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**Technical Reference Manual**

June 2012

**State of Pennsylvania**

**Act 129**

**Energy Efficiency and Conservation Program**

**&**

**Act 213**

**Alternative Energy Portfolio Standards**

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# Introduction

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[[1]](#footnote-2), 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 savings 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, unless an alternative measurement approach or custom measure protocols is submitted and approved for use.

## 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 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.
* 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 “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.
* 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.

For the Act 129 program, EDCs may, as an alternative to using the energy savings’ values for standard measures contained in the TRM, submit a custom measure protocol with 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 TRM stipulated values, measured values, customer data 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

ΔkWpeak = ΔkW X CF

ΔkWh = ΔkW X EFLH

**Where:**

ΔkW = Demand Savings

ΔkWpeak = Coincident Peak Demand Savings

ΔkWh = Annual Energy Savings

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,defined as the fraction of the total technology demand that is coincident with the utility system summer peak, as defined by Act 129.

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-3). 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. For Act 129 requirements, annual savings may be claimed starting in the month of the in-service date for the measure.

## 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. Any newly approved measure, whether in the TRM or approved as an interim protocol, may be applied retrospectively consistent with the EDC’s approved plan. If any errors are discovered in the TRM or clarifications are required, those corrections or clarifications should be applied to the associated measure calculations for the current program year, if applicable.

## 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 window, 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 | 8:00 a.m. to 8:00 p.m. Mon.-Fri. | 12:00 p.m. to 8:00 p.m. |
| Off-Peak | 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 (C&I) lighting, the energy savings is increased by an amount specified in the algorithm to account for HVAC interaction.

For C&I custom measures, interaction is accounted for in the site-specific analysis where relevant.

### Verified Gross Adjustments

Evaluation activities at a basic level consist of verification of the installation and operation of measures. In many cases, the number of widgets found on-site may differ from the number stated on the application, which represents the number of widgets paid for by the program. When the number of widgets found on-site is less than what is stated on the application, the savings will be adjusted by a realization rate. For example, if an application states 100 widgets but an on-site inspection only finds 85, the realization rate applied is 85% (assuming no other discrepancies). On-site widget counts within 5% of the application numbers can be considered to be within reasonable error without requiring realization rate adjustment.

On the other hand, if the number of widgets found on-site is more than what is stated on the application, the savings will be capped at the application findings. For example, if an application states 100 widgets but an on-site inspection finds 120, the realization rate applied is 100% (assuming no other discrepancies).

## 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 2011 TRC Order.

## 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[[3]](#footnote-4). 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 (TRC) Test for Act 129, measures cannot claim savings for more than 15 years.

In general, avoided cost savings for programs where measures replace units before the end of their useful life are measured from the efficient unit versus the replaced unit for the remaining life of the existing unit, then from the efficient unit versus a new standard unit for the remaining efficient measure’s life. Specific guidance will be provided through the 2011 TRC Order.

## Custom Measures

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 reference cities provide a representative sample of the various climate and utility regions in Pennsylvania. Pennsylvania zip codes are mapped to a reference city and shown in Appendix F: Zip Code Mapping. In general, zip codes were mapped to the closest reference city because the majority of the state resides in ASHRAE climate zone 5. However, Philadelphia and a small area southwest of Harrisburg are assigned to ASHRAE climate zone 4. Therefore, any zip code in ASHRAE climate zone 4 were manually assigned to Philadelphia, regardless of distance.

In addition, several protocols rely on the work and analysis completed in California, where savings values are adjusted for climate. There are sixteen California climate zones. Each of the seven reference cities are mapped to a California climate zone as shown in Table 1-2 based on comparable number of cooling degree days and average dry bulb temperatures. Any weather dependent protocol using California-based models will follow this mapping table.

Table 1‑2: California CZ Mapping Table

|  |  |
| --- | --- |
| **Reference City** | **California Climate Zone** |
| Allentown | 4 |
| Erie | 6 |
| Harrisburg | 8 |
| Philadelphia | 13 |
| Pittsburgh | 4 |
| Scranton | 16 |
| Williamsport | 4 |

## Measure Applicability Based on Sector

Protocols for the residential sector quantify savings for measures typically found in residential areas under residential meters. Likewise, protocols for the C&I sector quantify savings for measures typically found in C&I areas under C&I meters. However, there is some overlap where measure type, usage and the sector do not match.

Protocols in the residential and C&I sections describe measure savings based on the *application* or *usage characteristics* of the measure rather than how the measure is *metered*. For example, if a measure is found in a residential environment but is metered under a commercial meter, the residential sector protocol is used. On the other hand, if a measure is found in a commercial environment but is metered under a residential meter, the commercial sector protocol is used. This is particularly relevant for residential appliances that frequently appear in small commercial spaces (commercial protocol) and residential appliances that are used in residential settings but are under commercial meters (multi-family residences).

## Algorithms for Energy Efficient Measures

The following sections present measure-specific algorithms. Section 2 addresses residential sector measures and Section 3 addresses commercial and industrial sector measures.

Section 4 addresses demand response measures for both residential and commercial and industrial measures.

# Residential Measures

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

## Electric HVAC

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

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

Larger commercial air conditioning and heat pump applications are dealt with in Section 3.6.

### Algorithms

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

This algorithm is used for the installation of new high efficiency A/C and ASHP equipment.

ΔkWh = ΔkWhcool + ΔkWhheat

ΔkWhcool = CAPYcool/1000 X (1/SEERb – 1/SEERe ) X EFLHcool

ΔkWhheat (ASHP Only)= CAPYheat/1000 X (1/HSPFb - 1/HSPFe ) X EFLHheat

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

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

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

ΔkWh = ΔkWhcool + ΔkWhheat

ΔkWhcool = ((CAPYcool/(1000 X SEERm)) X EFLHcool) X MFcool

ΔkWhheat (ASHP Only) = ((CAPYheat/(1000 X HSPFm)) X EFLHheat) X MFheat

ΔkWpeak = ((CAPYcool/(1000 X EERm)) X CF) X MFcool

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

This algorithm is used for measures that improve duct systems by reducing air leakage.

ΔkWh = ΔkWhcool + ΔkWhheat

ΔkWhcool = (CAPYcool/(1000 X SEERe)) X EFLHcool X DuctSF

ΔkWhheat (ASHP Only) = (CAPYheat/(1000 X HSPFe)) X EFLHheat X DuctSF

ΔkWpeak = ((CAPYcool/(1000 X EERe)) X CF) X DuctSF

#### Ground Source Heat Pumps (GSHP)

This algorithm is used for the installation of new GSHP units. For GSHP systems over 65,000 BTUh, see commercial algorithm stated in Section 3.6.1.

ΔkWh = ΔkWhcool + ΔkWhheat

ΔkWhcool = CAPYcool/1000 X (1/SEERb – (1/(EERg X GSER))) X EFLHcool

ΔkWhheat = CAPYheat/1000 X (1/HSPFb – (1/(COPg X GSOP))) X EFLHheat

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

#### GSHP Desuperheater

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

ΔkWh = EDSH

ΔkW = PDSH

#### Furnace High Efficiency Fan

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

ΔkWhheat = HFS

ΔkWhcool = CFS

ΔkWpeak = PDFS

### Definition of Terms

CAPYcool = 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.

CAPYheat = The heating 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.

SEERe = 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.

EERe = 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 = Factor used to determine the SEER of a GSHP based on its EERg.

EFLHcool = Equivalent Full Load Hours of operation during the cooling season for the average unit.

EFLHheat = Equivalent Full Load Hours of operation during the heating season for the average unit.

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

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

MFheat = Maintenance Factor or assumed savings due to completing recommended maintenance on installed heating equipment.

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

CF =Demand Coincidence Factor (See Section 1.4)

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.

HSPFe = 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.[[4]](#footnote-5)

PDSH = Assumed peak-demand savings per desuperheater.

HSF = Assumed heating season savings per furnace high efficiency fan

CFS = Assumed cooling season savings per furnace high efficiency fan

PDFS = Assumed peak-demand savings per furnace high efficiency fan

1000 = Conversion from watts to kilowatts.

Table 2‑1: Residential Electric HVAC - References

| **Component** | **Type** | **Value** | **Sources** |
| --- | --- | --- | --- |
| CAPYcool  CAPYheat | Variable | EDC Data Gathering | AEPS Application; EDC Data Gathering |
| SEER*b* | Fixed | Replace on Burnout: 13 SEER | 1 |
| Variable | Early Retirement: EDC Data Gathering | EDC Data Gathering |
| SEER*e* | Variable | EDC Data Gathering | AEPS Application; EDC Data Gathering |
| SEER*m* | Fixed | 10 | 14 |
| EER*b* | Fixed | Replace on Burnout: 11.3 | 2 |
| Variable | Early Retirement: EDC Data Gathering | EDC Data Gathering |
| EER*e* | Fixed | (11.3/13) X SEERe | 2 |
| EER*g* | Variable | EDC Data Gathering | AEPS Application; EDC’s Data Gathering |
| EERm | Fixed | 8.69 | 15 |
| GSER | Fixed | 1.02 | 3 |
| EFLHcool | Fixed | Allentown Cooling = 784 Hours  Erie Cooling = 482 Hours  Harrisburg Cooling = 929 Hours  Philadelphia Cooling = 1,032 Hours  Pittsburgh Cooling = 737 Hours  Scranton Cooling = 621 Hours  Williamsport Cooling = 659 Hours | 4 |
| EFLHheat | 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 Hours | 4 |
| ESF | Fixed | 2.9% | 5 |
| MFcool | Fixed | 10% | 16 |
| MFheat | Fixed | 10% | 16 |
| DuctSF | Fixed | 18% | 13 |
| CF | Fixed | 70% | 6 |
| DSF | Fixed | 2.9% | 7 |
| HSPF*b* | Fixed | Replace on Burnout: 7.7 | 8 |
| Variable | Early Retirement: EDC Data Gathering | EDC Data Gathering |
| HSPF*e* | 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 |
| HFS | Fixed | 311 kWh | 17 |
| CFS | Fixed | 135 kWh | 18 |
| PDFS | Fixed | 0.114 kW | 19 |

**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. 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.
14. Minimum Federal Standard for new Central Air Conditioners between 1990 and 2006.
15. The same EER to SEER ratio used for SEER 13 units applied to SEER 10 units. EERm = (11.3/13) \* 10.
16. VEIC estimate. Conservatively assumes less savings than for QIV because of the retrofit context.
17. Scott Pigg (Energy Center of Wisconsin), “Electricity Use by New Furnaces: A Wisconsin Field Study”, Technical Report 230-1, October 2003, page 20. The average heating-mode savings of 400 kWh multiplied by the ratio of average heating degree days in PA compared to Madison, WI (5568/7172).
18. Ibid, page 34. The average cooling-mode savings of 88 kWh multiplied by the ratio of average EFLH in PA compared to Madison, WI (749/487).
19. Ibid, page 34. The average kW savings of 0.1625 multiplied by the coincidence factor from Table 2-1.

## 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.[[5]](#footnote-6)

The annual consumption of a standard unit with a moisture sensor (769 kWh) was based on estimates from EPRI[[6]](#footnote-7) and the Consumer Energy Center[[7]](#footnote-8) 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[[8]](#footnote-9) 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.[[9]](#footnote-10)

### 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 | 115 kWh for 0.93 Energy Factor  157 kWh for 0.94 Energy Factor  199 kWh for 0.95 Energy Factor |
| Unit Peak Demand Reduction | 0.0105 kW for 0.93 Energy Factor  0.0144 kW for 0.94 Energy Factor  0.0182 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 0.904.

### 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[[10]](#footnote-11). The factor is constructed as follows:

1) Obtain the average kW, as monitored for 82 water heaters in PJM territory[[11]](#footnote-12), 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[[12]](#footnote-13).

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: Efficient Electric Water Heater Calculation Assumptions

|  |  |  |  |
| --- | --- | --- | --- |
| **Component** | **Type** | **Values** | **Source** |
| EFbase, Energy Factor of baseline water heater | Fixed | 0.904 | 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 |
| Energy To Demand Factor | 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 0.904. “Energy Conservation Program: Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters” US Dept of Energy Docket Number: EE–2006–BT-STD–0129, p. 30
2. 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 | 199 | 0.0182 |
| 0.94 | 157 | 0.0144 |
| 0.93 | 115 | 0.0182 |

### 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**[[13]](#footnote-14)

### Evaluation Protocols

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

## Electroluminescent Nightlight

|  |  |
| --- | --- |
| **Measure Name** | **Electroluminescent Nightlight** |
| Target Sector | Residential Establishments |
| Measure Unit | Nightlight |
| Unit Energy Savings | 26 kWh |
| Unit Peak Demand Reduction | 0 kW |
| Measure Life | 8 years |

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 kW |
| Measure Life | 15 years |

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 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 | 2,184 kWh for 2.3 Energy Factor  1,896 kWh for 2.0 Energy Factor |
| Unit Peak Demand Reduction | 0.200 kW for 2.3 Energy Factor  0.174 kW for 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:

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[[14]](#footnote-15). The factor is constructed as follows:

1. Obtain the average kW, as monitored for 82 water heaters in PJM territory[[15]](#footnote-16), for each hour of the typical day summer, winter, and spring/fall days. Weight the results (91 summer days, 91 winter days, and 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[[16]](#footnote-17).
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: Heat Pump Water Heater Calculation Assumptions

|  |  |  |  |
| --- | --- | --- | --- |
| **Component** | **Type** | **Values** | **Source** |
| EFbase , Energy Factor of baseline water heater | Fixed | 0.904 | 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 |

**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 ,
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 dry bulb and 50% RH, which is °F 67.5 wet bulb.
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 wet bulb temperature. However, the average wet bulb temperature in PA is closer to 45 °F[[17]](#footnote-18). The heat pump performance is temperature dependent. The plot below shows relative coefficient of performance (COP) compared to the COP at rated conditions[[18]](#footnote-19). 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 wet-bulb 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 | 2184 | 0.200 |
| 2.0 | 1896 | 0.174 |

### 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**[[19]](#footnote-20).

### 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: Home Audit Conversion Kit Calculation Assumptions

| **Component** | **Value** | **Source** |
| --- | --- | --- |
| NCFL: Number of CFLs per kit | 4 | Program design[[20]](#footnote-21) |
| 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  SWE Data Gathering |
| CFLhours, hours of operation per day | 3.0 | PA TRM Table 2-43 |
| CF , CFL Summer Demand Coincidence Factor | 0.05 | PA TRM Table 2-43 |
| 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[[21]](#footnote-22) |
| SavingsSmartStrip (kWh) | 184 | FE Interim TRM |
| DemandReductionSmartStrip (kW) | .013 | FE Interim TRM |
| ISRSmartStrip | variable | EDC Data Gathering |
| SavingsNiteLite (kWh) | 26.3 | PA Interim TRM[[22]](#footnote-23) |
| DemandReductionNiteLite (kW) | 0 | PA Interim TRM |
| ISRNiteLite | variable | EDC Data Gathering |
| NNiteLite | 2 | Program Design |

### 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[[23]](#footnote-24). 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** | 22 kWh |
| **Unit Peak Demand Reduction** | 0 kW |
| **Measure Life** | 8 years |

Savings from installation of LED 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

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** | 60 kWh |
| **Unit Peak Demand Reduction** | 0.0056 kW |
| **Measure Life** | 12 years |

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

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

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

### Algorithms

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

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[[24]](#footnote-25). 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: Low Flow Faucet Aerator 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 | 0.904 | 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, and 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 Wisconsin 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 ×** **60 kWh/year** with a demand reduction of **ISR ×** **0.0056 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[[25]](#footnote-26)

GPMlow =Gallons per minute of low flow showerhead

people =Average number of people per household = 2.48[[26]](#footnote-27)

gals/day =Average gallons of hot water used by shower per day = 11.6[[27]](#footnote-28)

days/year =Number of days per year = 365

showers =Average number of showers in the home = 1.6[[28]](#footnote-29)

lbs/gal =Pounds per gallon = 8.3

TEMPft =Assumed temperature of water used by faucet = 120° F[[29]](#footnote-30)

TEMPin =Assumed temperature of water entering house = 55° F[[30]](#footnote-31)

EF =Recovery efficiency of electric hot water heater = 0.90[[31]](#footnote-32)

0.003412 =Constant to converts MMBtu to kWh

EnergyToDemandFactor=Summer peak coincidence factor for measure = 0.00009172[[32]](#footnote-33)

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[[33]](#footnote-34). 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, and 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 2‑5 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[[34]](#footnote-35)**.

### Evaluation Protocols

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

## Programmable Thermostat

|  |  |
| --- | --- |
| **Measure Name** | **Programmable Thermostat** |
| **Target Sector** | Residential Establishments |
| **Measure Unit** | Programmable 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 modifying the temperature set-points 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 = ΔkWhCOOL + ΔkWhHEAT

ΔkWhCOOL = CAPCOOL/1000 X (1/(SEER x Effduct) X EFLHCOOL X ESFCOOL

ΔkWhHEAT = CAPHEAT/1000 X (1/(HSPF X Effduct)) X EFLHHEAT X ESFHEAT

ΔkWpeak = 0

### Definition of Terms

CAPCOOL = Capacity of the air conditioning unit in BTUh, based on nameplate capacity.

CAPHEAT = Nominal heating capacity of the electric furnace in BTUh

Effduct = Duct system efficiency

SEER = Seasonal energy efficiency ratio of the cooling unit.

HSPF = Heating seasonal performance factor of the heating unit.

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

EFLHCOOL, HEAT = Equivalent full load hours

Table 2‑17: Residential Electric HVAC Calculation Assumptions

|  |  |  |  |
| --- | --- | --- | --- |
| **Component** | **Type** | **Value** | **Sources** |
| CAPCOOL | Variable | Nameplate data | EDC Data Gathering |
| Default: 36,000 BTUh | 1 |
| CAPHEAT | Variable | Nameplate Data | EDC Data Gathering |
| Default: 36,000 BTUh | 1 |
| SEER | Variable | Nameplate data | EDC Data Gathering |
| Default: 10 SEER | 2 |
| HSPF | Variable | Nameplate data | EDC Data Gathering |
| Default: 3.413 HSPF (equivalent to electric furnace COP of 1) | 2 |
| Effduct | Fixed | 0.8 | 3 |
| ESFCOOL | Fixed | 2% | 4 |
| ESFHEAT | Fixed | 3.6% | 5 |
| EFLHCOOL | Fixed | Allentown Cooling = 784 Hours  Erie Cooling = 482 Hours  Harrisburg Cooling = 929 Hours  Philadelphia Cooling = 1,032 Hours  Pittsburgh Cooling = 737 Hours  Scranton Cooling = 621 Hours  Williamsport Cooling = 659 Hours | 6 |
| EFLHHEAT | 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 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).

### Algorithms

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

#### Retirement-Only

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

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 (See Section 1.4), 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)

Table 2‑18: Room AC Retirement Calculation Assumptions

|  |  |  |  |
| --- | --- | --- | --- |
| **Component** | **Type** | **Value** | **Sources** |
| EFLHRAC | Varies | Table 2‑19, “Corrected Hours” | ---- |
| EFLHES-RAC | Varies | Table 2‑19, “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[[35]](#footnote-36)

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

**Sources:**

1. Full load hours for Pennsylvania cities from the ENERGY STAR Room AC Calculator[[36]](#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 of 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.

### Measure Life

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[[37]](#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 ENERGY STAR 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.

### 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: Smart Strip Plug Outlet 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 life 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** | 2,088 kWh |
| **Unit Peak Demand Reduction** | 0.376 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[[38]](#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[[39]](#footnote-40). The factor is constructed as follows:

1. Obtain the average kW, as monitored for 82 water heaters in PJM territory[[40]](#footnote-41), for each hour of the typical day summer, winter, and spring/fall days. Weight the results (91 summer days, 91 winter days, and 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[[41]](#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[[42]](#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: Solar Water Heater Calculation Assumptions

|  |  |  |  |
| --- | --- | --- | --- |
| **Component** | **Type** | **Values** | **Source** |
| EFbase , Energy Factor of baseline electric heater | Fixed | 0.904 | 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 | 4,104 |  |
| EnergyToDemandFactor: Ratio of average Noon to 8 PM usage during summer peak to annual energy usage | Fixed | 0.00009172 | 2-5 |

**Sources:**

1. The average energy factor for all solar water heaters with collector areas of 50 ft2 or smaller is 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 be 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 = 2,088 kWh

ΔkWpeak  = 0.376 kW

### Measure Life

The expected useful life is 20 years, according to ENERGY STAR[[43]](#footnote-44).

### Evaluation Protocols

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

## Electric Water Heater Pipe Insulation

|  |  |
| --- | --- |
| **Measure Name** | **Electric 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 and reducing the water heating set point from 3-4 degrees Fahrenheit 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.[[44]](#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[[45]](#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[[46]](#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, and 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[[47]](#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

|  |  |
| --- | --- |
| **Measure Name** | **Whole House Fans** |
| **Target Sector** | Residential Establishments |
| **Measure Unit** | Whole House Fan |
| **Unit Energy Savings** | Varies by location (187 kWh/yr to 232 kWh/yr) |
| **Unit Peak Demand Reduction** | 0 kW |
| **Measure Life** | 15 years |

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.[[48]](#footnote-49) Energy savings for this measure are based on whole house fan energy savings values reported by the energy modeling software, REM/Rate[[49]](#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.[[50]](#footnote-51)

Table 2‑23: Whole House Fan 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[[51]](#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** | Variable based on efficiency of systems |
| **Unit Peak Demand Reduction** | Variable based on efficiency of systems |
| **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 greater. This technology typically converts an electric resistance heated 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.[[52]](#footnote-53) The baseline heating system could be an existing electric resistance heating, a lower-efficiency ductless heat pump system, a ducted heat pump, electric furnace, or a non-electric fuel-based system. The baseline cooling system can be a standard efficiency heat pump system, central air conditioning system, or room air conditioner. In addition, this could be installed in new construction or an addition. For new construction or addition applications, the baseline assumption is a standard-efficiency ductless unit. The DHP systems could be installed as the primary heating or cooling system for the house or as a secondary heating or cooling 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 = CAPYheat/1000 X (1/HSPFb - 1/HSPFe ) X EFLHheat X LF

ΔkWhcool = CAPYcool/1000 X (1/SEERb – 1/SEERe ) X EFLHcool X LF

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

#### Multi-Zone:

ΔkWh = ΔkWhcool + ΔkWhheat

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

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

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

### Definition of Terms

CAPYcool, heat = The cooling or heating (at 47° F) capacity of the indoor unit, given in BTUH as appropriate for the calculation

EFLHcool, heat = Equivalent Full Load Hours – If the unit is installed as the primary heating or cooling system, as defined in Table 2-25, the EFLH will use the EFLH primary hours listed in Table 2-24. If the unit is installed as a secondary heating or cooling system, the EFLH will use the EFLH secondary hours listed in Table 2-24.

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** |
| --- | --- | --- | --- |
| CAPYcool  CAPYheat | Variable | EDC Data Gathering | 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 = 1,671 Hours  Erie Cooling = 149 Hours  Erie Heating = 2,138 Hours  Harrisburg Cooling = 288 Hours  Harrisburg Heating = 1,681 Hours  Philadelphia Cooling = 320 Hours  Philadelphia Heating = 1,565 Hours  Pittsburgh Cooling = 228 Hours  Pittsburgh Heating = 1,670 Hours  Scranton Cooling = 193 Hours  Scranton Heating = 1,806 Hours  Williamsport Cooling = 204 Hours  Williamsport Heating = 1,750 hours | 2, 3 |
| HSPFb | Fixed | Standard DHP: 7.7  Electric resistance: 3.413  ASHP: 7.7  Electric furnace: 3.242  No existing or non-electric heating: use standard DHP: 7.7 | 4, 6 |
| SEERb | Fixed | DHP, ASHP, or central AC: 13  Room AC: 11  No existing cooling for primary space: use DHP, ASHP, or central AC: 13  No existing cooling for secondary space: use Room AC: 11 | 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 | Variable | = (11.3/13) X SEERe  Based on nameplate information. Should be at least ENERGY STAR. | AEPS Application; EDC Data Gathering |
| 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 work paper that adjusted the central cooling hours to room AC cooling hours; see Section 2.12 Room AC Retirement measure.
3. Secondary heating hours based on a ratio of HDD base 68 and base 60 deg F. The ratio is used to reflect the heating requirement for secondary spaces is less than primary space as the thermostat set point in these spaces is generally lowered during unoccupied time periods.
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. The load factor is used to account for inverter-based DHP units operating at partial loads. The value was chosen to align savings with what is seen in other jurisdictions, based on 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/>>, and the results found in the “Ductless Mini Pilot Study” by KEMA, Inc., June 2009. This adjustment is required to account for partial load conditions and because the EFLH used are based on central ducted systems which may overestimate actual usage for baseboard systems.

### 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: DHP – Heating Zones

|  |  |
| --- | --- |
| **Component** | **Definition** |
| Primary Heating Zone | Living room Dining room  House hallway Kitchen areas Family Room Recreation Room |
| Secondary Heating Zone | Bedroom  Bathroom  Basement  Storage Room Office/Study  Laundry/Mudroom Sunroom/Seasonal 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.[[53]](#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: Domestic Hot Water 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[[54]](#footnote-55). The factor is constructed as follows:

1. Obtain the average kW, as monitored for 82 water heaters in PJM territory[[55]](#footnote-56), for each hour of the typical day summer, winter, and spring/fall days. Weight the results (91 summer days, 91 winter days, and 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[[56]](#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 ‑: 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 2‑26below.

Table 2‑26: Calculation Assumptions for Fuel Switching, Domestic Hot Water Electric to Gas

|  |  |  |  |
| --- | --- | --- | --- |
| **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 |

**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
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 for Fuel Switching, Domestic Hot Water Electric to Gas

|  |  |  |
| --- | --- | --- |
| **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 for Fuel Switching, Domestic Hot Water Electric to Gas

|  |  |
| --- | --- |
| **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[[57]](#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: Heat Pump Water Heater to Gas Water Heater

|  |  |
| --- | --- |
| **Measure Name** | **Fuel Switching: Heat Pump Water Heater to Gas Water Heater** |
| Target Sector | Residential |
| Measure Unit | Water Heater |
| Unit Energy Savings | 2208 kWh |
| Unit Peak Demand Reduction | 0.203 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 water heaters 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[[58]](#footnote-59). The factor is constructed as follows:

1. Obtain the average kW, as monitored for 82 water heaters in PJM territory[[59]](#footnote-60), for each hour of the typical day summer, winter, and spring/fall days. Weight the results (91 summer days, 91 winter days, and 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[[60]](#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.

Table 2‑29: Calculation Assumptions for Heat Pump Water Heater to Gas Water Heater

|  |  |  |  |
| --- | --- | --- | --- |
| **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 |

**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>
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 wet bulb temperature is 45 ± 1.3 °F. The wet bulb 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 wet bulb temperature.

### Heat Pump Water Heater Energy Factor

The Energy Factors are determined from a DOE testing procedure that is carried out at 56 °F wet bulb temperature. However, the average wet bulb temperature in PA is closer to 45 °F[[61]](#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[[62]](#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 for Heat Pump Water Heater to Gas Water Heater

|  |  |  |
| --- | --- | --- |
| **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 for Heat Pump Water Heater to Gas Water Heater

|  |  |
| --- | --- |
| **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[[63]](#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, Fuel Switching, Electric Heat to Gas Heat

|  |  |  |  |
| --- | --- | --- | --- |
| **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[[64]](#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 = Demand Coincidence Factor (See Section 1.4) for central AC systems

CFRAC = Demand Coincidence Factor (See Section 1.4) for Room AC systems

CFASHP = Demand Coincidence Factor (See Section 1.4) 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, Ceiling/Attic and Wall Insulation

| **Term** | **Type** | **Value** | **Source** |
| --- | --- | --- | --- |
| Aroof | Variable | Varies | EDC Data Gathering |
| Awall | Variable | Varies | EDC Data Gathering |
| DUA | Fixed | 0.75 | OH TRM[[65]](#footnote-66) |
| Rroof,bl[[66]](#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[[67]](#footnote-68) | Variable | 38 | Retrofit to R-38 total attic insulation |
| 49 | Retrofit to R-49 total attic insulation |
| Rwall,bl[[68]](#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[[69]](#footnote-70) | Variable | Default = 9.0 | Assumes adding R-6 per DOE recommendations[[70]](#footnote-71) |
| Retrofit Assembly R-value | EDC Data Gathering |
| SEERCAC | Variable | Default for equipment installed before 1/23/2006 = 10  Default for equipment installed after 1/23/2006 = 13 | Minimum Federal Standard for new Central Air Conditioners/Heat Pumps between 1990 and 2006  ASHRAE 90.1-2007 |
| 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 for equipment installed before 1/23/2006 = 10  Default for equipment installed after 1/23/2006 = 13 | Minimum Federal Standard for new Central Air Conditioners/Heat Pumps between 1990 and 2006  ASHRAE 90.1-2007 |
| Nameplate | EDC Data Gathering |
| HSPFASHP | Variable | Default for equipment installed before 1/23/2006 = 6.8  Default for equipment installed after 1/23/2006 = 7.7 | Minimum Federal Standard for new Central Air Conditioners/Heat Pumps between 1990 and 2006  ASHRAE 90.1-2007 |
| Nameplate | EDC Data Gathering |
| CFCAC | Fixed | 0.70 | Table 2-1 |
| CFRAC | Fixed | 0.58 | Table 2-41 |
| CFASHP | Fixed | 0.70 | Table 2-1 |
| FRoom,AC | Fixed | 0.38 | Calculated[[71]](#footnote-72) |

Table 2‑34: EFLH, CDD and HDD by City

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **City** | **EFLHcool**  **(Hours)[[72]](#footnote-73)** | **EFLHcool RAC**  **(Hours)[[73]](#footnote-74)** | **CDD (Base 65)[[74]](#footnote-75)** | **HDD (Base 65)[[75]](#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[[76]](#footnote-77).

## Refrigerator / Freezer Recycling and Replacement

|  |  |
| --- | --- |
| **Measure Name** | **Refrigerator/Freezer Recycling and Replacement** |
| Target Sector | Residential Establishments |
| Measure Unit | Refrigerator or Freezer |
| Unit Annual Energy Savings | 1205 kWh (Replace with ENERGY STAR Unit)  1,091 kWh (Replace with non-ENERGY STAR Unit) |
| Unit Peak Demand Reduction | 0.1494kW (Replace with ENERGY STAR Unit)  0,135 kW (Replace with non-ENERGY STAR Unit) |
| Measure Life | 7 years |

This measure is the recycling and replacement before end of life of an existing refrigerator or freezer with a new refrigerator or freezer. This protocol quantifies savings where the replacement refrigerator or freezer is ENERGY STAR and non-ENERGY STAR qualified. This protocol applies to both residential and non-residential sectors, as refrigerator usage and energy usage are assumed to be independent of customer rate class[[77]](#footnote-78).

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 a primary or secondary unit



### Algorithms

The deemed savings values are based on the following algorithms:

ΔkWh = kWhRecycled – kWhReplacement

ΔkWpeak  = ΔkWh/ HOURSRefRepl \* CFRefRepl

### Definition of Terms

The energy and demand savings shall be:

kWhRecycled = Annual energy consumption of the recycled appliance

kWhReplacement = Annual energy consumption of the replacement appliance

HOURSRefRepl = Average annual run hours

CFRefRepl = Demand Coincidence Factor (See Section 1.4)

| **Term** | **Type** | **Value** | **Source** |
| --- | --- | --- | --- |
| kWhRecycled | Fixed | 1,659 kWh | 1 |
| kWhReplacement | Fixed | ENERGY STAR unit: 454 kWh  Non-ENERGY STAR unit: 568 kWh | 2 |
| HOURSRefRepl | Fixed | 5,000 | 3 and 4 |
| CFRefRepl | Fixed | 0.620 | 4 |

**Sources:**

1. Energy Star Refrigerator Retirement Calculator, accessed 09/01/2011 at <http://www.energystar.gov/index.cfm?fuseaction=refrig.calculator>. 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. This value is subject to change based on further analysis of other evaluation reports on appliance recycling programs across the nation.
2. Energy Star Refrigerator Savings Calculator, accessed 09/01/2011 at <http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Consumer_Residential_Refrig_Sav_Calc.xls>. Values represent average energy consumption of all refrigerator configurations listed in the calculator based on default volume of 25.8 ft3 and federal minimum standards for non-ENERGY STAR units and ENERGY STAR standards for ENERGY STAR units.
3. Efficiency Vermont; Technical Reference User Manual (TRM). 2008. TRM User Manual No. 2008-53. Burlington, VT 05401. July 18, 2008.
4. Mid Atlantic TRM Version 1.0. May 2010. Prepared by Vermont Energy Investment Corporation. Facilitated and managed by Northeast Energy Efficiency Partnerships.



Table 2‑35: Refrigerator/Freezer Recycling and Replacement Default Savings

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Type** | **kWhRecycled** | **kWhReplacement** | **ΔkWh** | **ΔkWpeak** |
| Appliance Replaced with ENERGY STAR Unit | 1,659 | 454 | 1,205 | 0.149 |
| Appliance Replaced with non-ENERGY Star Unit | 1,659 | 568 | 1,091 | 0.135 |

### 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)[[78]](#footnote-86) 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\*13). 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[[79]](#footnote-87) |

This measure is the retirement of an existing refrigerator or freezer without replacement. This protocol applies to both residential and non-residential sectors, as refrigerator usage and energy usage are assumed to be independent of customer rate class[[80]](#footnote-88).

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)

### 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 = Demand Coincidence Factor (See Section 1.4)

**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.[[81]](#footnote-89)

Table 2‑36: Refrigerator/Freezer Retirement 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) | 1,659kWh[[82]](#footnote-90) |
| kWRetFridge = | 1659kWh/5000hours \* 0.620 | 0.2057kW |

## 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[[83]](#footnote-91) 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. For residential new construction, the building thermal envelope and/or system characteristics shall be based on the current state adopted 2009 International Residential Code (IRC 2009).

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 Section 2: Residential Measures of this Manual.

#### 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.[[84]](#footnote-92)

### Definition of Terms

PLb = Peak load of the baseline home in Btuh.

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

SEERb = Seasonal Energy Efficiency Ratio of the baseline unit.

BLEER = Factor to convert baseline SEERb to EERb.

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

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

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

CF = Demand Coincidence Factor (See Section 1.4)

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

Table 2‑37: Residential New Construction – References

|  |  |  |  |
| --- | --- | --- | --- |
| **Component** | **Type** | **Value** | **Sources** |
| PLb | Variable | EDC Calculated | 1, Software Output |
| OF*b* | Fixed | 1.6 | 2 |
| SEER*b* | Fixed | 13 | 3 |
| BLEER | Fixed | (11.3/13) | 4 |
| PL*q* | Variable | EDC Calculated | 5, Software Output |
| OF*q* | Fixed | 1.15 | 6 |
| EER*q* | Variable | EDC Data Gathering | AEPS Application; EDC’s Data Gathering |
| CF | Fixed | 0.70 | 7 |

**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. Ratio to calculate EER from SEER based average EER for SEER 13 units.
5. Calculation of peak load of energy efficient home from the home energy rating tool based on the specified home energy characteristics.
6. Program guideline for qualifying home.
7. Based on an analysis of six different utilities by Proctor Engineering.

The following table lists the building envelope characteristics of the baseline reference home based on IRC 2009 for the three climate zones in Pennsylvania..

Table 2‑38: Baseline Insulation and Fenestration Requirements by Component (Equivalent U-Factors)

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Climate Zone** | **Fenestration U-Factor** | **Skylight U-Factor** | **Ceiling U-Factor** | | **Frame Wall U-Factor** | **Mass Wall U-Factor** | **Floor**  **U-Factor** | **Basement Wall U*-*Factor** | **Slab**  **R-Value &Depth** | **Crawl Space Wall U-Factor** |
| 4A | 0.35 | 0.60 | 0.030 | | 0.082 | 0.141 | 0.047 | 0.059 | 10, 2 ft | 0.065 |
| 5A | 0.35 | 0.60 | 0.030 | | 0.060 | 0.082 | 0.033 | 0.059 | 10, 2 ft | 0.065 |
| 6A | 0.35 | 0.60 | 0.026 | | 0.060 | 0.060 | 0.033 | 0.059 | 10, 4 ft | 0.065 |

**Sources:**

1. 2009 International Residential Code Table N1102.1.2. Table N1102.1.2 Equivalent U-Factors presents the R-Value requirements of Table N1102.1.1 in an equivalent U-Factor format. Users may choose to follow Table N1102.1.1 instead. IRC 2009 supersedes this table in case of discrepancy. Additional requirements per Section N1102 of IRC 2009 must be followed even if not listed here.

