak load of baseline home from the home energy rating tool, based on the reference home energy characteristics.
2. PSE&G 1997 Residential New Construction baseline study.
3. Federal Register, Vol. 66, No. 14, Monday, January 22, 2001/Rules and Regulations, p. 7170-7200
4. Engineering calculation.
5. Program guideline for qualifying home.
6. Based on an analysis of six different utilities by Proctor Engineering.

The following tables describe the characteristics of the three reference homes.

Table 2‑39: ENERGY STAR Homes: REMRate User Defined Reference Homes[[90]](#footnote-90) – References

| **Data Point** | **Value[[91]](#footnote-91)** |
| --- | --- |
| Active Solar | None |
| Ceiling Insulation | U=0.031 (1) |
| Radiant Barrier | None |
| Rim/Band Joist | U=0.141 Type A-1, U=0.215 Type A-2 (1) |
| Exterior Walls - Wood | U=0.141 Type A-1, U=0.215 Type A-2 (1) |
| Exterior Walls - Steel | U=0.141 Type A-1, U=0.215 Type A-2 (1) |
| Foundation Walls | U=0.99 |
| Doors | U=0.141 Type A-1, U=0.215 Type A-2 (1) |
| Windows | U=0.141 Type A-1, U=0.215 Type A-2 (1), No SHGC req. |
| Glass Doors | U=0.141 Type A-1, U=0.215 Type A-2 (1), No SHGC req. |
| Skylights | U=0.031 (1), No SHGC req. |
| Floor over Garage | U=0.050 (1) |
| Floor over Unheated Basement | U=0.050 (1) |
| Floor over Crawlspace | U=0.050 (1) |
| Floor over Outdoor Air | U=0.031 (1) |
| Unheated Slab on Grade | R-0 edge/R-4.3 under |
| Heated Slab on Grade | R-0 edge/R-6.4 under |
| Air Infiltration Rate | 0.51 ACH winter/0.51 ACH summer |
| Duct Leakage | No Observable Duct Leakage |
| Mechanical Ventilation | None |
| Lights and Appliances | Use Default |
| Setback Thermostat | Yes for heating, no for cooling |
| Heating Efficiency |  |
| Furnace | 80% AFUE (3) |
| Boiler | 80% AFUE |
| Combo Water Heater | 76% AFUE (recovery efficiency) |
| Air Source Heat Pump | 7.7 HSPF |
| Geothermal Heat Pump | Open not modeled, 3.0 COP closed |
| PTAC / PTHP | Not differentiated from air source HP |
| Cooling Efficiency |  |
| Central Air Conditioning | 13.0 SEER |
| Air Source Heat Pump | 13.0 SEER |
| Geothermal Heat Pump | 3.4 COP (11.6 EER) |
| PTAC / PTHP | Not differentiated from central AC |
| Window Air Conditioners | Not differentiated from central AC |
| Domestic WH Efficiency |  |
| Electric | 0.97 EF (4) |
| Natural Gas | 0.67 EF (4) |
| Water Heater Tank Insulation | None |
| Duct Insulation | N/A |

Table 2‑40: ENERGY STAR Homes: REMRate User Defined Reference Homes[[92]](#footnote-92) – References

| Data Point | Value**[[93]](#footnote-93)** |
| --- | --- |
| Domestic WH Efficiency |  |
| Electric | EF = 0.97 - (0.00132 \* gallons) (1) |
| Natural Gas | EF = 0.67 - (0.0019 \* gallons) (1) |

## ENERGY STAR Appliances

### Algorithms

The general form of the equation for the ENERGY STAR Appliance measure savings’ algorithms is:

Total Savings = Number of Units x Savings per Unit

To determine resource savings, the per unit estimates in the algorithms will be multiplied by the number of appliance units. The number of units will be determined using market assessments and market tracking. Some of these market tracking mechanisms are under development. Per unit savings’ estimates are derived primarily from a 2000 Market Update Report by RLW for National Grid’s appliance program and from previous NEEP screening tool assumptions (clothes washers).

#### ENERGY STAR Refrigerators

ΔkWh = ESavREF

ΔkWpeak  = DSavREF X CFREF

#### ENERGY STAR Clothes Washers

ΔkWh = ESavCW

ΔkWpeak  = DSavCW X CFCW

#### ENERGY STAR Dishwashers

ΔkWh = ESavDW

ΔkWpeak  = DSavREF X CFDW

#### ENERGY STAR Dehumidifiers

ΔkWh = ESavDH

ΔkWpeak  = DSavDH X CFDH

#### ENERGY STAR Room Air Conditioners

ΔkWh = ESavRAC

ΔkWpeak  = DSavRAC X CFRAC

#### ENERGY STAR Freezer

ΔkW= kWBASE – kWEE

ΔkWh = ΔkW X HOURS

### Definition of Terms

ESavREF = Electricity savings per purchased ENERGY STAR refrigerator.

DSavREF = Summer demand savings per purchased ENERGY STAR refrigerator.

ESavCW = Electricity savings per purchased ENERGY STAR clothes washer.

DSavCW = Summer demand savings per purchased ENERGY STAR clothes washer.

ESavDW = Electricity savings per purchased ENERGY STAR dishwasher.

DSavDW = Summer demand savings per purchased ENERGY STAR dishwasher.

ESavDH = Electricity savings per purchased ENERGY STAR dehumidifier

DSavDH = Summer demand savings per purchased ENERGY STAR dehumidifier

ESavRAC = Electricity savings per purchased ENERGY STAR room AC.

DSavRAC = Summer demand savings per purchased ENERGY STAR room AC.

CFREF, CFCW, CFDW,

CFDH, CFRAC = Summer demand coincidence factor. The coincidence of average appliance demand to summer system peak equals 1 for demand impacts for all appliances reflecting embedded coincidence in the DSav factor (except for room air conditioners where the CF is 58%).

ΔkW= gross customer connected load kW savings for the measure

kWBASE = Baseline connected kW

kWEE = Energy efficient connected kW

HOURS = average hours of use per year

Table 2‑41: ENERGY STAR Appliances - References

| Component | Type | Value | Sources |
| --- | --- | --- | --- |
| ESavREF | Fixed | see below | 12 |
| DSavREF | Fixed | 0.0125 kW | 1 |
| REF Time Period Allocation Factors | Fixed | Summer/On-Peak 20.9% Summer/Off-Peak 21.7% Winter/On-Peak 28.0% Winter/Off-Peak 29.4% | 2 |
| ESavCW | Fixed | see below | 12 |
| DSavCW | Fixed | 0.0147 kW | 3 |
| CW Electricity Time Period Allocation Factors | Fixed | Summer/On-Peak 24.5% Summer/Off-Peak 12.8% Winter/On-Peak 41.7% Winter/Off-Peak 21.0% | 2 |
| ESavDW | Fixed | see below | 12 |
| DSavDW | Fixed | 0.0225 | 4 |
| DW Electricity Time Period Allocation Factors | Fixed | 19.8%, 21.8%, 27.8%, 30.6% | 2 |
| ESavDH | Fixed | see below | 12 |
| DSavDH | Fixed | .0098 kW | 10 |
| ESavRAC | Fixed | see below | 12 |
| DSavRAC | Fixed | 0.1018 kW | 6 |
| CFREF, CFCW, CFDW, CFDH, CFRAC | Fixed | 1.0, 1.0, 1.0, 1.0, 0.58 | 7 |
| RAC Time Period Allocation Factors | Fixed | 65.1%, 34.9%, 0.0%, 0.0% | 2 |
| kWBASE | Fixed | 0.0926 | 11 |
| kWEE | Fixed | 0.0813 | 11 |
| HOURS | Fixed | 5000 | 11 |
| ΔkW | Fixed | 0.0113 | 11 |

*Sources*:

1. ENERGY STAR Refrigerator Savings Calculator (Calculator updated: 2/15/05; Constants updated 05/07). Demand savings derived using refrigerator load shape.
2. Time period allocation factors used in cost-effectiveness analysis. From residential appliance load shapes.
3. Energy and water savings based on Consortium for Energy Efficiency estimates. Assumes 75% of participants have gas water heating and 60% have gas drying (the balance being electric). Demand savings derived using NEEP screening clothes washer load shape.
4. Energy and water savings from RLW Market Update. Assumes 37% electric hot water market share and 63% gas hot water market share. Demand savings derived using dishwasher load shape.
5. Energy and demand savings from engineering estimate based on 600 hours of use. Based on delta watts for ENERGY STAR and non-ENERGY STAR units in five different size (cooling capacity) categories. Category weights from LBNL *Technical Support Document for ENERGY STAR Conservation Standards for Room Air Conditioners*.
6. Average demand savings based on engineering estimate.
7. Coincidence factors already embedded in summer peak demand reduction estimates with the exception of RAC. RAC CF is based on data from PEPCO.
8. Prorated based on six months in the summer period and six months in the winter period.
9. ENERGY STAR Dehumidifier Savings Calculator (Calculator updated: 2/15/05; Constants updated 05/07). A weighted average based on the distribution of available ENERGY STAR products was used to determine savings.
10. Conservatively assumes same kW/kWh ratio as Refrigerators.
11. Efficiency Vermont. Technical Reference User Manual: Measure Savings Algorithms and Cost Assumptions (July 2008).
12. All values are taken from the ENERGY STAR Savings Calculators at www.energystar.gov.

Table 2‑42: Energy Savings from ENERGY STAR Calculator

| Measure | Energy Savings |
| --- | --- |
| Refrigerator |  |
| Manual Defrost | 72 kWh |
| Partial Automatic Defrost | 72 kWh |
| Top mount freezer without door ice | 80 kWh |
| Side mount freezer without door ice | 95 kWh |
| Bottom mount freezer without door ice | 87 kWh |
| Top mount freezer with door ice | 94 kWh |
| Side mount freezer with door ice | 100 kWh |
| Freezers |  |
| Upright with manual defrost | 55 kWh |
| Upright with automatic defrost | 80 kWh |
| Chest Freezer | 52 kWh |
| Compact Upright with manual defrost | 62 kWh |
| Compact Upright with automatic defrost | 83 kWh |
| Compact Chest Freezer | 55 kWh |
| Dehumidifier |  |
| 1-25 pints/day | 54 kWh |
| 25-35 pints/day | 117 kWh |
| 35-45 pints/day | 213 kWh |
| 45-54 pints/day | 297 kWh |
| 54-75 pints/day | 342 kWh |
| 75-185 pints/day | 374 kWh |
| Room Air Conditioner (Load hours in parentheses) |  |
| Allentown | 74 kWh (784 hours) |
| Erie | 46 kWh (482 hours) |
| Harrisburg | 88 kWh (929 hours) |
| Philadelphia | 98 kWh (1032 hours) |
| Pittsburgh | 70 kWh (737 hours) |
| Scranton | 59 kWh (621 hours) |
| Williamsport | 62 kWh (659 hours) |
| Dishwasher |  |
| With Gas Hot Water Heater | 77 kWh |
| With Electric Hot Water Heater | 137 kWh |
| Clothes Washer |  |
| With Gas Hot Water Heater | 26 kWh |
| With Electric Hot Water Heater | 258 kWh |

## ENERGY STAR Lighting

### Algorithms

Savings from installation of screw-in ENERGY STAR CFLs, ENERGY STAR fluorescent torchieres, ENERGY STAR indoor fixtures and ENERGY STAR outdoor fixtures 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 reflect the fact that not all lighting products purchased are actually installed.

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

Total Savings = Number of Units X Savings per Unit

Per unit savings estimates are derived primarily from a 2004 Nexus Market Research report evaluating similar retail lighting programs in New England (MA, RI and VT)

#### ENERGY STAR CFL Bulbs (screw-in)

ΔkWh = ((CFLwatts X (CFLhours X 365))/1000) X ISRCFL

ΔkWpeak = (CFLwatts)/1000 X CF X ISRCFL

#### ENERGY STAR Torchieres

ΔkWh = ((Torchwatts X (Torchhours X 365))/1000) X ISRTorch

ΔkWpeak  = (Torchwatts)/1000 X CF X ISRTorch

#### ENERGY STAR Indoor Fixture (hard-wired, pin-based)

ΔkWh = ((IFwatts X (IFhours X 365))/1000) X ISRIF

ΔkWpeak  = (IFwatts)/1000 X CF X ISRIF

#### ENERGY STAR Outdoor Fixture (hard wired, pin-based)

ΔkWh = ((OFwatts X (OFhours X 365))/1000) X ISROF

ΔkWpeak  = (OFwatts)/1000 X CF X ISROF

#### Ceiling Fan with ENERGY STAR Light Fixture

ΔkWh =180 kWh

ΔkWpeak = 0.01968

### Definition of Terms

CFLwatts = Average delta watts per purchased ENERGY STAR CFL

CFLhours = Average hours of use per day per CFL

ISRCFL = In-service rate per CFL

Torchwatts = Average delta watts per purchased ENERGY STAR torchiere

Torchhours = Average hours of use per day per torchiere

ISRTorch = In-service rate per Torchier

IFwatts = Average delta watts per purchased ENERGY STAR Indoor Fixture

IFhours = Average hours of use per day per Indoor Fixture

ISRIF = In-service rate per Indoor Fixture

OFwatts = Average delta watts per purchased ENERGY STAR Outdoor Fixture

OFhours = Average hours of use per day per Outdoor Fixture

ISROF = In-service rate per Outdoor Fixture

CF = Demand Coincidence Factor – the percentage of the total lighting connected load that is on during electric system’s peak window as defined in Section 1- Electric Resource Savings.

ΔkWh= Gross customer annual kWh savings for the measure

ΔkW= Gross customer connected load kW savings for the measure

Table 2‑43: ENERGY STAR Lighting - References

|  |  |  |  |
| --- | --- | --- | --- |
| Component | Type | Value | Sources |
| CFLwatts | Fixed | Variable | Data Gathering |
| CFLhours | Fixed | 1.9 | 6 |
| ISRCFL | Fixed | 84% | 3 |
| Torchwatts | Fixed | 115.8 | 1 |
| Torchhours | Fixed | 3.0 | 2 |
| ISRTorch | Fixed | 83% | 3 |
| IFwatts | Fixed | 48.7 | 1 |
| IFhours | Fixed | 2.6 | 2 |
| ISRIF | Fixed | 95% | 3 |
| OFwatts | Fixed | 94.7 | 1 |
| OFhours | Fixed | 4.5 | 2 |
| ISROF | Fixed | 87% | 3 |
| CF | Fixed | 5% | 4 |
| ΔkWh | Fixed | 180 kWh | 5 |
| ΔkW | Fixed | 0.01968 | 5 |

**Sources:**

1. Nexus Market Research, “Impact Evaluation of the Massachusetts, Rhode Island and Vermont 2003 Residential Lighting Programs”, Final Report, October 1, 2004, p. 43 (Table 4-9)
2. Ibid., p. 104 (Table 9-7). This table adjusts for differences between logged sample and the much larger telephone survey sample and should, therefore, have less bias.
3. Ibid., p. 42 (Table 4-7). These values reflect both actual installations and the % of units planned to be installed within a year from the logged sample. The logged % is used because the adjusted values (~~i.e~~ to account for differences between logging and telephone survey samples) were not available for both installs and planned installs. However, this seems appropriate because the % actual installed in the logged sample from this table is essentially identical to the % after adjusting for differences between the logged group and the telephone sample (p. 100, Table 9-3).
4. RLW Analytics, “Development of Common Demand Impacts for Energy Efficiency Measures/Programs for the ISO Forward Capacity Market (FCM)”, prepared for the New England State Program Working Group (SPWG), March 25, 2007, p. IV.
5. Efficiency Vermont. Technical Reference User Manual: Measure Savings Algorithms and Cost Assumptions (July 2008).
6. United States Department of Energy, *Energy Star CFL Market Profile: Data Trends and Market Insights*. Prepared by D&R International, Ltd.: September 2010; pg. 24.

The 1.9 average daily hours of use, for all household socket locations, for all bulbs is based upon two independent large scale comprehensive residential lighting metering studies (one national and on in California). National: U.S. Department of Energy. US Lighting Market Characterization, Volume 1: National Lighting Inventory and Energy Consumption Estimate. 2002. California: KEMA, Inc. “Final Evaluation Report: Upstream Lighting Program.” Prepared for the California Public Utilities Commission, Energy Division. February 6, 2010.

## ENERGY STAR Windows

### Algorithms

The general form of the equation for the ENERGY STAR or other high-efficiency windows energy savings’ algorithms is:

Total Savings = Square Feet of Window Area X Savings per Square Foot

To determine resource savings, the per square foot estimates in the algorithms will be multiplied by the number of square feet of window area. The number of square feet of window area will be determined using market assessments and market tracking. Some of these market tracking mechanisms are under development. The per unit energy and demand savings estimates are based on prior building simulations of windows.

Savings’ estimates for ENERGY STAR Windows are based on modeling a typical 2,500 square foot home using REM Rate, the home energy rating tool.[[94]](#footnote-94) Savings are per square foot of qualifying window area. Savings will vary based on heating and cooling system type and fuel. These fuel and HVAC system market shares will need to be estimated from prior market research efforts or from future program evaluation results.

#### Heat Pump HVAC System

ΔkWh = ESavHP

ΔkWpeak = DSavHP X CF

#### Electric Heat/Central Air Conditioning

ΔkWh = ESavRES/CAC

ΔkWpeak  = DSavCAC X CF

#### Electric Heat/No Central Air Conditioning

ΔkWh = ESavRES/NOCAC

ΔkWpeak  = DSavNOCAC X CF

### Definition of Terms

ESavHP= Electricity savings (heating and cooling) with heat pump installed.

ESavRES/CAC = Electricity savings with electric resistance heating and central AC installed.

ESavRES/NOCAC = Electricity savings with electric resistance heating and no central AC installed.

DSavHP= Summer demand savings with heat pump installed.

DSavCAC = Summer demand savings with central AC installed.

DSavNOCAC = Summer demand savings with no central AC installed.

CF = Demand Coincidence Factor – the percentage of the total HVAC connected load that is on during electric system’s peak window as defined in Section 1- Electric Resource Savings.

Table 2‑44: ENERGY STAR Windows - References

| Component | Type | Value | Sources |
| --- | --- | --- | --- |
| ESavHP | Fixed | 2.2395 kWh/ft2 | 1 |
| HP Time Period Allocation Factors | Fixed | Summer/On-Peak 10%  Summer/Off-Peak 7%  Winter/On-Peak 40%  Winter/Off-Peak 44% | 2 |
| ESavRES/CAC | Fixed | 4.0 kWh/ft2 | 1 |
| Res/CAC Time Period Allocation Factors | Fixed | Summer/On-Peak 10%  Summer/Off-Peak 7%  Winter/On-Peak 40%  Winter/Off-Peak 44% | 2 |
| ESavRES/NOCAC | Fixed | 3.97 kWh/ft2 | 1 |
| Res/No CAC Time Period Allocation Factors | Fixed | Summer/On-Peak 3%  Summer/Off-Peak 3%  Winter/On-Peak 45%  Winter/Off-Peak 49% | 2 |
| DSavHP | Fixed | 0.000602 kW/ft2 | 1 |
| DSavCAC | Fixed | 0.000602 kW/ft2 | 1 |
| DSavNOCAC | Fixed | 0.00 kW/ft2 | 1 |
| CF | Fixed | 0.75 | 3 |

**Sources:**

1. From REMRATE Modeling of a typical 2,500 sq. ft. NJ home. Savings expressed on a per square foot of window area basis. New Brunswick climate data.
2. Time period allocation factors used in cost-effectiveness analysis.
3. Based on reduction in peak cooling load.
4. Prorated based on 12% of the annual degree days falling in the summer period and 88% of the annual degree days falling in the winter period.

## ENERGY STAR Audit

### Algorithms

No algorithm was developed to measure energy savings for this program. The purpose of the program is to provide information and tools that residential customers can use to make decisions about what actions to take to improve energy efficiency in their homes. Many measure installations that are likely to produce significant energy savings are covered in other programs. These savings are captured in the measured savings for those programs. The savings produced by this program that are not captured in other programs would be difficult to isolate and relatively expensive to measure.

## ENERGY STAR Refrigerator/Freezer Retirement

### Algorithms

The general form of the equation for the Refrigerator/Freezer Retirement savings algorithm is:

Total Savings = Number of Units X Savings per Unit

To determine resource savings, the per unit estimates in the algorithms will be multiplied by the number of appliance units.

Unit savings are the product of average fridge/freezer consumption (gross annual savings).

ΔkWh = ESavRetFridge

ΔkWpeak  = DSavRetFridge X CFRetFridge

### Definition of Terms

ESavRetFridge = Gross annual energy savings per unit retired appliance

DSavRetFridge = Summer demand savings per retired refrigerator/freezer

CFRetFridge = Demand Coincidence Factor – the percentage of the retired appliance connected load that is on during electric system’s peak window as defined in Section 1- Electric Resource Savings.

Table 2‑45: Refrigerator/Freezer Recycling – References

| **Component** | **Type** | **Value** | **Sources** |
| --- | --- | --- | --- |
| ESavRetFridge | Fixed | 1,728 kWh | 1 |
| DSavRetFridge | Fixed | .2376 kW | 2 |
| CFRetFridge | Fixed | 1 | 3 |

**Sources:**

1. The average power consumption of units retired under similar recent programs:
   1. Fort Collins Utilities, February 2005. Refrigerator and Freezer Recycling Program 2004 Evaluation Report.
   2. Midwest Energy Efficiency Alliance, 2005. 2005 Missouri ENERGY STAR Refrigerator Rebate and Recycling Program Final Report
   3. Pacific Gas and Electric, 2007. PGE ARP 2006-2008 Climate Change Impacts Model (spreadsheet)
   4. Quantec, Aug 2005. Evaluation of the Utah Refrigerator and Freezer Recycling Program (Draft Final Report).
   5. CPUC DEER website, <http://eega.cpuc.ca.gov/deer/measure.asp?s=1&c=2&sc=7&m=389059>
   6. Snohomish PUD, February 2007. 2006 Refrigerator/Freezer Recycling Program Evaluation.
   7. Ontario Energy Board, 2006. Total Resource Cost Guide.
2. Applied the kW to kWh ratio derived from Refrigerator savings in the ENERGY STAR Appliances Program.
3. Coincidence factor already embedded in summer peak demand reduction estimates

## Home Performance with ENERGY STAR

In order to implement Home Performance with ENERGY STAR, there are various standards a program implementer must adhere to in order to deliver the program. 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:

1. A software tool whose performance has passed testing according to the National Renewable Energy Laboratory’s HERS BESTEST software energy simulation testing protocol.[[95]](#footnote-95)
2. Software approved by the US Department of Energy’s Weatherization Assistance Program.[[96]](#footnote-96)
3. RESNET approved rating software.[[97]](#footnote-97)

There are numerous software packages that comply with these standards. Some examples of the software packages are REM/Rate, EnergyGauge, TREAT, and HomeCheck. The HomeCheck software is described below as an example of a software that can be used to determine if a home qualifies for Home Performance with ENERGY STAR.

### HomeCheck Software Example

Conservation Services Group (CSG) implements Home Performance with ENERGY STAR in several states. CSG has developed proprietary software known as HomeCheck which is designed to enable an energy auditor to collect information about a customer’s site and based on what is found through the energy audit, recommend energy savings measures and demonstrate the costs and savings associated with those recommendations. The HomeCheck software is also used to estimate the energy savings that are reported for this program.

CSG has provided a description of the methods and inputs utilized in the HomeCheck software to estimate energy savings. CSG has also provided a copy of an evaluation report prepared by Nexant which assessed the energy savings from participants in the Home Performance with ENERGY STAR Program managed by the New York State Energy Research and Development Authority (NYSERDA)[[98]](#footnote-98). The report concluded that the savings estimated by HomeCheck and reported to NYSERDA were in general agreement with the savings estimates that resulted from the evaluation.

These algorithms incorporate the HomeCheck software by reference which will be utilized for estimating energy savings for Home Performance with ENERGY STAR. The following is a summary of the HomeCheck software which was provided by CSG: CSG’s HomeCheck software was designed to streamline the delivery of energy efficiency programs. The software provides the energy efficiency specialist with an easy-to-use guide for data collection, site and HVAC testing algorithms, eligible efficiency measures, and estimated energy savings. The software is designed to enable an auditor to collect information about customers’ sites and then, based on what he/she finds through the audit, recommend energy-saving measures, demonstrate the costs and savings associated with those recommendations. It also enables an auditor/technician to track the delivery of services and installation of measures at a site.

This software is a part of an end-to-end solution for delivering high-volume retrofit programs, covering administrative functions such as customer relationship management, inspection scheduling, sub-contractor arranging, invoicing and reporting. The range of existing components of the site that can be assessed for potential upgrades is extensive and incorporates potential modifications to almost all energy using aspects of the home. The incorporation of building shell, equipment, distribution systems, lighting, appliances, diagnostic testing and indoor air quality represents a very broad and comprehensive ability to view the needs of a home.

The software is designed to combine two approaches to assessing energy savings opportunities at the site. One is a measure specific energy loss calculation, identifying the change in use of BTU’s achieved by modifying a component of the site. Second, is the correlation between energy savings from various building improvements, and existing energy use patterns at a site. The use of both calculated savings and the analysis of existing energy use patterns, when possible, provides the most accurate prescription of the impact of changes at the site for an existing customer considering improvements on a retrofit basis.

This software is not designed to provide a load calculation for new equipment or a HERS rating to compare a site to a standard reference site. It is designed to guide facilities in planning improvements at the site with the goal of improved economics, comfort and safety. The software calculates various economic evaluations such as first year savings, simple payback, measure life cost-effectiveness, and Savings-to-Investment ratio (SIR).

### Site-Level Parameters and Calculations

There are a number of calculations and methodologies that apply across measures and form the basis for calculating savings potentials at a site.

### Heating Degree Days and Cooling Degree Hours

Heat transfer calculations depend fundamentally on the temperature difference between inside and outside temperature. This temperature difference is often summarized on a seasonal basis using fixed heating degree-days (HDD) and cooling degree-hours (CDH). The standard reference temperature for calculating HDD (the outside temperature at which the heating system is required), for example, has historically been 65°F. Modern houses have larger internal gains and more efficient thermal building envelopes than houses did when the 65°F standard was developed, leading to lower effective reference temperatures. This fact has been recognized in ASHRAE Fundamentals, which provides a variable-based degree-day method for calculating energy usage. CSG’s Building Model calculates both HDD and CDH based on the specific characteristics and location of the site being treated.

### Building Loads, Other Parameters, and the Building Model

CSG is of the opinion that, in practice, detailed building load simulation tools are quite limited in their potential to improve upon simpler approaches due to their reliance on many factors that are not measurable or known, as well as limitations to the actual models themselves. Key to these limitations is the Human Factor (e.g., sleeping with the windows open; extensive use of high-volume extractor fans, etc.) that is virtually impossible to model. As such, the basic concept behind the model was to develop a series of location specific lookup tables that would take the place of performing hourly calculations while allowing the model to perform for any location. The data in these tables would then be used along with a minimum set of technical data to calculate heating and cooling building loads.

