Technical Reference Manual

June ~~2011~~2012

State of Pennsylvania

Act 129

Energy Efficiency and Conservation Program

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Act 213

Alternative Energy Portfolio Standards

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1 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], 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.

1.1 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.

1.2 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.

[1] Note: Information in the TRM specifically relating to the AEPS Act is shaded in gray.

- 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.

1.3 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.

1.4 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.

$\Delta kW = kW_{base} - kW_{ee}$

$\Delta kW_{peak} = \Delta kW \times CF$

$\Delta kWh = \Delta kW \times EFLH$

Where:

ΔkW	= *Demand Savings*
ΔkW_{peak}	= *Coincident Peak Demand Savings*
ΔkWh	= *Annual Energy Savings*
kW_{base}	= *Connected load kW of baseline case.*
kW_{ee}	= *Connected load kW of energy efficient case.*
EFLH	= *Equivalent Full Load Hours of operation for the installed measure.*
CF	= *Demand Coincidence Factor, Thedefined as the fraction of the total technology demand that is coincident with the utility system summer peak, as defined by Act 129TheThe percentage of the total measure demand that is coincident with the electric system's summer peak window.*

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.

1.5 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]. 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.

1.6 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.

1.7 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.

1.8 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.

[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.

1.9 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 1-11-1: 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.

1.10 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.

1.11 Adjustments to Energy and Resource Savings

1.11.1 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.

1.11.2 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).

1.11.3 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.

1.11.4 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).

1.12 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 ~~Working Group~~Order.

1.13 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]. 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.

1.14 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

[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.

efficient measure's life. Specific guidance will be provided through the 2011 TRC Working Group, which is to be convened in 2011Order.

1.15 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.

1.16 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 1-21-2: California CZ Mapping Table

Reference City	**California Climate Zone**

Allentown	4
Erie	6
Harrisburg	8
Philadelphia	13
Pittsburgh	4
Scranton	16
Williamsport	4

1.17 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).

1.171.18 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. Measures belong to a particular sector based on the *application* 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).

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

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2 RESIDENTIAL MEASURES

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

2.1 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's or heat pump's cooling/heating energy use and peak demand contribution. Input data is based both on fixed assumptions and data supplied from the high efficiency equipment AEPS application form or EDC data gathering. The algorithms also include the calculation of additional energy and demand savings due to the required proper sizing of high-efficiency units.

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

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

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

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

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

ΔkWh_{cool} = $CAPY_{cool}/1000 \times (1/SEER_b - 1/SEER_q\ SEER_e) \times EFLH_{cool}$

ΔkWh_{heat} (ASHP Only) = $CAPY_{heat}/1000 \times (1/HSPF_b - 1/HSPF_q\ HSPF_e) \times EFLH_{heat}$

ΔkW_{peak} = $CAPY_{cool}/1000 \times (1/EER_b - 1/EER_q\ EER_e) \times CF$

Central A/C and ASHP (Proper Sizing)

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

ΔkWh_{cool} = $(CAPY_{cool}/(SEER_q\ SEER_e \times 1000)) \times EFLH_{cool} \times PSF$

ΔkWh_{heat} (ASHP Only) = $(CAPY_{heat}/(HSPF_e \times 1000)) \times EFLH_{heat} \times PSF$

ΔkW_{peak} = $((CAPY_{cool}/(EER_q\ EER_e \times 1000)) \times CF) \times PSF$

Central A/C and ASHP (Quality Installation)

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

ΔkWh_{cool} = $(((CAPY_{cool}/(1000 \times SEER_q SEER_e)) \times EFLH_{cool}) \times (1-PSF) \times QIF_{cool}$

ΔkWh_{heat} (ASHP Only) $= (((CAPY_{heat}/(1000 X HSPF_e)) X EFLH_{heat}) X (1-PSF) X QIF_{heat}$

ΔkW_{peak} $= ((CAPY_{cool}/(1000 X EER_q EER_e)) X CF) X (1-PSF) X QIF_{cool}$

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

ΔkWh_{cool} $= ((CAPY_{cool}/(1000 X SEER_m)) X EFLH_{cool}) X MF_{cool}$

ΔkWh_{heat} (ASHP Only) $= ((CAPY_{heat}/(1000 X HSPF_m)) X EFLH_{heat}) X MF_{heat}$

ΔkW_{peak} $= ((CAPY_{cool}/(1000 X EER_m)) X CF) X MF_{cool}$

Central A/C and ASHP (Duct Sealing)

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

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

ΔkWh_{cool} $= (CAPY_{cool}/(1000 X SEER_q SEER_e)) X EFLH_{cool} X DuctSF$

ΔkWh_{heat} (ASHP Only) $= (CAPY_{heat}/(1000 X HSPF_e)) X EFLH_{heat} X DuctSF$

ΔkW_{peak} $= ((CAPY_{cool}/(1000 X EER_q EER_e)) X CF) X DuctSF$

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

ΔkWh_{cool} $= CAPY_{cool}/1000 X (1/SEER_b – (1/(EER_g X GSER))) X EFLH_{cool}$

ΔkWh_{heat} $= CAPY_{heat}/1000 X (1/HSPF_b – (1/(COP_g X GSOP))) X EFLH_{heat}$

ΔkW $= CAPY_{cool}/1000 X (1/EER_b – (1/(EER_g X GSPK))) X CF$

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.

ΔkWh_{heat} = HFS

ΔkWh_{cool} = CFS

ΔkW_{peak} = PDFS

kW_{motor} X LF X ($EFLH_{cool}$ + $EFLH_{heat}$) X ((1/(η_{motor} - $\eta_{fan\text{-}base}$) -(1/(η_{motor} - $\eta_{fan\text{-}ee}$))

$$\Delta kWh = kW_{motor} * LF * (EFLHcool + EFLHheat) * \left(\frac{1}{\eta_{motor} * \eta_{fan\ base}} - \frac{1}{\eta_{motor} * \eta_{fan\ ee}}\right)$$

2.1.2 Definition of Terms

$CAPY_{cool}$ (cooling) = 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.

$CAPY_{heat}$ (heating) = 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

Load Factor = Ratio of the average operating load to the nameplate rating of the baseline motor or, if installed, an existing energy efficient motor ΔkW = 0.746 X HP X ($1/\eta_{base}$ – $1/\eta_{ee}$) X LF

$SEER_b$ = Seasonal Energy Efficiency Ratio of the Baseline Unit.

$SEER_q$ $SEER_e$ = 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.

$SEER_m$ = Seasonal Energy Efficiency Ratio of the Unit receiving maintenance

EER_b = Energy Efficiency Ratio of the Baseline Unit.

EER_q EER_e = 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.

EER_g = 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.

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$EFLH_{cool}$	= Equivalent Full Load Hours of operation during the cooling season for the average unit.
$EFLH_{heat}$	= 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.
PSF	= Proper Sizing Factor or the assumed savings due to proper sizing of cooling equipment.
QIF_{cool}	= Quality Installation factor or assumed savings due to a verified quality installation of cooling equipment.
QIF_{heat}	= Quality Installation factor or assumed savings due to a verified quality installation of heating equipment.
MF_{cool}	= Maintenance Factor or assumed savings due to completing recommended maintenance on installed cooling equipment.
MF_{heat}	= 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.
$HSPF_b$	= Heating Seasonal Performance Factor of the Baseline Unit.
$HSPF_q$ $HSPF_e$	= Heating Seasonal Performance Factor of the unit being installed. This data is obtained from the AEPS Application Form or EDC's data gathering.
COP_g	= 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]

[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.

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

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

$EFLH_{HT}$ = Equivalent Full Load Hours of operation for the average heating unit.

HFS = Heating fan savings.

CFS = Cooling fan savings.

kW_{motor} =Rated kW of the high efficiency furnace fan

η_{motor} =Nominal efficiency of the fan motor

$\eta_{fan\ base}$ =Nominal efficiency of the baseline case fan

$\eta_{fan\ ee}$ =Nominal efficiency of the efficient case fan

1000 = Conversion from watts to kilowatts.

Table 2-12-1: Residential Electric HVAC - References

Component	Type	Value	Sources
$CAPY_{cool}$ $CAPY_{heat}$	Variable	EDC Data Gathering	AEPS Application; EDC Data Gathering
$SEER_b$	Fixed	Replace on Burnout: Baseline = 13 SEER	1
	Variable	Early Retirement: EDC Data Gathering	EDC Data Gathering
$SEER_q$ $SEER_e$	Variable	EDC Data Gathering	AEPS Application; EDC Data Gathering
$SEER_m$	Fixed	10	1514
EER_b	Fixed	Replace on Burnout: Baseline = 11.3	2
	Variable	Early Retirement: EDC Data Gathering	EDC Data Gathering
EER_q EER_e	Fixed	(11.3/13) X $SEER_q$ $SEER_e$	2
EER_g	Variable	EDC Data Gathering	AEPS Application; EDC's Data Gathering
EER_m	Fixed	8.69	1915

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Component	Type	Value	Sources
GSER	Fixed	1.02	3
$EFLH_{cool}$	Fixed	Allentown Cooling = 784 Hours Allentown Heating = 2,492 Hours Erie Cooling = 482 Hours Erie Heating = 2,901 Hours Harrisburg Cooling = 929 Hours Harrisburg Heating = 2,371 Hours Philadelphia Cooling = 1,032 Hours Philadelphia Heating = 2,328 Hours Pittsburgh Cooling = 737 Hours Pittsburgh Heating = 2,380 Hours Scranton Cooling = 621 Hours Scranton Heating = 2,532 Hours Williamsport Cooling = 659 Hours Williamsport Heating = 2,502 Hours	4
$EFLH_{heat}$	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
PSF	Fixed	5%	14
QIF_{cool}	Fixed	9.2%	4
QIF_{heat}	Fixed	9.2%	4
MF_{cool}	Fixed	10%	2016
MF_{heat}	Fixed	10%	2016
DuctSF	Fixed	18%	1413
CF	Fixed	70%	6
DSF	Fixed	2.9%	7
$HSPF_b$	Fixed	Baseline Replace on Burnout:= 7.7	8
	Variable	Early Retirement: EDC Data Gathering	EDC Data Gathering
$HSPF_e HSPF_e$	Variable	EDC Data Gathering	AEPS Application; EDC's Data Gathering
COP_g	Variable	EDC Data Gathering	AEPS Application; EDC's Data Gathering

Component	Type	Value	Sources
GSOP	Fixed	3.413	9
GSPK	Fixed	0.8416	10
EDSH	Fixed	1842 kWh	11
PDSH	Fixed	0.34 kW	12
HFSkW$_{motor}$	Fixed	311 kWh	17
CFSLF	Fixed	135 kWh	18
PDFSη$_{motor}$	Fixed	0.114 kW	19
η$_{fan-base}$			
η$_{fan-ee}$			
Cooling - CAC Time Period Allocation Factors	Fixed	Summer/On-Peak 64.9% Summer/Off-Peak 35.1% Winter/On-Peak 0% Winter/Off-Peak 0%	13
Cooling – ASHP Time Period Allocation Factors	Fixed	Summer/On-Peak 59.8% Summer/Off-Peak 40.2% Winter/On-Peak 0% Winter/Off-Peak 0%	13
Cooling – GSHP Time Period Allocation Factors	Fixed	Summer/On-Peak 51.7% Summer/Off-Peak 48.3% Winter/On-Peak 0% Winter/Off-Peak 0%	13
Heating – ASHP & GSHP Time Period Allocation Factors	Fixed	Summer/On-Peak 0.0% Summer/Off-Peak 0.0% Winter/On-Peak 47.9% Winter/Off-Peak 52.1%	13
GSHP Desuperheater Time Period Allocation Factors	Fixed	Summer/On-Peak 4.5% Summer/Off-Peak 4.2% Winter/On-Peak 43.7% Winter/Off-Peak 47.6%	13
Capy$_q$	Variable	EDC Data Gathering	AEPS Application; EDC's Data Gathering

Component	Type	Value	Sources
~~$EFLH_{HFS}$~~	~~Fixed~~	~~Allentown Heating = 2,492 Hours~~ ~~Erie Heating = 2,901 Hours~~ ~~Harrisburg Heating = 2,371 Hours~~ ~~Philadelphia Heating = 2,328 Hours~~ ~~Pittsburgh Heating = 2,380 Hours~~ ~~Scranton Heating = 2,532 Hours~~ ~~Williamsport Heating = 2,502~~	~~4~~
~~HFS~~	~~Fixed~~	~~0.5 kWh~~	~~17~~
~~CFS~~	~~Fixed~~	~~105 kWh~~	~~18~~

Sources:

1. Federal Register, Vol. 66, No. 14, Monday, January 22, 2001/Rules and Regulations, p. 7170-7200.
2. Average EER for SEER 13 units.
3. VEIC estimate. Extrapolation of manufacturer data.
4. US Department of Energy, ENERGY STAR Calculator. Accessed 3/16/2009.
5. Xenergy, “New Jersey Residential HVAC Baseline Study”, (Xenergy, Washington, D.C., November 16, 2001).
6. Based on an analysis of six different utilities by Proctor Engineering.
7. Xenergy, “New Jersey Residential HVAC Baseline Study”, (Xenergy, Washington, D.C., November 16, 2001).
8. Federal Register, Vol. 66, No. 14, Monday, January 22, 2001/Rules and Regulations, p. 7170-7200.
9. Engineering calculation, HSPF/COP=3.413.
10. VEIC Estimate. Extrapolation of manufacturer data.
11. VEIC estimate, based on PEPCO assumptions.
12. VEIC estimate, based on PEPCO assumptions.

~~13. Time period allocation factors used in cost-effectiveness analysis.~~

~~14.~~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.

~~15.~~14. Minimum Federal Standard for new Central Air Conditioners between 1990 and 2006.

~~16. NJ utility analysis of heating customers, annual gas heating usage.~~

~~17. Scott Pigg (Energy Center of Wisconsin), “Electricity Use by New Furnaces: A Wisconsin Field Study”, Technical Report 230-1, October 2003.~~

18. Ibid. p. 34. ARI charts suggest there are about 20% more full load cooling hours in NJ than southern WI. Thus, average cooling savings in NJ are estimated at 95 to 115.

19.15. The same EER to SEER ratio used for SEER 13 units applied to SEER 10 units. EER_m = (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).

20.19. Ibid, page 34. The average kW savings of 0.1625 multiplied by the coincidence factor from Table 2-1.

2.2 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.

2.2.1 **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.

2.2.2 **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:

$$\Delta kWh = 905 - 769 = 136\ kWh$$

The annual consumption of a standard unit without a moisture sensor (905 kWh) was based on 2008 estimates from Natural Resources Canada.[5]

The annual consumption of a standard unit with a moisture sensor (769 kWh) was based on estimates from EPRI[6] and the Consumer Energy Center[7] that units equipped with moisture sensors (and energy efficient motors, EPRI) are about 15% more efficient than units without.

$$\Delta kWh = 905 - (905 * 0.15) = 769\ kWh$$

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

[5] Natural Resources Canada Report.pdf
[6] EPRI Electric Clothes Dryer Report.pdf
[7] Natural Living Guide.pdf

annual hours of use was based on 392[8] 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:

$\Delta kW_{peak} = 0.346 * 0.136 = 0.047$ 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)

2.2.3 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]

2.2.4 Evaluation Protocol

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

[8] Energy Star Clothes Washer Calculator Assumptions.pdf
[9] DEER EUL values, updated October 10, 2008

2.3 Efficient Electric Water Heaters

Measure Name	Efficient Electric Water Heaters
Target Sector	Residential Establishments
Measure Unit	Water Heater
Unit Energy Savings	~~133~~ 115 kWh for 0.93 Energy Factor ~~175~~ 157 kWh for 0.94 Energy Factor ~~217~~ 199 kWh for 0.95 Energy Factor
Unit Peak Demand Reduction	0.~~0122~~ 0105 kW for 0.93 Energy Factor 0.~~0161~~ 0144 kW for 0.94 Energy Factor 0.~~0199~~ 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.~~9.~~

2.3.1 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.

2.3.2 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:

$$\Delta kWh \ \text{~~Energy Savings~~} = \frac{\left\{\left(\frac{1}{EF_{Base}} - \frac{1}{EF_{Proposed}}\right) \times \left(HW \times 365 \times 8.3 \frac{lb}{gal} \times (T_{hot} - T_{cold})\right)\right\}}{3413 \frac{Btu}{kWh}}$$

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.

$$\Delta kW_{peak} = EnergyToDemandFactor \times Energy\ Savings$$

The Energy to Demand Factor is defined below:

$$EnergyToDemandFactor = \frac{Average\ Usage_{Summer\ WD\ Noon-8}}{Annual\ Energy\ Usage}$$

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]. The factor is constructed as follows:

1) Obtain the average kW, as monitored for 82 water heaters in PJM territory[11], 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].

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.

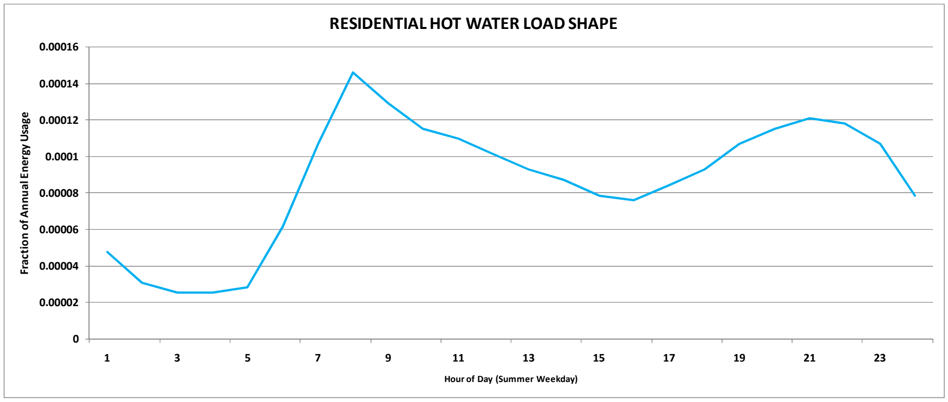

Figure 2-12-1: Load shapes for hot water in residential buildings taken from a PJM study.

[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

[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

[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.

2.3.3 Definition of Terms

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

Table 2-22-2: Efficient Electric Water Heater Calculation Assumptions

Component	Type	Values	Source
EF_{base}, Energy Factor of baseline water heater	Fixed	0.90904	1
$EF_{proposed}$, 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
T_{hot}, Temperature of hot water	Fixed	120 °F	3
T_{cold}, Temperature of cold water supply	Fixed	55 °F	4
EnergyToDemandFactorEnergy 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 approximately 0.904.90. "Energy Conservation Program: Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters" US Dept of Energy Docket Number: EE–2006–BT-STD–0129, p. 30
2. Energy Conservation Program for Consumer Products: Test Procedure for Water Heaters", Federal Register / Vol. 63, No. 90, p. 25996
3. Many states have plumbing codes that limit shower and bathtub water temperature to 120 °F.
4. Mid-Atlantic TRM, footnote #24

2.3.4 Deemed Savings

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

Table 2-32-3: Energy Savings and Demand Reductions

Energy Factor	Energy Savings (kWh)	Demand Reduction (kW)
0.95	217 199	0.0199 0.0182
0.94	175 157	0.0161 0.0144
0.93	133 115	0.01220.0182

2.3.5 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]

2.3.6 Evaluation Protocols

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

[13] DEER values, updated October 10, 2008 http://www.deeresources.com/deer0911planning/downloads/EUL_Summary_10-1-08.xls

2.4 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.

2.4.1 Algorithms

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

ΔkWh $= ((W_{inc} * h_{inc}) – (WNL * h_{NL})) * 365 / 1000 * ISRNL$

ΔkW_{peak} $= 0$ *(assumed)*

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

(Rounded to 26 kWh)

2.4.2 Definition of Terms

W_{NL} = *Watts per electroluminescent nightlight*

W_{inc} = *Watts per incandescent nightlight*

h_{NL} = *Average hours of use per day per electroluminescent nightlight*

h_{inc} = *Average hours of use per day per incandescent nightlight*

ISR_{NL} = *In-service rate per electroluminescent nightlight, to be revised through surveys*

Table 2-42-4: Electroluminescent Nightlight - References

Component	Type	Value	Sources
W_{NL}	Fixed	0.03	1
Winc	Fixed	7	2
h_{NL}	Fixed	24	3
h_{inc}	Fixed	12	2
ISR_{NL}	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.

2.5 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.

2.5.1 Algorithms

$\Delta kWh = MkW \times EFLH \times EI \times ISR$

$\Delta kW_{peak} = 0$

2.5.2 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 2-52-5: 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 2-62-6: 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 2-72-7: 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 2-82-8: 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 2-92-9: 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 2-102-10: 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 2-112-11: 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

2.6 Heat Pump Water Heaters

Measure Name	Heat Pump Water Heaters
Target Sector	Residential Establishments
Measure Unit	Water Heater
Unit Energy Savings	2,2022,184 kWh for 2.3 Energy Factor, 1,9141,896 kWh for 2.3, 2.0 Energy Factor
Unit Peak Demand Reduction	0.2020.200, kW for 2.3 Energy Factor 0.1750.174 kW for 2.3,2.0 Energy Factor
Measure Life	14 years

Heat Pump Water Heaters take heat from the surrounding air and transfer it to the water in the tank, unlike conventional water heaters, which use either gas (or sometimes other fuels) burners or electric resistance heating coils to heat the water.

2.6.1 Eligibility

This protocol documents the energy savings attributed to heat pump water heaters with Energy Factors of 2.0 to 2.I.II3. The target sector primarily consists of single-family residences.

2.6.2 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:

$$\Delta kWh = ((EF_{Base})^{-1} - (EF_{Proposed} \times F_{Derate})^{-1}) \times HW \times 365 \times 8.3 \times (T_{hot} - T_{cold}) \times 3413^{-1}$$

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$$\Delta kWh = \frac{\left\{\left(\frac{1}{EF_{Base}} - \left(\frac{1}{EF_{Proposed}} \times \frac{1}{F_{Adjust}}\right)\right) \times HW \times 365 \; X \; 8.3 \frac{lb}{gal} \; X \; (Thot - Tcold)\right\}}{3413 \frac{Btu}{kWh}}$$

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.

$$\Delta kW_{peak} = EnergyToDemandFactor \times Energy\ Savings$$

The Energy to Demand Factor is defined below:

$$EnergyToDemandFactor = \frac{Average\ Usage_{Summer\ WD\ Noon-8}}{Annual\ Energy\ Usage}$$

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]. The factor is constructed as follows:

1. Obtain the average kW, as monitored for 82 water heaters in PJM territory[15], 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].
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.

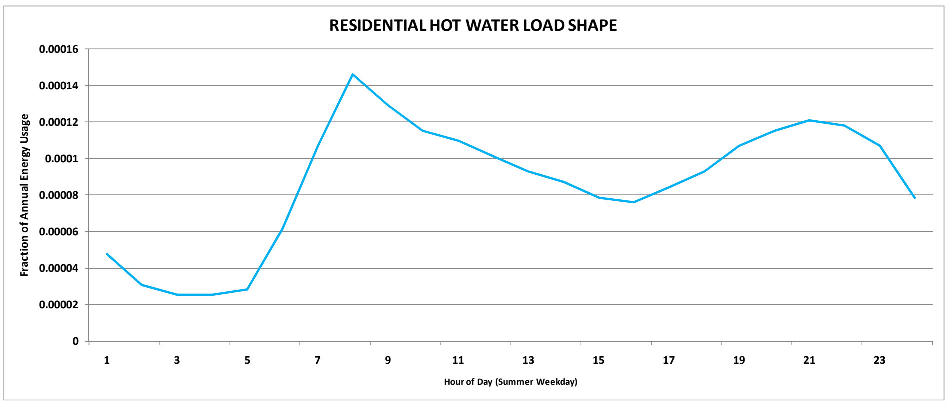

Figure 2-22-2: Load shapes for hot water in residential buildings taken from a PJM study.

[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

[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

[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

2.6.3 Definition of Terms

The parameters in the above equation are listed in Table 2-12.

Table 2-122-12: Heat Pump Water Heater Calculation Assumptions

Component	Type	Values	Source
EFbase , Energy Factor of baseline water heater	Fixed	0.90904	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.

2.6.4 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]. The heat pump performance is temperature dependent. The plot below shows relative coefficient of performance (COP) compared to the COP at rated conditions[18]. 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.

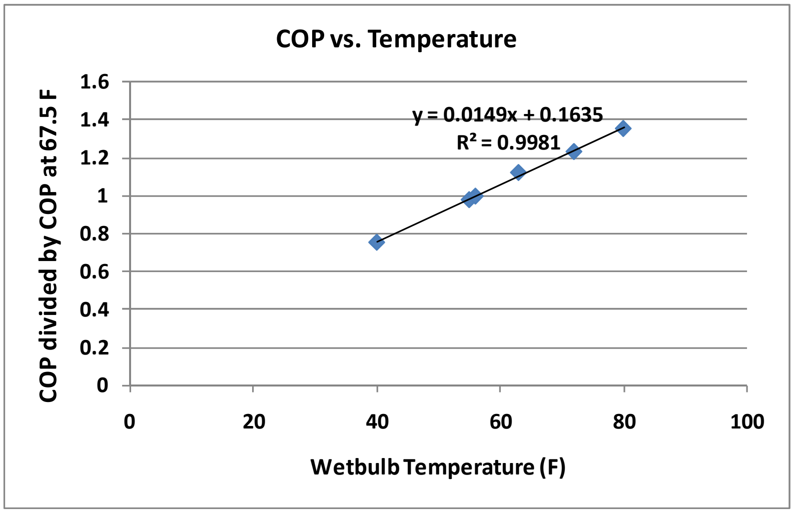

Figure 2-32-3: Dependence of COP on outdoor wet-bulb temperature.

[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.

[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.

2.6.5 Deemed Savings

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

Table 2-13~~2-13~~: Energy Savings and Demand Reductions

Energy Factor	Energy Savings (kWh)	Demand Reduction (kW)
2.3	~~2202~~ 2184	0.~~202~~200
2.0	~~1914~~ 1896	~~0.175~~0.174

2.6.6 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].

2.6.7 Evaluation Protocols

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

[19] DEER values, updated October 10, 2008
http://www.deeresources.com/deer0911planning/downloads/EUL_Summary_10-1-08.xls

2.7 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.

2.7.1 Eligibility

The conservation kits are sent to residential customers only.