**Table 2‑39: Energy Star Homes - User Defined Reference Home**

| **Data Point** | **Value**[[85]](#footnote-97) | **Source** |
| --- | --- | --- |
| Air Infiltration Rate | 0.30 ACH for windows, skylights, sliding glass doors  0.50 ACH for swinging doors | 1 |
| Duct Leakage | 12 cfm25 (12 cubic feet per minute per 100 square feet of conditioned space when tested at 25 pascals) | 1 |
| Duct Insulation | Supply ducts in attics shall be insulated to a minimum of R-8. All other ducts insulated to a minimum of R-6. | 1 |
| Duct Location | 50% in conditioned space, 50% unconditioned space | Program Design |
| Mechanical Ventilation | None | 1 |
| Lighting Systems | Minimum 50% of permanent installed fixtures to be high-efficacy lamps | 1 |
| Appliances | Use Default |  |
| Setback Thermostat | Maintain zone temperature down to 55 oF (13 oC) or up to 85 oF (29 oC) | 1 |
| Temperature Set Points | Heating: 70°F  Cooling: 78°F | 1 |
| Heating Efficiency |  |  |
| Furnace | 80% AFUE | 2 |
| Boiler | 80% AFUE | 2 |
| Combo Water Heater | 76% AFUE (recovery efficiency) | 2 |
| Air Source Heat Pump | 7.7 HSPF | 1 |
| Geothermal Heat Pump | 7.7 HSPF | 1 |
| PTAC / PTHP | Not differentiated from air source HP | 1 |
| Cooling Efficiency |  |  |
| Central Air Conditioning | 13.0 SEER | 1 |
| Air Source Heat Pump | 13.0 SEER | 1 |
| Geothermal Heat Pump | 13 SEER (11.2 EER) | 1 |
| PTAC / PTHP | Not differentiated from central AC | 1 |
| Window Air Conditioners | Not differentiated from central AC | 1 |
| Domestic WH Efficiency |  |  |
| Electric | EF = 0.97 - (0.00132 \* gallons) | 3 |
| Natural Gas | EF = 0.67 - (0.0019 \* gallons) | 3 |
| Additional Water Heater Tank Insulation | None |  |

**Sources:**

1. 2009 International Residential Code (IRC 2009, Sections N1102 – N1104)
2. Federal Register / Vol. 73, No. 145 / Monday, July 28, 2008 / Rules and Regulations, p. 43611-43613, 10 CFR Part 430, “Energy Conservation Program for Consumer Products: Energy Conservation Standards for Residential Furnaces and Boilers.”
3. Federal Register / Vol. 75, No. 73 / Friday, April 16, 2010 / Rules and Regulations, p. 20112-20236, 10 CFR Part 430, “Energy Conservation Program: Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters; Final Rule.”

## 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  = DSavDW 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:

ΔkWh = ESavFRE

ΔkWpeak  = DSavFRE X CFFRE

### 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.

ESavFRE = Electricity savings per purchased ENERGY STAR freezer.

DSavFRE = Summer demand savings per purchased ENERGY STAR freezer.

CFREF, CFCW, CFDW,

CFDH, CFRAC, CFFRE = Demand Coincidence Factor (See Section 1.4). 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%).

Table 2‑40: ENERGY STAR Appliances - References

| **Component** | **Type** | **Value** | **Sources** |
| --- | --- | --- | --- |
| ESavREF | Fixed | See Table 2‑41 | 9 |
| DSavREF | Fixed | 0.0125 kW | 1 |
| ESavCW | Fixed | See Table 2‑41 | 9 |
| DSavCW | Fixed | 0.0147 kW | 3 |
| ESavDW | Fixed | See Table 2‑41 | 9 |
| DSavDW | Fixed | 0.0225 | 4 |
| ESavDH | Fixed | See Table 2‑41 | 9 |
| DSavDH | Fixed | 0.0098 kW | 7 |
| ESavRAC | Fixed | See Table 2‑41 | 9 |
| DSavRAC | Fixed | 0.1018 kW | 5 |
| CFREF, CFCW, CFDW, CFDH, CFRAC, CFFRE | Fixed | 1.0, 1.0, 1.0, 1.0, 0.58, 1.0 | 6 |
| ESavFRE | Fixed | See Table 2‑41 | 9 |
| DSavFRE | Fixed | 0.0113 | 8 |

**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. Average demand savings based on engineering estimate.
6. Coincidence factors already embedded in summer peak demand reduction estimates with the exception of RAC. RAC CF is based on data from PEPCO.
7. Conservatively assumes same kW/kWh ratio as Refrigerators.
8. Efficiency Vermont. Technical Reference User Manual: Measure Savings Algorithms and Cost Assumptions (July 2008).
9. Values are taken from the ENERGY STAR Savings Calculators or, if a given configuration is not listed in the ENERGY STAR Savings Calculator, an average of all models of a given configuration from ENERGY STAR Refrigerators Qualified Products list. The ENERGY STAR Savings Calculator and ENERGY STAR Refrigerators Qualified Products list can be found at [www.energystar.gov](http://www.energystar.gov).

Table 2‑41: Energy Savings from ENERGY STAR

| **Measure** | **Energy Savings** |
| --- | --- |
| Refrigerator |  |
| Manual Defrost | 95 kWh |
| Partial Automatic Defrost | 95 kWh |
| Top mount freezer without door ice | 106 kWh |
| Side mount freezer without door ice | 127 kWh |
| Bottom mount freezer without door ice | 116 kWh |
| Bottom mount freezer with door ice | 154 kWh |
| Top mount freezer with door ice | 124 kWh |
| Side mount freezer with door ice | 133 kWh |
| Refrigerator only - single door without ice | 104 kWh |
| Refrigerator/Freezer – single door | 105 kWh |
| Freezers |  |
| Upright with manual defrost | 47 kWh |
| Upright with automatic defrost | 67 kWh |
| Chest Freezer | 42 kWh |
| Compact Upright with manual defrost | 53kWh |
| Compact Upright with automatic defrost | 71 kWh |
| Compact Chest Freezer | 45kWh |
| 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 | 185 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 Water Heater | 77 kWh |
| With Electric Water Heater | 137 kWh |
| Clothes Washer |  |
| Gas Water Heater and Gas Dryer or No Dryer | 24 kWh |
| Gas Water Heater and Electric Dryer | 97 kWh |
| Electric Water Heater and Electric Dryer | 224 kWh |
| Electric Water Heater and Gas Dryer or No Dryer | 141 kWh |

For dishwashers and clothes washers where fuel mix is unknown, calculate default savings using the algorithms below and EDC specific saturation values derived from residential appliance saturation study information (or similar studies). For EDCs where saturation information is not accessible, use a simple average (107 kWh for dishwashers and 122 kWh for clothes washers).[[86]](#footnote-98)

ESavDW = 77 x %GWHDW + 137 x %EWHDW

ESavCW = 24 x %GWH-GDCW + 97 x %GWH-EDCW + 141 x %EWH-GDCW + 224 x %EWH-EDCW

Where:

%GWHDW = Percent of dishwashers with non-electric water heater

%EWHDW = Percent of dishwashers with electric water heater

%GWH-GDCW = Percent of clothes washers with gas water heater and non-electric or no dryer fuel

%GWH-EDCW = Percent of clothes washers with gas water heater and electric dryer fuel

%EWH-GDCW = Percent of clothes washers with gas water heater and non-electric or no dryer fuel

%EWH-EDCW = Percent of clothes washers with gas water heater and electric dryer fuel

## 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 = (Wattsbase – WattsCFL) X CFLhours X 365 / 1000 X ISRCFL

ΔkWpeak = (Wattsbase – WattsCFL) / 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

Wattsbase = Wattage of baseline case for CFL. For general service lamps prior to EISA 2007 standards, use equivalent incandescent bulb wattage. For general service lamps past EISA 2007 standards, use new standards to determine wattage. See Table 2‑43.

WattsCFL = Wattage of 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 Torchiere

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 (See Section 1.4)

ΔkWh= Gross customer annual kWh savings for the measure

ΔkW= Gross customer connected load kW savings for the measure

Table 2‑42: ENERGY STAR Lighting - References

|  |  |  |  |
| --- | --- | --- | --- |
| **Component** | **Type** | **Value** | **Sources** |
| Wattsbase | Variable | See Table 2‑43 | Table 2‑43 |
| WattsCFL | Variable | Data Gathering | Data Gathering |
| CFLhours | Fixed | 3.0 | 6 |
| ISRCFL | Fixed | 84%[[87]](#footnote-99) | 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 (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. US Department of Energy, Energy Star Calculator. Accessed 3-16-2009.

Table 2‑43. Baseline Wattage by Lumen Output of CFL[[88]](#footnote-100)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Minimum Lumens  (a) | Maximum Lumens  (b) | Incandescent Equivalent  WattsBase  (Pre-EISA 2007)  (c) | WattsBase  (Post-EISA 2007)  **(d)** | Post-EISA 2007 Effective Date  **(e)** |
| 1490 | 2600 | 100 | 72 | 2012 TRM |
| 1050 | 1489 | 75 | 53 | 2013 TRM |
| 750 | 1049 | 60 | 43 | 2014 TRM |
| 310 | 749 | 40 | 29 | 2014 TRM |

To determine the WattsBase for a non-specialty CFL,[[89]](#footnote-101),, follow these steps:

1. Identify the CFL’s rated lumen output
2. In Table 2‑43, find the lumen range into which the CFL falls (see columns (a) and (b).
3. Find the baseline wattage (WattsBase) in column (c) or column (d). Values in column (c) are used for WattsBase until the TRM listed under column (e) is effective. Afterwards, values in column (d) are used for WattsBase.

## 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.[[90]](#footnote-102) 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 (See Section 1.4)

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.

## 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.[[91]](#footnote-103)
2. Software approved by the US Department of Energy’s Weatherization Assistance Program.[[92]](#footnote-104)
3. RESNET approved rating software.[[93]](#footnote-105)

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)[[94]](#footnote-106). 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. Non-interacted 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[[95]](#footnote-107).

### 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 = Demand Coincidence Factor (See Section 1.4)

365 = days per year.

Table 2‑45: 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 2‑46: ENERGY STAR TVs Version 4.1 and 5.1 maximum power consumption

|  |  |  |
| --- | --- | --- |
| **Screen Area[[96]](#footnote-108) (square inches)** | **Maximum Active Power (WES,active)**  **Version 4.1[[97]](#footnote-109)** | **Maximum Active Power (WES,active)**  **Version 5.1[[98]](#footnote-110)** |
| 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 2‑47: TV power consumption

|  |  |  |  |
| --- | --- | --- | --- |
| **Diagonal Screen Size (inches)[[99]](#footnote-111)** | **Baseline Active Power Consumption [Wbase,active][[100]](#footnote-112)** | **ENERGY STAR V. 4.1 Active Power Consumption [WES,active][[101]](#footnote-113)** | **ENERGY STAR V. 5.1 Active Power Consumption [WES,active][[102]](#footnote-114)** |
| < 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 2‑48. Coincident demand savings are given in Table 2‑49.

Table 2‑48: Deemed energy savings for ENERGY STAR Version 4.1 and 5.1 TVs.

|  |  |  |
| --- | --- | --- |
| **Diagonal Screen Size (inches)[[103]](#footnote-115)** | **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 2‑49: Deemed coincident demand savings for ENERGY STAR Version 4.1 and 5.1 TVs.

|  |  |  |
| --- | --- | --- |
| **Diagonal Screen Size (inches)[[104]](#footnote-116)** | **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[[105]](#footnote-117)

## ENERGY STAR Office Equipment

This protocol estimates savings for installing ENERGY STAR office equipment compared to standard efficiency equipment in residential applications. The measurement of energy and demand savings is based on a deemed savings value multiplied by the quantity of the measure.

### 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 = Demand Coincidence Factor (See Section 1.4). 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 2‑50: ENERGY STAR Office Equipment - References

| **Component** | **Type** | **Value** | **Sources** |
| --- | --- | --- | --- |
| ESavCOM  ESavFAX  ESavCOP  ESavPRI  ESavMUL  ESavMON | Fixed | see Table 2‑51 | 1 |
| DSavCOM  DSavFAX  DSavCOP  DSavPRI  DSavMUL  DSavMON | Fixed | see Table 2‑51 | 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 residential 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 2‑51: ENERGY STAR Office Equipment Energy and Demand Savings Values

| **Measure** | **Energy Savings (ESav)** | **Demand Savings (DSav)** |
| --- | --- | --- |
| Computer | 77 kWh | 0.0100 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 | 14 kWh | 0.0019 kW |

**Sources:**

1. **ENERGYSTAR office equipment calculators**

## ENERGY STAR LEDs

This protocol documents the energy and demand savings attributed to replacing standard incandescent lamps and fixtures in residential applications with ENERGY STAR® LED lamps, retrofit kits, and fixtures. LEDs provide an efficient alternative to incandescent lighting. The ENERGY STAR program began labeling qualified LED products in the latter half of 2010. Eligibility Requirements

All LED lamps, retrofit kits and fixtures must be:

* **ENERGY STAR qualified[[106]](#footnote-118)** – Criteria for ENERGY STAR qualified LED products vary by product type and include specifications for: light output (lumens), efficacy (lumens per Watt), zonal lumen density, Correlated Color Temperature (CCT), lumen maintenance (lifetime), Color Rendering Index (CRI), and power factor, among others. LED bulbs also have three-year (or longer) warranties covering material repair or replacement from the date of purchase and must turn on instantly (have no warm-up time),
* **Lighting Facts labeled[[107]](#footnote-119)** - Contains the manufacturer’s voluntary pledge that the product’s performance is accurately represented in the market. Through this DOE-sponsored program, the manufacturer discloses the product’s light output, efficacy, Watts, CCT, and CFI as measured by the IES LM-79-2008 testing procedure.
* **Dimmable** – product has dimming capability that is stated on the product package

### Algorithms

The LED measure savings are based on the algorithms in Section 2.26, but include several adjustments. Due to the wide range of efficacy (lumens/watt) for LEDs, and the resulting difficulty in determining equivalent incandescent bulb wattages, the savings algorithms for LED products are grouped by the lumen ranges given in EISA 2007.

#### GENERAL SERVICE LAMPS

Table 2‑52 shows lumen ranges and incandescent lamp equivalents for general service LEDs;**[[108]](#footnote-120)**

Table 2‑52. General Service Lamps

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Minimum Lumens  (a) | Maximum Lumens  (b) | Incandescent Equivalent  WattsBase  (Pre-EISA 2007)  (c) | WattsBase  (Post-EISA 2007)  **(d)** | Post-EISA 2007 Effective Date  **(e)** |
| 1490 | 2600 | 100 | 72 | 2012 TRM |
| 1050 | 1489 | 75 | 53 | 2013 TRM |
| 750 | 1049 | 60 | 43 | 2014 TRM |
| 310 | 749 | 40 | 29 | 2014 TRM |

To determine baseline wattage for an LED general service lamp:

1. Identify the LED’s rated lumen output
2. In Table 2‑52, find the lumen range into which the LED falls (see columns (a) and (b))
3. Find the baseline wattage in column (c) or column (d). Values in column (c) are used for WattsBase until the TRM listed under column (e). Afterwards, values in column (d) are used for WattsBase.

Note that this TRM section is applicable only to LEDs with rated outputs between 310 and 2600 lumens that replace general service medium screw base lamps such as A-shapes and globes, as well as candelabras. This TRM section is neither applicable to LEDs with rated lumen output lower than 310, nor to LEDs with rated lumen output greater than 2600. (For reflector lamps refer to Table 2‑53).

#### Residential LED, 40 Watt incandescent equivalent (rated lumens between 310 and 749)

Energy Impact (kWh) = ((WattsBase-WattsLED) \* (HoursLED \* 365) / 1000) \* ISRLED

Peak Demand Impact (kW) = ((WattsBase -WattsLED) / 1000) \* CF \* ISRLED

#### Residential LED, 60 Watt incandescent equivalent (rated lumens between 750 and 1049)

Energy Impact (kWh) = ((WattsBase -WattsLED) \* (HoursLED \* 365) / 1000) \* ISRLED

Peak Demand Impact (kW) = ((WattsBase -WattsLED ) / 1000) \* CF \* ISRLED

#### Residential LED, 75 Watt incandescent equivalent (rated lumens between 1050 and 1489)

Energy Impact (kWh) = ((WattsBase -WattsLED) \* (HoursLED \* 365) / 1000) \* ISRLED

Peak Demand Impact (kW) = ((WattsBase -WattsLED ) / 1000) \* CF \* ISRLED

#### Residential LED, 100 Watt incandescent equivalent (rated lumens between 1490 and 2600)

Energy Impact (kWh) = ((WattsBase -WattsLED) \* (HoursLED \* 365) / 1000) \* ISRLED

Peak Demand Impact (kW) = ((WattsBase -WattsLED ) / 1000) \* CF \* ISRLED

#### REFLECTOR LAMPS

Incandescent reflector lamps (IRLs) are the common cone-shaped light bulbs most typically used in track lighting and "recessed can" light fixtures (low-cost light fixtures that mount flush with the ceiling such that the socket and bulb are recessed into the ceiling). The cone is lined with a reflective coating to direct the light. PAR lamps are the most common type of IRLs; other common IRLs include "blown" PAR (BPAR) lamps, which are designed to be a low cost substitute for widely used PAR lamps, and "bulged" reflector (BR) lamps.[[109]](#footnote-121) Table 2‑53 shows lumen ranges and incandescent equivalents for LED reflector lamps based on the EISA 2007 amendment for reflector lamps in residential settings.[[110]](#footnote-122)

Table 2‑53: Reflector Lamps

|  |  |  |
| --- | --- | --- |
| Minimum Lumens  (a) | Maximum Lumens  (b) | Incandescent Equivalent  WattsBase  (c) |
| 2340 | 3075 | 150 |
| 1682 | 2339 | 120 |
| 1204 | 1681 | 100 |
| 838 | 1203 | 75 |
| 561 | 837 | 60 |
| 420 | 560 | 45 |

To determine baseline wattage for an LED reflector lamp:

1. Identify the LED’s rated lumen output
2. In Table 2‑53, find the lumen range into which the LED falls (see columns (a) and (b))
3. Find the incandescent equivalent wattage in column (c).

Note that this TRM section is applicable only to LEDs with rated outputs between 420 and 3,075 lumen that replace incandescent reflector lamps (floods, recessed lights); it is not applicable to LEDs with rated lumen output lower than 420 nor to LEDs with rated lumen output greater than 3,075.

#### Residential LED, 45 Watt incandescent reflector equivalent (rated lumens between 420 and 560)

Energy Impact (kWh) = ((WattsBase-WattsLED) \* (HoursLED \* 365) / 1000) \* ISRLED

Peak Demand Impact (kW) = ((WattsBase -WattsLED) / 1000) \* CF \* ISRLED

#### Residential LED, 60 Watt incandescent reflector equivalent (rated lumens between 561 and 837)

Energy Impact (kWh) = ((WattsBase -WattsLED) \* (HoursLED \* 365) / 1000) \* ISRLED

Peak Demand Impact (kW) = ((WattsBase -WattsLED) / 1000) \* CF \* ISRLED

#### Residential LED, 75 Watt incandescent reflector equivalent (rated lumens between 838 and 1203)

Energy Impact (kWh) = ((WattsBase -WattsLED) \* (HoursLED \* 365) / 1000) \* ISRLED

Peak Demand Impact (kW) = ((WattsBase -WattsLED) / 1000) \* CF \* ISRLED

#### Residential LED, 100 Watt incandescent reflector equivalent (rated lumens between 1204 and 1681)

Energy Impact (kWh) = ((WattsBase -WattsLED) \* (HoursLED \* 365) / 1000) \* ISRLED

Peak Demand Impact (kW) = ((WattsBase -WattsLED) / 1000) \* CF \* ISRLED

#### Residential LED, 120 Watt incandescent reflector equivalent (rated lumens between 1682 and 2339)

Energy Impact (kWh) = ((WattsBase -WattsLED) \* (HoursLED \* 365) / 1000) \* ISRLED

Peak Demand Impact (kW) = ((WattsBase -WattsLED) / 1000) \* CF \* ISRLED

#### Residential LED, 150 Watt incandescent reflector equivalent (rated lumens between 2340 and 3075)

Energy Impact (kWh) = ((WattsBase -WattsLED) \* (HoursLED \* 365) / 1000) \* ISRLED

Peak Demand Impact (kW) = ((WattsBase -WattsLED) / 1000) \* CF \* ISRLED

### Definition of Terms

WattsLED = Manufacturer-claimed wattage shown on product packaging

HoursLED = Average hours of use per day per LED

ISRLED = Residential LED in-service rate—the percentage of units rebated that actually get installed

CF= Demand Coincidence Factor (See Section 1.4)

Table 2‑54: Residential LED Variables

|  |  |  |  |
| --- | --- | --- | --- |
| Variable | Type | Value | Source |
| WattsBase | Fixed | See Table 2‑52 and Table 2‑53 | Table 2‑52 and Table 2‑53 |
| WattsLED | Fixed | Variable | Data Gathering |
| HoursLED | Fixed | 3 | 1 |
| CF | Fixed | 5% | 2 |
| ISRLED | Fixed | 95%[[111]](#footnote-123) | 3 |

**Sources**:

1. US Department of Energy, Energy Star Calculator. Accessed 3-16-2009
2. 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.
3. Mid-Atlantic TRM, version 2.0. Prepared by Vermont Energy Investment Corporation. Facilitated and managed by the Northeast Energy Efficiency Partnerships. July 2011.

### Measure Life

Residential LED Measure Life is 13.7 yrs[[112]](#footnote-124).

## Residential Occupancy Sensors

This protocol is for the installation of occupancy sensors inside residential homes or common areas.

### Algorithms

ΔkWh = kWcontrolled x 365 x (RHold – RHnew)

ΔkWpeak = 0

### Definition of Terms

kWcontrolled = Wattage of the fixture being controlled by the occupancy sensor (in kilowatts)

365 = Days per year

RHold = Daily run hours before installation

RHnew = Daily run hours after installation

Table 2‑55: Residential Occupancy Sensors Calculations Assumptions

|  |  |  |  |
| --- | --- | --- | --- |
| **Component** | **Type** | **Value** | **Source** |
| kWcontrolled | Variable | EDC’s Data Gathering | AEPS Application; EDC’s Data Gathering |
| RHold | Fixed | 3.0 | 1 |
| RHnew | Fixed | 2.1 (70% of RHold) | 2 |

**Sources:**

1. US Department of Energy, Energy Star Calculator. Accessed 3-16-2009.
2. Lighting control savings fractions consistent with current programs offered by National Grid, Northeast Utilities, Long Island Power Authority, NYSERDA, and Energy Efficient Vermont

### Measure Life

The expected measure life is10 years**[[113]](#footnote-125)**.

## Holiday Lights

|  |  |
| --- | --- |
| Measure Name | Holiday Lights |
| Target Sector | Residential Applications |
| Measure Unit | One 25-bulb Strand of Holiday lights |
| Unit Energy Savings | 10.6 kWh |
| Unit Peak Demand Reduction | 0 kW |
| Measure Life | 10 years |

Light Emitting Diode (LED) holiday lights are a relatively new application for this existing technology. LED holiday lights reduce energy consumption up to 90%. Up to 25 strands can be connected end-to-end in terms of residential grade lights. Commercial grade lights require different power adapters and as a result, more strands can be connected end-to-end.

### Eligibility

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

ΔkWh C9 = [ (INCC9 – LEDC9)) X #BULBS X #STRANDS X HR] / 1000

ΔkWh C7 = [ (INCC7 – LEDC7) X #BULBS X #STRANDS X HR] / 1000

ΔkWh mini = [ (INCmini - LEDmini) X #BULBS X #STRANDS X HR] / 1000

#### Key assumptions

* All estimated values reflect the use of residential (25ct.). per strand).) bulb LED holiday lighting.
* Secondary impacts for heating and cooling were not evaluated.
* It is assumed that 50% of rebated lamps are of the “mini” variety, 25% are of the “C7” variety, and 25% are of the “C9” variety1. If the lamp type is known or fixed by program design, then the savings can be calculated as described by the algorithms.follows. Otherwise, the savings for the “mini”, “C7”, and “C9” varieties should be weighted by 0.5, 0.25 and 0.25 respectively.

### Definition of Terms

LEDmini = Wattage of LED mini bulbs

INCmini = Wattage of incandescent mini bulbs

LEDC7 = Wattage of LED C7 bulbs

INCC7 = Wattage of incandescent C7bulbs

LEDC9 = Wattage of LED C9 bulbs

INCC9 = Wattage of incandescent C9 bulbs

#Bulbs = Number of bulbs per strand

#Strands = Number of strands of lights per package

Hr = Annual hours of operation

Table 2‑56: Holiday Lights Assumptions

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | **Type** | **Value** | **Source** |
| LEDmini | Fixed | 0.08 W | 1 |
| INCmini | Fixed | 0.48 W | 1 |
| LEDC7 | Fixed | 0.48 W | 1 |
| INCC7 | Fixed | 6.0 W | 1 |
| LEDC9 | Fixed | 2.0 W | 1 |
| INCC9 | Fixed | 7.0 W | 1 |
| WMini | Fixed | 0.5 | 1 |
| WC7 | Fixed | 0.25 | 1 |
| WC9 | Fixed | 0.25 | 1 |
| #Bulbs | Variable | Variable | EDC Data Gathering |
| #Strands | Variable | Variable | EDC Data Gathering |
| Hr | Fixed | 150 | 1 |

**Sources:**

1. The DSMore Michigan Database of Energy Efficiency Measures: Based on spreadsheet calculations using collected data
2. http://www.energyideas.org/documents/factsheets/HolidayLighting.pdf

### Deemed Savings

The deemed savings for installation of LED C9, C7, and mini lights is 18.7 kWh, 20.7 kWh, and 1.5 kWh, respectively. The weighted average savings are 10.6 kWh per strand. There are no demand savings as holiday lights only operate at night. Since the lights do not operate in the summer, the coincidence factor for this measure is 0.0.

### Measure Life

Measure life is 10 years[[114]](#footnote-126),[[115]](#footnote-127).

### Evaluation Protocol

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

## Low Income Lighting (FirstEnergy)

|  |  |
| --- | --- |
| **Measure Name** | **Low Income Lighting (FirstEnergy)** |
| Target Sector | Residential Low-Income Establishments |
| Measure Unit | CFL |
| Unit Energy Savings | Varies |
| Unit Peak Demand Reduction | Varies |
| Measure Life | 12.8 years |

This protocol documents the calculation methodology and the assumptions regarding certain CFLs that are installed directly by contractors as part of the “Warm Extra Measures” program administered in the FirstEnergy territories. These CFLs are specifically installed in locations that are reportedly in use 1 to 2 hours per day.

The Warm Extra Measures program is offered by the Metropolitan Edison, Pennsylvania Electric, and Pennsylvania Power Companies. Warm Extra Measures is a direct install program that layers on top of the existing Warm and Warm Plus programs.

### Eligibility

This protocol concerns the CFLs that are installed only under the WARM Extra Measures program, which are defined as CFLs in fixture that are used between one and two hours per day according to homeowners/tenants. This additional protocol is necessary because the PA TRM assumes three hours of usage per day for most residential lighting applications, while the CFLs in the WARM Extra Measures program are installed expressly in fixtures that are reported to have one to two hours of usage per day.

### Algorithms

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

ΔkW = (Basewatts – CFLwatts ) / 1000 X CF X ISRCFL

### Definition of Terms

Basewatts = Wattage of baseline bulb

CFLwatts = Wattage of CFL

CFLhours = Daily hours of operation for CFL

365 = Days per year

ISRCFL = In-service rate – percent of bulbs installed. Adjustment of this value can be made based on evaluation findings.

CF = Demand Coincidence Factor (See Section 1.4)

Table 2‑57: Low Income Lighting Calculations Assumptions

|  |  |  |  |
| --- | --- | --- | --- |
| **Component** | **Type** | **Value** | **Source** |
| Basewatts | Fixed | See Table 2‑58 | Table 2‑58 |
| CFLwatts | Fixed | Data Gathering | EDC Data Gathering |
| CFLhours: | Fixed | 1.5 | 1 |
| CF | Fixed | 0.05 | 2 |
| ISRCFL | Fixed | 84% | 3, 4 |

**Sources:**

1. Based on EDC program design and a recent CFL survey.
2. 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.
3. Nexus Market Research, “Impact Evaluation of the Massachusetts, Rhode Island and Vermont 2003 Residential Lighting Programs”, Final Report, October 1, 2004, 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 (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. Value subject to update through evaluation.

### Deemed Savings

The deemed savings for the installation of CFL lamps compared to incandescent bulbs are listed in Table 2‑58 below.

Table 2‑58: Energy Savings and Demand Reductions

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **CFLwatts** | **Basewatts** | **CFLhours** | **Energy Savings (kWh)** | **Demand Reduction (kW)** |
| 9 | 40 | 1.5 | 14.3 | 0.00155 |
| 11 | 40 | 1.5 | 13.3 | 0.00145 |
| 13 | 60 | 1.5 | 21.6 | 0.00235 |
| 14 | 60 | 1.5 | 21.2 | 0.00230 |
| 18 | 75 | 1.5 | 26.2 | 0.00285 |
| 19 | 75 | 1.5 | 25.8 | 0.00280 |
| 22 | 75 | 1.5 | 24.4 | 0.00390 |
| 23 | 100 | 1.5 | 35.4 | 0.00385 |
| 26 | 100 | 1.5 | 34.0 | 0.00370 |

### Measure Life

The assumed measure life for a compact fluorescent light bulb is 7,000 hours or 12.8 years for this measure.

### Evaluation Protocol

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

## Water Heater Tank Wrap

|  |  |
| --- | --- |
| **Measure Name** | **Water Heater Tank Wrap** |
| Target Sector | Residential |
| Measure Unit | Tank |
| Unit Energy Savings | Varies |
| Unit Peak Demand Reduction | Varies |
| Measure Life | 7 years |

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

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

### Algorithms

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

ΔkWh

ΔkWpeak

### Definition of Terms

Ubase = Overall heat transfer coefficient of water heater prior to adding tank wrap (Btu/Hr-F-ft­­2).

Uinsul = Overall heat transfer coefficient of water heater after addition of tank wrap (Btu/Hr-F-ft­­2).

Abase = Surface area of storage tank prior to adding tank wrap (square feet)[[116]](#footnote-128)

Ainsul = Surface area of storage tank after addition of tank wrap (square feet)[[117]](#footnote-129).

= Thermal efficiency of electric heater element

Tsetpoint = Temperature of hot water in tank (F).

Tambient = Temperature of ambient air (F).

HOU = Annual hours of use for water heater tank.

CF = Demand Coincidence Factor (See Section 1.4)

3412 = Conversion factor (Btu/kWh)

The U.S. Department of Energy recommends adding a water heater wrap of at least R-8 to any water heater with an existing R-value less than R-24[[118]](#footnote-130). The default inputs for the savings algorithms are given in Table 2‑59. Actual tank and blanket U-values can be used in the above algorithms as long as make/model numbers of the tank and blanket are recorded and tracked by the EDC.

Table 2‑59: Water Heater Tank Wrap – Default Values

|  |  |  |  |
| --- | --- | --- | --- |
| **Component** | **Type** | **Value** | **Source** |
| Rbase | Fixed | 12 | 1 |
| Rinsul | Fixed | 20 | 2 |
| ηElec | Fixed | 0.97 | 3 |
| Thot | Fixed | 120 | 5 |
| Tambient | Fixed | 70 | 5 |
| HOU | Fixed | 8760 | 4 |
| CF | Fixed | 1 | 4 |

**Sources:**

1. The baseline water heater is assumed to have 1 inch of polyurethane foam as factory insulation and an overall R-12.
2. The water heater wrap is assumed to be a fiberglass blanket with R-8, increasing the total to R-20.
3. New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs. October 15, 2010. Prepared by New York Advisory Contractor Team.
4. It is assumed that the tank wrap will insulate the tank during all hours of the year.
5. Program assumption

Table 2‑60: Deemed savings by water heater capacity.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Capacity (gal)** | **Rbase** | **Rinsul** | **Abase (ft2)[[119]](#footnote-131)** | **Ainsul (ft2)[[120]](#footnote-132)** | **ΔkWh** | **ΔkW** |
| 30 | 8 | 16 | 19.16 | 20.94 | 143 | 0.0164 |
| 30 | 10 | 18 | 19.16 | 20.94 | 100 | 0.0114 |
| 30 | 12 | 20 | 19.16 | 20.94 | 73 | 0.0083 |
| 30 | 8 | 18 | 19.16 | 20.94 | 163 | 0.0186 |
| 30 | 10 | 20 | 19.16 | 20.94 | 115 | 0.0131 |
| 30 | 12 | 22 | 19.16 | 20.94 | 85 | 0.0097 |
| 40 | 8 | 16 | 23.18 | 25.31 | 174 | 0.0198 |
| 40 | 10 | 18 | 23.18 | 25.31 | 120 | 0.0137 |
| 40 | 12 | 20 | 23.18 | 25.31 | 88 | 0.0100 |
| 40 | 8 | 18 | 23.18 | 25.31 | 197 | 0.0225 |
| 40 | 10 | 20 | 23.18 | 25.31 | 139 | 0.0159 |
| 40 | 12 | 22 | 23.18 | 25.31 | 103 | 0.0118 |
| 50 | 8 | 16 | 24.99 | 27.06 | 190 | 0.0217 |
| 50 | 10 | 18 | 24.99 | 27.06 | 131 | 0.0150 |
| 50 | 12 | 20 | 24.99 | 27.06 | 97 | 0.0111 |
| 50 | 8 | 18 | 24.99 | 27.06 | 214 | 0.0245 |
| 50 | 10 | 20 | 24.99 | 27.06 | 152 | 0.0173 |
| 50 | 12 | 22 | 24.99 | 27.06 | 113 | 0.0129 |
| 80 | 8 | 16 | 31.84 | 34.14 | 244 | 0.0279 |
| 80 | 10 | 18 | 31.84 | 34.14 | 171 | 0.0195 |
| 80 | 12 | 20 | 31.84 | 34.14 | 125 | 0.0143 |
| 80 | 8 | 18 | 31.84 | 34.14 | 276 | 0.0315 |
| 80 | 10 | 20 | 31.84 | 34.14 | 195 | 0.0223 |
| 80 | 12 | 22 | 31.84 | 34.14 | 145 | 0.0166 |

### Measure Life

The measure life is 7 years[[121]](#footnote-133).

## Pool Pump Load Shifting

|  |  |
| --- | --- |
| **Measure Name** | **Pool Pump Load Shifting** |
| Target Sector | Residential Establishments |
| Measure Unit | Pool Pump Load Shifting |
| Unit Energy Savings | Variable |
| Unit Peak Demand Reduction | Variable |
| Measure Life | 1 year |

Residential pool pumps can be scheduled to avoid the noon to 8 PM peak period.

### Eligibility

This protocol documents the energy savings attributed to schedule residential single speed pool pumps to avoid run during the peak hours from noon to 8PM. The target sector primarily consists of single-family residences. This measure is intended to be implemented by trade allies that participate in in-home audits, or by pool maintenance professionals.

### Algorithms

The residential pool pump reschedule measure is intended to produce demand savings, but if the final daily hours of operation are different than the initial daily hours of operation, an energy savings (or increase) may result. The demand savings result from not running pool pumps during the peak hours during noon to 8PM.

ΔkWh = Δhours/day × DaysOperating × kWpump

ΔkWpeak = (CF­pre - CF­post )× kWpump

The peak coincident factor, CF, is defined as the average coincident factor during noon and 8 PM on summer weekdays. Ideally, the demand coincidence factor for the supplanted single-speed pump can be obtained from the pump’s time clock. The coincidence factor is equal to the number of hours that the pump was set to run between noon and 8 PM, divided by 8.

### Definition of Terms

Δhours/day = The change in daily operating hours.

kWpump = Electric demand of single speed pump at a given flow rate. This quantity should be measured or taken from Table 2‑62

CFpre = Peak coincident factor of single speed pump from noon to 8PM in summer weekday prior to pump rescheduling. This quantity should be inferred from the timer settings

CFpost = Peak coincident factor of single speed pump from noon to 8PM in summer weekday after pump rescheduling. This quantity should be inferred from the new timer settings.

DaysOperating = Days per year pump is in operation. This quantity should be recorded by applicant.

Table 2‑61: Pool Pump Load Shifting Assumptions

|  |  |  |  |
| --- | --- | --- | --- |
| **Component** | **Type** | **Value** | **Source** |
| Δhours/day | Fixed | 0 | 2 |
| kWpump | Fixed | See Table 2‑62 | Table 2‑62 |
| CFpre | Fixed | 0.235 | 3 |
| CFpost | Fixed | 0 | 2 |
| DaysOperating | Fixed | 100 | 1 |

**Sources:**

1. Mid-Atlantic TRM, version 2.0. Prepared by Vermont Energy Investment Corporation. Facilitated and managed by the Northeast Energy Efficiency Partnerships. July 2011.
2. Program is designed to shift load to off-peak hours, not necessarily to reduce load.
3. Derived from Pool Pump and Demand Response Potential, DR 07.01 Report, SCE Design and Engineering, Table 16. Statewide value calculated using the non-weather dependent coincident peak demand calculator with inland valley data.

#### Average Single Speed Pump Electric Demand

Since this measure involves functional pool pumps, actual measurements of pump demand are encouraged. If this is not possible, then the pool pump power can be inferred from the nameplate horsepower. Table 2‑62 shows the average service factor (over-sizing factor), motor efficiency, and electrical power demand per pump size based on California Energy Commission (CEC) appliance database for single speed pool pump[[122]](#footnote-134). Note that the power to horsepower ratios appear high because many pumps, in particular those under 2 HP, have high ‘service factors’. The true motor capacity is the product of the nameplate horsepower and the service factor.