In summary, the model uses:

1. Lookup tables for various parameters that contain the following values for each of the 239 TMY2 weather stations:
   1. Various heating and cooling infiltration factors.
   2. Heating degree days and heating hours for a temperature range of 40 to 72°F.
   3. Cooling degree hours and cooling hours for a temperature range of 68 to 84°F.
   4. Heating and cooling season solar gain factors.
2. Simple engineering algorithms based on accepted thermodynamic principles, adjusted to reflect known errors, the latest research and measured results
3. Heating season iterative calculations to account for the feedback loop between conditioned hours, degree days, average “system on” indoor and outdoor temperatures and the building
4. The thermal behavior of homes is complex and commonly accepted algorithms will on occasion predict unreasonably high savings, HomeCheck uses a proprietary methodology to identify and adjust these cases. This methodology imposes limits on savings projected by industry standard calculations, to account for interactivities and other factors that are difficult to model. These limits are based on CSG’s measured experience in a wide variety of actual installations.

### Usage Analysis

The estimation of robust building loads through the modeling of a building is not always reliable. Thus, in addition to modeling the building, HomeCheck calculates a normalized annual consumption for heating and cooling, calculated from actual fuel consumption and weather data using a Seasonal Swing methodology. This methodology uses historic local weather data and site-specific usage to calculate heating and cooling loads. The methodology uses 30-year weather data to determine spring and fall shoulder periods when no heating or cooling is likely to be in use. The entered billing history is broken out into daily fuel consumption, and these daily consumption data along with the shoulder periods is used to calculate base load usage and summer and winter seasonal swing fuel consumption.

### Multiple HVAC Systems

HVAC system and distribution seasonal efficiencies are used in all thermal-shell measure algorithms. HVAC system and distribution seasonal efficiencies and thermostat load reduction adjustments are used when calculating the effect of interactivity between mechanical and architectural measures. If a site has multiple HVAC systems, weighted average seasonal efficiencies and thermostat load reduction adjustments are calculated based on the relative contributions (in terms of percent of total load) of each system.

### Multiple Heating Fuels

It is not unusual to find homes with multiple HVAC systems using different fuel types. In these cases, it is necessary to aggregate the NACs for all fuel sources for use in shell savings algorithms. This is achieved by assigning a percentage contribution to total NAC for each system, converting this into BTU’s, and aggregating the result. Estimated first year savings for thermal shell measures are then disaggregated into the component fuel types based on the pre-retrofit relative contributions of fuel types.

### Interactivity

To account for interactivity between architectural and mechanical measures, CSG’s HomeCheck employs the following methodology, in order:

1. Noninteracted first year savings are calculated for each individual measure.
2. Non-interacted SIR (RawSIR) is calculated for each measure.
3. Measures are ranked in descending order of RawSIR,
4. Starting with the most cost-effective measure (as defined by RawSIR), first year savings are adjusted for each measure as follows:
   1. Mechanical measures (such as thermostats, HVAC system upgrades or distribution system upgrades) are adjusted to account for the load reduction from measures with a higher RawSIR.
   2. Architectural measures are adjusted to account for overall HVAC system efficiency changes and thermostat load reduction changes. Architectural measures with a higher RawSIR than that of HVAC system measures are calculated using the existing efficiencies. Those with RawSIR’s lower than that of heating equipment use the new heating efficiencies.
5. Interacted SIR is then calculated for each measure, along with cumulative SIR for the entire job.
6. All measures are then re-ranked in descending order of SIR.
7. The process is repeated, replacing RawSIR with SIR until the order of measures does not change.

### Lighting

Quantification of additional savings due to the addition of high efficiency lighting will be based on the applicable algorithms presented for these appliances in the ENERGY STAR Lighting Algorithms section found in ENERGY STAR Products.

## ENERGY STAR Televisions (Versions 4.1 and 5.1)

This measure applies to the purchase of an ENERGY STAR TV meeting Version 4.1 or Version 5.1 standards. Version 4.1 standards are effective as of May 1, 2010, and Version 5.1 standards are effective as of May 1, 2012.

The baseline equipment is a TV meeting ENERGY STAR Version 3.0 requirements[[99]](#footnote-99).

### Algorithms

Energy Savings (per TV):

Coincident Demand Savings (per TV):

Savings calculations are based on power consumption while the TV is in active mode only, as requirements for standby power are the same for both baseline and new units.

### Definition of Terms

Wbase,active = power use (in Watts) of baseline TV while in active mode (i.e. turned on and operating).

WES,active = power use (in Watts) of ENERGY STAR Version 4.1 or 5.1 TV while in active mode (i.e. turned on and operating).

HOURSactive = number of hours per day that a typical TV is active (turned on and in use).

CF = summer peak coincidence factor.

365 = days per year.

Table 2‑46: ENERGY STAR TVs - References

|  |  |  |  |
| --- | --- | --- | --- |
| Component | Type | Value | Source |
| CF | Fixed | 0.28 | 1 |
| HOURSactive | Fixed | 5 | 2 |

*Sources*:

1. Deemed Savings Technical Assumptions, Program: ENERGY STAR Retailer Incentive Pilot Program, accessed October 2010, <http://www.xcelenergy.com/SiteCollectionDocuments/docs/ES-Retailer-Incentive-60-day-Tech-Assumptions.pdf>
2. Calculations assume TV is in active mode (or turned on) for 5 hours per day and standby mode for 19 hours per day. Based on assumptions from ENERGY STAR Calculator, *Life Cycle Cost Estimate for 100 ENERGY STAR Qualified Television(s)*, accessed October 2010, <http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_Televisions_Bulk.xls>

Table 2‑47: ENERGY STAR TVs Version 4.1 and 5.1 maximum power consumption

|  |  |  |
| --- | --- | --- |
| Screen Area[[100]](#footnote-100) (square inches) | Maximum Active Power (WES,active)  Version 4.1[[101]](#footnote-101) | Maximum Active Power (WES,active)  Version 5.1[[102]](#footnote-102) |
| A < 275 | Pmax = 0.190 \* A +5 | Pmax = 0.130 \* A +5 |
| 275 ≤ A ≤ 1068 | Pmax = 0.120 \* A +25 | Pmax = 0.084 \* A +18 |
| A > 1068 | Pmax = 0.120 \* A +25 | Pmax = 108 |

Table 2‑48: TV power consumption

|  |  |  |  |
| --- | --- | --- | --- |
| Diagonal Screen Size (inches)[[103]](#footnote-103) | Baseline Active Power Consumption [Wbase,active][[104]](#footnote-104) | ENERGY STAR V. 4.1 Active Power Consumption [WES,active][[105]](#footnote-105) | ENERGY STAR V. 5.1 Active Power Consumption [WES,active][[106]](#footnote-106) |
| < 20 | 51 | 23 | 17 |
| 20 < 30 | 85 | 56 | 40 |
| 30 < 40 | 137 | 88 | 62 |
| 40 < 50 | 235 | 129 | 91 |
| 50 < 60 | 353 | 180 | 108\* |
| ≥ 60 | 391 | 210 | 108\* |

\* Pmax = 108W

### Deemed Savings

Deemed annual energy savings for ENERGY STAR Version 4.1 and 5.1 TVs are given in Table 2‑49. Coincident demand savings are given in Table 2‑50.

Table 2‑49: Deemed energy savings for ENERGY STAR Version 4.1 and 5.1 TVs.

|  |  |  |
| --- | --- | --- |
| **Diagonal Screen Size (inches)[[107]](#footnote-107)** | **Energy Savings**  **ENERGY STAR V. 4.1 TVs (kWh/year)** | **Energy Savings**  **ENERGY STAR V. 5.1 TVs (kWh/year)** |
| < 20 | 51 | 62 |
| 20 < 30 | 54 | 83 |
| 30 < 40 | 89 | 136 |
| 40 < 50 | 193 | 263 |
| 50 < 60 | 315 | 446 |
| ≥ 60 | 331 | 516 |

Table 2‑50: Deemed coincident demand savings for ENERGY STAR Version 4.1 and 5.1 TVs.

|  |  |  |
| --- | --- | --- |
| **Diagonal Screen Size (inches)[[108]](#footnote-108)** | **Coincident Demand Savings ENERGY STAR V. 4.1 (kW)** | **Coincident Demand Savings ENERGY STAR V. 5.1 (kW)** |
| < 20 | 0.008 | 0.009 |
| 20 < 30 | 0.008 | 0.013 |
| 30 < 40 | 0.014 | 0.021 |
| 40 < 50 | 0.030 | 0.040 |
| 50 < 60 | 0.048 | 0.068 |
| ≥ 60 | 0.051 | 0.079 |

### Measure Life

Measure life = 15 years[[109]](#footnote-109)

# Commercial and Industrial Measures

## Baselines and Code Changes

All baselines are designed to reflect current market practices which are generally the higher of code or available equipment, that are updated periodically to reflect upgrades in code or information from evaluation results.

Pennsylvania has adopted the 2009 International Energy Conservation Code (IECC) per 34 Pa. Code Section 403.21, effective 12/31/09 by reference to the International Building code and the ICC electrical code. This family of codes references ASHRAE 90.1-2007 for minimum energy efficiency standards for commercial and industrial construction projects.

## Lighting Equipment Improvements

### Eligibility

Eligible lighting equipment and fixture/lamp types include fluorescent fixtures (lamps and ballasts), compact fluorescent lamps, LED exit signs, high intensity discharge (HID) lamps, interior and exterior LED lamps and fixtures, cold-cathode fluorescent lamps (CCFL), induction lamps, and lighting controls. The calculation of energy savings is based on algorithms through the stipulation of key variables (i.e. Coincidence Factor, Interactive Factor and Equivalent Full Load Hours) and through end-use metering referenced in historical studies or measured, as may be required, at the project level.

#### Solid State Lighting

Due to the immaturity of the SSL market, diversity of product technologies and quality, and current lack of uniform industry standards, it is impossible to point to one source as the complete list of qualifying SSL products for inclusion in Act 129 efficiency programs. A combination of industry-accepted references have been collected to generate minimum criteria for the most complete list of products while not sacrificing quality and legitimacy of savings. The following states the minimum requirements for SSL products that qualify under the TRM:

For Act 129 energy efficiency measure savings qualification, for SSL products for which there is an ENERGY STAR commercial product category[[110]](#footnote-110), the product shall meet the minimum ENERGY STAR requirements[[111]](#footnote-111) [[112]](#footnote-112) for the given product category. Products are not required to be on the ENERGY STAR Qualified Product List[[113]](#footnote-113), however, if a product is on the list it shall qualify for Act 129 energy efficiency programs and no additional supporting documentation shall be required. ENERGY STAR qualified commercial/non-residential product categories include:

* Omnidirectional: A, BT, P, PS, S, T
* Decorative: B, BA, C, CA, DC, F, G
* Directional: BR, ER, K, MR, PAR, R
* Non-standard
* Recessed, surface and pendant-mounted downlights
* Under-cabinet shelf-mounted task lighting
* Portable desk task lights
* Wall wash luminaires
* Bollards

For SSL products for which there is not an ENERGY STAR commercial product category, but for which there is a DLC commercial product category[[114]](#footnote-114), the product shall meet the minimum DLC requirements[[115]](#footnote-115) for the given product category. Products are not required to be on the DLC Qualified Product List[[116]](#footnote-116), however, if a product is on the list it shall qualify for Act 129 energy efficiency programs and no additional supporting documentation shall be required. DLC qualified commercial product categories include:

* Outdoor Pole or Arm mounted Area and Roadway Luminaires
* Outdoor Pole or arm mounted Decorative Luminaires
* Outdoor Wall-Mounted Area Luminaires
* Parking Garage Luminaire
* Track or Mono-point Directional Lighting Fixtures
* Refrigerated Case Lighting
* Display Case Lighting
* 2x2 Luminares
* High-bay and Low-bay fixtures for Commercial and Industrial buildings

For SSL products that are not on either of the listed qualified products lists, they can still be considered for inclusion in Act 129 energy efficiency programs by submitting the following documentation to show compliance with the minimum product category criteria as described above:

* Manufacturer’s product information sheet
* LED package/fixture specification sheet
* List the ENERGY STAR or DLC product category for which the luminaire qualifies
* Summary table listing the minimum reference criteria and the corresponding product values for the following variables:
  + Light output in lumens
  + Luminaire efficacy (lm/W)
  + Color rendering index (CRI)
  + Correlated color temperature (CCT)
  + LED lumen maintenance at 6000 hrs
  + Manufacturer’s estimated lifetime for L70 (70% lumen maintenance at end of useful life) (manufacturer should provide methodology for calculation and justification of product lifetime estimates)
* IESNA LM-79-08 test report(s) (from approved labs specified in DOE Manufacturers’ Guide) containing:
  + Photometric measurements (i.e. light output and efficacy)
  + Colorimetry report (i.e. CCT and CRI)
  + Electrical measurements (i.e. input voltage and current, power, power factor, etc.)
* Lumen maintenance report (select one of the two options and submit all of its corresponding required documents):
  + Option 1: Compliance through component performance (for the corresponding LED package)
    - IESNA LM-80 test report
    - In-situ temperature measurements test (ISTMT) report.
    - Schematic/photograph from LED package manufacturer that shows the specified temperature measurement point (TMP)
  + Option 2: Compliance through luminaire performance
    - IESNA LM-79-08 report at 0 hours (same file as point c)
    - IESNA LM-79-08 report at 6000 hours after continuous operation in the appropriate ANSI/UL 1598 environment (use ANSI/UL 1574 for track lighting systems).

### All supporting documentation must include a specific, relevant model or part number.Algorithms

For all lighting efficiency improvements, with and without control improvements, the following algorithms apply:

ΔkW = kWbase - kWee

ΔkWpeak  = ΔkW X CF X (1+IF demand)

ΔkWh = [kWbase X(1+IF energy) X EFLH] – [kWee X(1+IF energy) X EFLH X (1 – SVG)]

### Definition of Terms

ΔkW = Change in connected load from baseline (pre-retrofit) to installed (post-retrofit) lighting level.

kWbase = kW of baseline lighting as defined by project classification.

kWee = kW of of post-retrofit or energy-efficient lighting system as defined in Section 5.

CF = Demand Coincidence Factor – the percentage of the total lighting connected load that is on during electric system’s peak window as defined in Section 1- Electric Resource Savings.

EFLH = Equivalent Full Load Hours – the average annual operating hours of the baseline lighting equipment, which if applied to full connected load will yield annual energy use.

IF demand = Interactive HVAC Demand Factor – applies to C&I interior lighting in space that has air conditioning or refrigeration only. This represents the secondary demand savings in cooling required which results from decreased indoor lighting wattage.

IF energy = Interactive HVAC Energy Factor – applies to C&I interior lighting in space that has air conditioning or refrigeration only. This represents the secondary energy savings in cooling required which results from decreased indoor lighting wattage.

SVG = The percent of time that lights are off due to lighting controls relative to the baseline controls system (typically manual switch).

### Baseline Assumptions

The baseline assumptions will be adjusted from program year one to program year two. This adjustment will take into account standard building practices in order to estimate savings more accurately.

The following are acceptable methods for determining baseline conditions when verification by direct inspection is not possible as may occur in a rebate program where customers submit an application and equipment receipts only after installing efficient lighting equipment, or for a retroactive project as allowed by Act 129. In order of preference:

* Examination of replaced lighting equipment that is still on site waiting to be recycled or otherwise disposed of.
* Examination of replacement lamp and ballast inventories where the customer has replacement equipment for the retrofitted fixtures in stock. The inventory must be under the control of the customer or customer’s agent.
* Interviews with and written statements from customers, facility managers, building engineers or others with firsthand knowledge about purchasing and operating practices at the affected site(s) identifying the lamp and ballast configuration(s) of the baseline condition.
* Interviews with and written statements from the project’s lighting contractor or the customer’s project coordinator identifying the lamp and ballast configuration(s) of the baseline equipment

#### Program Year One

For new construction and building additions (not comprehensive retrofit projects), savings are calculated using assumptions that presume a decision to upgrade the lighting system from a baseline industry standard system, defined as the most efficient T-12 lamp and magnetic ballast.

For retrofit projects, the most efficient T12 fixture, with a magnetic ballast and the same number of bulbs as the retrofit fixture, serves as the baseline for most T8 fixture installations. Where T5 and T8 fixtures replace HID fixtures, ≥250 watt T12 fluorescent fixtures, or ≥ 250 watt incandescent fixtures, savings are calculated referencing pre-existing connected lighting load.

#### Program Year Two

For new construction and facility renovation projects, savings are calculated as described in Section 3.2.7, New Construction and Building Additions .

For retrofit projects, select the appropriate method from Section 3.2.7, Calculation Method Descriptions By Project Classification.

### Detailed Inventory Form

For lighting improvement projects, savings are generally proportional to the number of fixtures installed or replaced. The method of savings verification will vary depending on the size of the project because fixtures can be hand-counted to a reasonable degree to a limit.

#### Projects with connected load savings less than 20 kW

For projects having less than 20kW in connected load savings, a detailed inventory is not required but information sufficient to validate savings according to the algorithm above must be included in the documentation. This includes identification of baseline equipment utilized for quantifying kW base. Appendix C contains a prescriptive lighting table, which can estimate savings for small, simple projects under 20kW in savings provided that the user self-certifies the baseline condition.

#### Projects with connected load savings of 20 kW or higher

For projects having a connected load savings of 20 kW or higher, a detailed inventory is required. Using the algorithms in Section 5.2 “Algorithms”, ΔkW values will be multiplied by the number of fixtures installed. The total ΔkW savings is derived by summing the total ΔkW for each installed measure.

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

Appendix C was developed to automate the calculation of energy and demand impacts for retrofit lighting projects, based on a series of entries by the user defining key characteristics of the retrofit project. The main sheet, “Lighting Form”, is a detailed line-by-line inventory incorporating variables in Section 6.2.1. Each line item represents a specific area with common baseline fixtures, retrofit fixtures, controls strategy, space cooling, and space usage.

Baseline and retrofit fixture wattages are determined by selecting the appropriate fixture code from the “Wattage Table” sheet. The “Fixture Code Locator” sheet can be used to find the appropriate code for a particular lamp-ballast combination[[117]](#footnote-117). Actual wattages of fixtures determined by manufacturer’s equipment specification sheets or other independent sources may not be used unless (1) the wattage differs from the Standard Wattage Table referenced wattage by more than 10%[[118]](#footnote-118) 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 “User Input” sheet of Appendix C. 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 lighting projects, Appendix C must still be used. However, if a third-party lighting inventory form is provided, entries to Appendix C may be condensed into groups sharing common baseline fixtures, retrofit fixtures, space type, building type, and controls. Whereas Appendix C separates fixtures by location to facilitate evaluation and audit activities, third-party forms can serve that specific function if provided.

Appendix C will be updated periodically to include new fixtures and technologies available as may be appropriate. Additional guidance can be found in the “Manual” sheet of Appendix C.

### Quantifying Annual Hours of Operation

Projects with large impacts will typically include whole building lighting improvements in varying space types, which in turn may have different operating hours. Project specific EFLH will be determined by the following thresholds:

#### Projects with connected load savings less than 50kW

For lighting projects with savings less than 50 kW, stipulated whole building hours of use will be used as shown below in Table 3‑4.

#### Projects with connected load savings of 50kW or higher

For projects with connected load savings of 50 kW or higher, additional detail is required. For large projects, the likelihood that all fixtures do not behave uniformly is high. Therefore, the project must be separated into "usage groups", or groups of fixtures exhibiting similar usage patterns. The number of usage groups required is determined by facility type per Table 3‑1. EFLH values must be estimated for each group by facility interviews supplemented by either logging or stipulated values from Table 3‑2.

Table 3‑1: Hours of Use Groups Required per Building Type[[119]](#footnote-119)

|  |  |  |
| --- | --- | --- |
| **Building Type** | **Minimum Number of Usage Groups[[120]](#footnote-120)** | **Examples of Usage Group types** |
| Office Buildings | 6 | General offices, private offices, hallways, restrooms, conference, lobbies, 24-hr |
| Education (K-12) | 6 | Classrooms, offices, hallways, restrooms, admin, auditorium, gymnasium, 24-hr |
| Education (College/University) | 6 | Classrooms, offices, hallways, restrooms, admin, auditorium, library, dormitory, 24-hr |
| Hospitals/ Health Care Facilities | 8 | Patient rooms, operating rooms, nurses station, exam rooms, labs, offices, hallways |
| Retail Stores | 5 | Sales floor, storeroom, displays, private office, 24-hr |
| Industrial/ Manufacturing | 6 | Manufacturing, warehouse, shipping, offices, shops, 24-hr |
| Other | Variable | All major usage groups within building |

To the extent that retrofits are not comprehensive, are narrow and focused for usage groups, and are not the typical diversity in retrofit projects, the implementer can use fewer usage groups that reflect the actual diversity of use.

Table 3‑2: Hours of Use for Usage Groups

| **Building Type** | **Usage Group** | **Equivalent Full Load Hours** |
| --- | --- | --- |
|
|  |
| Education - Primary School | Classroom/Lecture | 2445 |
| Education - Primary School | Exercising Centers and Gymnasium | 2051 |
| Education - Primary School | Dining Area | 1347 |
| Education - Primary School | Kitchen and Food Preparation | 1669 |
| Education - Secondary School | Classroom/Lecture | 2445 |
| Education - Secondary School | Office (General) | 2323 |
| Education - Secondary School | Exercising Centers and Gymnasium | 2366 |
| Education - Secondary School | Computer Room (Instructional/PC Lab) | 2137 |
| Education - Secondary School | Dining Area | 2365 |
| Education - Secondary School | Kitchen and Food Preparation | 1168 |
| Education - Community College | Classroom/Lecture | 2471 |
| Education - Community College | Office (General) | 2629 |
| Education - Community College | Computer Room (Instructional/PC Lab) | 2189 |
| Education - Community College | Comm/Ind Work (General, Low Bay) | 3078 |
| Education - Community College | Dining Area | 2580 |
| Education - Community College | Kitchen and Food Preparation | 2957 |
| Education - University | Classroom/Lecture | 2522 |
| Education - University | Office (General) | 2870 |
| Education - University | Computer Room (Instructional/PC Lab) | 2372 |
| Education - University | Comm/Ind Work (General, Low Bay) | 3099 |
| Education - University | Dining Area | 2963 |
| Education - University | Kitchen and Food Preparation | 3072 |
| Education - University | Hotel/Motel Guest Room (incl. toilets) | 1196 |
| Education - University | Corridor | 2972 |
| Grocery | Retail Sales, Grocery | 4964 |
| Grocery | Office (General) | 4526 |
| Grocery | Comm/Ind Work (Loading Dock) | 4964 |
| Grocery | Refrigerated (Food Preparation) | 4380 |
| Grocery | Refrigerated (Walk-in Freezer) | 4380 |
| Grocery | Refrigerated (Walk-in Cooler) | 4380 |
| Hospitals | Office (General) | 4873 |
| Hospitals | Dining Area | 5858 |
| Hospitals | Kitchen and Food Preparation | 5858 |
| Hospitals | Medical and Clinical Care | 5193 |
| Hospitals | Laboratory, Medical | 4257 |
| Hospitals | Medical and Clinical Care | 5193 |
| Lodging - Hotel | Hotel/Motel Guest Room (incl. toilets) | 799 |
| Lodging - Hotel | Corridor | 7884 |
| Lodging - Hotel | Dining Area | 3485 |
| Lodging - Hotel | Kitchen and Food Preparation | 4524 |
| Lodging - Hotel | Bar, Cocktail Lounge | 3820 |
| Lodging - Hotel | Lobby (Hotel) | 7884 |
| Lodging - Hotel | Laundry | 4154 |
| Lodging - Hotel | Office (General) | 3317 |
| Lodging - Motel | Hotel/Motel Guest Room (incl. toilets) | 755 |
| Lodging - Motel | Office (General) | 5858 |
| Lodging - Motel | Laundry | 4709 |
| Lodging - Motel | Corridor | 7474 |
| Manufacturing - Light Industrial | Comm/Ind Work (General, High Bay) | 3068 |
| Manufacturing - Light Industrial | Storage (Unconditioned) | 3376 |
| Office - Large | Office (Open Plan) | 2641 |
| Office - Large | Office (Executive/Private) | 2641 |
| Office - Large | Corridor | 2641 |
| Office - Large | Lobby (Office Reception/Waiting) | 2692 |
| Office - Large | Conference Room | 2692 |
| Office - Large | Copy Room (photocopying equipment) | 2692 |
| Office - Large | Restrooms | 2692 |
| Office - Large | Mechanical/Electrical Room | 2692 |
| Office - Small | Office (Executive/Private) | 2594 |
| Office - Small | Corridor | 2594 |
| Office - Small | Lobby (Office Reception/Waiting) | 2594 |
| Office - Small | Conference Room | 2594 |
| Office - Small | Copy Room (photocopying equipment) | 2594 |
| Office - Small | Restrooms | 2594 |
| Office - Small | Mechanical/Electrical Room | 2594 |
| Restaurant - Sit-Down | Dining Area | 4836 |
| Restaurant - Sit-Down | Lobby (Main Entry and Assembly) | 4836 |
| Restaurant - Sit-Down | Kitchen and Food Preparation | 4804 |
| Restaurant - Sit-Down | Restrooms | 4606 |
| Restaurant - Fast-Food | Dining Area | 4850 |
| Restaurant - Fast-Food | Lobby (Main Entry and Assembly) | 4850 |
| Restaurant - Fast-Food | Kitchen and Food Preparation | 4812 |
| Restaurant - Fast-Food | Restrooms | 4677 |
| Retail - 3-Story Large | Retail Sales and Wholesale Showroom | 3546 |
| Retail - 3-Story Large | Storage (Conditioned) | 2702 |
| Retail - 3-Story Large | Office (General) | 2596 |
| Retail - Single-Story Large | Retail Sales and Wholesale Showroom | 4454 |
| Retail - Single-Story Large | Storage (Conditioned) | 2738 |
| Retail - Single-Story Large | Office (General) | 2714 |
| Retail - Single-Story Large | Auto Repair Workshop | 3429 |
| Retail - Single-Story Large | Kitchen and Food Preparation | 3368 |
| Retail - Small | Retail Sales and Wholesale Showroom | 3378 |
| Retail - Small | Storage (Conditioned) | 2753 |
| Storage - Conditioned | Storage (Conditioned) | 3441 |
| Storage - Conditioned | Office (General) | 3441 |
| Storage - Unconditioned | Storage (Unconditioned) | 3441 |
| Storage - Unconditioned | Office (General) | 3441 |

### Calculation Method Descriptions By Project Classification

#### New Construction and Building Additions

For new construction and building addition projects, savings are calculated using ASHRAE 90.1-2007 as the baseline (kWbase) and the new wattages and fixtures as the post-installation wattage. The baseline, pursuant to ASHRAE 90.1-2007, can be calculated using either the ASHRAE 90.1-2007 Building Area Method as shown in Table 3‑3 below, or the ASHRAE 90.1-2007 Space-by-Space Method as shown in Table 3‑4 below. The new fixture wattages are specified in the Lighting Audit and Design Tool shown in Appendix C.