2.7.2 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.

$$\Delta kWh = N_{CFL} \times ((CFL_{watts} \times (CFL_{hours} \times 365))/1000) \times ISR_{CFL} + N_{Aerator} \times Savings_{Aerator} \times ISR_{Aerator} + N_{SmartStrip} \times Savings_{SmartStrip} \times ISR_{SmartStrip} + N_{NiteLites} \times Savings_{NiteLite} \times ISR_{NiteLite}$$

$$\Delta kW_{peak} = N_{CFL} \times (CFL_{watts}/1000) \times CF \times ISR_{CFL} + N_{Aerator} \times DemandReduction_{Aerator} \times ISR_{Aerator} + N_{SmartStrip} \times DemandReduction_{SmartStrip} \times ISR_{SmartStrip} + N_{NiteLite} \times DemandReduction_{NiteLite} \times ISR_{NiteLite}$$

2.7.3 Definition of Terms

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

Table 2-142-14: Home Audit Conversion Kit Calculation Assumptions

Component	Value	Source
N_{CFL}: Number of CFLs per kit	4	Program design[20]
CFL_{Watts}, 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
CFL_{hours}, 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
$N_{Aerator}$: Number of faucet aerators per kit	4	Program design
$N_{SmartStrip}$: Number of Smart Strips per kit	2	Program design
$Savings_{Aerator}$ (kWh)	61	FE Interim TRM
$DemandReduction_{Aerator}$ (kW)	.006	FE Interim TRM
$ISR_{Aerator}$	variable	EDC Data Gathering[21]
$Savings_{SmartStrip}$ (kWh)	184	FE Interim TRM
$DemandReduction_{SmartStrip}$ (kW)	.013	FE Interim TRM
$ISR_{SmartStrip}$	variable	EDC Data Gathering
$Savings_{NiteLite}$ (kWh)	26.3	PA Interim TRM[22]
$DemandReduction_{NiteLite}$ (kW)	0	PA Interim TRM
$ISR_{NiteLite}$	variable	EDC Data Gathering
$N_{NiteLite}$	2	Program Design

[20] Four 23-W CFLs are sent out. We assume that one replaces a 100W lamp while the remaining CFLs replace 60W lamps.

[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.

[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.

2.7.4 Partially Deemed Savings

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

2.7.5 Measure Life

The measure life for CFLs is **6.4 years** according to ENERGY STAR[23]. 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**.

2.7.6 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.

[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/>.

2.8 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.

2.8.1 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:

$$\Delta kWh = ((NL_{watts} \times (NL_{hours} \times 365))/1000) \times ISR$$

$$\Delta kW_{peak} = 0 \text{ (assumed)}$$

2.8.2 Definition of Terms

NLwatts = *Average delta watts per LED Nightlight*

NL_{hours} = *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 2-152-15: LED Nightlight - References

Component	Type	Value	Sources
NL_{watts}	Fixed	6 Watts	Data Gathering
NL_{hours}	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.

2.8.3 **Deemed Savings**

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

2.9 Low Flow Faucet Aerators

Measure Name	Low Flow Faucet Aerators
Target Sector	Residential
Measure Unit	Aerator
Unit Energy Savings	~~61~~60 kWh
Unit Peak Demand Reduction	0.0056~~056~~ 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.

2.9.1 Algorithms

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

$$\Delta kWh = ISR \times [(F_B - F_P) \times T_{Person\text{-}Day} \times N_{Persons} \times 365 \times \Delta T_L \times U_H \times U_E \times Eff^{-1}] / (F/home)$$

$$\Delta kW_{peak} = ISR \times Energy\ Impact \times F_{ED}$$

The Energy to Demand Factor, F_{ED}, is defined below:

$$EnergyToDemandFactor = AverageUsage_{SummerWDNoon\text{-}8PM} / AnnualEnergyUsage$$

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]. 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.

[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

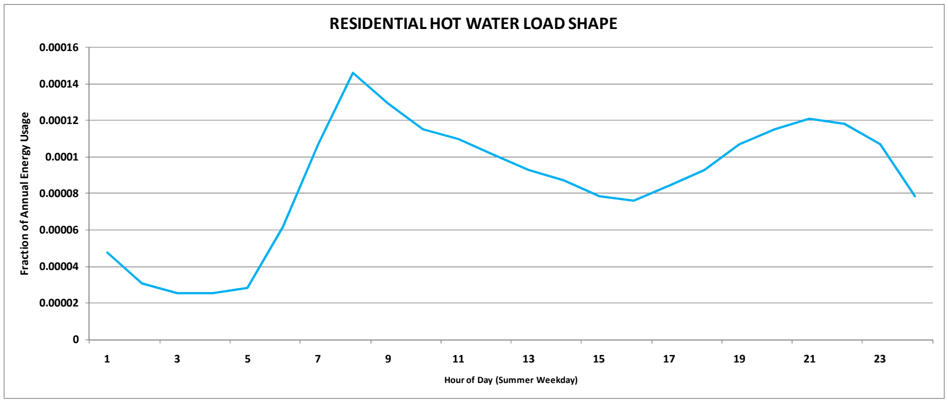

Figure 2-42-4: Load shapes for hot water in residential buildings taken from a PJM study.

2.9.2 Definition of Terms

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

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.*

Table 2-162-16: Low Flow Faucet Aerator Calculation Assumptions

Parameter	Description	Type	Value	Source
F_B	Average Baseline Flow Rate of aerator (GPM)	Fixed	2.2	2
F_P	Average Post Measure Flow Rate of Sprayer (GPM)	Fixed	1.5	2
$T_{Person\text{-}Day}$	Average time of hot water usage per person per day (minutes)	Fixed	4.95	3
N_{Per}	Average number of persons per household	Fixed	2.48	4
ΔT	Average temperature differential between hot and cold water (ºF)	Fixed	25	5
U_H	Unit Conversion: 8.33BTU/(Gallons-°F)	Fixed	8.33	Convention
U_E	Unit Conversion: 1 kWh/3413 BTU	Fixed	1/3413	Convention
Eff	Efficiency of Electric Water Heater	Fixed	0.90904	2
F_{ED}	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

2.9.3 Deemed Savings

The deemed energy savings for the installation of a low flow aerator compared to a standard aerator is **ISR × ~~61~~ 60 kWh/year** with a demand reduction of **ISR × 0.~~056~~0056 kW,** with ISR determined through data collection.

2.9.4 Measure Life

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

2.9.5 Evaluation Protocols

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

2.10 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.

2.10.1 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.

2.10.2 Algorithms

The annual energy savings are obtained through the following formula:

ΔkWh $= ((((GPM_{base} - GPM_{low}) / GPM_{base}) * people * gals/day * days/year) / showers) * lbs/gal * (TEMP_{ft} - TEMP_{in}) / 1{,}000{,}000) / EF / 0.003412$

ΔkW_{peak} $= \Delta kWh * EnergyToDemandFactor$

2.10.3 Definition of Terms

GPM_{base} =Gallons per minute of baseline showerhead = 2.5 GPM[25]

GPM_{low} =Gallons per minute of low flow showerhead

people =Average number of people per household = 2.48[26]

gals/day =Average gallons of hot water used by shower per day = 11.6[27]

days/year =Number of days per year = 365

[25] The Energy Policy Act of 1992 established the maximum flow rate for showerheads at 2.5 gallons per minute (GPM).
[26] Pennsylvania, Census of Population, 2000.
[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

showers =*Average number of showers in the home = 1.6*[28]

lbs/gal =*Pounds per gallon = 8.3*

$TEMP_{ft}$ =*Assumed temperature of water used by faucet = 120° F*[29]

$TEMP_{in}$ =*Assumed temperature of water entering house = 55° F*[30]

EF =*Recovery efficiency of electric hot water heater = 0.90*[31]

0.003412 =*Constant to converts MMBtu to kWh*

EnergyToDemandFactor=*Summer peak coincidence factor for measure = 0.00009172*[32]

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:

$$EnergyToDemandFactor = \frac{Average\ Usage_{Summer\ WD\ Noon-8}}{Annual\ Energy\ Usage}$$

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]. 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.

1.

[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

[29] Based upon a consensus achieved at Residential Measure Protocols for TRM Teleconference held on June 2, 2010.

[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

[31] Assumes an electric water heater that meets the current federal standard (0.90 EF).

[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

[33] Op. cit.

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.

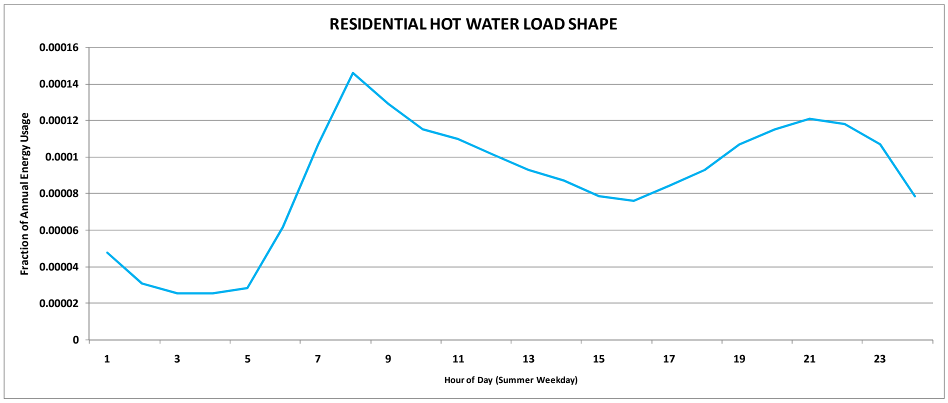

Figure 2-5: Load shapes for hot water in residential buildings taken from a PJM study.

2.10.4 Deemed Savings

ΔkWh = *461 kWh (assuming 1.5 GPM showerhead)*

ΔkW = *0.042 kW (assuming 1.5 GPM showerhead)*

2.10.5 Measure Life

According to the Efficiency Vermont Technical Reference User Manual (TRM), the expected measure life is **9 years**[34].

2.10.6 Evaluation Protocols

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

[34] Efficiency Vermont, Technical Reference User Manual: Measure Savings Algorithms and Cost Assumptions, TRM User Manual No. 2008-53, 07/18/08.

2.11 Programmable ~~Setback~~ Thermostat

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

Programmable thermostats are used to control heating and/or cooling loads in residential buildings by ~~setting back~~ 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.

2.11.1 Algorithms

ΔkWh = ΔkWh_{COOL} + ΔkWh_{HEAT}

ΔkWh_{COOL} = ~~(~~CAP_{COOL}/1000 X (1~~2~~/(SEER~~$_{COOL}$~~ x Eff_{duct}) X $EFLH_{COOL}$ X ESF_{COOL}~~)~~
~~+ (CAP_{HEAT} X (1/(EER_{HEAT} X 3.41 X Eff_{duct})) X EFLH X ESF_{HEAT})~~

ΔkWh_{HEAT} = CAP_{HEAT}/1000 X (1/(HSPF X Eff_{duct})) X $EFLH_{HEAT}$ X ESF_{HEAT}

ΔkW_{peak} = 0

2.11.2 Definition of Terms

CAP_{COOL} = ~~capacity~~ Capacity of the air conditioning unit in ~~tons~~BTUh, based on nameplate capacity.

CAP_{HEAT} = Nominal heating capacity of the electric furnace in BTUh

Eff_{duct} = Duct system efficiency

S~~EER~~$_{COOL,HEAT}$ = Seasonal ~~Seasonally averagedenergy~~ efficiency ~~rating~~ ratio of the ~~baseline~~ cooling unit. ~~For units > 65,000~~

~~BTUh, = refer to Commercial application.~~

HSPF = Heating seasonal performance factor of the heating unit.

~~Eff_{duct} = duct system efficiency~~

$ESF_{COOL,HEAT}$	= *~~energy~~ Energy savings factor for cooling and heating, respectively*
~~CAP_{HEAT}~~	~~= *nominal rating of the heating capacity of the electric furnace (kBtu/hr)*~~
$EFLH_{COOL, HEAT}$	= *~~equivalent~~ Equivalent full load hours*

Table 2-17~~2-17~~: Residential Electric HVAC Calculation Assumptions

Component	Type	Value	Sources
CAP_{COOL}	Variable	Nameplate data	EDC Data Gathering
		Default: 36,000 ~~tons~~BTUh	1
CAP_{HEAT}	Variable	Nameplate Data	EDC Data Gathering
		Default: 36,000 BTUh	1
~~$EER_{COOL, HEAT}$~~SEER	Variable	Nameplate data	EDC Data Gathering
		Default: ~~Cooling =~~ 10 SEER ~~Default: Heating = 1.0 (electric furnace COP)~~	2
HSPF	Variable	Nameplate data	EDC Data Gathering
		Default: 3.413 HSPF (equivalent to electric furnace COP of 1)	2
Eff_{duct}	Fixed	0.8	3
ESF_{COOL}	Fixed	2%	4
ESF_{HEAT}	Fixed	3.6%	5
$EFLH_{COOL}$	Fixed	Allentown Cooling = 784 Hours ~~Allentown Heating = 2,492 Hours~~ Erie Cooling = 482 Hours ~~Erie Heating = 2,901 Hours~~ Harrisburg Cooling = 929 Hours ~~Harrisburg Heating = 2,371 Hours~~ Philadelphia Cooling = 1,032 Hours ~~Philadelphia Heating = 2,328 Hours~~ Pittsburgh Cooling = 737 Hours ~~Pittsburgh Heating = 2,380 Hours~~ Scranton Cooling = 621 Hours ~~Scranton Heating = 2,532 Hours~~ Williamsport Cooling = 659 Hours ~~Williamsport Heating = 2,502 Hours~~	6
$EFLH_{HEAT}$	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	Fixed	11	7

(EUL)			

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.

2.12 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).

2.12.1 Algorithms

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

Retirement-Only

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

$$\Delta kWh = EFLH_{RAC} * (CAPY/1000) * (1/EER_{RetRAC})$$

$$\Delta kW_{peak} = (CAPY/1000) * (1/EER_{RetRAC}) * CF_{RAC}$$

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 $= EFLH_{RAC} * (CAPY/1000) * (1/EER_{RetRAC} – 1/EER_{ES})$

ΔkW_{peak} $= (CAPY/1000) * (1/EER_{RetRAC} – 1/EER_{ES}) * CF_{RAC}$

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

ΔkWh $= EFLH_{RAC} * (CAPY/1000) * (1/EER_b – 1/EER_{ES})$

ΔkW_{peak} $= (CAPY/1000) * (1/EER_b – 1/EER_{ES}) * CF_{RAC}$

2.12.2 Definition of Terms

$EFLH_{RAC}$ = *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 $EFLH_{RAC}$ 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:

$EFLH_{RAC} = EFLH_{ES\text{-}RAC} * AF$

Where:

$EFLH_{ES\text{-}RAC}$ = *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 $EFLH_{ES\text{-}RAC}$ 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.*

EER_{RetRAC} = *The Energy Efficiency Ratio of the unit being retired-recycled expressed as kBtuh/kW.*

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

EER_{ES} = *The Energy Efficiency Ratio for an ENERGY STAR RAC expressed as kBtuh/kW.*

CF_{RAC}	*= 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 2-182-18: Room AC Retirement Calculation Assumptions

Component	Type	Value	Sources
$EFLH_{RAC}$	Varies	Table 2-19, "Corrected Hours"	----
$EFLH_{ES\text{-}RAC}$	Varies	Table 2-19, "Original Hours"	1
AF	Fixed	0.31	2
CAPY (RAC capacity, Btuh)	Fixed	10,000	3
EER_{RetRAC}	Fixed	9.07	4
EER_b (for a 10,000 Btuh unit)	Fixed	9.8	5
EER_{ES} (for a 10,000 Btuh unit)	Fixed	10.8	5
CF_{RAC}	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 2-192-19: RAC Retirement-Only EFLH and Energy Savings by City[35]

City	Original Hours ($EFLH_{ES\text{-}RAC}$)	Corrected Hours ($EFLH_{RAC}$)	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	

[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.

Sources:

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

    a. 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:

    a. Energy savings for Allentown = 74 kWh and EFLH = 784 hrs:

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

    b. 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.

4. 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:

    a. 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

    b. "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

[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 .

typical for a room air conditioner in use in 1990s. However, page 21 indicates an 8.0 EER was typical for a NYSERDA program.

5. 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

6. PA TRM June 2010, coincident demand factor and Time Period Allocation Factors for ENERGY STAR Room AC.

2.12.3 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 Table 2-20, the results from a recent evaluation of ComEd's appliance recycling program[37] 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
   a. 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.
   b. 2005 DEER: EUL=15, did not have recycling RUL
   c. Appliance Magazine and ENERGY STAR calculator: EUL=9 years
   d. 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.

[37] Residential Appliance Recycling Program Year 1 Evaluation Report – Final Report, prepared for Commonwealth Edison by Itron (under contract to Navigant Consulting), November 2009.

Table 2-202-20: 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.

2.13 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.

2.13.1 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.

2.13.2 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:

$$k\Delta kWhWh\ Savings = \frac{(kW_{comp} \times Hr_{comp}) + (kW_{TV} \times Hr_{TV})}{2} \times 365 = 184\ kWh$$

$$\Delta kW_{kW\ Demand\ Reductionpeak} = \frac{CF \times (kW_{comp} + kW_{TV})}{2} = 0.013\ kW$$

2.13.3 Definition of Terms

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

Table 2-212-21: Smart Strip Plug Outlet Calculation Assumptions

Parameter	Component	Type	Value	Source
kW_{comp}	Idle kW of computer system	Fixed	0.0201	1
Hr_{comp}	Daily hours of computer idle time	Fixed	20	1
kW_{TV}	Idle kW of TV system	Fixed	0.0320	1
Hr_{TV}	Daily hours of TV idle time	Fixed	19	1
CF	Coincidence Factor	Fixed	0.50	1

Sources:

1. DSMore MI DB

2.13.4 -Deemed Savings

$\Delta kWh = 184\ kWh$

$\Delta kW_{peak} = 0.013\ kW$

2.13.5 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.

2.13.6 Evaluation Protocols

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

2.14 Solar Water Heaters

Measure Name	Solar Water Heaters
Target Sector	Residential Establishments
Measure Unit	Water Heater
Unit Energy Savings	2,~~106~~ 088 kWh
Unit Peak Demand Reduction	0.~~378~~ 376 kW
Measure Life	14 years

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

2.14.1 Eligibility

This protocol documents the energy savings attributed to solar water in PA. The target sector primarily consists of single-family residences.

2.14.2 Algorithms

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

$$\Delta \text{Energy Savings kWh} = \frac{\left\{\left(\frac{1}{EF_{Base}} - \frac{1}{EF_{Proposed}}\right) \times \left(HW \times 365 \times 8.3\frac{lb}{gal} \times (T_{hot} - T_{cold})\right)\right\}}{3413\frac{Btu}{kWh}}$$

The energy factor used in the above equation represents an average energy factor of market available solar water heaters[38]. 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.

$$\Delta kW_{peak} = EnergyToDemandFactor \times BaseEnergy\ Usage$$

The Energy to Demand Factor is defined below:

$$EnergyToDemandFactor = \frac{Average\ Usage_{Summer\ WD\ Noon-8}}{Annual\ Energy\ Usage}$$

[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.

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]. The factor is constructed as follows:

1. Obtain the average kW, as monitored for 82 water heaters in PJM territory[40], 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].
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].
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

[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

[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

[41] On the other hand, the band would have to expanded to at least 12 hours to capture all 100 hours.

[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.

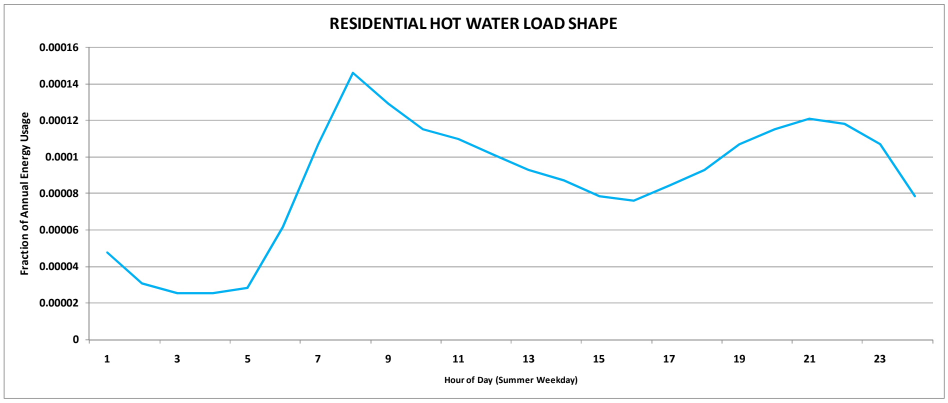

Figure 2-62-6: Load shapes for hot water in residential buildings taken from a PJM study.

2.14.3 Definition of Terms

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

Table 2-222-22: Solar Water Heater Calculation Assumptions

Component	Type	Values	Source
EF_{base} , Energy Factor of baseline electric heater	Fixed	0.904	6
$EF_{proposed,}$ 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
T_{hot} , Temperature of hot water	Fixed	120 F	8
T_{cold} , Temperature of cold water supply	Fixed	55 F	9
Baseline Energy Usage (kWh)	Calculated	4,122104	
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 ft^2 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

2.14.4 Deemed Savings

ΔkWh = 2,~~106~~ 088 kWh

ΔkW_{peak} = 0.~~378~~ 376 kW

2.14.5 Measure Life

The expected useful life is 20 years, according to ENERGY STAR[43].

2.14.6 Evaluation Protocols

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

43 http://www.energystar.gov/index.cfm?c=solar_wheat.pr_savings_benefits

2.15 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.

2.15.1 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.

2.15.2 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]

$$\Delta kWh = 124\ kWh$$

The summer coincident peak kW savings are calculated as follows:

$$\Delta kW_{peak} = \Delta kWh \ * \ EnergyToDemandFactor$$

2.15.3 Definition of Terms

ΔkWh = Annual kWh savings = 124kWh per fixture installed

$EnergyToDemandFactor$ = Summer peak coincidence factor for measure = 0.00009172[45]

ΔkW_{peak} = Summer peak kW savings = 0.011 kW.

[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.

[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

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:

$$EnergyToDemandFactor = \frac{Average\ Usage_{Summer\ WD\ Noon-8}}{Annual\ Energy\ Usage}$$

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]. 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

[46] Op. cit.

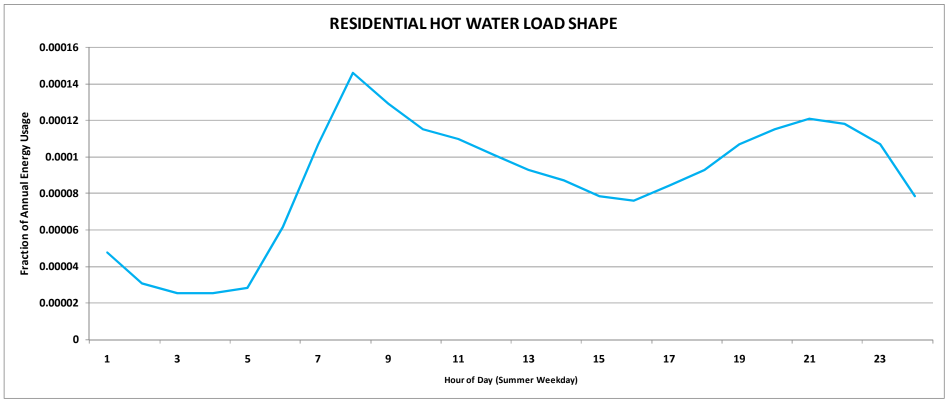

Figure 2-72-7: Load shapes for hot water in residential buildings taken from a PJM study.

2.15.4 Measure Life

According to the Efficiency Vermont Technical Reference User Manual (TRM), the expected measure life is **13 years**[47].

2.15.5 Evaluation Protocols

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

[47] Efficiency Vermont, Technical Reference User Manual: Measure Savings Algorithms and Cost Assumptions, TRM User Manual No. 2008-53, 07/18/08.

2.16 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.

2.16.1 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] Energy savings for this measure are based on whole house fan energy savings values reported by the energy modeling software, REM/Rate[49].

2.16.2 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]

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[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

[49] Architectural Energy Corporation, REM/Rate v12.85.

[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.

Table 2-232-23: 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.

2.16.3 Measure Life

Measure life = 20 years[51] (15 year maximum for PA TRM)

[51] *DEER EUL Summary*, Database for Energy Efficient Resources, accessed October 2010, http://www.deeresources.com/deer0911planning/downloads/EUL_Summary_10-1-08.xls

2.17 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.

2.17.1 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] 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.

2.17.2 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:

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

$$\Delta kWh_{heat} = CAPY_{heat}/1000 \times (1/HSPF_b - 1/HSPF_e) \times EFLH_{heat} \times LF$$

$$\Delta kWh_{cool} = CAPY_{cool}/1000 \times (1/SEER_b - 1/SEER_e) \times EFLH_{cool} \times LF$$

[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.

ΔkW_{peak} = $CAPY_{cool}/1000 \times (1/EER_b - 1/EER_e) \times CF$

Multi-Zone:

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

ΔkWh_{heat} = $[CAPY_{heat}/1000 \times (1/HSPF_b - 1/HSPF_e) \times EFLH_{heat} \times LF]_{ZONE1}$
$+ [CAPY_{heat}/1000 \times (1/HSPF_b - 1/HSPF_e) \times EFLH_{heat} \times LF]_{ZONE2}$
$+ [CAPY_{heat}/1000 \times (1/HSPF_b - 1/HSPF_e) \times EFLH_{heat} \times LF]_{ZONEn}$

ΔkWh_{cool} = $[CAPY_{cool}/1000 \times (1/SEER_b - 1/SEER_e) \times EFLH_{cool} \times LF]_{ZONE1}$
$+ [CAPY_{cool}/1000 \times (1/SEER_b - 1/SEER_e) \times EFLH_{cool} \times LF]_{ZONE2}$
$+ [CAPY_{cool}/1000 \times (1/SEER_b - 1/SEER_e) \times EFLH_{cool} \times LF]_{ZONEn}$

ΔkW_{peak} = $[CAPY_{cool}/1000 \times (1/EER_b - 1/EER_e) \times CF]_{ZONE1} +$
$[CAPY_{cool}/1000 \times (1/EER_b - 1/EER_e) \times CF]_{ZONE2} +$
$[CAPY_{cool}/1000 \times (1/EER_b - 1/EER_e) \times CF]_{ZONEn}$

2.17.3 Definition of Terms

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

$EFLH_{cool, heat}$ = 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.