Table 2‑62: Single Speed Pool Pump Specification[[123]](#footnote-135)

|  |  |  |  |
| --- | --- | --- | --- |
| **Pump Horse Power (HP)** | **Average Pump Service Factor\*** | **Average Pump Motor Efficiency\*** | **Average Pump Power (W)\*** |
| 0.50 | 1.62 | 0.66 | 946 |
| 0.75 | 1.29 | 0.65 | 1,081 |
| 1.00 | 1.28 | 0.70 | 1,306 |
| 1.50 | 1.19 | 0.75 | 1,512 |
| 2.00 | 1.20 | 0.78 | 2,040 |
| 2.50 | 1.11 | 0.77 | 2,182 |
| 3.00 | 1.21 | 0.79 | 2,666 |

### Measure Life

The measure life is initially assumed to be one year. If there is significant uptake of this measure then a retention study may be warranted.

### Evaluation Protocol

The most appropriate evaluation protocol for this measure is verification of pool pump run time.

## High Efficiency Two-Speed Pool Pump

The following protocol for the measurement of energy and demand savings applies to the installation of efficient two-speed residential pool pump motors in place of a standard single speed motor of equivalent horsepower for residents with swimming pools. Pool pumps and motors are one of a home’s highest energy consuming technologies.

### Eligibility

High efficiency motors (capacitor start, capacitor run) and high efficiency pumps should be required. Qualifying two speed systems must be able to reduce flow rate by 50% and provide temporary override to full flow for startup and cleaning. All systems should be encouraged to perform filtering and cleaning during off peak hours.

### Algorithms

ΔkWh = kWhbase – kWhtwo speed

ΔkWpeak =(kWbase – kWtwo speed) x CF

### Definition of Terms

kWhbase = Assumed annual kWh consumption for a standard single speed pump motor in a cool climate (assumes 100 day pool season)

kWhtwo speed = Assumed annual kWh consumption for two speed pump motor in a cool climate

kWbase = Assumed connected load of a standard two speed pump motor

RHRS = Annual run hours of the baseline and efficient motor

CF = Demand Coincidence Factor (See Section 1.4)

Table 2‑63: High Efficiency Pool and Motor – Two Speed Pump Calculations Assumptions

|  |  |  |  |
| --- | --- | --- | --- |
| **Component** | **Type** | **Value** | **Source** |
| kWhBase | Fixed | 707 kWh | 1 |
| kWhTwo Speed | Fixed | 177 kWh | 1 |
| kWBase | Fixed | 1.364 kW | 1 |
| kWTwo Speed | Fixed | 0.171 kW | 1 |
| RHRSBase | Fixed | 518 | 1 and 2 |
| RHRSTwo Speed | Fixed | 1,036 | 1 and 2 |
| CF | Fixed | 0.235% | 3 |

**Sources:**

1. Mid-Atlantic TRM, version 2.0. Prepared by Vermont Energy Investment Corporation. Facilitated and managed by the Northeast Energy Efficiency Partnerships. July 2011.
2. Assumes 100 day pool season and 5.18 hours per day for the base condition and an identically sized two speed pump operating at 50% speed for 10.36 hours per day.
3. Derived from Pool Pump and Demand Response Potential, DR 07.01 Report, SCE Design and Engineering, Table 16. Statewide value calculated using the non-weather dependent coincident peak demand calculator with inland valley data.

Table 2‑64: Two-Speed Pool Pump Deemed Savings Values

|  |  |
| --- | --- |
| **Average Annual kWh Savings per Unit** | **Average Summer Coincident Peak kW Savings per unit** |
| 530 kWh | 0.280 kW |

### Measure Life

The estimated useful life for a variable speed pool pump is 10 years.[[124]](#footnote-136)

## Variable Speed Pool Pumps (with Load Shifting Option)

|  |  |
| --- | --- |
| **Measure Name** | **Residential VFD Pool Pumps** |
| Target Sector | Residential Establishments |
| Measure Unit | VFD Pool Pumps |
| Unit Energy Savings | Variable |
| Unit Peak Demand Reduction | Variable |
| Measure Life | 10 years |

This measure has two potential components. First, a variable speed pool pump must be purchased and installed on a residential pool. Second, the variable speed pool pump may be commissioned such that it does not operate in the noon to 8 PM period (on weekdays). This second, optional step is referred to as *load shifting*. Residential variable frequency drive pool pumps can be adjusted so that the minimal required flow is achieved for each application. Reducing the flow rate results in significant energy savings because pump power and pump energy usage scale with the cubic and quadratic powers of the flow rate respectively. Additional savings are achieved because the VSD pool pumps typically employ premium efficiency motors. Since the only difference between the VSD pool pump without load shifting and VSD pool pump with load shifting measures pertains to the pool pump operation schedule, this protocol is written in such that it may support both measures at once.

### Eligibility

To qualify for the load shifting rebate, the pumps are required to be off during the hours of noon to 8 PM. This practice results in additional demand reductions.

### Algorithms

This protocol documents the energy savings attributed to variable frequency drive pool pumps in various pool sizes. The target sector primarily consists of single-family residences.

ΔkWh = kWhbase - kWhVFD

kWhbase = (hSS­ X kWSS) X Days/year

kWhVFD = (hVFD XkWVFD) X Days/year

The demand reductions are obtained through the following formula:

ΔkWpeak = kWbase - kWVFD

kWbase = (CFSS­ × kWSS)

kWVFD = (CFVFD × kWVFD)

The peak coincident factor, CF, is defined as the average coincident factor during noon and 8 PM on summer weekdays. Ideally, the demand coincidence factor for the supplanted single-speed pump can be obtained from the pump’s time clock. The coincidence factor is equal to the number of hours that the pump was set to run between noon and 8 PM, divided by 8. If this information is not available, the recommended daily hours of operation to use are 5.18 and the demand coincidence factor is 0.27. These operation parameters are derived from the 2011 Mid Atlantic TRM.

### Definition of Terms

The parameters in the above equation are listed below.

HSS = Hours of operation per day for Single Speed Pump. This quantity should be recorded by the applicant.

HVFD = Hours of operation per day for Variable Frequency Drive Pump. This quantity should be recorded by the applicant.

Days/yr = Pool pump days of operation per year.

WSS = Electric demand of single speed pump at a given flow rate. This quantity should be recorded by the applicant or looked up through the horsepower in Table 1-1.

WVFD = Electric demand of variable frequency drive pump at a given flow rate. This quantity should be measured and recorded by the applicant.

CFSS = Peak coincident factor of single speed pump from noon to 8 PM in summer weekday. This quantity can be deduced from the pool pump timer settings for the old pump.

CFVFD = Peak coincident factor of VFD pump from noon to 8 PM in summer weekday. This quantity should be inferred from the new timer settings.

Table 2‑65: Residential VFD Pool Pumps Calculations Assumptions

|  |  |  |  |
| --- | --- | --- | --- |
| **Component** | **Type** | **Values** | **Source** |
| HSS | Variable | Default: 5.18 | 2 |
| HVFD | Variable | Default: 13.00 | 2 |
| Days/yr | Fixed | Default: 100 | 2 |
| WSS | Variable | EDC Data Gathering  Default: See Table 2‑66 | 1 and Table 2‑66 |
| WVFD | Variable | EDC Data Gathering | EDC Data Gathering |
| CFSS | Variable | Default: 0.235 | 3 |
| CFVFD | Fixed | 0 | Program Design |

**Sources:**

1. “CEC Appliances Database – Pool Pumps.” *California Energy Commission.* Updated Feb 2008. Accessed March 2008.  [http://www.energy.ca.gov/appliances/database/historical\_excel\_files/2009-03-01\_excel\_based\_files/Pool\_Products/Pool\_Pumps.zip]( http://www.energy.ca.gov/appliances/database/historical_excel_files/2009-03-01_excel_based_files/Pool_Products/Pool_Pumps.zip)
2. Mid-Atlantic TRM, version 2.0. Prepared by Vermont Energy Investment Corporation. Facilitated and managed by the Northeast Energy Efficiency Partnerships. July 2011.
3. Derived from Pool Pump and Demand Response Potential, DR 07.01 Report, SCE Design and Engineering, Table 16. Statewide value calculated using the non-weather dependent coincident peak demand calculator with inland valley data.

#### Average Single Speed Pump Electric Demand

Since this measure involves functional pool pumps, actual measurements of pump demand are encouraged. If this is not possible, then the pool pump power can be inferred from the nameplate horsepower. Table 2‑66 shows the average service factor (over-sizing factor), motor efficiency, and electrical power demand per pump size based on California Energy Commission (CEC) appliance database for single speed pool pump[[125]](#footnote-137). Note that the power to horsepower ratios appear high because many pumps, in particular those under 2 HP, have high ‘service factors’. The true motor capacity is the product of the nameplate horsepower and the service factor.

Table 2‑66: Single Speed Pool Pump Specification[[126]](#footnote-138)

|  |  |  |  |
| --- | --- | --- | --- |
| **Pump Horse Power (HP)** | **Average Pump Service Factor** | **Average Pump Motor Efficiency** | **Average Pump Power (W)** |
| 0.50 | 1.62 | 0.66 | 946 |
| 0.75 | 1.29 | 0.65 | 1,081 |
| 1.00 | 1.28 | 0.70 | 1,306 |
| 1.50 | 1.19 | 0.75 | 1,512 |
| 2.00 | 1.20 | 0.78 | 2,040 |
| 2.50 | 1.11 | 0.77 | 2,182 |
| 3.00 | 1.21 | 0.79 | 2,666 |

#### Electric Demand and Pump Flow Rate

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

Demand (W) = 0.0978f2 + 10.989f +10.281

Where f is the pump flow rate in gallons per minute.

This regression can be used if the flow rate is known but the wattage is unknown. However, most VFD pool pumps can display instantaneous flow and power. Power measurements or readings in the final flow configuration are encouraged.

### Deemed Savings

The energy savings and demand reductions are prescriptive according to the above formulae. All other factors held constant, the sole difference between quantifying demand reductions for the *VSD Pool Pump* and the *VSD Pool Pump with Load Shifting* measures resides in the value of the parameter **CFVFD.**

### Measure Life

According to an October 2008 report for the CA Database for Energy Efficiency Resources[[127]](#footnote-139), a variable speed drive’s lifespan is 10 years.

### Evaluation Protocol

The most appropriate evaluation protocol for this measure is verification of installation coupled with survey on run time and speed settings.

# Commercial and Industrial Measures

The following section of the TRM contains savings protocols for 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. Per Section 501.1 of IECC 2009, “[t]he requirements contained in [chapter 5 of IECC 2009] are applicable to commercial buildings, or portions of commercial buildings. These commercial buildings shall meet either the requirements of ANSI/ASHRAE/IESNA Standard 90.1, *Energy Stadnard for Buildings Except for Low-Rise Residnetial Buildings*, or the requirements contain in [chapter 5 of IECC 2009]”. As noted in Section 501.2, as an alternative to complying with Sections 502, 503, 504, and 505 of IECC 2009, commercial building projects “shall comply with the requirements of ANSI/ASHRAE/IESNA 90.1 in its entirety.”

In accordance with IECC 2009, commercial protocols relying on code standards as the baseline condition may refer to either IECC 2009 or ASHRAE 90.1-2007 per the program design.

## 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.

For solid state lighting products, please see Section 5.5 for specific eligibility requirements.

### 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 = kWhbase – kWhee

kWhbase = kWbase X(1+IF energy) X HOU

kWhee = kWee X(1+IF energy) X HOU X (1 – SVG)

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, Prescriptive Lighting Improvements.

### 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 post-retrofit or energy-efficient lighting system as defined in Section 3.2.5.

CF = Demand Coincidence Factor (See Section 1.4)

HOU = Hours of Use – 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 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

### 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 in Section 3.2.2 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, and information on pre-installation conditions include, at a minimum, lamp type, lamp wattage, ballast type and fixture configuration (2 lamp, 4 lamp, etc.).

#### 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 3.2.2, 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 (HOU), coincidence factors (CF) or interactive factors (IF), the ΔkW will be broken out to account for these different factors. This will be accomplished using Appendix C, a Microsoft Excel inventory form that specifies the lamp and ballast configuration using the Standard Wattage Table and SVG, HOU, CF and IF values for each line entry. The inventory will also specify the location and number of fixtures for reference and validation.

Appendix 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 required to calculate savings. 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[[128]](#footnote-147). 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%[[129]](#footnote-148) 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 connected load savings less than 20 kW

For projects with connected load savings less than 20 kW, apply stipulated whole building hours shown in Table 3‑4. If the project cannot be described by the categories listed in Table 3‑4, select the “other” category and determine hours using facility staff interviews, posted schedules, or metered data.

EDC evaluation contractors are permitted to revise HOU values if the perceived difference in hours stated in tables is greater than 10%.

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

For projects with connected load savings of 20 kW or higher, fixtures should be separated into "usage groups" that exhibit similar usage patterns. Usage groups should be considered and used at the discretion of the EDCs’ implementation and evaluation contractors in place of stipulated whole building hours, but are not required. Use of usage groups may be subject to SWE review. Annual hours of use values should be estimated for each group using Table 3‑4, facility staff interviews, posted schedules, or metered data.

Metered data is required for projects with high uncertainty, i.e. where hours are unknown, variable, or difficult to verify. Exact conditions of “high uncertainty” are to be determined by the EDC evaluation contractors to appropriately manage variance. Metering is also required when the connected load savings for a project exceeds 200 kW. Metering completed by the implementation contractor maybe leveraged by the evaluation contractor, subject to a reasonableness review. Sampling methodologies within a site are to be discerned by the EDC evaluation contractor based on the characteristics of the facility in question.

For all projects, annual hours are subject to adjustment by EDC evaluators or SWE.







### 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 to determine the baseline demand (kWbase) and the new fixtures’ wattages as the post-installation demand (kWee). Pursuant to ASHRAE 90.1-2007, the interior lighting baseline is calculated using either the Building Area Method[[130]](#footnote-154) as shown in Table 3‑1, or the Space-by-Space Method[[131]](#footnote-155) as shown in Table 3‑2. For exterior lighting, the baseline is calculated using the Baseline Exterior Lighting Power Densities[[132]](#footnote-156) as shown in Table 3‑3. The new fixture wattages are specified in the Lighting Audit and Design Tool shown in Appendix C.

CF and IF values are the same as those shown in Table 3‑4 and Table 3‑5. HOU shall be determined in accordance with Section 3.2.6.

HOU and CF values for dusk-to-dawn lighting isare the same as those shown in Table 3‑4 unless shorter hours are required by ASHRAE or the fixtures are demonstrated to operate longer hours (e.g. for signage or shading in a parking garage).

Table 3‑1: Lighting Power Densities from ASHRAE 90.1-2007 Building Area Method[[133]](#footnote-158)

| **Building Area Type[[134]](#footnote-159)** | **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 | 1.2 |
| Hotel | 1.0 | Sports arena | 1.1 |
| Library | 1.3 | 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 3‑2: Lighting Power Densities from ASHRAE 90.1-2007 Space-by-Space Method[[135]](#footnote-160)

| **Common Space Type[[136]](#footnote-161)** | **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 |

Table 3‑3: Baseline Exterior Lighting Power Densities[[137]](#footnote-162)

| **Building Exterior** | **Space Description** | **LPD** |
| --- | --- | --- |
| Uncovered Parking Area | Parking Lots and Drives | 0.15 W/ft2 |
| Building Grounds | Walkways less than 10 ft wide | 1.0 W/linear foot |
| Walkways 10 ft wide or greater | 0.2 W/ft2 |
| Plaza areas |
| Special feature areas |
| Stairways | 1.0 W/ft2 |
| Building Entrances and Exits | Main entries | 30 W/linear foot of door width |
| Other doors | 20 W/linear foot of door width |
| Canopies and Overhangs | Free standing and attached and overhangs | 1.25 W/ft2 |
| Outdoor sales | Open areas (including vehicle sales lots) | 0.5 W/ft2 |
| Street frontage for vehicle sales lots in addition to “open area” allowance | 20 W/linear foot |
| Building facades |  | 0.2 W/ft2 foreach illuminated wall or surface or 5.0 W/linear foot for each illuminated wall or surface length |
| Automated teller machines and night depositories |  | 270 W per location plus 90 W per additional ATM per location |
| Entrances and gatehouse inspection stations at guarded facilities |  | 1.25 W/ft2 of uncovered area |
| Loading areas for law enforcement, fire, ambulance, and other emergency service vehicles |  | 0.5 W/ft2 of uncovered area |
| Drive-through windows at fast food restaurants |  | 400 W per drive-through |
| Parking near 24-hour retail entrances |  | 800 W per main entry |

#### 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 fixtures with the existing lamps and ballast as defined in Appendix C. Other factors required to calculate savings are shown in Table 3‑4 and Table 3‑5. Note that if HOU is stated and verified by logging lighting hours of use groupings, actual hours should be applied. The IF factors shown in Table 3‑5 are to be used only when the facilities are air conditioned and only for fixtures in conditioned or refrigerated space. The HOU for refrigerated spaces are to be estimated or logged separately. To the extent that operating schedules are known, site-specific coincidence factors may be calculated using the non-weather dependent peak demand calculator in place of the default coincidence factors provided in Table 3‑4.

Table 3‑4: Lighting HOU and CF by Building Type or Function

| **Building Type** | **HOU** | **CF[[138]](#footnote-163)** | **Source** |
| --- | --- | --- | --- |
| Auto Related | 4,056 | 0.77\* | 5 |
| Daycare | 2,590 | 0.77\* | 6 |
| Dusk-to-Dawn Lighting | 4,300 | 0.00 | 1 |
| 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[[139]](#footnote-164) | 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[[140]](#footnote-165) | 1.00 | 1 |
| Light Manufacturing (Assy) | 2,610 | 0.77\* | 5 |
| Manufacturing – Light Industrial | 4,290 | 0.63 | 1 |
| Nursing Home | 5,840 | 0.77\* | 5 |
| 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 |
| Warehouse (Refrigerated) | 2,602 | 0.77\* | 5 |
| 24/7 Facilities or Spaces | 8,760 | 1.00 | N/A |
| Other[[141]](#footnote-166) | Varies | Varies | 1 |

\* 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 library 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 Floor space, 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 Floor space, 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 3‑5: Interactive Factors and Other Lighting Variables

|  |  |  |  |
| --- | --- | --- | --- |
| **Component** | **Type** | **Value** | **Source** |
| IFdemand | Fixed | Cooled space (68 °F – 79 °F) = 0.34 | 1 |
| Freezer spaces (-20 °F – 27 °F) = 0.50 |
| Medium-temperature refrigerated spaces (28 °F – 40 °F) = 0.29 |
| High-temperature refrigerated spaces (47 °F – 60 °F) = 0.18 |
| Un-cooled space = 0 |
| IFenergy | Fixed | Cooled space (68 °F – 79 °F) = 0.12 | 1 |
| Freezer spaces (-20 °F – 27 °F) = 0.50 |
| Medium-temperature refrigerated spaces (28 °F – 40 °F) = 0.29 |
| High-temperature refrigerated spaces (47 °F – 60 °F) = 0.18 |
| Un-cooled 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 turn lights on and off automatically, which are activated by time, light, motion, or sound. The measurement of energy savings is based on algorithms with key variables (e.g. coincidence factor, hours of use) 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 3‑6.

If a lighting improvement consists of solely lighting controls, the lighting fixture baseline is the existing fixtures with the existing lamps and ballasts or, if retrofitted, new 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.

For new construction scenarios, baseline for lighting controls is defined by either IECC or ASHRAE 90.1, based on the EDC program design. See Section 3.1 for more detail.

Table 3‑6: 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%[[142]](#footnote-167) | 2 and 3 |
| Daylight Dimmer System=50%[[143]](#footnote-168) |
| Based on metering | EDC Data Gathering |
| CF | Variable | By building type and size | See Table 3‑4 |
| HOU | Variable | By building type and size | See Table 3‑4 |
| IF | Variable | By building type and size | See Table 3‑5 |

**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[[144]](#footnote-169).

#### LED Traffic Signals

Traffic signal lighting improvements use the lighting algorithms with the assumptions set forth below. Projects implementing LED traffic signs and no other lighting measures are not required to fill out Appendix C because the assumptions effectively deem savings.

Table 3‑7: Assumptions for LED Traffic Signals

|  |  |  |  |
| --- | --- | --- | --- |
| **Component** | **Type** | **Value** | **Source** |
| ΔkW | Variable | See Table 3‑8 | PECO |
| CF | Red Round | 55% | PECO |
| Yellow Round | 2% |
| Round Green | 43% |
| Turn Yellow | 8% |
| Turn Green | 8% |
| Pedestrian | 100% |
| HOU | Variable | See Table 3‑8 | PECO |
| IF | Fixed | 0 |  |

Table 3‑8: LED Traffic Signals[[145]](#footnote-170)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Type** | **Wattage** | **% Burn** | **HOU** | **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 3‑9: 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. If the exit signs match those listed in Table 3‑10, the deemed savings value for LED exit signs can be used without completing Appendix C. The deemed savings for this measure are:

#### Single-Sided LED Exit Signs replacing Incandescent Exit Signs

ΔkWh = 176 kWh

ΔkWpeak = 0.024 kW

#### Dual-Sided LED Exit Signs replacing Incandescent Exit Signs

ΔkWh = 353 kWh

ΔkWpeak = 0.048 kWh

#### Single-Sided LED Exit Signs replacing Fluorescent Exit Signs

ΔkWh = 69 kWh

ΔkWpeak = 0.009 kW

#### Dual-Sided LED Exit Signs replacing Fluorescent Exit Signs

ΔkWh = 157 kWh

ΔkWpeak = 0.021 kW

The savings are calculated using the algorithms in Section 3.2.2 with assumptions in Table 3‑10.

Table 3‑10: LED Exit Signs

|  |  |  |  |
| --- | --- | --- | --- |
| **Component** | **Type** | **Value** | **Source** |
| kW*base* | Fixed | Single-Sided Incandescent: 20W  Dual-Sided Incandescent: 40W  Single-Sided Fluorescent: 9W  Dual-Sided Fluorescent: 20W | Appendix C: Standard Wattage Table |
| Actual Wattage | EDC Data Gathering |
| kW*inst* | Fixed | Single-Sided: 2W  Dual-Sided: 4W | Appendix C: Standard Wattage Table |
| Actual Wattage | EDC Data Gathering |
| CF | Fixed | 1.0 | 1 |
| HOU | Fixed | 8760 | 1 |
| IFenergy | Fixed | Cooled Space: 0.12 | Table 3-6 |
| IFdemand | Fixed | Cooled Space: 0.34 | Table 3-6 |

**Sources:**

1. WI Focus on Energy,“*Business Programs: Deemed Savings Manual V1.0*.” Update Date: March 22, 2010. LED Exit Sign.

## Premium Efficiency Motors

For constant speed and uniformly loaded motors, the prescriptive measurement and verification protocols described below apply for replacement of old motors with new energy efficient motors of the same rated horsepower and for New Construction. Replacements where the old motor and new motor have different horsepower ratings are considered custom measures. Motors with variable speeds, variable loading, or industrial-specific applications are also considered custom measures.

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:

ΔkWh = kWhbase - kWhee

kWhbase = 0.746 X HP X LF/ηbase X RHRS

kWhee = 0.746 X HP X LF/ηee X RHRS

ΔkWpeak = kWbase - kWee

kWbase = 0.746 X HP X LF/ηbase X CF

kWee = 0.746 X HP X LF/ηee X CF

### Definition of Terms

HP = Rated horsepower of the baseline and energy efficient motor

LF = Load Factor. Ratio between the actual load and the rated load. Motor efficiency curves typically result in motors being most efficient at approximately 75% of the rated load. The default value is 0.75. Variable loaded motors should use custom measure protocols.; LF = Measured motor kW / (Rated motor HP x 0.746 /nameplate efficiency)[[146]](#footnote-171)

ηbase = Efficiency of the baseline motor

ηee = Efficiency of the energy-efficient motor

RHRS = Annual run hours of the motor

CF = Demand Coincidence Factor (See Section 1.4)

### Description of Calculation Method

Relative to the algorithms in section (3.3.1), ΔkW values will be calculated for each motor improvement in any project (account number). For the efficiency of the baseline motor, if a new motor was purchased as an alternative to rewinding an old motor, the nameplate efficiency of the old motor may be used as the baseline.

Table 3‑11: Building Mechanical System Variables for Premium Efficiency Motor Calculations

|  |  |  |  |
| --- | --- | --- | --- |
| **Component** | **Type** | **Value** | **Source** |
| HP | Variable | Nameplate | EDC Data Gathering |
| RHRS[[147]](#footnote-172) | Variable | Based on logging and modeling | EDC Data Gathering |
| Default Table 3‑14 | From Table 3‑14 |
| LF[[148]](#footnote-173) | Variable | Based on spot metering[[149]](#footnote-174) | EDC Data Gathering |
| Default 75% | 1 |
| ηbase | Variable | Early Replacement: Nameplate | EDC Data Gathering |
| New Construction or Replace on Burnout: Default comparable standard motor.  For PY1 and PY2, EPACT Standard (See Table 3-13). For PY3 and PY3, NEMA Premium (See Table 3-14) | From Table 3‑12 for PY1 and PY2.  From Table 3‑13 for PY3 and PY4. |
| ηee | Variable | Nameplate | EDC Data Gathering |
| CF[[150]](#footnote-175) | Variable | Single Motor Configuration: 74%  Duplex Motor Configuration: 37% | 1 |

**Sources:**

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

Table 3‑12: Baseline Motor Nominal Efficiencies for PY1 and PY2[[151]](#footnote-176)

| **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 3‑13: Baseline Motor Nominal Efficiencies for PY3 and PY4[[152]](#footnote-177)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **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 3‑14: Stipulated Hours of Use for Motors in Commercial Buildings

| **Building Type** | **Motor Usage Group** | **RHRS[[153]](#footnote-178)** |
| --- | --- | --- |
| 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 | 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 | Chilled Water Pump | 2170 |
| Heating Hot Water Pump | 4959 |
| Condenser Water Pump | 2170 |
| HVAC Fan | 5236 |
| Cooling Tower Fan | 1032 |
| Other | 3113 |

**Sources:**

1. Motor Inventory Form, PA Technical Working Group. (See notes below in Table 3‑15)
2. Other category calculated based on simple averages.

Table 3‑15: 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[[154]](#footnote-179) (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>

### Evaluation Protocol

Motor projects achieving reported savings greater than 50,000 kWh and selected in the evaluator sample must be metered to verify reported savings. In addition, if any motor within a sampled project uses the other category to stipulate hours, the threshold is decreased to 25,000 kWh. Metering is not mandatory where the motors in question are constant speed and hours can be easily verified through a building automation system schedule that clearly shows motor run time.

## 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 3‑17: The baseline condition is a motor without a VFD control. The efficient condition is a motor with a VFD control.

### Algorithms

ΔkWh = 0.746 X HP X LF / ηmotor X RHRSbase X ESF

ΔkWpeak = 0.746 X HP X LF / ηmotor X CF X DSF

### Definitions of Terms

HP = Rated horsepower of the motor

LF = Load Factor. Ratio between the actual load and the rated load. Motor efficiency curves typically result in motors being most efficient at approximately 75% of the rated load. The default value is 0.75. Variable loaded motors should use custom measure protocols.[[155]](#footnote-181)

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 (See Section 1.4)

ESF = Energy Savings Factor. Percent of baseline energy consumption saved by installing VFD.

DSF = Demand Savings Factor. Percent of baseline demand saved by installing VFD

### Description of Calculation Method

Relative to the algorithms in section (3.4.1), ΔkW values will be calculated for each VFD improvement in any project (account number).

Table 3‑16: Variables for VFD Calculations

|  |  |  |  |
| --- | --- | --- | --- |
| **Component** | **Type** | **Value** | **Source** |
| Motor HP | Variable | Nameplate | EDC Data Gathering |
| RHRS[[156]](#footnote-184) | Variable | Based on logging and modeling | EDC Data Gathering |
| Table 3‑14 | See Table 3‑14 |
| LF[[157]](#footnote-185) | Variable | Based on spot metering and nameplate | EDC Data Gathering |
| Default 75% | 1 |
| ESF | Variable | See Table 3‑17 | See Table 3‑17 |
| DSF | Variable | See Table 3‑17 | See Table 3‑17 |
| Efficiency - ηbase | Fixed | Nameplate | EDC Data Gathering |
| CF[[158]](#footnote-186) | Fixed | 74% | 1 |

**Sources:**

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

Table 3‑17: ESF and DSF for Typical Commercial VFD Installations[[159]](#footnote-187)

|  |  |  |
| --- | --- | --- |
| **HVAC Fan VFD Savings Factors** | | |
| **Baseline** | **ESF** | **DSF** |
| Constant Volume | 0.717 | 0.466 |
| Air Foil/Backward Incline | 0.475 | 0.349 |
| Air Foil/Backward Incline with Inlet Guide Vanes | 0.304 | 0.174 |
| Forward Curved | 0.240 | 0.182 |
| Forward Curved with Inlet Guide Vanes | 0.123 | 0.039 |
| **HVAC Pump VFD Savings Factors** | | |
| **System** | **ESF** | **DSF** |
| Chilled Water Pump | 0.580 | 0.401 |
| Hot Water Pump | 0.646 | 0.000 |



### Evaluation Protocol

VFD projects achieving reported savings greater than 50,000 kWh and selected in the evaluator sample must be metered to verify reported savings. In addition, if any VFD within a sampled project uses the other category to stipulate hours, the threshold is decreased to 25,000 kWh. Metering is not mandatory where hours can be easily verified through a building automation system schedule that clearly shows motor run time.

## Variable Frequency Drive (VFD) 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 that have 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 Terms

HP = Rated horsepower of the motor

LF = Load Factor. Ratio between the actual load and the rated load. Motor efficiency curves typically result in motors being most efficient at approximately 75% of the rated load. The default value is 0.75.[[160]](#footnote-188)

ηbase = Efficiency of the baseline motor

RHRS = Annual run hours of the motor

CF = Demand Coincidence Factor (See Section 1.4)

Table 3‑18: 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.[[161]](#footnote-189)

## HVAC Systems

The energy and demand savings for Commercial and Industrial HVAC is determined from the algorithms listed in below. This protocol excludes water source, ground source, and groundwater source heat pumps.

### Algorithms

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

For A/C units < 65,000 BtuH, use SEER instead of EER to calculate ΔkWh and convert SEER to EER to calculate ΔkWpeak using 11.3/13 as the conversion factor.

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

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

#### Air Source and Packaged Terminal Heat Pump

For ASHP units < 65,000 BtuH, use SEER instead of EER to calculate ΔkWhcool and HSPF instead of COP to calculate ΔkWhheat. Convert SEER to EER to calculate ΔkWpeak using 11.3/13 as the conversion factor.

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

### Definition of Terms

BtuHcool = Rated cooling capacity of the energy efficient unit in BtuHcool

BtuHheat = Rated heating capacity of the energy efficient unit in BtuHheat

EERbase = Efficiency rating of the baseline unit. For air-source AC and ASHP units < 65,000 BtuH, SEER should be used for cooling savings.

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

SEERbase = Seasonal efficiency rating of the baseline unit. For units > 65,000 BtuH, EER should be used for cooling savings.

SEERee = Seasonal efficiency rating of the energy efficiency unit. For units > 65,000 BtuH, EER should be used for cooling savings.

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

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

HSPFbase = Heating seasonal performance factor of the baseline unit. For units > 65,000 BtuH, COP should be used for heating savings.

HSPFee = Heating seasonal performance factor of the energy efficiency unit. For units > 65,000 BtuH, COP should be used for heating savings.

CF = Demand Coincidence Factor (See Section 1.4)

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.

11.3/13 = Conversion factor from SEER to EER, based on average EER of a SEER 13 unit. See Section 2.1.

Table 3‑19: Variables for HVAC Systems

| **Component** | **Type** | **Value** | **Source** |
| --- | --- | --- | --- |
| BtuH | Variable | Nameplate data (AHRI or AHAM) | EDC’s Data Gathering |
| EERbase | Variable | Early Replacement: Nameplate data | EDC’s Data Gathering |
| New Construction or Replace on Burnout: Default values from Table 3‑20 | See Table 3‑20 |
| EERee | Variable | Nameplate data (AHRI or AHAM) | EDC’s Data Gathering |
| SEERbase | Variable | Early Replacement: Nameplate data | EDC’s Data Gathering |
| New Construction or Replace on Burnout: Default values from Table 3‑20 | See Table 3‑20 |
| SEERee | Variable | Nameplate data (AHRI or AHAM) | EDC’s Data Gathering |
| COPbase | Variable | Early Replacement: Nameplate data | EDC’s Data Gathering |
| New Construction or Replace on Burnout: Default values from Table 3‑20 | See Table 3‑20 |
| COPee | Variable | Nameplate data (AHRI or AHAM) | EDC’s Data Gathering |
| HSPFbase | Variable | Early Replacement: Nameplate data | EDC’s Data Gathering |
| New Construction or Replace on Burnout: Default values from Table 3‑20 | See Table 3‑20 |
| HSPFee | Variable | Nameplate data (AHRI or AHAM) | EDC’s Data Gathering |
| CF | Fixed | 80% | 2 |
| EFLHcool | Variable | Based on Logging or Modeling | EDC’s Data Gathering |
| Default values from Table 3‑21 | See Table 3‑21 |
| EFLHheat | Variable | Based on Logging or Modeling | EDC’s Data Gathering |
| Default values from Table 3‑22 | See Table 3‑22 |

**Sources:**

1. US Department of Energy. ENERGY STAR Calculator and Bin Analysis Models
2. Average based on coincidence factors from Ohio, New Jersey, Mid-Atlantic, Massachusetts, Connecticut, Illinois, New York, CEE and Minnesota. (74%, 67%, 81%, 94%, 82%, 72%, 100%, 70% and 76% respectively)

Table 3‑20: HVAC Baseline Efficiencies[[162]](#footnote-191)

| **Equipment Type and Capacity** | **Cooling Baseline** | **Heating Baseline** |
| --- | --- | --- |
| Air-Source Air Conditioners | | |
| < 65,000 BtuH | 13.0 SEER | N/A |
| > 65,000 BtuH and <135,000 BtuH | 11.2 EER | N/A |
| > 135,000 BtuH and < 240,000 BtuH | 11.0 EER | N/A |
| > 240,000 BtuH and < 760,000 BtuH  (IPLV for units with capacity-modulation only) | 10.0 EER / 9.7 IPLV | N/A |
| > 760,000 BtuH  (IPLV for units with capacity-modulation only) | 9.7 EER / 9.4 IPLV | N/A |
| Water-Source and Evaporatively-Cooled Air Conditioners | | |
| < 65,000 BtuH | 12.1 EER | N/A |
| > 65,000 BtuH and <135,000 BtuH | 11.5 EER | N/A |
| > 135,000 BtuH and < 240,000 BtuH | 11.0 EER | N/A |
| > 240,000 BtuH | 11.5 EER | N/A |
| Air-Source Heat Pumps | | |
| < 65,000 BtuH | 13 SEER | 7.7 HSPF |
| > 65,000 BtuH and <135,000 BtuH | 11.0 EER | 3.3 COP |
| > 135,000 BtuH and < 240,000 BtuH | 10.6 EER | 3.2 COP |
| > 240,000 BtuH  (IPLV for units with capacity-modulation only) | 9.5 EER / 9.2 IPLV | 3.2 COP |
| Water-Source Heat Pumps | | |
| < 17,000 BtuH | 11.2 EER | 4.2 COP |
| > 17,000 BtuH and < 135,000 BtuH | 12.0 EER | 4.2 COP |
| Ground Water Source Heat Pumps | | |
| < 135,000 BtuH | 16.2 EER | 3.6 COP |
| Ground Source Heat Pumps | | |
| < 135,000 BtuH | 13.4 EER | 3.1 COP |
| Packaged Terminal Systems (Replacements)[[163]](#footnote-192) | | |
| PTAC (cooling) | 10.9 - (0.213 x Cap / 1000) EER |  |
| PTHP | 10.8 - (0.213 x Cap / 1000) EER | 2.9 - (0.026 x Cap / 1000) COP |
| Packaged Terminal Systems (New Construction) | | |
| PTAC (cooling) | 12.5 - (0.213 x Cap / 1000) EER |  |
| PTHP | 12.3 - (0.213 x Cap / 1000) EER | 3.2 - (0.026 x Cap / 1000) COP |