EFLH, CF and IF values are the same as those shown in and .

Table 3‑3: ASHRAE 90.1-2007 Building Area Method[[121]](#footnote-121)

| **Building Area Type[[122]](#footnote-122)** | **LPD (W/ft2)** | **Building Area Type** | **LPD (W/ft2)** |
| --- | --- | --- | --- |
| Automotive facility | 0.9 | Multifamily | 0.7 |
| Convention center | 1.2 | Museum | 1.1 |
| Courthouse | 1.2 | Office | 1.0 |
| Dining: bar lounge/leisure | 1.3 | Parking garage | 0.3 |
| Dining: cafeteria/fast food | 1.4 | Penitentiary | 1.0 |
| Dining: family | 1.6 | Performing arts theater | 1.6 |
| Dormitory | 1.0 | Police/fire station | 1.0 |
| Exercise center | 1.0 | Post office | 1.1 |
| Gymnasium | 1.1 | Religious building | 1.3 |
| Health-care clinic | 1.0 | Retail | 1.5 |
| Hospital | 1.2 | School/university | 0.2 |
| Hotel | 1.0 | Sports arena | 1.1 |
| Library | .3 | Town hall | 1.1 |
| Manufacturing facility | 1.3 | Transportation | 1.0 |
| Motel | 1.0 | Warehouse | 0.8 |
| Motion picture theater | 1.2 | Workshop | 1.4 |

Table 3‑4: ASHRAE 90.1-2007 Space-by-Space Method[[123]](#footnote-123)

| **Common Space Type[[124]](#footnote-124)** | **LPD (W/ft2)** | **Building Specific Space Types** | **LPD (W/ft2)** |
| --- | --- | --- | --- |
| Office-Enclosed | 1.1 | Gymnasium/Exercise Center | |
| Office-Open Plan | 1.1 | Playing Area | 1.4 |
| Conference/Meeting/Multipurpose | 1.3 | Exercise Area | 0.9 |
| Classroom/Lecture/Training | 1.4 | Courthouse/Police Station/Penitentiary | |
| For Penitentiary | 1.3 | Courtroom | 1.9 |
| Lobby | 1.3 | Confinement Cells | 0.9 |
| For Hotel | 1.1 | Judges Chambers | 1.3 |
| For Performing Arts Theater | 3.3 | Fire Stations | |
| For Motion Picture Theater | 1.1 | Fire Station Engine Room | 0.8 |
| Audience/Seating Area | 0.9 | Sleeping Quarters | 0.3 |
| For Gymnasium | 0.4 | Post Office-Sorting Area | 1.2 |
| For Exercise Center | 0.3 | Convention Center-Exhibit Space | 1.3 |
| For Convention Center | 0.7 | Library | |
| For Penitentiary | 0.7 | Card File and Cataloging | 1.1 |
| For Religious Buildings | 1.7 | Stacks | 1.7 |
| For Sports Arena | 0.4 | Reading Area | 1.2 |
| For Performing Arts Theater | 2.6 | Hospital | |
| For Motion Picture Theater | 1.2 | Emergency | 2.7 |
| For Transportation | 0.5 | Recovery | 0.8 |
| Atrium—First Three Floors | 0.6 | Nurse Station | 1.0 |
| Atrium—Each Additional Floor | 0.2 | Exam/Treatment | 1.5 |
| Lounge/Recreation | 1.2 | Pharmacy | 1.2 |
| For Hospital | 0.8 | Patient Room | 0.7 |
| Dining Area | 0.9 | Operating Room | 2.2 |
| For Penitentiary | 1.3 | Nursery | 0.6 |
| For Hotel | 1.3 | Medical Supply | 1.4 |
| For Motel | 1.2 | Physical Therapy | 0.9 |
| For Bar Lounge/Leisure Dining | 1.4 | Radiology | 0.4 |
| For Family Dining | 2.1 | Laundry—Washing | 0.6 |
| Food Preparation | 1.2 | Automotive—Service/Repair | 0.7 |
| Laboratory | 1.4 | Manufacturing | |
| Restrooms | 0.9 | Low (<25 ft Floor to Ceiling Height) | 1.2 |
| Dressing/Locker/Fitting Room | 0.6 | High (>25 ft Floor to Ceiling Height) | 1.7 |
| Corridor/Transition | 0.5 | Detailed Manufacturing | 2.1 |
| For Hospital | 1.0 | Equipment Room | 1.2 |
| For Manufacturing Facility | 0.5 | Control Room | 0.5 |
| Stairs—Active | 0.6 | Hotel/Motel Guest Rooms | 1.1 |
| Active Storage | 0.8 | Dormitory—Living Quarters | 1.1 |
| For Hospital | 0.9 | Museum | |
| Inactive Storage | 0.3 | General Exhibition | 1.0 |
| For Museum | 0.8 | Restoration | 1.7 |
| Electrical/Mechanical | 1.5 | Bank/Office—Banking Activity Area | 1.5 |
| Workshop | 1.9 | Religious Buildings | |
| Sales Area | 1.7 | Worship Pulpit, Choir | 2.4 |
|  |  | Fellowship Hall | 0.9 |
|  |  | Retail [For accent lighting, see 9.3.1.2.1(c)] | |
|  |  | Sales Area | 1.7 |
|  |  | Mall Concourse | 1.7 |
|  |  | Sports Arena | |
|  |  | Ring Sports Area | 2.7 |
|  |  | Court Sports Area | 2.3 |
|  |  | Indoor Playing Field Area | 1.4 |
|  |  | Warehouse | |
|  |  | Fine Material Storage | 1.4 |
|  |  | Medium/Bulky Material Storage | 0.9 |
|  |  | Parking Garage—Garage Area | 0.2 |
|  |  | Transportation | |
|  |  | Airport—Concourse | 0.6 |
|  |  | Air/Train/Bus—Baggage Area | 1.0 |
|  |  | Terminal—Ticket Counter | 1.5 |

#### Prescriptive Lighting Improvements

Prescriptive Lighting Improvements include fixture or lamp and ballast replacement in existing commercial and industrial customers’ facilities.

The baseline is the existing fluorescent fixtures with the existing lamps and ballast as defined in Lighting Audit and Design Tool shown in Appendix C. Other factors required to calculate savings are shown in and . Note that if EFLH is stated and verified by logging lighting hours of use groupings, actual hours should be applied. The IF factors shown in are to be used only when the facilities are air conditioned and only for fixtures in conditioned or refrigerated space. The EFLH for refrigerated spaces are to be estimated or logged separately.

Table 3‑5: Lighting EFLH and CF by Building Type or Function

| **Building Type** | **EFLH** | **CF[[125]](#footnote-125)** | **Source** |
| --- | --- | --- | --- |
| Daycare | 2,590 | 0.77\* | 6 |
| Education – Primary School | 1,440 | 0.57 | 1 |
| Education – Secondary School | 2,305 | 0.57 | 1 |
| Education – Community College | 3,792 | 0.64 | 1 |
| Education – University | 3,073 | 0.64 | 1 |
| Grocery | 5,824 | 0.94 | 1 |
| Hospitals | 6,588[[126]](#footnote-126) | 0.84 | 1 |
| Industrial Manufacturing – 1 Shift | 2,857 | 0.77\* | 4 |
| Industrial Manufacturing – 2 Shift | 4,730 | 0.77\* | 4 |
| Industrial Manufacturing – 3 Shift | 6,631 | 0.77\* | 4 |
| Medical – Clinic | 4,212 | 0.86 | 1 |
| Libraries | 2,566 | 0.77\* | 2 |
| Lodging –Guest Rooms | 1,145 | 0.84 | 1 |
| Lodging –Common Spaces | 8,736[[127]](#footnote-127) | 1.00 | 1 |
| Light Manufacturing (Assy) | 2,610 | 0.77\* | 5 |
| Manufacturing – Light Industrial | 4,290 | 0.63 | 1 |
| Office- Large | 2,808 | 0.84 | 1 |
| Office-Small | 2,808 | 0.84 | 1 |
| Parking Garages | 6,552 | 0.77\* | 4 |
| Police and Fire Station – 24 Hour | 7,665 | 0.77\* | 8 |
| Police and Fire Station – Unmanned | 1,953 | 0.77\* | 8 |
| Public Order and Safety | 5,366 | 0.77\* | 7 |
| Religious Worship | 1,810 | 0.77\* | 3, 4 |
| Restaurant – Sit-Down | 4,368 | 0.88 | 1 |
| Restaurant – Fast-Food | 6,188 | 0.88 | 1 |
| Retail – 3-Story Large | 4,259 | 0.89 | 1 |
| Retail – Single-Story Large | 4,368 | 0.89 | 1 |
| Retail – Small | 4,004 | 0.89 | 1 |
| Storage Conditioned | 4,290 | 0.85 | 1 |
| Storage Unconditioned | 4,290 | 0.85 | 1 |
| Warehouse | 3,900 | 0.85 | 1 |
| Dusk-to-Dawn Lighting | 4,300 | 0.00 | 1 |
| Other[[128]](#footnote-128) | As Measured | As Measured | 1 |

\* Coincidence Factors were not agreed upon prior to release of this document in October 2010. 0.77 represents the simple average of all existing coincidence factors (16.19 divided by 21).

**Sources:**

1. New Jersey’s Clean Energy Program Protocols, November 2009
   1. California Public Utility Commission. *Database for Energy Efficiency Resources,* 2005
   2. RLW Analytics, *Coincident Factor Study, Residential and Commercial & Industrial Lighting Measures*, 2007.
   3. Quantum Consulting, Inc., for Pacific Gas & Electric Company , *Evaluation of Pacific Gas & Electric Company’s 1997 Commercial Energy Efficiency Incentives Program: Lighting Technologies*”, March 1, 1999
   4. KEMA. *New Jersey’s Clean Energy Program Energy Impact Evaluation and Protocol Review*. 2009.
2. Southern California Edison Company, Design & Engineering Services, Work Paper WPSCNRMI0054, Revision 0, September 17, 2007, Ventura County Partnership Program, Fillmore Public Library (Ventura County); Two 8-Foot T8 Lamp and Electronic Ballast to Four 4-Foot T8 Lamps and Premium Electronic Ballast. Reference: "The Los Angeles County building study was used to determine the lighting operating hours for this work paper. At Case Site #19A (L.A. County Montebello Public Library), the lights were at full load during work hours, and at zero load during non-work hours. This and the L.A. County Claremont Library (also referenced in the Los Angeles County building study) are small libraries branches similar to those of this work paper’s library (Ventura County’s Fillmore Library). As such, the three locations have the same lighting profile. Therefore, the lighting operating hour value of 1,664 hours/year stated above is reasonably accurate." Duquesne Light customer data on 29 libraries (SIC 8231) reflects an average load factor 26.4% equivalent to 2285 hours per year. Connecticut Light and Power and United Illuminating Company (CL&P and UI) program savings documentation for 2008 Program Year Table 2.0.0 C&I Hours, page 246 - Libraries 3,748 hours. An average of the three references is 2,566 hours.
3. DOE 2003 Commercial Building Energy Survey (CBECS), Table B1. Summary Table: Total and Means of Floorspace, Number of Workers, and Hours of Operation for Non-Mall Buildings, Released: June 2006 - 32 Mean Hours per Week for 370,000 Building Type: "Religious Worship" - 32 X 52 weeks = 1,664 hour per year.
4. CL&P and UI 2008 program documentation (referenced above) cites an estimated 4,368 hours, only 68 hours greater than dusk to down operating hours. ESNA RP-20-98; Lighting for Parking Facilities acknowledges "Garages usually require supplemental daytime luminance in above-ground facilities, and full day and night lighting for underground facilities." Emphasis added. The adopted assumption of 6,552 increases the CL&P and UI value by 50% (suggest data logging to document greater hours i.e., 8760 hours per year).
5. 2008 DEER Update – Summary of Measure Energy Analysis Revisions, August, 2008; available at [www.deeresources.com](http://www.deeresources.com)
6. Analysis of 3-"Kinder Care" daycare centers serving 150-160 children per day - average 9,175 ft2; 4.9 Watts per ft2; load factor 23.1% estimate 2,208 hours per year. Given an operating assumption of five days per week, 12 hours per day (6:00AM to 6:00 PM) closed weekends (260 days); Closed on 6 NERC holidays that fall on weekdays (2002, 2008 and 2013) deduct 144 hours: (260 X 12)-144 = 2,976 hours per year; assumption adopts an average of measured and operational bases or 2,592 hours per year.
7. DOE 2003 Commercial Building Energy Survey (CBECS), Table B1. Summary Table: Total and Means of Floorspace, Number of Workers, and Hours of Operation for Non-Mall Buildings, Released: June 2006 - 103 Mean Hours per Week for 71,000 Building Type: "Public Order and Safety" - 32 X 52 weeks = 5,366 hour per year.
8. Police and Fire Station operating hour data taken from the CL&P and UI 2008 program documentation (referenced above).

Table 3‑6: Interactive Factors and Other Lighting Variables

|  |  |  |  |
| --- | --- | --- | --- |
| Component | Type | Value | Source |
| IFdemand | Fixed | Cooled space = 0.34 | 1 |
| Freezer spaces = 0.50 |
| Medium-temperature refrigerated spaces = 0.29 |
| High-temperature refrigerated spaces = 0.18 |
| Uncooled space = 0 |
| IFenergy | Fixed | Cooled space = 0.12 | 1 |
| Freezer spaces = 0.50 |
| Medium-temperature refrigerated spaces = 0.29 |
| High-temperature refrigerated spaces = 0.18 |
| Uncooled space = 0 |
| kWbase | Variable | See Standard Wattage Table in Appendix C | 2 |
| kWinst | Variable | See Standard Wattage Table in Appendix C | 2 |

*Sources*:

1. PA TRM, Efficiency Vermont. Technical Reference User Manual: Measure Savings Algorithms and Cost Assumptions (July 2008).
2. NYSERDA Table of Standard Wattages (November 2009)

#### Lighting Control Adjustments

Lighting controls include HID controls, daylight dimmer systems, occupancy sensors, and occupancy controlled hi-low controls for fluorescent fixtures. The measurement of energy savings is based on algorithms with key variables (e.g. coincidence factor, equivalent full load hours) provided through existing end-use metering of a sample of facilities or from other utility programs with experience with these measures (i.e., % of annual lighting energy saved by lighting control). These key variables are listed in Table 3‑7.

If a lighting improvement consists of solely lighting controls, the lighting fixture baseline is the existing fluorescent fixtures with the existing lamps and ballasts or, if retrofitted, new fluorescent fixtures with new lamps and ballasts as defined in Lighting Audit and Design Tool shown in Appendix C. In either case, the kWinstfor the purpose of the algorithm is set to kWbase.

Table 3‑7: Lighting Controls Assumptions

|  |  |  |  |
| --- | --- | --- | --- |
| **Component** | **Type** | **Value** | **Source** |
| kW*base* | Variable | Lighting Audit and Design Tool in Appendix C | 1 |
| kW*inst* | Variable | Lighting Audit and Design Tool in Appendix C | 1 |
| SVG | Fixed | Occupancy Sensor, Controlled Hi-Low Fluorescent Control and controlled HID = 30%[[129]](#footnote-129) | 2 and 3*[[130]](#footnote-130)* |
| Daylight Dimmer System=50%[[131]](#footnote-131) |
| CF | Variable | By building type and size | See |
| EFLH | Variable | By building type and size | See |
| IF | Variable | By building type and size | See Table 3‑6 |

**Sources:**

1. NYSERDA Table of Standard Wattages
2. Levine, M., Geller, H., Koomey, J., Nadel S., Price, L., "Electricity Energy Use Efficiency: Experience with Technologies, Markets and Policies” ACEEE, 1992
3. Lighting control savings fractions consistent with current programs offered by National Grid, Northeast Utilities, Long Island Power Authority, NYSERDA, and Energy Efficient Vermont.

#### LED Traffic Signals

Traffic signal lighting improvements use the lighting algorithms with the assumptions set forth below.

Table 3‑8: Assumptions for LED Traffic Signals

|  |  |  |  |
| --- | --- | --- | --- |
| **Component** | **Type** | **Value** | **Source** |
| ΔkW | Variable | See 7 | PECo |
| CF | Red Round | 55% | PECo |
| Yellow Round | 2% |
| Round Green | 43% |
| Turn Yellow | 8% |
| Turn Green | 8% |
| Pedestrian | 100% |
| EFLH | Variable | See 7 | PECo |
| IF | Fixed | 0 |  |

Table 3‑9: LED Traffic Signals[[132]](#footnote-132)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Type** | **Wattage** | **% Burn** | **EFLH** | **kWh** | **ΔkW  using LED** | **ΔkWh  using LED** |
| Round Traffic Signals | | | | | | |
| Red 8" | 69 | 55% | 4,818 | 332 | - | - |
| Red 8" LED | 7 | 55% | 4,818 | 34 | 0.062 | 299 |
| Yellow 8" | 69 | 2% | 175 | 12 | - | - |
| Yellow 8" LED | 10 | 2% | 175 | 2 | 0.059 | 10 |
| Green 8" | 69 | 43% | 3,767 | 260 | - | - |
| Green 8" LED | 9 | 43% | 3,767 | 34 | 0.060 | 226 |
| Red 12" | 150 | 55% | 4,818 | 723 | - | - |
| Red 12" LED | 6 | 55% | 4,818 | 29 | 0.144 | 694 |
| Yellow 12" | 150 | 2% | 175 | 26 | - | - |
| Yellow 12" LED | 13 | 2% | 175 | 2 | 0.137 | 24 |
| Green 12" | 150 | 43% | 3,767 | 565 | - | - |
| Green 12" LED | 12 | 43% | 3,767 | 45 | 0.138 | 520 |
| Turn Arrows | | | | | | |
| Yellow 8" | 116 | 8% | 701 | 81 | - | - |
| Yellow 8" LED | 7 | 8% | 701 | 5 | 0.109 | 76 |
| Yellow 12" | 116 | 8% | 701 | 81 | - | - |
| Yellow 12" LED | 9 | 8% | 701 | 6 | 0.107 | 75 |
| Green 8" | 116 | 8% | 701 | 81 | - | - |
| Green 8" LED | 7 | 8% | 701 | 5 | 0.109 | 76 |
| Green 12" | 116 | 8% | 701 | 81 | - | - |
| Green 12" LED | 7 | 8% | 701 | 5 | 0.109 | 76 |
| Pedestrian Signs | | | | | | |
| Hand/Man 12" | 116 | 100% | 8,760 | 1,016 | - | - |
| Hand/Man 12" LED | 8 | 100% | 8,760 | 70 | 0.108 | 946 |
| Note: Energy Savings (kWh) are Annual & Demand Savings (kW) listed are per lamp. | | | | | | |

Table 3‑10: Reference Specifications for Above Traffic Signal Wattages

|  |  |
| --- | --- |
| **Type** | **Manufacturer & Model** |
| 8” Incandescent traffic signal bulb | General Electric Traffic Signal Model 17325-69A21/TS |
| 12” Incandescent traffic signal bulb | General Electric Traffic Signal Model 35327-150PAR46/TS |
| Incandescent Arrows &  Hand/Man Pedestrian Signs | General Electric Traffic Signal Model 19010-116A21/TS |
| 8” and 12” LED traffic signals | Leotek Models TSL-ES08 and TSL-ES12 |
| 8” LED Yellow Arrow | General Electric Model DR4-YTA2-01A |
| 8” LED Green Arrow | General Electric Model DR4-GCA2-01A |
| 12” LED Yellow Arrow | Dialight Model 431-3334-001X |
| 12" LED Green Arrow | Dialight Model 432-2324-001X |
| LED Hand/Man Pedestrian Sign | Dialight Model 430-6450-001X |

#### LED Exit Signs

This measure includes the early replacement of existing incandescent or fluorescent exit signs with a new LED exit sign. The deemed savings for this measure are:

ΔkWh = 332 kWh

ΔkWpeak = 0.041 kW

The savings are calculated using the lighting algorithms in Section with assumptions in .

Table 3‑11: LED Exit Signs

|  |  |  |  |
| --- | --- | --- | --- |
| **Component** | **Type** | **Value** | **Source** |
| kW*base* | Fixed | 0.037 | 1 |
| kW*inst* | Fixed | 0.0029 | 2 |
| CF | Fixed | 1.0 | 3 |
| EFLH | Fixed | 8760 | 3 |
| IFenergy | Fixed | 0.11 | 4 |
| IFdemand | Fixed | 0.21 | 4 |

*Sources*:

1. kWbase assumes 90% of existing exit signs are incandescent and 10% fluorescent with average sign wattages of 40W and 11W respectively. Weighted average existing exit sign wattage = 0.9\*40W+0.1\*11W = 37.1W. Assumptions are from WI Focus on Energy,“*Business Programs: Deemed Savings Manual V1.0*.” Update Date: March 22, 2010.
2. Average wattage of LED exit signs per WI Focus on Energy,“*Business Programs: Deemed Savings Manual V1.0*.” Update Date: March 22, 2010.
3. WI Focus on Energy,“*Business Programs: Deemed Savings Manual V1.0*.” Update Date: March 22, 2010. LED Exit Sign.
4. Mid-Atlantic Technical Reference Manual V1.0. May 2010. LED Exit Sign.

## Premium Efficiency Motors

For constant speed and uniformly loaded motors used in commercial and industrial buildings, the prescriptive measurement and verification protocols described below apply for replacement of old motors with new energy efficient motors of the same rated horsepower. Replacements where the old motor and new motor have different horsepower ratings are considered custom measures. For motors with variable speeds, variable loading, or industrial-specific applications, Custom Measure Protocols and Measurement and Verification Plans are required.

Note that the Coincidence Factor and Run Hours of Use for motors specified below do not take into account systems with multiple motors serving the same load, such as duplex motor sets with a lead-lag setup. Under these circumstances, a custom measure protocol is required. Duplex motor sets in which the second motor serves as a standby motor can utilize this protocol with an adjustment made such that savings are correctly attributed to a single motor.

### Algorithms

From AEPS application form or EDC data gathering calculate ΔkW where:

ΔkW = 0.746 X HP X (1/ηbase –1/ηee) X LF

ΔkWpeak = ΔkW X CF

ΔkWh = ΔkW X RHRS

### Definition of Variables

HP = Rated horsepower of the baseline motor and energy efficient motor

LF = Load Factor. Ratio of the average operating load to the nameplate rating of the baseline motor or, if installed, an existing energy efficient motor

ηbase = Efficiency of the baseline motor

ηee = Efficiency of the energy-efficient motor

RHRS = Annual run hours of the motor

CF = Demand Coincidence Factor. The percentage of the connected load that is on during electric system’s peak window as defined in Section 1- Electric Resource Savings.

### Description of Calculation Method

Relative to the above algorithm, ΔkW values will be calculated for each motor improvement in any project (account number). Each motor and the respective variables required to calculate the demand and energy savings for that motor will be entered into an inventory in Excel format, the Motor & Variable Frequency Drive (VFD) Inventory Form. The inventory will also specify the location for reference and validation. A sample of the Motor & VFD Inventory Form incorporating the algorithms for savings calculation is included in Appendix D.