$HSPF_b$ = Heating efficiency of baseline unit

$HSPB_e$ = Efficiency of the installed DHP

$SEER_b$ = Cooling efficiency of baseline unit

$SEER_e$ = Efficiency of the installed DHP

EER_b = The Energy Efficiency Ratio of the baseline unit

EER_e = The Energy Efficiency Ratio of the efficient unit

LF = Load factor

Table 2-242-24: DHP – Values and References

Component	Type	Values	Sources
$CAPY_{cool}$ $CAPY_{heat}$	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
$HSPF_b$	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

Component	Type	Values	Sources
$SEER_b$	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
$HSPF_e$	Variable	Based on nameplate information. Should be at least ENERGY STAR.	AEPS Application; EDC Data Gathering
$SEER_e$	Variable	Based on nameplate information. Should be at least ENERGY STAR.	AEPS Application; EDC Data Gathering
CF	Fixed	70%	8
EER_b	Fixed	= (11.3/13) X $SEER_b$ for DHP or central AC = 9.8 room AC	5,9
EER_e	Variable	= (11.3/13) X $SEER_e$ 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.

2.17.4 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 2-252-25: 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

2.17.5 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]

2.17.6 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.

[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

2.18 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.

2.18.1 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.

2.18.2 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:

$$\Delta kWh \text{ ~~Energy Savings~~} = \frac{\left\{\left(\frac{1}{EF_{Elec,bl}}\right) \times \left(HW \times 365 \times 8.3\frac{lb}{gal} \times (T_{hot} - T_{cold})\right)\right\}}{3413\frac{Btu}{kWh}}$$

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:

$$\text{Gas Consumption (MMBtu)} = \frac{\left\{\left(\frac{1}{EF_{NG,inst}}\right) \times \left(HW \times 365 \times 8.3\frac{lb}{gal} \times (T_{hot} - T_{cold})\right)\right\}}{1{,}000{,}000\frac{Btu}{MMBtu}}$$

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

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ΔkW_{peak} = *EnergyToDemandFactor* × *Energy Savings*

The Energy to Demand Factor is defined below:

$$EnergyToDemandFactor = \frac{Average\ Usage_{Summer\ WD\ Noon\text{-}8}}{Annual\ Energy\ Usage}$$

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]. The factor is constructed as follows:

1. Obtain the average kW, as monitored for 82 water heaters in PJM territory[55], 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].
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.

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[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

[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

[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.

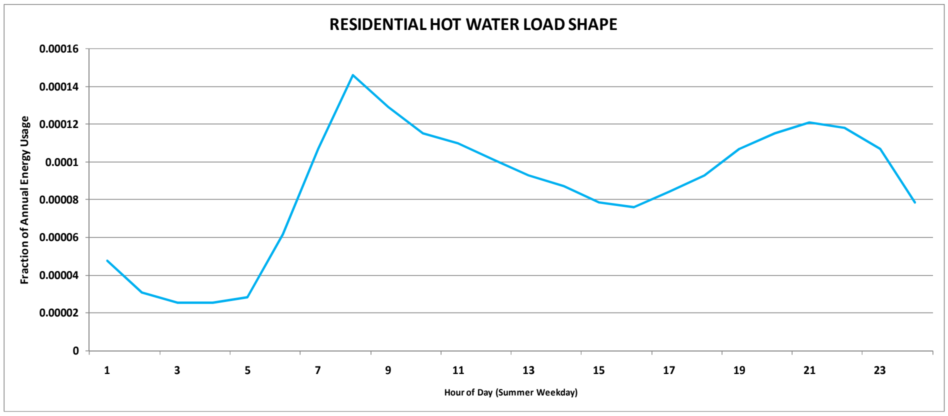

Figure 2-8: Load shapes for hot water in residential buildings taken from a PJM.

2.18.3 Definition of Terms

The parameters in the above equation are listed in Table 2-26 below.

Table 2-262-26: Calculation Assumptions for Fuel Switching, Domestic Hot Water Electric to Gas

Component	Type	Values	Source
$EF_{elect,bl}$, Energy Factor of baseline water heater	Fixed	0.904	4
$EF_{NG,inst}$, 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
T_{hot}, Temperature of hot water	Fixed	120 °F	7
T_{cold}, 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

2.18.4 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 2-272-27: 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 2-282-28: Gas Consumption for Fuel Switching, Domestic Hot Water Electric to Gas

Gas unit Energy Factor	Gas Consumption (MMBtu)
0.594	21.32

2.18.5 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].

2.18.6 Evaluation Protocols

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

[57] DEER values, updated October 10, 2008: http://www.deeresources.com/deer0911planning/downloads/EUL_Summary_10-1-08.xls

2.19 Fuel Switching: Heat Pump Water Heater to Gas Water Heater

Measure Name	Fuel Switching: ~~DHW~~ Heat Pump Water Heater to Gas Water Heater
Target Sector	Residential
Measure Unit	Water Heater
Unit Energy Savings	~~4104~~ 2208 kWh
Unit Peak Demand Reduction	~~0.376~~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.

2.19.1 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.

2.19.2 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:

$$\Delta kWh \quad \text{~~Energy Savings~~} = \frac{\left\{\left(\frac{1}{EF_{HP,bl} \times F_{Derate}}\right) \times \left(HW \times 365 \times 8.3\frac{lb}{gal} \times (T_{hot} - T_{cold})\right)\right\}}{3413\frac{Btu}{kWh}}$$

Although there is a significant electric savings, there is

$$\text{Gas Consumption (MMBtu)} = \frac{\left\{\left(\frac{1}{EF_{NG,inst}}\right) \times \left(HW \times 365 \times 8.3\frac{lb}{gal} \times (T_{hot} - T_{cold})\right)\right\}}{1,000,000\frac{Btu}{MMBtu}}$$

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.

$$\text{Demand Savings} = \text{EnergyToDemandFactor}$$

~~ultipl~~The Energy to Demand Factor is defined below:

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$$EnergyToDemandFactor = \frac{Average\ Usage_{Summer\ WD\ Noon-8}}{Annual\ Energy\ Usage}$$

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]. The factor is constructed as follows:

1. Obtain the average kW, as monitored for 82 water heaters in PJM territory[59], 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].
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

[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

[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

[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.

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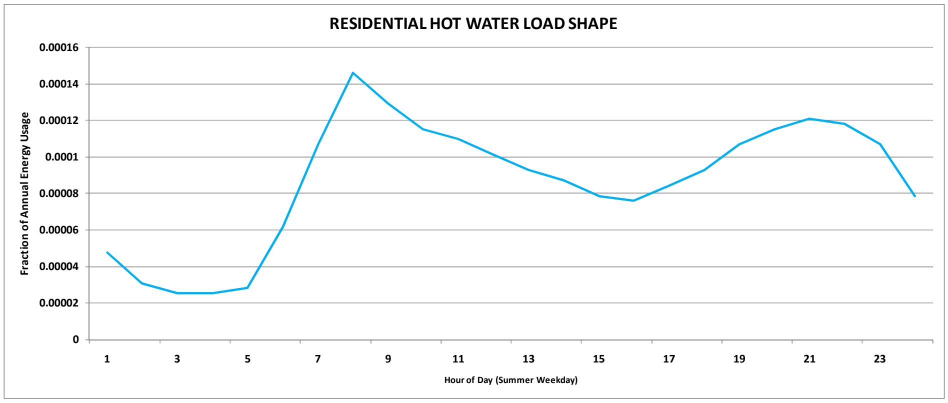

Figure 2-92-9: Load shapes for hot water in residential buildings taken from a PJM.

2.19.3 Definition of Terms

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

Table 2-292-29: Calculation Assumptions for Fuel Switching, Domestic Hot Water Heat Pump Water Heater to Gas Water Heater

Component	Type	Values	Source
$EF_{HP,bl}$, Energy Factor of baseline heat pump water heater	Fixed	≥ 2.0	4
$EF_{NG,inst}$. 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
T_{hot}, Temperature of hot water	Fixed	120 °F	7
T_{cold}, Temperature of cold water supply	Fixed	55 °F	8
F_{Derate}, 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.

2.19.4 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]. 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]. 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.

[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.

[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.

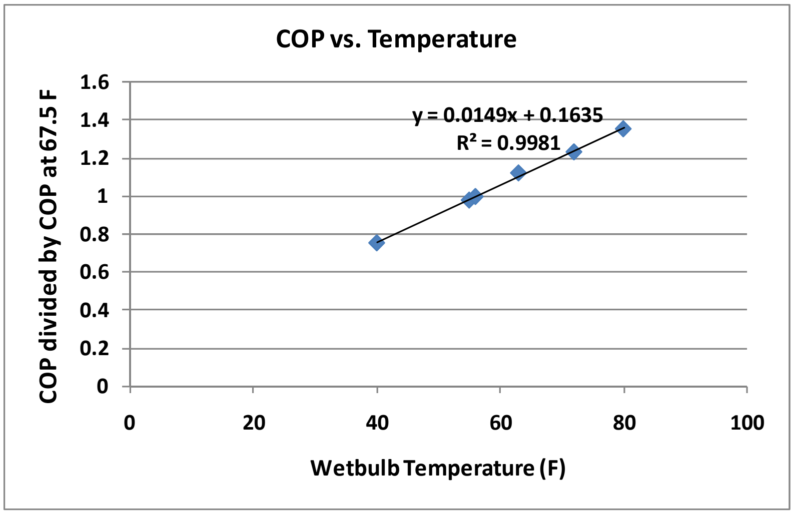

Figure 2-102-10: Dependence of COP on Outdoor Wet-Bulb Temperature

2.19.5 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 2-302-30: Energy Savings and Demand Reductions for Fuel Switching, Domestic Hot Water 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 2-312-31: Gas Consumption for Fuel Switching, Domestic Hot Water Heat Pump Water Heater to Gas Water Heater

Gas unit Energy Factor	Gas Consumption (MMBtu)
0.594	21.32

2.19.6 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].

2.19.7 Evaluation Protocols

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

[63] DEER values, updated October 10, 2008 http://www.deeresources.com/deer0911planning/downloads/EUL_Summary_10-1-08.xls

2.20 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.

2.20.1 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:

$$\Delta kWh_{elec\ heat} = \frac{CAPY_{elec\ heat} \times EFLH_{heat}}{3412\frac{Btu}{kWh}} - \frac{HP_{motor} \times \left(746\frac{W}{HP}\right) \times EFLH_{heat}}{\eta_{motor} \times 1000\frac{W}{kW}}$$

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Heating savings with electric air source heat pump:

Energy Impact:

$$\Delta kWh_{ASHP\ heat} = \frac{CAPY_{ASHP\ heat} \times EFLH_{heat}}{HSPF_{ASHP} \times 1000\frac{W}{kW}} - \frac{HP_{motor} \times \left(746\frac{W}{HP}\right) \times EFLH_{heat}}{\eta_{motor} \times 1000\frac{W}{kW}}$$

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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:

$$Gas\ Consumption\ (MMBtu) = \frac{CAPY_{Gas\ heat} \times EFLH_{heat}}{AFUE_{Gas\ heat} \times 1{,}000{,}000\frac{Btu}{MMBtu}}$$

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2.20.2 Definition of Terms

$CAPY_{elec\ heat}$	= *Total heating capacity of existing electric baseboards or electric furnace (BtuH)*
$CAPY_{ASHP\ heat}$	= *Total heating capacity of existing electric ASHP (BtuH)*
$CAPY_{Gas\ heat}$	= *Total heating capacity of new natural gas furnace (BtuH)*
$EFLH_{heat}$	= *Equivalent Full Load Heating hours*
$HSPF_{ASHP}$	= *Heating Seasonal Performance Factor for existing heat pump (Btu/W▪hr)*
$AFUE_{Gas\ heat}$	= *Annual Fuel Utilization Efficiency for the new gas furnace (%)*
HP_{motor}	= *Gas furnace blower motor horsepower (hp)*
η_{motor}	= *Efficiency of furnace blower motor*

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

Table 2-322-32: Default values for algorithm terms, Fuel Switching, Electric Heat to Gas Heat

Term	Type	Value	Source
$CAPY_{elec\ heat}$	Variable	Nameplate	EDC Data Gathering
$CAPY_{ASHP\ heat}$	Variable	Nameplate	EDC Data Gathering
$CAPY_{Gas\ heat}$	Variable	Nameplate	EDC Data Gathering
$EFLH_{heat}$	Fixed	Allentown = 2492 Erie = 2901 Harrisburg = 2371 Philadelphia = 2328 Pittsburgh = 2380 Scranton = 2532 Williamsport = 2502	2010 PA TRM Table 2-1
$HSPF_{ASHP}$	Variable	Default = 7.7	2010 PA TRM Table 2-1
		Nameplate	EDC Data Gathering
$AFUE_{Gas\ heat}$	Variable	Default = 78%	IECC 2009 minimum efficiency
		Nameplate	EDC Data Gathering
HP_{motor}	Variable	Default = ½ hp	Average blower motor capacity for gas furnace (typical range = ¼ hp to ¾ hp)
		Nameplate	EDC Data Gathering
η_{motor}	Variable	Default = 0.50	Typical efficiency of ½ hp blower motor
		Nameplate	EDC Data Gathering

2.20.3 Measure Life

Measure life = 20 years[64]

[64] PA 2010 TRM Appendix A: Measure Lives. Note that PA Act 129 savings can be claimed for no more than 15 years.

2.21 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.

2.21.1 Algorithms

The savings values are based on the following algorithms.

Cooling savings with central A/C:

$$\Delta kWh_{CAC} = \frac{CDD \times 24\frac{hr}{day} \times DUA}{SEER_{CAC} \times 1000\frac{W}{kW}} \times \left[A_{roof}\left(\frac{1}{R_{roof,bl}} - \frac{1}{R_{roof,ee}}\right) + A_{wall}\left(\frac{1}{R_{wall,bl}} - \frac{1}{R_{wall,ee}}\right)\right]$$

$$\Delta kW_{peak\text{-}CAC} = \frac{\Delta kWh_{CAC}}{EFLH_{cool}} \times CF_{CAC}$$

Cooling savings with room A/C:

$$\Delta kWh_{RAC} = \frac{CDD \times 24\frac{hr}{day} \times DUA \times F_{Room\ AC}}{EER_{RAC} \times 1000\frac{W}{kW}} \times \left[A_{roof}\left(\frac{1}{R_{roof,bl}} - \frac{1}{R_{roof,ee}}\right) + A_{wall}\left(\frac{1}{R_{wall,bl}} - \frac{1}{R_{wall,ee}}\right)\right]$$

$$\Delta kW_{peak\text{-}RAC} = \frac{\Delta kWh_{RAC}}{EFLH_{cool\ RAC}} \times CF_{RAC}$$

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

$$\Delta kWh_{ASHP\ cool} = \frac{CDD \times 24\frac{hr}{day} \times DUA}{SEER_{ASHP} \times 1000\frac{W}{kW}} \times \left[A_{roof}\left(\frac{1}{R_{roof,bl}} - \frac{1}{R_{roof,ee}}\right) + A_{wall}\left(\frac{1}{R_{wall,bl}} - \frac{1}{R_{wall,ee}}\right)\right]$$

$$\Delta kW_{peak\text{-}ASHP\ cool} = \frac{\Delta kWh_{ASHP\ cool}}{EFLH_{cool}} \times CF_{ASHP}$$

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

$$\Delta kWh_{ASHP\ heat} = \frac{HDD \times 24\frac{hr}{day}}{HSPF_{ASHP} \times 1000\frac{W}{kW}} \times \left[A_{roof}\left(\frac{1}{R_{roof,bl}} - \frac{1}{R_{roof,ee}}\right) + A_{wall}\left(\frac{1}{R_{wall,bl}} - \frac{1}{R_{wall,ee}}\right)\right]$$

$$\Delta kW_{peak\text{-}ASHP\ heat} = 0$$

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

$$\Delta kWh_{elec\ heat} = \frac{HDD \times 24\frac{hr}{day}}{3412\frac{Btu}{kWh}} \times \left[A_{roof}\left(\frac{1}{R_{roof,bl}} - \frac{1}{R_{roof,ee}}\right) + A_{wall}\left(\frac{1}{R_{wall,bl}} - \frac{1}{R_{wall,ee}}\right)\right]$$

$$\Delta kW_{peak\text{-}elec\ heat} = 0$$

2.21.2 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.*
A_{roof} ~~A_{roof}~~ ~~A_{roof}~~	= *Area of the ceiling/attic with upgraded insulation* (ft^2)
A_{wall} ~~A_{wall}~~ ~~A_{wall}~~	= *Area of the wall with upgraded insulation* (ft^2)
$R_{roof,bl}$ ~~$R_{roof,bl}$~~ ~~$R_{roof,bl}$~~	= *Assembly R-value of ceiling/attic before retrofit* (ft^2*°F*hr/Btu)
$R_{roof,ee}$ ~~$R_{roof,ee}$~~ ~~$R_{roof,ee}$~~	= *Assembly R-value of ceiling/attic after retrofit* (ft^2*°F*hr/Btu)
$R_{wall,bl}$ ~~$R_{wall,bl}$~~ ~~$R_{wall,bl}$~~	= *Assembly R-value of wall before retrofit* (ft^2*°F*hr/Btu)
$R_{wall,ee}$ ~~$R_{wall,ee}$~~ ~~$R_{wall,ee}$~~	= *Assembly R-value of wall after retrofit* (ft^2*°F*hr/Btu)
$SEER_{CAC}$	= *Seasonal Energy Efficiency Ratio of existing home central air conditioner (Btu/W▪hr)*
EER_{RAC} ~~EER_{RAC}~~ ~~EER_{RAC}~~	= *Average Energy Efficiency Ratio of existing room air conditioner (Btu/W▪hr)*
$SEER_{ASHP}$	= *Seasonal Energy Efficiency Ratio of existing home air source heat pump (Btu/W▪hr)*
$HSPF_{ASHP}$	= *Heating Seasonal Performance Factor for existing home heat pump (Btu/W▪hr)*
CF_{CAC}	= *Demand Coincidence Factor (See Section 1.4) for central AC systems*
CF_{RAC}	= *Demand Coincidence Factor (See Section 1.4) for Room AC systems*
CF_{ASHP}	= *Demand Coincidence Factor (See Section 1.4) for ASHP systems*
$EFLH_{cool}$	= *Equivalent Full Load Cooling hours for Central AC and ASHP*

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$EFLH_{cool\ RAC}$ = *Equivalent Full Load Cooling hours for Room AC*

$F_{Room\ AC}$ = *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 2-332-33: Default values for algorithm terms, Ceiling/Attic and Wall Insulation

Term	Type	Value	Source
A_{roof}	Variable	Varies	EDC Data Gathering
A_{wall}	Variable	Varies	EDC Data Gathering
DUA	Fixed	0.75	OH TRM[65]
$R_{roof,bl}$[66]	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
$R_{roof,ee}$[67]	Variable	38	Retrofit to R-38 total attic insulation
		49	Retrofit to R-49 total attic insulation
$R_{wall,bl}$[68]	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
$R_{wall,ee}$[69]	Variable	Default = 9.0	Assumes adding R-6 per DOE recommendations[70]
		Retrofit Assembly R-value	EDC Data Gathering

[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.
[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.
[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.
[68] Used eQuest 6.64 to derive wall assembly R-values.
[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.
[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

Term	Type	Value	Source
$SEER_{CAC}$	Variable	Default for equipment installed before 1/23/2006 = 10 Default for equipment installed after 1/23/2006 = 13Early Replacement = 10 Replace on Burnout = 13	Minimum Federal Standard for new Central Air Conditioners/Heat Pumps between 1990 and 2006 ASHRAE 90.1-2007Table 2-1
		Nameplate	EDC Data Gathering
EER_{RAC}	Variable	Default = 9.8	DOE Federal Test Procedure 10 CFR 430, Appendix F (Used in ES Calculator for baseline)
		Nameplate	EDC Data Gathering
$SEER_{ASHP}$	Variable	Default for equipment installed before 1/23/2006 = 10 Default for equipment installed after 1/23/2006 = 13Early Replacement = 10 Replace on Burnout = 13	Minimum Federal Standard for new Central Air Conditioners/Heat Pumps between 1990 and 2006 ASHRAE 90.1-2007Table 2-1
		Nameplate	EDC Data Gathering
$HSPF_{ASHP}$	Variable	Default for equipment installed before 1/23/2006 = 6.8 Default for equipment installed after 1/23/2006 = 7.7Early Replacement = 6.8 Replace on Burnout = 8.1	Minimum Federal Standard for new Central Air Conditioners/Heat Pumps between 1990 and 2006 ASHRAE 90.1-2007Table 2-1
		Nameplate	EDC Data Gathering
CF_{CAC}	Fixed	0.70	Table 2-1
CF_{RAC}	Fixed	0.58	Table 2-41
CF_{ASHP}	Fixed	0.70	Table 2-1
$F_{Room,AC}$	Fixed	0.38	Calculated[71]

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

Table 2-342-34: EFLH, CDD and HDD by City

City	$EFLH_{cool}$ (Hours)[72]	$EFLH_{cool\ RAC}$ (Hours)[73]	CDD (Base 65)[74]	HDD (Base 65)[75]
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

2.21.3 Measure Life

Measure life = 25 years[76].

[72] Table 2-1.
[73] PA SWE Interim Approved TRM Protocol – Residential Room AC Retirement
[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
[75] Ibid.
[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.

2.22 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 ENERGY STAR 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].

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
3. Replacement unit is an ENERGY STAR refrigerator or freezer

BASE	Baseline Unit Energy Consumption
EE	Energy Efficient Replacement Unit - e.g. Consumption (kWh_{EE})
RefRpl	Refrigerator Replacement - e.g. Energy savings from replacement($\Delta kWh_{RefRepl}$)

2.22.1 Algorithms

The deemed savings values are based on the following algorithms:

Energy Savings:

$$(\Delta kWh_{RefRepl}) = kWh_{BASE}\ kWh_{Recycled} - kWh_{EE}\ kWh_{Replacement}$$

Coincident peak demand savings

$$(\Delta kW_{RefRepl})_{peak} = \Delta kWh_{RefRepl} / HOURS_{RefRepl} * CF_{RefRepl}$$

[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.

2.22.2 Definition of Terms

The energy and demand savings shall be:

$kWh_{Recycled}$ = Annual energy consumption of the recycled appliance

$kWh_{Replacement}$ = Annual energy consumption of the replacement appliance

$\Delta kWh_{RefRepl}$ = 1659 kWh - 454kWh = 1205 kWh/unit

$\Delta kW_{RefRepl}$ = 1205 kWh/5000 hrs * 0.62 =0.1494 kW/unit

These savings numbers are derived from the following assumptions:

$CF_{RefRepl}$ = Demand Coincidence Factor (See Section 1.4) = 0.620[78]

$HOURS_{RefRepl}$ = Average annual run timehours = 5000 hrs[79,80]

$CF_{RefRepl}$ = Demand Coincidence Factor (See Section 1.4)

Term	Type	Value	Source
$kWh_{Recycled}$	Fixed	1,659 kWh	1
$kWh_{Replacement}$	Fixed	ENERGY STAR unit: 454 kWh Non-ENERGY STAR unit: 568 kWh	2
$HOURS_{RefRepl}$	Fixed	5,000	3 and 4
$CF_{RefRepl}$	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.

78 Mid Atlantic TRM Version 1.0. May 2010. Prepared by Vermont Energy Investment Corporation. Facilitated and managed by Northeast Energy Efficiency Partnerships.
79 Ibid.
80 Efficiency Vermont; Technical Reference User Manual (TRM). 2008. TRM User Manual No. 2008-53. Burlignton, VT 05401. July 18, 2008.

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 ft^3 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.

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

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

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

Table 2-352-36: Average Energy Savings for Refrigerator/Freezer Recycling and Replacement Default Savings

Source/ReferenceType	**$kWh_{Recycled}$Baseline Energy Consumption (kWh_{BASE})**	**$kWh_{Replacement}$ ENERGY STAR Refrigerator Energy Consumption (kWh_{EE})**	**ΔkWh Estimated Energy Savings ($\Delta kWh_{RefRepl}$)**	**ΔkW_{peak}**
RefrigeratorAppliance Replaced with ENERGY STAR Unit	1,659[83]	454[84]	1,205	0.149

81 Energy Star Refrigerator Retirement Calculator, accessed 10/15/2011 at http://www.energystar.gov/index.cfm?fuseaction=refrig.calculator

82 SWE received appliance collection databases from Allegheny, PPL, Duquesne and FirstEnergy. SWE did not receive databases from PECO.

83 See Table 1.

84 Average savings of Energy Star units from EnergyStar Residential Refrigerator Savings Calculator. Accessed June 18, 2010 at http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Consumer_Residential_Refrig_Sav_Calc.xls

Appliance Replaced with non-ENERGY Star Unit	1,659	568	1,091	0.135

2.22.3 Measure Life

Refrigerator/Freezer Replacement programs: Measure Life = 7 yrs

Measure Life Rationale

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

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

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

Example Measure savings over lifetime

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

For non-Low-Income specific programs, the measure life would be 13 years and an RUL of 4 yrs (1/3*~~15~~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*

85 2004 - 2005 Final Report: A Measurement and Evaluation Study of the 2004-2005 Limited Income Refrigerator Replacement & Lighting Program, Prepared for: San Diego Gas & Electric, July 31, 2006

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*

2.23 Refrigerator / Freezer Retirement (and Recycling)

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

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[87].

The deemed savings values for this measure can be applied to refrigerator and freezer retirements meeting the following criteria:

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

2.23.1 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:

$\Delta kWh = kWh_{RetFridge}$

$\Delta kW_{peak} = kW_{RetFridge} / hours * CF_{RetFridge}$

2.23.2 Definition of Terms

$kWh_{RetFridge}$ = *Gross annual energy savings per unit retired appliance*

$kW_{RetFridge}$ = *Summer demand savings per retired refrigerator/freezer*

$CF_{RetFridge}$ = *Demand Coincidence Factor (See Section 1.4)*

Where:

kWhRetFridge =*1659 kWh*

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[86] Vermont Energy Investment Corporation (VEIC) for NEEP, Mid Atlantic TRM Version 1.1. October 2010. Pg.27.

[87] 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.