Table 3‑21: Cooling EFLH for Pennsylvania Cities[[164]](#footnote-194)

| **Space and/or Building Type** | **Allentown** | **Erie** | **Harrisburg** | **Pittsburgh** | **Williamsport** | **Philadelphia** | **Scranton** |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Arena/Auditorium/Convention Center | 602 | 332 | 640 | 508 | 454 | 711 | 428 |
| College: Classes/Administrative | 690 | 380 | 733 | 582 | 520 | 815 | 490 |
| Convenience Stores | 1,216 | 671 | 1,293 | 1,026 | 917 | 1,436 | 864 |
| Dining: Bar Lounge/Leisure | 912 | 503 | 969 | 769 | 688 | 1,077 | 648 |
| Dining: Cafeteria / Fast Food | 1,227 | 677 | 1,304 | 1,035 | 925 | 1,449 | 872 |
| Dining: Restaurants | 912 | 503 | 969 | 769 | 688 | 1,077 | 648 |
| Gymnasium/Performing Arts Theatre | 690 | 380 | 733 | 582 | 520 | 815 | 490 |
| Hospitals/Health care | 1,396 | 770 | 1,483 | 1,177 | 1,052 | 1,648 | 992 |
| Industrial: 1 Shift/Light Manufacturing | 727 | 401 | 773 | 613 | 548 | 859 | 517 |
| Industrial: 2 Shift | 988 | 545 | 1,050 | 833 | 745 | 1,166 | 702 |
| Industrial: 3 Shift | 1,251 | 690 | 1,330 | 1,055 | 944 | 1,478 | 889 |
| Lodging: Hotels/Motels/Dormitories | 756 | 418 | 805 | 638 | 571 | 894 | 538 |
| Lodging: Residential | 757 | 418 | 805 | 638 | 571 | 894 | 538 |
| Multi-Family (Common Areas) | 1,395 | 769 | 1,482 | 1,176 | 1,052 | 1,647 | 991 |
| Museum/Library | 851 | 469 | 905 | 718 | 642 | 1,005 | 605 |
| Nursing Homes | 1,141 | 630 | 1,213 | 963 | 861 | 1,348 | 811 |
| Office: General/Retail | 851 | 469 | 905 | 718 | 642 | 1,005 | 605 |
| Office: Medical/Banks | 851 | 469 | 905 | 718 | 642 | 1,005 | 605 |
| Parking Garages & Lots | 938 | 517 | 997 | 791 | 707 | 1,107 | 666 |
| Penitentiary | 1,091 | 602 | 1,160 | 920 | 823 | 1,289 | 775 |
| Police/Fire Stations (24 Hr) | 1,395 | 769 | 1,482 | 1,176 | 1,052 | 1,647 | 991 |
| Post Office/Town Hall/Court House | 851 | 469 | 905 | 718 | 642 | 1,005 | 605 |
| Religious Buildings/Church | 602 | 332 | 640 | 508 | 454 | 711 | 428 |
| Retail | 894 | 493 | 950 | 754 | 674 | 1,055 | 635 |
| Schools/University | 634 | 350 | 674 | 535 | 478 | 749 | 451 |
| Warehouses (Not Refrigerated) | 692 | 382 | 735 | 583 | 522 | 817 | 492 |
| Warehouses (Refrigerated) | 692 | 382 | 735 | 583 | 522 | 817 | 492 |
| Waste Water Treatment Plant | 1,265 | 1,473 | 1,204 | 1,208 | 1,270 | 1,182 | 1,285 |

Table 3‑22: Heating EFLH for Pennsylvania Cities[[165]](#footnote-195)

| **Space and/or Building Type** | **Allentown** | **Erie** | | **Harrisburg** | **Pittsburgh** | **Williamsport** | | **Philadelphia** | **Scranton** | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Arena/Auditorium/Convention Center | 1,719 | 2,002 | | 1,636 | 1,642 | 1,726 | | 1,606 | 1,747 | |
| College: Classes/Administrative | 1,559 | 1,815 | | 1,484 | 1,489 | 1,565 | | 1,457 | 1,584 | |
| Convenience Stores | 603 | 3,148 | | 2,573 | 2,582 | 2,715 | | 2,526 | 2,747 | |
| Dining: Bar Lounge/Leisure | 1,156 | 1,346 | | 1,100 | 1,104 | 1,161 | | 1,080 | 1,175 | |
| Dining: Cafeteria / Fast Food | 582 | 2,066 | | 1,689 | 1,695 | 1,782 | | 1,658 | 1,803 | |
| Dining: Restaurants | 1,156 | 1,346 | | 1,100 | 1,104 | 1,161 | | 1,080 | 1,175 | |
| Gymnasium/Performing Arts Theatre | 1,559 | 1,815 | | 1,484 | 1,489 | 1,565 | | 1,457 | 1,584 | |
| Hospitals/Health care | 276 | 321 | | 263 | 264 | 277 | | 2,526 | 280 | |
| Industrial: 1 Shift/Light Manufacturing | 1,491 | 1,737 | | 1,420 | 1,425 | 1,498 | | 1,394 | 1,516 | |
| Industrial: 2 Shift | 1,017 | 1,184 | | 968 | 972 | 1,022 | | 951 | 1,034 | |
| Industrial: 3 Shift | 538 | 626 | | 512 | 513 | 540 | | 502 | 546 | |
| Lodging: Hotels/Motels/Dormitories | 1,438 | 1,675 | | 1,369 | 1,374 | 1,444 | | 1,344 | 1,462 | |
| Lodging: Residential | 1,438 | 1,675 | | 1,369 | 1,374 | 1,444 | | 1,344 | 1,462 | |
| Multi-Family (Common Areas) | 277 | 3,148 | | 2,573 | 2,582 | 2,715 | | 2,526 | 2,747 | |
| Museum/Library | 1,266 | 1,474 | | 1,205 | 1,209 | 1,271 | | 1,183 | 1,286 | |
| Nursing Homes | 738 | 3,148 | | 2,573 | 2,582 | 2,715 | | 2,526 | 2,747 | |
| Office: General/Retail | 1,266 | 884 | | 722 | 725 | 762 | | 709 | 771 | |
| Office: Medical/Banks | 1,266 | 1,474 | | 1,205 | 1,209 | 1,271 | | 1,183 | 1,286 | |
| Parking Garages & Lots | 1,110 | 1,292 | | 1,056 | 1,060 | 1,114 | | 1,037 | 1,128 | |
| Penitentiary | 829 | 3,148 | | 2,573 | 2,582 | 2,715 | | 2,526 | 2,747 | |
| Police/Fire Stations (24 Hr) | 277 | 3,148 | | 2,573 | 2,582 | 2,715 | | 2,526 | 2,747 | |
| Post Office/Town Hall/Court House | 1,266 | 1,474 | | 1,205 | 1,209 | 1,271 | | 1,183 | 1,286 | |
| Religious Buildings/Church | 1,718 | 2,001 | | 1,635 | 1,641 | 1,725 | | 1,605 | 1,746 | |
| Retail | 1,188 | 1,383 | | 1,130 | 1,135 | 1,193 | | 1,110 | 1,207 | |
| Schools/University | 1,661 | 984 | | 805 | 808 | 849 | | 790 | 859 | |
| Warehouses (Not Refrigerated) | 538 | 567 | | 463 | 465 | 489 | | 455 | 495 | |
| Warehouses (Refrigerated) | 1,555 | 1,810 | | 1,480 | 1,485 | 1,561 | | 1,453 | 1,580 | |
| Waste Water Treatment Plant | 1,265 | 1,473 | | 1,204 | 1,208 | 1,270 | | 1,182 | 1,285 | |

## Electric Chillers

This protocol estimates savings for installing high efficiency electric chillers as compared to chillers that meet the minimum performance allowed by the current PA Energy Code. The measurement of energy and demand savings for chillers is based on algorithms with key variables (i.e., Efficiency, Coincidence Factor, and 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 appropriately sized for site design load condition.

All other chiller applications, including existing multiple chiller configurations, existing chillers serving multiple load groups, and chillers in industrial applications are defined as non-standard applications and must follow a site specific custom protocol. Situations with existing non-VFD chillers upgrading to VFD chillers may use the protocol algorithm. The algorithms, assumptions and default factors in this Section may be applied to New Construction applications.

### Algorithms

#### Efficiency ratings in EER

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

ΔkWpeak = Tonsee X 12 X (1 / EERbase – 1 / EERee) X CF

#### Efficiency ratings in kW/ton

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

ΔkWpeak = Tonsee X (kW/tonbase – kW/tonee) X CF

### Definition of Terms

Tonsee  = 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 3‑23 for values.

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

EERbase =Energy Efficiency Ratio of the baseline unit. See Table 3-24 for values.

EERee =Energy Efficiency Ratio of the efficient unit from the manufacturer data and equipment ratings in accordance with ARI Standards.

CF = Demand Coincidence Factor (See Section 1.4)

EFLH = Equivalent Full Load Hours – The kWh during the entire operating season divided by the kW at design conditions. The most appropriate EFLH from Table 3-26 shall be utilized in the calculation.

Table 3‑23: Electric Chiller Variables

| **Component** | **Type** | **Value** | **Source** |
| --- | --- | --- | --- |
| Tonsee | Variable | Nameplate Data | EDC Data Gathering |
| kW/tonbase | Variable | New Construction or Replace on Burnout: Default value from Table 3‑24 | See Table 3‑24 |
| Early Replacement: Nameplate Data | EDC Data Gathering |
| kW/tonee | Variable | Nameplate Data (ARI Standards 550/590). At minimum, must satisfy standard listed in Table 3‑24 | EDC Data Gathering |
| EERbase | Variable | New Construction or Replace on Burnout: Default value from Table 3‑24 | See Table 3‑24 |
| Early Replacement: Nameplate Data | EDC Data Gathering |
| EERee | Variable | Nameplate Data (ARI Standards 550/590). At minimum, must satisfy standard listed in Table 3‑24 | EDC Data Gathering |
| CF | Fixed | 80% | 1 |
| EFLH | Fixed | Default value from Table 3‑25 | See Table 3‑25 |

**Sources:**

1. Average based on coincidence factors from Ohio, New Jersey, Mid-Atlantic, Massachusetts, Connecticut, Illinois, New York, CEE and Minnesota. (74%, 67%, 81%, 94%, 82%, 72%, 100%, 70% and 76% respectively)

Table 3‑24: Electric Chiller Baseline Efficiencies (IECC 2009)[[166]](#footnote-196)

| **Chiller Type** | **Size** | **Path A** | **Path B** | **Source** |
| --- | --- | --- | --- | --- |
| Air Cooled Chillers | < 150 tons | Full load: 9.562 EER  IPLV: 12.500 EER | N/A | IECC 2009 Table 503.2.3 (7) Post 1/1/2010 |
| >=150 tons | Full load: 9.562 EER  IPLV: 12.750 EER | N/A |
| Water Cooled Positive Displacement or Reciprocating Chiller | < 75 tons | Full load: 0.780 kW/ton  IPLV: 0.630 kW/ton | Full load: 0.800 kW/ton  IPLV: 0.600 kW/ton |
| >=75 tons and < 150 tons | Full load: 0.775 kW/ton  IPLV: 0.615 kW/ton | Full load: 0.790 kW/ton  IPLV: 0.586 kW/ton |
| >=150 tons and < 300 tons | Full load: 0.680 kW/ton  IPLV: 0.580 kW/ton | Full load: 0.718 kW/ton  IPLV: 0.540 kW/ton |
| >=300 tons | Full load: 0.620 kW/ton  IPLV: 0.540 kW/ton | Full load: 0.639 kW/ton  IPLV: 0.490 kW/ton |
| Water Cooled Centrifugal Chiller | <300 tons | Full load: 0.634 kW/ton  IPLV: 0.596 kW/ton | Full load: 0.639 kW/ton  IPLV: 0.450 kW/ton |
| >=300 tons and < 600 tons | Full load: 0.576 kW/ton  IPLV: 0.549 kW/ton | Full load: 0.600 kW/ton  IPLV: 0.400 kW/ton |
| >=600 tons | Full load: 0.570 kW/ton  IPLV: 0.539 kW/ton | Full load: 0.590 kW/ton  IPLV: 0.400 kW/ton |

Table 3‑25: Chiller Cooling EFLH by Location[[167]](#footnote-197)

| **Space and/or Building Type** | | **Allentown** | | **Erie** | **Harrisburg** | | **Pittsburgh** | | **Williamsport** | | **Philadelphia** | | **Scranton** | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Arena/Auditorium/Convention Center | | 602 | | 332 | 640 | | 508 | | 454 | | 711 | | 428 | |
| College: Classes/Administrative | | 690 | | 380 | 733 | | 582 | | 520 | | 815 | | 490 | |
| Convenience Stores | | 1,216 | | 671 | 1,293 | | 1,026 | | 917 | | 1,436 | | 864 | |
| Dining: Bar Lounge/Leisure | | 912 | | 503 | 969 | | 769 | | 688 | | 1,077 | | 648 | |
| Dining: Cafeteria / Fast Food | | 1,227 | | 677 | 1,304 | | 1,035 | | 925 | | 1,449 | | 872 | |
| Dining: Restaurants | | 912 | | 503 | 969 | | 769 | | 688 | | 1,077 | | 648 | |
| Gymnasium/Performing Arts Theatre | | 690 | | 380 | 733 | | 582 | | 520 | | 815 | | 490 | |
| Hospitals/Health care | | 1,396 | | 770 | 1,483 | | 1,177 | | 1,052 | | 1,648 | | 992 | |
| Lodging: Hotels/Motels/Dormitories | | 756 | | 418 | 805 | | 638 | | 571 | | 894 | | 538 | |
| Lodging: Residential | | 757 | | 418 | 805 | | 638 | | 571 | | 894 | | 538 | |
| Multi-Family (Common Areas) | | 1,395 | | 769 | 1,482 | | 1,176 | | 1,052 | | 1,647 | | 991 | |
| Museum/Library | | 851 | | 469 | 905 | | 718 | | 642 | | 1,005 | | 605 | |
| Nursing Homes | | 1,141 | | 630 | 1,213 | | 963 | | 861 | | 1,348 | | 811 | |
| Office: General/Retail | | 851 | | 469 | 905 | | 718 | | 642 | | 1,005 | | 605 | |
| Office: Medical/Banks | | 851 | | 469 | 905 | | 718 | | 642 | | 1,005 | | 605 | |
| Parking Garages & Lots | | 938 | | 517 | 997 | | 791 | | 707 | | 1,107 | | 666 | |
| Penitentiary | | 1,091 | | 602 | 1,160 | | 920 | | 823 | | 1,289 | | 775 | |
| Police/Fire Stations (24 Hr) | | 1,395 | | 769 | 1,482 | | 1,176 | | 1,052 | | 1,647 | | 991 | |
| Post Office/Town Hall/Court House | | 851 | | 469 | 905 | | 718 | | 642 | | 1,005 | | 605 | |
| Religious Buildings/Church | | 602 | | 332 | 640 | | 508 | | 454 | | 711 | | 428 | |
| Retail | | 894 | | 493 | 950 | | 754 | | 674 | | 1,055 | | 635 | |
| Schools/University | | 634 | | 350 | 674 | | 535 | | 478 | | 749 | | 451 | |
| Warehouses (Not Refrigerated) | | 692 | | 382 | 735 | | 583 | | 522 | | 817 | | 492 | |
| Warehouses (Refrigerated) | | 692 | | 382 | 735 | | 583 | | 522 | | 817 | | 492 | |
| Waste Water Treatment Plant | | 1,265 | | 1,473 | 1,204 | | 1,208 | | 1,270 | | 1,182 | | 1,285 | |

## 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 3‑26 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 3‑27 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 linear ft |
| Peak Demand Impact | 0.0275 kW per door | 0.0110 kW per linear ft |
| Freezer |  |  |
| Energy Impact | 1,882 kWh per door | 753 kWh per linear ft |
| Peak Demand Impact | 0.0287 kW per door | 0.0115 kW per linear ft |
| Default (case service temperature unknown) | | |
| Energy Impact | 1,298 kWh per door | 519 kWh per linear ft |
| Peak Demand Impact | 0.0279 kW per door | 0.0112 kW per linear ft |

### Measure Life

12 Years (DEER 2008, Regional Technical Forum)

## High-Efficiency Refrigeration/Freezer Cases

This protocol estimates savings for installing high efficiency refrigeration and freezer cases that qualify under the ENERGY STAR rating compared to refrigeration and freezer cases allowed by federal standards. The measurement of energy and demand savings is based on algorithms with volume as the key variable.

### 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; under counter 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 = Demand Coincidence Factor (See Section 1.4)

V = Internal Volume

Table 3‑28: Refrigeration Cases - References

|  |  |  |  |
| --- | --- | --- | --- |
| **Component** | **Type** | **Value** | **Sources** |
| kWhbase | Calculated | See Table 3‑29 and Table 3‑30 | 1 |
| kWhee | Calculated | See Table 3‑29 and Table 3‑30 | 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 3‑29: 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 3‑30: 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 3‑31: 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 3‑32: Freezer Case Savings

| **Volume (ft3)** | **Annual Energy Savings (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 |

### Measure Life

12 years

**Sources:**

1. 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 3‑33: Variables for High-Efficiency Evaporator Fan Motor

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable** | **Type** | **Value** | **Source** |
| Wbase | Fixed | Default | Table 3‑34 |
| Nameplate Input Wattage | EDC Data Gathering |
| Wee | Variable | Default | Table 3‑34 |
| 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 3‑34: Variables for HE Evaporator Fan Motor

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Motor Category | Weighting Percentage (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 3‑35: 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 3‑36: 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 3‑37: 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 3‑38: 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 3‑39: Variables for High-Efficiency Evaporator Fan Motor

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable** | **Type** | **Value** | **Source** |
| Wbase | Fixed | Default | Table 3‑40 |
| Nameplate Input Wattage | EDC Data Gathering |
| Wee | Variable | Default | Table 3‑40 |
| 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 3‑40: 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 3‑41: 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 3‑42: 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) | 93 | 30 | 0.9 | 94.4% | 0.98 | 1.3 | 0.0955 | 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 3‑43: 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

This protocol estimates savings for installing ENERGY STAR office equipment compared to standard efficiency equipment. The measurement of energy and demand savings is based on a deemed savings value multiplied by the quantity of the measure.

### 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 = Demand Coincidence Factor (See Section 1.4). 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 3‑44: ENERGY STAR Office Equipment - References

| **Component** | **Type** | **Value** | **Sources** |
| --- | --- | --- | --- |
| ESavCOM  ESavFAX  ESavCOP  ESavPRI  ESavMUL  ESavMON | Fixed | see Table 3‑45 | 1 |
| DSavCOM  DSavFAX  DSavCOP  DSavPRI  DSavMUL  DSavMON | Fixed | see Table 3‑45 | 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 3‑45: ENERGY STAR 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**

### ****Measure Life****

Table 3‑46: ENERGY STAR Office Equipment Measure 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 strips 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 3‑47: 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 x 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%[[168]](#footnote-198),[[169]](#footnote-199),[[170]](#footnote-200),[[171]](#footnote-201). 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 Table 3‑48. 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 3‑48: Beverage Machine Controls Energy Savings[[172]](#footnote-202)

|  |  |  |
| --- | --- | --- |
| **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

**Sources:**

1. DEER EUL Summary, Database for Energy Efficient Resources, accessed 8/2010, <http://www.deeresources.com/deer0911planning/downloads/EUL_Summary_10-1-08.xls>
2. Deru et al. suggest that beverage machine life will be extended from this measure due to fewer lifetime compressor cycles.
3. 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[[173]](#footnote-203). 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 = Demand Coincidence Factor (See Section 1.4)

The reference values for each component of the energy impact algorithm are shown in Table 3‑49. 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 3‑49: Ice Machine Reference values for algorithm components

|  |  |  |  |
| --- | --- | --- | --- |
| **Term** | **Type** | **Value** | **Source** |
| kWhbase | Variable | Table 3‑50 | 1 |
| kWhhe | Variable | Table 3‑50 | 2 |
| H | Variable | Manufacturer Specs | EDC Data Gathering |
| D | Variable | Default = 0.4[[174]](#footnote-204) | 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 Table 3‑50. 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[[175]](#footnote-205). The two energy consumption values are then applied to the energy savings algorithm above.

Table 3‑50: Ice Machine Energy Usage[[176]](#footnote-206)

|  |  |  |  |
| --- | --- | --- | --- |
| **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[[177]](#footnote-207).

**Sources:**

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 = Demand Coincidence Factor (See Section 1.4)

EER = efficiency of the cooling system

COP = efficiency of the heating system

Table 3‑51: 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 Table 3‑52 and Table 3‑53 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 Table 3‑52 and Table 3‑53 for values by building type | AEPS Application; EDC Data Gathering; 3, 4 |
| Rf | Variable |  | AEPS Application; EDC Data Gathering; |
| EFLHcool | Fixed | See Table 3‑55 | 5 |
| CF | Fixed | 67% | 5 |
| EER | Fixed | See Table 3‑54 | 6, 7 |
| COP | Fixed | See Table 3‑54 | 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 3‑52: 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 3‑53: 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 3‑54: HVAC Baseline Efficiencies for Non-Residential Buildings

|  | **Existing Building[[178]](#footnote-208)** | | **New Construction[[179]](#footnote-209)** | |
| --- | --- | --- | --- | --- |
| **Equipment Type and Capacity** | **Cooling Efficiency** | **Heating Efficiency** | **Cooling Efficiency** | **Heating Efficiency** |
| Air-Source Air Conditioners | | | | |
| < 65,000 BtuH | 10.0 SEER | N/A | 13.0 SEER | N/A |
| > 65,000 BtuH and <135,000 BtuH | 10.3 EER | N/A | 11.2 EER | N/A |
| > 135,000 BtuH and < 240,000 BtuH | 9.7 EER | N/A | 11.0 EER | N/A |
| > 240,000 BtuH and < 760,000 BtuH  (IPLV for units with capacity-modulation only) | 9.5 EER | N/A | 10.0 EER /  9.7 IPLV | N/A |
| > 760,000 BtuH  (IPLV for units with capacity-modulation only) | 9.2 EER | N/A | 9.7 EER /  9.4 IPLV | N/A |
| Water-Source and Evaporatively-Cooled Air Conditioners | | | | |
| < 65,000 BtuH | 12.1 EER | N/A | 12.1 EER | N/A |
| > 65,000 BtuH and <135,000 BtuH | 11.5 EER | N/A | 11.5 EER | N/A |
| > 135,000 BtuH and < 240,000 BtuH | 11.0 EER | N/A | 11.0 EER | N/A |
| > 240,000 BtuH | 11.0 EER | N/A | 11.5 EER | N/A |
| Air-Source Heat Pumps | | | | |
| < 65,000 BtuH | 10.0 SEER | 6.8 HSPF | 13 SEER | 7.7 HSPF |
| > 65,000 BtuH and <135,000 BtuH | 10.1 EER | 3.2 COP | 11.0 EER | 3.3 COP |
| > 135,000 BtuH and < 240,000 BtuH | 9.3 EER | 3.1 COP | 10.6 EER | 3.2 COP |
| > 240,000 BtuH (IPLV for units with capacity-modulation only) | 9.0 EER | 3.1 COP | 9.5 EER /  9.2 IPLV | 3.2 COP |
| Water-Source Heat Pumps | | | | |
| < 17,000 BtuH | 11.2 EER | 4.2 COP | 11.2 EER | 4.2 COP |
| > 17,000 BtuH and < 65,000 BtuH | 12.0 EER | 4.2 COP | 12.0 EER | 4.2 COP |
| Ground Water Source Heat Pumps | | | | |
| < 135,000 BtuH | 16.2 EER | 3.6 COP | 16.2 EER | 3.6 COP |
| Ground Source Heat Pumps | | | | |
| < 135,000 BtuH | 13.4 EER | 3.1 COP | 13.4 EER | 3.1 COP |
| Packaged Terminal Systems | | | | |
| PTAC (cooling) | 10.9 - (0.213 x Cap / 1000) EER | N/A | 12.5 - (0.213 x Cap / 1000) EER | N/A |
| PTHP | 10.8 - (0.213 x Cap / 1000) EER | 2.9 - (0.026 x Cap / 1000) COP | 12.3 - (0.213 x Cap / 1000) EER | 3.2 - (0.026 x Cap / 1000) COP |

Table 3‑55: Cooling EFLH for Key PA Cities[[180]](#footnote-210)

| **Space and/or Building Type** | **Allentown** | **Erie** | **Harrisburg** | **Pittsburgh** | **Williamsport** | **Philadelphia** | **Scranton** |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Arena/Auditorium/Convention Center | 602 | 332 | 640 | 508 | 454 | 711 | 428 |
| College: Classes/Administrative | 690 | 380 | 733 | 582 | 520 | 815 | 490 |
| Convenience Stores | 1,216 | 671 | 1,293 | 1,026 | 917 | 1,436 | 864 |
| Dining: Bar Lounge/Leisure | 912 | 503 | 969 | 769 | 688 | 1,077 | 648 |
| Dining: Cafeteria / Fast Food | 1,227 | 677 | 1,304 | 1,035 | 925 | 1,449 | 872 |
| Dining: Restaurants | 912 | 503 | 969 | 769 | 688 | 1,077 | 648 |
| Gymnasium/Performing Arts Theatre | 690 | 380 | 733 | 582 | 520 | 815 | 490 |
| Hospitals/Health care | 1,396 | 770 | 1,483 | 1,177 | 1,052 | 1,648 | 992 |
| Lodging: Hotels/Motels/Dormitories | 756 | 418 | 805 | 638 | 571 | 894 | 538 |
| Lodging: Residential | 757 | 418 | 805 | 638 | 571 | 894 | 538 |
| Multi-Family (Common Areas) | 1,395 | 769 | 1,482 | 1,176 | 1,052 | 1,647 | 991 |
| Museum/Library | 851 | 469 | 905 | 718 | 642 | 1,005 | 605 |
| Nursing Homes | 1,141 | 630 | 1,213 | 963 | 861 | 1,348 | 811 |
| Office: General/Retail | 851 | 469 | 905 | 718 | 642 | 1,005 | 605 |
| Office: Medical/Banks | 851 | 469 | 905 | 718 | 642 | 1,005 | 605 |
| Parking Garages & Lots | 938 | 517 | 997 | 791 | 707 | 1,107 | 666 |
| Penitentiary | 1,091 | 602 | 1,160 | 920 | 823 | 1,289 | 775 |
| Police/Fire Stations (24 Hr) | 1,395 | 769 | 1,482 | 1,176 | 1,052 | 1,647 | 991 |
| Post Office/Town Hall/Court House | 851 | 469 | 905 | 718 | 642 | 1,005 | 605 |
| Religious Buildings/Church | 602 | 332 | 640 | 508 | 454 | 711 | 428 |
| Retail | 894 | 493 | 950 | 754 | 674 | 1,055 | 635 |
| Schools/University | 634 | 350 | 674 | 535 | 478 | 749 | 451 |
| Warehouses (Not Refrigerated) | 692 | 382 | 735 | 583 | 522 | 817 | 492 |
| Warehouses (Refrigerated) | 692 | 382 | 735 | 583 | 522 | 817 | 492 |
| Waste Water Treatment Plant | 1,265 | 1,473 | 1,204 | 1,208 | 1,270 | 1,182 | 1,285 |

### Measure Life

15 years

**Source:**

1. DEER uses 20 years; Northwest Regional Technical Forum uses 45 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.

## Strip Curtains for Walk-In Freezers and Coolers

|  |  |
| --- | --- |
| **Measure Name** | **Strip Curtains for Walk-In Coolers and Freezers** |
| Target Sector | Commercial Refrigeration |
| Measure Unit | Walk-in unit door |
| Unit Energy Savings | Fixed |
| Unit Peak Demand Reduction | Fixed |
| Measure Life | 4 years |

Strip curtains are used to reduce the refrigeration load associated with the infiltration of non-refrigerated air into the refrigerated spaces of walk-in coolers or freezers.

The primary cause of air infiltration into walk-in coolers and freezers is the air density difference between two adjacent spaces of different temperatures. The total refrigeration load due to infiltration through the main door into the unit depends on the temperature differential between the refrigerated and non-refrigerated airs, the door area and height, and the duration and frequency of door openings. The avoided infiltration depends on the efficacy of the newly installed strip curtains as infiltration barriers[[181]](#footnote-211), and on the efficacy of the supplanted infiltration barriers, if applicable. The calculation of the refrigeration load due to air infiltration and the energy required to meet that load is rather straightforward, but relies on critical assumptions regarding the aforementioned operating parameters. All the assumptions in this protocol are based on values that were determined by direct measurement and monitoring of over 100 walk-in units in the 2006-2008 evaluation for the CA Public Utility Commission[[182]](#footnote-212).

### Eligibility

This protocol documents the energy savings attributed to strip curtains applied on walk-in cooler and freezer doors in commercial applications. The most likely areas of application are large and small grocery stores, supermarkets, restaurants and refrigerated warehouse. The baseline case is a walk-in cooler or freezer that previously had either no strip curtain installed or an old, ineffective strip curtain installed. The efficient equipment is a strip curtain added to a walk-in cooler or freezer. Strip curtains must be at least 0.06 inches thick. Low temp strip curtains must be used on low temp applications[[183]](#footnote-213).

### Algorithms

ΔkWh = ΔkWh/sqft x A

ΔkWpeak = ΔkW/sqft x A

The annual energy savings due to infiltration barriers is quantified by multiplying savings per square foot by area using assumptions for independent variables described in the protocol introduction. The source algorithm from which the savings per square foot values are determined is based on Tamm’s equation[[184]](#footnote-214) (an application of Bernoulli’s equation) and the ASHRAE handbook[[185]](#footnote-215). To the extent that evaluation findings are able to provide more reliable site specific inputs assumptions, they may be used in place of the default per square foot savings using the following equation.

ΔkWh = 365 x topen x (ηnew - ηold) x 20CD x A x {[(Ti - Tr)/Ti]gH}0.5 x 60 x (ρihi – ρrhr) / (3413 x COPadj)

The peak demand reduction is quantified by multiplying savings per square foot by area. The source algorithm is the annual energy savings divided by 8760. This assumption is based on general observation that refrigeration is constant for food storage, even outside of normal operating conditions. This is the most conservative approach in lieu of a more sophisticated model.

ΔkWpeak = ΔkWh / 8760

The ratio of the average energy usage during Peak hours to the total annual energy usage is taken from the load shape data collected by ADM for a recent evaluation for the CA Public Utility Commission[[186]](#footnote-216) in the study of strip curtains in supermarkets, convenience stores, and restaurants.

### Definition of Terms

The variables in the main equations are defined below:

ΔkWh/sqft = Average annual kWh savings per square foot of infiltration barrier

ΔkW/sqft = Average kW savings per square foot of infiltration barrier

A = Doorway area, ft2

The variables in the source equation are defined below:

topen  = Minutes walk-in door is open per day

ηnew = Efficacy of the new strip curtain – an efficacy of 1 corresponds to the strip curtain thwarting all infiltration, while an efficacy of zero corresponds to the absence of strip curtains.

ηold = Efficacy of the old strip curtain

20 = Product of 60 minutes per hour and an integration factor of 1/3[[187]](#footnote-217)

C­D = Discharge Coefficient: empirically determined scale factors that account for differences between infiltration as rates predicted by application Bernoulli’s law and actual observed infiltration rates

Ti = Dry-bulb temperature of infiltrating air, Rankine

Tr = Dry-bulb temperature of refrigerated air, Rankine

g = Gravitational constant = 32.174 ft/s2

H = Doorway height, ft

hi = Enthalpy of the infiltrating air, Btu/lb. Based on 55% RH.

hr = Enthalpy of the refrigerated air, Btu/lb. Based on 80% RH.

ρi = Density of the infiltration air, lb/ft3. Based on 55% RH.

ρr = Density of the refrigerated air, lb/ft3. Based on 80% RH.

3413 = Conversion factor: number of BTUs in one kWh

COPadj = Time-dependent (weather dependent) coefficient of performance of the refrigeration system. Based on nominal COP of 1.5 for freezers and 2.5 for coolers.

ETD = Average UsagePeak / Annual Energy Usage

The default savings values are listed in Table 3‑56. Default parameters used in the source equations are listed in Table 3‑57, Table 3‑58, Table 3‑59, and Table 3‑60. The source equations and the values for the input parameters are adapted from the 2006-2008 California Public Utility Commission’s evaluation of strip curtains[[188]](#footnote-218). The original work included 8760-hourly bin calculations. The values used herein represent annual average values. For example, the differences in the temperature between the refrigerated and infiltrating airs are averaged over all times that the door to the walk-in unit is open. Recommendations made by the evaluation team have been adopted to correct for errors observed in the ex ante savings calculation.

Table 3‑56: Deemed Energy Savings and Demand Reductions for Strip Curtains

|  |  |  |  |
| --- | --- | --- | --- |
| **Type** | **Pre-existing Curtains** | **Energy Savings ΔkWh/sqft** | **Demand Savings ΔkW/sqft** |
| Supermarket - Cooler | Yes | 37 | 0.0042 |
| Supermarket - Cooler | No | 108 | 0.0123 |
| Supermarket - Cooler | Unknown | 108 | 0.0123 |
| Supermarket - Freezer | Yes | 119 | 0.0136 |
| Supermarket - Freezer | No | 349 | 0.0398 |
| Supermarket - Freezer | Unknown | 349 | 0.0398 |
| Convenience Store - Cooler | Yes | 5 | 0.0006 |
| Convenience Store - Cooler | No | 20 | 0.0023 |
| Convenience Store - Cooler | Unknown | 11 | 0.0013 |
| Convenience Store - Freezer | Yes | 8 | 0.0009 |
| Convenience Store - Freezer | No | 27 | 0.0031 |
| Convenience Store - Freezer | Unknown | 17 | 0.0020 |
| Restaurant - Cooler | Yes | 8 | 0.0009 |
| Restaurant - Cooler | No | 30 | 0.0034 |
| Restaurant - Cooler | Unknown | 18 | 0.0020 |
| Restaurant - Freezer | Yes | 34 | 0.0039 |
| Restaurant - Freezer | No | 119 | 0.0136 |
| Restaurant - Freezer | Unknown | 81 | 0.0092 |
| Refrigerated Warehouse | Yes | 254 | 0.0290 |
| Refrigerated Warehouse | No | 729 | 0.0832 |
| Refrigerated Warehouse | Unknown | 287 | 0.0327 |

Table 3‑57: Strip Curtain Calculation Assumptions for Supermarkets

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Component** | **Type** | Value | | Source |
| **Cooler** | Freezer |
| ηnew | Fixed | 0.88 | 0.88 | 1 |
| ηold  with Pre-existing curtain  with no Pre-existing curtain  unknown | Fixed | 0.58  0.00  0.00 | 0.58  0.00  0.00 | 1 |
| C­D | Fixed | 0.366 | 0.415 | 1 |
| topen (minutes/day) | Fixed | 132 | 102 | 1 |
| A (ft2) | Fixed | 35 | 35 | 1 |
| H (ft) | Fixed | 7 | 7 | 1 |
| Ti (°F) | Fixed | 71 | 67 | 1 and 2 |
| T­r (°F) | Fixed | 37 | 5 | 1 |
| ρi | Fixed | 0.074 | 0.074 | 3 |
| hi | Fixed | 26.935 | 24.678 | 3 |
| ρr | Fixed | 0.079 | 0.085 | 3 |
| hr | Fixed | 12.933 | 2.081 | 3 |
| COPadj | Fixed | 3.07 | 1.95 | 1 and 2 |

Table 3‑58: Strip Curtain Calculation Assumptions for Convenience Stores

| **Component** | **Type** | Value | | Source |
| --- | --- | --- | --- | --- |
| **Cooler** | Freezer |
| ηnew | Fixed | 0.79 | 0.83 | 1 |
| ηold  with Pre-existing curtain  with no Pre-existing curtain  unknown | Fixed | 0.58  0.00  0.34 | 0.58  0.00  0.30 | 1 |
| C­D | Fixed | 0.348 | 0.421 | 1 |
| topen (minutes/day) | Fixed | 38 | 9 | 1 |
| A (ft2) | Fixed | 21 | 21 | 1 |
| H (ft) | Fixed | 7 | 7 | 1 |
| Ti (°F) | Fixed | 68 | 64 | 1 and 2 |
| T­r (°F) | Fixed | 39 | 5 | 1 |
| ρi | Fixed | 0.074 | 0.075 | 3 |
| hi | Fixed | 25.227 | 23.087 | 3 |
| ρr | Fixed | 0.079 | 0.085 | 3 |
| hr | Fixed | 13.750 | 2.081 | 3 |
| COPadj | Fixed | 3.07 | 1.95 | 1 and 2 |

Table 3‑59: Strip Curtain Calculation Assumptions for Restaurant

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Component** | **Type** | Value | | Source |
| **Cooler** | Freezer |
| ηnew | Fixed | 0.80 | 0.81 | 1 |
| ηold  with Pre-existing curtain  with no Pre-existing curtain  unknown | Fixed | 0.58  0.00  0.33 | 0.58  0.00  0.26 | 1 |
| C­D | Fixed | 0.383 | 0.442 | 1 |
| topen (minutes/day) | Fixed | 45 | 38 | 1 |
| A (ft2) | Fixed | 21 | 21 | 1 |
| H (ft) | Fixed | 7 | 7 | 1 |
| Ti (°F) | Fixed | 70 | 67 | 1 and 2 |
| T­r (°F) | Fixed | 39 | 8 | 1 |
| ρi | Fixed | 0.074 | 0.074 | 3 |
| hi | Fixed | 26.356 | 24.678 | 3 |
| ρr | Fixed | 0.079 | 0.085 | 3 |
| hr | Fixed | 13.750 | 2.948 | 3 |
| COPadj | Fixed | 3.07 | 1.95 | 1 and 2 |

Table 3‑60: Strip Curtain Calculation Assumptions for Refrigerated Warehouse

|  |  |  |  |
| --- | --- | --- | --- |
| **Component** | **Type** | Value | Source |
| ηnew | Fixed | 0.89 | 1 |
| ηold  with Pre-existing curtain  with no Pre-existing curtain  unknown | Fixed | 0.58  0.00  0.54 | 1 |
| C­D | Fixed | 0.425 | 1 |
| topen (minutes/day) | Fixed | 494 | 1 |
| A (ft2) | Fixed | 80 | 1 |
| H (ft) | Fixed | 10 | 1 |
| Ti (°F) | Fixed | 59 | 1 and 2 |
| T­r (°F) | Fixed | 28 | 1 |
| ρi | Fixed | 0.076 | 3 |
| hi | Fixed | 20.609 | 3 |
| ρr | Fixed | 0.081 | 3 |
| hr | Fixed | 9.462 | 3 |
| COPadj | Fixed | 1.91 | 1 and 2 |

**Sources:**

1. http://www.calmac.org/publications/ComFac\_Evaluation\_V1\_Final\_Report\_02-18-2010.pdf. The scale factors have been determined with tracer gas measurements on over 100 walk-in refrigeration units during the California Public Utility Commission’s evaluation of the 2006-2008 CA investor owned utility energy efficiency programs. The door-open and close times, and temperatures of the infiltrating and refrigerated airs are taken from short-term monitoring of over 100 walk-in units.
2. For refrigerated warehouses, we used a bin calculation method to weight the outdoor temperature by the infiltration that occurs at that outdoor temperature. This tends to shift the average outdoor temperature during times of infiltration higher (e.g. from 54 °F year-round average to 64 °F). We also performed the same exercise to find out effective outdoor temperatures to use for adjustment of nominal refrigeration system COPs.
3. Density and enthalpy of infiltrating and refrigerated air are based on psychometric equations based on the dry bulb temperature and relative humidity. Relative humidity is estimated to be 55% for infiltrating air and 80% for refrigerated air. Dry bulb temperatures were determined through the evaluation cited in Source 1.