Table 3‑12: Building Mechanical System Variables for Premium Efficiency Motor Calculations

|  |  |  |  |
| --- | --- | --- | --- |
| **Component** | **Type** | **Value** | **Source** |
| Motor HP | Variable | Nameplate (pre and post same) | EDC Data Gathering |
| RHRS[[133]](#footnote-133) | Variable | Based on logging and modeling | EDC Data Gathering |
| Default Table 3‑15 | From Table 3‑15 |
| LF[[134]](#footnote-134) | Variable | Based on spot metering/ nameplate | EDC Data Gathering |
| Default 75% | 1 |
| ηbase | Variable | Early Replacement: Nameplate | EDC Data Gathering |
| New or Replace on Burnout: Default comparable standard motor | From for PY1 and PY2.  From Table 3‑14 for PY3 and PY4. |
| ηee | Variable | Nameplate | EDC Data Gathering |
| CF[[135]](#footnote-135) | Variable | Single Motor Configuration: 74%  Duplex Motor Configuration: 37% | 1 |

*Sources*:

1. California Public Utility Commission. *Database for Energy Efficiency Resources* 2005

Table 3‑13: Baseline Motor Efficiencies for PY1 and PY2[[136]](#footnote-136)

| **Size HP** | **Open Drip Proof (ODP)**  **# of Poles** | | | **Totally Enclosed Fan-Cooled (TEFC)**  **# of Poles** | | |
| --- | --- | --- | --- | --- | --- | --- |
| **6** | **4** | **2** | **6** | **4** | **2** |
| Speed (RPM) | | | Speed (RPM) | | |
| 1200 | 1800 | 3600 | 1200 | 1800 | 3600 |
| 1 | 80.0% | 82.5% | 75.5% | 80.0% | 82.5% | 75.5% |
| 1.5 | 84.0% | 84.0% | 82.5% | 85.5% | 84.0% | 82.5% |
| 2 | 85.5% | 84.0% | 84.0% | 86.5% | 84.0% | 84.0% |
| 3 | 86.5% | 86.5% | 84.0% | 87.5% | 87.5% | 85.5% |
| 5 | 87.5% | 87.5% | 85.5% | 87.5% | 87.5% | 87.5% |
| 7.5 | 88.5% | 88.5% | 87.5% | 89.5% | 89.5% | 88.5% |
| 10 | 90.2% | 89.5% | 88.5% | 89.5% | 89.5% | 89.5% |
| 15 | 90.2% | 91.0% | 89.5% | 90.2% | 91.0% | 90.2% |
| 20 | 91.0% | 91.0% | 90.2% | 90.2% | 91.0% | 90.2% |
| 25 | 91.7% | 91.7% | 91.0% | 91.7% | 92.4% | 91.0% |
| 30 | 92.4% | 92.4% | 91.0% | 91.7% | 92.4% | 91.0% |
| 40 | 93.0% | 93.0% | 91.7% | 93.0% | 93.0% | 91.7% |
| 50 | 93.0% | 93.0% | 92.4% | 93.0% | 93.0% | 92.4% |
| 60 | 93.6% | 93.6% | 93.0% | 93.6% | 93.6% | 93.0% |
| 75 | 93.6% | 94.1% | 93.0% | 93.6% | 94.1% | 93.0% |
| 100 | 94.1% | 94.1% | 93.0% | 94.1% | 94.5% | 93.6% |
| 125 | 94.1% | 94.5% | 93.6% | 94.1% | 94.5% | 94.5% |
| 150 | 94.5% | 95.0% | 93.6% | 95.0% | 95.0% | 94.5% |
| 200 | 94.5% | 95.0% | 94.5% | 95.0% | 95.0% | 95.0% |

Table 3‑14: Baseline Motor Efficiencies-for PY3 and PY4[[137]](#footnote-137)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Size HP** | **Open Drip Proof (ODP)**  **# of Poles** | | | **Totally Enclosed Fan-Cooled (TEFC)**  **# of Poles** | | |
|
| **6** | **4** | **2** | **6** | **4** | **2** |
| Speed (RPM) | | | Speed (RPM) | | |
| 1200 | 1800 | 3600 | 1200 | 1800 | 3600 |
| 1 | 82.50% | 85.50% | 77.00% | 82.50% | 85.50% | 77.00% |
| 1.5 | 86.50% | 86.50% | 84.00% | 87.50% | 86.50% | 84.00% |
| 2 | 87.50% | 86.50% | 85.50% | 88.50% | 86.50% | 85.50% |
| 3 | 88.50% | 89.50% | 85.50% | 89.50% | 89.50% | 86.50% |
| 5 | 89.50% | 89.50% | 86.50% | 89.50% | 89.50% | 88.50% |
| 7.5 | 90.20% | 91.00% | 88.50% | 91.00% | 91.70% | 89.50% |
| 10 | 91.70% | 91.70% | 89.50% | 91.00% | 91.70% | 90.20% |
| 15 | 91.70% | 93.00% | 90.20% | 91.70% | 92.40% | 91.00% |
| 20 | 92.40% | 93.00% | 91.00% | 91.70% | 93.00% | 91.00% |
| 25 | 93.00% | 93.60% | 91.70% | 93.00% | 93.60% | 91.70% |
| 30 | 93.60% | 94.10% | 91.70% | 93.00% | 93.60% | 91.70% |
| 40 | 94.10% | 94.10% | 92.40% | 94.10% | 94.10% | 92.40% |
| 50 | 94.10% | 94.50% | 93.00% | 94.10% | 94.50% | 93.00% |
| 60 | 94.50% | 95.00% | 93.60% | 94.50% | 95.00% | 93.60% |
| 75 | 94.50% | 95.00% | 93.60% | 94.50% | 95.40% | 93.60% |
| 100 | 95.00% | 95.40% | 93.60% | 95.00% | 95.40% | 94.10% |
| 125 | 95.00% | 95.40% | 94.10% | 95.00% | 95.40% | 95.00% |
| 150 | 95.40% | 95.80% | 94.10% | 95.80% | 95.80% | 95.00% |
| 200 | 95.40% | 95.80% | 95.00% | 95.80% | 96.20% | 95.40% |
| 250 | 95.40% | 95.80% | 95.00% | 95.80% | 96.20% | 95.80% |
| 300 | 95.40% | 95.80% | 95.40% | 95.80% | 96.20% | 95.80% |
| 350 | 95.40% | 95.80% | 95.40% | 95.80% | 96.20% | 95.80% |
| 400 | 95.80% | 95.80% | 95.80% | 95.80% | 96.20% | 95.80% |
| 450 | 96.20% | 96.20% | 95.80% | 95.80% | 96.20% | 95.80% |
| 500 | 96.20% | 96.20% | 95.80% | 95.80% | 96.20% | 95.80% |

Table 3‑15: Stipulated Hours of Use for Motors in Commercial Buildings

| **Building Type** | **Motor Usage Group** | **RHRS[[138]](#footnote-138)** |
| --- | --- | --- |
| Office - Large | Chilled Water Pump | 1610 |
| Heating Hot Water Pump | 4959 |
| Condenser Water Pump | 1610 |
| HVAC Fan | 4414 |
| Cooling Tower Fan | 1032 |
| Office - Small | Chilled Water Pump | 1375 |
| Heating Hot Water Pump | 4959 |
| Condenser Water Pump | 1375 |
| HVAC Fan | 3998 |
| Cooling Tower Fan | 1032 |
| Hospitals & Healthcare - Pumps | Chilled Water Pump | 3801 |
| Heating Hot Water Pump | 4959 |
| Condenser Water Pump | 3801 |
| HVAC Fan | 7243 |
| Cooling Tower Fan | 1032 |
| Education - K-12 | Chilled Water Pump | 1444 |
| Heating Hot Water Pump | 4959 |
| Condenser Water Pump | 1444 |
| HVAC Fan | 4165 |
| Cooling Tower Fan | 1032 |
| Education - College & University | Chilled Water Pump | 1718 |
| Heating Hot Water Pump | 4959 |
| Condenser Water Pump | 1718 |
| HVAC Fan | 4581 |
| Cooling Tower Fan | 1032 |
| Retail | Chilled Water Pump | 2347 |
| Heating Hot Water Pump | 4959 |
| Condenser Water Pump | 2347 |
| HVAC Fan | 5538 |
| Cooling Tower Fan | 1032 |
| Restaurants - Fast Food | Chilled Water Pump | 2901 |
| Heating Hot Water Pump | 4959 |
| Condenser Water Pump | 2901 |
| HVAC Fan | 6702 |
| Cooling Tower Fan | 1032 |
| Restaurants - Sit Down | Chilled Water Pump | 2160 |
| Heating Hot Water Pump | 4959 |
| Condenser Water Pump | 2160 |
| HVAC Fan | 5246 |
| Cooling Tower Fan | 1032 |
| Other | All | As Measured |

*Source*:

1. Motor Inventory Form, PA Technical Working Group. (See notes below in Table 3‑16)

Table 3‑16: Notes for Stipulated Hours of Use Table

|  |  |
| --- | --- |
| **Motor Usage Group** | **Method of Operating Hours Calculation** |
| Chilled Water Pump | Hours when ambient temperature is above 60°F during building operating hours |
| Heating Hot Water Pump | Hours when ambient temperature is below 60°F during all hours |
| Condenser Water Pump | Hours when ambient temperature is above 60°F during building operating hours |
| HVAC Fan | Operating hours plus 20% of unoccupied hours |
| Cooling Tower Fan | Cooling EFLH according to EPA 2002[[139]](#footnote-139) (1032 hours for Philadelphia) |

Notes:

1. Ambient temperature is derived from BIN Master weather data from Philadelphia.
2. Operating hours for each building type is estimated for typical use.
3. Hospital & Healthcare operating hours differ for pumps and HVAC.
4. Back up calculations and reference material can be found on the PA PUC website at the following address: <http://www.puc.state.pa.us/electric/xls/Act129/TRM-Motor_Operating_Hours_Worksheet.xls>

## Variable Frequency Drive (VFD) Improvements

The following protocol for the measurement of energy and demand savings applies to the installation of Variable Frequency Drives (VFDs) in standard commercial building applications shown in Table 3‑18: HVAC fans, cooling tower fans, chilled water pumps, condenser water pumps and hot water pumps. This protocol estimates savings relative to a constant volume system as the baseline condition.

VFDs in any other application than those referenced Table 3‑18 must follow a custom measure protocol, including industrial applications. Relative to HVAC fans, the protocol applies to conventional variable air volume (VAV) systems with terminal VAV boxes on the supply registers. A VAV system without terminal VAV boxes is subject to various control strategies and system configurations and must be evaluated using the custom approach. For systems in which the baseline condition is not a constant volume system (e.g. vortex dampers), a custom measure protocol must be used[[140]](#footnote-140). When changes in run hours are anticipated in conjunction with the installation of a VFD, a custom path must also be used.

### Algorithms

ΔkWh = kWhbase - kWhee

ΔkWpeak = kWbase - kWee

kWhbase = 0.746 X HP X LF/ηmotor X RHRSbase

kWhee = kWhbase X ESF

kWbase = 0.746 X HP X LF/ηmotor X CF

kWee = kWbase X DSF

### Definitions of Variables

HP = Rated horsepower of the motor

LF = Load Factor. Ratio of the average operating load to the nameplate rating of the motor

ηmotor = Motor efficiency at the full-rated load. For VFD installations, this can be either an energy efficient motor or standard efficiency motor. Motor efficiency varies with load and decreases dramatically below 50% load; this is reflected in the ESF term of the algorithm.

RHRSbase = Annual run hours of the baseline motor

CF = Demand Coincidence Factor. The percentage of the connected load that is on during the top 100 hours.

ESF = Energy Savings Factor. The energy savings factor is the percent baseline kWh consumption anticipated to occur as a result of the installation of the VFD (See Table 3‑18). This factor can also be computed according to fan and pump affinity laws by modeling the flow reduction and related efficiency factors for both the motor and VFD under different load conditions. Hourly temperature bin data is used for this purpose.

DSF = Demand Savings Factor. The demand savings factor is calculated by determining the ratio of the power requirement for the baseline and the VFD control at peak conditions (See Table 3‑18). Since systems are customarily sized to 95% of cooling conditions and the peak 100 hours load represent a loading condition of 99%, and because VFDs are not 100% efficient, the demand savings for VFDs is relatively low for commercial HVAC applications where system loads tracks cooling requirements (DSF approaches 1).

### Description of Calculation Method

Relative to the above algorithm, ΔkW values will be calculated for each VFD improvement in any project (account number). Each motor and the respective variables required to calculate the demand and energy savings for that motor will be entered into an inventory in Excel format, the Motor & VFD Inventory Form. The inventory will also specify the location for reference and validation. A sample of the Motor & VFD Inventory Form incorporating the algorithms for savings calculation is included in Appendix D.

Table 3‑17: Variables for VFD Calculations

|  |  |  |  |
| --- | --- | --- | --- |
| **Component** | **Type** | **Value** | **Source** |
| Motor HP | Variable | Nameplate | EDC Data Gathering |
| RHRS[[141]](#footnote-141) | Variable | Based on logging and modeling | EDC Data Gathering |
| Table 3‑15 | See Table 3‑15 |
| LF[[142]](#footnote-142) | Variable | Based on spot metering and nameplate | EDC Data Gathering |
| Default 75% | 1 |
| ESF | Variable | See | See Table 3‑18 |
| DSF | Variable | See Table 3‑18 | See Table 3‑18 |
| Efficiency - ηbase | Fixed | Nameplate | EDC Data Gathering |
| CF[[143]](#footnote-143) | Fixed | 74% | 1 |

*Source*:

1. California Public Utility Commission. *Database for Energy Efficiency Resources* 2005

Table 3‑18: ESF and DSF for Typical Commercial VFD Installations

| **Building Type** | **Motor Usage Group** | **PECO,**  **First Energy** | | **Alleghany, Duquesne** | | **PPL** | |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **ESF** | **DSF** | **ESF** | **DSF** | **ESF** | **DSF** |
| Office - Large | Chilled Water Pump | 0.305 | 0.792 | 0.283 | 0.596 | 0.282 | 0.548 |
| Heating Hot Water Pump | 0.321 | 1.000 | 0.278 | 1.000 | 0.275 | 1.000 |
| Condenser Water Pump | 0.270 | 0.792 | 0.244 | 0.596 | 0.245 | 0.548 |
| HVAC Fan | 0.293 | 0.849 | 0.278 | 0.694 | 0.276 | 0.657 |
| Cooling Tower Fan | 0.270 | 0.792 | 0.244 | 0.596 | 0.245 | 0.548 |
| Office - Small | Chilled Water Pump | 0.308 | 0.781 | 0.286 | 0.586 | 0.286 | 0.548 |
| Heating Hot Water Pump | 0.321 | 1.000 | 0.278 | 1.000 | 0.275 | 1.000 |
| Condenser Water Pump | 0.273 | 0.781 | 0.246 | 0.586 | 0.248 | 0.548 |
| HVAC Fan | 0.295 | 0.841 | 0.279 | 0.686 | 0.278 | 0.657 |
| Cooling Tower Fan | 0.273 | 0.781 | 0.246 | 0.586 | 0.248 | 0.548 |
| Hospitals & Healthcare | Chilled Water Pump | 0.275 | 0.869 | 0.262 | 0.675 | 0.257 | 0.594 |
| Heating Hot Water Pump | 0.321 | 1.000 | 0.278 | 1.000 | 0.275 | 1.000 |
| Condenser Water Pump | 0.231 | 0.869 | 0.211 | 0.750 | 0.206 | 0.594 |
| HVAC Fan | 0.276 | 0.907 | 0.261 | 0.758 | 0.260 | 0.694 |
| Cooling Tower Fan | 0.245 | 0.869 | 0.222 | 0.675 | 0.217 | 0.594 |
| Education –  K-12 | Chilled Water Pump | 0.300 | 0.770 | 0.280 | 0.571 | 0.278 | 0.535 |
| Heating Hot Water Pump | 0.321 | 1.000 | 0.278 | 1.000 | 0.275 | 1.000 |
| Condenser Water Pump | 0.263 | 0.771 | 0.238 | 0.571 | 0.237 | 0.535 |
| HVAC Fan | 0.288 | 0.832 | 0.271 | 0.675 | 0.270 | 0.646 |
| Cooling Tower Fan | 0.263 | 0.771 | 0.238 | 0.571 | 0.237 | 0.535 |
| Education – College & University | Chilled Water Pump | 0.304 | 0.796 | 0.283 | 0.599 | 0.280 | 0.548 |
| Heating Hot Water Pump | 0.321 | 1.000 | 0.278 | 1.000 | 0.275 | 1.000 |
| Condenser Water Pump | 0.270 | 0.796 | 0.243 | 0.599 | 0.243 | 0.548 |
| HVAC Fan | 0.293 | 0.852 | 0.277 | 0.696 | 0.275 | 0.657 |
| Cooling Tower Fan | 0.270 | 0.796 | 0.243 | 0.599 | 0.243 | 0.548 |
| Retail | Chilled Water Pump | 0.305 | 0.869 | 0.283 | 0.675 | 0.239 | 0.594 |
| Heating Hot Water Pump | 0.321 | 1.000 | 0.278 | 1.000 | 0.275 | 1.000 |
| Condenser Water Pump | 0.271 | 0.869 | 0.244 | 0.675 | 0.239 | 0.594 |
| HVAC Fan | 0.295 | 0.907 | 0.278 | 0.758 | 0.276 | 0.694 |
| Cooling Tower Fan | 0.271 | 0.869 | 0.244 | 0.675 | 0.239 | 0.594 |
| Restaurants - Fast Food | Chilled Water Pump | 0.291 | 0.869 | 0.229 | 0.675 | 0.267 | 0.594 |
| Heating Hot Water Pump | 0.321 | 1.000 | 0.278 | 1.000 | 0.275 | 1.000 |
| Condenser Water Pump | 0.253 | 0.869 | 0.273 | 0.675 | 0.224 | 0.594 |
| HVAC Fan | 0.282 | 0.907 | 0.266 | 0.758 | 0.264 | 0.694 |
| Cooling Tower Fan | 0.253 | 0.869 | 0.273 | 0.675 | 0.224 | 0.594 |
| Restaurants - Sit Down | Chilled Water Pump | 0.307 | 0.869 | 0.284 | 0.675 | 0.279 | 0.594 |
| Heating Hot Water Pump | 0.321 | 1.000 | 0.278 | 1.000 | 0.275 | 1.000 |
| Condenser Water Pump | 0.272 | 0.869 | 0.246 | 0.675 | 0.241 | 0.594 |
| HVAC Fan | 0.295 | 0.907 | 0.278 | 0.758 | 0.277 | 0.694 |
| Cooling Tower Fan | 0.272 | 0.869 | 0.246 | 0.675 | 0.241 | 0.594 |
| Other | All | As determined by worksheet | | | | | |

|  |
| --- |
| **NOTE FOR** |
| 1. Back up calculations and reference material can be found on the PA PUC website at the following address: <http://www.puc.state.pa.us/electric/xls/Act129/TRM-ESF-DSF_Worksheet.xls> |

*Source*:

1. Motor Inventory Workbook, PA Technical Working Group

## Variable Frequency Drive Improvement for Industrial Air Compressors

The energy and demand savings for variable frequency drives (VFDs) installed on industrial air compressors is based on the loading and hours of use of the compressor. In industrial settings, these factors can be highly variable and may be best evaluated using a custom path. The method for measurement set forth below may be appropriate for systems with a single compressor servicing a single load and that have some of the elements of both a deemed and custom approach.

Systems with multiple compressors are defined as non-standard applications and must follow a custom measure protocol.

### Algorithms

ΔkWh = 0.129 X HP X LF/ηmotor X RHRSbase

ΔkW = 0.129 X HP

ΔkWpeak = 0.106 X HP

### Definition of Variables

HP = Rated horsepower of the motor

LF = Load Factor. Ratio of the average operating load to the nameplate rating of the motor

ηbase = Efficiency of the baseline motor

RHRS = Annual run hours of the motor

CF = Demand Coincidence Factor. The percentage of the connected load that is on during electric system’s peak window.

Table 3‑19: Variables for Industrial Air Compressor Calculation

|  |  |  |  |
| --- | --- | --- | --- |
| **Component** | **Type** | **Value** | **Source** |
| Motor HP | Variable | Nameplate | EDC Data Gathering |
| RHRS | Variable | Based on logging and modeling | EDC Data Gathering |
| kW/motor HP, Saved | Fixed | 0.129 | 1 |
| Coincident Peak kW/motor HP | Fixed | 0.106 | 1 |
| LF | Variable | Based on spot metering/ nameplate | EDC Data Gathering |

*Sources*:

1. Aspen Systems Corporation, Prescriptive Variable Speed Drive Incentive Development Support for Industrial Air Compressors, Executive Summary, June 20, 2005.[[144]](#footnote-144)

## HVAC Systems

The energy and demand savings for Commercial and Industrial HVAC is determined from the algorithms listed in below.

### Algorithms

#### Air Conditioning (includes room AC, central AC, air-cooled DX, split systems, and packaged terminal AC).

ΔkWh = (BtuH / 1000) X (1/EERbase – 1/EERee) X EFLH

ΔkWpeak  = (BtuH / 1000) X (1/EERbase – 1/EERee) X CF

#### Heat Pump (includes air source HP, packaged terminal HP, water source HP, ground source HP and groundwater source HP).

ΔkWh = ΔkWhcool + ΔkWhheat

ΔkWhcool = (BtuHcool / 1000) X (1/EERbase – 1/EERee) X EFLHcool  
= (BtuHcool / 1000) X (1/SEERbase – 1/SEERee) X EFLHcool

ΔkWhheat = (BtuHheat / 1000) / 3.412 X (1/COPbase – 1/COPee ) X EFLHheat   
= (BtuHheat / 1000) X (1/HSPFbase – 1/HSPFee ) X EFLHheat

ΔkWpeak  = (BtuHcool / 1000) X (1/EERbase – 1/EERee) X CF   
= (BtuHcool / 1000) X (1/SEERbase – 1/SEERee) X CF

### Definition of Terms

BtuH = Capacity in Btu/Hour.

EERbase = Efficiency rating of the baseline unit. For units < 65,000 BtuH, SEER should be used for cooling saving.

EERee = Efficiency rating of the energy efficiency unit. For units < 65,000 BtuH, SEER should be used for cooling savings.

COPbase = Efficiency rating of the baseline unit. For units < 65,000 BtuH, HSPF should be used for heating savings.

COPee = Efficiency rating of the energy efficiency unit. For units < 65,000 BtuH, HSPF should be used for heating savings.

CF = Demand Coincidence Factor. The percentage of the connected load that is on during electric system’s peak window as defined in Section 1- Electric Resource Savings

EFLHcool = Equivalent Full Load Hours for the cooling season – The kWh during the entire operating season divided by the kW at design conditions.

EFLHheat = Equivalent Full Load Hours for the heating season – The kWh during the entire operating season divided by the kW at design conditions.

Table 3‑20: Variables for AC and Heat Pumps

| **Component** | **Type** | **Value** | **Source** |
| --- | --- | --- | --- |
| BtuH | Variable | Nameplate data (ARI or AHAM) | EDC’s Data Gathering |
| EERbase | Variable | Nameplate data | EDC’s Data Gathering |
|  | See |
| EERee | Variable | Nameplate data (ARI or AHAM) | EDC’s Data Gathering |
| CF | Fixed | 67% | Engineering estimate[[145]](#footnote-145) |
| EFLHc  EFLHh | Variable | Based on Logging or Modeling | EDC’s Data Gathering |
| Default values from and | See and |
| Cooling Time Period Allocation Factors | Fixed | Summer/On-Peak 45%  Summer/Off-Peak 39%  Winter/On-Peak 7%  Winter/Off-Peak 9% |  |
| Heating Time Period Allocation Factors | Fixed | Summer/On-Peak 0%  Summer/Off-Peak 0%  Winter/On-Peak 41%  Winter/Off-Peak 58% |  |

*Sources*:

1. US Department of Energy. ENERGY STAR Calculator and Bin Analysis Models

Table 3‑21: HVAC Baseline Efficiencies[[146]](#footnote-146)

| **Equipment Type and Capacity** | **Cooling Baseline** | **Heating Baseline** |
| --- | --- | --- |
| Air-Source Air Conditioners |  |  |
| < 5.41 tons | 13.0 SEER | N/A |
| > 5.41 tons and <11.25 tons | 11.2 EER | N/A |
| > 11.25 tons and < 20.00 tons | 11.0 EER | N/A |
| > 20.00 tons and < 63.33 tons | 10.0 EER | N/A |
| > 63.33 tons | 9.7 EER | N/A |
| Water-Source and Evaporatively-Cooled Air Conditioners |  |  |
| < 5.41 tons | 12.1 EER | N/A |
| > 5.41 tons and < 11.25 tons | 11.5 EER | N/A |
| > 11.25 tons and < 20.00 tons | 11.0 EER | N/A |
| > 20.00 tons | 11.5 EER | N/A |
| Air-Source Heat Pumps |  |  |
| < 5.41 tons: | 13 SEER | 7.7 HSPF |
| > 5.41 tons and < 11.25 tons | 11.0 EER | 3.3 COP |
| > 11.25 tons and < 20.00 tons | 10.6 EER | 3.2 COP |
| > 20.00 tons | 9.5 EER | 3.2 COP |
| Water-Source Heat Pumps |  |  |
| < 1.42 tons | 11.2 EER | 4.2 COP |
| > 1.42 tons and < 5.41 tons | 12.0 EER | 4.2 COP |
| Ground Water Source Heat Pumps |  |  |
| < 11.25 tons | 16.2 EER | 3.6 COP |
| Ground Source Heat Pumps |  |  |
| < 11.25 tons | 13.4 EER | 3.1 COP |
| Packaged Terminal Systems (Replacements) |  |  |
| PTAC (cooling) | 10.9 - (0.213 x Cap / 1000) EER |  |
| PTHP (cooling) | 10.8 - (0.213 x Cap / 1000) EER | 2.9 - (0.213 x Cap / 1000) COP |

Table 3‑22: Cooling and Heating EFLH for Erie, Harrisburg, and Pittsburgh[[147]](#footnote-147)

| **Space Type** | **Erie** | | **Harrisburg** | | **Pittsburgh** | |
| --- | --- | --- | --- | --- | --- | --- |
| **Cooling EFLH** | **Heating EFLH** | **Cooling EFLH** | **Heating EFLH** | **Cooling EFLH** | **Heating EFLH** |
| Arena/Auditorium/Convention Center | 332 | 2,002 | 640 | 1,636 | 508 | 1,642 |
| College: Classes/Administrative | 380 | 1,815 | 733 | 1,484 | 582 | 1,489 |
| Convenience Stores | 671 | 3,148 | 1,293 | 2,573 | 1,026 | 2,582 |
| Dining: Bar Lounge/Leisure | 503 | 1,346 | 969 | 1,100 | 769 | 1,104 |
| Dining: Cafeteria / Fast Food | 677 | 2,066 | 1,304 | 1,689 | 1,035 | 1,695 |
| Dining: Restaurants | 503 | 1,346 | 969 | 1,100 | 769 | 1,104 |
| Gymnasium/Performing Arts Theatre | 380 | 1,815 | 733 | 1,484 | 582 | 1,489 |
| Hospitals/Health care | 770 | 321 | 1,483 | 263 | 1,177 | 264 |
| Industrial: 1 Shift/Light Manufacturing | 401 | 1,737 | 773 | 1,420 | 613 | 1,425 |
| Industrial: 2 Shift | 545 | 1,184 | 1,050 | 968 | 833 | 972 |
| Industrial: 3 Shift | 690 | 626 | 1,330 | 512 | 1,055 | 513 |
| Lodging: Hotels/Motels/Dormitories | 418 | 1,675 | 805 | 1,369 | 638 | 1,374 |
| Lodging: Residential | 418 | 1,675 | 805 | 1,369 | 638 | 1,374 |
| Multi-Family (Common Areas) | 769 | 3,148 | 1,482 | 2,573 | 1,176 | 2,582 |
| Museum/Library | 469 | 1,474 | 905 | 1,205 | 718 | 1,209 |
| Nursing Homes | 630 | 3,148 | 1,213 | 2,573 | 963 | 2,582 |
| Office: General/Retail | 469 | 884 | 905 | 722 | 718 | 725 |
| Office: Medical/Banks | 469 | 1,474 | 905 | 1,205 | 718 | 1,209 |
| Parking Garages & Lots | 517 | 1,292 | 997 | 1,056 | 791 | 1,060 |
| Penitentiary | 602 | 3,148 | 1,160 | 2,573 | 920 | 2,582 |
| Police/Fire Stations (24 Hr) | 769 | 3,148 | 1,482 | 2,573 | 1,176 | 2,582 |
| Post Office/Town Hall/Court House | 469 | 1,474 | 905 | 1,205 | 718 | 1,209 |
| Religious Buildings/Church | 332 | 2,001 | 640 | 1,635 | 508 | 1,641 |
| Retail | 493 | 1,383 | 950 | 1,130 | 754 | 1,135 |
| Schools/University | 350 | 984 | 674 | 805 | 535 | 808 |
| Warehouses (Not Refrigerated) | 382 | 567 | 735 | 463 | 583 | 465 |
| Warehouses (Refrigerated) | 382 | 1,810 | 735 | 1,480 | 583 | 1,485 |
| Waste Water Treatment Plant | 690 | 1,473 | 1,330 | 1,204 | 1,055 | 1,208 |

Table 3‑23: Cooling and Heating EFLH for Williamsport, Philadelphia and Scranton[[148]](#footnote-148)

| Space Type | Williamsport | | Philadelphia | | Scranton | |
| --- | --- | --- | --- | --- | --- | --- |
| Cooling EFLH | Heating EFLH | Cooling EFLH | Heating EFLH | Cooling EFLH | Heating EFLH |
| Arena/Auditorium/Convention Center | 454 | 1,726 | 711 | 1,606 | 428 | 1,747 |
| College: Classes/Administrative | 520 | 1,565 | 815 | 1,457 | 490 | 1,584 |
| Convenience Stores | 917 | 2,715 | 1,436 | 2,526 | 864 | 2,747 |
| Dining: Bar Lounge/Leisure | 688 | 1,161 | 1,077 | 1,080 | 648 | 1,175 |
| Dining: Cafeteria / Fast Food | 925 | 1,782 | 1,449 | 1,658 | 872 | 1,803 |
| Dining: Restaurants | 688 | 1,161 | 1,077 | 1,080 | 648 | 1,175 |
| Gymnasium/Performing Arts Theatre | 520 | 1,565 | 815 | 1,457 | 490 | 1,584 |
| Hospitals/Health care | 1,052 | 277 | 1,648 | 2,526 | 992 | 280 |
| Industrial: 1 Shift/Light Manufacturing | 548 | 1,498 | 859 | 1,394 | 517 | 1,516 |
| Industrial: 2 Shift | 745 | 1,022 | 1,166 | 951 | 702 | 1,034 |
| Industrial: 3 Shift | 944 | 540 | 1,478 | 502 | 889 | 546 |
| Lodging: Hotels/Motels/Dormitories | 571 | 1,444 | 894 | 1,344 | 538 | 1,462 |
| Lodging: Residential | 571 | 1,444 | 894 | 1,344 | 538 | 1,462 |
| Multi-Family (Common Areas) | 1,052 | 2,715 | 1,647 | 2,526 | 991 | 2,747 |
| Museum/Library | 642 | 1,271 | 1,005 | 1,183 | 605 | 1,286 |
| Nursing Homes | 861 | 2,715 | 1,348 | 2,526 | 811 | 2,747 |
| Office: General/Retail | 642 | 762 | 1,005 | 709 | 605 | 771 |
| Office: Medical/Banks | 642 | 1,271 | 1,005 | 1,183 | 605 | 1,286 |
| Parking Garages & Lots | 707 | 1,114 | 1,107 | 1,037 | 666 | 1,128 |
| Penitentiary | 823 | 2,715 | 1,289 | 2,526 | 775 | 2,747 |
| Police/Fire Stations (24 Hr) | 1,052 | 2,715 | 1,647 | 2,526 | 991 | 2,747 |
| Post Office/Town Hall/Court House | 642 | 1,271 | 1,005 | 1,183 | 605 | 1,286 |
| Religious Buildings/Church | 454 | 1,725 | 711 | 1,605 | 428 | 1,746 |
| Retail | 674 | 1,193 | 1,055 | 1,110 | 635 | 1,207 |
| Schools/University | 478 | 849 | 749 | 790 | 451 | 859 |
| Warehouses (Not Refrigerated) | 522 | 489 | 817 | 455 | 492 | 495 |
| Warehouses (Refrigerated) | 522 | 1,561 | 817 | 1,453 | 492 | 1,580 |
| Waste Water Treatment Plant | 944 | 1,270 | 1,478 | 1,182 | 889 | 1,285 |

## Electric Chillers

This protocol estimates savings for installing high efficiency electric chillers compared to standard efficiency chillers. The measurement of energy and demand savings for C/I Chillers is based on algorithms with key variables (i.e., Efficiency, Coincidence Factor, Equivalent Full Load Hours). These prescriptive algorithms and stipulated values are valid for standard commercial applications, defined as unitary electric chillers serving a single load at the system or sub-system level. The savings calculated using the prescriptive algorithms need to be supported by a certification that the chiller is operating at site design load condition.