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.[88]

Table 2-362-37: Refrigerator/Freezer Retirement Energy and Demand Savings

	Source/Reference	Energy and Demand Savings
$kWh_{RetFridge}$	Combined average refrigerator and freezer annual kWh consumption for Pennsylvania (based on all available PA EDC appliance recycling databases from JACO)	1,659kWh[89]
$kW_{RetFridge}$ =	1659kWh/5000hours * 0.620	0.2057kW

[88] Energy Star Refrigerator Retirement Calculator, accessed 10/15/2011 at http://www.energystar.gov/index.cfm?fuseaction=refrig.calculator

[89] 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.

2.24 Residential New Construction

2.24.1 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[90] 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 ~~the ENERGY STAR Lighting Algorithms and the ENERGY STAR Appliances Algorithms, respectively. These algorithms are found in ENERGY STAR Products~~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.[91]

2.24.2 Definition of Terms

PLb = *Peak load of the baseline home in Btuh.*

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[90] DoE's Building Energy Software Tools Directory (http://apps1.eere.energy.gov/buildings/tools_directory/software).

[91] No source provided for these savings figure. Additional research and updated values are recommended.

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

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

BLEER = *Factor to convert baseline SEERb to EERb.*

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

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

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

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

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

Table 2-372-~~38~~: Residential New Construction – References~~[92]~~

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Component	Type	Value	Sources
PLb	Variable	EDC Calculated	~~1~~1, Software Output
OF*b*	Fixed	1.6	2
SEER*b*	Fixed	13	3
BLEER	Fixed	~~0.92~~(11.3/13)	4
PL*q*	Variable	EDC Calculated	5, Software Output
OF*q*	Fixed	1.15	~~5~~6
EER*q*	Variable	EDC Data Gathering	AEPS Application; EDC's Data Gathering
CF	Fixed	0.70	~~6~~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. ~~Engineering calculation.~~
4. Ratio to calculate EER from SEER based average EER for SEER 13 units.

~~[92] Applicable to buildings completed from April 2003 to present.~~

5. Calculation of peak load of energy efficient home from the home energy rating tool based on the specified home energy characteristics.

5.6. Program guideline for qualifying home.

6.7. Based on an analysis of six different utilities by Proctor Engineering.

The following tables describetable lists the building envelope characteristics of the threebaseline reference homes.home based on IRC 2009 for the three climate zones in Pennsylvania..

Table 2-382-39: ENERGY STAR Homes: REMRate User Defined Reference Homes[93] – ReferencesBaseline Insulation and Fenestration Requirements by Component (Equivalent U-Factors)

Data Point	Value[94]								
Active Solar	None								
Ceiling Insulation	U=0.031 (1)								
Radiant Barrier	None								
Climate Zone	Fenestration U-Factor	Skylight U-Factor	Rim/Band JoistCeiling U-Factor	Frame Wall U-Factor	U=0.141 Type A-1, U=0.215 Type A-2 (1)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	Exterior Walls – Wood0.030	0.082	U=0.141 Type A-1, U=0.215 Type A-2 (1)	0.047	0.059	10, 2 ft	0.065
5A	0.35	0.60	Exterior Walls – Steel0.030	0.060	U=0.141 Type A-1, U=0.215 Type A-2 (1)0.082	0.033	0.059	10, 2 ft	0.065
Foundation Walls	U=0.99								
6A	0.35	0.60	Doors0.026	0.060	U=0.141 Type A-1, U=0.215 Type A-2 (1)0.060	0.033	0.059	10, 4 ft	0.065
Windows	U=0.141 Type A-1, U=0.215 Type A-2 (1), No SHGC req.								

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[93] Applicable to buildings completed from April 2003 to present. Reflects MEC 95.
[94] Single and multiple family as noted.

Data Point	Value[94]
Glass Doors	U=0.141 Type A-1, U=0.215 Type A-2 (1), No SHGC req.
Skylights	U=0.031 (1), No SHGC req.
Floor over Garage	U=0.050 (1)
Floor over Unheated Basement	U=0.050 (1)
Floor over Crawlspace	U=0.050 (1)
Floor over Outdoor Air	U=0.031 (1)
Unheated Slab on Grade	R-0 edge/R-4.3 under
Heated Slab on Grade	R-0 edge/R-6.4 under
Air Infiltration Rate	0.51 ACH winter/0.51 ACH summer
Duct Leakage	No Observable Duct Leakage
Mechanical Ventilation	None
Lights and Appliances	Use Default
Setback Thermostat	Yes for heating, no for cooling
Heating Efficiency Furnace Boiler Combo Water Heater Air Source Heat Pump Geothermal Heat Pump PTAC / PTHP	- 80% AFUE (3) 80% AFUE 76% AFUE (recovery efficiency) 7.7 HSPF Open not modeled, 3.0 COP closed Not differentiated from air source HP
Cooling Efficiency Central Air Conditioning Air Source Heat Pump Geothermal Heat Pump PTAC / PTHP Window Air Conditioners	- 13.0 SEER 13.0 SEER 3.4 COP (11.6 EER) Not differentiated from central AC Not differentiated from central AC
Domestic WH Efficiency Electric Natural Gas	- 0.97 EF (4) 0.67 EF (4)
Water Heater Tank Insulation	None
Duct Insulation	N/A

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 2-392-40: ENERGY STAREnergy Star Homes: REMRate - User Defined Reference Homes95 – ReferencesHome

Data Point	Value[96]	Source
Air Infiltration Rate	0.30 ACH for windows, skylights, sliding glass doors 0.50 ACH for swinging doors	1
Duct Leakage	No observable duct leakage12 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 °F (13 °C) or up to 85 °F (29 °C)	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	Open not modeled, 3.0 COP closed7.7 HSPF	1

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[95] Applicable to buildings completed from January 2008 to present.

[96] Single and multiple family as noted.

Data Point	Value[96]	Source
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	~~3.4 COP (11.6 EER)~~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) ~~(1)~~	3
Natural Gas	EF = 0.67 - (0.0019 * gallons) ~~(1)~~	3
Additional Water Heater Tank Insulation	None	

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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."

2.25 ENERGY STAR Appliances

2.25.1 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:

$\Delta kWh = ESav_{REF}$

$\Delta kW_{peak} = DSav_{REF} \times CF_{REF}$

ENERGY STAR Clothes Washers:

$\Delta kWh = ESav_{CW}$

$\Delta kW_{peak} = DSav_{CW} \times CF_{CW}$

ENERGY STAR Dishwashers:

$\Delta kWh = ESav_{DW}$

$\Delta kW_{peak} = DSav_{DW} \times CF_{DW}$

ENERGY STAR Dehumidifiers:

$\Delta kWh = ESav_{DH}$

$\Delta kW_{peak} = DSav_{DH} \times CF_{DH}$

ENERGY STAR Room Air Conditioners:

$\Delta kWh = ESav_{RAC}$

$\Delta kW_{peak} = DSav_{RAC} \times CF_{RAC}$

ENERGY STAR Freezer:

$\Delta kWh = ESav_{FRE}$

$\Delta kW_{peak} = DSav_{FRE} \times CF_{FRE}$

~~2.25.2 ΔkW = kW_{BASE} – kW_{EE}~~

~~2.25.3 ΔkWh = ΔkW X HOURS~~

~~2.25.4~~2.25.2 Definition of Terms

$ESav_{REF}$	= Electricity savings per purchased ENERGY STAR refrigerator.
$DSav_{REF}$	= Summer demand savings per purchased ENERGY STAR refrigerator.
$ESav_{CW}$	= Electricity savings per purchased ENERGY STAR clothes washer.
$DSav_{CW}$	= Summer demand savings per purchased ENERGY STAR clothes washer.
$ESav_{DW}$	= Electricity savings per purchased ENERGY STAR dishwasher.
$DSav_{DW}$	= Summer demand savings per purchased ENERGY STAR dishwasher.
$ESav_{DH}$	= Electricity savings per purchased ENERGY STAR dehumidifier
$DSav_{DH}$	= Summer demand savings per purchased ENERGY STAR dehumidifier
$ESav_{RAC}$	= Electricity savings per purchased ENERGY STAR room AC.
$DSav_{RAC}$	= Summer demand savings per purchased ENERGY STAR room AC.
$ESav_{FRE}$	= Electricity savings per purchased ENERGY STAR freezer.
$DSav_{FRE}$	= Summer demand savings per purchased ENERGY STAR freezer.
CF_{REF}, CF_{CW}, CF_{DW}, CF_{DH}, CF_{RAC}, CF_{FRE}	= 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%).
~~ΔkW~~	~~= gross customer connected load kW savings for the measure~~
~~kW_{BASE}~~	~~= Baseline connected kW~~
~~kW_{EE}~~	~~= Energy efficient connected kW~~

HOURS = average hours of use per year

Table 2-402-41: ENERGY STAR Appliances - References

Component	Type	Value	Sources
$ESav_{REF}$	Fixed	See Table 2-41	9
$DSav_{REF}$	Fixed	0.0125 kW	1
REF Time Period Allocation Factors	Fixed	Summer/On-Peak 20.9% Summer/Off-Peak 21.7% Winter/On-Peak 28.0% Winter/Off-Peak 29.4%	2
$ESav_{CW}$	Fixed	See Table 2-41	9
$DSav_{CW}$	Fixed	0.0147 kW	3
CW Electricity Time Period Allocation Factors	Fixed	Summer/On-Peak 24.5% Summer/Off-Peak 12.8% Winter/On-Peak 41.7% Winter/Off-Peak 21.0%	2
$ESav_{DW}$	Fixed	See Table 2-41	9
$DSav_{DW}$	Fixed	0.0225	4
DW Electricity Time Period Allocation Factors	Fixed	19.8%, 21.8%, 27.8%, 30.6%	2
$ESav_{DH}$	Fixed	See Table 2-41	9
$DSav_{DH}$	Fixed	0.0098 kW	7
$ESav_{RAC}$	Fixed	See Table 2-41	9
$DSav_{RAC}$	Fixed	0.1018 kW	5
CF_{REF}, CF_{CW}, CF_{DW}, CF_{DH}, CF_{RAC}, CF_{FRE}	Fixed	1.0, 1.0, 1.0, 1.0, 0.58, 1.0	6
RAC Time Period Allocation Factors	Fixed	65.1%, 34.9%, 0.0%, 0.0%	2
kW_{BASE}	Fixed	0.0926	8
kW_{EE}	Fixed	0.0813	8
HOURS	Fixed	5000	8
ΔkW	Fixed	0.0113	8
$ESav_{FRE}$	Fixed	See Table 2-41	9
$DSav_{FRE}$	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. All valuesvValuesvalues 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.
9. Unknown fuel mix values taken from 2011 Mid-Atlantic TRM. Mid-Atlantic Technical Reference Manual, version 1.2. Prepared by Vermont Energy Investment Corporation. Facilitated and managed by Northeast Energy Efficiency Partnerships. July 2011.

Table 2-412-42: Energy Savings from ENERGY STAR Calculator

Measure	Energy Savings
Refrigerator	
Manual Defrost	95 kWh72 kWh
Partial Automatic Defrost	95 kWh72 kWh
Top mount freezer without door ice	106 kWh80 kWh
Side mount freezer without door ice	127 kWh95 kWh
Bottom mount freezer without door ice	116 kWh87 kWh
Bottom mount freezer with door ice	154 kWh
Top mount freezer with door ice	124 kWh94 kWh
Side mount freezer with door ice	133 kWh100 kWh
Refrigerator only - single door without ice	104 kWh
Refrigerator/Freezer – single door	105 kWh
Freezers	
Upright with manual defrost	47 kWh55 kWh
Upright with automatic defrost	67 kWh80 kWh
Chest Freezer	42 kWh52 kWh
Compact Upright with manual defrost	53kWh62 kWh
Compact Upright with automatic defrost	71 kWh83 kWh
Compact Chest Freezer	45kWh55 kWh
Dehumidifier	
1-25 pints/day	54 kWh
25-35 pints/day	117 kWh
35-45 pints/day	213 kWh
45-54 pints/day	297 kWh
54-75 pints/day	342 185 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)

Measure	Energy Savings
Williamsport	62 kWh (659 hours)
Dishwasher	
With Gas Hot Water Heater	77 kWh
With Electric Hot Water Heater	137 kWh
Clothes Washer	
Gas Hot Water Heater and Gas Dryer or No DryerWith Gas Hot Water Heater	23.824 kWh26 kWh
Gas Hot Water Heater and Electric DryerWith Electric Hot Water Heater	97 kWh258 kWh
Electric Hot Water Heater and Electric Dryer	224 kWh
Electric Hot Water Heater and Gas Dryer or No Dryer	141 kWh
Unknown Fuel Mix	153 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).[97]

$ESav_{DW} = 77 \times \%GWH_{DW} + 137 \times \%EWH_{DW}$

$ESav_{CW} = 24 \times \%GWH\text{-}GD_{CW} + 97 \times \%GWH\text{-}ED_{CW} + 141 \times \%EWH\text{-}GD_{CW} + 224 \times \%EWH\text{-}ED_{CW}$

Where:

$\%GWH_{DW}$ = Percent of dishwashers with non-electric water heater

$\%EWH_{DW}$ = Percent of dishwashers with electric water heater

$\%GWH\text{-}GD_{CW}$ = Percent of clothes washers with gas water heater and non-electric or no dryer fuel

$\%GWH\text{-}ED_{CW}$ = Percent of clothes washers with gas water heater and electric dryer fuel

$\%EWH\text{-}GD_{CW}$ = Percent of clothes washers with gas water heater and non-electric or no dryer fuel

$\%EWH\text{-}ED_{CW}$ = Percent of clothes washers with gas water heater and electric dryer fuel

[97] 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.

2.26 ENERGY STAR Lighting

2.26.1 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 = ~~((~~(~~CFL_{watts}~~ $Watts_{base}$ – $Watts_{CFL}$) X ~~(~~CFL_{hours} X 365~~)~~ ~~)~~/ 1000~~)~~ X ISR_{CFL}

ΔkW_{peak} = ~~(~~($Watts_{base}$ – $Watts_{CFL}$) ~~CFL_{watts})~~/ 1000 X CF X ISR_{CFL}

ENERGY STAR Torchieres:

ΔkWh = ~~((~~$Torch_{watts}$ X ~~(~~$Torch_{hours}$ X 365~~))~~ / 1000~~)~~ X ISR_{Torch}

ΔkW_{peak} = ~~(~~$Torch_{watts}$~~)~~ / 1000 X CF X ISR_{Torch}

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

ΔkWh = ~~((~~IF_{watts} X ~~(~~IF_{hours} X 365~~))~~ / 1000~~)~~ X ISR_{IF}

ΔkW_{peak} = ~~(~~IF_{watts}~~)~~ / 1000 X CF X ISR_{IF}

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

ΔkWh = ~~((~~OF_{watts} X ~~(~~OF_{hours} X 365~~))~~ / 1000~~)~~ X ISR_{OF}

ΔkW_{peak} = ~~(~~OF_{watts}~~)~~ / 1000 X CF X ISR_{OF}

Ceiling Fan with ENERGY STAR Light Fixture:

ΔkWh =180 kWh

ΔkW_{peak} = 0.01968

2.26.2 Definition of Terms

~~CFL_{watts}~~ $Watts_{base}$ = ~~Average delta watts per purchased ENERGY STAR CFL~~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.
$Watts_{CFL}$	= Wattage of CFL
CFL_{hours}	= Average hours of use per day per CFL
ISR_{CFL}	= In-service rate per CFL.
$Torch_{watts}$	= Average delta watts per purchased ENERGY STAR torchiere
$Torch_{hours}$	= Average hours of use per day per torchiere
ISR_{Torch}	= In-service rate per Torchiere
IF_{watts}	= Average delta watts per purchased ENERGY STAR Indoor Fixture
IF_{hours}	= Average hours of use per day per Indoor Fixture
ISR_{IF}	= In-service rate per Indoor Fixture
OF_{watts}	= Average delta watts per purchased ENERGY STAR Outdoor Fixture
OF_{hours}	= Average hours of use per day per Outdoor Fixture
ISR_{OF}	= 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 2-422-43: ENERGY STAR Lighting - References

Component	Type	Value	Sources
CFL_{watts} $Watts_{base}$	FixedVariable	VariableSee Table 2-43	Table 2-43Data Gathering
$Watts_{CFL}$	Variable	Data Gathering	Data Gathering
CFL_{hours}	Fixed	3.0	6
ISR_{CFL}	Fixed	84%[98]	3
$Torch_{watts}$	Fixed	115.8	1
$Torch_{hours}$	Fixed	3.0	2
ISR_{Torch}	Fixed	83%	3
IF_{watts}	Fixed	48.7	1
IF_{hours}	Fixed	2.6	2
ISR_{IF}	Fixed	95%	3
OF_{watts}	Fixed	94.7	1
OF_{hours}	Fixed	4.5	2
ISR_{OF}	Fixed	87%	3
CF	Fixed	5%	4
∆kWh	Fixed	180 kWh	5
∆kW	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).

[98] Subject to verification through evaluation. The value can be updated if evaluation findings reveal a value that differs from the defaultSubject to adjustment based on evaluation results

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 2-432-44. Baseline Wattage by Lumen Output of CFL[99]

Minimum Lumens (a)	Maximum Lumens (b)	Incandescent Equivalent $Watts_{Base}$ (Pre-EISA 2007) (c)	$Watts_{Base}$ (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	20134 TRM
310	749	40	29	2014 TRM

To determine the $Watts_{Base}$ for a non-specialty CFL,[100],, 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).
1.3. Find the baseline wattage ($Watts_{Base}$) in column (c) or column (d). Values in column (c) are used for $Watts_{Base}$ until the TRM listed under column (e) is effective. Afterwards, values in column (d) are used for $Watts_{Base}$.

[99] 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

[100] 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.*

2.27 ENERGY STAR Windows

2.27.1 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.[101] 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:

$\Delta kWh = ESav_{HP}$

$\Delta kW_{peak} = DSav_{HP} \times CF$

Electric Heat/Central Air Conditioning:

$\Delta kWh = ESav_{RES/CAC}$

$\Delta kW_{peak} = DSav_{CAC} \times CF$

Electric Heat/No Central Air Conditioning:

$\Delta kWh = ESav_{RES/NOCAC}$

$\Delta kW_{peak} = DSav_{NOCAC} \times CF$

2.27.2 Definition of Terms

$ESav_{HP}$ = *Electricity savings (heating and cooling) with heat pump installed.*

$ESav_{RES/CAC}$ = *Electricity savings with electric resistance heating and central AC installed.*

$ESav_{RES/NOCAC}$ = *Electricity savings with electric resistance heating and no central AC installed.*

[101] Energy Information Administration. *Residential Energy Consumption Survey*. 2005. http://www.eia.doe.gov/emeu/recs/recs2005/hc2005_tables/detailed_tables2005.html

$DSav_{HP}$	*= Summer demand savings with heat pump installed.*
$DSav_{CAC}$	*= Summer demand savings with central AC installed.*
$DSav_{NOCAC}$	*= Summer demand savings with no central AC installed.*
CF	*= Demand Coincidence Factor (See Section 1.4)*

Table 2-442-45: ENERGY STAR Windows - References

Component	Type	Value	Sources
$ESav_{HP}$	Fixed	2.2395 kWh/ft^2	1
HP Time Period Allocation Factors	Fixed	Summer/On-Peak 10% Summer/Off-Peak 7% Winter/On-Peak 40% Winter/Off-Peak 44%	2
$ESav_{RES/CAC}$	Fixed	4.0 kWh/ft^2	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
$ESav_{RES/NOCAC}$	Fixed	3.97 kWh/ft^2	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
$DSav_{HP}$	Fixed	0.000602 kW/ft^2	1
$DSav_{CAC}$	Fixed	0.000602 kW/ft^2	1
$DSav_{NOCAC}$	Fixed	0.00 kW/ft^2	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.

2.28 ENERGY STAR Audit

2.28.1 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.

2.29 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.[102]
2. Software approved by the US Department of Energy's Weatherization Assistance Program.[103]
3. RESNET approved rating software.[104]

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.

2.29.1 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)[105]. 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

[102] 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.~~developed.~~ The existing 1995 standard can be found at http://www.nrel.gov/docs/legosti/fy96/7332a.pdf~~A new standard for BESTEST is currently being developed. The existing 1995 standard can be found at http://www.nrel.gov/docs/legosti/fy96/7332a.pdf~~.

[103] A listing of the approved software available at http://www.waptac.org/si.asp?id=736 .

[104] A listing of the approved software available at http://resnet.us .

[105] 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.

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Formatted: Default Paragraph Font, Font: 8 pt 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).

2.29.2 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.

2.29.3 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.

2.29.4 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:
   a. Various heating and cooling infiltration factors.
   b. Heating degree days and heating hours for a temperature range of 40 to 72°F.
   c. Cooling degree hours and cooling hours for a temperature range of 68 to 84°F.
   d. 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.

2.29.5 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.

2.29.6 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.

2.29.7 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.

2.29.8 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:

a. 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.

b. 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.

2.29.9 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.

2.30 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[106].

2.30.1 Algorithms

Energy Savings (per TV):

$$\Delta kWh = \left[\frac{(W_{base,\ active} - W_{ES,\ active})}{1000} \times HOURS_{active} \times 365\right]$$

Coincident Demand Savings (per TV):

$$\Delta kW = \left[\frac{(W_{base,active} - W_{ES,\ active})}{1000} \times CF\right]$$

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.

2.30.2 Definition of Terms

$W_{base,active}$ = *power use (in Watts) of baseline TV while in active mode (i.e. turned on and operating).*

$W_{ES,active}$ = *power use (in Watts) of ENERGY STAR Version 4.1 or 5.1 TV while in active mode (i.e. turned on and operating).*

$HOURS_{active}$ = *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 2-452-46: ENERGY STAR TVs - References

Component	Type	Value	Source
CF	Fixed	0.28	1
$HOURS_{active}$	Fixed	5	2

Sources:

1. Deemed Savings Technical Assumptions, Program: ENERGY STAR Retailer Incentive Pilot Program, accessed October 2010,

[106] 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.

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 2-462-47: ENERGY STAR TVs Version 4.1 and 5.1 maximum power consumption

Screen Area[107] (square inches)	**Maximum Active Power ($W_{ES,active}$) Version 4.1[108]**	**Maximum Active Power ($W_{ES,active}$) Version 5.1[109]**
A < 275	P_{max} = 0.190 * A +5	P_{max} = 0.130 * A +5
275 ≤ A ≤ 1068	P_{max} = 0.120 * A +25	P_{max} = 0.084 * A +18
A > 1068	P_{max} = 0.120 * A +25	P_{max} = 108

[107] 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

[108] *TVs Key ENERGY STAR Product Criteria*, accessed October 2010, http://www.energystar.gov/index.cfm?c=tv_vcr.pr_crit_tv_vcr

[109] Ibid.

Table 2-472-48: TV power consumption

Diagonal Screen Size (inches)[110]	Baseline Active Power Consumption [$W_{base,active}$][111]	ENERGY STAR V. 4.1 Active Power Consumption [$W_{ES,active}$][112]	ENERGY STAR V. 5.1 Active Power Consumption [$W_{ES,active}$][113]
< 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*

* P_{max} = 108W

2.30.3 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 2-482-49: Deemed energy savings for ENERGY STAR Version 4.1 and 5.1 TVs.

Diagonal Screen Size (inches)[114]	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

[110] 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".
[111] 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
[112] *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
[113] Ibid.
[114] 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".

Table 2-492-50: Deemed coincident demand savings for ENERGY STAR Version 4.1 and 5.1 TVs.

Diagonal Screen Size (inches)[115]	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

2.30.4 Measure Life

Measure life = 15 years[116]

[115] Ibid.

[116] 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

2.31 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.

2.31.1 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

$\Delta kWh = ESav_{COM}$

$\Delta kW_{peak} = DSav_{COM} \times CF_{COM}$

ENERGY STAR Fax Machine

$\Delta kWh = ESav_{FAX}$

$\Delta kW_{peak} = DSav_{FAX} \times CF_{FAX}$

ENERGY STAR Copier

$\Delta kWh = ESav_{COP}$

$\Delta kW_{peak} = DSav_{COP} \times CF_{COP}$

ENERGY STAR Printer

$\Delta kWh = ESav_{PRI}$

$\Delta kW_{peak} = DSav_{PRI} \times CF_{PRI}$

ENERGY STAR Multifunction

$\Delta kWh = ESav_{MUL}$

$\Delta kW_{peak} = DSav_{MUL} \times CF_{MUL}$

ENERGY STAR Monitor

$\Delta kWh = ESav_{MON}$

$\Delta kW_{peak} = DSav_{MON} \times CF_{MON}$

2.31.2 Definition of Terms

$ESav_{COM}$	= Electricity savings per purchased ENERGY STAR computer.
$DSav_{COM}$	= Summer demand savings per purchased ENERGY STAR computer.
$ESav_{FAX}$	= Electricity savings per purchased ENERGY STAR fax machine.
$DSav_{FAX}$	= Summer demand savings per purchased ENERGY STAR fax machine.
$ESav_{COP}$	= Electricity savings per purchased ENERGY STAR copier.
$DSav_{COP}$	= Summer demand savings per purchased ENERGY STAR copier.
$ESav_{PRI}$	= Electricity savings per purchased ENERGY STAR printer.
$DSav_{PRI}$	= Summer demand savings per purchased ENERGY STAR printer.
$ESav_{MUL}$	= Electricity savings per purchased ENERGY STAR multifunction machine.
$DSav_{MUL}$	= Summer demand savings per purchased ENERGY STAR multifunction machine.
$ESav_{MON}$	= Electricity savings per purchased ENERGY STAR monitor.
$DSav_{MON}$	= Summer demand savings per purchased ENERGY STAR monitor.
CF_{COM}, CF_{FAX}, CF_{COP},	
CF_{PRI}, CF_{MUL}, CF_{MON}	= 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 2-502-51: ENERGY STAR Office Equipment - References

Component	Type	Value	Sources
$ESav_{COM}$ $ESav_{FAX}$ $ESav_{COP}$ $ESav_{PRI}$ $ESav_{MUL}$ $ESav_{MON}$	Fixed	see Table 2-51	1
$DSav_{COM}$ $DSav_{FAX}$ $DSav_{COP}$ $DSav_{PRI}$ $DSav_{MUL}$ $DSav_{MON}$	Fixed	see Table 2-51	2
CF_{COM},CF_{FAX},CF_{COP},CF_{PRI},CF_{MUL},CF_{MON}	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 2-512-52: 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

2.32 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. This protocol is designed to be generic and replace earlier protocols submitted that are specific to a particular make and model of LED lamp.