### Measure Life

The measure life is estimated to be 4 years.

**Sources:**

1. Commercial Facilities Contract Group 2006-2008 Direct Impact Evaluation, <http://www.calmac.org/publications/ComFac_Evaluation_V1_Final_Report_02-18-2010.pdf>
2. The Measure Life Report for Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc., June 2007

### Evaluation Protocols

The most appropriate evaluation protocol for this measure is verification of installation coupled with assignment of stipulated energy savings according to store type. The strip curtains are not expected to be installed directly. As such, the program tracking / evaluation effort must capture the following key information:

* Fraction of strip curtains installed in each of the categories (e.g. freezer / cooler and store type)
* Fraction of customers that had pre-existing strip curtains

The rebate forms should track the above information. During the M&V process, interviews with site contacts should track this fraction, and savings should be adjusted accordingly.

## Geothermal Heat Pumps

This protocol shall apply to ground source, groundwater source, and water source heat pumps in commercial applications as further described below. This measure may apply to early replacement of an existing system, replacement on burnout, or installation of a new unit in a new or existing non-residential building for HVAC applications. The base case may employ a different system than the retrofit case.

### Eligibility

In order for this characterization to apply, the efficient equipment is a high-efficiency groundwater source, water source, or ground source heat pump system that meets or exceeds the energy efficiency requirements of the International Energy Conservation Code (IECC) 2009, Table 503.2.3(2). The following retrofit scenarios are considered:

* Ground source heat pumps for existing or new non-residential HVAC applications
* Groundwater source heat pumps for existing or new non-residential HVAC applications
* Water source heat pumps for existing or new non-residential HVAC applications

These retrofits reduce energy consumption by the improved thermodynamic efficiency of the refrigeration cycle of new equipment, by improving the efficiency of the cooling and heating cycle, and by lowering the condensing temperature when the system is in cooling mode and raising the evaporating temperature when the equipment is in heating mode as compared to the base case heating or cooling system. It is expected that the retrofit system will use a similar conditioned-air distribution system as the base case system.

Heat pump systems coupled with a non-heat pump system such as a chiller shall not be included in this protocol. Projects that use unique, combined systems such as this should use a site-specific M&V plan (SSMVP) to describe the particulars of the project and how savings are calculated.

#### Definition of Baseline Equipment

In order for this protocol to apply, the baseline equipment could be a standard-efficiency air source, water source, groundwater source, or ground source heat pump system, or an electric chiller and boiler system, or other chilled/hot water loop system. To calculate savings, the baseline system type is assumed to be an air source heat pump of similar size except for cases where the project is replacing a ground source, groundwater source, or water source heat pump; in those cases, the baseline system type is assumed to be a similar system at code.

Table 3‑61: Geothermal Heat Pump Baseline Assumptions

| **Baseline Scenario** | | **Baseline Efficiency Assumptions** |
| --- | --- | --- |
| New Construction | | Standard efficiency air source heat pump system |
| Retrofit | Replacing any technology besides a ground source, groundwater source, or water source heat pump | Standard efficiency air source heat pump system |
| Replacing a ground source, groundwater source, or water source heat pump | Efficiency of the replaced geothermal system for early replacement only (if known), else code for a similar system |

### Algorithms

There are two primary components that must be accounted for in the energy and demand calculations. The first component is the heat pump unit energy and power, and the second is the circulating pump in the ground/water loop system energy and power. For projects where the retrofit system is similar to the baseline system, such as a standard efficiency ground source system replaced with a high efficiency ground source system, the pump energy is expected to be the same for both conditions and does not need to be calculated. The kWh savings should be calculated using the basic equations below.

#### For air-cooled base case units with cooling capacities less than 65 kBtu/h:

ΔkWh = ΔkWh cool + ΔkWh heat + ΔkWh pump

ΔkWh cool = {( BtuHcool/ 1000) X (1/SEERbase) X EFLHcool} - {( BtuHcool/ 1000) X (1/EERee) X EFLHcool}

ΔkWh heat = {( BtuHheat/ 1000) X (1/HSPFbase) X EFLHheat} - {( BtuHheat/ 1000) X (1/COPee) X (1/3.412) X EFLHheat}

ΔkWh pump = {(HPbasemotor X LFbase X 0.746 X (1/ηbasemotor) X (1/ηbasepump) X (HOURSbasepump)} - {(HPeemotor X LFee X 0.746 X (1/ηeemotor) \* (1/ηeepump) X (HOURSeepump)}

ΔkWpeak = ΔkWpeak cool + ΔkWpeak pump

ΔkWpeak cool = {( BtuHcool/ 1000) X [(1/EERbase)] X CFcool} - {( BtuHcool/ 1000) X [(1/EERee)] X CFcool}

ΔkWpeak pump = {HPbasemotor X LFbase X 0.746 X (1/ηbasemotor) X (1/ηbasepump) X CFpump} - {HPeemotor X LFee X 0.746 X (1/ηeemotor) X (1/ηeepump)] X CFpump}

#### For air-cooled base case units with cooling capacities equal to or greater than 65 kBtu/h, and all other units:

ΔkWh = ΔkWh cool + ΔkWh heat + ΔkWh pump

ΔkWh cool = {( BtuHcool/ 1000) X (1/EERbase) X EFLHcool} - {( BtuHcool/ 1000) X (1/EERee) X EFLHcool}

ΔkWh heat = {( BtuHheat/ 1000) X (1/COPbase) X (1/3.412) X EFLHheat} - {( BtuHheat/ 1000) X (1/COPee) X (1/3.412) X EFLHheat}

ΔkWh pump = {(HPbasemotor X LFbase X 0.746 X (1/ηbasemotor) X (1/ηbasepump) X (HOURSbasepump)} - {(HPeemotor X LFee X 0.746 X (1/ηeemotor) \* (1/ηeepump) X (HOURSeepump)}

ΔkWpeak = ΔkWpeak cool + ΔkWpeak pump

ΔkWpeak cool = {( BtuHcool/ 1000) X [(1/EERbase)] X CFcool} - {( BtuHcool/ 1000) X [ (1/EERee)] X CFcool}

ΔkWpeak pump = {HPbasemotor X LFbase X 0.746 X (1/ηbasemotor) X (1/ηbasepump) X CFpump} - {HPeemotor X LFee X 0.746 X (1/ηeemotor) X (1/ηeepump)] X CFpump}

### Definition of Terms

BtuHcool = Rated cooling capacity of the energy efficient unit in BtuHcool /hour

BtuHheat = Rated heating capacity of the energy efficient unit in BtuHheat /hour

SEERbase = the cooling SEER of the baseline unit

EERbase = the cooling EER of the baseline unit

HSPFbase = Heating Season Performance Factor of the Baseline Unit

COPbase = Coefficient of Performance of the Baseline Unit

EERee = the cooling EER of the new ground source, groundwater source, or water source heat pumpground being installed

COPee = Coefficient of Performance of the new ground source, groundwater source, or water source heat pump being installed

EFLHcool = Cooling annual Equivalent Full Load Hours EFLH for Commercial HVAC for different occupancies

EFLHheat = Heating annual Equivalent Full Load Hours EFLH for Commercial HVAC for different occupancies

CFcool = Demand Coincidence Factor (See Section 1.4) for Commercial HVAC

CFpump = Demand Coincidence Factor (See Section 1.4) for ground source loop pump

HPbasemotor = Horsepower of base case ground loop pump motor

LFbase = Load factor of the base case ground loop pump motor; Ratio of the peak running load to the nameplate rating of the pump motor.

ηbasemotor = efficiency of base case ground loop pump motor

ηbasepump = efficiency of base case ground loop pump at design point

HOURSbasepump = Run hours of base case ground loop pump motor

HPeemotor = Horsepower of retrofit case ground loop pump motor

LFee = Load factor of the retrofit case ground loop pump motor; Ratio of the peak running load to the nameplate rating of the pump motor.

ηeemotor = efficiency of retrofit case ground loop pump motor

ηeepump = efficiency of retrofit case ground loop pump at design point

HOURSeepump = Run hours of retrofit case ground loop pump motor

3.412 = kBtu per kWh

0.746 = conversion factor from horsepower to kW (kW/hp)

Table 3‑62: Geothermal Heat Pump– Values and References

| **Component** | **Type** | **Values** | **Sources** |
| --- | --- | --- | --- |
| BtuHcool | Variable | Nameplate data (ARI or AHAM) | EDC Data Gathering |
| BtuH*heat* | Variable | Nameplate data (ARI or AHAM)  Use BtuHcool if the heating capacity is not known | EDC Data Gathering |
| SEERbase | Fixed | Early Replacement: Nameplate data | EDC Data Gathering |
| New Construction or Replace on Burnout: Default values from Table 3‑65 | See Table 3‑65 |
| EERbase | Fixed | Early Replacement: Nameplate data | EDC Data Gathering |
| New Construction or Replace on Burnout: Default values from Table 3‑65 | See Table 3‑65 |
| HSPFbase | Fixed | Early Replacement: Nameplate data | EDC Data Gathering |
| New Construction or Replace on Burnout: Default values from Table 3‑65 | See Table 3‑65 |
| COPbase | Fixed | Early Replacement: Nameplate data | EDC Data Gathering |
| New Construction or Replace on Burnout: Default values from Table 3‑65 | See Table 3‑65 |
| EERee | Variable | Nameplate data (ARI or AHAM) | EDC Data Gathering |
| COPee | Variable | Nameplate data (ARI or AHAM) | EDC Data Gathering |
| EFLHcool | Variable | Based on Logging or Modeling | EDC Data Gathering |
| Default values from Table 3‑21 and Table 3‑22 | See Table 3‑21 and Table 3‑22 |
| EFLHheat | Variable | Based on Logging or Modeling | EDC Data Gathering |
| Default values from Table 3‑21 and Table 3‑22 | See Table 3‑21 and Table 3‑22 |
| CFcool | Fixed | Default = 0.80 | 3 |
| CFpump | Fixed | if unit runs 24/7/365, default = 1.0;  if unit runs only with heat pump unit compressor, default = 0.67 | 4 |
| HPbasemotor | Variable | Nameplate | EDC Data Gathering |
| LFbase | Variable | Based on spot metering | EDC Data Gathering |
| Default 75% | 1 |
| ηbasemotor | Variable | Nameplate | EDC’s Data Gathering |
| If unknown, assume the federal minimum efficiency requirements in Table 3‑63 | See Table 3‑63 |
| ηbasepump | Variable | Nameplate | EDC’s Data Gathering |
| If unknown, assume program compliance efficiency in Table 3‑64 | See Table 3‑64 |
| HOURSbasepump | Fixed | Based on Logging or Modeling | EDC’s Data Gathering |
| EFLHcool + EFLHheat [[189]](#footnote-219)  Default values from Table 3‑21 and Table 3‑22 | 2 |
| HPeemotor | Variable | Nameplate | EDC’s Data Gathering |
| LFee | Variable | Based on spot metering | EDC Data Gathering |
| Default 75% | 1 |
| ηeemotor | Variable | Nameplate | EDC’s Data Gathering |
| If unknown, assume the federal minimum efficiency requirements in Table 3‑63 | Table 3‑63 |
| ηeepump | Variable | Nameplate | EDC’s Data Gathering |
| If unknown, assume program compliance efficiency in Table 3‑64 | See Table 3‑64 |
| HOURSeepump | Variable | Based on Logging or Modeling | EDC Data Gathering |
| EFLHcool + EFLHheat [[190]](#footnote-220)  Default values from Table 3‑21 and Table 3‑22 | 2 |

**Sources:**

1. California Public Utility Commission. *Database for Energy Efficiency Resources* 2005
2. Provides a conservative estimate in the absence of logging or modeling data.
3. Average based on coincidence factors from Ohio, New Jersey, Mid-Atlantic, Massachusetts, Connecticut, Illinois, New York, CEE and Minnesota. (74%, 67%, 81%, 94%, 82%, 72%, 100%, 70% and 76% respectively)
4. Engineering Estimate - See definition in section 3.3.2 for specific algorithm to be used when performing spot metering analysis to determine alternate load factor.

Table 3‑63: Federal Minimum Efficiency Requirements for Motors[[191]](#footnote-221)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Size HP** | **Open Drip Proof (ODP) # of Poles** | | | **Totally Enclosed Fan-Cooled (TEFC)** | | |
| *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% |

Table 3‑64:: Ground Loop Pump Efficiency[[192]](#footnote-222)

|  |  |
| --- | --- |
| **HP** | **Minimum Pump Efficiency at Design Point (ηpump)** |
| 1.5 | 65% |
| 2 | 65% |
| 3 | 67% |
| 5 | 70% |
| 7.5 | 73% |
| 10 | 75% |
| 15 | 77% |
| 20 | 77% |

Table 3‑65: Default Baseline Equipment Efficiencies

| **Equipment Type and Capacity** | **Cooling Baseline** | **Heating Baseline** |
| --- | --- | --- |
| Air-Source Air Conditioners | | |
| < 65,000 BtuH | 13.0 SEER | N/A |
| > 65,000 BtuH and <135,000 BtuH | 11.2 EER | N/A |
| > 135,000 BtuH and < 240,000 BtuH | 11.0 EER | N/A |
| > 240,000 BtuH and < 760,000 BtuH  (IPLV for units with capacity-modulation only) | 10.0 EER / 9.7 IPLV | N/A |
| > 760,000 BtuH  (IPLV for units with capacity-modulation only) | 9.7 EER / 9.4 IPLV | N/A |
| Water-Source and Evaporatively-Cooled Air Conditioners | | |
| < 65,000 BtuH | 12.1 EER | N/A |
| > 65,000 BtuH and <135,000 BtuH | 11.5 EER | N/A |
| > 135,000 BtuH and < 240,000 BtuH | 11.0 EER | N/A |
| > 240,000 BtuH | 11.5 EER | N/A |
| Air-Source Heat Pumps | | |
| < 65,000 BtuH | 13 SEER | 7.7 HSPF |
| > 65,000 BtuH and <135,000 BtuH | 11.0 EER | 3.3 COP |
| > 135,000 BtuH and < 240,000 BtuH | 10.6 EER | 3.2 COP |
| > 240,000 BtuH  (IPLV for units with capacity-modulation only) | 9.5 EER / 9.2 IPLV | 3.2 COP |
| Water-Source Heat Pumps | | |
| < 17,000 BtuH | 11.2 EER | 4.2 COP |
| > 17,000 BtuH and < 135,000 BtuH | 12.0 EER | 4.2 COP |
| Ground Water Source Heat Pumps | | |
| < 135,000 BtuH | 16.2 EER | 3.6 COP |
| Ground Source Heat Pumps | | |
| < 135,000 BtuH | 13.4 EER | 3.1 COP |
| Packaged Terminal Systems (Replacements)[[193]](#footnote-223) | | |
| PTAC (cooling) | 10.9 - (0.213 x Cap / 1000) EER |  |
| PTHP | 10.8 - (0.213 x Cap / 1000) EER | 2.9 - (0.026 x Cap / 1000) COP |
| Packaged Terminal Systems (New Construction) | | |
| PTAC (cooling) | 12.5 - (0.213 x Cap / 1000) EER |  |
| PTHP | 12.3 - (0.213 x Cap / 1000) EER | 3.2 - (0.026 x Cap / 1000) COP |

### Measure Life

The expected measure life is assumed to be 15 years.[[194]](#footnote-224)

### Evaluation Protocols

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

## Ductless Mini-Split Heat Pumps – Commercial < 5.4 tons

|  |  |
| --- | --- |
| **Measure Name** | **Ductless Heat Pumps** |
| Target Sector | Commercial (non-residential) Establishments |
| Measure Unit | Ductless Heat Pumps |
| Unit Energy Savings | Variable based on efficiency of systems |
| Unit Peak Demand Reduction | Variable based on efficiency of systems |
| Measure Life | 15 |

ENERGY STAR ductless “mini-split” heat pumps (DHP) utilize high efficiency SEER/EER and HSPF energy performance factors of 14.5/12 and 8.2, respectively, or greater. This technology typically converts an electric resistance heated space into a space heated/cooled with a single or multi-zonal ductless heat pump system.

### Eligibility

This protocol documents the energy savings attributed to ENERGY STAR ductless mini-split heat pumps with energy-efficiency performance of 14.5/12 SEER/EER and 8.2 HSPF or greater with inverter technology.[[195]](#footnote-225) The baseline heating system could be an existing electric resistance, a lower-efficiency ductless heat pump system, a ducted heat pump, packaged terminal heat pump (PTHP), electric furnace, or a non-electric fuel-based system. The baseline cooling system could be a standard efficiency heat pump system, central air conditioning system, packaged terminal air conditioner (PTAC), or room air conditioner. The DHP could be a new device in an existing space, a new device in a new space, or could replace an existing heating/cooling device. The DHP systems could be installed as a single-zone system (one indoor unit, one outdoor unit) or a multi-zone system (multiple indoor units, one outdoor unit).

### Algorithms

The savings depend on three main factors: baseline condition, usage, 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 = CAPYheat / 1000 X (1/COPb - 1/COPe ) / 3.413 X EFLHheat X LF

ΔkWhcool = CAPYcool / 1000 X (1/EERb – 1/EERe ) X EFLHcool X LF

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

#### Multi-Zone:

ΔkWh = ΔkWhcool + ΔkWhheat

ΔkWhheat = [CAPYheat / 1000 X (1/COPb - 1/COPe ) / 3.413 X EFLHheat X LF]ZONE1 + [CAPYheat / 1000 X (1/COPb - 1/COPe ) / 3.413 X EFLHheat X LF]ZONE2 + [CAPYheat / 1000 X (1/COPb - 1/COPe ) / 3.413 X EFLHheat X LF]ZONEn

ΔkWhcool = [CAPYcool / 1000 X (1/EERb – 1/EERe ) X EFLHcool X LF]ZONE1 + [CAPYcool / 1000 X (1/EERb – 1/EERe ) X EFLHcool X LF]ZONE2 + [CAPYcool / 1000 X (1/EERb – 1/EERe ) X EFLHcool X LF]ZONEn

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

### Definition of Terms

CAPYcool =The cooling capacity of the indoor unit, given in BTUH as appropriate for the calculation. This protocol is limited to units < 65,000 BTUh (5.4 tons)

CAPYheat =The heating capacity of the indoor unit, given in BTUH as appropriate for the calculation.

EFLHcool  = Equivalent Full Load Hours for cooling

EFLHheat = Equivalent Full Load Hours for heating

COPb = Coefficient Of Performance heating efficiency of baseline unit

COPe = Efficiency of the installed DHP (based on HSPF)

EERb = Energy Efficiency Ratio cooling efficiency of baseline unit

EERe = Efficiency of the installed DHP

LF = Load factor

CF = Demand Coincidence Factor (See Section 1.4)

Table 3‑66: DHP – Values and References

| **Component** | **Type** | **Values** | **Sources** |
| --- | --- | --- | --- |
| CAPYcool  CAPYheat | Variable | Nameplate | AEPS Application; EDC Data Gathering |
| EFLHcool EFLHheat | Fixed | See Table 3‑67: and Table 3‑68: | 1 |
| COPb | Fixed | Standard DHP: 2.26  Electric resistance: 1.00  ASHP: 2.26  PTHP: 3.2-(0.026xCAPYheat/1000)  Electric furnace: 0.95  For new space, no heat in an existing space, or non-electric heating in an existing space: use standard DHP: 2.26 | 2, 4,9 |
| EERb | Fixed | DHP, ASHP, or central AC: 11.3  Room AC: 9.8  PTAC: 12.5-(0.213xCAPYcool/1000)  PTHP: 12.3-(0.213xCAPYcool/1000)  For new space or no cooling in an existing space: use Central AC: 11.3 | 3,4,5,7,9 |
| COPe | Variable | = (HSPFe / 3.413) Based on nameplate information. Should be at least ENERGY STAR. | AEPS Application; EDC Data Gathering |
| EERe | Variable | Based on nameplate information. Should be at least ENERGY STAR.  = SEERe X (11.3/13) if EER not available | AEPS Application; EDC Data Gathering |
| CF | Fixed | 70% | 6 |
| LF | Fixed | 25% | 8 |

**Sources:**

1. US Department of Energy. ENERGY STAR Calculator and Bin Analysis Models.
2. COP = HSPF/3.413. HSPF = 3.413 for electric resistance heating, HSPF = 7.7 for standard DHP. Electric furnace COP typically varies from 0.95 to 1.00 and thereby assumed a COP 0.95 (HSPF = 3.242).
3. Federal Register, Vol. 66, No. 14, Monday, January 22, 2001/Rules and Regulations, p. 7170-7200.
4. Air-Conditioning, Heating, and Refrigeration Institute (AHRI); the directory of the available ductless mini-split heat pumps and corresponding efficiencies (lowest efficiency currently available). Accessed 8/16/2010.
5. SEER based on average EER of 9.8 for room AC unit. From Pennsylvania’s Technical Reference Manual.
6. Based on an analysis of six different utilities by Proctor Engineering. From Pennsylvania’s Technical Reference Manual.
7. Average EER for SEER 13 unit. From Pennsylvania’s Technical Reference Manual.
8. The load factor is used to account for inverter-based DHP units operating at partial loads. The value was chosen to align savings with what is seen in other jurisdictions: based on 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/>>, and the results found in the “Ductless Mini Pilot Study” by KEMA, Inc., June 2009. The adjustment is required to account for partial load conditions and because the EFLH used are based on central ducted systems which may overestimate actual usage for baseboard systems.
9. Package terminal air conditioners (PTAC) and package terminal heat pumps (PTHP) COP and EER minimum efficiency requirements is based on CAPY value. If the unit’s capacity is less than 7,000 BTUH, use 7,000 BTUH in the calculation. If the unit’s capacity is greater than 15,000 BTUH, use 15,000 BTUH in the calculation.

Table 3‑67: Cooling EFLH for Pennsylvania Cities[[196]](#footnote-226), [[197]](#footnote-227), [[198]](#footnote-228)

| **Space and/or Building Type** | **Allentown** | **Erie** | **Harrisburg** | **Pittsburgh** | **Williamsport** | **Philadelphia** | **Scranton** |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Arena/Auditorium/Convention Center | 602 | 332 | 640 | 508 | 454 | 711 | 428 |
| College: Classes/Administrative | 690 | 380 | 733 | 582 | 520 | 815 | 490 |
| Convenience Stores | 1,216 | 671 | 1,293 | 1,026 | 917 | 1,436 | 864 |
| Dining: Bar Lounge/Leisure | 912 | 503 | 969 | 769 | 688 | 1,077 | 648 |
| Dining: Cafeteria / Fast Food | 1,227 | 677 | 1,304 | 1,035 | 925 | 1,449 | 872 |
| Dining: Restaurants | 912 | 503 | 969 | 769 | 688 | 1,077 | 648 |
| Gymnasium/Performing Arts Theatre | 690 | 380 | 733 | 582 | 520 | 815 | 490 |
| Hospitals/Health care | 1,396 | 770 | 1,483 | 1,177 | 1,052 | 1,648 | 992 |
| Industrial: 1 Shift/Light Manufacturing | 727 | 401 | 773 | 613 | 548 | 859 | 517 |
| Industrial: 2 Shift | 988 | 545 | 1,050 | 833 | 745 | 1,166 | 702 |
| Industrial: 3 Shift | 1,251 | 690 | 1,330 | 1,055 | 944 | 1,478 | 889 |
| Lodging: Hotels/Motels/Dormitories | 756 | 418 | 805 | 638 | 571 | 894 | 538 |
| Lodging: Residential | 757 | 418 | 805 | 638 | 571 | 894 | 538 |
| Multi-Family (Common Areas) | 1,395 | 769 | 1,482 | 1,176 | 1,052 | 1,647 | 991 |
| Museum/Library | 851 | 469 | 905 | 718 | 642 | 1,005 | 605 |
| Nursing Homes | 1,141 | 630 | 1,213 | 963 | 861 | 1,348 | 811 |
| Office: General/Retail | 851 | 469 | 905 | 718 | 642 | 1,005 | 605 |
| Office: Medical/Banks | 851 | 469 | 905 | 718 | 642 | 1,005 | 605 |
| Parking Garages & Lots | 938 | 517 | 997 | 791 | 707 | 1,107 | 666 |
| Penitentiary | 1,091 | 602 | 1,160 | 920 | 823 | 1,289 | 775 |
| Police/Fire Stations (24 Hr) | 1,395 | 769 | 1,482 | 1,176 | 1,052 | 1,647 | 991 |
| Post Office/Town Hall/Court House | 851 | 469 | 905 | 718 | 642 | 1,005 | 605 |
| Religious Buildings/Church | 602 | 332 | 640 | 508 | 454 | 711 | 428 |
| Retail | 894 | 493 | 950 | 754 | 674 | 1,055 | 635 |
| Schools/University | 634 | 350 | 674 | 535 | 478 | 749 | 451 |
| Warehouses (Not Refrigerated) | 692 | 382 | 735 | 583 | 522 | 817 | 492 |
| Warehouses (Refrigerated) | 692 | 382 | 735 | 583 | 522 | 817 | 492 |
| Waste Water Treatment Plant | 1,265 | 1,473 | 1,204 | 1,208 | 1,270 | 1,182 | 1,285 |

Table 3‑68: Heating EFLH for Pennsylvania Cities[[199]](#footnote-229), [[200]](#footnote-230), [[201]](#footnote-231)

| **Space and/or Building Type** | **Allentown** | **Erie** | **Harrisburg** | **Pittsburgh** | **Williamsport** | **Philadelphia** | **Scranton** |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Arena/Auditorium/Convention Center | 1,719 | 2,002 | 1,636 | 1,642 | 1,726 | 1,606 | 1,747 |
| College: Classes/Administrative | 1,559 | 1,815 | 1,484 | 1,489 | 1,565 | 1,457 | 1,584 |
| Convenience Stores | 603 | 3,148 | 2,573 | 2,582 | 2,715 | 2,526 | 2,747 |
| Dining: Bar Lounge/Leisure | 1,156 | 1,346 | 1,100 | 1,104 | 1,161 | 1,080 | 1,175 |
| Dining: Cafeteria / Fast Food | 582 | 2,066 | 1,689 | 1,695 | 1,782 | 1,658 | 1,803 |
| Dining: Restaurants | 1,156 | 1,346 | 1,100 | 1,104 | 1,161 | 1,080 | 1,175 |
| Gymnasium/Performing Arts Theatre | 1,559 | 1,815 | 1,484 | 1,489 | 1,565 | 1,457 | 1,584 |
| Hospitals/Health care | 276 | 321 | 263 | 264 | 277 | 2,526 | 280 |
| Industrial: 1 Shift/Light Manufacturing | 1,491 | 1,737 | 1,420 | 1,425 | 1,498 | 1,394 | 1,516 |
| Industrial: 2 Shift | 1,017 | 1,184 | 968 | 972 | 1,022 | 951 | 1,034 |
| Industrial: 3 Shift | 538 | 626 | 512 | 513 | 540 | 502 | 546 |
| Lodging: Hotels/Motels/Dormitories | 1,438 | 1,675 | 1,369 | 1,374 | 1,444 | 1,344 | 1,462 |
| Lodging: Residential | 1,438 | 1,675 | 1,369 | 1,374 | 1,444 | 1,344 | 1,462 |
| Multi-Family (Common Areas) | 277 | 3,148 | 2,573 | 2,582 | 2,715 | 2,526 | 2,747 |
| Museum/Library | 1,266 | 1,474 | 1,205 | 1,209 | 1,271 | 1,183 | 1,286 |
| Nursing Homes | 738 | 3,148 | 2,573 | 2,582 | 2,715 | 2,526 | 2,747 |
| Office: General/Retail | 1,266 | 884 | 722 | 725 | 762 | 709 | 771 |
| Office: Medical/Banks | 1,266 | 1,474 | 1,205 | 1,209 | 1,271 | 1,183 | 1,286 |
| Parking Garages & Lots | 1,110 | 1,292 | 1,056 | 1,060 | 1,114 | 1,037 | 1,128 |
| Penitentiary | 829 | 3,148 | 2,573 | 2,582 | 2,715 | 2,526 | 2,747 |
| Police/Fire Stations (24 Hr) | 277 | 3,148 | 2,573 | 2,582 | 2,715 | 2,526 | 2,747 |
| Post Office/Town Hall/Court House | 1,266 | 1,474 | 1,205 | 1,209 | 1,271 | 1,183 | 1,286 |
| Religious Buildings/Church | 1,718 | 2,001 | 1,635 | 1,641 | 1,725 | 1,605 | 1,746 |
| Retail | 1,188 | 1,383 | 1,130 | 1,135 | 1,193 | 1,110 | 1,207 |
| Schools/University | 1,661 | 984 | 805 | 808 | 849 | 790 | 859 |
| Warehouses (Not Refrigerated) | 538 | 567 | 463 | 465 | 489 | 455 | 495 |
| Warehouses (Refrigerated) | 1,555 | 1,810 | 1,480 | 1,485 | 1,561 | 1,453 | 1,580 |
| Waste Water Treatment Plant | 1,265 | 1,473 | 1,204 | 1,208 | 1,270 | 1,182 | 1,285 |

### Measure Life

According to an October 2008 report for the CA Database for Energy Efficiency Resources, a heat pump’s lifespan is 15 years.[[202]](#footnote-232)

### Evaluation Protocols

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

## ENERGY STAR Electric Steam Cooker

This measure applies to the installation of electric ENERGY STAR steam cookers as either a new item or replacement for an existing unit. Gas steam cookers are not eligible. The steam cookers must meet minimum ENERGY STAR efficiency requirements. A qualifying steam cooker must meet a minimum cooking efficiency of 50 percent and meet idle energy rates specified by pan capacity.

The baseline equipment is a unit with efficiency specifications that do not meet the minimum ENERGY STAR efficiency requirements.

### Algorithms

The savings depend on three main factors: pounds of food steam cooked per day, pan capacity, and cooking efficiency.

ΔkWh = ΔkWhcooking+ ΔkWhidle

ΔkWhcooking = lbsfood X EnergyToFood X (1/Effb – 1/Effee)

ΔkWhidle = [(Poweridle-b X (1- %HOURSconsteam) + %HOURSconsteam X CAPYb X Qtypans X (EnergyToFood/Effb) X (HOURSop - lbsfood/(CAPYb X Qtypans) - HOURSpre)] –

[(Poweridle-ee X (1- %HOURSconsteam) + %HOURSconsteam X CAPYee X Qtypans X (EnergyToFood/Effee) X (HOURSop - lbsfood/(CAPYee X Qtypans) - HOURSpre)]

ΔkWpeak  = (ΔkWh / EFLH) X CF

### Definition of Terms

lbsfood = Pounds of food cooked per day in the steam cooker

EnergyToFood = ASTM energy to food ratio; energy (kilowatt-hours) required per pound of food during cooking

Effee = Cooking energy efficiency of the new unit

Effb = Cooking energy efficiency of the baseline unit

Poweridle-b = Idle power of the baseline unit in kilowatts

Poweridle-ee = Idle power of the new unit in kilowatts

%HOURSconsteam = Percentage of idle time per day the steamer is in continuous steam mode instead of timed cooking. The power used in this mode is the same as the power in cooking mode.

HOURSop = Total operating hours per day

` HOURSpre = Daily hours spent preheating the steam cooker

CAPYb = Production capacity per pan of the baseline unit in pounds per hour of the baseline unit

CAPYee = Production capacity per pan of the new unit in pounds per hour

Qtypans = Quantity of pans in the unit

EFLH = Equivalent full load hours per year

CF = Demand Coincidence Factor (See Section 1.4) 1000 = Conversion from watts to kilowatts

Table 3‑69: Steam Cooker - Values and References

| **Component** | **Type** | **Values** | **Sources** |
| --- | --- | --- | --- |
| Lbsfood | Variable | Nameplate | EDC Data Gathering |
| Default values in Table 3‑70 | Table 3‑70 |
| EnergyToFood | Fixed | 0.0308 kWh/pound | 1 |
| Effee | Variable | Nameplate | EDC Data Gathering |
| Default values in Table 3‑70 | Table 3‑70 |
| Effb | Fixed | See Table 3‑70 | Table 3‑70 |
| Poweridle-b | Variable | See Table 3‑70 | Table 3‑70 |
| Poweridle-ee | Variable | Nameplate | EDC Data Gathering |
| Default values in Table 3‑70 | Table 3‑70 |
| HOURSop | Variable | Nameplate | EDC Data Gathering |
| 12 hours | 1 |
| HOURSpre | Fixed | 0.25 | 1 |
| %HOURSconsteam | Fixed | 40% | 1 |
| CAPYb | Fixed | See Table 3‑70 | Table 3‑70 |
| CAPYee | Fixed | See Table 3‑70 | Table 3‑70 |
| Qtypans | Variable | Nameplate | EDC Data Gathering |
| EFLH | Fixed | 4380 | 2 |
| CF | Fixed | 0.84 | 4, 5 |

**Sources:**

1. US Department of Energy. ENERGY STAR Calculator.
2. Food Service Technology Center (FSTC), based on an assumption that the restaurant is open 12 hours a day, 365 days a year.
3. FSTC (2002). *Commercial Cooking Appliance Technology Assessment*. Chapter 8: Steamers.
4. *State of Ohio Energy Efficiency Technical Reference Manual* cites a CF = 0.84 as adopted from the Efficiency Vermont TRM. Assumes CF is similar to that for general commercial industrial lighting equipment.
5. RLW Analytics. Coincidence Factor Study – Residential and Commercial Industrial Lighting Measures. Spring 2007.

Table 3‑70: Default Values for Electric Steam Cookers by Number of Pans[[203]](#footnote-233)

| **# of Pans** | **Parameter** | **Baseline Model** | **Efficient Model** | **Savings** |
| --- | --- | --- | --- | --- |
| 3 | Poweridle (kW)[[204]](#footnote-234) | 1.000 | 0.27 |  |
| CAPY (lb/h) | 23.3 | 16.7 |  |
| lbsfood | 100 | 100 |  |
| Eff[[205]](#footnote-235) | 30% | 59% |  |
| ΔkWh |  |  | 2,813 |
| ΔkWpeak |  |  | 0.54 |
| 4 | Poweridle (kW) | 1.325 | 0.30 |  |
| CAPY (lb/h) | 21.8 | 16.8 |  |
| lbsfood | 128 | 128 |  |
| Eff | 30% | 57% |  |
| ΔkWh |  |  | 3,902 |
| ΔkWpeak |  |  | 0.75 |
| 5 | Poweridle (kW) | 1.675 | 0.31 |  |
| CAPY (lb/h) | 20.6 | 16.6 |  |
| lbsfood | 160 | 160 |  |
| Eff | 30% | 70% |  |
| ΔkWh |  |  | 5,134 |
| ΔkWpeak |  |  | 0.98 |
| 6 | Poweridle (kW) | 2.000 | 0.31 |  |
| CAPY (lb/h) | 20.0 | 16.7 |  |
| lbsfood | 192 | 192 |  |
| Eff | 30% | 65% |  |
| ΔkWh |  |  | 6,311 |
| ΔkWpeak |  |  | 1.21 |

### Measure Life

According to Food Service Technology Center (FSTC) data provided to ENERGY STAR, the lifetime of a steam cooker is 12 years[[206]](#footnote-236).

### Evaluation Protocols

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

## Refrigeration – Night Covers for Display Cases

|  |  |
| --- | --- |
| **Measure Name** | **Night Covers for Display Cases** |
| Target Sector | Commercial Refrigeration |
| Measure Unit | Display Cases |
| Unit Energy Savings | Variable |
| Unit Peak Demand Reduction | Variable |
| Measure Life | 5 years |

This measure is the installation of night covers on existing open-type refrigerated display cases, where covers are deployed during the facility unoccupied hours in order to reduce refrigeration energy consumption.. These types of display cases can be found in small and medium to large size grocery stores. The air temperature inside low-temperature display cases is below 0°F[[207]](#footnote-237) and between 0°F to 30°F for medium-temperature and between 35°F to 55°F for high-temperature display cases[[208]](#footnote-238). The main benefit of using night covers on open display cases is a reduction of infiltration and radiation cooling loads. It is recommended that these covers have small, perforated holes to decrease moisture buildup.