All other chiller applications, including multiple chiller configurations, chillers with Variable Frequency Drives (VFDs), chillers serving multiple load groups, and chillers in industrial applications are defined as non-standard applications and must follow a site specific custom protocol.

### Algorithms

#### Efficiency ratings in EER

ΔkWh = Tons X 12 X (1 / EERbase – 1 / EERee) X EFLH

ΔkWpeak = Tons X 12 X (1 / EERbase – 1 / EERee) X PLCF

#### Efficiency ratings in kW/ton

ΔkWh = Tons X (kW/tonbase – kW/tonee) X EFLH

ΔkWpeak = Tons X (kW/tonbase – kW/tonee) X PLCF

### Definition of Variables

Tons = The capacity of the chiller (in tons) at site design conditions accepted by the program.

kW/tonbase = Design Rated Efficiency of the baseline chiller. See Table 3‑24 for values.

kW/tonee = Design Rated Efficiency of the energy efficient chiller from the manufacturer data and equipment ratings in accordance with ARI Standards.

IPLVbase = Integrated Part Load Value of the baseline chiller. See Table 3‑24 for values

IPLVee = Integrated Part Load Value of the energy efficient chiller from the manufacturer data and equipment ratings in accordance with ARI Standards.

PLCF = Peak Load Coincidence Factor – Represents the percentage of the total load which is on during electric system’s Peak Window.

EFLH = Equivalent Full Load Hours – The kWh during the entire operating season divided by the kW at design conditions.

Table 3‑24: Electric Chiller Variables

| **Component** | **Type** | **Value** | **Source** |
| --- | --- | --- | --- |
| Tons | Variable | From AEPS Application; | EDC Data Gathering |
| kW/tonbase  EERbase | Variable | Default value from Table 3‑25 | See Table 3‑25 |
| kW/tonee  EERee | Variable | Nameplate Data. ARI Standards 550/590 | AEPS Application; EDC Data Gathering |
| PLCF | Fixed | 90% | Engineering Estimate |
| EFLH | Fixed | Default values from Table 3‑26 | See Table 3‑26 |

Table 3‑25: Electric Chiller Baseline Efficiencies (IECC 2009)[[149]](#footnote-149)

| **Chiller Type** | **Size** | **Path A (Primarily Full Load)[[150]](#footnote-150)** | **Path B (Primarily Part Load)[[151]](#footnote-151)** | **Source** |
| --- | --- | --- | --- | --- |
| Air Cooled Chillers | < 150 tons | Full load: 9.562 EER | IPLV: 12.500 EER | IECC 2009 Table 503.2.3 (7) Post 1/1/2010 |
| >=150 tons | Full load: 9.562 EER | IPLV: 12.500 EER |
| Water Cooled Positive Displacement or Reciprocating Chiller | < 75 tons | Full load: 0.780 kW/ton | IPLV: 0.600 kW/ton |
| >=75 tons and < 150 tons | Full load: 0.775 kW/ton | IPLV: 0.586 kW/ton |
| >=150 tons and < 300 tons | Full load: 0.680 kW/ton | IPLV: 0.540 kW/ton |
| >=300 tons | Full load: 0.620 kW/ton | IPLV: 0.490 kW/ton |
| Water Cooled Centrifugal Chiller | <300 tons | Full load: 0.634 kW/ton | IPLV: 0.450 kW/ton |
| >=300 tons and < 600 tons | Full load: 0.576 kW/ton | IPLV: 0.400 kW/ton |
| >=600 tons | Full load: 0.570 kW/ton | IPLV: 0.400 kW/ton |

Table 3‑26: Chiller Cooling EFLH by Location[[152]](#footnote-152)

| **Space Type** | **Erie** | **Harris-burg** | **Pitts-burgh** | **William-sport** | **Phila-delphia** | **Scran-ton** |
| --- | --- | --- | --- | --- | --- | --- |
| Arena/Auditorium/Convention Center | 332 | 640 | 508 | 454 | 711 | 428 |
| College: Classes/Administrative | 380 | 733 | 582 | 520 | 815 | 490 |
| Convenience Stores | 671 | 1,293 | 1,026 | 917 | 1,436 | 864 |
| Dining: Bar Lounge/Leisure | 503 | 969 | 769 | 688 | 1,077 | 648 |
| Dining: Cafeteria / Fast Food | 677 | 1,304 | 1,035 | 925 | 1,449 | 872 |
| Dining: Restaurants | 503 | 969 | 769 | 688 | 1,077 | 648 |
| Gymnasium/Performing Arts Theatre | 380 | 733 | 582 | 520 | 815 | 490 |
| Hospitals/Health care | 770 | 1,483 | 1,177 | 1,052 | 1,648 | 992 |
| Lodging: Hotels/Motels/Dormitories | 418 | 805 | 638 | 548 | 859 | 517 |
| Lodging: Residential | 418 | 805 | 638 | 571 | 894 | 538 |
| Multi-Family (Common Areas) | 769 | 1,482 | 1,176 | 1,052 | 1,647 | 991 |
| Museum/Library | 469 | 905 | 718 | 642 | 1,005 | 605 |
| Nursing Homes | 630 | 1,213 | 963 | 861 | 1,348 | 811 |
| Office: General/Retail | 469 | 905 | 718 | 642 | 1,005 | 605 |
| Office: Medical/Banks | 469 | 905 | 718 | 642 | 1,005 | 605 |
| Parking Garages & Lots | 517 | 997 | 791 | 707 | 1,107 | 666 |
| Penitentiary | 602 | 1,160 | 920 | 823 | 1,289 | 775 |
| Police/Fire Stations (24 Hr) | 769 | 1,482 | 1,176 | 1,052 | 1,647 | 991 |
| Post Office/Town Hall/Court House | 469 | 905 | 718 | 642 | 1,005 | 605 |
| Religious Buildings/Church | 332 | 640 | 508 | 454 | 711 | 428 |
| Retail | 493 | 950 | 754 | 674 | 1,055 | 635 |
| Schools/University | 350 | 674 | 535 | 478 | 749 | 451 |
| Warehouses (Not Refrigerated) | 382 | 735 | 583 | 522 | 817 | 492 |
| Warehouses (Refrigerated) | 382 | 735 | 583 | 522 | 817 | 492 |
| Waste Water Treatment Plant | 690 | 1,330 | 1,055 | 944 | 1,478 | 889 |

## Anti-Sweat Heater Controls

Anti-sweat heater (ASH) controls sense the humidity in the store outside of reach-in, glass door refrigerated cases and turn off anti-sweat heaters during periods of low humidity. Without controls, anti-sweat heaters run continuously whether they are necessary or not. Savings are realized from the reduction in energy used by not having the heaters running at all times. In addition, secondary savings result from reduced cooling load on the refrigeration unit when the heaters are off. The ASH control is applicable to glass doors with heaters, and the savings given below are based on adding controls to doors with uncontrolled heaters. The savings calculated from these algorithms is on a per door basis for two temperatures: Refrigerator/Coolers and Freezers. A default value to be used when the case service temperature is unknown is also calculated. Furthermore, impacts are calculated for both a per-door and a per-linear-feet of case unit basis, because both are used for Pennsylvania energy efficiency programs.

### Algorithms

#### Refrigerator/Cooler

ΔkWhper unit = (kWCoolerBase / DoorFt) \* (8,760 \* CHAoff ) \* (1+RH/COPCool)

ΔkWpeak per unit = (kWCoolerBase / DoorFt) \* CHPoff \* (1+RH/COPCool) \* DF

ΔkWh = N \* ΔkWhper unit

ΔkWpeak = N \* ΔkWpeak per unit

#### Freezer

ΔkWhper unit = (kWFreezerBase / DoorFt) \* (8,760 \* FHAoff) \* (1+RH/COPFreeze)

ΔkWpeak per unit = (kWFreezerBase / DoorFt) \* FHPoff \* (1+RH/COPFreeze) \* DF

ΔkWh = N \* ΔkWhper unit

ΔkWpeak = N \* ΔkWpeak per unit

#### Default (case service temperature is unknown)

This algorithm should only be used when the refrigerated case type or service temperature is unknown or this information is not tracked as part of the EDC data collection.

ΔkWhper unit = {(1-PctCooler) \* kWhFreezer/ DoorFt + PctCooler\*kWhCooler/ DoorFt }

ΔkWpeak per unit = {(1- PctCooler) \* kWFreezer/ DoorFt + PctCooler \*kWCooler/ DoorFt }

ΔkWh = N \* ΔkWhper unit

ΔkWpeak = N \* ΔkWpeak per unit

### Definition of Terms

N = Number of doors or case length in linear feet having ASH controls installed

kWCoolerBase = Per door power consumption (kW) of cooler case ASHs without controls

kWFreezerBase = Per door power consumption (kW) of freezer case ASHs without controls

8760= Operating hours (365 days \* 24 hr/day)

CHPoff = Percent of time cooler case ASH with controls will be off during the peak period

CHAoff = Percent of time cooler case ASH with controls will be off annually

FHPoff = Percent of time freezer case ASH with controls will be off during the peak period

FHAoff = Percent of time freezer case ASH with controls will be off annually

DF = Demand diversity factor, accounting for the fact that not all anti-sweat heaters in all buildings in the population are operating at the same time.

RH = residual heat fraction; estimated percentage of the heat produced by the heaters that remains in the freezer or cooler case and must be removed by the refrigeration unit.

COPCool = coefficient of performance of cooler

COPFreeze = coefficient of performance of freezer

DoorFt = Conversion factor to go between per door or per linear foot basis. Either 1 if per door or linear feet per door if per linear foot. Both unit basis values are used in Pennsylvania energy efficiency programs.

PctCooler = Typical percent of cases that are medium-temperature refrigerator/cooler cases.

Table 3‑27 Anti-Sweat Heater Controls – Values and References

| **Component** | **Type** | **Value** | **Sources** |
| --- | --- | --- | --- |
| N | Variable | # of doors or case length in linear feet | EDC Data Gathering |
| RH | Fixed | 0.65 | 1 |
| Unit | Fixed | Door = 1  Linear Feet= 2.5 | 2 |
| Refrigerator/Cooler |  |  |  |
| kWCoolerBase | Fixed | 0.109 | 1 |
| CHPoff | Fixed | 20% | 1 |
| CHAoff | Fixed | 85% | 1 |
| DF Cool | Fixed | 1 | 3 |
| COP­Cool | Fixed | 2.5 | 1 |
| Freezer |  |  |  |
| kWFreezerBase | Fixed | 0.191 | 1 |
| FHPoff | Fixed | 10% | 1 |
| FHAoff | Fixed | 75% | 1 |
| DFFreeze | Fixed | 1 | 3 |
| COPFreeze | Fixed | 1.3 | 1 |
| PctCooler | Fixed | 68% | 4 |

Sources:

1. State of Wisconsin, Public Service Commission of Wisconsin, Focus on Energy Evaluation, Business Programs Deemed Savings Manual, March 22, 2010.
   1. Three door heating configurations are presented in this reference: Standard, low-heat, and no-heat. The standard configuration was chosen on the assumption that low-heat and no-heat door cases will be screened from participation.
2. Review of various manufacturers’ web sites yields 2.5’ average door length. Sites include:
   1. <http://www.bushrefrigeration.com/bakery_glass_door_coolers.php>
   2. <http://www.brrr.cc/home.php?cat=427>
   3. <http://refrigeration-equipment.com/gdm_s_c_series_swing_door_reac.html>
3. New York Standard Approach for Estimating Energy Savings from Energy Efficiency Measures in Commercial and Industrial Programs, Sept 1, 2009.
4. 2010 ASHRAE Refrigeration Handbook, page 15.1 “Medium- and low-temperature display refrigerator line-ups account for roughly 68 and 32%, respectively, of a typical supermarket’s total display refrigerators.”

Table 3‑28 Recommended Fully Deemed Impact Estimates

|  |  |  |
| --- | --- | --- |
| **Description** | **Per Door**  **Impact** | **Per Linear Ft of Case**  **Impact** |
| Refrigerator/Cooler |  |  |
| Energy Impact | 1,023 kWh per door | 409 kWh per lin ft |
| Peak Demand Impact | 0.0275 kW per door | 0.0110 kW per lin ft |
| Freezer |  |  |
| Energy Impact | 1,882 kWh per door | 753 kWh per lin ft |
| Peak Demand Impact | 0.0287 kW per door | 0.0115 kW per lin ft |
| Default (case service temperature unknown) | | |
| Energy Impact | 1,298 kWh per door | 519 kWh per lin ft |
| Peak Demand Impact | 0.0279 kW per door | 0.0112 kW per lin ft |

**Measure Life**

12 Years (DEER 2008, Regional Technical Forum)

## High-Efficiency Refrigeration/Freezer Cases

### Algorithms

#### Products that can be ENERGY STAR 2.0 qualified:

Examples of product types that may be eligible for qualification include: reach-in, roll-in, or pass-through units; merchandisers; undercounter units; milk coolers; back bar coolers; bottle coolers; glass frosters; deep well units; beer-dispensing or direct draw units; and bunker freezers.

ΔkWh = (kWhbase – kWhee)\*days/year

ΔkWpeak = (kWhbase – kWhee) \* CF/24

#### Products that cannot be ENERGY STAR qualified:

Drawer cabinets, prep tables, deli cases, and open air units are not eligible for ENERGY STAR under the Version 2.0 specification.

For these products, savings should be treated under a high-efficiency case fan, Electronically Commutated Motor (ECM) option.

### Definition of Terms

kWhbase = The unit energy consumption of a standard unit (kWh/day)

kWhee = The unit energy consumption of the ENERGY STAR-qualified unit (kWh/day)

CF = The coincidence factor which equates the installed unit’s connected load to its demand at time of system peak.

V = Internal Volume

Table 3‑29: Refrigeration Cases - References

|  |  |  |  |
| --- | --- | --- | --- |
| **Component** | **Type** | **Value** | **Sources** |
| kWhbase | Calculated | See Table 3‑30 and Table 3‑31 | 1 |
| kWhee | Calculated | See Table 3‑30 and Table 3‑31 | 1 |
| V | Variable |  | EDC data gathering |
| Days/year | Fixed | 365 | 1 |
| CF | Fixed | 1.0 | 2 |

*Sources:*

1. ENERGY STAR calculator, March, 2010 update.
2. Load shape for commercial refrigeration equipment

Table 3‑30: Refrigeration Case Efficiencies

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Volume (ft3)** | **Glass Door** | | **Solid Door** | |
| **kWhee/day** | **kWhbase/day** | **kWhee/day** | **kWhbase/day** |
| V < 15 | 0.118\*V + 1.382 | 0.12\*V + 3.34 | 0.089\*V + 1.411 | 0.10\*V + 2.04 |
| 15 ≤ V < 30 | 0.140\*V + 1.050 | 0.037\*V + 2.200 |
| 30 ≤ V < 50 | 0.088\*V + 2.625 | 0.056\*V + 1.635 |
| 50 ≤ V | 0.110\*V + 1.50 | 0.060\*V + 1.416 |

Table 3‑31: Freezer Case Efficiencies

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Volume (ft3)** | **Glass Door** | | **Solid Door** | |
| **kWhee/day** | **kWhbase/day** | **kWhee/day** | **kWhbase/day** |
| V < 15 | 0.607\*V+0.893 | 0.75\*V + 4.10 | 0.250\*V + 1.25 | 0.4\*V + 1.38 |
| 15 ≤ V < 30 | 0.733\*V - 1.00 | 0.40\*V – 1.00 |
| 30 ≤ V < 50 | 0.250\*V + 13.50 | 0.163\*V + 6.125 |
| 50 ≤ V | 0.450\*V + 3.50 | 0.158\*V + 6.333 |

If precise case volume is unknown, default savings given in tables below can be used

Table 3‑32: Refrigeration Case Savings

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Volume (ft3)** | **Annual Energy Savings (kWh)** | | **Demand Impacts (kW)** | |
| **Glass Door** | **Solid Door** | **Glass Door** | **Solid Door** |
| V < 15 | 722 | 268 | 0.0824 | 0.0306 |
| 15 ≤ V < 30 | 683 | 424 | 0.0779 | 0.0484 |
| 30 ≤ V < 50 | 763 | 838 | 0.0871 | 0.0957 |
| 50 ≤ V | 927 | 1,205 | 0.1058 | 0.1427 |

Table 3‑33: Freezer Case Savings

| **Volume (ft3)** | **Annual EnergySavings (kWh)** | | **Demand Impacts (kW)** | |
| --- | --- | --- | --- | --- |
| **Glass Door** | **Solid Door** | **Glass Door** | **Solid Door** |
| V < 15 | 1,901 | 814 | 0.2170 | 0.0929 |
| 15 ≤ V < 30 | 1,992 | 869 | 0.2274 | 0.0992 |
| 30 ≤ V < 50 | 4,417 | 1,988 | 0.5042 | 0.2269 |
| 50 ≤ V | 6,680 | 3,405 | 0.7625 | 0.3887 |

### Effective Useful Life

12 years

According to the Food Service Technology Center (as stated in ENERGY STAR calculator).

## High-Efficiency Evaporator Fan Motors for Reach-In Refrigerated Cases

This protocol covers energy and demand savings associated with retrofit of existing shaded-pole evaporator fan motors in reach-in refrigerated display cases with either an Electronically Commutated (ECM) or Permanent Split Capacitor (PSC) motor. PSC motors must replace shaded pole (SP) motors, and ECM motors can replace either SP or PSC motors. A default savings option is offered if case temperature and/or motor size are not known. However, these parameters should be collected by EDCs for greatest accuracy.

There are two sources of energy and demand savings through this measure. There are the direct savings associated with replacement of an inefficient motor with a more efficient one, and there are the indirect savings of a reduced cooling load on the refrigeration unit due to less heat gain from the more efficient evaporator fan motor in the air-stream.

### Algorithms

#### Cooler

ΔkWpeak per unit = (Wbase – Wee) / 1,000 \* LF \* DCEvapCool \* (1 + 1 / (DG \* COPcooler))

ΔkWhper unit = ΔkWpeak per unit \* 8,760

ΔkWpeak = N \*ΔkWpeak per unit

ΔkWh = N \* ΔkWhper unit

#### Freezer

ΔkWpeak per unit = (Wbase – Wee) / 1,000 \* LF \* DCEvapFreeze \* (1 + 1 / (DG \* COPfreezer))

ΔkWhper unit = ΔkWpeak per unit \* 8,760

ΔkWpeak = N \*ΔkWpeak per unit

ΔkWh= N \* ΔkWhper unit

#### Default (case service temperature not known)

ΔkWpeak per unit = {(1-PctCooler) \* kWFreezer/motor + PctCooler\*kWCooler/motor}

ΔkWhper unit = ΔkWpeak per unit \* 8,760

ΔkWpeak = N \*ΔkWpeak per unit

ΔkWh= N \* kWhdefault/motor

### Definition of Terms

N = Number of motors replaced

Wbase = Input wattage of existing/baseline evaporator fan motor

Wee = Input wattage of new energy efficient evaporator fan motor

LF = Load factor of evaporator fan motor

DCEvapCool = Duty cycle of evaporator fan motor for cooler

DCEvapFreeze = Duty cycle of evaporator fan motor for freezer

DG = Degradation factor of compressor COP

COPcooler = Coefficient of performance of compressor in the cooler

COPfreezer = Coefficient of performance of compressor in the freezer

PctCooler = Percentage of coolers in stores vs total of freezers and coolers

8760 = Hours per year

Table 3‑34: Variables for High-Efficiency Evaporator Fan Motor

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable** | **Type** | **Value** | **Source** |
| Wbase | Fixed | Default | Table X-2 |
| Nameplate Input Wattage | EDC Data Gathering |
| Wee | Variable | Default | Table X-2 |
| Nameplate Input Wattage | EDC Data Gathering |
| LF | Fixed | 0.9 | 1 |
| DCEvapCool | Fixed | 100% | 2 |
| DCEvapFreeze | Fixed | 94.4% | 2 |
| DG | Fixed | 0.98 | 3 |
| COPcooler | Fixed | 2.5 | 1 |
| COPfreezer | Fixed | 1.3 | 1 |
| PctCooler | Fixed | 68% | 4 |

*Sources*:

1. PSC of Wisconsin, Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0, p. 4-103 to 4-106.

Table 3‑35: Variables for HE Evaporator Fan Motor

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Motor Category | Weighting Number (population)1 | Motor Output Watts | SP Efficiency1 | SP Input Watts | PSC Efficiency2 | PSC Input Watts | ECM Efficiency1 | ECM Input Watts |
| 1-14 watts (Using 9 watt as industry average) | 91% | 9 | 18% | 50 | 41% | 22 | 66% | 14 |
| 16-23 watts (Using 19.5 watt as industry average) | 3% | 19.5 | 21% | 93 | 41% | 48 | 66% | 30 |
| 1/20 HP (~37 watts) | 6% | 37 | 26% | 142 | 41% | 90 | 66% | 56 |

**Sources:**

1. Regional Technical Forum (RTF) as part of the Northwest Power & Conservation Council, Deemed Measures List. Grocery Display Case ECM, FY2010, V2. Accessed from RTF website http://www.nwcouncil.org/rtf/measures/Default.asp on July 30, 2010.
2. AO Smith New Product Notification. I-motor 9 & 16 Watt. Stock Numbers 9207F2 and 9208F2. Web address: http://www.aosmithmotors.com/uploadedFiles/Bulletin%206029B\_6-09\_web.pdf. Accessed July 30, 2010.

Table 3‑36: Shaded Pole to PSC Deemed Savings

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Measure | Wbase (Shaded Pole) | Wee (PSC) | LF | DCEvap | DG | COP per case Temp | Demand Impact (kW) | Energy Impact (kWh) |
| Cooler: Shaded Pole to PSC: 1-14 Watt | 50 | 22 | 0.9 | 100% | 0.98 | 2.5 | 0.0355 | 311 |
| Cooler: Shaded Pole to PSC: 16-23 Watt | 93 | 48 | 0.9 | 100% | 0.98 | 2.5 | 0.0574 | 503 |
| Cooler: Shaded Pole to PSC: 1/20 HP (37 Watt) | 142 | 90 | 0.9 | 100% | 0.98 | 2.5 | 0.0660 | 578 |
| Freezer: Shaded Pole to PSC: 1-14 Watt | 50 | 22 | 0.9 | 94.4% | 0.98 | 1.3 | 0.0425 | 373 |
| Freezer: Shaded Pole to PSC: 16-23 Watt | 93 | 48 | 0.9 | 94.4% | 0.98 | 1.3 | 0.0687 | 602 |
| Freezer: Shaded Pole to PSC: 1/20 HP (37 Watt) | 142 | 90 | 0.9 | 94.4% | 0.98 | 1.3 | 0.0790 | 692 |

Table 3‑37: PSC to ECM Deemed Savings

| **Measure** | **Wbase (PSC)** | **Wee (ECM)** | **LF** | **DCEvap** | **DG** | **COP per case Temp** | **Demand Impact (kW)** | **Energy Impact (kWh)** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Cooler: PSC to ECM: 1-14 Watt | 22 | 14 | 0.9 | 100% | 0.98 | 2.5 | 0.0105 | 92 |
| Cooler: PSC to ECM: 16-23 Watt | 48 | 30 | 0.9 | 100% | 0.98 | 2.5 | 0.0228 | 200 |
| Cooler: PSC to ECM: 1/20 HP (37 Watt) | 90 | 56 | 0.9 | 100% | 0.98 | 2.5 | 0.0433 | 380 |
| Freezer: PSC to ECM: 1-14 Watt | 22 | 14 | 0.9 | 94.4% | 0.98 | 1.3 | 0.0126 | 110 |
| Freezer: PSC to ECM: 16-23 Watt | 48 | 30 | 0.9 | 94.4% | 0.98 | 1.3 | 0.0273 | 239 |
| Freezer: PSC to ECM: 1/20 HP (37 Watt) | 90 | 56 | 0.9 | 94.4% | 0.98 | 1.3 | 0.0518 | 454 |

Table 3‑38: Shaded Pole to ECM Deemed Savings

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Measure** | **Wbase (Shaded Pole)** | **Wee (ECM)** | **LF** | **DCEvap** | **DG** | **COP per case Temp** | **Demand Impact (kW)** | **Energy Impact (kWh)** |
| Cooler: Shaded Pole to ECM: 1-14 Watt | 50 | 14 | 0.9 | 100% | 0.98 | 2.5 | 0.0461 | 404 |
| Cooler: Shaded Pole to ECM: 16-23 Watt | 93 | 30 | 0.9 | 100% | 0.98 | 2.5 | 0.0802 | 703 |
| Cooler: Shaded Pole to ECM: 1/20 HP (37 Watt) | 142 | 56 | 0.9 | 100% | 0.98 | 2.5 | 0.1093 | 958 |
| Freezer: Shaded Pole to ECM: 1-14 Watt | 50 | 14 | 0.9 | 94.4% | 0.98 | 1.3 | 0.0551 | 483 |
| Freezer: Shaded Pole to ECM: 16-23 Watt | 93 | 30 | 0.9 | 94.4% | 0.98 | 1.3 | 0.0960 | 841 |
| Freezer: Shaded Pole to ECM: 1/20 HP (37 Watt) | 142 | 56 | 0.9 | 94.4% | 0.98 | 1.3 | 0.1308 | 1146 |

Table 3‑39: Default High-Efficiency Evaporator Fan Motor Deemed Savings

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Measure** | **Cooler Weighted Demand Impact (kW)** | **Cooler Weighted Energy Impact (kWh)** | **Freezer Weighted Demand Impact (kW)** | **Freezer Weighted Energy Impact (kWh)** | **Default Demand Impact (kW)** | **Default Energy Impact (kWh)** |
| Shaded Pole to PSC | 0.0380 | 333 | 0.0455 | 399 | 0.0404 | 354 |
| PSC to ECM | 0.0129 | 113 | 0.0154 | 135 | 0.0137 | 120 |
| Shaded Pole to ECM | 0.0509 | 446 | 0.0609 | 534 | 0.0541 | 474 |

### Measure Life

15 years

**Sources:**

1. “ActOnEnergy; Business Program-Program Year 2, June, 2009 through May, 2010. Technical Reference Manual, No. 2009-01.” Published 12/15/2009.
2. “Efficiency Maine; Commercial Technical Reference User Manual , No. 2007-1.” Published 3/5/07.
3. Regional Technical Forum (RTF) as part of the Northwest Power & Conservation Council, Deemed Measures List. *Grocery Display Case ECM, FY2010, V2*. Accessed from RTF website http://www.nwcouncil.org/rtf/measures/Default.asp on July 30, 2010.