Eligibility Requirements

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All LED lamps, retrofit kits and fixtures must be:

- **ENERGY STAR qualified**[117] – 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**[118] - 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

2.32.1 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;[119]

[117] http://www.energystar.gov/ia/partners/product_specs/program_reqs/SSL_Key_Product_Criteria.pdf
[118] http://www.lightingfacts.com/
[119] http://www1.eere.energy.gov/buildings/appliance_standards/residential/incandescent_lamps.html

Table 2-52. General Service Lamps

Minimum Lumens (a)	Maximum Lumens (b)	Incandescent Equivalent $Watts_{Base}$ (Pre-EISA 2007) (c)	$Watts_{Base}$ (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	~~2013~~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 $Watts_{Base}$ until the TRM listed under column (e). Afterwards, values in column (d) are used for $Watts_{Base}$.

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) $= ((Watts_{Base} - Watts_{LED}) * (Hours_{LED} * 365) / 1000) * ISR_{LED}$

Peak Demand Impact (kW) $= ((Watts_{Base} - Watts_{LED}) / 1000) * CF * ISR_{LED}$

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

Energy Impact (kWh) $= ((Watts_{Base} - Watts_{LED}) * (Hours_{LED} * 365) / 1000) * ISR_{LED}$

Peak Demand Impact (kW) $= ((Watts_{Base} - Watts_{LED}) / 1000) * CF * ISR_{LED}$

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

Energy Impact (kWh) $= ((Watts_{Base} - Watts_{LED}) * (Hours_{LED} * 365) / 1000) * ISR_{LED}$

Peak Demand Impact (kW) $= ((Watts_{Base} - Watts_{LED}) / 1000) * CF * ISR_{LED}$

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

Energy Impact (kWh) $= ((Watts_{Base} - Watts_{LED}) * (Hours_{LED} * 365) / 1000) * ISR_{LED}$

Peak Demand Impact (kW) $= ((Watts_{Base} - Watts_{LED}) / 1000) * CF * ISR_{LED}$

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.[120] 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.[121]

Table 2-53: Reflector Lamps

Minimum Lumens (a)	Maximum Lumens (b)	Incandescent Equivalent $Watts_{Base}$ (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.

[120] http://www.standardsasap.org/products/incd_reflector.html

[121] 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

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

Energy Impact (kWh) = $((Watts_{Base} - Watts_{LED}) * (Hours_{LED} * 365) / 1000) * ISR_{LED}$

Peak Demand Impact (kW) = $((Watts_{Base} - Watts_{LED}) / 1000) * CF * ISR_{LED}$

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

Energy Impact (kWh) = $((Watts_{Base} - Watts_{LED}) * (Hours_{LED} * 365) / 1000) * ISR_{LED}$

Peak Demand Impact (kW) = $((Watts_{Base} - Watts_{LED}) / 1000) * CF * ISR_{LED}$

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

Energy Impact (kWh) = $((Watts_{Base} - Watts_{LED}) * (Hours_{LED} * 365) / 1000) * ISR_{LED}$

Peak Demand Impact (kW) = $((Watts_{Base} - Watts_{LED}) / 1000) * CF * ISR_{LED}$

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

Energy Impact (kWh) = $((Watts_{Base} - Watts_{LED}) * (Hours_{LED} * 365) / 1000) * ISR_{LED}$

Peak Demand Impact (kW) = $((Watts_{Base} - Watts_{LED}) / 1000) * CF * ISR_{LED}$

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

Energy Impact (kWh) = $((Watts_{Base} - Watts_{LED}) * (Hours_{LED} * 365) / 1000) * ISR_{LED}$

Peak Demand Impact (kW) = $((Watts_{Base} - Watts_{LED}) / 1000) * CF * ISR_{LED}$

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

Energy Impact (kWh) = $((Watts_{Base} - Watts_{LED}) * (Hours_{LED} * 365) / 1000) * ISR_{LED}$

Peak Demand Impact (kW) = $((Watts_{Base} - Watts_{LED}) / 1000) * CF * ISR_{LED}$

2.32.2 Definition of Terms

$Watts_{LED}$ = Manufacturer-claimed wattage shown on product packaging

$Hours_{LED}$ = Average hours of use per day per LED

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

CF = ~~Demand coincidence factor—the percentage of the total lighting connected load that is on during the electric system's peak window~~ Demand Coincidence Factor (See Section 1.4)~~= Coincidence Factor, defined as the fraction of the technology demand that is coincident with the utility peak~~

Table 2-54: Residential LED Variables

Variable	Type	Value	Source
$Watts_{Base}$	Fixed	See Table 2-52 and Table 2-53	Table 2-52 and Table 2-53
$Watts_{LED}$	Fixed	Variable	Data Gathering
$Hours_{LED}$	Fixed	3	1
CF	Fixed	5%	2
ISR_{LED}	Fixed	95%[122]	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.

2.32.3 Measure Life

Residential LED Measure Life is 13.7 yrs[123].

[122] Subject to verification through evaluation. The value can be updated if evaluation findings reveal a value that differs from the default.

[123] 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 .

2.33 Residential Occupancy Sensors

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

2.33.1 Algorithms

ΔkWh $= kW_{controlled} \times 365 \times (RH_{old} - RH_{new})$

ΔkW_{peak} $= 0$

2.33.2 Definition of Terms

$kW_{controlled}$ = Wattage of the fixture being controlled by the occupancy sensor (in kilowatts)

365 = Days per year

RH_{old} = Daily run hours before installation

RH_{new} = Daily run hours after installation

Table 2-55: Residential Occupancy Sensors Calculations Assumptions

Component	Type	Value	Source
$kW_{controlled}$	Variable	EDC's Data Gathering	AEPS Application; EDC's Data Gathering
RH_{old}	Fixed	3.0	1
RH_{new}	Fixed	2.1 (70% of RH_{old})	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

2.33.3 Measure Life

The expected measure life is 10 years[124].

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

2.34 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.

2.34.1 Eligibility

This protocol documents the energy savings attributed to the installation of LED holiday lights indoors and outdoors. LED lights must replace traditional incandescentstyle holiday lights. Typical requirements for applicants to receive incentives for this measure are as follows:

A deadline for purchase and installation.

Provide proof of purchase and installation.

An incentive form where customer is to provide information (name, address etc.)

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2.34.2 Algorithms

$\Delta kWh_{C9} = [(INC_{C9} - LED_{C9})) \times \#BULBS \times \#STRANDS \times HR] / 1000$

$\Delta kWh_{C7} = [(INC_{C7} - LED_{C7}) \times \#BULBS \times \#STRANDS \times HR] / 1000$

$\Delta kWh_{mini} = [(INC_{mini} - LED_{mini}) \times \#BULBS \times \#STRANDS \times HR] / 1000$

Key assumptions

- Cost estimates include material costs only. Installation costs and potential maintenance savings are not included.
- 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” variety[1]. If the lamp type is known or fixed by program design, then the savings can be calculated as followsdescribed 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.

2.34.3 Definition of Terms

LED_{mini} = Wattage of LED mini bulbs

INC_{mini} = Wattage of incandescent mini bulbs

LED_{C7} = Wattage of LED C7 bulbs

INC_{C7} = Wattage of incandescent C7bulbs

LED_{C9} = Wattage of LED C9 bulbs

INC_{C9} = Wattage of incandescent C9 bulbs

W_{Mini} = Weight factor of mini bulbs

W_{C7} = Weight factor of C7 bulbs

W_{C9} = Weight factor of 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
LED_{mini}	Fixed	0.08 W	1
INC_{mini}	Fixed	0.48 W	1
LED_{C7}	Fixed	0.48 W	1
INC_{C7}	Fixed	6.0 W	1
LED_{C9}	Fixed	2.0 W	1
INC_{C9}	Fixed	7.0 W	1
W_{Mini}	Fixed	0.5	1
W_{C7}	Fixed	0.25	1
W_{C9}	Fixed	0.25	1
$\#_{Bulbs}$	Variable	Variable	EDC Data Gathering
$\#_{Strands}$	Variable	Variable	EDC Data Gathering
Hr	Fixed	150	1

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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

2.34.4 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.

2.34.5 Measure Life

Measure life is 10 years[125,126].

2.34.6 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.

[125] 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"

[126] http://www.energyideas.org/documents/factsheets/HolidayLighting.pdf

2.35 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.

2.35.1 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.

2.35.2 Algorithms

$\Delta kWh = (Base_{watts} - CFL_{watts}) \times CFL_{hours} \times 365 / 1000 \times ISR_{CFL}$

$\Delta kW = (Base_{watts} - CFL_{watts}) / 1000 \times CF \times ISR_{CFL}$

2.35.3 Definition of Terms

$Base_{watts}$ = Wattage of baseline bulb

CFL_{watts} = Wattage of CFL

CFL_{hours} = Daily hours of operation for CFL

365 = Days per year

ISR_{CFL} = 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)~~Coincidence factor~~

Table 2-57: Low Income Lighting Calculations Assumptions

Component	Type	Value	Source
$Base_{watts}$	Fixed	See Table 2-58	Table 2-58
CFL_{watts}	Fixed	Data Gathering	EDC Data Gathering
CFL_{hours}:	Fixed	1.5	1
CF	Fixed	0.05	2
ISR_{CFL}	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.

2.35.4 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

CFL_{watts}	$Base_{watts}$	CFL_{hours}	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

2.35.5 Measure Life

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

2.35.6 Evaluation Protocol

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

2.36 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.

2.36.1 Algorithms

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

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

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

Field Code Changed

Field Code Changed

2.36.2 Definition of Terms

U_{base} = Overall heat transfer coefficient of water heater prior to adding tank wrap (Btu/Hr-F-ft^2).

U_{insul} = Overall heat transfer coefficient of water heater after addition of tank wrap (Btu/Hr-F-ft^2).

A_{base} = Surface area of storage tank prior to adding tank wrap (square feet)[127]

A_{insul} = Surface area of storage tank after addition of tank wrap (square feet)[128].

η_{Elec} = Thermal efficiency of electric heater element

Field Code Changed

$T_{setpoint}$ = Temperature of hot water in tank (F).

[127] Area includes tank sides and top to account for typical wrap coverage.
[128] Ibid.

$T_{ambient}$	*= Temperature of ambient air (F).*
HOU	*= Annual hours of use for water heater tank.*
CF	*= Demand Coincidence Factor (See Section 1.4)~~Summer peak coincidence factor.~~*
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[129]. 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**
R_{base}	Fixed	12	1
R_{insul}	Fixed	20	2
η_{Elec}	Fixed	0.97	3
T_{hot}	Fixed	120	5
$T_{ambient}$	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

[129] "Energy Savers", U.S. Department of Energy, accessed November, 2010 http://www.energysavers.gov/your_home/water_heating/index.cfm/mytopic=13070

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

Capacity (gal)	R_{base}	R_{insul}	A_{base} (ft^2)[130]	A_{insul} (ft^2)[131]	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

2.36.3 Measure Life

The measure life is 7 years[132].

[130] 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.

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

2.37 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.

2.37.1 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.

2.37.2 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.

$$\Delta kWh = \Delta hours/day \times Days_{Operating} \times kW_{pump}$$

$$\Delta kW_{peak} = (CF_{pre} - CF_{post}) \times kW_{pump}$$

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.

2.37.3 Definition of Terms

$\Delta hours/day$ = *The change in daily operating hours.*

kW_{pump} = *Electric demand of single speed pump at a given flow rate. This quantity should be measured or taken from Table 2-62*

CF_{pre} = *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*

[132] DEER Version 2008.2.05, December 16, 2008.

CF_{post} = 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.

$Days_{Operating}$ = 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
∆hours/day	Fixed	0	2
kW_{pump}	Fixed	See Table 2-62	Table 2-62
CF_{pre}	Fixed	0.27273527235	13 1
CF_{post}	Fixed	0	2
$Days_{Operating}$	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[133]. 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.

[133] “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>

Field Code Changed

Table 2-62: Single Speed Pool Pump Specification[134]

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

2.37.4 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.

2.37.5 Evaluation Protocol

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

[134] 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.

2.38 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.

2.38.1 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.

2.38.2 Algorithms

$\Delta kWh = kWh_{base} - kWh_{two\ speed}$

$\Delta kW_{peak} = (kW_{base} - kW_{two\ speed}) \times CF$

2.38.3 Definition of Terms

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

$kWh_{two\ speed}$ = Assumed annual kWh consumption for two speed pump motor in a cool climate

kW_{base} = 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)Demand Coincidence Factor for summer

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

Component	Type	Value	Source
kWh_{Base}	Fixed	707 kWh	1
$kWh_{Two\ Speed}$	Fixed	177 kWh	1
kW_{Base}	Fixed	1.364 kW	1
$kW_{Two\ Speed}$	Fixed	0.171 kW	1
$RHRS_{Base}$	Fixed	518	1 and 2
$RHRS_{Two\ Speed}$	Fixed	1,036	1 and 2
CF	Fixed	270.235%	13

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	0.31280 kW

2.38.4 Measure Life

The estimated useful life for a variable speed pool pump is 10 years.[135]

[135] Mid-Atlantic TRM, version 2.0. Prepared by Vermont Energy Investment Corporation. Facilitated and managed by the Northeast Energy Efficiency Partnerships. July 2011

2.39 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.

2.39.1 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.

2.39.2 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.

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

$$kWh_{base} = (h_{SS} \times kW_{SS}) \times Days/year$$

$$kWh_{VFD} = (h_{VFD} \times kW_{VFD}) \times Days/year$$

The demand reductions are obtained through the following formula:

$$\Delta kW_{peak} = kW_{base} - kW_{VFD}$$

$$kW_{base} = (CF_{SS} \times kW_{SS})$$

$$kW_{VFD} = (CF_{VFD} \times kW_{VFD})$$

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.

2.39.3 Definition of Terms

The parameters in the above equation are listed below.

H_{SS} = *Hours of operation per day for Single Speed Pump. This quantity should be recorded by the applicant.*

H_{VFD} = *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.*

W_{SS} = *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.*

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

CF_{SS} = *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.*

CF_{VFD} = *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
H_{SS}	Variable	Default: 5.18	2
H_{VFD}	Variable	Default: 13.00	2
Days/yr	Fixed	Default: 100	2
W_{SS}	Variable	EDC Data Gathering Default: See Table 2-66	1 and Table 2-66
W_{VFD}	Variable	EDC Data Gathering	EDC Data Gathering
CF_{SS}	Variable	Default: 0.2357	23
CF_{VFD}	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
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[136]. 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[137]

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

[136] "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>

[137] 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.

Field Code Changed

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:

$$Demand\ (W) = 0.0978f^2 + 10.989f + 10.281$$

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.

2.39.4 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 $\mathbf{CF_{VFD}}$.

2.39.5 Measure Life

According to an October 2008 report for the CA Database for Energy Efficiency Resources[138], a variable speed drive's lifespan is 10 years.

2.39.6 Evaluation Protocol

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

[138] DEER values, updated October 10, 2008 http://www.deeresources.com/deer0911planning/downloads/EUL_Summary_10-1-08.xls

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3 Commercial and Industrial Measures

The following section of the TRM contains savings protocols for commercial and industrial measures.

3.1 Baselines and Code Changes

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

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

3.2 Lighting Equipment Improvements

3.2.1 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.

3.2.2 Solid State Lighting

3.2.3 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:

3.2.4 For Act 129 energy efficiency measure savings qualification, for SSL products for which there is an ENERGY STAR commercial product category[139], the product shall meet the minimum ENERGY STAR requirements[140] [141] for the given product category. Products are not required to be on the ENERGY STAR Qualified Product List[142], 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:

3.2.5 Omni-directional: A, BT, P, PS, S, T

3.2.6 Decorative: B, BA, C, CA, DC, F, G

3.2.7 Directional: BR, ER, K, MR, PAR, R

3.2.8 Non-standard

3.2.9 Recessed, surface and pendant-mounted down-lights

3.2.10 Under-cabinet shelf-mounted task lighting

3.2.11 Portable desk task lights

3.2.12 Wall wash luminaires

3.2.13 Bollards

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[139] ENERGY STAR website for Commercial LED Lighting: http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=LTG

[140] "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

[141] "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

[142] ENERGY STAR Qualified LED Lighting list http://www.energystar.gov/index.cfm?fuseaction=ssl.display_products_res_html

3.2.14 **For SSL products for which there is not an ENERGY STAR commercial product category, but for which there is a DLC commercial product category[143], the product shall meet the minimum DLC requirements[144] for the given product category. Products are not required to be on the DLC Qualified Product List[145], 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:**

3.2.15 **Outdoor Pole or Arm mounted Area and Roadway Luminaires**

3.2.16 **Outdoor Pole or arm mounted Decorative Luminaires**

3.2.17 **Outdoor Wall-Mounted Area Luminaires**

3.2.18 **Parking Garage Luminaires**

3.2.19 **Track or Mono-point Directional Lighting Fixtures**

3.2.20 **Refrigerated Case Lighting**

3.2.21 **Display Case Lighting**

3.2.22 **2x2 Luminaires**

3.2.23 **2x2 Luminaires**

3.2.24 **High-bay and Low-bay fixtures for Commercial and Industrial buildings**

3.2.25 **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:**

3.2.26 **Manufacturer's product information sheet**

3.2.27 **LED package/fixture specification sheet**

3.2.28 **List the ENERGY STAR or DLC product category for which the luminaire qualifies**

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[143] 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

[144] Ibid.

[145] 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."

~~3.2.29 Summary table listing the minimum reference criteria and the corresponding product values for the following variables:~~

~~3.2.30 Light output in lumens~~

~~3.2.31 Luminaire efficacy (lm/W)~~

~~3.2.32 Color rendering index (CRI)~~

~~3.2.33 Correlated color temperature (CCT)~~

~~3.2.34 LED lumen maintenance at 6000 hrs~~

~~3.2.35 Manufacturer's estimated lifetime for L_{70} (70% lumen maintenance at end of useful life) (manufacturer should provide methodology for calculation and justification of product lifetime estimates)~~

~~3.2.36 Operating frequency of the lamp~~

~~3.2.37 IESNA LM-79-08 test report(s) (from approved labs specified in DOE Manufacturers' Guide) containing:~~

~~3.2.38 Photometric measurements (i.e. light output and efficacy)~~

~~3.2.39 Colorimetry report (i.e. CCT and CRI)~~

~~3.2.40 Electrical measurements (i.e. input voltage and current, power, power factor, etc.)~~

~~3.2.41 Lumen maintenance report (select one of the two options and submit all of its corresponding required documents):~~

~~3.2.42 Option 1: Compliance through component performance (for the corresponding LED package)~~

~~3.2.43 IESNA LM-80 test report~~

~~3.2.44 In-situ temperature measurements test (ISTMT) report.~~

~~3.2.45 Schematic/photograph from LED package manufacturer that shows the specified temperature measurement point (TMP)~~

~~3.2.46 Option 2: Compliance through luminaire performance~~

~~3.2.47 IESNA LM-79-08 report at 0 hours (same file as point c)~~

~~3.2.48 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).~~

~~3.2.49 All supporting documentation must include a specific, relevant model or part number.~~

3.2.503.2.2 Algorithms

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

ΔkW = kW_{base} - kW_{ee}

ΔkW_{peak} = ΔkW X CF X (1+IF demand)

ΔkWh = kWh_{base}[kW_{base} X(1+IF energy) X EFLH] – [kW_{ee} X(1+IF energy) X EFLH X (1 – SVG)]kWh_{ee}

kWh_{base} = kW_{base} X(1+IF energy) X HOU

kWh_{ee} = kW_{ee} 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.

3.2.513.2.3 Definition of Terms

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

kW_{base} = kW of baseline lighting as defined by project classification.

kW_{ee} = kW of post-retrofit or energy-efficient lighting system as defined in Section 3.2.5.

CF = Demand Coincidence Factor (See Section 1.4)

EFLH HOU = Equivalent Full Load 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).*

~~3.2.52~~3.2.4 Baseline Assumptions

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

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

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

~~**Program Year One**~~

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

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

~~Program Year Two~~

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

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

3.2.533.2.5 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 Section 3.2.23.2.2 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 types, and fixture configurations (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 3.2.23.2.2 "Algorithms", ∆kW values will be multiplied by the number of fixtures installed. The total ∆kW savings is derived by summing the total ∆kW for each installed measure.

Within a single project, to the extent there are different control strategies (SVG), hours of use (EFLHHOU), coincidence factors (CF) or interactive factors (IF), the ∆kW 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, EFLHHOU, CF and IF values for each line entry. The inventory will also specify the location and number of fixtures for reference and validation.

Appendix C was developed to automate the calculation of energy and demand impacts for retrofit lighting projects, based on a series of entries by the user defining key characteristics of the retrofit project. The main sheet, "Lighting Form", is a detailed line-by-line inventory incorporating variables in Section 6.2.1 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[146]. 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%[147] 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"

[146] 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.

[147] This value was agreed upon by the Technical Working Group convened to discuss updates to the TRM. This value is subject to adjustment for the 2012 Update based on implementation feedback during PY2 and PY3.

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.

~~3.2.54~~3.2.6 Quantifying Annual Hours of Operation

~~Projects with large impacts will typically include whole building lighting improvements in varying space types, which in turn may have different operating hours.~~

Projects with connected load savings less than ~~50~~20 kW

For ~~lighting~~ projects with connected load savings less than ~~50~~ 20 kW, applying the stipulated whole building hours ~~of use must be used as~~ shown in Table 3-4~~Table 3-5~~ is required. If the project cannot be described by the categories listed in Table 3-4~~Table 3-5~~, select the “other” category ~~must be used~~should be selected, with the hours and ~~. The proper EFLH for the “other” category will be determined~~determine hours using ~~by~~ facility staff interviews, posted schedules, ~~either logging~~ or metered data~~other suitable documentation~~.

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 ~~50~~20 kW or higher

For projects with connected load savings of ~~50~~ 20 kW or higher, ~~additional detail is required. For large projects, the likelihood that all fixtures do not behave uniformly is high. Therefore, the project must~~fixtures should be separated into "usage groups" that~~, or groupings of fixtures~~ exhibit~~ing~~ 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 ~~The number of usage groups recommended is determined by facility type per Table 3-1[148]. EFLH~~hours of use values should~~must~~ be estimated for each group using~~by~~ Table 3-4~~Table 3-5~~, facility staff interviews, posted schedules, or metered data ~~supplemented by either logging or stipulated values from Table 3-2~~.

~~[148] To the extent that retrofits are not comprehensive, are narrow and focused for usage groups, and are not the typical diversity in retrofit projects, the implementer can use fewer usage groups that reflect the actual diversity of use.~~

Metered data is required in casesfor 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 , or 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 evaluators. Facility interviews must first identify the usage group in which each fixture qualifies. Then either results from logging or Table 3-2 will determine the appropriate EFLH for each usage group. Where participants disagree with stipulated values[149] or the appropriate facility type and/or space type is not listed in Table 3-2, logging hours is appropriate.

Coincidence factors are not stipulated by usage group and instead inherit the CF value from the whole building table (Table 3-5).[150]

Table 3-1: Usage Groups Recommended per Building Type[151]

Field Code Changed

Field Code Changed

Building Type	**Recommended Number of Usage Groups[152]**	**Examples of Usage Group types**
Office Buildings	6	General offices, private offices, hallways, restrooms, conference, lobbies, 24-hr
Education (K-12)	6	Classrooms, offices, hallways, restrooms, admin, auditorium, gymnasium, 24-hr
Education (College/University)	6	Classrooms, offices, hallways, restrooms, admin, auditorium, library, dormitory, 24-hr
Hospitals/ Health Care Facilities	8	Patient rooms, operating rooms, nurses station, exam rooms, labs, offices, hallways
Retail Stores	5	Sales floor, storeroom, displays, private office, 24-hr
Industrial/ Manufacturing	6	Manufacturing, warehouse, shipping, offices, shops, 24-hr
Other	Variable	All major usage groups within building

[149] The initial Table 3-2 was set forth by an EM&V contractor, purported to be from California DEER. Due to comments received, TWG will perform further review of these values and recommend any needed revisions for the following update to the TRM.
[150] Similar to EFLHH, there is also reason for the coincidence factor to vary by usage group as opposed to assuming a single factor for the entire facility. Due to time constraints, the described approach should be followed for the current program year. The TWG will review and recommend an appropriate solution to resolving this issue.
[151] CenterPoint Energy Program Manual v4.0
[152] EDC's have the option to provide additional data in support of different numbers of lighting hours of use sub-groups on a case by case basis.