### Algorithms

The energy savings and demand reduction are obtained through the following calculations[[209]](#footnote-239).

ΔkWh = W x SF x HOU

There are no demand savings for this measure because the covers will not be in use during the peak period[[210]](#footnote-240).

### Definition of Terms

The variables in the above equation are defined below:

W = Width of the opening that the night covers protect (ft)

SF = Savings factor based on the temperature of the case (kW/ft)

HOU = Annual hours that the night covers are in use

Table 3‑71: Night Covers Calculations Assumptions

|  |  |  |  |
| --- | --- | --- | --- |
| **Component** | **Type** | **Value** | **Source** |
| W | Variable | EDC’s Data Gathering | EDC’s Data Gathering |
| SF | Fixed | Default values in Table 3‑72: Savings Factors | 1 |
| HOU | Variable | EDC’s Data Gathering  Default: 2190[[211]](#footnote-241) | EDC’s Data Gathering |

**Sources:**

1. CL&P Program Savings Documentation for 2011 Program Year (2010). Factors based on Southern California Edison (1997). *Effects of the Low Emissive Shields on Performance and Power Use of a Refrigerated Display Case*.

Table 3‑72: Savings Factors

|  |  |
| --- | --- |
| **Cooler Case Temperature** | **Savings Factor** |
| Low Temperature (-35 F to -5 F) | 0.03 kW/ft |
| Medium Temperature (0 F to 30 F) | 0.02 kW/ft |
| High Temperature (35 F to 55 F) | 0.01 kW/ft |

The demand and energy savings assumptions are based on analysis performed by Southern California Edison (SCE). SCE conducted this test at its Refrigeration Technology and Test Center (RTTC). The RTTC’s sophisticated instrumentation and data acquisition system provided detailed tracking of the refrigeration system’s critical temperature and pressure points during the test period. These readings were then utilized to quantify various heat transfer and power related parameters within the refrigeration cycle. The results of SCE’s test focused on three typical scenarios found mostly in supermarkets.

### Measure Life

The expected measure life is 5 years[[212]](#footnote-242),[[213]](#footnote-243).

## Office Equipment – Network Power Management Enabling

Over the last three years, a number of strategies have evolved to save energy in desktop computers. One class of products uses software implemented at the network level for desktop computers that manipulates the internal power settings of the central processing unit (CPU) and of the monitor. These power settings are an integral part of a computer’s operating system (most commonly, Microsoft Windows) including “on”, “standby”, “sleep”, and “off” modes and can be set by users from their individual desktops.

Most individual computer users are unfamiliar with these energy saving settings, and hence, settings are normally set by an IT administrator to minimize user complaints related to bringing the computer back from standby, sleep, or off modes. However, these strategies use a large amount of energy during times when the computer is not in active use. Studies have shown that energy consumed during non-use periods is large, and is often the majority of total energy consumed.

Qualifying software must control desktop computer and monitor power settings within a network from a central location.

### Deemed Savings

The energy savings per unit found in various studies specific to the Verdiem Surveyor software varied from 33.8 kWh/year to 330 kWh/year, with an average savings of about 200 kWh/year. This includes the power savings from the PC as well as the monitor. Deemed savings are based on actual field measurements from Duquesne’s service territory of the Verdiem Surveyor product.

Demand reduction was closely monitored in the study by Southern California Edison over a period of one month. This included 120 PC’s operating in nine different departments within SCE’s network. The study found that statistically the average PC did use less power during peak periods by about 20W. The use of individual PC’s could vary dramatically, but with a sample size of about 12 units or greater the pattern for demand reduction was very clear.

Table 3‑73: Network Power Controls, Per Unit Summary Table

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Measure Name** | **Unit** | **Gross Peak kW Reduction per Unit** | **Gross Peak kWh Reduction per Unit** | **Effective Useful Life** | **IMC per unit ($)** | **Net to Gross Ratio** |
| Network PC Plug Load Power Management Software | One copy of licensed software installed on a PC workstation | 0.020 | 148 | 5 | 20 | 0.8 |

### Effective Useful Life

The EUL for this technology is estimated to be five (5) years. While DEER lists the EUL of electro-mechanical plug load sensors at ten years, this product is subject to the cyclical nature of the PC software and hardware industry, so a more conservative number is appropriate. This is the same value used in the SDG&E program.

**Sources:**

1. Dimetrosky, S., Luedtke, J. S., & Seiden, K. (2005). *Surveyor Network Energy Manager: Market Progress Evaluation Report, No. 2* (Northwest Energy Efficiency Alliance report #E05-136). Portland, OR: Quantec LLC. <http://www.nwalliance.org/research/reports/136.pdf>
2. Dimetrosky, S., Steiner, J., & Vellinga, N. (2006). *San Diego Gas & Electric 2004-2005 Local Energy Savers Program Evaluation Report* (Study ID: SDG0212). Portland, OR: Quantec LLC. <http://www.calmac.org/publications/SDGE_ESP_EMV_Report_073106_Final.pdf>
3. Greenberg, D. (2004). *Network Power Management Software: Saving Energy by Remote Control* (E source report No. ER-04-15). Boulder, CO: Platts Research & Consulting.
4. Roth, K., Larocque, G., & Kleinman, J. (2004). *Energy Consumption by Office and Telecommunications Equipment in Commercial Buildings Volume II: Energy Savings Potential* (U.S. DOE contract No. DE-AM26-99FT40465). Cambridge, MA: TIAX LLC. <http://www.eere.energy.gov/buildings/info/documents/pdfs/office_telecom-vol2_final.pdf>
5. Southern California Edison. (May 31, 2005). *Surveyor Consumption Report* (contact: Leonel Campoy).

## Refrigeration – Auto Closers

|  |  |
| --- | --- |
| **Measure Name** | **Auto Closers** |
| Target Sector | Commercial Refrigeration |
| Measure Unit | Walk-in Coolers and Freezers |
| Unit Energy Savings | Fixed |
| Unit Peak Demand Reduction | Fixed |
| Measure Life | 8 years |

The auto-closer should be applied to the main insulated opaque door(s) of a walk-in cooler or freezer. Auto-closers on freezers and coolers can reduce the amount of time that doors are open, thereby reducing infiltration and refrigeration loads. These measures are for retrofit of doors not previously equipped with auto-closers, and assume the doors have strip curtains.

### Eligibility[[214]](#footnote-244)

This protocol documents the energy savings attributed to installation of auto closers in walk-in coolers and freezers. The auto-closer must be able to firmly close the door when it is within one inch of full closure. The walk-in door perimeter must be ≥16 ft.

### Algorithms

Auto-Closers are treated in Database for Energy Efficient Resources (DEER) as weather-sensitive; therefore the recommended deemed savings values indicated below are derived from the DEER runs in California climate zones most closely associated to the climate zones of the main seven Pennsylvania cities, The association between California climate zones and the Pennsylvania cities is based on Cooling Degree Days (CDDs). Savings estimates for each measure are averaged across six building vintages for each climate-zone for building type 9, Grocery Stores.

**Main Cooler Doors**

ΔkWh = ΔkWhcooler

ΔkWpeak = ΔkWcooler

**Main Freezer Doors**

ΔkWh = ΔkWhfreezer

ΔkWpeak = ΔkWfreezer

### Definition of Terms

ΔkWhcooler, = Annual kWh savings for main cooler doors

ΔkWcooler = Summer peak kW savings for main cooler doors

ΔkWhfreezer, = Annual kWh savings for main freezer doors

ΔkWfreezer = Summer peak kW savings for main freezer doors

Table 3‑74: Refrigeration Auto Closers Calculations Assumptions

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Reference City** | **Associated California Climate Zone** | **Value** | | | | **Source** |
| **Cooler** | | **Freezer** | |
| **kWhcooler** | **kWcooler** | **kWhfreezer** | **kWfreezer** |
| Allentown | 4 | 961 kWh | 0.135 kW | 2319 kWh | 0.327 kW | 1 |
| Williamstown | 4 | 961 kWh | 0.135 kW | 2319 kWh | 0.327 kW | 1 |
| Pittsburgh | 4 | 961 kWh | 0.135 kW | 2319 kWh | 0.327 kW | 1 |
| Harrisburg | 8 | 981 kWh | 0.108 kW | 2348 kWh | 0.272 kW | 1 |
| Philadelphia | 13 | 1017 kWh | 0.143 kW | 2457 kWh | 0.426 kW | 1 |
| Scranton | 16 | 924 kWh | 0.146 kW | 2329 kWh | 0.296 kW | 1 |
| Erie | 6 | 952 kWh | 0.116 kW | 2329 kWh | 0.191 kW | 1 |

**Sources:**

1. 2005 DEER weather sensitive commercial data; DEER Database, http://www.deeresources.com/

### Measure Life

The expected measure life is **8 years[[215]](#footnote-245)**.

## Refrigeration – Door Gaskets for Walk-in Coolers and Freezers

The following protocol for the measurement of energy and demand savings is applicable to commercial refrigeration and applies to the replacement of worn-out gaskets with new better-fitting gaskets. Applicable gaskets include those located on the doors of walk-in coolers and freezers.

Tight fitting gaskets inhibit infiltration of warm, moist air into the cold refrigerated space, thereby reducing the cooling load. Aside from the direct reduction in cooling load, the associated decrease in moisture entering the refrigerated space also helps prevent frost on the cooling coils. Frost build-up adversely impacts the coil’s ,heat transfer effectiveness, reduces air passage (lowering heat transfer efficiency), and increases energy use during the defrost cycle. Therefore, replacing defective door gaskets. reduces compressor run time and improves the overall effectiveness of heat removal from a refrigerated cabinet.

### Eligibility

This protocol applies to the main doors of both low temperature (“freezer” – below 32°F) and medium temperature (“cooler” – above 32°F) walk-ins.

### Algorithms

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

ΔkWh = ΔkWh/ft X L

ΔkWpeak = ΔkW/ft X L

### Definition of Terms

ΔkWh/ft = Annual energy savings per linear foot of gasket

ΔkW/ft = Demand savings per linear foot of gasket

L = Total gasket length in linear feet

Table 3‑75: Door Gasket Assumptions

|  |  |  |  |
| --- | --- | --- | --- |
| **Component** | **Type** | **Value** | **Source** |
| ΔkWh/ft | Variable | From Table 3‑76 to  Table **3‑80** | 1 |
| ΔkW/ft | Variable | From Table 3‑76 to  Table **3‑80** | 1 |
| L | Variable | As Measured | EDC Data Gathering |

**Sources:**

1. Southern California Edison Company, Design & Engineering Services, Work Paper WPSCNRRN0001, 2006 – 2008 Program Planning Cycle.

The deemed savings values below are weather sensitive, therefore the values for each reference city are taken from the associated California climate zones listed in the Southern California Edison work paper. The Commercial Facilities Contract Group 2006-2008 Direct Impact Evaluation[[216]](#footnote-246) prepared for the California Public Utilities Commission, which mainly focuses on refrigerated display cases versus walk-in coolers, have shown low realization rates and net-to-gross ratios compared to the SCE work papers, mostly attributable to the effectiveness of baseline door gaskets being much higher than assumed. Due to the relatively small contribution of savings toward EDC portfolios as a whole and lack of Pennsylvania specific data, the ex ante savings based on the SCE work paper will be used until further research is conducted.

Table 3‑76: Door Gasket Savings per Linear Foot (CZ 4 Allentown, Pittsburgh, Williamstown)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Building Type** | **Coolers** | | **Freezers** | |
| **ΔkW/ft** | **ΔkWh/ft** | **ΔkW/ft** | **ΔkW/ft** |
| Restaurant | 0.000886 | 18 | 0.001871 | 63 |
| Small Grocery Store/ Convenience Store | 0.000658 | 15 | 0.001620 | 64 |
| Medium/Large Grocery Store/ Supermarkets | 0.000647 | 15 | 0.001593 | 91 |

Table 3‑77: Door Gasket Savings per Linear Foot (CZ 8 Harrisburg)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Building Type** | **Coolers** | | **Freezers** | |
| **ΔkW/ft** | **ΔkWh/ft** | **ΔkW/ft** | **ΔkWh/ft** |
| Restaurant | 0.000908 | 19 | 0.001928 | 65 |
| Small Grocery Store/ Convenience Store | 0.000675 | 15 | 0.001669 | 67 |
| Medium/Large Grocery Store/ Supermarkets | 0.000663 | 15 | 0.001642 | 95 |

Table 3‑78: Door Gasket Savings per Linear Foot (CZ 13 Philadelphia)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Building Type** | **Coolers** | | **Freezers** | |
| **ΔkW/ft** | **ΔkWh/ft** | **ΔkW/ft** | **ΔkWh/ft** |
| Restaurant | 0.001228 | 23 | 0.002729 | 80 |
| Small Grocery Store/ Convenience Store | 0.000915 | 18 | 0.002368 | 81 |
| Medium/Large Grocery Store/ Supermarkets | 0.000899 | 18 | 0.002336 | 115 |

Table 3‑79: Door Gasket Savings per Linear Foot (CZ 16 Scranton)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Building Type** | **Coolers** | | **Freezers** | |
| **ΔkW/ft** | **ΔkWh/ft** | **ΔkW/ft** | **ΔkWh/ft** |
| Restaurant | 0.000908 | 17 | 0.001928 | 58 |
| Small Grocery Store/ Convenience Store | 0.000675 | 14 | 0.001669 | 60 |
| Medium/Large Grocery Store/ Supermarkets | 0.000663 | 14 | 0.001642 | 85 |

Table 3‑80: Door Gasket Savings per Linear Foot (CZ 6 Erie)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Building Type** | **Coolers** | | **Freezers** | |
| **ΔkW/ft** | **ΔkWh/ft** | **ΔkW/ft** | **ΔkWh/ft** |
| Restaurant | 0.000803 | 17 | 0.001659 | 59 |
| Small Grocery Store/ Convenience Store | 0.000596 | 14 | 0.001435 | 61 |
| Medium/Large Grocery Store/ Supermarkets | 0.000586 | 14 | 0.001410 | 86 |

### Measure Life

The expected measure life is 4 years[[217]](#footnote-247).

## Refrigeration – Suction Pipes Insulation

|  |  |
| --- | --- |
| **Measure Name** | **Refrigeration Suction Pipes Insulation** |
| Target Sector | Commercial Refrigeration |
| Measure Unit | Refrigeration |
| Unit Energy Savings | Fixed |
| Unit Peak Demand Reduction | Fixed |
| Measure Life | 11 years |

This measure applies to installation of insulation on existing bare suction lines (the larger diameter lines that run from the evaporator to the compressor) that are located outside of the refrigerated space. Insulation impedes heat transfer from the ambient air to the suction lines, thereby reducing undesirable system superheat. This decreases the load on the compressor, resulting in decreased compressor operating hours, and energy savings.

### Eligibility

This protocol documents the energy savings attributed to insulation of bare refrigeration suction pipes. The following are the eligibility requirements[[218]](#footnote-248):

* Must insulate bare refrigeration suction lines of 1-5/8 inches in diameter or less on existing equipment only
* Medium temperature lines require 3/4 inch of flexible, closed-cell, nitrite rubber or an equivalent insulation
* Low temperature lines require 1-inch of insulation that is in compliance with the specifications above
* Insulation exposed to the outdoors must be protected from the weather (i.e. jacketed with a medium-gauge aluminum jacket)

### Algorithms

The demand and energy savings assumptions are based on analysis performed by Southern California Edison (SCE)[[219]](#footnote-249). Measure savings per linear foot of insulation installed on bare suction lines in Grocery Stores is provided in Table 3‑81: Insulate Bare Refrigeration Suction Pipes Calculations Assumptions Table 3‑82 below lists the “deemed” savings for the associated California Climate zones and their respective Pennsylvania city.

ΔkWh = ΔkWh/ft X L

ΔkWpeak = ΔkW/ft X L

### Definition of Terms

The variables in the above equation are defined below:

ΔkWh/ft = Annual energy savings per linear foot of insulation

ΔkW/ft = Demand savings per linear foot of insulation

L = Total insulation length in linear feet

Table 3‑81: Insulate Bare Refrigeration Suction Pipes Calculations Assumptions

|  |  |  |  |
| --- | --- | --- | --- |
| **Component** | **Type** | **Value** | **Source** |
| ΔkW/ft | Variable | Table 3‑82 | 1 |
| ΔkWh/ft | Variable | Table 3‑82 | 1 |
| L | Variable | As Measured | EDC Data Gathering |

Table 3‑82: Insulate Bare Refrigeration Suction Pipes Savings per Linear Foot[[220]](#footnote-251)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **City** | **Associated California Climate Zone** | **Medium-TemperatureCoolers** | | **Low-TemperatureFreezers** | |
| **ΔkW/ft** | **ΔkWh/ft** | **ΔkW/ft** | **ΔkWh/ft** |
| Allentown | 4 | 0.001507 | 8.0 | 0.0023 | 13.0 |
| Williamstown | 4 | 0.001507 | 8.0 | 0.0023 | 13.0 |
| Pittsburgh | 4 | 0.001507 | 8.0 | 0.0023 | 13.0 |
| Philadelphia | 13 | 0.002059 | 11.0 | 0.00233 | 13.4 |
| Erie | 6 | 0.001345 | 7.3 | 0.002175 | 12.4 |
| Harrisburg | 8 | 0.001548 | 8.4 | 0.00233 | 13.4 |
| Scranton | 16 | 0.001548 | 7.5 | 0.00233 | 12.0 |

**Sources:**

1. Southern California Edison Company, “Insulation of Bare Refrigeration Suction Lines”, Work Paper WPSCNRRN0003.1

### Measure Life

The expected measure life is 11 years[[221]](#footnote-252),[[222]](#footnote-253).

## Refrigeration – Evaporator Fan Controllers

This measure is for the installation of evaporator fan controls[[223]](#footnote-254) in medium-temperature walk-in coolers with no pre-existing controls. Evaporator fans run constantly to provide cooling when the compressor is running, and to provide air circulation when the compressor is not running. The equations specified in the Algorithms section are for fans that are turned off and/or cycled.A fan controller saves energy by reducing fan usage, by reducing the refrigeration load resulting from the heat given off by the fan and by reducing compressor energy resulting from the electronic temperature control. This protocol documents the energy savings attributed to evaporator fan controls.

### Eligibility

This protocol documents the energy savings attributed to installation of evaporator fan controls in medium-temperature walk-in coolers and low temperature walk-in freezers.

### Algorithms[[224]](#footnote-255)

∆kWh = ∆kWhFan + ∆kWhHeat +∆kWhControl

∆kWhFan = kWFan X 8760 X %Off

∆kWhHeat = ∆kWhFan X 0.28 X Eff RS

∆kWhControl = [kWCP X HoursCP + kWFan X 8760 X (1 − %Off)] X 5%

∆kW = ∆kWh / 8760

### Definition of Terms

∆kWhFan = Energy savings due to evaporator being shut off

∆kWhHeat = Heat energy savings due to reduced heat from evaporator fans

∆kWhControl = Control energy savings due to electronic controls on compressor and evaporator

kWFan = Power demand of evaporator fan calculated from equipment nameplate data and estimated power factor/adjustment. See Table 3‑83: Evaporator Fan Controller Calculations Assumptions for power factor value.

%Off = Percent of annual hours that the evaporator is turned off

0.28 = Conversion of kW to tons: 3,413 Btuh/kW divided by 12,000 Btuh/ton

EffRS  = Efficiency of typical refrigeration system

kWCP  = Total power demand of compressor motor and condenser fan calculated from nameplate data and estimated power factor. See Table 3‑83: Evaporator Fan Controller Calculations Assumptions for power factor value.

HoursCP = Equivalent annual full load hours of compressor operation[[225]](#footnote-256)

5% = Reduced run-time of compressor and evaporator due to electronic controls[[226]](#footnote-257)

Table 3‑83: Evaporator Fan Controller Calculations Assumptions

|  |  |  |  |
| --- | --- | --- | --- |
| **Component** | **Type** | **Value** | **Source** |
| Power Factor: kWFan | Fixed | Default: 0.55 | 1 |
| %Off | Fixed | Default: 46% | 2 |
| EffRS | Fixed | Default: 1.6 kW/ton | 3 |
| Power Factor: kWCP | Fixed | Default: 0.85 | 4 |
| HoursCP | Variable | EDC Data Gathering | EDC Data Gathering |
| kWFan | Variable | EDC Data Gathering[[227]](#footnote-258) | EDC Data Gathering |

**Sources:**

1. Conservative value based on 15 years of NRM field observations and experience,
2. Select Energy (2004). *Analysis of Cooler Control Energy Conservation Measures. Pre*pared for NSTAR.
3. Estimated average refrigeration efficiency for small business customers, Massachusetts Technical Reference Manual
4. This value is an estimate by NRM based on hundreds of downloads of hours of use data from the electronic controller

### Measure Life

The expected measure life is 10 years[[228]](#footnote-259).

## ENERGY STAR Clothes Washer

|  |  |
| --- | --- |
| **Measure Name** | **Clothes Washer** |
| Target Sector | Multifamily Common Area Laundry |
| Measure Unit | Per Washing Machine |
| Unit Energy Savings | See Table 3‑85: DeemedExample Savings for ENERGY STAR Clothesft3 Washermachine |
| Unit Peak Demand Reduction | See Table 3‑85: DeemedExample Savings for ENERGY STAR Clothesft3 Washermachine |
| Measure Life | 10 years |

This protocol discusses the calculation methodology and the assumptions regarding baseline equipment, efficient equipment, and usage patterns used to estimate annual energy savings expected from the replacement of a standard clothes washer with an ENERGY STAR clothes washer with a minimum Modified Energy Factor (MEF) of >2.0 (ft3 ×cycle)/ (kWh). The Federal efficiency standard is >1.26 (ft3 ×cycle)/ (kWh)[[229]](#footnote-260).

### Eligibility

This protocol documents the energy savings attributed to efficient clothes washers meeting ENERGY STAR or CEE Tier 1 standards or better in small commercial applications. This protocol is limited to clothes washers in laundry rooms in multifamily establishments.

### Algorithms

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

*ΔkWh = ΔkWhload X Loads*

*ΔkWpeak = kWh Savings X UF*

The utilization factor, (UF) is equal to the average energy usage between noon and 8PM on summer weekdays to the annual energy usage. The utilization rate is derived as follows:

1. Obtain normalized, hourly load shape data for residential clothes washing
2. Smooth the load shape by replacing each hourly value with a 5-hour average centered about that hour. This step is necessary because the best available load shape data exhibits erratic behavior commonly associated with metering of small samples. The smoothing out effectively simulates diversification.
3. Take the UF to be the average of all load shape elements corresponding to the hours between noon and 8PM on weekdays from June to September.

The value is the June-September, weekday noon to 8PM average of the normalized load shape values associated with residential clothes washers in PG&E service territory (northern CA). Although Northern CA is far from PA, the load shape data is the best available at the time and the temporal dependence washer usage is not expected to have a strong geographical dependency.

Figure 3‑1: Utilization factor for a sample week in July

Figure 3‑1 shows the utilization factor for each hour of a sample week in July. Because the load shape data derived from monitoring of in-house clothes washers is being imputed to multifamily laundry room washers (which have higher utilization rates – 950 loads/year compared to 392), it is important to check that the resulting minutes of usage per hour is significantly smaller than 60. If the minutes of usage per hour approach 60, then it should be assumed that the load shape for multi-family laundry room clothes washers must be different than the load shape for in-house clothes washers. The maximum utilization per hour is 36.2 minutes.



Figure 3‑1: Utilization factor for a sample week in July[[230]](#footnote-261)

### Definition of Terms

The parameters in the above equation are listed in Table 3‑84: Commercial Clothes Washer Calculation Assumptionsbelow.

Table 3‑84: Commercial Clothes Washer Calculation Assumptions

|  |  |  |  |
| --- | --- | --- | --- |
| **Component** | **Type** | **Values** | **Source** |
| MEFB, Base Federal Standard Modified Energy Factor | Fixed | 1.26[[231]](#footnote-262) | 1 |
| MEFP, Modified Energy Factor of Qualified Washing Machine (Name Plate) | Variable | Nameplate  Tier 1: ≥2.00  Tier 2: ≥2.20  Tier 3: ≥2.40 | 1 |
| ΔkWhload[[232]](#footnote-263), Difference in Electricity Consumption per Load of Laundry between Baseline and Efficient Equipment | Fixed | Table 3-85 | 2 |
| Loads, Number of Loads per Year | Fixed | 950 loads | 2 |
| UF, Utilization Factor | Fixed | 0.0002382 | 3 |

**Sources:**

1. Consortium for Energy Efficiency: http://www.cee1.org/resid/seha/rwsh/reswash\_specs.pdf
2. ENERGY STAR calculator for Commercial Clothes Washers, Multi-Family Laundry Association, July 2011
3. Annual hourly load shapes taken from Energy Environment and Economics (E3), Resviewer2: <http://www.ethree.com/cpuc_cee_tools.html>. The average normalized usage for the hours noon to 8 PM, Monday through Friday, June 1 to September 30 is 0.000243

### Deemed Savings

The deemed savings for the installation of a washing machine with a MEF of 2.0 or higher, is dependent on the energy source for washer. The table below shows savings for washing machines for different combinations of water heater and dryer types.The values are based on the difference between the average of all qualified models and the average of all unqualified models.

Table 3‑85: Deemed Savings for ENERGY STAR Clothes Washer

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Fuel Source** | **Cycles/ Year** | **ΔkWhload** | **Energy Savings (kWh)** | **Demand Reduction (kW)** |
| Electric Hot Water Heater, Electric Dryer | 950 | 0.57 | 541 | 0.129 |
| Electric Hot Water Heater, Gas Dryer | 950 | 0.36 | 342 | 0.081 |
| Electric Hot Water Heater, No Dryer | 950 | 0.36 | 342 | 0.081 |
| Gas Hot Water Heater, Gas Dryer | 950 | 0.06 | 57 | 0.013 |
| Gas Hot Water Heater, Electric Dryer | 950 | 0.25 | 237 | 0.056 |
| Gas Hot Water Heater, No Dryer | 950 | 0.06 | 57 | 0.013 |

### Measure Life

The Database for Energy Efficiency Resources estimates the measure life at 10 years[[233]](#footnote-264).

### Evaluation Protocols

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

## Electric Resistance Water Heaters

|  |  |
| --- | --- |
| **Measure Name** | **Efficient Electric Water Heaters** |
| Target Sector | Small Commercial Establishments |
| Measure Unit | Water Heater |
| Unit Energy Savings | Varies |
| Unit Peak Demand Reduction | Varies |
| Measure Life | 15 years |

Efficient electric resistance water heaters use resistive heating coils to heat the water. Premium efficiency models primarily generally use increased tank insulation to achieve energy factors of 0.93 to 0.96.

### Eligibility

This protocol documents the energy savings attributed to efficient electric resistance water heaters with a minimum energy factor of 0.93 compared to a baseline electric resistance water heater with an energy factor of 0.904. However, other energy factors are accommodated with the partially deemed scheme. The target sector includes domestic hot water applications in small commercial settings such as small retail establishments, small offices, small clinics, and small lodging establishments such as small motels.

### Algorithms

The energy savings calculation utilizes average performance data for available premium and standard electric resistance water heaters and typical hot water usages. The energy savings are obtained through the following formula:

For efficient resistive water heaters, demand savings result primarily from reduction in standby losses. The demand reduction is taken as the annual energy savings multiplied by the ratio of the average energy usage during noon and 8 PM on summer weekdays to the total annual energy usage.

ΔkWpeak = EnergyToDemandFactor × Energy Savings × ResistiveDiscountFactor

The Energy to Demand Factor is defined below:

**Loads**

The annual loads are taken from data from the DEER database[[234]](#footnote-265). The DEER database has data for gas energy usage for the domestic hot water end use for various small commercial buildings. The loads are averaged over all 16 climate zones and all six vintage types in the DEER database. Finally, the loads are converted to average annual gallons of use using the algorithm below. The loads are summarized in HW (

Table 3‑86.

Table 3‑86: Typical water heating loads.

|  |  |  |  |
| --- | --- | --- | --- |
| **Building Type** | **Typical Square Footage** | **Average Annual Load In kBTU** | **Average Annual Use, Gallons** |
| Motel | 30,000 | 2,963 | 97,870 |
| Small Office | 10,000 | 2,214 | 24,377 |
| Small Retail | 7,000 | 1,451 | 11,183 |

**Energy to Demand Factor**

The ratio of the average energy usage during noon and 8 PM on summer weekdays to the total annual energy usage is taken from usage profile data collected for commercial water heaters in CA[[235]](#footnote-266). The usage profiles are shown in Figure 3‑2. To ensure that the load shape data derived from observations in CA can be applied to PA, we compared the annual energy usage to peak demand factors for two disparate climate zones in CA. The results, shown in Figure 3‑3, indicate that the ratio of peak demand to annual energy usage is not strongly influenced by climate. Also, though the actual usage profiles may be different, the average usage between noon and 8 PM on summer weekdays is quite similar for al building types. The close level of agreement between disparate climate zones and building types suggest that the results will carry over to Pennsylvania[[236]](#footnote-267).

****

Figure 3‑2: Load shapes for hot water in four commercial building types

****

Figure 3‑3: Energy to demand factors for four commercial building types

### Definition of Terms

The parameters in the above equation are listed in Table 3‑87.

Table 3‑87: Electric Resistance Water Heater Calculation Assumptions

|  |  |  |  |
| --- | --- | --- | --- |
| **Component** | **Type** | **Values** | **Source** |
| EFbase, Energy Factor of baseline water heater | Fixed | 0.904 | 1 |
| EFproposed, Energy Factor of proposed efficient water heater | Variable | ≥0.93 | Program Design |
| Load, Average annual Load in kBTU | Fixed | Varies | DEER Database |
| Thot, Temperature of hot water | Fixed | 120 °F | 2 |
| Tcold, Temperature of cold water supply | Fixed | 55 °F | 3 |
| EnergyToDemandFactor | Fixed | 0.0001916 | 4 |
| HW, Average annual gallons of Use | Fixed | Varies | See Table 3-86 |
| EFNG, base, Energy Factor of baseline gas water heater | Fixed | 0.594 | 5 |
| ResistiveDiscountFactor | Fixed | 1.0 | 6 |

**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. Many states have plumbing codes that limit shower and bathtub water temperature to 120 °F.
3. Mid-Atlantic TRM, footnote #24
4. The load shapes can be accessed online: <http://www.ethree.com/CPUC/PG&ENonResViewer.zip>
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. Engineering Estimate. No discount factor is needed because this measure is already an electric resisitance water heater system.

### Deemed Savings

The deemed savings for the installation of efficient electric water heaters in various applications are listed below.

Table 3‑88: Energy Savings and Demand Reductions

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Building Type** | **Average Annual Use, Gallons** | **EF** | **Energy Savings (kWh)** | **Demand Reduction (kW)** |
| Motel | 97,870 | 0.95 | 829 | 0.16 |
| Small Office | 24,377 | 0.95 | 207 | 0.04 |
| Small Retail | 11,183 | 0.95 | 95 | 0.02 |

### Measure Life

According to an October 2008 report for the CA Database for Energy Efficiency Resources, an electric water heater’s lifespan is 15 years[[237]](#footnote-268).

### Evaluation Protocols

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

## Heat Pump Water Heaters

|  |  |
| --- | --- |
| **Measure Name** | **Heat Pump Water Heaters** |
| Target Sector | Commercial Establishments |
| Measure Unit | Water Heater |
| Unit Energy Savings | Varies |
| Unit Peak Demand Reduction | Varies |
| Measure Life | 10 years |

Heat Pump Water Heaters take heat from the surrounding air and transfer it to the water in the tank, unlike conventional electrical water heaters which use resistive heating coils to heat the water.

### Eligibility

This protocol documents the energy savings attributed to heat pump water heaters with Energy Factors of 2.2. However, other energy factors are accommodated with the partially deemed scheme. The target sector includes domestic hot water applications in small commercial settings such as small retail establishments, small offices, small clinics, and small lodging establishments such as small motels. The measure described here involves a direct retrofit of a resistive electric water heater with a heat pump water heater. It does not cover systems where the heat pump is a pre-heater or is combined with other water heating sources. More complicated installations can be treated as custom projects.

### Algorithms

The energy savings calculation utilizes average performance data for available heat pump and standard electric resistance water heaters and typical hot water usages. The energy savings are obtained through the following formula:

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 × ResistiveDiscountFactor

The Energy to Demand Factor is defined below:

#### Loads

The annual loads are taken from data from the DEER database[[238]](#footnote-269). The DEER database has data for gas energy usage for the domestic hot water end use for various small commercial buildings. The loads are averaged over all 16 climate zones and all six vintage types in the DEER database. Finally, the loads are converted to average annual gallons of use using the algorithm below. The loads are summarized in

Table 3‑86 below.

Table 3‑89: Typical water heating loads

|  |  |  |  |
| --- | --- | --- | --- |
| **Building Type** | **Typical Square Footage** | **Average Annual Load In kBTU** | **Average Annual Use, Gallons** |
| Motel | 30,000 | 2,963 | 97,870 |
| Small Office | 10,000 | 2,214 | 24,377 |
| Small Retail | 7,000 | 1,451 | 11,183 |

#### Energy to Demand Factor

The ratio of the average energy usage during noon and 8 PM on summer weekdays to the total annual energy usage is taken from usage profile data collected for commercial water heaters in CA[[239]](#footnote-270). The usage profiles are shown in Figure 3‑4. To ensure that the load shape data derived from observations in CA can be applied to PA, we compared the annual energy usage to peak demand factors for two disparate climate zones in CA. The results, shown in Figure 3‑5, indicate that the ratio of peak demand to annual energy usage is not strongly influenced by climate. Also, though the actual usage profiles may be different, the average usage between noon and 8 PM on summer weekdays is quite similar for al building types. The close level of agreement between disparate climate zones and building types suggest that the results will carry over to Pennsylvania[[240]](#footnote-271).

****

Figure 3‑4: Load shapes for hot water in four commercial building types

****

Figure 3‑5: Energy to demand factors for four commercial building types

#### Resistive Heating Discount Factor

The resistive heating discount factor is an attempt to account for possible increased reliance on back-up resistive heating elements during peak usage conditions. Although a brief literature review failed to find data that may lead to a quantitative adjustment, two elements of the demand reduction calculation are worth considering.

* The hot water temperature in this calculation is somewhat conservative at 120 °F.
* The peak usage window is eight hours long.
* In conditioned space, heat pump capacity is somewhat higher in the peak summer window.
* In unconditioned space, heat pump capacity is dramatically higher in the peak summer window.

Under these operating conditions, one would expect a properly sized heat pump water heater with adequate storage capacity to require minimal reliance on resistive heating elements. A resistive heating discount factor of 0.9, corresponding to a 10% reduction in COP during peak times, is therefore taken as a conservative estimation for this adjustment.

#### Heat Pump COP Adjustment 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[[241]](#footnote-272), while the average wetbulb temperature in conditioned typically ranges from 50 °F to 80 °F. The heat pump performance is temperature dependent. Figure 3‑6 below shows relative coefficient of performance (COP) compared to the COP at rated conditions[[242]](#footnote-273). According to the plotted profile, the following adjustments are recommended.

Table 3‑90: COP Adjustment Factors

|  |  |  |
| --- | --- | --- |
| **Heat Pump Placement** | **Typical WB Temperature °F** | **COP Adjustment Factor** |
| Unconditioned Space | 44 | 0.80 |
| Conditioned Space | 63 | 1.09 |
| Kitchen | 80 | 1.30 |



Figure 3‑6: Dependence of COP on outdoor wetbulb temperature.

### Definition of Terms

The parameters in the above equation are listed in Table 3‑91.

Table 3‑91: Electric Resistance Water Heater Calculation Assumptions

|  |  |  |  |
| --- | --- | --- | --- |
| **Component** | **Type** | **Values** | **Source** |
| EFbase, Energy Factor of baseline water heater | Fixed | 0.904 | 1 |
| EFproposed, Energy Factor of proposed efficient water heater | Variable | Nameplate | EDC Data Gathering |
| Load, Average annual Load in kBTU | Fixed | Varies | 5 |
| Thot, Temperature of hot water | Fixed | 120 °F | 2 |
| Tcold, Temperature of cold water supply | Fixed | 55 °F | 3 |
| EnergyToDemandFactor | Fixed | 0.0001916 | 4 |
| FAdjust, COP Adjustment factor | Fixed | 0.80 if outdoor  1.09 if indoor  1.30 if in kitchen | 4 |
| ResistiveDiscountFactor | Fixed | 0.90 | 6 |
| HW, Average annual gallons of Use | Fixed | Varies | See Table 3-89 |
| EFNG, base, Energy Factor of baseline gas water heater | Fixed | 0.594 | 7 |

**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. Many states have plumbing codes that limit shower and bathtub water temperature to 120 °F.
3. Mid-Atlantic TRM, footnote #24
4. The load shapes can be accessed online: <http://www.ethree.com/CPUC/PG&ENonResViewer.zip>
5. DEER Database
6. Engineering Estimate
7. 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

### Deemed Savings

The deemed savings for the installation of heat pump electric water heaters in various applications are listed below.