## High-Efficiency Evaporator Fan Motors for Walk-in Refrigerated Cases

This protocol covers energy and demand savings associated with retrofit of existing shaded-pole (SP) or permanent-split capacitor (PSC) evaporator fan motors in walk-in refrigerated display cases with an electronically commutated motor (ECM). A default savings option is offered if case temperature and/or motor size are not known. However, these parameters should be collected by EDCs for greatest accuracy.

There are two sources of energy and demand savings through this measure. There are the direct savings associated with replacement of an inefficient motor with a more efficient one, and there are the indirect savings of a reduced cooling load on the refrigeration unit due to less heat gain from the more efficient evaporator fan motor in the air-stream.

### Algorithms

#### Cooler

ΔkWpeak per unit = (Wbase – Wee) / 1,000 \* LF \* DCEvapCool \* (1 + 1 / (DG \* COPcooler))

ΔkWhper unit = ΔkWpeak per unit \* HR

ΔkWpeak = N \*ΔkWpeak per unit

ΔkWh = N \* ΔkWhper unit

#### Freezer

ΔkWpeak per unit = (Wbase – Wee) / 1,000 \* LF \* DCEvapFreeze \* (1 + 1 / (DG \* COPfreezer))

ΔkWhper unit = ΔkWpeak per unit \* HR

ΔkWpeak = N \*ΔkWpeak per unit

ΔkWh= N \* ΔkWhper unit

#### Default (case service temperature not known)

ΔkWpeak per unit = {(1-PctCooler) \* kWFreezer/motor + PctCooler\*kWCooler/motor}

ΔkWhper unit = ΔkWpeak per unit \* HR

ΔkWpeak = N \*ΔkWpeak per unit

ΔkWh= N \* ΔkWhper unit

### Definition of Terms

N = Number of motors replaced

Wbase = Input wattage of existing/baseline evaporator fan motor

Wee = Input wattage of new energy efficient evaporator fan motor

LF = Load factor of evaporator fan motor

DCEvapCool = Duty cycle of evaporator fan motor for cooler

DCEvapFreeze = Duty cycle of evaporator fan motor for freezer

DG = Degradation factor of compressor COP

COPcooler = Coefficient of performance of compressor in the cooler

COPfreezer = Coefficient of performance of compressor in the freezer

PctCooler = Percentage of walk-in coolers in stores vs. total of freezers and coolers

HR = Operating hours per year

Table 3‑40: Variables for High-Efficiency Evaporator Fan Motor

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable** | **Type** | **Value** | **Source** |
| Wbase | Fixed | Default | Table 3‑41 |
| Nameplate Input Wattage | EDC Data Gathering |
| Wee | Variable | Default | Table 3‑41 |
| Nameplate Input Wattage | EDC Data Gathering |
| LF | Fixed | 0.9 | 1 |
| DCEvapCool | Fixed | 100% | 2 |
| DCEvapFreeze | Fixed | 94.4% | 2 |
| DG | Fixed | 0.98 | 3 |
| COPcooler | Fixed | 2.5 | 1 |
| COPfreezer | Fixed | 1.3 | 1 |
| PctCooler | Fixed | 69% | 3 |
| HR | Fixed | 8,273 | 2 |

**Sources:**

1. PSC of Wisconsin, Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0, p. 4-103 to 4-106.
2. Efficiency Vermont, Technical Reference Manual 2009-54, 12/08. Hours of operation accounts for defrosting periods where motor is not operating.
3. PECI presentation to Regional Technical Forum (RTF) as part of the Northwest Power & Conservation Council, Energy Smart March 2009 SP to ECM – 090223.ppt. Accessed from RTF website http://www.nwcouncil.org/energy/rtf/meetings/2009/03/default.htm on September 7, 2010.

Table 3‑41: Variables for HE Evaporator Fan Motor

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Motor Category** | **Weighting Number (population)2** | **Motor Output Watts** | **SP Efficiency1,2** | **SP Input Watts** | **PSC Efficiency3** | **PSC Input Watts** | **ECM Efficiency1** | **ECM Input Watts** |
| 1/40 HP (16-23 watts) (Using 19.5 watt as industry average) | 25% | 19.5 | 21% | 93 | 41% | 48 | 66% | 30 |
| 1/20 HP (~37 watts) | 11.5% | 37 | 26% | 142 | 41% | 90 | 66% | 56 |
| 1/15 HP (~49 watts) | 63.5% | 49 | 26% | 191 | 41% | 120 | 66% | 75 |

**Sources:**

1. Regional Technical Forum (RTF) as part of the Northwest Power & Conservation Council, Deemed Measures List. Grocery Display Case ECM, FY2010, V2. Accessed from RTF website: http://www.nwcouncil.org/rtf/measures/Default.asp on July 30, 2010
2. Regional Technical Forum (RTF) as part of the Northwest Power & Conservation Council, Deemed Measures List. Deemed MeasuresV26 \_walkinevapfan. Provided by Adam Hadley (adam@hadleyenergy.com). Should be made available on RTF website http://www.nwcouncil.org/rtf/measures/Default.asp
3. AO Smith New Product Notification. I-motor 9 & 16 Watt. Stock Numbers 9207F2 and 9208F2. Web address: http://www.aosmithmotors.com/uploadedFiles/Bulletin%206029B\_6-09\_web.pdf. Accessed July 30, 2010.

Table 3‑42: PSC to ECM Deemed Savings

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Measure** | **Wbase (PSC)** | **Wee (ECM)** | **LF** | **DCEvap** | **DG** | **COP per case Temp** | **Demand Impact (kW)** | **Energy Impact (kWh)** |
| Cooler: PSC to ECM: 1/40 HP (16-23 Watt) | 48 | 30 | 0.9 | 100% | 0.98 | 2.5 | 0.0228 | 189 |
| Cooler: PSC to ECM: 1/20 HP (37 Watt) | 90 | 56 | 0.9 | 100% | 0.98 | 2.5 | 0.0431 | 356 |
| Cooler: PSC to ECM: 1/15 HP (49 Watt) | 120 | 75 | 0.9 | 100% | 0.98 | 2.5 | 0.0570 | 472 |
| Freezer: PSC to ECM: 1/40 HP (16-23 Watt) | 48 | 30 | 0.9 | 94.4% | 0.98 | 1.3 | 0.0273 | 226 |
| Freezer: PSC to ECM: 1/20 HP (37 Watt) | 90 | 56 | 0.9 | 94.4% | 0.98 | 1.3 | 0.0516 | 427 |
| Freezer: PSC to ECM: 1/15 HP (49 Watt) | 120 | 75 | 0.9 | 94.4% | 0.98 | 1.3 | 0.0682 | 565 |

Table 3‑43: Shaded Pole to ECM Deemed Savings

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Measure** | **Wbase (Shaded Pole)** | **Wee (ECM)** | **LF** | **DCEvap** | **DG** | **COP per case Temp** | **Demand Impact (kW)** | **Energy Impact (kWh)** |
| Cooler: Shaded Pole to ECM: 1/40 HP (16-23 Watt) | 93 | 30 | 0.9 | 100% | 0.98 | 2.5 | 0.0798 | 661 |
| Cooler: Shaded Pole to ECM: 1/20 HP (37 Watt) | 142 | 56 | 0.9 | 100% | 0.98 | 2.5 | 0.1090 | 902 |
| Cooler: Shaded Pole to ECM: 1/15 HP (49 Watt) | 191 | 75 | 0.9 | 100% | 0.98 | 2.5 | 0.1470 | 1,216 |
| Freezer: Shaded Pole to ECM: 1/40 HP (16-23 Watt) | 85 | 30 | 0.9 | 94.4% | 0.98 | 1.3 | 0.0834 | 790 |
| Freezer: Shaded Pole to ECM: 1/20 HP (37 Watt) | 142 | 56 | 0.9 | 94.4% | 0.98 | 1.3 | 0.1304 | 1,079 |
| Freezer: Shaded Pole to ECM: 1/15 HP (49 Watt) | 191 | 75 | 0.9 | 94.4% | 0.98 | 1.3 | 0.1759 | 1,455 |

Table 3‑44: Default High-Efficiency Evaporator Fan Motor Deemed Savings

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Measure** | **Cooler Weighted Demand Impact (kW)** | **Cooler Weighted Energy Impact (kWh)** | **Freezer Weighted Demand Impact (kW)** | **Freezer Weighted Energy Impact (kWh)** | **Default Demand Impact (kW)** | **Default Energy Impact (kWh)** |
| PSC to ECM | 0.0469 | 388 | 0.0561 | 464 | 0.0499 | 413 |
| Shaded Pole to ECM | 0.1258 | 1,041 | 0.1506 | 1,246 | 0.1335 | 1,105 |

### Measure Life

15 years

*Sources:*

1. “ActOnEnergy; Business Program-Program Year 2, June, 2009 through May, 2010. Technical Reference Manual, No. 2009-01.” Published 12/15/2009.
2. “Efficiency Maine; Commercial Technical Reference User Manual , No. 2007-1.” Published 3/5/07.
3. Regional Technical Forum (RTF) as part of the Northwest Power & Conservation Council, Deemed Measures List. Deemed MeasuresV26 \_walkinevapfan. Provided by Adam Hadley (adam@hadleyenergy.com). Should be made available on RTF website <http://www.nwcouncil.org/rtf/measures/Default.asp>

## ENERGY STAR Office Equipment

### Algorithms

The general form of the equation for the ENERGY STAR Office Equipment measure savings’ algorithms is:

Number of Units X Savings per Unit

To determine resource savings, the per unit estimates in the algorithms will be multiplied by the number of units. Per unit savings are primarily derived from the June 2010 release of the ENERGY STAR calculator for office equipment.

#### ENERGY STAR Computer

ΔkWh = ESavCOM

ΔkWpeak = DSavCOM x CFCOM

#### ENERGY STAR Fax Machine

ΔkWh = ESavFAX

ΔkWpeak = DSavFAX x CFFAX

#### ENERGY STAR Copier

ΔkWh = ESavCOP

ΔkWpeak = DSavCOP x CFCOP

#### ENERGY STAR Printer

ΔkWh = ESavPRI

ΔkWpeak = DSavPRI x CFPRI

#### ENERGY STAR Multifunction

ΔkWh = ESavMUL

ΔkWpeak = DSavMUL x CFMUL

#### ENERGY STAR Monitor

ΔkWh = ESavMON

ΔkWpeak = DSavMON x CFMON

### Definition of Terms

ESavCOM = Electricity savings per purchased ENERGY STAR computer.

DSavCOM = Summer demand savings per purchased ENERGY STAR computer.

ESavFAX = Electricity savings per purchased ENERGY STAR fax machine.

DSavFAX = Summer demand savings per purchased ENERGY STAR fax machine.

ESavCOP = Electricity savings per purchased ENERGY STAR copier.

DSavCOP = Summer demand savings per purchased ENERGY STAR copier.

ESavPRI = Electricity savings per purchased ENERGY STAR printer.

DSavPRI = Summer demand savings per purchased ENERGY STAR printer.

ESavMUL = Electricity savings per purchased ENERGY STAR multifunction machine.

DSavMUL = Summer demand savings per purchased ENERGY STAR multifunction machine.

ESavMON = Electricity savings per purchased ENERGY STAR monitor.

DSavMON = Summer demand savings per purchased ENERGY STAR monitor.

CFCOM, CFFAX, CFCOP,

CFPRI, CFMUL, CFMON = Summer demand coincidence factor. The coincidence of average office equipment demand to summer system peak equals 1 for demand impacts for all office equipment reflecting embedded coincidence in the DSav factor.

Table 3‑45: ENERGY STAR Office Equipment - References

| **Component** | **Type** | **Value** | **Sources** |
| --- | --- | --- | --- |
| ESavCOM  ESavFAX  ESavCOP  ESavPRI  ESavMUL  ESavMON | Fixed | see Table 3‑46 | 1 |
| DSavCOM  DSavFAX  DSavCOP  DSavPRI  DSavMUL  DSavMON | Fixed | see Table 3‑46 | 2 |
| CFCOM,CFFAX,CFCOP,CFPRI,CFMUL,CFMON | Fixed | 1.0, 1.0, 1.0, 1.0, 1.0, 1.0 | 3 |

*Sources:*

1. ENERGY STAR Office Equipment Savings Calculator (Calculator updated: June 2010). Default values were used.
2. Using a commercial office equipment load shape, the percentage of total savings that occur during the top 100 system hours was calculated and multiplied by the energy savings.
3. Coincidence factors already embedded in summer peak demand reduction estimates.

Table 3‑46: ES Office Equipment Energy and Demand Savings Values

| **Measure** | **Energy Savings (ESav)** | **Demand Savings (DSav)** |
| --- | --- | --- |
| Computer | 133 kWh | 0.018 kW |
| Fax Machine (laser) | 78 kWh | 0.0105 kW |
| Copier (monochrome) |  |  |
| 1-25 images/min | 73 kWh | 0.0098 kW |
| 26-50 images/min | 151 kWh | 0.0203 kW |
| 51+ images/min | 162 kWh | 0.0218 kW |
| Printer (laser, monochrome) |  |  |
| 1-10 images/min | 26 kWh | 0.0035 kW |
| 11-20 images/min | 73 kWh | 0.0098 kW |
| 21-30 images/min | 104 kWh | 0.0140 kW |
| 31-40 images/min | 156 kWh | 0.0210 kW |
| 41-50 images/min | 133 kWh | 0.0179 kW |
| 51+ images/min | 329 kWh | 0.0443 kW |
| Multifunction (laser, monochrome) |  |  |
| 1-10 images/min | 78 kWh | 0.0105 kW |
| 11-20 images/min | 147 kWh | 0.0198 kW |
| 21-44 images/min | 253 kWh | 0.0341 kW |
| 45-99 images/min | 422 kWh | 0.0569 kW |
| 100+ images/min | 730 kWh | 0.0984 kW |
| Monitor | 15 kWh | 0.0020 kW |

**Sources:**

1. **ENERGYSTAR office equipment calculators**

### ****Effective Useful Life****

Table 3‑47: Effective Useful Life

|  |  |  |
| --- | --- | --- |
| **Equipment** | **Residential Life (years)** | **Commercial Life (years)** |
| **Computer** | **4** | **4** |
| **Monitor** | **5** | **4** |
| **Fax** | **4** | **4** |
| **Multifunction Device** | **6** | **6** |
| **Printer** | **5** | **5** |
| **Copier** | **6** | **6** |

**Sources:**

1. **ENERGYSTAR office equipment calculators**

## Smart Strip Plug Outlets

Smart Strips are power strips that contain a number of controlled sockets with at least one uncontrolled socket. When the appliance that is plugged into the uncontrolled socket is turned off, the power strips then shuts off the items plugged into the controlled sockets. Qualified power strip must automatically turn off when equipment is unused / unoccupied.

### Eligibility

This protocol documents the energy savings attributed to the installation of smart strip plugs. The most likely area of application is within commercial spaces such as isolated workstations and computer systems with standalone printers, scanners or other major peripherals that are not dependent on an uninterrupted network connection (e.g. routers and modems).

### Algorithms

The DSMore Michigan Database of Energy Efficiency Measures performed engineering calculations using standard standby equipment wattages for typical computer and TV systems and idle times. This commercial protocol will use the computer system assumptions except it will utilize a lower idle time for commercial office use.

The computer system usage is assumed to be 10 hours per day for 5 workdays per week. The average daily idle time including the weekend (2 days of 100% idle) is calculated as follows:

*(Hours per week – (Workdays x daily computer usage))/days per week = average daily commercial computer system idle time*

*(168 hours – (5 x 10 hours))/7 days = 16.86 hours*

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

### Definition of Terms

The parameters in the above equation are listed below.

Table 3‑48: Smart Strip Calculation Assumptions

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Parameter** | **Component** | **Type** | **Value** | **Source** |
| kWcomp | Idle kW of computer system | Fixed | 0.0201 | 1 |
| Hrcomp | Daily hours of computer idle time | Fixed | 16.86 | 1 |
| CF | Coincidence Factor | Fixed | 0.50 | 1 |

### Sources:

1. DSMore Michigan Database of Energy Efficiency Measures

### Deemed Savings

ΔkWh = 124 kWh

ΔkWpeak = 0.0101 kW

### Measure Life

To ensure consistency with the annual savings calculation procedure used in the DSMore MI database, the measure of **5 years** is taken from DSMore.

### Evaluation Protocols

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

## Beverage Machine Controls

This measure is intended for the addition of control systems to existing, non-ENERGY STAR, beverage vending machines. The applicable machines contain refrigerated non-perishable beverages that are kept at an appropriate temperature. The control systems are intended to reduce energy consumption due to lighting and refrigeration during times of lower customer sales. Typical control systems contain a passive infrared occupancy sensor to shut down the machine after a period of inactivity in the area. The compressor will power on one to three hour intervals sufficient to maintain beverage temperature, and when powered on at any time will be allowed to complete at least one cycle to prevent excessive wear and tear.

The baseline equipment is taken to be an existing standard refrigerated beverage vending machine that does not contain control systems to shut down the refrigeration components and lighting during times of low customer use.

### Algorithms

Energy savings are dependent on decreased machine lighting and cooling loads during times of lower customer sales. The savings will be dependent on the machine environment, noting that machines placed in locations such as a day-use office will result in greater savings than those placed in high-traffic areas such as hospitals that operate around the clock. The algorithm below takes into account varying scenarios and can be taken as representative of a typical application.

ΔkWh = kWhbase \* E

ΔkWpeak  = 0

There are no peak demand savings because this measure is aimed to reduce demand during times of low beverage machine use, which will typically occur during off-peak hours.

### Definition of Terms

kWhbase = baseline annual beverage machine energy consumption (kWh/year)

E = efficiency factor due to control system, which represents percentage of energy reduction from baseline

### Energy Savings Calculations

The decrease in energy consumption due to the addition of a control system will depend on the number or hours per year during which lighting and refrigeration components of the beverage machine are powered down. The average decrease in energy use from refrigerated beverage vending machines with control systems installed is 46%[[153]](#footnote-153),[[154]](#footnote-154),[[155]](#footnote-155),[[156]](#footnote-156). It should be noted that various studies found savings values ranging between 30-65%, most likely due to differences in customer occupation.

The default baseline energy consumption and default energy savings are shown in . The default energy savings were derived by applying a default efficiency factor of Edefault = 46% to the energy savings algorithm above. Where it is determined that the default efficiency factor (E) or default baseline energy consumption (kWhbase) is not representative of specific applications, EDC data gathering can be used to determine an application specific energy savings factor (E), and/or baseline energy consumption (kWhbase), for use in the Energy Savings algorithm.

Table 3‑49: Beverage Machine Controls Energy Savings[[157]](#footnote-157)

|  |  |  |
| --- | --- | --- |
| **Machine Can Capacity** | **Default Baseline Energy Consumption (kWhbase) (kWh/year)** | **Default Energy Savings (ΔkWh); (kWh/year)** |
| < 500 | 3,113 | 1,432 |
| 500 | 3,916 | 1,801 |
| 600 | 3,551 | 1,633 |
| 700 | 4,198 | 1,931 |
| 800+ | 3,318 | 1,526 |

### Measure Life

Measure life = 5 years[[158]](#footnote-158),[[159]](#footnote-159)

### Further Reference Data

1. U.S. Department of Energy Appliances and Commercial Equipment Standards, <http://www1.eere.energy.gov/buildings/appliance_standards/commercial/beverage_machines.html>

## High-Efficiency Ice Machines

This measure applies to the installation of a high-efficiency ice machine as either a new item or replacement for an existing unit. The machine must be air-cooled to qualify, which can include self-contained, ice-making heads, or remote-condensing units. The machine must conform with the minimum ENERGY STAR efficiency requirements, which are equivalent to the CEE Tier 2 specifications for high-efficiency commercial ice machines[[160]](#footnote-160). A qualifying machine must also meet the ENERGY STAR requirements for water usage given under the same criteria.

The baseline equipment is taken to be a unit with efficiency specifications less than or equal to CEE Tier 1 equipment.

### Algorithms

The energy savings are dependent on machine type and capacity of ice produced on a daily basis. A machine’s capacity is generally reported as an ice harvest rate, or amount of ice produced each day.

ΔkWh =

ΔkWpeak  =

### Definition of Terms

kWhbase = baseline ice machine energy usage per 100 lbs of ice (kWh/100lbs)

kWhhe = high-efficiency ice machine energy usage per 100 lbs of ice (kWh/100lbs)

H = Ice harvest rate per 24 hrs (lbs/day)

D = duty cycle of ice machine expressed as a percentage of time machine produces ice.

365 = (days/year)

100 = conversion to obtain energy per pound of ice (lbs/100lbs)

8760 = (hours/year)

CF = Summer peak coincidence factor

The reference values for each component of the energy impact algorithm are shown in . A default duty cycle (D) is provided as based on referenced values from several studies, however, EDC data gathering may be used to adjust the duty cycle for custom applications.

Table 3‑50: Ice Machine Reference values for algorithm components

|  |  |  |  |
| --- | --- | --- | --- |
| **Term** | **Type** | **Value** | **Source** |
| kWhbase | Variable |  | 1 |
| kWhhe | Variable |  | 2 |
| H | Variable | Manufacturer Specs | EDC Data Gathering |
| D | Variable | Default = 0.4[[161]](#footnote-161) | 3 |
| Custom | EDC Data Gathering |
| Ice maker type | Variable | Manufacturer Specs | EDC Data Gathering |
| CF | Fixed | 0.77 | 4 |

**Sources:**

1. Specifications for CEE Tier 1 ice machines.
2. Specifications for CEE Tier 2 ice machines.
3. *State of Ohio Energy Efficiency Technical Reference Manual* cites a default duty cycle of 40% as a conservative value. Other studies range as high as 75%.
4. *State of Ohio Energy Efficiency Technical Reference Manual* cites a CF = 0.772 as adopted from the Efficiency Vermont TRM. Assumes CF for ice machines is similar to that for general commercial refrigeration equipment.

### Energy Savings Calculations

Ice machine energy usage levels are dependent on the ice harvest rate (H), and are calculated using CEE specifications as shown in . The default energy consumption for the baseline ice machine (kWhbase) is calculated using the formula for CEE Tier 1 specifications, and the default energy consumption for the high-efficiency ice machine (kWhhe) is calculated using the formula for CEE Tier 2 specifications[[162]](#footnote-162). The two energy consumption values are then applied to the energy savings algorithm above.

Table 3‑51: Ice Machine Energy Usage[[163]](#footnote-163)

|  |  |  |  |
| --- | --- | --- | --- |
| **Ice machine type** | **Ice harvest rate (H)**  **(lbs/day)** | **Baseline energy use per 100 lbs of ice**  **(kWhbase)** | **High-efficiency energy use per 100 lbs of ice**  **(kWhhe)** |
| Ice-Making Head | <450 | 10.26 – 0.0086\*H | 9.23 – 0.0077\*H |
| ≥450 | 6.89 – 0.0011\*H | 6.20 – 0.0010\*H |
| Remote-Condensing w/out remote compressor | <1000 | 8.85 – 0.0038\*H | 8.05 – 0.0035\*H |
| ≥1000 | 5.1 | 4.64 |
| Remote-Condensing with remote compressor | <934 | 8.85 – 0.0038\*H | 8.05 – 0.0035\*H |
| ≥934 | 5.3 | 4.82 |
| Self-Contained | <175 | 18 – 0.0469\*H | 16.7 – 0.0436\*H |
| ≥175 | 9.8 | 9.11 |

### Measure Life

Measure life = 10 years[[164]](#footnote-164).

### Further Reference Data

1. Karas, A., Fisher, D. (2007), *A Field Study to Characterize Water and Energy Use of Commercial Ice-Cube Machines and Quantify Saving Potential*, Food Service Technology Center, December 2007, <http://www.fishnick.com/publications/appliancereports/special/Ice-cube_machine_field_study.pdf>
2. *Energy-Efficient Products, How to Buy an Energy-Efficient Commercial Ice Machine*, U.S. Department of Energy, Energy Efficiency and Renewable Energy, accessed August 2010 at <http://www1.eere.energy.gov/femp/procurement/eep_ice_makers.html>

## Wall and Ceiling Insulation

Wall and ceiling insulation is one of the most important aspects of the energy system of a building. Insulation dramatically minimizes energy expenditure on heating and cooling. Increasing the R-value of wall insulation above building code requirements generally lowers heating and cooling costs. Incentives are offered with regard to increases in R-value rather than type, method, or amount of insulation.