Table 3-2: Hours of Use for Usage Groups

Field Code Changed

Field Code Changed

Building Type	Usage Group	Equivalent Full Load Hours
Education - Primary School	Classroom/Lecture	2445
Education - Primary School	Exercising Centers and Gymnasium	2051
Education - Primary School	Dining Area	1347
Education - Primary School	Kitchen and Food Preparation	1669
Education - Secondary School	Classroom/Lecture	2445
Education - Secondary School	Office (General)	2323
Education - Secondary School	Exercising Centers and Gymnasium	2366
Education - Secondary School	Computer Room (Instructional/PC Lab)	2137
Education - Secondary School	Dining Area	2365
Education - Secondary School	Kitchen and Food Preparation	1168
Education - Community College	Classroom/Lecture	2471
Education - Community College	Office (General)	2629
Education - Community College	Computer Room (Instructional/PC Lab)	2189
Education - Community College	Comm/Ind Work (General, Low Bay)	3078
Education - Community College	Dining Area	2580
Education - Community College	Kitchen and Food Preparation	2957
Education - University	Classroom/Lecture	2522
Education - University	Office (General)	2870
Education - University	Computer Room (Instructional/PC Lab)	2372
Education - University	Comm/Ind Work (General, Low Bay)	3099
Education - University	Dining Area	2963
Education - University	Kitchen and Food Preparation	3072
Education - University	Hotel/Motel Guest Room (incl. toilets)	1196
Education - University	Corridor	2972
Grocery	Retail Sales, Grocery	4964
Grocery	Office (General)	4526
Grocery	Comm/Ind Work (Loading Dock)	4964
Grocery	Refrigerated (Food Preparation)	4380
Grocery	Refrigerated (Walk-in Freezer)	4380

Building Type	Usage Group	Equivalent Full Load Hours
Grocery	Refrigerated (Walk-in Cooler)	4380
Hospitals	Office (General)	4873
Hospitals	Dining Area	5858
Hospitals	Kitchen and Food Preparation	5858
Hospitals	Medical and Clinical Care	5193
Hospitals	Laboratory, Medical	4257
Hospitals	Medical and Clinical Care	5193
Manufacturing - Light Industrial	Comm/Ind Work (General, High Bay)	3068
Manufacturing - Light Industrial	Storage (Unconditioned)	3376
Office - Large	Office (Open Plan)	2641
Office - Large	Office (Executive/Private)	2641
Office - Large	Corridor	2641
Office - Large	Lobby (Office Reception/Waiting)	2692
Office - Large	Conference Room	2692
Office - Large	Copy Room (photocopying equipment)	2692
Office - Large	Restrooms	2692
Office - Large	Mechanical/Electrical Room	2692
Office - Small	Office (Executive/Private)	2594
Office - Small	Corridor	2594
Office - Small	Lobby (Office Reception/Waiting)	2594
Office - Small	Conference Room	2594
Office - Small	Copy Room (photocopying equipment)	2594
Office - Small	Restrooms	2594
Office - Small	Mechanical/Electrical Room	2594
Restaurant - Sit-Down	Dining Area	4836
Restaurant - Sit-Down	Lobby (Main Entry and Assembly)	4836
Restaurant - Sit-Down	Kitchen and Food Preparation	4804
Restaurant - Sit-Down	Restrooms	4606
Restaurant - Fast-Food	Dining Area	4850
Restaurant - Fast-Food	Lobby (Main Entry and Assembly)	4850
Restaurant - Fast-Food	Kitchen and Food Preparation	4812
Restaurant - Fast-Food	Restrooms	4677
Retail - 3-Story Large	Retail Sales and Wholesale Showroom	3546
Retail - 3-Story Large	Storage (Conditioned)	2702

Building Type	Usage Group	Equivalent Full Load Hours
Retail - 3-Story Large	Office (General)	2596
Retail - Single-Story Large	Retail Sales and Wholesale Showroom	4454
Retail - Single-Story Large	Storage (Conditioned)	2738
Retail - Single-Story Large	Office (General)	2714
Retail - Single-Story Large	Auto Repair Workshop	3429
Retail - Single-Story Large	Kitchen and Food Preparation	3368
Retail - Small	Retail Sales and Wholesale Showroom	3378
Retail - Small	Storage (Conditioned)	2753
Storage - Conditioned	Storage (Conditioned)	3441
Storage - Conditioned	Office (General)	3441
Storage - Unconditioned	Storage (Unconditioned)	3441
Storage - Unconditioned	Office (General)	3441

3.2.553.2.7 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 as the baseline demand (kW_{base}) and the new fixtures' wattages and fixtures as the post-installation wattagedemand (kW_{ee}). Pursuant towattage. The baseline, pursuant to ASHRAE 90.1-2007, the interior lighting baseline is can be calculated using either the ASHRAE 90.1-2007 Building Area Method[153] (Table 9.5.1) as shown in Table 3-3Table 3-1, or the ASHRAE 90.1-2007 Space-by-Space Method[154] (Table 9.6.1) as shown in Table 3-2 for interior lighting. For exterior lighting, the baseline The baseline can beisbe calculated using and the ASHRAE 90.1-2007 Baseline Exterior Lighting Power Densities[155] Table as Table 9.4.5 as shown in Table 3-3Table 3-5 for exterior lighting. The new fixture wattages are specified in the Lighting Audit and Design Tool shown in Appendix C.

EFLHHOU, 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..

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

[153] ASHRAE 90.1-2007, Table 9.5.1 – Building Area Method
[154] ASHRAE 90.1-2007, Table 9.6.1 – Space-by-Space Method
[155] ASHRAE 90.1-2007, Table 9.4.5 – Baseline Exterior Lighting Power Densities

Table 3-3: Lighting Power Densities from ASHRAE 90.1-2007 Building Area Method[156]

Table 3-1: Lighting Power Densities from ASHRAE 90.1-2007 Building Area Method[157]

Field Code Changed

Field Code Changed

Building Area Type[158]	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	01.2
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

[156] ASHRAE 90.1-2007, "Table 9.5.1 Lighting Power Densities Using the Building Area Method."
[157] ASHRAE 90.1-2007, "Table 9.5.1 Lighting Power Densities Using the Building Area Method."
[158] In cases where both a common space type and a building specific type are listed, the building specific space type shall apply.

Table 3-23-4: Lighting Power Densities from ASHRAE 90.1-2007 Space-by-Space Method[159]

Common Space Type[160]	**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

[159] ASHRAE 90.1-2007, "Table 9.6.1 Lighting Power Densities Using the Space-by-Space Method."
[160] In cases where both a common space type and a building specific type are listed, the building specific space type shall apply.

Common Space Type[160]	LPD (W/ft2)	Building Specific Space Types	LPD (W/ft2)
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[161]

Building Exterior	**Space Description**	**LPD**
Uncovered Parking Area	Parking Lots and Drives	0.15 W/ft^2
Building Grounds	Walkways less than 10 ft wide	1.0 W/linear foot
	Walkways 10 ft wide or greater	0.2 W/ft^2
	Plaza areas	
	Special feature areas	
	Stairways	1.0 W/ft^2
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/ft^2
Outdoor sales	Open areas (including vehicle sales lots)	0.5 W/ft^2
	Street frontage for vehicle sales lots in addition to "open area" allowance	20 W/linear foot
Building facades		0.2 W/ft^2 for each 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/ft^2 of uncovered area
Loading areas for law enforcement, fire, ambulance, and other emergency service vehicles		0.5 W/ft^2 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

[161] ASHRAE 90.1-2007 Table 9.4.5

Prescriptive Lighting Improvements

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

The baseline is the existing ~~fluorescent~~ fixtures with the existing lamps and ballast as defined in Appendix C~~Lighting Audit and Design Tool shown in Appendix C~~. Other factors required to calculate savings are shown in Table 3-4 and Table 3-5. Note that if ~~EFLH~~ 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 ~~EFLH~~ 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~~3-5~~: Lighting ~~EFLH~~ HOU and CF by Building Type or Function

Building Type	~~EFLH~~HOU	CF[162]	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[163]	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[164]	1.00	1
Light Manufacturing (Assy)	2,610	0.77*	5
Manufacturing – Light Industrial	4,290	0.63	1

[162] 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.
[163] Average of NJ Clean Energy from JCP&L data and 2004-2005 DEER update study (December 2005).
[164] To be used only for lights illuminated on a continuous basis.

Building Type	EFLHHOU	CF[162]	Source
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
Dusk-to-Dawn Lighting	4,300	0.00	1
24/7 Facilities or Spaces	8,760	1.00	N/A
Other[165]	As MeasuredVaries	As	1

* Coincidence Factors were not agreed upon prior to release of this document in January 2011. 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
   a. California Public Utility Commission. *Database for Energy Efficiency Resources,* 2005
   b. RLW Analytics, *Coincident Factor Study, Residential and Commercial & Industrial Lighting Measures*, 2007.
   c. 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

[165] To be used only when no other category is applicable. Hours of operation must be documented by facility staff interviews, posted schedules, or metered databuilding facility staff interviews or logging hours of use. The SWE reserves the right to require logging hours of use groups for evaluation purposes.

d. 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
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~~3-6~~: Interactive Factors and Other Lighting Variables

Component	Type	Value	Source
IF_{demand}	Fixed	Cooled space (68 °F – 79 °F) = 0.34 Freezer spaces (-20 °F – ~~0~~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	1
IF_{energy}	Fixed	Cooled space (68 °F – 79 °F) = 0.12 Freezer spaces (-20 °F – ~~0~~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	1
kW_{base}	Variable	See Standard Wattage Table in Appendix C	2
kW_{inst}	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. include HID controls, daylight dimmer systems, occupancy sensors, and occupancy controlled hi-low controls for fluorescent fixtures. The measurement of energy savings is based on algorithms with key variables (e.g. coincidence factor, equivalent full load hours 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 fluorescent fixtures with the existing lamps and ballasts or, if retrofitted, new fluorescent fixtures with new lamps and ballasts as defined in Lighting Audit and Design Tool shown in Appendix C. In either case, the kW_{inst} for the purpose of the algorithm is set to kW_{base}.

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 3-63-7: Lighting Controls Assumptions

Component	Type	Value	Source
kW_{base}	Variable	Lighting Audit and Design Tool in Appendix C	1
kW_{inst}	Variable	Lighting Audit and Design Tool in Appendix C	1
SVG	Fixed	Occupancy Sensor, Controlled Hi-Low Fluorescent Control and controlled HID = 30%[166] Daylight Dimmer System=50%[167]	2 and 3
		Based on metering	EDC Data Gathering
CF	Variable	By building type and size	See Table 3-4
EFLHHOU	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 Vermont168.

[166] Subject to verification by EDC Evaluation or SWE
[167] Subject to verification by EDC Evaluation or SWE

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 3-73-8: Assumptions for LED Traffic Signals

Component	Type	Value	Source
∆kW	Variable	See Table 3-87	PECO
CF	Red Round	55%	PECO
	Yellow Round	2%	
	Round Green	43%	
	Turn Yellow	8%	
	Turn Green	8%	
	Pedestrian	100%	
EFLHHOU	Variable	See Table 3-87	PECO
IF	Fixed	0	

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[168] This reference cannot be validated and is rooted in the NJ Clean Energy Program Protocols to Measure Resource Savings dated 12/23/2004

Table 3-83-9: LED Traffic Signals[169]

Type	Wattage	% Burn	EFLHHOU	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.						

[169] Source: PECO Comments on the PA TRM, received March 30, 2009.

Table 3-93-10: Reference Specifications for Above Traffic Signal Wattages

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

LED Exit Signs

This measure includes the early replacement of existing incandescent or fluorescent exit signs with a new LED exit sign. If the exit signs match those listed in Table 3-10, The 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

$\Delta kWh = 176\ kWh$

$\Delta kW_{peak} = 0.024\ kW$

Dual-Sided LED Exit Signs replacing Incandescent Exit Signs

$\Delta kWh = 353\ kWh$

$\Delta kW_{peak} = 0.048\ kWh$

Single-Sided LED Exit Signs replacing Fluorescent Exit Signs

$\Delta kWh = 69\ kWh$

$\Delta kW_{peak} = 0.009\ kW$

Dual-Sided LED Exit Signs replacing Fluorescent Exit Signs

$\Delta kWh = 157\ kWh$

$\Delta kW_{peak} = 0.021\ kW$

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

Table 3-103-11: 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
EFLHHOU	Fixed	8760	1
IF_{energy}	Fixed	Cooled Space: 0.12	Table 3-6
IF_{demand}	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.

3.3 Premium Efficiency Motors

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

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

3.3.1 Algorithms

From AEPS application form or EDC data gathering calculate ∆kW where:

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

$\Delta kW_{peak} = kW_{base} - kW_{ee}$

$kWh_{base} = 0.746 \times HP \times LF/\eta_{base} \times RHRS$

$kWh_{ee} = 0.746 \times HP \times LF/\eta_{ee} \times RHRS$

$\Delta kW_{peak} = kW_{base} - kW_{ee}$

$kW_{base} = 0.746 \times HP \times LF/\eta_{base} \times CF$

$kW_{ee} = 0.746 \times HP \times LF/\eta_{ee} \times CF$

3.3.2 Definition of Terms

HP = Rated horsepower of the baseline motor 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)[170]

η_{base} = Efficiency of the baseline motor

[170] 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.

η_{ee}	= *Efficiency of the energy-efficient motor*
RHRS	= *Annual run hours of the motor*
CF	= *Demand Coincidence Factor (See Section 1.4)*

3.3.3 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.~~Each motor and the respective variables required to calculate the demand and energy savings for that motor will be entered into an inventory in Excel format, the Motor & Variable Frequency Drive (VFD) Inventory Form. The inventory will also specify the location for reference and validation. A sample of the Motor & VFD Inventory Form incorporating the algorithms for savings calculation is included in Appendix D.~~

Table 3-113-12: Building Mechanical System Variables for Premium Efficiency Motor Calculations

Component	Type	Value	Source
HP	Variable	Nameplate	EDC Data Gathering
RHRS[171]	Variable	Based on logging and modeling	EDC Data Gathering
		Default Table 3-14	From Table 3-14
LF[172]	Variable	Based on spot metering[173]	EDC Data Gathering
		Default 75%	1
η_{base}	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.
η_{ee}	Variable	Nameplate	EDC Data Gathering
CF[174]	Variable	Single Motor Configuration: 74% Duplex Motor Configuration: 37%	1

Sources:

171 Default Value can be used by EDC but is subject to metering and adjustment by evaluators or SWE
172 Default Value can be used by EDC but is subject to metering and adjustment by evaluators or SWE
173 See definition in section 3.3.2 for specific algorithm to be used when performing spot metering analysis to determine alternate load factor.
174 Need to confirm source through TWG

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

Table 3-123-13: Baseline Motor Nominal Efficiencies for PY1 and PY2[175]

	Open Drip Proof (ODP) # of Poles			Totally Enclosed Fan-Cooled (TEFC) # of Poles		
	6	**4**	**2**	**6**	**4**	**2**
	Speed (RPM)			Speed (RPM)		
Size HP	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%

[175] 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

Table 3-133-14: Baseline Motor Nominal Efficiencies for PY3 and PY4[176]

	Open Drip Proof (ODP) # of Poles			Totally Enclosed Fan-Cooled (TEFC) # of Poles		
	6	4	2	6	4	2
	Speed (RPM)			Speed (RPM)		
Size HP	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%

[176] 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

Table 3-143-15: Stipulated Hours of Use for Motors in Commercial Buildings

Building Type	Motor Usage Group	RHRS[177]
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

[177] Operating hours subject to adjustment with data provided by EDCs and accepted by SWE

Building Type	Motor Usage Group	RHRS[177]
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 PumpAll	2170As Measured
	Heating Hot Water Pump	49594959
	Condenser Water Pump	21702901
	HVAC Fan	52366702
	Cooling Tower Fan	10321032
	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 3-153-16: Notes for Stipulated Hours of Use Table

Motor Usage Group	Method of Operating Hours Calculation
Chilled Water Pump	Hours when ambient temperature is above 60°F during building operating hours
Heating Hot Water Pump	Hours when ambient temperature is below 60°F during all hours
Condenser Water Pump	Hours when ambient temperature is above 60°F during building operating hours
HVAC Fan	Operating hours plus 20% of unoccupied hours
Cooling Tower Fan	Cooling EFLH according to EPA 2002[178] (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

3.3.4 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.

[178] http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls

3.4 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: HVAC fans, cooling tower fans, chilled water pumps, condenser water pumps and hot water pumps. This protocol estimates savings relative to a constant volume system as the baseline condition. The baseline condition is a motor without a VFD control. The efficient condition is a motor with a VFD control.

VFDs in any other application than those referenced Table 3-18 must follow a custom measure protocol, including industrial applications. Relative to HVAC fans, the protocol applies to conventional variable air volume (VAV) systems with terminal VAV boxes on the supply registers. A VAV system without terminal VAV boxes is subject to various control strategies and system configurations and must be evaluated using the custom approach. For systems in which the baseline condition is not a constant volume system (e.g. vortex dampers), a custom measure protocol must be used[179]. When changes in run hours are anticipated in conjunction with the installation of a VFD, a custom path must also be used.

3.4.1 Algorithms

ΔkWh = $0.746 \times HP \times LF / \eta_{motor} \times RHRS_{base} \times ESF$ $kWh_{base} - kWh_{ee}$

ΔkW_{peak} = $0.746 \times HP \times LF / \eta_{motor} \times CF \times DSF$

$kW_{base} - kW_{ee}$

kWh_{base} = $0.746 \times HP \times LF/\eta_{motor} \times RHRS_{base}$

kWh_{ee} = $kWh_{base} \times ESF$

kW_{base} = $0.746 \times HP \times LF/\eta_{motor} \times CF$

kW_{ee} = $kW_{base} \times DSF$

3.4.2 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.*[180]

[179] Currently, the protocol is modeled against a constant volume system. Therefore, using a baseline system that is not a constant volume system is an inappropriate use of this protocol. Additional models are in development by the TWG in order to accommodate additional baseline systems, including vortex dampers and other non-constant volume systems that still benefit from VFD applications, to be included in a future update of the TRM.

[180] 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.

η_{motor}	= 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.
$RHRS_{base}$	= Annual run hours of the baseline motor
CF	= Demand Coincidence Factor (See Section 1.4)
ESF	= Energy Savings Factor. The energy savings factor is the percent of baseline of kWh consumption anticipated to occur as a result of the installation of the VFD (See Table 3-18). This factor can also be computed according to fan and pump affinity laws by modeling the flow reduction and related efficiency factors for both the motor and VFD under different load conditions. Hourly temperature bin data is used for this purpose.[181] Percent of baseline energy consumption saved by installing VFD.
DSF	= Demand Savings Factor. The demand savings factor is calculated by determining the ratio of the power requirement for the baseline and the VFD control at peak conditions (See Table 3-18). Since systems are customarily sized to 95% of cooling conditions and the peak 100 hours load represent a loading condition of 99%, and because VFDs are not 100% efficient, the demand savings for VFDs is relatively low for commercial HVAC applications where system loads tracks cooling requirements (DSF approaches 1).[182] Percent of baseline demand saved by installing VFD

3.4.3 Description of Calculation Method

Relative to the algorithms in section (3.4.1), ∆kW values will be calculated for each VFD improvement in any project (account number). Each motor and the respective variables required to calculate the demand and energy savings for that motor will be entered into an inventory in Excel format, the Motor & VFD Inventory Form. The inventory will also specify the location for reference and validation. A sample of the Motor & VFD Inventory Form incorporating the algorithms for savings calculation is included in Appendix D.

[181] Based on optimum control strategies implemented tracking heating and cooling load.
[182] Based on optimum control strategies implemented tracking heating and cooling load.

Table 3-163-17: Variables for VFD Calculations

Component	Type	Value	Source
Motor HP	Variable	Nameplate	EDC Data Gathering
RHRS[183]	Variable	Based on logging and modeling	EDC Data Gathering
		Table 3-14	See Table 3-14
LF[184]	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 - η_{base}	Fixed	Nameplate	EDC Data Gathering
CF[185]	Fixed	74%	1

Sources:

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

Table 3-173-18: ESF and DSF for Typical Commercial VFD Installations[186]

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

183 Default Value can be used by EDC but is subject to metering and adjustment by evaluators or SWE
184 Default Value can be used by EDC but is subject to metering and adjustment by evaluators or SWE
185 Need to confirm source through TWG
186 Mid-Atlantic TRM Version 2.0, July 2011. Page 174.

NOTE FOR TABLE 3-18
1. Back-up calculations and reference material can be found on the PA PUC website at the following address: http://www.puc.state.pa.us/electric/xls/Act129/TRM-ESF-DSF_Worksheet.xls

3.4.4 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.**Sources:**

Motor Inventory Workbook, PA Technical Working Group

3.5 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.

3.5.1 Algorithms

$\Delta kWh = 0.129 \text{ X } HP \text{ X } LF/\eta_{motor} \text{ X } RHRS_{base}$

$\Delta kW = 0.129 \text{ X } HP$

$\Delta kW_{peak} = 0.106 \text{ X } HP$

3.5.2 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.[187]

η_{base} = Efficiency of the baseline motor

RHRS = Annual run hours of the motor

CF = Demand Coincidence Factor (See Section 1.4)

[187] 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.

Table 3-183-19: Variables for Industrial Air Compressor Calculation

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

Sources:

1. Aspen Systems Corporation, Prescriptive Variable Speed Drive Incentive Development Support for Industrial Air Compressors, Executive Summary, June 20, 2005.[188]

[188] The basis for these factors has not been determined or independently verified.

3.6 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.

3.6.1 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 ΔkW_{peak} using 11.3/13 as the conversion factor.

$\Delta kWh = (BtuH_{cool} / 1000) \times (1/EER_{base} - 1/EER_{ee}) \times EFLH_{cool}$

$= (BtuH_{cool} / 1000) \times (1/SEER_{base} - 1/SEER_{ee}) \times EFLH_{cool}$

$\Delta kW_{peak} = (BtuH_{cool} / 1000) \times (1/EER_{base} - 1/EER_{ee}) \times CF$

Air Source and Packaged Terminal Heat Pump (includes air source HP, packaged terminal HP, water source HP, ground source HP and groundwater source HP).

For ASHP units < 65,000 BtuH, use SEER instead of EER to calculate ΔkWh_{cool} and HSPF instead of COP to calculate ΔkWh_{heat}. Convert SEER to EER to calculate ΔkW_{peak} using 11.3/13 as the conversion factor.

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

$\Delta kWh_{cool} = (BtuH_{cool} / 1000) \times (1/EER_{base} - 1/EER_{ee}) \times EFLH_{cool}$

$= (BtuH_{cool} / 1000) \times (1/SEER_{base} - 1/SEER_{ee}) \times EFLH_{cool}$

$\Delta kWh_{heat} = (BtuH_{heat} / 1000) / 3.412 \times (1/COP_{base} - 1/COP_{ee}) \times EFLH_{heat}$

$= (BtuH_{heat} / 1000) \times (1/HSPF_{base} - 1/HSPF_{ee}) \times EFLH_{heat}$

$\Delta kW_{peak} = (BtuH_{cool} / 1000) \times (1/EER_{base} - 1/EER_{ee}) \times CF$

$= (BtuH_{cool} / 1000) \times (1/SEER_{base} - 1/SEER_{ee}) \times CF$

3.6.2 Definition of Terms

$BtuH_{cool}$ = *Rated cooling capacity of the energy efficient unit in $BtuH_{cool}$ /hour*

$BtuH_{heat}$ = *Rated heating capacity of the energy efficient unit in $BtuH_{heat}$ /hour*

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

EER_{ee}	= Efficiency rating of the energy efficiency unit. For air-source AC and ASHP units < 65,000 BtuH, SEER should be used for cooling savings.
$SEER_{base}$	= Seasonal efficiency rating of the baseline unit. For units > 65,000 BtuH, EER should be used for cooling savings.
$SEER_{ee}$	= Seasonal efficiency rating of the energy efficiency unit. For units > 65,000 BtuH, EER should be used for cooling savings.
COP_{base}	= Efficiency rating of the baseline unit. For ASHP units < 65,000 BtuH, HSPF should be used for heating savings.
COP_{ee}	= Efficiency rating of the energy efficiency unit. For ASHP units < 65,000 BtuH, HSPF should be used for heating savings.
$HSPF_{base}$	= Heating seasonal performance factor of the baseline unit. For units > 65,000 BtuH, COP should be used for heating savings.
$HSPF_{ee}$	= 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)
$EFLH_{cool}$	= Equivalent Full Load Hours for the cooling season – The kWh during the entire operating season divided by the kW at design conditions.
$EFLH_{heat}$	= 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~~3-20~~: Variables for HVAC Systems

Component	Type	Value	Source
BtuH	Variable	Nameplate data (AHRI or AHAM)	EDC's Data Gathering
EER_{base}	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
EER_{ee}	Variable	Nameplate data (AHRI or AHAM)	EDC's Data Gathering
$SEER_{base}$	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
$SEER_{ee}$	Variable	Nameplate data (AHRI or AHAM)	EDC's Data Gathering
COP_{base}	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
COP_{ee}	Variable	Nameplate data (AHRI or AHAM)	EDC's Data Gathering
$HSPF_{base}$	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
$HSPF_{ee}$	Variable	Nameplate data (AHRI or AHAM)	EDC's Data Gathering
CF	Fixed	~~67%~~80%	2~~Engineering estimate~~[189]
$EFLH_{cool}$	Variable	Based on Logging or Modeling	EDC's Data Gathering
		Default values from Table 3-21 ~~and Table 3-23~~	See Table 3-21 ~~and Table 3-23~~
$EFLH_{heat}$	Variable	Based on Logging or Modeling	EDC's Data Gathering
		Default values from ~~Table 3-22 and~~ Table 3-22	See ~~Table 3-22 and~~ Table 3-22

Sources:

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

~~[189] Modification to CF to be addressed through Technical Working Group~~

~~1.~~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~~3-21~~: HVAC Baseline Efficiencies[190]

Equipment Type and Capacity	Cooling Baseline	Heating Baseline
Air-Source Air Conditioners		
< ~~5.41 tons~~65,000 BtuH	13.0 SEER	N/A
≥ ~~5.41 tons~~65,000 BtuH and <~~11.25 tons~~135,000 BtuH	11.2 EER	N/A
≥ ~~11.25~~135,000 BtuH ~~tons~~ and < ~~20.00 tons~~240,000 BtuH	11.0 EER	N/A
≥ ~~20.00 tons~~240,000 BtuH and < ~~63.33~~760,000 BtuH ~~tons~~ (IPLV for units with capacity-modulation only)	10.0 EER / 9.7 IPLV	N/A
≥ ~~63.33 tons~~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~~< 5.41 tons~~	12.1 EER	N/A
> 65,000 BtuH and <135,000 BtuH~~≥ 5.41 tons and < 11.25 tons~~	11.5 EER	N/A
> 135,000 BtuH and < 240,000 BtuH~~≥ 11.25 tons and < 20.00 tons~~	11.0 EER	N/A
≥ ~~20.00 tons~~240,000 BtuH	11.5 EER	N/A
Air-Source Heat Pumps		
< 65,000 BtuH~~< 5.41 tons~~	13 SEER	7.7 HSPF
> 65,000 BtuH and <135,000 BtuH~~≥ 5.41 tons and < 11.25 tons~~	11.0 EER	3.3 COP
> 135,000 BtuH and < 240,000 BtuH~~≥ 11.25 tons and < 20.00 tons~~	10.6 EER	3.2 COP
≥ ~~20.00 tons~~240,000 BtuH (IPLV for units with capacity-modulation only)	9.5 EER / 9.2 IPLV	3.2 COP
Water-Source Heat Pumps		
< ~~1.42 tons~~17,000 BtuH	11.2 EER	4.2 COP
≥ 17,000 BtuH~~.42 tons~~ and ≤ ~~5.41 tons~~135,000 BtuH	12.0 EER	4.2 COP
Ground Water Source Heat Pumps		
< ~~11.25 tons~~135,000 BtuH	16.2 EER	3.6 COP
Ground Source Heat Pumps		
< 135,000 BtuH~~< 11.25 tons~~	13.4 EER	3.1 COP
Packaged Terminal Systems (Replacements)[191]		
PTAC (cooling)	10.9 - (0.213 x Cap /	

[190] Baseline values from IECC 2009, after Jan 1, 2010 or Jan 23, 2010 as applicable.

[191] 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.