Table 3‑92: Energy Savings and Demand Reductions

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Building Type** | **Location Installed** | **Average Annual Use, Gallons** | **EF** | **COP Adjustment Factor** | **Energy Savings (kWh)** | **Demand Reduction (kW)** |
| Motel | Unconditioned Space | 97,870 | 2.2 | 0.80 | 8,324 | 1.44 |
| Motel | Conditioned Space | 97,870 | 2.2 | 1.09 | 10,662 | 1.84 |
| Motel | Kitchen | 97,870 | 2.2 | 1.30 | 11,704 | 2.02 |
| Small Office | Unconditioned Space | 24,377 | 2.2 | 0.80 | 2,073 | 0.36 |
| Small Office | Conditioned Space | 24,377 | 2.2 | 1.09 | 2,656 | 0.46 |
| Small Office | Kitchen | 24,377 | 2.2 | 1.30 | 2,915 | 0.50 |
| Small Retail | Unconditioned Space | 11,183 | 2.2 | 0.80 | 951 | 0.16 |
| Small Retail | Conditioned Space | 11,183 | 2.2 | 1.09 | 1,218 | 0.21 |
| Small Retail | Kitchen | 11,183 | 2.2 | 1.30 | 1,338 | 0.23 |

### Measure Life

According to an October 2008 report for the CA Database for Energy Efficiency Resources, an electric water heater’s lifespan is 10 years[[243]](#footnote-274).

### Evaluation Protocols

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

## LED Channel Signage

Channel signage refers to the illuminated signs found inside and outside shopping malls to identify store names. Typically these signs are constructed from sheet metal sides forming the shape of letters and a translucent plastic lens. Luminance is most commonly provided by single or double strip neon lamps, powered by neon sign transformers. Retrofit kits are available to upgrade existing signage from neon to LED light sources, substantially reducing the electrical power and energy required for equivalent sign luminance. Red, green, blue, yellow, and white LEDs are available, but at higher cost than red. Red is the most common color and the most cost-effective to retrofit, currently comprising approximately 80% of the market.

### Eligibility Requirements

This measure must replace incandescent-lighted or neon-lighted channel letter signs. Retrofit kits or complete replacement LED signs are eligible. Replacement signs cannot use more than 20%[[244]](#footnote-275) of the actual input power of the sign that is replaced. Measure the length of the sign as follows:

* Measure the length of each individual letter at the centerline. Do not measure the distance between letters.
* Add up the measurements of each individual letter to get the length of the entire sign being replaced.

### Algorithms

The savings are calculated using the equations below and the assumptions in Table 1-1.

ΔkW = kWbase - kWee

kWbase = kWN/ft X Q X N

kWee = kWLED/ft X Q X N

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

ΔkWh = Annual energy savings (kWh/ft)

ΔkW = Change in connected load from baseline (pre-retrofit) to installed (post-retrofit) lighting level (kW/ft of sign)

kWN/ft = kW of the baseline (neon) lighting per foot (kWN/ft)

kWLED/ft = kW of post-retrofit or energy-efficient lighting system (LED) lighting per foot (kWLED/ft)

L = length of the sign (feet)

Q[[245]](#footnote-276) = Average Stroke Length per Letter *Width (*Avg. feet/letter width) *, i.e. average length of neon (ft) / letter width (ft)*

N = Number of Letters in the sign

CF = Demand Coincidence Factor (See Section 1.4) 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).

Table 3‑93: LED Channel Signage Calculation Assumptions

|  |  |  |  |
| --- | --- | --- | --- |
| **Component** | **Type** | **Value** | **Source** |
| kWN/ft | Variable | EDC Data Gathering  Default: 0.00457[[246]](#footnote-277) | EDC Data Gathering |
| kWLED/ft | Variable | EDC Data Gathering  Default: 0.00136[[247]](#footnote-278) | EDC Data Gathering |
| Q | Fixed | 5.20 | 1 |
| CF | Fixed | See Table 3-6 | Table 3-6 |
| EFLH | Fixed | EDC Data Gathering  Default: See Table 3-6 | EDC Data Gathering  Table 3-6 |
| IFdemand | Fixed | See Table 3-7 | Table 3-7 |
| IFenergy | Fixed | See Table 3-7 | Table 3-7 |
| N | Variable | EDC Data Gathering | EDC Data Gathering |

**Sources:**

1. Southern California Edison Company, *LED Channel Letter Signage (Red)*, Work Paper WPSCNRLG0052, Revision 1.

### Measure Life

Expected measure life is 15 years[[248]](#footnote-279).

## Low Flow Pre-Rinse Sprayers

|  |  |
| --- | --- |
| **Measure Name** | **Low Flow Pre-Rinse Sprayers** |
| Target Sector | Commercial Kitchens |
| Measure Unit | Pre Rinse Sprayer |
| Unit Energy Savings | Groceries: 151152 kWh; Non-Groceries: 1,222227 kWh |
| Unit Peak Demand Reduction | Groceries: 0.03kW; Non-Groceries: 0.2322 kW |
| Measure Life | 5 years |

This protocol documents the energy savings and demand reductions attributed to efficient low flow pre-rinse sprayers in grocery and non-grocery (primarily food service) applications. The most likely areas of application are kitchens in restaurants and hotels. Only premises with electric water heating may qualify for this incentive. Low flow pre-rinse sprayers reduce hot water usage and save energy associated with water heating. The maximum flow rate of qualifying pre-rinse sprayers is 1.6 gpm.

### Algorithms

The energy savings and demand reduction are calculated through the protocols documented below.

ΔkWh for Non-Groceries **=** ((FBNG×UBNG)-(FPNG×UPNG)) × 365 × 8.33 x (THNG)× (TMNG-TC) / ×(EF x 3413 Btu/kWh)

ΔkWh for Groceries = ((FBG×UBG)-(FPG×UPG)) × 365 × 8.33 x (THG)× (TMG-TC) / (EF x 3413 Btu/kWh)×

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 usage profile data collected for commercial water heaters in CA. The usage profiles are shown in Figure 3‑7. To ensure that the load shape data derived from observations in CA can be applied to PA, we compared the annual energy usage to peak demand factors for two disparate climate zones in CA. The results, shown in Figure 3‑8, indicate that the ratio of peak demand to annual energy usage is not strongly influenced by climate. Also, though the actual usage profiles may be different, the average usage between noon and 8 PM on summer weekdays is quite similar for al building types. The close level of agreement between disparate climate zones and building types suggest that the results will carry over to Pennsylvania[[249]](#footnote-280).

****

Figure 3‑7: Load shapes for hot water in four commercial building types

****

Figure 3‑8: Energy to demand factors for four commercial building types.

### Definition of Terms

The parameters in the above equation are listed in Table 3‑94 below. The values for all parameters except incoming water temperature are taken from impact evaluation of the 2004-2005 California Urban Water council Pre-Rinse Spray Valve Installation Program.

FBNG = Baseline Flow Rate of Sprayer for Non-Grocery Applications

FPNG = Post Measure Flow Rate of Sprayer for Non-Grocery Applications

UBNG = Baseline Water Usage Duration for Non-Grocery Applications

UPNG = Post Measure Water Usage Duration for Non-Grocery Applications

FBG = Baseline Flow Rate of Sprayer for Grocery Applications

FPG = Post Measure Flow Rate of Sprayer for Grocery Applications

UBG = Baseline Water Usage Duration for Grocery Applications

UPG = Post Measure Water Usage Duration for Grocery Applications

THNG = Temperature of hot water coming from the spray nozzle for Non-Grocery Application

TC = Incoming cold water temperature for Grocery and Non-Grocery Application

THG = Temperature of hot water coming from the spray nozzle for Grocery Application

EF = Energy Factor of existing Electric Water Heater System

Table 3‑94: Low Flow Pre-Rinse Sprayer Calculations Assumptions

|  |  |  |  |
| --- | --- | --- | --- |
| **Description** | **Type** | **Value** | **Source** |
| FBNG | Fixed | 2.25 gpm | 1 |
| FPNG | Fixed | 1.12 gpm | 1 |
| UBNG | Fixed | 32.4min/day | 2 |
| UPNG | Fixed | 43.8 min/day | 2 |
| FBG | Fixed | 2.15 gpm | 1 |
| FPG | Fixed | 1.12 gpm | 1 |
| UBG | Fixed | 4.8 min/day | 2 |
| UPG | Fixed | 6 min/day | 2 |
| THNG | Fixed | 107ºF | 3 |
| TC | Fixed | 55ºF | 6 |
| THG | Fixed | 97.6ºF | 3 |
| EF | Fixed | 0.904 | 4 |
| EnergyToDemandFactor | Fixed | 0.0001916 | 5 |

**Sources:**

1. *Impact and Process Evaluation Final Report for California Urban Water Conservation Council 2004-5 Pre-Rinse Spray Valve Installation Program (Phase 2),* SBW Consulting, 2007, Table 3-4, p. 23
2. *Impact and Process Evaluation Final Report for California Urban Water Conservation Council 2004-5 Pre-Rinse Spray Valve Installation Program (Phase 2),* SBW Consulting, 2007, Table 3-6, p. 24
3. *Impact and Process Evaluation Final Report for California Urban Water Conservation Council 2004-5 Pre-Rinse Spray Valve Installation Program (Phase 2),* SBW Consulting, 2007, Table 3-5, p. 23
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. The load shapes can be accessed online: <http://www.ethree.com/CPUC/PG&ENonResViewer.zip>
6. Mid-Atlantic TRM, footnote #24

### Deemed Savings

The deemed energy savings for the installation of a low flow pre-rinse sprayer compared to a standard efficiency sprayer is 152 kWh/year for pre-rinse sprayers installed in grocery stores and 1227kWh/year for pre-rinse sprayers installed in non-groceries building typessuch as restaurants. The deemed demand reductions for the installation of a low flow pre-rinse sprayer compared to a standard efficiency sprayer is 0.029 kW for pre-rinse sprayers installed in grocery stores and 0.238 kW for pre-rinse sprayers installed in non-groceries building types such as restaurants.

### Measure Life

The effective life for this measure is 5 years[[250]](#footnote-281).

### Evaluation Protocol

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

## Small C/I HVAC Refrigerant Charge Correction

|  |  |
| --- | --- |
| **Measure Name** | **Refrigerant Charge Correction** |
| Target Sector | Small C/I HVAC |
| Measure Unit | Tons of Refrigeration Capacity |
| Unit Energy Savings | Varies |
| Unit Peak Demand Reduction | Varies |
| Measure Life | 10 years |

This protocol describes the assumptions and algorithms used to quantify energy savings for refrigerant charging on packaged AC units and heat pumps operating in small commercial applications. The protocol herein describes a partially deemed energy savings and demand reduction estimation.

### Eligibility

This protocol is applicable for small commercial and industrial customers, and applies to documented tune-ups for package or split systems up to 20 tons.

### Algorithms

This section describes the process of creating energy savings and demand reduction calculations.

#### For Cooling:

ΔkWh = (EFLHC ×CAPYCCAPC/1000 )× (1/[EER×RCF]-1/EER)

ΔkWpeak = (CF × CAPYCCAPC/1000 ) × (1/[EER×RCF]-1/EER)

#### Additional Heating Savings for Heat Pumps:

ΔkWh = (EFLHMH ×CAPYHCAPH/1000 )× (1/[HSPF×RCF]-1/HSPF)

### Definition of Terms

CAPYC = Unit Capacity, in Btu/h for cooling

CAPYH = Unit Capacity, in Btu/h for heating

EER = Energy Efficiency Ratio

HSPF = Heating Seasonal Performance Factor

EFLHC = Equivalent Full-Load Hours for Mechanical Cooling

EFLHMH = Equivalent Full-Load Hours for Mechanical Heating[[251]](#footnote-282)

RCF = COP Degradation Factor for Cooling

CF = Demand Coincidence Factor (See Section 1.4)

The values and sources are listed in Table 3‑95.

Table 3‑95: Refrigerant Charge Correction Calculations Assumptions

|  |  |  |  |
| --- | --- | --- | --- |
| **Component** | **Type** | **Value** | **Source** |
| CAPYC | Variable | Nameplate | EDC Data Gathering |
| CAPYH | Variable | Nameplate | EDC Data Gathering |
| EER | Variable | Nameplate  Default: 9.0 | EDC Data Gathering |
| HSPF | Variable | Default: 7.0 | EDC Data Gathering |
| EFLH­C | Variable | Table 3-22 and Table 3-23 in 2011 PA TRM | 2011 PA TRM |
| EFLH­MH | Variable | Take EFLHHM as 70% of the listed EFLHH in Table 3-22 and 3-23 | 2 |
| RCF | Variable | See Table 3‑96 | 1 |
| CF | Fixed | 67% | Table 3-20 in 2011 PA TRM |

**Sources:**

1. CA 2003 RTU Survey
2. Assumes 70% of heating is done by compressor, 30% by fan and supplemental resistive heat

Table 3‑96: Refrigerant charge correction COP degradation factor (RCF) for various relative charge adjustments for both TXV metered and non-TXV units.[[252]](#footnote-283).

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **% of nameplate charge added (removed)** | **RCF (TXV)** | **RCF (Orifice)** | **% of nameplate charge added (removed)** | **RCF (TXV)** | **RCF (Orifice)** | **% of nameplate charge added (removed)** | **RCF (TXV)** | **RCF (Orifice)** |
| 60% | 68% | 13% | 28% | 95% | 83% | (4%) | 100% | 100% |
| 59% | 70% | 16% | 27% | 96% | 84% | (5%) | 100% | 99% |
| 58% | 71% | 19% | 26% | 96% | 85% | (6%) | 100% | 99% |
| 57% | 72% | 22% | 25% | 97% | 87% | (7%) | 99% | 99% |
| 56% | 73% | 25% | 24% | 97% | 88% | (8%) | 99% | 99% |
| 55% | 74% | 28% | 23% | 97% | 89% | (9%) | 99% | 98% |
| 54% | 76% | 31% | 22% | 98% | 90% | (10%) | 99% | 98% |
| 53% | 77% | 33% | 21% | 98% | 91% | (11%) | 99% | 97% |
| 52% | 78% | 36% | 20% | 98% | 92% | (12%) | 99% | 97% |
| 51% | 79% | 39% | 19% | 98% | 92% | (13%) | 99% | 96% |
| 50% | 80% | 41% | 18% | 99% | 93% | (14%) | 98% | 96% |
| 49% | 81% | 44% | 17% | 99% | 94% | (15%) | 98% | 95% |
| 48% | 82% | 46% | 16% | 99% | 95% | (16%) | 98% | 95% |
| 47% | 83% | 48% | 15% | 99% | 95% | (17%) | 98% | 94% |
| 46% | 84% | 51% | 14% | 99% | 96% | (18%) | 98% | 93% |
| 45% | 85% | 53% | 13% | 100% | 97% | (19%) | 98% | 93% |
| 44% | 86% | 55% | 12% | 100% | 97% | (20%) | 97% | 92% |
| 43% | 86% | 57% | 11% | 100% | 98% | (21%) | 97% | 91% |
| 42% | 87% | 60% | 10% | 100% | 98% | (22%) | 97% | 90% |
| 41% | 88% | 62% | 9% | 100% | 98% | (23%) | 97% | 90% |
| 40% | 89% | 64% | 8% | 100% | 99% | (24%) | 97% | 89% |
| 39% | 89% | 65% | 7% | 100% | 99% | (25%) | 96% | 88% |
| 38% | 90% | 67% | 6% | 100% | 99% | (26%) | 96% | 87% |
| 37% | 91% | 69% | 5% | 100% | 100% | (27%) | 96% | 86% |
| 36% | 91% | 71% | 4% | 100% | 100% | (28%) | 96% | 85% |
| 35% | 92% | 73% | 3% | 100% | 100% | (29%) | 95% | 84% |
| 34% | 92% | 74% | 2% | 100% | 100% | (30%) | 95% | 83% |
| 33% | 93% | 76% | 1% | 100% | 100% | (31%) | 95% | 82% |
| 32% | 94% | 77% | (0%) | 100% | 100% | (32%) | 95% | 81% |
| 31% | 94% | 79% | (1%) | 100% | 100% | (33%) | 95% | 80% |
| 30% | 95% | 80% | (2%) | 100% | 100% | (34%) | 94% | 78% |
| 29% | 95% | 82% | (3%) | 100% | 100% | (35%) | 94% | 77% |

### Measure Life

According to the 2008 Database for Energy Efficiency Resources (DEER) EUL listing, the measure life for refrigerant charging is **10 years[[253]](#footnote-284)**.

## Refrigeration – Special Doors with Low or No Anti-Sweat Heat for Low Temp Case

|  |  |
| --- | --- |
| **Measure Name** | **Special Doors with Low or No Anti-Sweat Heat for Low Temp Case** |
| Target Sector | Commercial Refrigeration |
| Measure Unit | Display Cases |
| Unit Energy Savings | Variable |
| Unit Peak Demand Reduction | Variable |
| Measure Life | 15 years |

Traditional clear glass display case doors consist of two-pane glass (three-pane in low and medium temperature cases), and aluminum doorframes and door rails. Glass heaters may be included to eliminate condensation on the door or glass. The door heaters are traditionally designed to overcome the highest humidity conditions as cases are built for nation-wide applications. New low heat/no heat door designs incorporate heat reflective coatings on the glass, gas inserted between the panes, non-metallic spacers to separate the glass panes, and/or non-metallic frames (such as fiberglass).

This protocol documents the energy savings attributed to the installation of special glass doors w/low/no anti-sweat heaters for low temp cases. The primary focus of this rebate measure is on new cases to incent customers to specify advanced doors when they are purchasing refrigeration cases.

### Eligibility

For this measure, a no-heat/low-heat clear glass door must be installed on an upright display case. It is limited to door heights of 57 inches or more. Doors must have either heat reflective treated glass, be gas filled, or both. This measure applies to low temperature cases only—those with a case temperature below 0°F. Doors must have 3 or more panes. Total door rail, glass, and frame heater amperage (@ 120 volt) cannot exceed 0.39[[254]](#footnote-285) amps per linear foot for low temperature display cases. Rebate is based on the door width (not including case frame).

### Algorithms

The energy savings and demand reduction are obtained through the following calculations adopted from California’s Southern California Edison[[255]](#footnote-286).

Assumptions: Indoor Dry-Bulb Temperature of 75oF and Relative Humidity of 55%, (4-minute opening intervals for 16-second), neglect heat conduction through doorframe / assembly.

#### Compressor Savings (excluding condenser):

Δ kWcompressor = [Q-coolingsvg/EER/1000]

Δ kWhcompressor = Δ kW x EFLH

Q-coolingsvg = Q-cooling x K-ASH

#### Anti-Sweat Heater Savings:

Δ kWASH = Δ ASH / 1000

Δ kWhASH = Δ kWASH x t

### Definition of Terms

The variables in the above equation are defined below:

Q-cooling = Case rating by manufacturer (Btu/hr/door)

Q-coolingsvg  = Cooling savings (Btu/hr/door)

Δ kWcompressor = Compressor power savings (kW/door)

Δ kWASH = Reduction due to ASH (kW/door)

K-ASH = % of cooling load reduction due to low anti-sweat heater (Btu/hr/door reduction)

Δ ASH = Reduction in ASH power per door (watts/door)

Δ kWhcompressor = Annual compressor energy savings (excluding condenser energy), (kWh/door)

Δ kWhASH = Annual Reduction in energy (kWh/door)

EER = Compressor rating from manufacturer (Btu/hr/Watts)

EFLH = Equivalent full load annual operating hours

t = Annual operating hours of Anti-sweat heater

Table 3‑97: Special Doors with Low or No Anti-Sweat Heat for Low Temp Case Calculations Assumptions

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | **Type** | **Value** | **Source** |
| Q-cooling | Variable | Nameplate | EDC Data Gathering |
| K-ASH | Fixed | 1.5% | 1 |
| EER | Variable | Nameplate | EDC Data Gathering |
| EFLH | Fixed | 5,700[[256]](#footnote-287) | 1 |
| Δ ASH | Fixed | 83[[257]](#footnote-288) | 1 |
| t | Fixed | 8,760 | 1 |

**Sources:**

1. Southern California Edison. Non-Residential Express 2003 Refrigeration Work Paper. Pg. 27

### Measure Life

The expected measure life is 15 years[[258]](#footnote-289).

## ENERGY STAR Room Air Conditioner

This protocol is for ENERGY STAR room air conditioner units installed in small commercial spaces. Only ENERGY STAR units qualify for this protocol.

### Algorithms

ΔkWh = (BtuHcool / 1000) X (1/EERbase – 1/EERee) X EFLHcool

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

### Definition of Terms

BtuHcool = Rated cooling capacity of the energy efficient unit in BtuHcool

EERbase = Efficiency rating of the baseline unit.

EERee = Efficiency rating of the energy efficiency unit.

CF = Demand Coincidence Factor (See Section 1.4)

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

Table 3‑98: Variables for HVAC Systems

| **Component** | **Type** | **Value** | **Source** |
| --- | --- | --- | --- |
| BtuH | Variable | Nameplate data (AHRI or AHAM) | EDC’s Data Gathering |
| EERbase | Variable | Default values from Table 3‑99 | See Table 3‑99 |
| EERee | Variable | Nameplate data (AHRI or AHAM) | EDC’s Data Gathering |
| CF | Fixed | 80% | 2 |
| EFLHcool | Variable | Based on Logging or Modeling | EDC’s Data Gathering |
| Default values from Table 3‑100 | See Table 3‑100 |

**Sources:**

1. Average based on coincidence factors from Ohio, New Jersey, Mid-Atlantic, Massachusetts, Connecticut, Illinois, New York, CEE and Minnesota. (74%, 67%, 81%, 94%, 82%, 72%, 100%, 70% and 76% respectively)

Table 3‑99: Room Air Conditioner Baseline Efficiencies[[259]](#footnote-290)

| **Equipment Type and Capacity** | **Cooling Baseline** | **Heating Baseline** |
| --- | --- | --- |
| Room AC | | |
| < 8,000 BtuH | 9.7 EER | N/A |
| > 8,000 BtuH and <14,000 BtuH | 9.8 EER | N/A |
| > 14,000 BtuH and < 20,000 BtuH | 9.7 EER | N/A |
| > 20,000 BtuH | 8.5 EER | N/A |

Table 3‑100: Cooling EFLH for Pennsylvania Cities[[260]](#footnote-291)

| **Space and/or Building Type** | **Allentown** | **Erie** | **Harrisburg** | **Pittsburgh** | **Williamsport** | **Philadelphia** | **Scranton** |
| --- | --- | --- | --- | --- | --- | --- | --- |
| College: Classes/Administrative | 690 | 380 | 733 | 582 | 520 | 815 | 490 |
| Convenience Stores | 1,216 | 671 | 1,293 | 1,026 | 917 | 1,436 | 864 |
| Dining: Bar Lounge/Leisure | 912 | 503 | 969 | 769 | 688 | 1,077 | 648 |
| Dining: Cafeteria / Fast Food | 1,227 | 677 | 1,304 | 1,035 | 925 | 1,449 | 872 |
| Dining: Restaurants | 912 | 503 | 969 | 769 | 688 | 1,077 | 648 |
| Lodging: Hotels/Motels/Dormitories | 756 | 418 | 805 | 638 | 571 | 894 | 538 |
| Lodging: Residential | 757 | 418 | 805 | 638 | 571 | 894 | 538 |
| Multi-Family (Common Areas) | 1,395 | 769 | 1,482 | 1,176 | 1,052 | 1,647 | 991 |
| Nursing Homes | 1,141 | 630 | 1,213 | 963 | 861 | 1,348 | 811 |
| Office: General/Retail | 851 | 469 | 905 | 718 | 642 | 1,005 | 605 |
| Office: Medical/Banks | 851 | 469 | 905 | 718 | 642 | 1,005 | 605 |
| Penitentiary | 1,091 | 602 | 1,160 | 920 | 823 | 1,289 | 775 |
| Police/Fire Stations (24 Hr) | 1,395 | 769 | 1,482 | 1,176 | 1,052 | 1,647 | 991 |
| Post Office/Town Hall/Court House | 851 | 469 | 905 | 718 | 642 | 1,005 | 605 |
| Religious Buildings/Church | 602 | 332 | 640 | 508 | 454 | 711 | 428 |
| Retail | 894 | 493 | 950 | 754 | 674 | 1,055 | 635 |
| Schools/University | 634 | 350 | 674 | 535 | 478 | 749 | 451 |
| Warehouses (Not Refrigerated) | 692 | 382 | 735 | 583 | 522 | 817 | 492 |
| Warehouses (Refrigerated) | 692 | 382 | 735 | 583 | 522 | 817 | 492 |

# Demand Response

The following sections provide guidance for calculating Act 129 peak load reductions for demand response measures. All references to PJM Business Rules in this section address computation of hourly load reductions during Act 129 load reduction events, rather than other events under PJM programs.

## Determination of Act 129 Peak Load Reductions

### Step 1a

Hourly peak load reductions from demand response (DR) measures for Direct Load Control (DLC) and Load Curtailment (LC) will be determined in accordance with PJM measurement & verification protocols, related business rules, protocol approval processes and settlement clearing due diligence practices[[261]](#footnote-292) that will be in place during the 2012 summer period (June 1 - September 30, 2012), as verified by the EDC and reviewed by both the EDCs’ independent evaluators and the SWE. Peak load reductions from critical peak pricing (CPP) programs will be determined consistent with EDC EM&V Plans and consistent with PJM Customer Baseline methods and business rules, as they may be reasonably applied to the CPP programs. Peak load reductions from DLC, CPP and LC will be determined for each Act 129 DR event hour for June 1, 2012, through September 30, 2012. When determining customer baselines, Act 129 DR event days and PJM DR event days (e.g., for PJM emergencies and economic events for which participants have settlements) will be excluded to the extent that they are known.

Where customer baseline methods using day-of adjustments may produce conservative savings estimates if a customer participates in multiple events with differing starting times within a single day. In these situations where the Act 129 event starts after a PJM event, calculate the day-of adjustments using the first event so as to preserve the intent of the day-of adjustment,

### Step 1b

Hourly peak load reductions from energy efficiency (EE) measures, CPP programs, conservation voltage control, and DR programs other than DLC and LC will be determined in accordance with the Technical Reference Manual (TRM) or a custom measure protocol vetted with the SWE. Peak load reductions from EE measures installed before June 1, 2012, occur equally in all event hours during the summer of 2012. Peak load reductions from EE measures installed between June 1, 2012, and September 30, 2012, occur equally in all event hours after the measure’s installation date. *Example: an energy efficiency measure installed on July 5, 2012, will contribute to peak load reduction event hours from July 5, 2012, forward.*

### Step 1c

The EDC’s independent evaluator and the SWE will verify hourly peak load reductions for DR measures, and values to be applied for EE measures, pricing programs, and conservation voltage control in accordance with the EDC’s approved Evaluation Plan. For DLC and LC, the verification method is to confirm that the peak load reductions were determined in accordance with PJM protocols, related business rules, protocol approval processes and settlement clearing due diligence practices. The verification method for other programs will vary according to that program’s evaluation plan and more specific measurement protocols vetted with the SWE, i.e. conservation voltage control.

### Step 1d

Total Hourly Act 129 Peak Load Reduction in Each Hour (June 1 - September 30, 2012) = Peak load reductions from LC, CPP, and DLC DR Measures[[262]](#footnote-293) + Constant Load Reductions from non-dispatchable measures (i.e., peak load reductions from EE measures + peak load reductions from DR programs other than DLC and LC to the extent they either follow PJM economic protocols or protocols otherwise specifically vetted with the SWE + reductions from conservation voltage control, etc.) An EDC will gross up the Total Hourly Peak Load Reduction in Each Hour (calculated at the customer level) to reflect transmission and distribution losses if the EDC’s peak load reduction targets were determined at the system level.

## Determine the “Top 100 Hours” (100 hours of highest peak load)

### Step 2a

The EDC will record actual system load data for every hour from June 1, 2012, through September 30, 2012.

### Step 2b

The EDC will reconstruct its system load curve by applying Act 129 “add-backs” (i.e., the Act 129 peak load reductions determined in Step 1d for every hour during the summer of 2012) to represent what the system load would have been if there were no Act 129 peak load reductions.[[263]](#footnote-294) If the load curve is not reconstructed, the actual load in an event hour will be lower than it would have been without the event, possibly excluding that event hour from the top 100 hours, which would inappropriately undermine assessment of the intended outcome. The reconstruction will include the following components:

* Add back the Act 129 peak load reductions determined in Step 1d for every hour during the summer of 2012. The EDCs’ independent evaluators and the SWE may assess the impact of including or excluding add-backs for non-dispatchable measures.[[264]](#footnote-295)
* Each EDC, and the SWE, will determine if pre-cooling and snapback effects from their Act 129 DR programs (increased usage occurring immediately before and immediately after control period) are significant enough to influence whether a non-event hour could become a peak hour if these effects are not addressed in the load reconstruction (by reducing system load in that hour by the magnitude of the snapback or pre-cooling). Depending on the types of actions that customers take to curtail load, e.g. shutting down air conditioning, failure to address pre-cooling and snapback could cause a non-event hour to become (incorrectly appear to be) a peak hour. If determined by the EDC, subject to SWE review and recommendation, pre-cooling and snapback information can be used to inform possible future versions of Act 129 EE&C (post-2013). Act 129 DR compliance for 2012 will not include pre-cooling and snapback in the reconstruction of the system load curve.

### Step 2c

The EDC will identify the 100 specific hours (June 1, 2012, through September 30, 2012) in the reconstructed load data with the highest load. These are the “Top 100 Hours” (100 hours of highest peak load).

### Step 2d

The EDC’s independent evaluator and the SWE will review records to confirm these are the top 100 hours during June 1, 2012, through September 30, 2012.

### Step 2 Notes

**Note 1:** There is no reason to add back PJM events for the Act 129 load reconstruction. Not to be confused with “add-backs” for participants in an EDC program who also participate in unrelated PJM DR program/events (“add-backs” for these events will be needed to accurately compute participant baselines). The Act 129 reconstruction should address Act 129 influences only, not unrelated influences such as unrelated PJM DR program participation, thunderstorms, and outages etc.

**Note 2:** For the purpose of calculating Customer Baselines (CBLs), and to ensure the most accurate representation of an Act 129 DR participant’s end-use load pattern is utilized when computing event performance, EDCs shall calculate CBLs per PJM business rules.

**Note 3:** For the purpose of calculating CBLs for Act 129 events using PJM economic protocols, any DR events (PJM or Act 129) or outages should be excluded from the baseline calculation. While unrelated PJM DR events and outages are not relevant in determining the EDCs’ system loads without Act 129, the purpose of calculating a CBL is to accurately estimate what the DR participant’s load would have been if no Act 129 event had been called. For the purpose of accuracy, this requires utilizing days in the look back window that reflect normal operating demand (weekends/holidays are excluded from a weekday event calculation for the same reason). To no exclude PJM events and outages from the look back window will lead to demand reduction calculations and EDC system load reconstructions that less accurately reflect what peak demand would have been had there been no Act 129, which, in turn, could skew measured load reductions.

## Determine the Act 129 Average Peak Load Reduction During the 100 Peak Hours

### Step 3a

Sum the total Act 129 peak load reductions (determined for each hour in Step 1d) for each of the Top 100 Hours (determined in Step 2c). This is the Act 129 Total Peak Load Reduction During the Top 100 Hours.

### Step 3b

Divide the Act 129 Total Peak Load Reductions During the Top 100 Hours (from Step 3a) by 100. This is The Act 129 Average Peak Load Reduction During the 100 Peak Hours.

*Example:*

90 hours in the “Top 100 Hours” each achieved 115 MW of Act 129 Peak Load Reduction. 10 hours in the “Top 100 Hours” achieved 0 MW of Act 129 Peak Load Reduction. Step 3a-- Act 129 Total Peak Load Reductions During the Top 100 Hours = (90 x 115) + (10 x 0) = 10,350 MW. Step 3b--Act 129 Average Peak Load Reductions During the 100 Peak Hours = 10,350 MW/100 = 103.5 MW.

### Step 3 Notes

If the EDC’s Act 129 peak load reduction target is 100 MW, then the example above meets (exceeds) the compliance target.

There are many other combinations that could produce 100 MW of Act 129 Average Peak Load Reductions During the 100 Peak Hours. For example, compliance with a 100 MW target can be achieved by any of the following:

* 1,000 MW Act 129 Peak Load Reduction in 10 of the top 100 hours (the other 90 top hours have 0 MW reduction)
* 100 MW Act 129 Peak Load Reduction in 100 of the top 100 hours
* 200 MW Act 129 Peak Load Reduction in 50 of the top 100 hours (the other 50 top hours have 0 MW reduction)
* 500 MW Act 129 Peak Load Reduction in 20 of the top 100 hours (the other 80 top hours have 0 MW reduction)



Figure 4‑1: Demand Response Definitions and Calculations



Figure 4‑2: EDC Example Daily Load Curve



Figure 4‑3: 5 Daily Load Curve Example

# Appendices

## Appendix A: Measure Lives

|  |  |
| --- | --- |
| **Measure Lives Used in Cost-Effectiveness Screening**  **February 2008[[265]](#footnote-296)** | |
| **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\* |
|  |  |
|  |  |
| 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 |
| Room Air Conditioner Retirement | 4 |
| *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 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>.

## Appendix E: Eligibility Requirements for Solid State Lighting Products in Commercial and Industrial Applications

The SSL market, still setting up its foundations, has been inundated with a great variety of products, including those that do not live up to manufacturers’ claims. Several organizations, such as ENERGY STAR and Design Lights Consortium have responded by following standardized testing procedures and setting minimum requirements to be identified as a qualified product under those organizations.

### 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[[266]](#footnote-297), the product shall meet the minimum ENERGY STAR requirements[[267]](#footnote-298) [[268]](#footnote-299) for the given product category. Products are not required to be on the ENERGY STAR Qualified Product List[[269]](#footnote-300), 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:

* Omni-directional: 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 down-lights
* 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[[270]](#footnote-301), the product shall meet the minimum DLC requirements[[271]](#footnote-302) for the given product category. Products are not required to be on the DLC Qualified Product List[[272]](#footnote-303), 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 Luminaires
* Track or Mono-point Directional Lighting Fixtures
* Refrigerated Case Lighting
* Display Case Lighting
* 2x2 Luminaires
* 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)
  + Operating frequency of the lamp
* 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.