An R-value indicates the insulation’s resistance to heat flow – the higher the R-value, the greater the insulating effectiveness. The R-value depends on the type of insulation and its material, thickness, and density. When calculating the R-value of a multilayered installation, add the R-values of the individual layers.

### Eligibility

This measure applies to non-residential buildings heated and/or cooled using electricity. Existing construction buildings are required to meet or exceed the code requirement. New construction buildings must exceed the code requirement. Eligibility may vary by PA EDC; savings from chiller-cooled buildings are not included.

### Algorithms

The savings depend on four main factors: baseline condition, heating system type and size, cooling system type and size, and location. The algorithm for Central AC and Air Source Heat Pumps (ASHP) is as follows

#### Ceiling Insulation

ΔkWh= ΔkWhcool + ΔkWhheat

ΔkWhcool = (A X CDD X 24)/(EER X 1000) X (1/Ri – 1/Rf)

ΔkWhheat = (A X HDD X 24)/(COP X 3413) X (1/Ri – 1/Rf)

ΔkWpeak = ΔkWhcool / EFLHcool X CF

#### Wall Insulation

ΔkWh= ΔkWhcool + ΔkWhheat

ΔkWhcool = (A X CDD X 24)/(EER X 1000) X (1/Ri – 1/Rf)

ΔkWhheat = (A X HDD X 24)/(COP X 3413) X (1/Ri – 1/Rf)

ΔkWpeak = ΔkWhcool / EFLHcool X CF

### Definition of Terms

A = area of the insulation that was installed in square feet

HDD = heating degree days with 65 degree base

CDD = cooling degree days with a 65 degree base

24 = hours per day

1000 = W per kW

3413 = Btu per kWh

Ri = the R-value of the insulation and support structure before the additional insulation is installed

Rf = the total R-value of all insulation after the additional insulation is installed

EFLH = effective full load hours

CF = coincidence factor

EER = efficiency of the cooling system

COP = efficiency of the heating system

Table 3‑52: Non-Residential Insulation – Values and References

|  |  |  |  |
| --- | --- | --- | --- |
| **Component** | **Type** | **Values** | **Sources** |
| A | Variable | Application | AEPS Application; EDC Data Gathering |
| HDD | Fixed | Allentown = 5318  Erie = 6353  Harrisburg = 4997  Philadelphia = 4709  Pittsburgh = 5429  Scranton = 6176  Williamsport = 5651 | 1 |
| CDD | Fixed | Allentown = 787  Erie = 620  Harrisburg = 955  Philadelphia = 1235  Pittsburgh = 726  Scranton = 611  Williamsport = 709 | 1 |
| 24 | Fixed | 24 | n/a |
| 1000 | Fixed | 1000 | n/a |
| Ceiling Ri | Existing:Variable  New Construction: Fixed | For new construction buildings and when variable is unknown for existing buildings: See and for values by building type | AEPS Application; EDC Data Gathering; 2; 4 |
| Wall Ri | Existing:Variable  New Construction: Fixed | For new construction buildings and when variable is unknown for existing buildings: See and for values by building type | AEPS Application; EDC Data Gathering; 3; 4 |
| Rf | Variable |  | AEPS Application; EDC Data Gathering; |
| EFLHcool | Fixed | See | 5 |
| CF | Fixed | 67% | 5 |
| EER | Fixed | See Table 3‑55 | 6, 7 |
| COP | Fixed | See Table 3‑55 | 6, 7 |

**Sources:**

1. U.S. Department of Commerce. Climatography of the United States No. 81 Supplement No. 2. Annual Degree Days to Selected Bases 1971 – 2000. Scranton uses the values for Wilkes-Barre. HDD were adjusted downward to account for business hours. CDD were not adjusted for business hours, as the adjustment resulted in an increase in CDD and so not including the adjustment provides a conservative estimate of energy savings.
2. The initial R-value for a ceiling for existing buildings is based on the EDC eligibility requirement that at least R-11 be installed and that the insulation must meet at least IECC 2009 code. The initial R-value for new construction buildings is based on IECC 2009 code for climate zone 5.
3. The initial R-value for a wall assumes that there was no existing insulation, or that it has fallen down resulting in an R-value equivalent to that of the building materials. Building simulation modeling using DOE-2.2 model (eQuest) was performed for a building with no wall insulation. The R-value is dependent upon the construction materials and their thickness. Assumptions were made about the building materials used in each sector.
4. 2009 International Energy Conservation Code. Used climate zone 5 which covers the majority of Pennsylvania. The R-values required by code were used as inputs in the eQuest building simulation model to calculate the total R-value for the wall including the building materials.
5. EFLH values and coincidence factors for HVAC peak demand savings calculations come from the Pennsylvania Technical Reference Manual. June 2010.
6. Baseline values from ASHRAE 90.1-2004 for existing buildings.
7. Baseline values from IECC 2009 for new construction buildings.

Table 3‑53: Ceiling R-Values by Building Type

|  |  |  |
| --- | --- | --- |
| **Building Type** | **Ceiling Ri-Value  (New Construction)** | **Ceiling Ri-Value  (Existing)** |
| Large Office  Large Retail  Lodging  Health  Education  Grocery | 20 | 9 |
| Small Office  Warehouse | 24.4 | 13.4 |
| Small Retail  Restaurant  Convenience Store | 20 | 9 |

Table 3‑54: Wall R-Values by Building Type

|  |  |  |
| --- | --- | --- |
| **Building Type** | **Wall Ri-Value  (New Construction)** | **Wall Ri-Value (Existing)** |
| Large Office | 14 | 1.6 |
| Small Office  Large Retail  Small Retail  Convenience Store | 14 | 3.0 |
| Lodging  Health  Education  Grocery | 13 | 2.0 |
| Restaurant | 14 | 3.2 |
| Warehouse | 14 | 2.5 |

Table 3‑55: HVAC Baseline Efficiencies for Non-Residential Buildings

|  | **Existing** | | **New Construction** | |
| --- | --- | --- | --- | --- |
| **Equipment Type and Capacity** | **Cooling Baseline** | **Heating Baseline** | **Cooling Baseline** | **Heating Baseline** |
| Air-Source Air Conditioners | | | | |
| < 5.41 tons | 10.0 SEER | N/A | 13.0 SEER | N/A |
| > 5.41 tons and <11.25 tons | 10.3 EER | N/A | 11.2 EER | N/A |
| > 11.25 tons and < 20.00 tons | 9.7 EER | N/A | 11.0 EER | N/A |
| > 20.00 tons and < 63.33 tons | 9.5 EER | N/A | 10.0 EER | N/A |
| > 63.33 tons | 9.2 EER | N/A | 9.7 EER | N/A |
| Water-Source and Evaporatively-Cooled Air Conditioners | | | | |
| < 5.41 tons | 12.1 EER | N/A | 12.1 EER | N/A |
| > 5.41 tons and < 11.25 tons | 11.5 EER | N/A | 11.5 EER | N/A |
| > 11.25 tons and < 20.00 tons | 11.0 EER | N/A | 11.0 EER | N/A |
| > 20.00 tons | 11.0 EER | N/A | 11.5 EER | N/A |
| Air-Source Heat Pumps | | | | |
| < 5.41 tons: | 10.0 SEER | 6.8 HSPF | 13 SEER | 7.7 HSPF |
| > 5.41 tons and < 11.25 tons | 10.1 EER | 3.2 COP | 11.0 EER | 3.3 COP |
| > 11.25 tons and < 20.00 tons | 9.3 EER | 3.1 COP | 10.6 EER | 3.2 COP |
| > 20.00 tons | 9.0 EER | 3.1 COP | 9.5 EER | 3.2 COP |
| Water-Source Heat Pumps | | | | |
| < 1.42 tons | 11.2 EER | 4.2 COP | 11.2 EER | 4.2 COP |
| > 1.42 tons and < 5.41 tons | 12.0 EER | 4.2 COP | 12.0 EER | 4.2 COP |
| Ground Water Source Heat Pumps | | | | |
| < 11.25 tons | 16.2 EER | 3.6 COP | 16.2 EER | 3.6 COP |
| Ground Source Heat Pumps | | | | |
| < 11.25 tons | 13.4 EER | 3.1 COP | 13.4 EER | 3.1 COP |
| Packaged Terminal Systems (Replacements) | | | | |
| PTAC (cooling) | 10.9 - (0.213 x Cap / 1000) EER | N/A | 10.9 - (0.213 x Cap / 1000) EER | N/A |
| PTHP (cooling) | 10.8 - (0.213 x Cap / 1000) EER | 2.9 - (0.213 x Cap / 1000) COP | 10.8 - (0.213 x Cap / 1000) EER | 2.9 - (0.213 x Cap / 1000) COP |

Table 3‑56: Cooling EFLH for Erie, Harrisburg, and Pittsburgh[[165]](#footnote-165)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Space Type** | **Erie** | **Harris-burg** | **Pitts-burgh** | **Williams-port** | **Phila-delphia** | **Scran-ton** |
| Arena/Auditorium/Convention Center | 332 | 640 | 508 | 454 | 711 | 428 |
| College: Classes/Administrative | 380 | 733 | 582 | 520 | 815 | 490 |
| Convenience Stores | 671 | 1,293 | 1,026 | 917 | 1,436 | 864 |
| Dining: Bar Lounge/Leisure | 503 | 969 | 769 | 688 | 1,077 | 648 |
| Dining: Cafeteria / Fast Food | 677 | 1,304 | 1,035 | 925 | 1,449 | 872 |
| Dining: Restaurants | 503 | 969 | 769 | 688 | 1,077 | 648 |
| Gymnasium/Performing Arts Theatre | 380 | 733 | 582 | 520 | 815 | 490 |
| Hospitals/Health care | 770 | 1,483 | 1,177 | 1,052 | 1,648 | 992 |
| Industrial: 1 Shift/Light Manufacturing | 401 | 773 | 613 | 548 | 859 | 517 |
| Industrial: 2 Shift | 545 | 1,050 | 833 | 745 | 1,166 | 702 |
| Industrial: 3 Shift | 690 | 1,330 | 1,055 | 944 | 1,478 | 889 |
| Lodging: Hotels/Motels/Dormitories | 418 | 805 | 638 | 571 | 894 | 538 |
| Lodging: Residential | 418 | 805 | 638 | 571 | 894 | 538 |
| Multi-Family (Common Areas) | 769 | 1,482 | 1,176 | 1,052 | 1,647 | 991 |
| Museum/Library | 469 | 905 | 718 | 642 | 1,005 | 605 |
| Nursing Homes | 630 | 1,213 | 963 | 861 | 1,348 | 811 |
| Office: General/Retail | 469 | 905 | 718 | 642 | 1,005 | 605 |
| Office: Medical/Banks | 469 | 905 | 718 | 642 | 1,005 | 605 |
| Parking Garages & Lots | 517 | 997 | 791 | 707 | 1,107 | 666 |
| Penitentiary | 602 | 1,160 | 920 | 823 | 1,289 | 775 |
| Police/Fire Stations (24 Hr) | 769 | 1,482 | 1,176 | 1,052 | 1,647 | 991 |
| Post Office/Town Hall/Court House | 469 | 905 | 718 | 642 | 1,005 | 605 |
| Religious Buildings/Church | 332 | 640 | 508 | 454 | 711 | 428 |
| Retail | 493 | 950 | 754 | 674 | 1,055 | 635 |
| Schools/University | 350 | 674 | 535 | 478 | 749 | 451 |
| Warehouses (Not Refrigerated) | 382 | 735 | 583 | 522 | 817 | 492 |
| Warehouses (Refrigerated) | 382 | 735 | 583 | 522 | 817 | 492 |
| Waste Water Treatment Plant | 690 | 1,330 | 1,055 | 944 | 1,478 | 889 |

### Measure Life

15 years

Capped based on the requirements of the Pennsylvania Technical Reference Manual (June 2010). This value is less than that used by other jurisdictions for insulation.**[[166]](#footnote-166)**

# Appendices

## Appendix A: Measure Lives

|  |  |  |
| --- | --- | --- |
| **Measure Lives Used in Cost-Effectiveness Screening**  **February 2008[[167]](#footnote-167)** | | |
| **Program/Measure**  \*For the purpose of calculating the total Resource Cost Test for Act 129, measure cannot claim savings for more than fifteen years. | | **Measure**  **Life** |
| RESIDENTIAL PROGRAMS | |  |
| *ENERGY STAR Appliances* | |  |
| ENERGY STAR Refrigerator post-2001 | | 13 |
| ENERGY STAR Refrigerator 2001 | | 13 |
| ENERGY STAR Dishwasher | | 11 |
| ENERGY STAR Clothes Washer | | 11 |
| ENERGY STAR Dehumidifier | | 12 |
| ENERGY STAR Room Air Conditioners | | 10 |
|  | |  |
| *ENERGY STAR Lighting* | |  |
| Compact Fluorescent Light Bulb | | 6.4 |
| Recessed Can Fluorescent Fixture | | 20\* |
| Torchieres (Residential) | | 10 |
| Fixtures Other | | 20\* |
|  | |  |
| *ENERGY STAR Windows* | |  |
| WINDOW -heat pump | | 20\* |
| WINDOW -gas heat with central air conditioning | | 20\* |
| WIN-oil heat/CAC | | 20 |
| WIN-oil No CAC | | 20 |
| WINDOW – electric heat without central air conditioning | | 20\* |
| WINDOW – electric heat with central air conditioning | | 20\* |
|  | |  |
| *Refrigerator/Freezer Retirement* | |  |
| Refrigerator/Freezer retirement | | 8 |
|  | |  |
| *Residential New Construction* | |  |
| Single Family - gas heat with central air conditioner | | 20\* |
| Single Family - oil heat with central air conditioner | | 20\* |
| Single Family - all electric | | 20\* |
| Multiple Single Family (Townhouse) – gas heat with central air conditioner | | 20\* |
| Multiple Single Family (Townhouse) – oil heat with central air conditioner | | 20\* |
| Multiple Single Family (Townhouse) - all electric | | 20\* |
| Multi-Family – gas heat with central air conditioner | | 20\* |
| Multi-Family - oil heat with central air conditioner | | 20\* |
| Multi-Family - all electric | | 20\* |
| ENERGY STAR Clothes Washer | | 11 |
| Recessed Can Fluorescent Fixture | | 20\* |
| Fixtures Other | | 20\* |
| Efficient Ventilation Fans with Timer | | 10 |
|  | |  |
| *Residential Electric HVAC* | |  |
| Central Air Conditioner SEER 13 | | 14 |
| Central Air Conditioner SEER 14 | | 14 |
| Air Source Heat Pump SEER 13 | | 12 |
| Air Source Heat Pump SEER 14 | | 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 | | 14 |
| 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\* |
| Central Air Conditioner SEER 15 | | 14 |
| Air Source Heat Pump SEER 15 | | 12 |
|  | |  |
| *Home Performance with ENERGY STAR* | |  |
| Blue Line Innovations – PowerCost MonitorTM | | 5 |
|  | |  |
| NON-RESIDENTIAL PROGRAMS | |  |
| *C&I Construction* | |  |
| Commercial Lighting (Non-SSL) — New | | 15 |
| Commercial Lighting (Non-SSL) — Remodel/Replacement | | 15 |
| Commercial Lighting (SSL – 25,000 hours) — New | | 6 |
| Commercial Lighting (SSL – 30,000 hours) — New | | 7 |
| Commercial Lighting (SSL – 35,000 hours) — New | | 8 |
| Commercial Lighting (SSL – 40,000 hours) — New | | 10 |
| Commercial Lighting (SSL – 45,000 hours) — New | | 11 |
| Commercial Lighting (SSL – 50,000 hours) — New | | 12 |
| Commercial Lighting (SSL – 55,000 hours) — New | | 13 |
| Commercial Lighting (SSL – 60,000 hours) — New | | 14 |
| Commercial Lighting (SSL – ≥60,000 hours) — New | | 15\* |
| Commercial Lighting (SSL – 25,000 hours) — Remodel/Replacement | | 6 |
| Commercial Lighting (SSL – 30,000 hours) — Remodel/Replacement | | 7 |
| Commercial Lighting (SSL – 35,000 hours) — Remodel/Replacement | | 8 |
| Commercial Lighting (SSL – 40,000 hours) — Remodel/Replacement | | 10 |
| Commercial Lighting (SSL – 45,000 hours) — Remodel/Replacement | | 11 |
| Commercial Lighting (SSL – 50,000 hours) — Remodel/Replacement | | 12 |
| Commercial Lighting (SSL – 55,000 hours) — Remodel/Replacement | | 13 |
| Commercial Lighting (SSL – 60,000 hours) — Remodel/Replacement | | 14 |
| Commercial Lighting (SSL – ≥60,000 hours) — Remodel/Replacement | | 15\* |
| Commercial Custom — New | | 18\* |
| Commercial Chiller Optimization | | 18\* |
| Commercial Unitary HVAC — New - Tier 1 | | 15 |
| Commercial Unitary HVAC — Replacement - Tier 1 | | 15 |
| Commercial Unitary HVAC — New - Tier 2 | | 15 |
| Commercial Unitary HVAC — Replacement Tier 2 | | 15 |
| Commercial Chillers — New | | 20\* |
| Commercial Chillers — Replacement | | 20\* |
| Commercial Small Motors (1-10 horsepower) — New or Replacement | | 20\* |
| Commercial Medium Motors (11-75 horsepower) — New or Replacement | | 20\* |
| Commercial Large Motors (76-200 horsepower) — New or Replacement | | 20\* |
| Commercial Variable Speed Drive — New | | 15 |
| Commercial Variable Speed Drive — Retrofit | | 15 |
| Commercial Comprehensive New Construction Design | | 18\* |
| Commercial Custom — Replacement | | 18\* |
| Industrial Lighting — New | | 15 |
| Industrial Lighting — Remodel/Replacement | | 15 |
| Industrial Unitary HVAC — New - Tier 1 | | 15 |
| Industrial Unitary HVAC — Replacement - Tier 1 | | 15 |
| Industrial Unitary HVAC — New - Tier 2 | | 15 |
| Industrial Unitary HVAC — Replacement Tier 2 | | 15 |
| Industrial Chillers — New | | 20\* |
| Industrial Chillers — Replacement | | 20\* |
| Industrial Small Motors (1-10 horsepower) — New or Replacement | | 20\* |
| Industrial Medium Motors (11-75 horsepower) — New or Replacement | | 20\* |
| Industrial Large Motors (76-200 horsepower) — New or Replacement | | 20\* |
| Industrial Variable Speed Drive — New | | 15 |
| Industrial Variable Speed Drive — Retrofit | | 15 |
| Industrial Custom — Non-Process | | 18\* |
| Industrial Custom — Process | | 10 |
|  | |  |
| *Building O&M* | |  |
| O&M savings | | 3 |

## Appendix B: Relationship between Program Savings and Evaluation Savings

There is a distinction between activities required to conduct measurement and verification of savings at the program participant level and the activities conducted by program evaluators and the SWE to validate those savings. However, the underlying standard for the measurement of the savings for both of these activities is the measurement and verification protocols approved by the PA PUC. These protocols are of three different types:

1. TRM specified protocols for standard measures, originally approved in the May 2009 order adopting the TRM, and updated annually thereafter
2. Interim Protocols for standard measures, reviewed and recommended by the SWE and approved for use by the Director of the CEEP, subject to modification and incorporation into succeeding TRM versions to be approved by the PA PUC
3. Custom Measure Protocols reviewed and recommended by the SWE and approved for use by the Director of the CEEP

These protocols are to be uniform and used to measure and calculate savings throughout Pennsylvania. The TRM protocols are comprised of Deemed Measures and Partially Deemed Measures. Deemed Measures specify saving per energy efficiency measure and require verifying that the measure has been installed, or in cases where that is not feasible, that the measure has been purchased by a utility customer. Partially Deemed Measures require both verification of installation and the measurement or quantification of open variables in the protocol.

Stipulated and deemed numbers are valid relative to a particular classification of “standard” measures. In the determination of these values, a normal distribution of values should have been incorporated. Therefore, during the measurement and verification process, participant savings measures cannot be arbitrarily treated as “custom measures” if the category allocation is appropriate.

Utility evaluators and the SWE will adjust the savings reported by program staff based on the application of the PA PUC approved protocols to a sample population and realization rates will be based on the application of these same standards. To the extent that the protocols or deemed values included in these protocols require modification, the appropriate statewide approval process will be utilized. These changes will be prospective.

## Appendix C: Lighting Audit and Design Tool

The Lighting Audit and Design Tool is located on the Public Utility Commission’s website at:  <http://www.puc.state.pa.us/electric/Act129/TRM.aspx>.

## Appendix D: Motor & VFD Audit and Design Tool

The Motor and VFD Inventory Form is located on the Public Utility Commission’s website at:  <http://www.puc.state.pa.us/electric/Act129/TRM.aspx>.

1. Note: Information in the TRM specifically relating to the AEPS Act is shaded in gray. [↑](#footnote-ref-1)
2. Values for lighting, air conditioners, chillers and motors are based on measured usage from a large sample of participants from 1995 through 1999. Values for heat pumps reflect metered usage from 1996 through 1998 and variable speed drives reflect metered usage from 1995 through 1998. [↑](#footnote-ref-2)
3. Monday through Friday [↑](#footnote-ref-3)
4. Weekends and Holidays [↑](#footnote-ref-4)
5. Note: Programs where measures are replaced before the end of their useful life are considered Custom Measures. In these programs, savings are measured from the efficient unit versus the replaced unit for the existing life of the unit, then from the efficiency unit versus a new standard unit for the remaining life of the efficient measure. [↑](#footnote-ref-5)
6. GSHP desuperheaters are generally small, auxiliary heat exchangers that uses superheated gases from the GSHP’s compressor to heat water. This hot water then circulates through a pipe to the home’s storage water heater tank.  [↑](#footnote-ref-6)
7. Natural Resources Canada Report.pdf [↑](#footnote-ref-7)
8. EPRI Electric Clothes Dryer Report.pdf [↑](#footnote-ref-8)
9. Natural Living Guide.pdf [↑](#footnote-ref-9)
10. Energy Star Clothes Washer Calculator Assumptions.pdf [↑](#footnote-ref-10)
11. DEER EUL values, updated October 10, 2008 [↑](#footnote-ref-11)
12. Deemed Savings Estimates for Legacy Air Conditioning and Water Heating Direct Load Control Programs in PJM Region. The report can be accessed online: <http://www.pjm.com/~/media/committees-groups/working-groups/lrwg/20070301/20070301-pjm-deemed-savings-report.ashx> [↑](#footnote-ref-12)
13. The average is over all 82 water heaters and over all summer, spring/fall, or winter days. The load shapes are taken from the fourth columns, labeled “Mean”, in tables 14,15, and 16 in pages 5-31 and 5-32 [↑](#footnote-ref-13)
14. The 5th column, labeled “Mean” of Table 18 in page 5-34 is used to derive an adjustment factor that scales average summer usage to summer *weekday* usage. The conversion factor is 0.925844. A number smaller than one indicates that for residential homes, the hot water usage from noon to 8 PM is slightly higher is the weekends than on weekdays. [↑](#footnote-ref-14)
15. DEER values, updated October 10, 2008

    http://www.deeresources.com/deer0911planning/downloads/EUL\_Summary\_10-1-08.xls [↑](#footnote-ref-15)
16. Deemed Savings Estimates for Legacy Air Conditioning and Water Heating Direct Load Control Programs in PJM Region. The report can be accessed online: <http://www.pjm.com/~/media/committees-groups/working-groups/lrwg/20070301/20070301-pjm-deemed-savings-report.ashx> [↑](#footnote-ref-16)
17. The average is over all 82 water heaters and over all summer, spring/fall, or winter days. The load shapes are taken from the fourth columns, labeled “Mean”, in tables 14,15, and 16 in pages 5-31 and 5-32 [↑](#footnote-ref-17)
18. The 5th column, labeled “Mean” of Table 18 in page 5-34 is used to derive an adjustment factor that scales average summer usage to summer weekday usage. The conversion factor is 0.925844. A number smaller than one indicates that for residential homes, the hot water usage from noon to 8 PM is slightly higher is the weekends than on weekdays [↑](#footnote-ref-18)
19. Based on TMY2 weather files from DOE2.com for Erie, Harrisburg, Pittsburgh, Wilkes-Barre, And Williamsport, the average annual wetbulb temperature is 45  1.3 °F. The wetbulb temperature in garages or attics, where the heat pumps are likely to be installed, are likely to be two or three degrees higher, but for simplicity, 45 °F is assumed to be the annual average wetbulb temperature. [↑](#footnote-ref-19)
20. The performance curve is adapted from Table 1 in http://wescorhvac.com/HPWH%20design%20details.htm#Single-stage%20HPWHs

    The performance curve depends on other factors, such as hot water set point. Our adjustment factor of 0.84 is a first order approximation based on the information available in literature. [↑](#footnote-ref-20)
21. DEER values, updated October 10, 2008  
    http://www.deeresources.com/deer0911planning/downloads/EUL\_Summary\_10-1-08.xls [↑](#footnote-ref-21)
22. Four 23-W CFLs are sent out. We assume that one replaces a 100W lamp while the remaining CFLs replace 60W lamps. [↑](#footnote-ref-22)
23. The ISR calculation for aerators is averaged from observations of a binary variable that takes on value 1 if the aerator is installed and the home has electric water heating, 0 otherwise. [↑](#footnote-ref-23)
24. The savings for night lights are 22.07 kWh in the PA Interim TRM, p. 24. However, these savings are the product of 26.3 kWh and an ISR of 0.84. Since the ISR for the conservation kit items are determined by data gathering during the impact evaluation, the savings for night lights herein are cast as 26.3 × ISR, with ISR as a program-specific empirically determined variable. [↑](#footnote-ref-24)
25. Energy Star Appliances, Energy Star Lighting, and several Residential Electric HVAC measures lives updated February 2008. U.S. Environmental Protection Agency and U.S. Department of Energy, Energy Star. <http://www.energystar.gov/>. [↑](#footnote-ref-25)
26. Deemed Savings Estimates for Legacy Air Conditioning and Water Heating Direct Load Control Programs in PJM Region. The report can be accessed online: <http://www.pjm.com/~/media/committees-groups/working-groups/lrwg/20070301/20070301-pjm-deemed-savings-report.ashx> The summer load shapes are taken from tables 14,15, and 16 in pages 5-31 and 5-32, and table 18 in page 5-34 is used to derive an adjustment factor that scales average summer usage to summer weekday usage. The factor is constructed as follows: 1) Obtain the average kW, as monitored for 82 water heaters in PJM territory, for each hour of the typical day summer, winter, and spring/fall days. Weight the results (91 summer days, 91 winter days, 183 spring/fall days) to obtain annual energy usage. 2) Obtain the average kW during noon to 8 PM on summer days from the same data. 3) The average noon to 8 PM demand is converted to average *weekday* noon to 8 PM demand through comparison of weekday and weekend monitored loads from the same PJM study. 4) The ratio of the average weekday noon to 8 PM energy demand to the annual energy usage obtained in step 1. The resulting number, 0.00009172, is the *EnergyToDemandFactor.* [↑](#footnote-ref-26)
27. The Energy Policy Act of 1992 established the maximum flow rate for showerheads at 2.5 gallons per minute (GPM). [↑](#footnote-ref-27)
28. Pennsylvania, Census of Population, 2000. [↑](#footnote-ref-28)
29. The most commonly quoted value for the amount of hot water used for showering per person per day is 11.6 GPD. See the U.S. Environmental Protection Agency’s “water sense” documents: http://www.epa.gov/watersense/docs/home\_suppstat508.pdf [↑](#footnote-ref-29)
30. Estimate based on review of a number of studies:

    Pacific Northwest Laboratory; "Energy Savings from Energy-Efficient Showerheads: REMP Case Study Results, Proposed Evaluation Algorithm, and Program Design Implications" http://www.osti.gov/bridge/purl.cover.jsp;jsessionid=80456EF00AAB94DB204E848BAE65F199?purl=/10185385-CEkZMk/native/

    East Bay Municipal Utility District; "Water Conservation Market Penetration Study" http://www.ebmud.com/sites/default/files/pdfs/market\_penetration\_study\_0.pdf [↑](#footnote-ref-30)
31. Based upon a consensus achieved at Residential Measure Protocols for TRM Teleconference held on June 2, 2010. [↑](#footnote-ref-31)
32. A good approximation of annual average water main temperature is the average annual ambient air temperature. Average water main temperature = 55° F based on:

    http://lwf.ncdc.noaa.gov/img/documentlibrary/clim81supp3/tempnormal\_hires.jpg [↑](#footnote-ref-32)
33. Assumes an electric water heater that meets the current federal standard (0.90 EF). [↑](#footnote-ref-33)
34. Deemed Savings Estimates for Legacy Air Conditioning and Water Heating Direct Load Control Programs in PJM Region. The report can be accessed online: http://www.pjm.com/~/media/committees-groups/working-groups/lrwg/20070301/20070301-pjm-deemed-savings-report.ashx [↑](#footnote-ref-34)
35. Op. cit. [↑](#footnote-ref-35)
36. Efficiency Vermont, Technical Reference User Manual: Measure Savings Algorithms and Cost Assumptions, TRM User Manual No. 2008-53, 07/18/08. [↑](#footnote-ref-36)
37. The Room AC calculator can be found here <http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/CalculatorConsumerRoomAC.xls> and the Central AC calculator is here: <http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls> . [↑](#footnote-ref-37)
38. Residential Appliance Recycling Program Year 1 Evaluation Report – Final Report, prepared for Commonwealth Edison by Itron (under contract to Navigant Consulting), November 2009. [↑](#footnote-ref-38)
39. We have taken the average energy factor for all solar water heaters with collector areas of 50 ft2 or smaller from http://www.solar-rating.org/ratings/ratings.htm. 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. [↑](#footnote-ref-39)
40. Deemed Savings Estimates for Legacy Air Conditioning and Water Heating Direct Load Control Programs in PJM Region. The report can be accessed online: http://www.pjm.com/~/media/committees-groups/working-groups/lrwg/20070301/20070301-pjm-deemed-savings-report.ashx [↑](#footnote-ref-40)
41. The average is over all 82 water heaters and over all summer, spring/fall, or winter days. The load shapes are taken from the fourth columns, labeled “Mean”, in tables 14,15, and 16 in pages 5-31 and 5-32 [↑](#footnote-ref-41)
42. On the other hand, the band would have to expanded to at least 12 hours to capture all 100 hours. [↑](#footnote-ref-42)
43. The 5th column, labeled “Mean” of Table 18 in page 5-34 is used to derive an adjustment factor that scales average summer usage to summer weekday usage. The conversion factor is 0.925844. A number smaller than one indicates that for residential homes, the hot water usage from noon to 8 PM is slightly higher is the weekends than on weekdays. [↑](#footnote-ref-43)
44. http://www.energystar.gov/index.cfm?c=solar\_wheat.pr\_savings\_benefits [↑](#footnote-ref-44)
45. 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. [↑](#footnote-ref-45)
46. Deemed Savings Estimates for Legacy Air Conditioning and Water Heating Direct Load Control Programs in PJM Region. The report can be accessed online: <http://www.pjm.com/~/media/committees-groups/working-groups/lrwg/20070301/20070301-pjm-deemed-savings-report.ashx> [↑](#footnote-ref-46)
47. Op. cit. [↑](#footnote-ref-47)
48. Efficiency Vermont, Technical Reference User Manual: Measure Savings Algorithms and Cost Assumptions, TRM User Manual No. 2008-53, 07/18/08. [↑](#footnote-ref-48)
49. *Whole House Fan, Technology Fact Sheet*, (March 1999), Department of Energy Building Technologies Program, DOE/GO-10099-745, accessed October 2010 <http://www.energysavers.gov/your_home/space_heating_cooling/related.cfm/mytopic=12357> [↑](#footnote-ref-49)
50. Architectural Energy Corporation, REM/Rate v12.85. [↑](#footnote-ref-50)
51. EIA (2005), Table HC1.1.3: “Housing Unit Characteristics by Average Floorspace”, <http://www.eia.doe.gov/emeu/recs/recs2005/hc2005_tables/hcfloorspace/pdf/tablehc1.1.3.pdf> Used Single Family Detached “Heated” value for Mid-Atlantic region as representative of the living space cooled by a 10 SEER Split A/C unit. The floorspace recorded for “Cooling” is likely to be affected by Room A/C use. [↑](#footnote-ref-51)
52. *DEER* *EUL Summary*, Database for Energy Efficient Resources, accessed October 2010, <http://www.deeresources.com/deer0911planning/downloads/EUL_Summary_10-1-08.xls> [↑](#footnote-ref-52)
53. The measure energy efficiency performance is based on ENERGY STAR minimum specification requirements as specified in ARHI and CEE directory for ductless mini-split heat pumps. Ductless heat pumps fit these criteria and can easily exceed SEER levels of 16 or greater. [↑](#footnote-ref-53)
54. DEER values, updated October 10, 2008. Various sources range from 12 to 20 years, DEER represented a reasonable mid-range. http://www.deeresources.com/deer0911planning/downloads/EUL\_Summary\_10-1-08.xls [↑](#footnote-ref-54)
55. Deemed Savings Estimates for Legacy Air Conditioning and Water Heating Direct Load Control Programs in PJM Region. The report can be accessed online: http://www.pjm.com/~/media/committees-groups/working-groups/lrwg/20070301/20070301-pjm-deemed-savings-report.ashx [↑](#footnote-ref-55)
56. The average is over all 82 water heaters and over all summer, spring/fall, or winter days. The load shapes are taken from the fourth columns, labeled “Mean”, in tables 14,15, and 16 in pages 5-31 and 5-32 [↑](#footnote-ref-56)
57. The 5th column, labeled “Mean” of Table 18 in page 5-34 is used to derive an adjustment factor that scales average summer usage to summer weekday usage. The conversion factor is 0.925844. A number smaller than one indicates that for residential homes, the hot water usage from noon to 8 PM is slightly higher is the weekends than on weekdays. [↑](#footnote-ref-57)
58. DEER values, updated October 10, 2008: http://www.deeresources.com/deer0911planning/downloads/EUL\_Summary\_10-1-08.xls [↑](#footnote-ref-58)
59. Deemed Savings Estimates for Legacy Air Conditioning and Water Heating Direct Load Control Programs in PJM Region. The report can be accessed online: http://www.pjm.com/~/media/committees-groups/working-groups/lrwg/20070301/20070301-pjm-deemed-savings-report.ashx [↑](#footnote-ref-59)
60. The average is over all 82 water heaters and over all summer, spring/fall, or winter days. The load shapes are taken from the fourth columns, labeled “Mean”, in tables 14,15, and 16 in pages 5-31 and 5-32 [↑](#footnote-ref-60)
61. The 5th column, labeled “Mean” of Table 18 in page 5-34 is used to derive an adjustment factor that scales average summer usage to summer weekday usage. The conversion factor is 0.925844. A number smaller than one indicates that for residential homes, the hot water usage from noon to 8 PM is slightly higher is the weekends than on weekdays. [↑](#footnote-ref-61)
62. Based on TMY2 weather files from DOE2.com for Erie, Harrisburg, Pittsburgh, Wilkes-Barre, And Williamsport, the average annual wetbulb temperature is 45 ± 1.3 °F. The wetbulb temperature in garages or attics, where the heat pumps are likely to be installed, are likely to be two or three degrees higher, but for simplicity, 45 °F is assumed to be the annual average wetbulb temperature. [↑](#footnote-ref-62)
63. The performance curve is adapted from Table 1 in <http://wescorhvac.com/HPWH%20design%20details.htm#Single-stage%20HPWHs>  
    The performance curve depends on other factors, such as hot water set point. Our adjustment factor of 0.84 is a first order approximation based on the information available in literature. [↑](#footnote-ref-63)
64. DEER values, updated October 10, 2008  
    <http://www.deeresources.com/deer0911planning/downloads/EUL_Summary_10-1-08.xls> [↑](#footnote-ref-64)
65. PA 2010 TRM Appendix A: Measure Lives. Note that PA Act 129 savings can be claimed for no more than 15 years. [↑](#footnote-ref-65)
66. “State of Ohio Energy Efficiency Technical Reference Manual,” prepared for the Public Utilities Commission of Ohio by Vermont Energy Investment Corporation. August 6, 2010. [↑](#footnote-ref-66)
67. 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. [↑](#footnote-ref-67)
68. Generally as insulation is added beyond R-30 (10”), the insulation has cleared the joists and the R-value of the insulation above the joists can be added as a series heat transfer rather than a parallel heat transfer condition. Therefore, above R-30 insulation levels, the additional R-value can be added directly to the assembly value of R-30 insulation. [↑](#footnote-ref-68)
69. Used eQuest 6.64 to derive wall assembly R-values. [↑](#footnote-ref-69)
70. Used eQuest 6.64 to derive wall assembly R-values. It is coincidence that adding R-6 to a 2x4 stud wall essentially yields R-9 assembly value even though this was done using a parallel heat transfer calculation. This was due to rounding. The defaults are based on conservative assumptions of wall construction. [↑](#footnote-ref-70)
71. DOE recommendation on ENERGY STAR website for adding wall insulation to existing homes in Zones 5-8. Insulation may be loose fill in stud cavities or board insulation beneath siding. <http://www.energystar.gov/index.cfm?c=home_sealing.hm_improvement_insulation_table> [↑](#footnote-ref-71)
72. From PECO baseline study, average home size = 2323 ft2, average number of room AC units per home = 2.1. Average Room AC capacity = 10,000 BtuH per ENERGY STAR Room AC Calculator, which serves 425 ft2 (average between 400 and 450 ft2 for 10,000 BtuH unit per ENERGY STAR Room AC sizing chart). FRoom,AC = (425 ft2 \* 2.1)/(2323 ft2) = 0.38 [↑](#footnote-ref-72)
73. PA 2010 TRM Table 2-1. [↑](#footnote-ref-73)
74. PA SWE Interim Approved TRM Protocol – Residential Room AC Retirement [↑](#footnote-ref-74)
75. 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> [↑](#footnote-ref-75)
76. Ibid. [↑](#footnote-ref-76)
77. *Massachusetts Statewide Technical Reference Manual for Estimating Savings from Energy Efficiency Measures*, Version 1.0, accessed August 2010 at <http://www.ma-eeac.org/docs/091023-MA-TRMdraft.pdf>. Note that PA Act 129 savings can be claimed for no more than 15 years. [↑](#footnote-ref-77)
78. Mid Atlantic TRM Version 1.0. May 2010. Prepared by Vermont Energy Investment Corporation. Facilitated and managed by Northeast Energy Efficiency Partnerships. [↑](#footnote-ref-78)
79. Mid Atlantic TRM Version 1.0. May 2010. Prepared by Vermont Energy Investment Corporation. Facilitated and managed by Northeast Energy Efficiency Partnerships. [↑](#footnote-ref-79)
80. Efficiency Vermont; Technical Reference User Manual (TRM). 2008. TRM User Manual No. 2008-53. Burlignton, VT 05401. July 18, 2008. [↑](#footnote-ref-80)
81. Energy Star Refrigerator Retirement Calculator, accessed 10/15/2011 at http://www.energystar.gov/index.cfm?fuseaction=refrig.calculator [↑](#footnote-ref-81)
82. SWE received appliance collection databases from Allegheny, PPL, Duquesne and FirstEnergy. SWE did not receive databases from PECO. [↑](#footnote-ref-82)
83. See Table 1. [↑](#footnote-ref-83)
84. Average savings of Energy Star units from EnergyStar Residential Refrigerator Savings Calculator. Accessed June 18, 2010 at http://www.energystar.gov/ia/business/bulk\_purchasing/bpsavings\_calc/Consumer\_Residential\_Refrig\_Sav\_Calc.xls [↑](#footnote-ref-84)
85. 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 [↑](#footnote-ref-85)
86. Vermont Energy Investment Corporation (VEIC) for NEEP, *Mid Atlantic TRM* Version 1.1. October 2010. Pg.27. [↑](#footnote-ref-86)
87. Energy Star Refrigerator Retirement Calculator, accessed 10/15/2011 at http://www.energystar.gov/index.cfm?fuseaction=refrig.calculator [↑](#footnote-ref-87)
88. Savings value derived from the JACO Appliance Collection Databases received from all EDCs (Allegheny, PPL, PECO, Duquesne and FirstEnergy). [↑](#footnote-ref-88)
89. Applicable to buildings completed from April 2003 to present. [↑](#footnote-ref-89)
90. Applicable to buildings completed from April 2003 to present. Reflects MEC 95. [↑](#footnote-ref-90)
91. Single and multiple family as noted. [↑](#footnote-ref-91)
92. Applicable to buildings completed from January 2008 to present. [↑](#footnote-ref-92)
93. Single and multiple family as noted. [↑](#footnote-ref-93)
94. Energy Information Administration. *Residential Energy Consumption Survey*. 2005. <http://www.eia.doe.gov/emeu/recs/recs2005/hc2005_tables/detailed_tables2005.html> [↑](#footnote-ref-94)
95. A new standard for BESTEST is currently being developed. The existing 1995 standard can be found at <http://www.nrel.gov/docs/legosti/fy96/7332a.pdf> . [↑](#footnote-ref-95)
96. A listing of the approved software available at <http://www.waptac.org/si.asp?id=736> . [↑](#footnote-ref-96)
97. A listing of the approved software available at <http://resnet.us> . [↑](#footnote-ref-97)
98. M&V Evaluation, Home Performance with Energy Star Program, Final Report, Prepared for the New York State Energy Research and Development Authority, Nexant, June 2005. [↑](#footnote-ref-98)
99. This baseline assumption is made because there is no federal standard that specifies minimum TV efficiencies. ENERGY STAR Version 3.0 predates Version 4.1 standards. [↑](#footnote-ref-99)
100. 16:9 aspect ratio is assumed for TV viewable screen size (to convert from diagonal dimensions to viewable screen area). *ENERGY STAR Program Requirements for Televisions, Partner Commitments Versions 4.1 and 5.1*, accessed October 2010, <http://www.energystar.gov/ia/partners/product_specs/program_reqs/tv_vcr_prog_req.pdf> [↑](#footnote-ref-100)
101. *TVs Key ENERGY STAR Product Criteria*, accessed October 2010, <http://www.energystar.gov/index.cfm?c=tv_vcr.pr_crit_tv_vcr> [↑](#footnote-ref-101)
102. Ibid. [↑](#footnote-ref-102)
103. Calculations are based on TV dimensions at the midpoint of the specified range. For example, a diagonal of 25” was used to compute values for the range of 20”-30”. 15” was used to compute the value for sizes < 20”. [↑](#footnote-ref-103)
104. Based on ENERGY STAR Version 3.0 requirements, from *ENERGY STAR Program Requirements for Televisions, Partner Commitments*, accessed October 2010, <http://www.energystar.gov/ia/partners/prod_development/revisions/downloads/tv_vcr/FinalV3.0_TV%20Program%20Requirements.pdf> [↑](#footnote-ref-104)
105. *ENERGY STAR Program Requirements for Televisions, Partner Commitments Versions 4.1 and 5.1*, accessed October 2010, <http://www.energystar.gov/ia/partners/product_specs/program_reqs/tv_vcr_prog_req.pdf> [↑](#footnote-ref-105)
106. Ibid. [↑](#footnote-ref-106)
107. Calculations are based on TV dimensions at the midpoint of the specified range. For example, a diagonal of 25” was used to compute values for the range of 20”-30”. 15” was used to compute the value for sizes < 20”. [↑](#footnote-ref-107)
108. Ibid. [↑](#footnote-ref-108)
109. Deemed Savings Technical Assumptions, Program: ENERGY STAR Retailer Incentive Pilot Program, accessed October 2010, <http://www.xcelenergy.com/SiteCollectionDocuments/docs/ES-Retailer-Incentive-60-day-Tech-Assumptions.pdf> [↑](#footnote-ref-109)
110. ENERGY STAR website for Commercial LED Lighting:

     <http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=LTG> [↑](#footnote-ref-110)
111. “ENERGY STAR® Program Requirements for Integral LED Lamps

     Partner Commitments.” *LED Lamp Specification V1.1*, modified 03/22/10. Accessed from the ENERGY STAR website on September 28, 2010. <http://www.energystar.gov/ia/partners/manuf_res/downloads/IntegralLampsFINAL.pdf> [↑](#footnote-ref-111)
112. “ENERGY STAR® Program Requirements for Solid State Lighting Luminaires” *Eligibility Criteria V1.1*, Final 12/19/08. Accessed from the ENERGY STAR website on September 28, 2010. <http://www.energystar.gov/ia/partners/product_specs/program_reqs/SSL_prog_req_V1.1.pdf> [↑](#footnote-ref-112)
113. ENERGY STAR Qualified LED Lighting list <http://www.energystar.gov/index.cfm?fuseaction=ssl.display_products_res_html> [↑](#footnote-ref-113)
114. DesignLights Consortium (DLC) Technical Requirements Table v1.4. Accessed from the DLC website on September 24, 2010. (File is embedded at the end of this document) <http://www.designlights.org/solidstate.manufacturer.requirements.php> [↑](#footnote-ref-114)
115. Ibid. [↑](#footnote-ref-115)
116. DesignLights Consortium (DLC) Qualified Product List. <http://www.designlights.org/solidstate.about.QualifiedProductsList_Publicv2.php>

     “This Qualified Products List (QPL) of LED luminaires signifies that the proper documentation has been submitted to DesignLights (DLC) and the luminaire has met the criteria noted in the technical requirements table shown on the DesignLights website (www.designlights.org). This list is exclusively used and owned by DesignLights Members. Manufacturers, vendors and other non DesignLights members may use the QPL as displayed herein subject to the DLC Terms of Use, and are prohibited from tampering with any portion or all of its contents. For information on becoming a member please go to DesignLights.org.” [↑](#footnote-ref-116)
117. The Locator is only 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. [↑](#footnote-ref-117)
118. This value was agreed upon by the Technical Working Group convened to discuss updates to the TRM. This value is subject to adjustment for the 2012 Update based on implementation feedback during PY2 and PY3. [↑](#footnote-ref-118)
119. CenterPoint Energy Program Manual v4.0 [↑](#footnote-ref-119)
120. EDC’s have the option to provide additional data in support of different numbers of lighting hours of use sub-groups on a case by case basis. [↑](#footnote-ref-120)
121. ASHRAE 90.1-2007, “Table 9.5.1 Lighting Power Densities Using the Building Area Method.” [↑](#footnote-ref-121)
122. In cases where both a common space type and a building specific type are listed, the building specific space type shall apply. [↑](#footnote-ref-122)
123. ASHRAE 90.1-2007, “Table 9.6.1 Lighting Power Densities Using the Space-by-Space Method.” [↑](#footnote-ref-123)
124. In cases where both a common space type and a building specific type are listed, the building specific space type shall apply. [↑](#footnote-ref-124)
125. Average of CF in NJ Clean Energy Program Protocols and 1.0 for CFs above 65% in NJ Protocol. Compromise based on PECo proposal to account for potential selection of high use circuits for retrofit. Subject to revision based on detailed measurement or additional research in subsequent TRM Updates. [↑](#footnote-ref-125)
126. Average of NJ Clean Energy from JCP&L data and 2004-2005 DEER update study (December 2005). [↑](#footnote-ref-126)
127. To be used only for lights illuminated on a continuous basis. [↑](#footnote-ref-127)
128. To be used only when no other category is applicable. Hours of operation must be documented by building facility staff interviews or logging hours of use. The SWE reserves the right to require logging hours of use groups for evaluation purposes. [↑](#footnote-ref-128)
129. Subject to verification by EDC Evaluation or SWE [↑](#footnote-ref-129)
130. This reference cannot be validated and is rooted in the NJ Clean Energy Program Protocols to Measure Resource Savings dated 12/23/2004 [↑](#footnote-ref-130)
131. Subject to verification by EDC Evaluation or SWE [↑](#footnote-ref-131)
132. Source: PECO Comments on the PA TRM, received March 30, 2009. [↑](#footnote-ref-132)
133. Default Value can be used by EDC but is subject to metering and adjustment by evaluators or SWE [↑](#footnote-ref-133)
134. Default Value can be used by EDC but is subject to metering and adjustment by evaluators or SWE [↑](#footnote-ref-134)
135. Need to confirm source through TWG [↑](#footnote-ref-135)
136. http://www.nema.org/stds/complimentary-docs/upload/MG1premium.pdf [↑](#footnote-ref-136)
137. http://www.nema.org/stds/complimentary-docs/upload/MG1premium.pdf [↑](#footnote-ref-137)
138. Operating hours subject to adjustment with data provided by EDCs and accepted by SWE [↑](#footnote-ref-138)
139. http://www.energystar.gov/ia/business/bulk\_purchasing/bpsavings\_calc/Calc\_CAC.xls [↑](#footnote-ref-139)
140. Currently, the protocol is modeled against a constant volume system. Therefore, using a baseline system that is not a constant volume system is an inappropriate use of this protocol. Additional models are in development by the TWG in order to accommodate additional baseline systems, including vortex dampers and other non-constant volume systems that still benefit from VFD applications, to be included in a future update of the TRM. [↑](#footnote-ref-140)
141. Default Value can be used by EDC but is subject to metering and adjustment by evaluators or SWE [↑](#footnote-ref-141)
142. Default Value can be used by EDC but is subject to metering and adjustment by evaluators or SWE [↑](#footnote-ref-142)
143. Need to confirm source through TWG [↑](#footnote-ref-143)
144. The basis for these factors has not been determined or independently verified. [↑](#footnote-ref-144)
145. Need to confirm source through TWG [↑](#footnote-ref-145)
146. Baseline values from IECC 2009, after Jan 1, 2010 or Jan 23, 2010 as applicable. [↑](#footnote-ref-146)
147. US Department of Energy. Energy Star Calculator and Bin Analysis Models [↑](#footnote-ref-147)
148. US Department of Energy. Energy Star Calculator and Bin Analysis Models [↑](#footnote-ref-148)
149. Table shows the efficiency rating to be used in the savings estimation algorithms. See IECC 2009 for complete Full Load and IPLV minimum efficiency requirements for each category. [↑](#footnote-ref-149)
150. Use Path A when chiller will be running primarily at Full load. [↑](#footnote-ref-150)
151. Use Path B when chiller will be running primarily at Part load. [↑](#footnote-ref-151)
152. US Department of Energy. Energy Star Calculator and Bin Analysis Models [↑](#footnote-ref-152)
153. Deru, M., et al., (2003), *Analysis of NREL Cold-Drink Vending Machines for Energy Savings*, National Renewable Energy Laboratory, NREL/TP-550-34008, <http://www.nrel.gov/docs/fy03osti/34008.pdf> [↑](#footnote-ref-153)
154. Ritter, J., Hugghins, J., (2000), *Vending Machine Energy Consumption and VendingMiser Evaluation*, Energy Systems Laboratory, Texas A&M University System, <http://repository.tamu.edu/bitstream/handle/1969.1/2006/ESL-TR-00-11-01.pdf;jsessionid=6E215C09FB80BC5D2593AC81E627DA97?sequence=1> [↑](#footnote-ref-154)
155. *State of Ohio Energy Efficiency Technical Reference Manual*, *Including Predetermined Savings Values and Protocols for Determining Energy and Demand Savings*, August 6, 2010. Prepared for the Public Utilities Commission of Ohio by Vermont Energy Investment Corporation [↑](#footnote-ref-155)
156. *Vending Machine Energy Savings*, Michigan Energy Office Case Study 05-0042, <http://www.michigan.gov/documents/CIS_EO_Vending_Machine_05-0042_155715_7.pdf> [↑](#footnote-ref-156)
157. ENERGY STAR Calculator, Assumptions for Vending Machines, accessed 8/2010 <http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_Vend_MachBulk.xls> [↑](#footnote-ref-157)
158. *DEER* *EUL Summary*, Database for Energy Efficient Resources, accessed 8/2010, <http://www.deeresources.com/deer0911planning/downloads/EUL_Summary_10-1-08.xls> [↑](#footnote-ref-158)
159. It has also been suggested by Deru et al. that beverage machine life will be extended from this measure due to fewer lifetime compressor cycles. [↑](#footnote-ref-159)
160. *Commercial Ice Machines Key Product Criteria*, ENERGY STAR, accessed 8/2010, <http://www.energystar.gov/index.cfm?c=comm_ice_machines.pr_crit_comm_ice_machines> [↑](#footnote-ref-160)
161. *State of Ohio Energy Efficiency Technical Reference Manual*, *Including Predetermined Savings Values and Protocols for Determining Energy and Demand Savings*, August 6, 2010. Prepared for the Public Utilities Commission of Ohio by Vermont Energy Investment Corporation. [↑](#footnote-ref-161)
162. *High Efficiency Specifications for Commercial Ice Machines*, Consortium for Energy Efficiency, accessed 8/2010, <http://www.cee1.org/com/com-kit/files/IceSpecification.pdf> [↑](#footnote-ref-162)
163. Specifications for Tier 1 and Tier 2 ice machines are being revised by CEE, however exact criteria and timeline have not been set as of the time of this report. [↑](#footnote-ref-163)
164. *DEER* *EUL Summary*, Database for Energy Efficient Resources, accessed 8/2010, <http://www.deeresources.com/deer0911planning/downloads/EUL_Summary_10-1-08.xls> [↑](#footnote-ref-164)
165. US Department of Energy. ENERGY STAR Calculator and Bin Analysis Models [↑](#footnote-ref-165)
166. DEER uses 20 years, Northwest Regional Technical Forum uses 45 years [↑](#footnote-ref-166)
167. Energy Star Appliances, Energy Star Lighting, and several Residential Electric HVAC measures lives updated February 2008. U.S. Environmental Protection Agency and U.S. Department of Energy, Energy Star. <http://www.energystar.gov/>. [↑](#footnote-ref-167)