Equipment Type and Capacity	Cooling Baseline	Heating Baseline
	1000) x EER	
PTHP	10.8 - (0.213 x Cap / 1000) x EER	2.9 - (0.026 x Cap / 1000) COP
Packaged Terminal Systems (New Construction)[192]		
PTAC (cooling)	12.5 - (0.213 x Cap / 1000) x EER	
PTHP	12.3 - (0.213 x Cap / 1000) x EER	3.2 - (0.026 x Cap / 1000) x COP

Table 3-213-22: Cooling and Heating EFLH for Erie, Harrisburg, and PittsburghPennsylvania Cities[193]

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

[192] 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.

[193] US Department of Energy. Energy Star Calculator and Bin Analysis Models

Space and/or Building Type	Allentown	Erie	Harrisburg	Pittsburgh	Williamsport	Philadelphia	Scranton
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 3-223-23: Cooling and Heating EFLH for Williamsport, Philadelphia and ScrantonPennsylvania Cities[194]

Space and/or Building Type	Williams port	Philadelphia			Scranton		
Space and/or Building Type	AllentownCooling EFLH	ErieHeating EFLH	HarrisburgCooling EFLH	PittsburghHeating EFLH	WilliamsportCooling EFLH	Heating EFLHPhiladelphia	Scranton
Arena/Auditorium/Convention Center	1,7194 54	2,0021 ,726	1,6367 11	1,6421 ,606	1,7264 28	1,6061 ,747	1,747
College: Classes/Administrative	1,5595 20	1,8151 ,565	1,4848 15	1,4891 ,457	1,5654 90	1,4571 ,584	1,584
Convenience Stores	60391 7	3,1482 ,715	2,5731 ,436	2,5822 ,526	2,7158 64	2,5262 ,747	2,747
Dining: Bar Lounge/Leisure	1,1566 88	1,3461 ,161	1,1001 ,077	1,1041 ,080	1,1616 48	1,0801 ,175	1,175
Dining: Cafeteria / Fast Food	58292 5	2,0661 ,782	1,6891 ,449	1,6951 ,658	1,7828 72	1,6581 ,803	1,803
Dining: Restaurants	1,1566 88	1,3461 ,161	1,1001 ,077	1,1041 ,080	1,1616 48	1,0801 ,175	1,175
Gymnasium/Performing Arts Theatre	1,5595 20	1,8151 ,565	1,4848 15	1,4891 ,457	1,5654 90	1,4571 ,584	1,584
Hospitals/Health care	2761,0 52	32127 7	2631,6 48	2642,5 26	27799 2	2,5262 80	280
Industrial: 1 Shift/Light Manufacturing	1,4915 48	1,7371 ,498	1,4208 59	1,4251 ,394	1,4985 17	1,3941 ,516	1,516
Industrial: 2 Shift	1,0177 45	1,1841 ,022	9681,1 66	97295 1	1,0227 02	9511,0 34	1,034
Industrial: 3 Shift	53894 4	62654 0	5121,4 78	51350 2	54088 9	50254 6	546
Lodging: Hotels/Motels/Dormitories	1,4385 71	1,6751 ,444	1,3698 94	1,3741 ,344	1,4445 38	1,3441 ,462	1,462
Lodging: Residential	1,4385 71	1,6751 ,444	1,3698 94	1,3741 ,344	1,4445 38	1,3441 ,462	1,462
Multi-Family (Common Areas)	2771,0 52	3,1482 ,715	2,5731 ,647	2,5822 ,526	2,7159 91	2,5262 ,747	2,747

[194] US Department of Energy. Energy Star Calculator and Bin Analysis Models

Space and/or Building Type	Williams port		Philadelphia		Scranton		
Space and/or Building Type	AllentownCooling EFLH	ErieHeating EFLH	HarrisburgCooling EFLH	PittsburghHeating EFLH	WilliamsportCooling EFLH	Heating EFLHPhiladelphia	Scranton
Museum/Library	1,2666 42	1,4741 ,271	1,2051 ,005	1,2091 ,183	1,2716 05	1,1831 ,286	1,286
Nursing Homes	73886 1	3,1482 ,715	2,5731 ,348	2,5822 ,526	2,7158 11	2,5262 ,747	2,747
Office: General/Retail	1,2666 42	88476 2	7221,0 05	72570 9	76260 5	70977 1	771
Office: Medical/Banks	1,2666 42	1,4741 ,271	1,2051 ,005	1,2091 ,183	1,2716 05	1,1831 ,286	1,286
Parking Garages & Lots	1,1107 07	1,2921 ,114	1,0561 ,107	1,0601 ,037	1,1146 66	1,0371 ,128	1,128
Penitentiary	82982 3	3,1482 ,715	2,5731 ,289	2,5822 ,526	2,7157 75	2,5262 ,747	2,747
Police/Fire Stations (24 Hr)	2771,0 52	3,1482 ,715	2,5731 ,647	2,5822 ,526	2,7159 91	2,5262 ,747	2,747
Post Office/Town Hall/Court House	1,2666 42	1,4741 ,271	1,2051 ,005	1,2091 ,183	1,2716 05	1,1831 ,286	1,286
Religious Buildings/Church	1,7184 54	2,0011 ,725	1,6357 11	1,6411 ,605	1,7254 28	1,6051 ,746	1,746
Retail	1,1886 74	1,3831 ,193	1,1301 ,055	1,1351 ,110	1,1936 35	1,1101 ,207	1,207
Schools/University	1,6614 78	98484 9	80574 9	80879 0	84945 1	79085 9	859
Warehouses (Not Refrigerated)	53852 2	56748 9	46381 7	46545 5	48949 2	45549 5	495
Warehouses (Refrigerated)	1,5555 22	1,8101 ,561	1,4808 17	1,4851 ,453	1,5614 92	1,4531 ,580	1,580
Waste Water Treatment Plant	1,2659 44	1,4731 ,270	1,2041 ,478	1,2081 ,182	1,2708 89	1,1821 ,285	1,285

3.7 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 C/I Cchillers 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 with Variable Frequency Drives (VFDs), and 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.

3.7.1 Algorithms

Efficiency ratings in EER

ΔkWh = $Tons_{ee} \times 12 \times (1 / EER_{base} - 1 / EER_{ee}) \times EFLH$

ΔkW_{peak} = $Tons_{ee} \times 12 \times (1 / EER_{base} - 1 / EER_{ee}) \times CF$

Efficiency ratings in kW/ton

ΔkWh = $Tons_{ee} \times (kW/ton_{base} - kW/ton_{ee}) \times EFLH$

ΔkW_{peak} = $Tons_{ee} \times (kW/ton_{base} - kW/ton_{ee}) \times CF$

3.7.2 Definition of Terms

$Tons_{ee}$ = *The capacity of the chiller (in tons) at site design conditions accepted by the program.*

kW/ton_{base} = *Design Rated Efficiency of the baseline chiller. See Table 3-23 for values.*

kW/ton_{ee} = *Design Rated Efficiency of the energy efficient chiller from the manufacturer data and equipment ratings in accordance with ARI Standards.*

EER_{base} =*Energy Efficiency Ratio of the baseline unit. See Table 3-24 for values.*

EER_{ee} =*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 3-233-24: Electric Chiller Variables

Component	Type	Value	Source
$Tons_{ee}$	Variable	Nameplate Data	EDC Data Gathering
kW/ton_{base}	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/ton_{ee}	Variable	Nameplate Data (ARI Standards 550/590). At minimum, must satisfy standard listed in Table 3-24	EDC Data Gathering
EER_{base}	Variable	New Construction or Replace on Burnout: Default value from Table 3-24	See Table 3-24
		Early Replacement: Nameplate Data	EDC Data Gathering
EER_{ee}	Variable	Nameplate Data (ARI Standards 550/590). At minimum, must satisfy standard listed in Table 3-24	EDC Data Gathering
CF	Fixed	90%80%	Engineering Estimate1
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 3-243-25: Electric Chiller Baseline Efficiencies (IECC 2009)[195]

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: 0.549 539 kW/ton	Full load: 0.590 kW/ton IPLV: 0.400 kW/ton	

[195] IECC 2009 – Table 403503.2.3(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.

Table 3-253-26: Chiller Cooling EFLH by Location[196]

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

[196] US Department of Energy. Energy Star Calculator and Bin Analysis Models

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

3.8 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.

3.8.1 Algorithms

Refrigerator/Cooler

$\Delta kWh_{per\ unit} = (kW_{CoolerBase} / DoorFt) * (8{,}760 * CHA_{off}) * (1+R_H/COP_{Cool})$

$\Delta kW_{peak\ \ per\ unit} = (kW_{CoolerBase} / DoorFt) * CHP_{off} * (1+R_H/COP_{Cool}) * DF$

$\Delta kWh = N * \Delta kWh_{per\ unit}$

$\Delta kW_{peak} = N * \Delta kW_{peak\ per\ unit}$

Freezer

$\Delta kWh_{per\ unit} = (kW_{FreezerBase} / DoorFt) * (8{,}760 * FHA_{off}) * (1+R_H/COP_{Freeze})$

$\Delta kW_{peak\ \ per\ unit} = (kW_{FreezerBase} / DoorFt) * FHP_{off} * (1+R_H/COP_{Freeze}) * DF$

$\Delta kWh = N * \Delta kWh_{per\ unit}$

$\Delta kW_{peak} = N * \Delta kW_{peak\ per\ unit}$

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.

$\Delta kWh_{per\ unit} = \{(1-PctCooler) * kWh_{Freezer}/ DoorFt + PctCooler*kWh_{Cooler}/ DoorFt \}$

$\Delta kW_{peak\ \ per\ unit} = \{(1- PctCooler) * kW_{Freezer}/ DoorFt + PctCooler *kW_{Cooler}/ DoorFt \}$

$\Delta kWh = N * \Delta kWh_{per\ unit}$

$\Delta kW_{peak} = N * \Delta kW_{peak\ per\ unit}$

3.8.2 Definition of Terms

N	*= Number of doors or case length in linear feet having ASH controls installed*
$kW_{CoolerBase}$	*= Per door power consumption (kW) of cooler case ASHs without controls*
$kW_{FreezerBase}$	*= Per door power consumption (kW) of freezer case ASHs without controls*
8760	*= Operating hours (365 days * 24 hr/day)*
CHP_{off}	*= Percent of time cooler case ASH with controls will be off during the peak period*
CHA_{off}	*= Percent of time cooler case ASH with controls will be off annually*
FHP_{off}	*= Percent of time freezer case ASH with controls will be off during the peak period*
FHA_{off}	*= 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.*
R_H	*= ~~residual~~ 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.*
COP_{Cool}	*= ~~coefficient~~ Coefficient of performance of cooler*
COP_{Freeze}	*= ~~coefficient~~ 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 3-263-27 Anti-Sweat Heater Controls – Values and References

Component	Type	Value	Sources
N	Variable	# of doors or case length in linear feet	EDC Data Gathering
R_H	Fixed	0.65	1
Unit	Fixed	Door = 1 Linear Feet= 2.5	2
Refrigerator/Cooler			
$kW_{CoolerBase}$	Fixed	0.109	1
CHP_{off}	Fixed	20%	1
CHA_{off}	Fixed	85%	1
DF_{Cool}	Fixed	1	3
COP_{Cool}	Fixed	2.5	1
Freezer			
$kW_{FreezerBase}$	Fixed	0.191	1
FHP_{off}	Fixed	10%	1
FHA_{off}	Fixed	75%	1
DF_{Freeze}	Fixed	1	3
COP_{Freeze}	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.
   a. 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:
   a. http://www.bushrefrigeration.com/bakery_glass_door_coolers.php
   b. http://www.brrr.cc/home.php?cat=427
   c. 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 3-273-28 Recommended Fully Deemed Impact Estimates

Description	Per Door Impact	Per Linear Ft of Case Impact
Refrigerator/Cooler		
Energy Impact	1,023 kWh per door	409 kWh per 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

3.8.3 Measure Life

12 Years (DEER 2008, Regional Technical Forum)

3.9 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.

3.9.1 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.

$\Delta kWh = (kWh_{base} - kWh_{ee}) * days/year$

$\Delta kW_{peak} = (kWh_{base} - kWh_{ee}) * CF/24$

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.

3.9.2 Definition of Terms

kWh_{base} = *The unit energy consumption of a standard unit (kWh/day)*

kWh_{ee} = *The unit energy consumption of the ENERGY STAR-qualified unit (kWh/day)*

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

V = *Internal Volume*

Table 3-283-29: Refrigeration Cases - References

Component	Type	Value	Sources
kWh_{base}	Calculated	See Table 3-29 and Table 3-30	1
kWh_{ee}	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 3-293-30: Refrigeration Case Efficiencies

Volume (ft^3)	Glass Door		Solid Door	
	kWh_{ee}/day	kWh_{base}/day	kWh_{ee}/day	kWh_{base}/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 3-303-31: Freezer Case Efficiencies

Volume (ft^3)	Glass Door		Solid Door	
	kWh_{ee}/day	kWh_{base}/day	kWh_{ee}/day	kWh_{base}/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 3-313-32: Refrigeration Case Savings

Volume (ft^3)	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 3-323-33: Freezer Case Savings

Volume (ft^3)	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

3.9.3 **Measure Life**

12 years

Sources:

1. Food Service Technology Center (as stated in ENERGY STAR calculator).

3.10 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.

3.10.1 Algorithms

Cooler

$\Delta kW_{peak\ per\ unit}$ = $(W_{base} – W_{ee}) / 1{,}000 * LF * DC_{EvapCool} * (1 + 1 / (DG * COP_{cooler}))$

$\Delta kWh_{per\ unit}$ = $\Delta kW_{peak\ per\ unit} * 8{,}760$

ΔkW_{peak} = $N * \Delta kW_{peak\ per\ unit}$

ΔkWh = $N * \Delta kWh_{per\ unit}$

Freezer

$\Delta kW_{peak\ per\ unit}$ = $(W_{base} – W_{ee}) / 1{,}000 * LF * DC_{EvapFreeze} * (1 + 1 / (DG * COP_{freezer}))$

$\Delta kWh_{per\ unit}$ = $\Delta kW_{peak\ per\ unit} * 8{,}760$

ΔkW_{peak} = $N * \Delta kW_{peak\ per\ unit}$

ΔkWh = $N * \Delta kWh_{per\ unit}$

Default (case service temperature not known)

$\Delta kW_{peak\ per\ unit}$ = $\{(1\text{-}PctCooler) * kW_{Freezer}/motor + PctCooler*kW_{Cooler}/motor\}$

$\Delta kWh_{per\ unit}$ = $\Delta kW_{peak\ per\ unit} * 8{,}760$

ΔkW_{peak} = $N * \Delta kW_{peak\ per\ unit}$

ΔkWh = $N * kWh_{default}/motor$

3.10.2 Definition of Terms

N	= *Number of motors replaced*
W_{base}	= *Input wattage of existing/baseline evaporator fan motor*
W_{ee}	= *Input wattage of new energy efficient evaporator fan motor*
LF	= *Load factor of evaporator fan motor*
$DC_{EvapCool}$	= *Duty cycle of evaporator fan motor for cooler*
$DC_{EvapFreeze}$	= *Duty cycle of evaporator fan motor for freezer*
DG	= *Degradation factor of compressor COP*
COP_{cooler}	= *Coefficient of performance of compressor in the cooler*
$COP_{freezer}$	= *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 3-333-34: Variables for High-Efficiency Evaporator Fan Motor

Variable	Type	Value	Source
W_{base}	Fixed	Default	Table 3-34
		Nameplate Input Wattage	EDC Data Gathering
W_{ee}	Variable	Default	Table 3-34
		Nameplate Input Wattage	EDC Data Gathering
LF	Fixed	0.9	1
$DC_{EvapCool}$	Fixed	100%	2
$DC_{EvapFreeze}$	Fixed	94.4%	2
DG	Fixed	0.98	3
COP_{cooler}	Fixed	2.5	1
$COP_{freezer}$	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 3-343-35: Variables for HE Evaporator Fan Motor

Motor Category	Weighting Percentage (population)[1]	Motor Output Watts	SP Efficiency[1]	SP Input Watts	PSC Efficiency[2]	PSC Input Watts	ECM Efficiency[1]	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 3-353-36: Shaded Pole to PSC Deemed Savings

Measure	W_{base} (Shaded Pole)	W_{ee} (PSC)	LF	DC_{Evap}	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 3-363-37: PSC to ECM Deemed Savings

Measure	W_{base} (PSC)	W_{ee} (ECM)	LF	DC_{Evap}	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 3-373-38: Shaded Pole to ECM Deemed Savings

Measure	W_{base} (Shaded Pole)	W_{ee} (ECM)	LF	DC_{Evap}	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 3-383-39: Default High-Efficiency Evaporator Fan Motor Deemed Savings

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

3.10.3 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.

3.11 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.

3.11.1 Algorithms

Cooler

$\Delta kW_{peak\ per\ unit} = (W_{base} – W_{ee}) / 1,000 * LF * DC_{EvapCool} * (1 + 1 / (DG * COP_{cooler}))$

$\Delta kWh_{per\ unit} = \Delta kW_{peak\ per\ unit} * HR$

$\Delta kW_{peak} = N * \Delta kW_{peak\ per\ unit}$

$\Delta kWh = N * \Delta kWh_{per\ unit}$

Freezer

$\Delta kW_{peak\ per\ unit} = (W_{base} – W_{ee}) / 1,000 * LF * DC_{EvapFreeze} * (1 + 1 / (DG * COP_{freezer}))$

$\Delta kWh_{per\ unit} = \Delta kW_{peak\ per\ unit} * HR$

$\Delta kW_{peak} = N * \Delta kW_{peak\ per\ unit}$

$\Delta kWh = N * \Delta kWh_{per\ unit}$

Default (case service temperature not known)

$\Delta kW_{peak\ per\ unit} = \{(1\text{-}PctCooler) * kW_{Freezer}/motor + PctCooler*kW_{Cooler}/motor\}$

$\Delta kWh_{per\ unit} = \Delta kW_{peak\ per\ unit} * HR$

$\Delta kW_{peak} = N * \Delta kW_{peak\ per\ unit}$

$\Delta kWh = N * \Delta kWh_{per\ unit}$

3.11.2 Definition of Terms

N	= *Number of motors replaced*
W_{base}	= *Input wattage of existing/baseline evaporator fan motor*
W_{ee}	= *Input wattage of new energy efficient evaporator fan motor*
LF	= *Load factor of evaporator fan motor*
$DC_{EvapCool}$	= *Duty cycle of evaporator fan motor for cooler*
$DC_{EvapFreeze}$	= *Duty cycle of evaporator fan motor for freezer*
DG	= *Degradation factor of compressor COP*
COP_{cooler}	= *Coefficient of performance of compressor in the cooler*
$COP_{freezer}$	= *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 3-393-40: Variables for High-Efficiency Evaporator Fan Motor

Variable	Type	Value	Source
W_{base}	Fixed	Default	Table 3-40
		Nameplate Input Wattage	EDC Data Gathering
W_{ee}	Variable	Default	Table 3-40
		Nameplate Input Wattage	EDC Data Gathering
LF	Fixed	0.9	1
$DC_{EvapCool}$	Fixed	100%	2
$DC_{EvapFreeze}$	Fixed	94.4%	2
DG	Fixed	0.98	3
COP_{cooler}	Fixed	2.5	1
$COP_{freezer}$	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 3-403-41: Variables for HE Evaporator Fan Motor

Motor Category	Weighting Number (population)[2]	Motor Output Watts	SP Efficiency[1,2]	SP Input Watts	PSC Efficiency[3]	PSC Input Watts	ECM Efficiency[1]	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 3-413-42: PSC to ECM Deemed Savings

Measure	W_{base} (PSC)	W_{ee} (ECM)	LF	DC_{Evap}	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 3-423-43: Shaded Pole to ECM Deemed Savings

Measure	W_{base} (Shaded Pole)	W_{ee} (ECM)	LF	DC_{Evap}	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)	8593	30	0.9	94.4%	0.98	1.3	0.08340955	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 3-433-44: Default High-Efficiency Evaporator Fan Motor Deemed Savings

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

3.11.3 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

3.12 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.

3.12.1 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

$\Delta kWh = ESav_{COM}$

$\Delta kW_{peak} = DSav_{COM} \times CF_{COM}$

ENERGY STAR Fax Machine

$\Delta kWh = ESav_{FAX}$

$\Delta kW_{peak} = DSav_{FAX} \times CF_{FAX}$

ENERGY STAR Copier

$\Delta kWh = ESav_{COP}$

$\Delta kW_{peak} = DSav_{COP} \times CF_{COP}$

ENERGY STAR Printer

$\Delta kWh = ESav_{PRI}$

$\Delta kW_{peak} = DSav_{PRI} \times CF_{PRI}$

ENERGY STAR Multifunction

$\Delta kWh = ESav_{MUL}$

$\Delta kW_{peak} = DSav_{MUL} \times CF_{MUL}$

ENERGY STAR Monitor

$\Delta kWh = ESav_{MON}$

$\Delta kW_{peak} = DSav_{MON} \times CF_{MON}$

3.12.2 Definition of Terms

$ESav_{COM}$	*= Electricity savings per purchased ENERGY STAR computer.*
$DSav_{COM}$	*= Summer demand savings per purchased ENERGY STAR computer.*
$ESav_{FAX}$	*= Electricity savings per purchased ENERGY STAR fax machine.*
$DSav_{FAX}$	*= Summer demand savings per purchased ENERGY STAR fax machine.*
$ESav_{COP}$	*= Electricity savings per purchased ENERGY STAR copier.*
$DSav_{COP}$	*= Summer demand savings per purchased ENERGY STAR copier.*
$ESav_{PRI}$	*= Electricity savings per purchased ENERGY STAR printer.*
$DSav_{PRI}$	*= Summer demand savings per purchased ENERGY STAR printer.*
$ESav_{MUL}$	*= Electricity savings per purchased ENERGY STAR multifunction machine.*
$DSav_{MUL}$	*= Summer demand savings per purchased ENERGY STAR multifunction machine.*
$ESav_{MON}$	*= Electricity savings per purchased ENERGY STAR monitor.*
$DSav_{MON}$	*= Summer demand savings per purchased ENERGY STAR monitor.*
CF_{COM}, CF_{FAX}, CF_{COP},	
CF_{PRI}, CF_{MUL}, CF_{MON}	*= 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 3-443-45: ENERGY STAR Office Equipment - References

Component	Type	Value	Sources
$ESav_{COM}$ $ESav_{FAX}$ $ESav_{COP}$ $ESav_{PRI}$ $ESav_{MUL}$ $ESav_{MON}$	Fixed	see Table 3-45	1
$DSav_{COM}$ $DSav_{FAX}$ $DSav_{COP}$ $DSav_{PRI}$ $DSav_{MUL}$ $DSav_{MON}$	Fixed	see Table 3-45	2
CF_{COM},CF_{FAX},CF_{COP},CF_{PRI},CF_{MUL},CF_{MON}	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 3-453-46: 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:

4. ENERGYSTAR office equipment calculators

3.12.3 Measure Life

Table 3-463-47: 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

3.13 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.

3.13.1 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).

3.13.2 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:

$$\Delta kWh \quad kWh\ Savings = (kW_{comp} \times Hr_{comp}) \times 365 = \mathbf{123.69kWh\ (rounded\ to\ 124kWh)}$$

$$\Delta kWpeak \quad kW\ Demand\ Reduction = CF \times kW_{comp} = \mathbf{0.0101\ kW}$$

3.13.3 Definition of Terms

The parameters in the above equation are listed below.

Table 3-473-48: Smart Strip Calculation Assumptions

Parameter	Component	Type	Value	Source
kW_{comp}	Idle kW of computer system	Fixed	0.0201	1
Hr_{comp}	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

3.13.4 Deemed Savings

ΔkWh = 124 kWh

ΔkW_{peak} = 0.0101 kW

3.13.5 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.

3.13.6 Evaluation Protocols

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

3.14 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.

3.14.1 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.

$\Delta kWh = kWh_{base} \times E$

$\Delta kW_{peak} = 0$

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.

3.14.2 Definition of Terms

kWh_{base} = *baseline annual beverage machine energy consumption (kWh/year)*

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

3.14.3 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%[197,198,199,200]. It should be noted that

[197] 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

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 $E_{default}$ = 46% to the energy savings algorithm above. Where it is determined that the default efficiency factor (E) or default baseline energy consumption (kWh_{base}) 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 (kWh_{base}), for use in the Energy Savings algorithm.

Table 3-483-49: Beverage Machine Controls Energy Savings[201]

Machine Can Capacity	Default Baseline Energy Consumption (kWh_{base}) (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

3.14.4 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

[198] 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

[199] *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

[200] *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

[201] ENERGY STAR Calculator, Assumptions for Vending Machines, accessed 8/2010 http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_Vend_MachBulk.xls

3.15 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[202]. 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.

3.15.1 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 $= \frac{(kWh_{base} - kWh_{he})}{100} \times H \times 365 \times D$

ΔkW_{peak} $= \frac{\Delta kWh}{8760 * D} \times CF$

Field Code Changed

Field Code Changed

3.15.2 Definition of Terms

kWh_{base}	*= baseline ice machine energy usage per 100 lbs of ice (kWh/100lbs)*
kWh_{he}	*= 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.

[202] *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

Table 3-493-50: Ice Machine Reference values for algorithm components

Term	Type	Value	Source
kWh_{base}	Variable	Table 3-50	1
kWh_{he}	Variable	Table 3-50	2
H	Variable	Manufacturer Specs	EDC Data Gathering
D	Variable	Default = 0.4[203]	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.

3.15.3 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 (kWh_{base}) is calculated using the formula for CEE Tier 1 specifications, and the default energy consumption for the high-efficiency ice machine (kWh_{he}) is calculated using the formula for CEE Tier 2 specifications[204]. The two energy consumption values are then applied to the energy savings algorithm above.

[203] *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.
[204] *High Efficiency Specifications for Commercial Ice Machines*, Consortium for Energy Efficiency, accessed 8/2010, http://www.cee1.org/com/com-kit/files/IceSpecification.pdf

Table 3-503-51: Ice Machine Energy Usage[205]

Ice machine type	Ice harvest rate (H) (lbs/day)	Baseline energy use per 100 lbs of ice (kWh_{base})	High-efficiency energy use per 100 lbs of ice (kWh_{he})
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

3.15.4 Measure Life

Measure life = 10 years[206].

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

[205] 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.
[206] *DEER EUL Summary*, Database for Energy Efficient Resources, accessed 8/2010, http://www.deeresources.com/deer0911planning/downloads/EUL_Summary_10-1-08.xls

3.16 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.