## Appendix F: Zip Code Mapping

Per Section 1.16, the following table is to be used to determine the appropriate reference city for each Pennsylvania zip code.

| **Zip** | **Reference City** |
| --- | --- |
| 15001 | Pittsburgh |
| 15003 | Pittsburgh |
| 15004 | Pittsburgh |
| 15005 | Pittsburgh |
| 15006 | Pittsburgh |
| 15007 | Pittsburgh |
| 15009 | Pittsburgh |
| 15010 | Pittsburgh |
| 15012 | Pittsburgh |
| 15014 | Pittsburgh |
| 15015 | Pittsburgh |
| 15017 | Pittsburgh |
| 15018 | Pittsburgh |
| 15019 | Pittsburgh |
| 15020 | Pittsburgh |
| 15021 | Pittsburgh |
| 15022 | Pittsburgh |
| 15024 | Pittsburgh |
| 15025 | Pittsburgh |
| 15026 | Pittsburgh |
| 15027 | Pittsburgh |
| 15028 | Pittsburgh |
| 15030 | Pittsburgh |
| 15031 | Pittsburgh |
| 15032 | Pittsburgh |
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| 15143 | Pittsburgh |
| 15144 | Pittsburgh |
| 15145 | Pittsburgh |
| 15146 | Pittsburgh |
| 15147 | Pittsburgh |
| 15148 | Pittsburgh |
| 15189 | Pittsburgh |
| 15201 | Pittsburgh |
| 15202 | Pittsburgh |
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| 19331 | Philadelphia |
| 19333 | Philadelphia |
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| 19360 | Philadelphia |
| 19362 | Philadelphia |
| 19363 | Philadelphia |
| 19365 | Philadelphia |
| 19366 | Philadelphia |
| 19367 | Philadelphia |
| 19369 | Philadelphia |
| 19371 | Philadelphia |
| 19372 | Philadelphia |
| 19373 | Philadelphia |
| 19374 | Philadelphia |
| 19375 | Philadelphia |
| 19376 | Philadelphia |
| 19380 | Philadelphia |
| 19381 | Philadelphia |
| 19382 | Philadelphia |
| 19383 | Philadelphia |
| 19388 | Philadelphia |
| 19390 | Philadelphia |
| 19395 | Philadelphia |
| 19397 | Philadelphia |
| 19398 | Philadelphia |
| 19399 | Philadelphia |
| 19401 | Philadelphia |
| 19403 | Philadelphia |
| 19404 | Philadelphia |
| 19405 | Philadelphia |
| 19406 | Philadelphia |
| 19407 | Philadelphia |
| 19408 | Philadelphia |
| 19409 | Philadelphia |
| 19415 | Philadelphia |
| 19420 | Philadelphia |
| 19421 | Philadelphia |
| 19422 | Philadelphia |
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| 19437 | Philadelphia |
| 19438 | Philadelphia |
| 19440 | Philadelphia |
| 19441 | Philadelphia |
| 19442 | Philadelphia |
| 19443 | Philadelphia |
| 19444 | Philadelphia |
| 19446 | Philadelphia |
| 19450 | Philadelphia |
| 19451 | Philadelphia |
| 19453 | Philadelphia |
| 19454 | Philadelphia |
| 19455 | Philadelphia |
| 19456 | Philadelphia |
| 19457 | Philadelphia |
| 19460 | Philadelphia |
| 19462 | Philadelphia |
| 19464 | Philadelphia |
| 19465 | Philadelphia |
| 19468 | Philadelphia |
| 19470 | Philadelphia |
| 19472 | Philadelphia |
| 19473 | Philadelphia |
| 19474 | Philadelphia |
| 19475 | Philadelphia |
| 19477 | Philadelphia |
| 19478 | Philadelphia |
| 19480 | Philadelphia |
| 19481 | Philadelphia |
| 19482 | Philadelphia |
| 19483 | Philadelphia |
| 19484 | Philadelphia |
| 19485 | Philadelphia |
| 19486 | Philadelphia |
| 19487 | Philadelphia |
| 19488 | Philadelphia |
| 19489 | Philadelphia |
| 19490 | Philadelphia |
| 19492 | Philadelphia |
| 19493 | Philadelphia |
| 19494 | Philadelphia |
| 19495 | Philadelphia |
| 19496 | Philadelphia |
| 19501 | Allentown |
| 19503 | Allentown |
| 19504 | Allentown |
| 19505 | Allentown |
| 19506 | Allentown |
| 19507 | Harrisburg |
| 19508 | Allentown |
| 19510 | Allentown |
| 19511 | Allentown |
| 19512 | Allentown |
| 19516 | Allentown |
| 19518 | Allentown |
| 19519 | Allentown |
| 19520 | Philadelphia |
| 19522 | Allentown |
| 19523 | Allentown |
| 19525 | Philadelphia |
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| 19543 | Allentown |
| 19544 | Harrisburg |
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| 19548 | Allentown |
| 19549 | Allentown |
| 19550 | Harrisburg |
| 19551 | Allentown |
| 19554 | Allentown |
| 19555 | Allentown |
| 19557 | Allentown |
| 19559 | Allentown |
| 19560 | Allentown |
| 19562 | Allentown |
| 19564 | Allentown |
| 19565 | Allentown |
| 19567 | Harrisburg |
| 19601 | Allentown |
| 19602 | Allentown |
| 19603 | Allentown |
| 19604 | Allentown |
| 19605 | Allentown |
| 19606 | Allentown |
| 19607 | Allentown |
| 19608 | Allentown |
| 19609 | Allentown |
| 19610 | Allentown |
| 19611 | Allentown |
| 19612 | Allentown |
| 19640 | Allentown |

1. Note: Information in the TRM specifically relating to the AEPS Act is shaded in gray. [↑](#footnote-ref-2)
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-3)
3. The 1.11 factor is to be used for the AEPS portfolio and is not binding for the purpose of cost-effectiveness calculations or coincident peak demand savings calculations for Act 129. [↑](#footnote-ref-4)
4. 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-5)
5. Natural Resources Canada Report.pdf [↑](#footnote-ref-6)
6. EPRI Electric Clothes Dryer Report.pdf [↑](#footnote-ref-7)
7. Natural Living Guide.pdf [↑](#footnote-ref-8)
8. Energy Star Clothes Washer Calculator Assumptions.pdf [↑](#footnote-ref-9)
9. DEER EUL values, updated October 10, 2008 [↑](#footnote-ref-10)
10. 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-11)
11. 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-12)
12. 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-13)
13. DEER values, updated October 10, 2008

    http://www.deeresources.com/deer0911planning/downloads/EUL\_Summary\_10-1-08.xls [↑](#footnote-ref-14)
14. 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-15)
15. 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-16)
16. 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-17)
17. 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-18)
18. 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-19)
19. DEER values, updated October 10, 2008  
    http://www.deeresources.com/deer0911planning/downloads/EUL\_Summary\_10-1-08.xls [↑](#footnote-ref-20)
20. Four 23-W CFLs are sent out. We assume that one replaces a 100W lamp while the remaining CFLs replace 60W lamps. [↑](#footnote-ref-21)
21. 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-22)
22. 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-23)
23. 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-24)
24. 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-25)
25. The Energy Policy Act of 1992 established the maximum flow rate for showerheads at 2.5 gallons per minute (GPM). [↑](#footnote-ref-26)
26. Pennsylvania, Census of Population, 2000. [↑](#footnote-ref-27)
27. 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-28)
28. 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-29)
29. Based upon a consensus achieved at Residential Measure Protocols for TRM Teleconference held on June 2, 2010. [↑](#footnote-ref-30)
30. 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-31)
31. Assumes an electric water heater that meets the current federal standard (0.90 EF). [↑](#footnote-ref-32)
32. 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-33)
33. Op. cit. [↑](#footnote-ref-34)
34. Efficiency Vermont, Technical Reference User Manual: Measure Savings Algorithms and Cost Assumptions, TRM User Manual No. 2008-53, 07/18/08. [↑](#footnote-ref-35)
35. 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. This table will be developed in the context of the TWG. [↑](#footnote-ref-36)
36. 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)
37. 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)
38. 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)
39. 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)
40. 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)
41. On the other hand, the band would have to expanded to at least 12 hours to capture all 100 hours. [↑](#footnote-ref-42)
42. 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)
43. http://www.energystar.gov/index.cfm?c=solar\_wheat.pr\_savings\_benefits [↑](#footnote-ref-44)
44. 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)
45. 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)
46. Op. cit. [↑](#footnote-ref-47)
47. Efficiency Vermont, Technical Reference User Manual: Measure Savings Algorithms and Cost Assumptions, TRM User Manual No. 2008-53, 07/18/08. [↑](#footnote-ref-48)
48. *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)
49. Architectural Energy Corporation, REM/Rate v12.85. [↑](#footnote-ref-50)
50. 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)
51. *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)
52. 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)
53. 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)
54. 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)
55. 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)
56. 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)
57. DEER values, updated October 10, 2008: http://www.deeresources.com/deer0911planning/downloads/EUL\_Summary\_10-1-08.xls [↑](#footnote-ref-58)
58. 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)
59. 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)
60. 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)
61. 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)
62. 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)
63. DEER values, updated October 10, 2008  
    <http://www.deeresources.com/deer0911planning/downloads/EUL_Summary_10-1-08.xls> [↑](#footnote-ref-64)
64. 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)
65. “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)
66. 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)
67. 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)
68. Used eQuest 6.64 to derive wall assembly R-values. [↑](#footnote-ref-69)
69. 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)
70. 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)
71. 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)
72. Table 2-1. [↑](#footnote-ref-73)
73. PA SWE Interim Approved TRM Protocol – Residential Room AC Retirement [↑](#footnote-ref-74)
74. 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)
75. Ibid. [↑](#footnote-ref-76)
76. *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)
77. For example, non-residential rate class usage cases include residential dwellings that are master-metered, usage in offices or any other applications that involve typical refrigerator usage. [↑](#footnote-ref-78)
78. 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-86)
79. Vermont Energy Investment Corporation (VEIC) for NEEP, Mid Atlantic TRM Version 1.1. October 2010. Pg.27. [↑](#footnote-ref-87)
80. For example, non-residential rate class usage cases include residential dwellings that are master-metered, usage in offices or any other applications that involve typical refrigerator usage. [↑](#footnote-ref-88)
81. Energy Star Refrigerator Retirement Calculator, accessed 10/15/2011 at http://www.energystar.gov/index.cfm?fuseaction=refrig.calculator [↑](#footnote-ref-89)
82. Savings value derived from the JACO Appliance Collection Databases received from all EDCs (Allegheny, PPL, PECO, Duquesne and FirstEnergy). This value is subject to change in future TRMs based on further analysis of other evaluation reports on appliance recycling programs across the nation. [↑](#footnote-ref-90)
83. DoE’s Building Energy Software Tools Directory (http://apps1.eere.energy.gov/buildings/tools\_directory/software). [↑](#footnote-ref-91)
84. No source provided for these savings figure. Additional research and updated values are recommended. [↑](#footnote-ref-92)
85. Single and multiple family as noted. [↑](#footnote-ref-97)
86. According to information submitted by EDCs, fuel mix varies greatly across different territories (e.g. Duquesne reported 90/10 split between gas and electric water heating, whereas PECO reported a 69/31 split and PPL reported a 49/51 split. This extreme differential behooves EDC-specific values. [↑](#footnote-ref-98)
87. Subject to verification through evaluation. The value can be updated if evaluation findings reveal a value that differs from the default [↑](#footnote-ref-99)
88. United States Department of Energy. *Impact of EISA 2007 on General Service Incandescent Lamps: FACT SHEET.* http://www1.eere.energy.gov/buildings/appliance\_standards/residential/pdfs/general\_service\_incandescent\_factsheet.pdf [↑](#footnote-ref-100)
89. The EISA 2007 standards apply to general service incandescent lamps. A non-specialty CFL is considered any lamp that does not replace one of the 22 incandescent lamps exempt from the EISA 2007 standards.. A complete list of the 22 incandescent lamps exempt from EISA 2007 is listed in the United States Department of *Energy Impact of EISA 2007 on General Service Incandescent Lamps: FACT SHEET.* [↑](#footnote-ref-101)
90. Energy Information Administration. *Residential Energy Consumption Survey*. 2005. <http://www.eia.doe.gov/emeu/recs/recs2005/hc2005_tables/detailed_tables2005.html> [↑](#footnote-ref-102)
91. A new standard for BESTEST-EX for existing homes is currently being deveoped - status is found at http://www.nrel.gov/buildings/bestest\_Ex.html. The existing 1995 standard can be found at http://www.nrel.gov/docs/legosti/fy96/7332a.pdf. [↑](#footnote-ref-103)
92. A listing of the approved software available at <http://www.waptac.org/si.asp?id=736> . [↑](#footnote-ref-104)
93. A listing of the approved software available at <http://resnet.us> . [↑](#footnote-ref-105)
94. 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-106)
95. 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-107)
96. 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-108)
97. *TVs Key ENERGY STAR Product Criteria*, accessed October 2010, <http://www.energystar.gov/index.cfm?c=tv_vcr.pr_crit_tv_vcr> [↑](#footnote-ref-109)
98. Ibid. [↑](#footnote-ref-110)
99. 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-111)
100. 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-112)
101. *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-113)
102. Ibid. [↑](#footnote-ref-114)
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-115)
104. Ibid. [↑](#footnote-ref-116)
105. 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-117)
106. http://www.energystar.gov/ia/partners/product\_specs/program\_reqs/SSL\_Key\_Product\_Criteria.pdf [↑](#footnote-ref-118)
107. <http://www.lightingfacts.com/> [↑](#footnote-ref-119)
108. <http://www1.eere.energy.gov/buildings/appliance_standards/residential/incandescent_lamps.html> [↑](#footnote-ref-120)
109. <http://www.standardsasap.org/products/incd_reflector.html> [↑](#footnote-ref-121)
110. The amendment provided nominal lamp wattages and minimum average efficacies for standard incandescent reflector lamps and general service lamps, Table 2‑53 adapts those averages. See: <http://www1.eere.energy.gov/buildings/appliance_standards/residential/incandescent_lamps_standards_final_rule.html> [↑](#footnote-ref-122)
111. Subject to verification through evaluation. The value can be updated if evaluation findings reveal a value that differs from the default. [↑](#footnote-ref-123)
112. All LED bulbs listed on the qualified ENERGY STAR product list have a lifetime of at least 15,000 hours. Assuming 3 hours per day usage, this equates to 13.7 years . [↑](#footnote-ref-124)
113. GDS Associates, Inc. (2007). Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures. Prepared for The New England State Program Working Group. [↑](#footnote-ref-125)
114. The DSMore Michigan Database of Energy Efficiency Measures: Based on spreadsheet calculations using collected data: Franklin Energy Services; "FES-L19 – LED Holiday Lighting Calc Sheet" [↑](#footnote-ref-126)
115. http://www.energyideas.org/documents/factsheets/HolidayLighting.pdf [↑](#footnote-ref-127)
116. Area includes tank sides and top to account for typical wrap coverage. [↑](#footnote-ref-128)
117. Ibid. [↑](#footnote-ref-129)
118. “Energy Savers”, U.S. Department of Energy, accessed November, 2010 http://www.energysavers.gov/your\_home/water\_heating/index.cfm/mytopic=13070 [↑](#footnote-ref-130)
119. Area values were calculated from average dimensions of several commercially available units, with radius values measured to the center of the insulation. Area includes tank sides and top to account for typical wrap coverage. [↑](#footnote-ref-131)
120. Ainsul was calculated by assuming that the water heater wrap is a 2” thick fiberglass material. [↑](#footnote-ref-132)
121. DEER Version 2008.2.05, December 16, 2008. [↑](#footnote-ref-133)
122. “CEC Appliances Database – Pool Pumps.” *California Energy Commission.* Updated Feb 2008. Accessed March 2008. [< http://www.energy.ca.gov/appliances/database/historical\_excel\_files/2009-03-01\_excel\_based\_files/Pool\_Products/Pool\_Pumps.zip](C:\\Documents and Settings\\unzipped\\< http:\\www.energy.ca.gov\\appliances\\database\\historical_excel_files\\2009-03-01_excel_based_files\\Pool_Products\\Pool_Pumps.zip)> [↑](#footnote-ref-134)
123. Averaged for all listed single-speed pumps in the last available version of the CEC appliance efficiency database. The powers are for 'CEC Curve A' which represents hydraulic properties of 2" PVC pipes rather than older, 1.5" copper pipes. [↑](#footnote-ref-135)
124. Mid-Atlantic TRM, version 2.0. Prepared by Vermont Energy Investment Corporation. Facilitated and managed by the Northeast Energy Efficiency Partnerships. July 2011 [↑](#footnote-ref-136)
125. “CEC Appliances Database – Pool Pumps.” *California Energy Commission.* Updated Feb 2008. Accessed March 2008. [< http://www.energy.ca.gov/appliances/database/historical\_excel\_files/2009-03-01\_excel\_based\_files/Pool\_Products/Pool\_Pumps.zip](C:\\unzipped\\< http:\\www.energy.ca.gov\\appliances\\database\\historical_excel_files\\2009-03-01_excel_based_files\\Pool_Products\\Pool_Pumps.zip)> [↑](#footnote-ref-137)
126. Averaged for all listed single-speed pumps in the last available version of the CEC appliance efficiency database. The powers are for 'CEC Curve A' which represents hydraulic properties of 2" PVC pipes rather than older, 1.5" copper pipes. [↑](#footnote-ref-138)
127. DEER values, updated October 10, 2008  
     http://www.deeresources.com/deer0911planning/downloads/EUL\_Summary\_10-1-08.xls [↑](#footnote-ref-139)
128. The Locator is intended to assist users locate codes in the Standard Wattage Table. It does not generate new codes or wattages. In a few cases, the fixture code noted in the Standard Wattage Table may not use standard notation. Therefore, these fixtures may not be able to be found using the Locator and a manual search may be necessary to locate the code. [↑](#footnote-ref-147)
129. This value was agreed upon by the Technical Working Group convened to discuss updates to the TRM. This value is subject to adjustment based on implementation feedback during PY2 and PY3. [↑](#footnote-ref-148)
130. ASHRAE 90.1-2007, Table 9.5.1 – Building Area Method [↑](#footnote-ref-154)
131. ASHRAE 90.1-2007, Table 9.6.1 – Space-by-Space Method [↑](#footnote-ref-155)
132. ASHRAE 90.1-2007, Table 9.4.5 – Baseline Exterior Lighting Power Densities [↑](#footnote-ref-156)
133. ASHRAE 90.1-2007, “Table 9.5.1 Lighting Power Densities Using the Building Area Method.” [↑](#footnote-ref-158)
134. In cases where both a common space type and a building specific type are listed, the building specific space type shall apply. [↑](#footnote-ref-159)
135. ASHRAE 90.1-2007, “Table 9.6.1 Lighting Power Densities Using the Space-by-Space Method.” [↑](#footnote-ref-160)
136. In cases where both a common space type and a building specific type are listed, the building specific space type shall apply. [↑](#footnote-ref-161)
137. ASHRAE 90.1-2007 Table 9.4.5 [↑](#footnote-ref-162)
138. 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-163)
139. Average of NJ Clean Energy from JCP&L data and 2004-2005 DEER update study (December 2005). [↑](#footnote-ref-164)
140. To be used only for lights illuminated on a continuous basis. [↑](#footnote-ref-165)
141. To be used only when no other category is applicable. Hours of operation must be documented by facility staff interviews, posted schedules, or metered data. [↑](#footnote-ref-166)
142. Subject to verification by EDC Evaluation or SWE [↑](#footnote-ref-167)
143. Subject to verification by EDC Evaluation or SWE [↑](#footnote-ref-168)
144. 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-169)
145. Source: PECO Comments on the PA TRM, received March 30, 2009. [↑](#footnote-ref-170)
146. In order to use Motor Master you would need to log. This can be done for custom measure but is not allowed for stipulated measures. [↑](#footnote-ref-171)
147. Default Value can be used by EDC but is subject to metering and adjustment by evaluators or SWE [↑](#footnote-ref-172)
148. Default Value can be used by EDC but is subject to metering and adjustment by evaluators or SWE [↑](#footnote-ref-173)
149. See definition in section 3.3.2 for specific algorithm to be used when performing spot metering analysis to determine alternate load factor. [↑](#footnote-ref-174)
150. Need to confirm source through TWG [↑](#footnote-ref-175)
151. Table is based on NEMA EPACT efficiency motor standards. Source to the table can be found at: <http://www.cee1.org/ind/motrs/CEE_NEMA.pdf> [↑](#footnote-ref-176)
152. Table is based on NEMA premium efficiency motor standards. Source to the table can be found at: http://www.nema.org/stds/complimentary-docs/upload/MG1premium.pdf [↑](#footnote-ref-177)
153. Operating hours subject to adjustment with data provided by EDCs and accepted by SWE [↑](#footnote-ref-178)
154. http://www.energystar.gov/ia/business/bulk\_purchasing/bpsavings\_calc/Calc\_CAC.xls [↑](#footnote-ref-179)
155. In order to use Motor Master you would need to log. This can be done for custom measure but is not allowed for stipulated measures. A standard practice and/or load shape study would be required. [↑](#footnote-ref-181)
156. Default Value can be used by EDC but is subject to metering and adjustment by evaluators or SWE [↑](#footnote-ref-184)
157. Default Value can be used by EDC but is subject to metering and adjustment by evaluators or SWE [↑](#footnote-ref-185)
158. Need to confirm source through TWG [↑](#footnote-ref-186)
159. Mid-Atlantic TRM Version 2.0, July 2011. Page 174. [↑](#footnote-ref-187)
160. In order to use Motor Master you would need to log. This can be done for custom measures but is not allowed for stipulated measures. A standard practice and/or load shape study would be required. [↑](#footnote-ref-188)
161. The basis for these factors has not been determined or independently verified. [↑](#footnote-ref-189)
162. Baseline values from IECC 2009, after Jan 1, 2010 or Jan 23, 2010 as applicable. [↑](#footnote-ref-191)
163. Cap represents the rated cooling capacity of the product in Btu/h. If the unit’s capacity is less than 7,000 Btu/h, 7,000 Btu/h is used in the calculation. If the unit’s capacity is greater than 15,000 Btu/h, 15,000 Btu/h is used in the calculation. [↑](#footnote-ref-192)
164. US Department of Energy. Energy Star Calculator and Bin Analysis Models [↑](#footnote-ref-194)
165. US Department of Energy. Energy Star Calculator and Bin Analysis Models [↑](#footnote-ref-195)
166. IECC 2009 – Table 503.2.3(7). Chillers must satisfy efficiency requirements for both full load and IPLV efficiencies for either Path A or Path B. The table shows the efficiency ratings to be used for the baseline chiller efficiency in the savings estimation algorithm, which must be consistent with the expected operating conditions of the efficient chiller. For example, if the efficient chiller satisfies Path A and generally performs at part load, the appropriate baseline chiller efficiency is the IPLV value under Path A for energy savings. If the efficient chiller satisfies Path B and generally performs at full load, the appropriate baseline chiller efficiency is the full load value under Path B for energy savings. Generally, chillers operating above 70 percent load for a majority (50% or more) of operating hours should use Path A and chillers below 70% load for a majority of operating hours should use Path B. The “full load” efficiency from the appropriate Path A or B should be used to calculate the Peak Demand Savings as it is expected that the chillers would be under full load during the peak demand periods. [↑](#footnote-ref-196)
167. US Department of Energy. Energy Star Calculator and Bin Analysis Models [↑](#footnote-ref-197)
168. 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-198)
169. 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-199)
170. *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-200)
171. *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-201)
172. 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-202)
173. *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-203)
174. *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-204)
175. *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-205)
176. 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-206)
177. *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-207)
178. ASHRAE 90.1-2004, Tables 6.8.1A, 6.8.1B, and 6.8.1D [↑](#footnote-ref-208)
179. IECC 2009, Tables 503.2.3(1), 503.2.3(2), and 503.2.3(3) [↑](#footnote-ref-209)
180. US Department of Energy. ENERGY STAR Calculator and Bin Analysis Models [↑](#footnote-ref-210)
181. We define *curtain efficacy* as the fraction of the potential airflow that is blocked by an infiltration barrier. For example, a brick wall would have an efficacy of 1.0, while the lack of any infiltration barrier corresponds to an efficacy of 0. [↑](#footnote-ref-211)
182. See source 1 for Table 3‑11. [↑](#footnote-ref-212)
183. http://energysmartonline.org/documents/EnergySmart\_BPA\_T&Cs.pdf [↑](#footnote-ref-213)
184. *Kalterveluste durch kuhlraumoffnungen*. Tamm W,.Kaltetechnik-Klimatisierung 1966;18;142-144 [↑](#footnote-ref-214)
185. American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE). 2006. *ASHRAE Handbook,* Refrigeration:13.4, 13.6 [↑](#footnote-ref-215)
186. http://www.calmac.org/publications/ComFac\_Evaluation\_V1\_Final\_Report\_02-18-2010.pdf [↑](#footnote-ref-216)
187. In the original equation (Tamm’s equation) the height is taken to be the difference between the midpoint of the opening and the ‘neutral pressure level’ of the cold space. In the case that there is just one dominant doorway through which infiltration occurs, the neutral pressure level is half the height of the doorway to the walk-in refrigeration unit. The refrigerated air leaks out through the lower half of the door, and the warm, infiltrating air enters through the top half of the door. We deconstruct the lower half of the door into infinitesimal horizontal strips of width W and height dh. Each strip is treated as a separate window, and the air flow through each infinitesimal strip is given by 60 x CD x A x {[(Ti – Tr ) / Ti ] x g x ΔHNPL }^0.5 where ΔHNPL represents the distance to the vertical midpoint of the door. In effect, this replaces the implicit wh1.5 (one power from the area, and the other from ΔHNPL ) with the integral from 0 to h/2 of wh’0.5 dh’ which results in wh1.5/(3×20.5­). For more information see: Are They Cool(ing)?:Quantifying the Energy Savings from Installing / Repairing Strip Curtains, Alereza, Baroiant, Dohrmann, Mort, Proceedings of the 2008 IEPEC Conference. [↑](#footnote-ref-217)
188. <http://www.cpuc.ca.gov/PUC/energy/Energy+Efficiency/EM+and+V/2006-2008+Energy+Efficiency+Evaluation+Report.htm>. The scale factors have been determined with tracer gas measurements on over 100 walk-in refrigeration units during the California Public Utility Commission’s evaluation of the 2006-2008 CA investor owned utility energy efficiency programs. The door-open and close times, and temperatures of the infiltrating and refrigerated airs are taken from short-term monitoring of over 100 walk-in units. The temperature and humidity of the infiltrating air and the COP of the units have been modified to reflect the PA climate. [↑](#footnote-ref-218)
189. EFLHcool + EFLHheat represent the addition of cooling and heating annual equivalent full load hours for commercial HVAC for different occupancies, respectively. [↑](#footnote-ref-219)
190. EFLHcool + EFLHheat represent the addition of cooling and heating annual equivalent full load hours for commercial HVAC for different occupancies, respectively. [↑](#footnote-ref-220)
191. Table is based on NEMA premium efficiency motor standards. Source to the table can be found at: http://www.nema.org/stds/complimentary-docs/upload/MG1premium.pdf [↑](#footnote-ref-221)
192. Based on program requirements submitted during protocol review. [↑](#footnote-ref-222)
193. Cap represents the rated cooling capacity of the product in Btu/h. If the unit’s capacity is less than 7,000 Btu/h, 7,000 Btu/h is used in the calculation. If the unit’s capacity is greater than 15,000 Btu/h, 15,000 Btu/h is used in the calculation. [↑](#footnote-ref-223)
194. Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc., June 2007. [↑](#footnote-ref-224)
195. 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-225)
196. US Department of Energy. Energy Star Calculator and Bin Analysis Models [↑](#footnote-ref-226)
197. A zip code mapping table is located in Appendix F. This table should be used to identify the reference Pennsylvania city for all zip codes in Pennsylvania [↑](#footnote-ref-227)
198. US Department of Energy. Energy Star Calculator and Bin Analysis Models [↑](#footnote-ref-228)
199. US Department of Energy. Energy Star Calculator and Bin Analysis Models [↑](#footnote-ref-229)
200. A zip code mapping table is located in Appendix F. This table should be used to identify the referenec Pennsylvania city for all zip codes in Pennsylvania [↑](#footnote-ref-230)
201. US Department of Energy. Energy Star Calculator and Bin Analysis Models [↑](#footnote-ref-231)
202. 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-232)
203. Values for ASTM parameters for baseline and efficient conditions (unless otherwise noted) were determined by FSTC according to ASTM F1484, the Standard Test Method for Performance of Steam Cookers. Pounds of Food Cooked per Day based on the default value for a 3 pan steam cooker (100 lbs from FSTC) and scaled up based on the assumption that steam cookers with a greater number of pans cook larger quantities of food per day. [↑](#footnote-ref-233)
204. Efficient values calculated from a list of ENERGY STAR qualified products. [↑](#footnote-ref-234)
205. Ibid. [↑](#footnote-ref-235)
206. http://www.energystar.gov/index.cfm?fuseaction=find\_a\_product.showProductGroup&pgw\_code=COC [↑](#footnote-ref-236)
207. <http://www.smud.org/en/business/rebates/Pages/express-refrigeration.aspx> [↑](#footnote-ref-237)
208. Massachusetts 2011 Technical Reference Manual [↑](#footnote-ref-238)
209. “Effects Of The Low Emissivity Shields On Performance And Power Use Of A Refrigerated Display Case” *Southern California Edison Refrigeration Technology and Test Center Energy Efficiency Division* August 8,1997. [↑](#footnote-ref-239)
210. Assumed that the continuous covers are deployed at night (usually 1:00 a.m. – 5:00 a.m.); therefore no demand savings is usually reported for this measure. [↑](#footnote-ref-240)
211. Hours should be determined on a case-by-case basis. Default value of 2190 hours is estimated assuming that the annual operating hours of the refrigerated case is 8,760 hours as per Ohio 2010 Technical Reference Manual and night covers must be applied for a period of at least six hours in a 24-hour period. <http://energysmartonline.org/documents/EnergySmart_BPA_T&Cs.pdf> [↑](#footnote-ref-241)
212. 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, “Effective/Remaining Useful Life Values”, California Public Utilities Commission, December 16, 2008. [↑](#footnote-ref-242)
213. The Measure Life Report for Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc., June 2007 [↑](#footnote-ref-243)
214. <http://energysmartonline.org/documents/EnergySmart_BPA_T&Cs.pdf> [↑](#footnote-ref-244)
215. http://energysmartonline.org/documents/EnergySmart\_BPA\_T&Cs.pdf [↑](#footnote-ref-245)
216. http://www.calmac.org/publications/ComFac\_Evaluation\_V1\_Final\_Report\_02-18-2010.pdf [↑](#footnote-ref-246)
217. <http://www.calmac.org/publications/ComFac_Evaluation_V1_Final_Report_02-18-2010.pdf> [↑](#footnote-ref-247)
218. <http://www.energysmartgrocer.org/pdfs/PGE/2010_2012%20External%20Equipment%20SpecificationTandCs%20v3.pdf> [↑](#footnote-ref-248)
219. Work papers developed by SCE filed with the CA PUC in support of its 2006 – 2008 energy efficiency program plans [↑](#footnote-ref-249)
220. A zip code mapping table is located in Appendix F. This table should be used to identify the referenec Pennsylvania city for all zip codes in Pennsylvania [↑](#footnote-ref-251)
221. California Measurement Advisory Committee Public Workpapers on PY 2001 Energy Efficiency Programs. September 2000. Appendix F, P.14 [↑](#footnote-ref-252)
222. DEER database, EUL/RUL for insulation bare suction pipes [↑](#footnote-ref-253)
223. An evaporator fan controller is a device or system that lowers airflow across an evaporator in medium-temperature walk-in coolers when there is no refrigerant flow through the evaporator (i.e., when the compressor is in an off-cycle). [↑](#footnote-ref-254)
224. The assumptions and algorithms used in this section are specific to NRM products and are taken from the Massachusetts Statewide Technical Reference Manual for Estimating Savings from Energy Efficiency Measures, Version 1.0 <http://www.ma-eeac.org/docs/MA%20TRM_2011%20PLAN%20VERSION.PDF> [↑](#footnote-ref-255)
225. Conservative value based on 15 years of NRM field observations and experience [↑](#footnote-ref-256)
226. Conservative estimate supported by less conservative values given by several utility-sponsored 3rd party studies including: Select Energy (2004). *Analysis of Cooler Control Energy Conservation Measures*. Prepared for NSTAR. [↑](#footnote-ref-257)
227. Evaporator fan power**,** in kilowatts (kW), is determined by multiplying the values for Voltage and Amperage from nameplate data with the power factor listed in Table 1-1. <http://www.touchstoneenergy.com/efficiency/bea/Documents/EvaporatorFanControllers.pdf> [↑](#footnote-ref-258)
228. Energy & Resource Solutions (2005). Measure Life Study. Prepared for The Massachusetts Joint Utilities; Table 1-1. [↑](#footnote-ref-259)
229. Consortium for Energy Efficiency: http://www.cee1.org/resid/seha/rwsh/reswash\_specs.pdf [↑](#footnote-ref-260)
230. The solid green profile is derived from a normalized load shape based on metering of residential in-unit dryers. The dashed black profile is a smoothed version of the green profile and represents the utilization factors for common laundry facilities in multifamily establishments [↑](#footnote-ref-261)
231. Standard clothes washer that is DOE 2007 compliant [↑](#footnote-ref-262)
232. Dependent on energy source for washer [↑](#footnote-ref-263)
233. 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, “Effective/Remaining Useful Life Values” [↑](#footnote-ref-264)
234. http://www.deeresources.com/deer0911planning/downloads/DEER2008-CommercialResultsReview-NonUpdatedMeasures.exe [↑](#footnote-ref-265)
235. ibid [↑](#footnote-ref-266)
236. One reason for the close agreement is that the factor is a ratio of the energy usage to peak demand for the same location. Even though the energy usages may vary significantly in different climate zones, the hot water usage patterns may be driven by underlying practices that carry over well from state to state (e.g. dishwashing after lunch or dinner in restaurants). [↑](#footnote-ref-267)
237. DEER values, updated October 10, 2008  
     http://www.deeresources.com/deer0911planning/downloads/EUL\_Summary\_10-1-08.xls [↑](#footnote-ref-268)
238. http://www.deeresources.com/deer0911planning/downloads/DEER2008-CommercialResultsReview-NonUpdatedMeasures.exe [↑](#footnote-ref-269)
239. ibid [↑](#footnote-ref-270)
240. One reason for the close agreement is that the factor is a ratio of the energy usage to peak demand for the same location. Even though the energy usages may vary significantly in different climate zones, the hot water usage patterns may be driven by underlying practices that carry over well from state to state (e.g. dishwashing after lunch or dinner in restaurants). [↑](#footnote-ref-271)
241. 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-272)
242. The performance curve is adapted from Table 1 in [http://wescorhvac.com/HPWH%20design%20details.htm#Single-stage%20HPWHs](http://wescorhvac.com/HPWH%20design%20details.htm" \l "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-273)
243. DEER values, updated October 10, 2008. http://www.deeresources.com/deer0911planning/downloads/EUL\_Summary\_10-1-08.xls [↑](#footnote-ref-274)
244. http://www.aepohio.com/global/utilities/lib/docs/save/programs/Application\_Steps\_Incentive\_Process.pdf [↑](#footnote-ref-275)
245. The average length of neon per foot of letter is dependent on many variables, such as how long the neon stroke length is for each letter, how often the letter occurs, and how wide the letter is. The stroke length per letter is estimated using a simple LED alphanumeric display module. The height of the letter is assumed to be two units high and one unit wide. The stroke length per letter width is calculated by dividing the stroke length for each letter by its width. All letters are assumed to have one unit width except the letter “I.” Southern California Edison Company, LED Channel Letter Signage (Red), Work Paper WPSCNRLG0052, Revision 1. [↑](#footnote-ref-276)
246. Average values were estimated based on wattages data obtained from major channel letter lighting product manufacturers. Southern California Edison Company, LED Channel Letter Signage (Red), Work Paper WPSCNRLG0052, Revision 1. [↑](#footnote-ref-277)
247. ibid [↑](#footnote-ref-278)
248. Southern California Edison Company, LED Channel Letter Signage (Red), Work Paper WPSCNRLG0052, Revision 1, DEER only includes an LED Exit Sign measure which was used to estimate the effective useful life of the LED Channel Letter Signage. Actual life is 15 years. Capped at 15 years per Act 129. [↑](#footnote-ref-279)
249. One reason for the close agreement is that the factor is a ratio of the energy usage to peak demand for the same location. Even though the energy usages may vary significantly in different climate zones, the hot water usage patterns may be driven by underlying practices that carry over well from state to state (e.g. dishwashing after lunch or dinner in restaurants). [↑](#footnote-ref-280)
250. *Impact and Process Evaluation Final Report for California Urban Water Conservation Council 2004-5 Pre-Rinse Spray Valve Installation Program (Phase 2),* SBW Consulting, 2007, p. 30 [↑](#footnote-ref-281)
251. Here it is assumed that the compressor provides 70% of the heat, while the fan and supplemental heat strips provide the remaining 30% of the heating. The efficiency gains from refrigerant charging do not apply to the fan or supplemental heat strips. [↑](#footnote-ref-282)
252. CA 2003 RTU Survey [↑](#footnote-ref-283)
253. http://www.deeresources.com/deer0911planning/downloads/EUL\_Summary\_10-1-08.xls [↑](#footnote-ref-284)
254. http://www.energysmartgrocer.org/pdfs/PGE/BridgeEquipment%20SpecificationTandCs.pdf [↑](#footnote-ref-285)
255. Southern California Edison. Non-Residential Express 2003 Refrigeration Work Paper. Pg. 27. [↑](#footnote-ref-286)
256. EFLH was determined by multiplying annual available operation hours of 8,760 by overall duty cycle factors. Duty cycle is a function of compressor capacity, defrost and weather factor. The units are assumed to be operating 24/7, 8760 hrs/yr. [↑](#footnote-ref-287)
257. From Actual Test: 0.250 kW per 3 doors [↑](#footnote-ref-288)
258. <http://energysmartonline.org/documents/EnergySmart_BPA_T&Cs.pdf> [↑](#footnote-ref-289)
259. Baseline values from IECC 2009, after Jan 1, 2010 or Jan 23, 2010 as applicable. [↑](#footnote-ref-290)
260. US Department of Energy. Energy Star Calculator and Bin Analysis Models [↑](#footnote-ref-291)
261. See the Secretarial Letter issued by the Commission on January 12, 2011, at Docket No. M-2008-2069887. [↑](#footnote-ref-292)
262. This will be 0 MW if there was not a curtailment event in that hour. [↑](#footnote-ref-293)
263. There is no need to weather normalize the reconstructed load curve. The peak load reduction targets were established using weather normalized data but actual load should not be weather normalized because it is intended to be the actual peaks for that summer regardless of weather. [↑](#footnote-ref-294)
264. EDCs will have predictive models for identifying days and hours for initiating Act 129 DR events. Such models are informed by actual load information and active DR events (to the extent practicable), but will generally not include impacts of non-dispatchable measures that are based on data, information and verification sometimes months after-the-fact. Whether non-dispatchable impacts should be included as add-backs may, at the option of the EDC, be informed by evaluation. Whether included in add-back calculations or not, Constant Load Reductions installed during the June – September period would be included in calculation of Average Peak Load Reductions based on installation date. [↑](#footnote-ref-295)
265. 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-296)
266. ENERGY STAR website for Commercial LED Lighting:

     <http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=LTG> [↑](#footnote-ref-297)
267. “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-298)
268. “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-299)
269. ENERGY STAR Qualified LED Lighting list <http://www.energystar.gov/index.cfm?fuseaction=ssl.display_products_res_html> [↑](#footnote-ref-300)
270. DesignLights Consortium (DLC) Technical Requirements Table v1.4. Accessed from the DLC website on September 24, 2010. <http://www.designlights.org/solidstate.manufacturer.requirements.php> [↑](#footnote-ref-301)
271. Ibid. [↑](#footnote-ref-302)
272. 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-303)