3.16.1 **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.

3.16.2 **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

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

$\Delta kWh_{cool} = (A \times CDD \times 24)/(EER \times 1000) \times (1/R_i - 1/R_f)$

$\Delta kWh_{heat} = (A \times HDD \times 24)/(COP \times 3413) \times (1/R_i - 1/R_f)$

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

Wall Insulation

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

$\Delta kWh_{cool} = (A \times CDD \times 24)/(EER \times 1000) \times (1/R_i - 1/R_f)$

$\Delta kWh_{heat} = (A \times HDD \times 24)/(COP \times 3413) \times (1/R_i - 1/R_f)$

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

3.16.3 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*

R_i = *the R-value of the insulation and support structure before the additional insulation is installed*

R_f = *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 3-513-52: Non-Residential Insulation – Values and References

Component	Type	Values	Sources
A	Variable	Application	AEPS Application; EDC Data Gathering
HDD	Fixed	Allentown = 5318 Erie = 6353 Harrisburg = 4997 Philadelphia = 4709 Pittsburgh = 5429 Scranton = 6176 Williamsport = 5651	1
CDD	Fixed	Allentown = 787 Erie = 620 Harrisburg = 955 Philadelphia = 1235 Pittsburgh = 726 Scranton = 611	1

Component	Type	Values	Sources
		Williamsport = 709	
24	Fixed	24	n/a
1000	Fixed	1000	n/a
Ceiling R_i	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 R_i	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
R_f	Variable		AEPS Application; EDC Data Gathering;
$EFLH_{cool}$	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 3-523-53: Ceiling R-Values by Building Type

Building Type	Ceiling R_i-Value (New Construction)	Ceiling R_i-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 3-533-54: Wall R-Values by Building Type

Building Type	Wall R_i-Value (New Construction)	Wall R_i-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~~3-55~~: HVAC Baseline Efficiencies for Non-Residential Buildings

	Existing Building[207]		New Construction[208]	
Equipment Type and Capacity	**Cooling Efficiency**	**Heating Efficiency**	**Cooling Efficiency**	**Heating Efficiency**
Air-Source Air Conditioners				
< 65,000 BtuH~~< 5.41 tons~~	10.0 SEER	N/A	13.0 SEER	N/A
> 65,000 BtuH and <135,000 BtuH~~> 5.41 tons and <11.25 tons~~	10.3 EER	N/A	11.2 EER	N/A
> 135,000 BtuH and < 240,000 BtuH~~> 11.25 tons and < 20.00 tons~~	9.7 EER	N/A	11.0 EER	N/A
> 240,000 BtuH and < 760,000 BtuH (IPLV for units with capacity-modulation only)~~> 20.00 tons and < 63.33 tons (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)~~> 63.33 tons (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~~< 5.41 tons~~	12.1 EER	N/A	12.1 EER	N/A
> 65,000 BtuH and <135,000 BtuH~~> 5.41 tons and < 11.25 tons~~	11.5 EER	N/A	11.5 EER	N/A
> 135,000 BtuH and < 240,000 BtuH~~> 11.25 tons and < 20.00 tons~~	11.0 EER	N/A	11.0 EER	N/A
> 240,000 BtuH~~20.00 tons~~	11.0 EER	N/A	11.5 EER	N/A
Air-Source Heat Pumps				
< 65,000 BtuH~~< 5.41 tons:~~	10.0 SEER	6.8 HSPF	13 SEER	7.7 HSPF
> 65,000 BtuH and <135,000 BtuH~~> 5.41 tons and < 11.25 tons~~	10.1 EER	3.2 COP	11.0 EER	3.3 COP
> 135,000 BtuH and < 240,000 BtuH~~> 11.25 tons and < 20.00 tons~~	9.3 EER	3.1 COP	10.6 EER	3.2 COP
> ~~20.00 tons~~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				
< ~~1.42 tons~~17,000 BtuH	11.2 EER	4.2 COP	11.2 EER	4.2 COP
> ~~1.42 tons~~17,000 BtuH and < ~~5.41 tons~~65,000 BtuH	12.0 EER	4.2 COP	12.0 EER	4.2 COP
Ground Water Source Heat Pumps				
< 1~~1.25 tons~~35,000 BtuH	16.2 EER	3.6 COP	16.2 EER	3.6 COP
Ground Source Heat Pumps				
< 135,000 BtuH~~< 11.25 tons~~	13.4 EER	3.1 COP	13.4 EER	3.1 COP

[207] ASHRAE 90.1-2004, Tables 6.8.1A, 6.8.1B, and 6.8.1D
[208] IECC 2009, Tables 503.2.3(1), 503.2.3(2), and 503.2.3(3)

	Existing Building[207]		New Construction[208]	
Equipment Type and Capacity	**Cooling Efficiency**	**Heating Efficiency**	**Cooling Efficiency**	**Heating Efficiency**
Packaged Terminal Systems				
PTAC (cooling)	10.9 - (0.213 x Cap / 1000) x EER	N/A	12.5 - (0.213 x Cap / 1000) x EER	N/A
PTHP	10.8 - (0.213 x Cap / 1000) x EER	2.9 - (0.026 x Cap / 1000) x COP	12.3 - (0.213 x Cap / 1000) x EER	3.2 - (0.026 x Cap / 1000) x COP

Table 3-553-56: Cooling EFLH for Erie, Harrisburg, Pittsburgh, Williamsport, Philadelphia, and ScrantonKey PA Cities[209]

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

[209] US Department of Energy. ENERGY STAR Calculator and Bin Analysis Models

Space and/or Building Type	Allentown	Erie	Harrisburg	Pittsburgh	Williamsport	Philadelphia	Scranton
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

3.16.4 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.

3.17 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[210], 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[211].

3.17.1 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[212].

3.17.2 Algorithms

$$\Delta kWh = \Delta kWh/sqft \times A$$

$$\Delta kW_{peak} = \Delta kW/sqft \times A$$

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[210] 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.

[211] See source 1 for Table 3-11.

[212] http://energysmartonline.org/documents/EnergySmart_BPA_T&Cs.pdf

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[213] (an application of Bernoulli's equation) and the ASHRAE handbook[214]. To the extent that evaluation findings are able to ~~find more accurate assumptions~~provide more reliable site specific inputs assumptions, they may be used in place of the default per square foot savings using the following equation.

$$\Delta kWh = 365 \times t_{open} \times (\eta_{new} - \eta_{old}) \times 20C_D \times A \times \{[(T_i - T_r)/T_i]gH\}^{0.5} \times 60 \times (\rho_i h_i - \rho_r h_r) / (3413 \times COP_{adj})$$

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.

$$\Delta kW_{peak} = \Delta kWh / 8760$$

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[215] in the study of strip curtains in supermarkets, convenience stores, and restaurants.

3.17.3 Definition of Terms

The variables in the main equations are defined below:

$\Delta kWh/sqft$ = *Average annual kWh savings per square foot of infiltration barrier*

$\Delta kW/sqft$ = *Average kW savings per square foot of infiltration barrier*

A = *Doorway area, ft2*

The variables in the source equation are defined below:

t_{open} = *Minutes walk-in door is open per day*

η_{new} = *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.*

η_{old} = *Efficacy of the old strip curtain*

[213] *Kalterveluste durch kuhlraumoffnungen*. Tamm W,.Kaltetechnik-Klimatisierung 1966;18;142-144

[214] American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE). 2006. *ASHRAE Handbook, Refrigeration:* 13.4, 13.6

[215] http://www.calmac.org/publications/ComFac_Evaluation_V1_Final_Report_02-18-2010.pdf

20	*= Product of 60 minutes per hour and an integration factor of 1/3*[216]
C_D	*= 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*
T_i	*= Dry-bulb temperature of infiltrating air, Rankine*
T_r	*= Dry-bulb temperature of refrigerated air, Rankine*
g	*= Gravitational constant = 32.174 ft/s2*
H	*= Doorway height, ft*
h_i	*= Enthalpy of the infiltrating air, Btu/lb. Based on 55% RH.*
h_r	*= Enthalpy of the refrigerated air, Btu/lb. Based on 80% RH.*
ρ_i	*= Density of the infiltration air, lb/ft3. Based on 55% RH.*
ρ_r	*= Density of the refrigerated air, lb/ft3. Based on 80% RH.*
3413	*= Conversion factor: number of BTUs in one kWh*
COP_{adj}	*= 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 Usage*$_{Peak}$ */ 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[217]. The original work included 8760-hourly bin calculations. The values used herein represent annual average values. For example, the

[216] 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 C_D x A x {[(T_i – T_r) / T_i] x g x ΔH_{NPL} }^0.5 where ΔH_{NPL} 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 ΔH_{NPL}) 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.

[217] 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.

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	
η_{new}	Fixed	0.88	0.88	1
η_{old} with Pre-existing curtain with no Pre-existing curtain unknown	Fixed	 0.58 0.00 0.00	 0.58 0.00 0.00	1
C_D	Fixed	0.366	0.415	1
t_{open} (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
ρ_i	Fixed	0.074	0.074	3
h_i	Fixed	26.935	24.678	3
ρ_r	Fixed	0.079	0.085	3
h_r	Fixed	12.933	2.081	3
COP_{adj}	Fixed	3.07	1.95	1 and 2

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

Component	**Type**	Value		Source
		Cooler	Freezer	
η_{new}	Fixed	0.79	0.83	1
η_{old} with Pre-existing curtain with no Pre-existing curtain unknown	Fixed	 0.58 0.00 0.34	 0.58 0.00 0.30	1
C_D	Fixed	0.348	0.421	1
t_{open} (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

Component	Type	Value		Source
		Cooler	Freezer	
ρ_i	Fixed	0.074	0.075	3
h_i	Fixed	25.227	23.087	3
ρ_r	Fixed	0.079	0.085	3
h_r	Fixed	13.750	2.081	3
COP_{adj}	Fixed	3.07	1.95	1 and 2

Table 3-59: Strip Curtain Calculation Assumptions for Restaurant

Component	Type	Value		Source
		Cooler	Freezer	
η_{new}	Fixed	0.80	0.81	1
η_{old} with Pre-existing curtain with no Pre-existing curtain unknown	Fixed	 0.58 0.00 0.33	 0.58 0.00 0.26	1
C_D	Fixed	0.383	0.442	1
t_{open} (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
ρ_i	Fixed	0.074	0.074	3
h_i	Fixed	26.356	24.678	3
ρ_r	Fixed	0.079	0.085	3
h_r	Fixed	13.750	2.948	3
COP_{adj}	Fixed	3.07	1.95	1 and 2

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

Component	Type	Value	Source
η_{new}	Fixed	0.89	1
η_{old} with Pre-existing curtain with no Pre-existing curtain unknown	Fixed	 0.58 0.00 0.54	1
C_D	Fixed	0.425	1
t_{open} (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
ρ_i	Fixed	0.076	3
h_i	Fixed	20.609	3
ρ_r	Fixed	0.081	3
h_r	Fixed	9.462	3
COP_{adj}	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.

3.17.4 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

3.17.5 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.

3.18 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.

3.18.1 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

3.18.2 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:

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

$\Delta kWh_{cool} = \Sigma\{(BtuH_{cool} / 1000) \times (1/SEER_{base}) \times EFLH_{cool}\} - \Sigma\{(BtuH_{cool} / 1000) \times (1/EER_{ee}) \times EFLH_{cool}\}$

$\Delta kWh_{heat} = \Sigma\{(BtuH_{heat} / 1000) \times (1/HSPF_{base}) \times EFLH_{heat}\} - \Sigma\{(BtuH_{heat} / 1000) \times (1/COP_{ee}) \times (1/3.412) \times EFLH_{heat}\}$

$\Delta kWh_{pump} = \Sigma\{(HP_{basemotor} \times LF_{base} \times 0.746 \times (1/\eta_{basemotor}) \times (1/\eta_{basepump}) \times (HOURS_{basepump})\} - \Sigma\{(HP_{eemotor} \times LF_{ee} \times 0.746 \times (1/\eta_{eemotor}) * (1/\eta_{eepump}) \times (HOURS_{eepump})\}$

$\Delta kW_{peak} = \Delta kW_{peak\ cool} + \Delta kW_{peak\ pump}$

$\Delta kW_{peak\ cool} = \Sigma\{(BtuH_{cool} / 1000) \times [(1/EER_{base})] \times CF_{cool}\} - \Sigma\{(BtuH_{cool} / 1000) \times [(1/EER_{ee})] \times CF_{cool}\}$

$\Delta kW_{peak\ pump} = \Sigma\{HP_{basemotor} \times LF_{base} \times 0.746 \times (1/\eta_{basemotor}) \times (1/\eta_{basepump}) \times CF_{pump}\} - \Sigma\{HP_{eemotor} \times LF_{ee} \times 0.746 \times (1/\eta_{eemotor}) \times (1/\eta_{eepump})] \times CF_{pump}\}$

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} = Σ{($BtuH_{cool}$/ 1000) X (1/EER_{base}) X $EFLH_{cool}$} - Σ{($BtuH_{cool}$/ 1000) X (1/EER_{ee}) X $EFLH_{cool}$}

ΔkWh_{heat} = Σ{($BtuH_{heat}$/ 1000) X (1/COP_{base}) X (1/3.412) X $EFLH_{heat}$} - Σ{($BtuH_{heat}$/ 1000) X (1/COP_{ee}) X (1/3.412) X $EFLH_{heat}$}

ΔkWh_{pump} = Σ{($HP_{basemotor}$ X LF_{base} X 0.746 X (1/$\eta_{basemotor}$) X (1/$\eta_{basepump}$) X ($HOURS_{basepump}$)} - Σ{($HP_{eemotor}$ X LF_{ee} X 0.746 X (1/$\eta_{eemotor}$) * (1/η_{eepump}) X ($HOURS_{eepump}$)}

ΔkW_{peak} = $\Delta kW_{peak\ cool}$ + $\Delta kW_{peak\ pump}$

$\Delta kW_{peak\ cool}$ = Σ{($BtuH_{cool}$/ 1000) X [(1/EER_{base})] X CF_{cool}} - Σ{($BtuH_{cool}$/ 1000) X [(1/EER_{ee})] X CF_{cool}}

$\Delta kW_{peak\ pump}$ = Σ{$HP_{basemotor}$ X LF_{base} X 0.746 X (1/$\eta_{basemotor}$) X (1/$\eta_{basepump}$) X CF_{pump}} - Σ{$HP_{eemotor}$ X LF_{ee} X 0.746 X (1/$\eta_{eemotor}$) X (1/η_{eepump})] X CF_{pump}}

3.18.3 Definition of Terms

$BtuH_{cool}$ = Rated cooling capacity of the energy efficient unit in $BtuH_{cool}$ /hour

$BtuH_{heat}$ = Rated heating capacity of the energy efficient unit in $BtuH_{heat}$ /hour

$SEER_{base}$ = the cooling SEER of the baseline unit

EER_{base} = the cooling EER of the baseline unit

$HSPF_{base}$ = Heating Season Performance Factor of the Baseline Unit

COP_{base} = Coefficient of Performance of the Baseline Unit~~of the base case ground source heat pump~~

EER_{ee} = the cooling EER of the new ground source, groundwater source, or water source heat pump~~groundground source or groundwater source heat pump~~ being installed

COP_{ee} = Coefficient of Performance of the new ground source, groundwater source, or water source heat pump being installed~~ground or groundwater source heat pump~~

$EFLH_{cool}$ = Cooling annual Equivalent Full Load Hours EFLH for Commercial HVAC for different occupancies

$EFLH_{heat}$ = Heating annual Equivalent Full Load Hours EFLH for Commercial HVAC for different occupancies

CF_{cool} = Demand Coincidence Factor (See Section 1.4) for Commercial HVAC

CF_{pump} = Demand Coincidence Factor (See Section 1.4) for ground source loop pump

$HP_{basemotor}$ = Horsepower of base case ground loop pump motor

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

$\eta_{basemotor}$ = efficiency of base case ground loop pump motor

$\eta_{basepump}$ = efficiency of base case ground loop pump at design point

$HOURS_{basepump}$ = Run hours of base case ground loop pump motor

$HP_{eemotor}$ = Horsepower of retrofit case ground loop pump motor

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

$\eta_{eemotor}$ = efficiency of retrofit case ground loop pump motor

η_{eepump} = efficiency of retrofit case ground loop pump at design point

$HOURS_{eepump}$ = 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**
$BtuH_{cool}$	Variable	Nameplate data (ARI or AHAM)	EDC Data Gathering
$BtuH_{heat}$	Variable	Nameplate data (ARI or AHAM) Use ~~$CAPY_{cool}$~~ $BtuH_{cool}$ if the heating capacity is not known	EDC Data Gathering
$SEER_{base}$	Fixed	Early Replacement: Nameplate data	EDC Data Gathering
		New Construction or Replace on Burnout: Default values from Table 3-65~~Table 3-20~~	See Table 3-65~~Table 3-21~~
EER_{base}	Fixed	Early Replacement: Nameplate data	EDC Data Gathering

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Component	Type	Values	Sources
		New Construction or Replace on Burnout: Default values from Table 3-65Table 3-20	See Table 3-65Table 3-21
$HSPF_{base}$	Fixed	Early Replacement: Nameplate data	EDC Data Gathering
		New Construction or Replace on Burnout: Default values from Table 3-65Table 3-20	See Table 3-65Table 3-21
COP_{base}	Fixed	Early Replacement: Nameplate data	EDC Data Gathering
		New Construction or Replace on Burnout: Default values from Table 3-65Table 3-20	See Table 3-65Table 3-21
EER_{ee}	Variable	Nameplate data (ARI or AHAM)	EDC Data Gathering
COP_{ee}	Variable	Nameplate data (ARI or AHAM)	EDC Data Gathering
$EFLH_{cool}$	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
$EFLH_{heat}$	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
CF_{cool}	Fixed	Default = 0.80	3
CF_{pump}	Fixed	if unit runs 24/7/365, default = 1.0; if unit runs only with heat pump unit compressor, default = 0.67	4
$HP_{basemotor}$	Variable	Nameplate	EDC Data Gathering
LF_{base}	Variable	Based on spot metering	EDC Data Gathering
		Default 75%	1
$\eta_{basemotor}$	Variable	Nameplate	EDC's Data Gathering
		If unknown, assume the federal minimum efficiency requirements in Table 3-63	See Table 3-63
$\eta_{basepump}$	Variable	Nameplate	EDC's Data Gathering
		If unknown, assume program compliance efficiency in Table 3-64	See Table 3-64
$HOURS_{basepump}$	Fixed	Based on Logging or Modeling	EDC's Data Gathering

Component	Type	Values	Sources
		$EFLH_{cool}$ + $EFLH_{heat}$ [218] Default values from Table 3-21 and Table 3-22Default = 8760 hours Default = 8760 hours	2
$HP_{eemotor}$	Variable	Nameplate	EDC's Data Gathering
LF_{ee}	Variable	Based on spot metering	EDC Data Gathering
		Default 75%	1
$\eta_{eemotor}$	Variable	Nameplate	EDC's Data Gathering
		If unknown, assume the federal minimum efficiency requirements in Table 3-63	Table 3-63
η_{eepump}	Variable	Nameplate	EDC's Data Gathering
		If unknown, assume program compliance efficiency in Table 3-64	See Table 3-64Table 2
$HOURS_{eepump}$	Variable	Based on Logging or Modeling	EDC Data Gathering
		$EFLH_{cool}$ + $EFLH_{heat}$ [219] $EFLH_{cool}$ + $EFLH_{heat}$ Default values from Table 3-21 and Table 3-22 Default = 8760 hours Default = 8760 hours	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[220]

	Open Drip Proof (ODP) # of Poles			Totally Enclosed Fan-Cooled (TEFC)		
Size HP	*6*	*4*	*2*	*6*	*4*	*2*

[218] $EFLH_{cool}$ + $EFLH_{heat}$ represent the addition of cooling and heating annual equivalent full load hours for commercial HVAC for different occupancies, respectively.

[219] $EFLH_{cool}$ + $EFLH_{heat}$ represent the addition of cooling and heating annual equivalent full load hours for commercial HVAC for different occupancies, respectively.

[220] 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

	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[221]

HP	Minimum Pump Efficiency at Design Point (η_{pump})
1.5	65%
2	65%
3	67%
5	70%
7.5	73%
10	75%
15	77%
20	77%

[221] Based on program requirements submitted during protocol review.

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)[222]		
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

[222] 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.

3.18.4 Measure Life

The expected measure life is assumed to be 15 years.[223]

3.18.5 Evaluation Protocols

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

[223] Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc., June 2007.

3.19 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.

3.19.1 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.[224] 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).

3.19.2 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:

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

$$\Delta kWh_{heat} = CAPY_{heat} / 1000 \times (1/COP_b - 1/COP_e) / 3.413 \times EFLH_{heat} \times LF$$

$$\Delta kWh_{cool} = CAPY_{cool} / 1000 \times (1/EER_b - 1/EER_e) \times EFLH_{cool} \times LF$$

$$\Delta kW_{peak} = CAPY_{cool} / 1000 \times (1/EER_b - 1/EER_e) \times CF$$

[224] 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.

Multi-Zone:

ΔkWh = ΔkWh_{cool} + ΔkWh_{heat}

ΔkWh_{heat} = [$CAPY_{heat}$ / 1000 X (1/COP_b - 1/COP_e) / 3.413 X $EFLH_{heat}$ X $LF]_{ZONE1}$ + [$CAPY_{heat}$ / 1000 X (1/COP_b - 1/COP_e) / 3.413 X $EFLH_{heat}$ X $LF]_{ZONE2}$ + [$CAPY_{heat}$ / 1000 X (1/COP_b - 1/COP_e) / 3.413 X $EFLH_{heat}$ X $LF]_{ZONEn}$

ΔkWh_{cool} = [$CAPY_{cool}$ / 1000 X (1/EER_b – 1/EER_e) X $EFLH_{cool}$ X $LF]_{ZONE1}$ + [$CAPY_{cool}$ / 1000 X (1/EER_b – 1/EER_e) X $EFLH_{cool}$ X $LF]_{ZONE2}$ + [$CAPY_{cool}$ / 1000 X (1/EER_b – 1/EER_e) X $EFLH_{cool}$ X $LF]_{ZONEn}$

ΔkW_{peak} = [$CAPY_{cool}$ / 1000 X (1/EER_b – 1/EER_e) X $CF]_{ZONE1}$ + [$CAPY_{cool}$ / 1000 X (1/EER_b – 1/EER_e) X $CF]_{ZONE2}$ + [$CAPY_{cool}$ / 1000 X (1/EER_b – 1/EER_e) X $CF]_{ZONEn}$

3.19.3 Definition of Terms

$CAPY_{cool}$ =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)

$CAPY_{heat}$ =The heating capacity of the indoor unit, given in BTUH as appropriate for the calculation.

$EFLH_{cool}$ = Equivalent Full Load Hours for cooling

$EFLH_{heat}$ = Equivalent Full Load Hours for heating

COP_b = Coefficient Of Performance heating efficiency of baseline unit

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

EER_b = Energy Efficiency Ratio cooling efficiency of baseline unit

EER_e = 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
$CAPY_{cool}$ $CAPY_{heat}$	Variable	Nameplate	AEPS Application; EDC Data Gathering
$EFLH_{cool}$ $EFLH_{heat}$	Fixed	See Table 3-67: and Table 3-68:	1
COP_b	Fixed	Standard DHP: 2.26 Electric resistance: 1.00 ASHP: 2.26 PTHP: 3.2-(0.026x$CAPY_{heat}$/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
EER_b	Fixed	DHP, ASHP, or central AC: 11.3 Room AC: 9.8 PTAC: 12.5-(0.213x$CAPY_{cool}$/1000) PTHP: 12.3-(0.213x$CAPY_{cool}$/1000) For new space or no cooling in an existing space: use Central AC: 11.3	3,4,5,7,9
COP_e	Variable	= ($HSPF_e$ / 3.413) Based on nameplate information. Should be at least ENERGY STAR.	AEPS Application; EDC Data Gathering
EER_e	Variable	Based on nameplate information. Should be at least ENERGY STAR. = $SEER_e$ 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[225, 226, 227]

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

[225] US Department of Energy. Energy Star Calculator and Bin Analysis Models
[226] A zip code mapping table is located in Appendix F. This table should be used to identify the referenece Pennsylvania city for all zip codes in Pennsylvania
[227] US Department of Energy. Energy Star Calculator and Bin Analysis Models

Space and/or Building Type	Allentown	Erie	Harrisburg	Pittsburgh	Williamsport	Philadelphia	Scranton
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[228, 229, 230]

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

[228] US Department of Energy. Energy Star Calculator and Bin Analysis Models

[229] 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

[230] US Department of Energy. Energy Star Calculator and Bin Analysis Models

Space and/or Building Type	Allentown	Erie	Harrisburg	Pittsburgh	Williamsport	Philadelphia	Scranton
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

3.19.4 Measure Life

According to an October 2008 report for the CA Database for Energy Efficiency Resources, a heat pump's lifespan is 15 years.[231]

3.19.5 Evaluation Protocols

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

[231] 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

3.20 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.

3.20.1 Algorithms

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

$\Delta kWh = \Delta kWh_{cooking} + \Delta kWh_{idle}$

$\Delta kWh_{cooking} = lbsfood \times EnergyToFood \times (1/Eff_b - 1/Eff_{ee})$

$\Delta kWh_{idle} = [(Power_{idle-b} \times (1- \%HOURS_{consteam}) + \%HOURS_{consteam} \times CAPY_b \times Qty_{pans} \times (EnergyToFood/Eff_b) \times (HOURS_{op} - lbsfood/(CAPY_b \times Qty_{pans}) - HOURS_{pre})] -$

$[(Power_{idle-ee} \times (1- \%HOURS_{consteam}) + \%HOURS_{consteam} \times CAPY_{ee} \times Qty_{pans} \times (EnergyToFood/Eff_{ee}) \times (HOURS_{op} - lbsfood/(CAPY_{ee} \times Qty_{pans}) - HOURS_{pre})]$

$\Delta kW_{peak} = (\Delta kWh / EFLH) \times CF$

3.20.2 Definition of Terms

$lbsfood$ = pPounds of food cooked per day in the steam cooker

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

Eff_{ee} = the cCooking energy efficiency of the new unit

Eff_b = the cCooking energy efficiency of the baseline unit

$Power_{idle-b}$ = the iIdle power of the baseline unit in kilowatts

$Power_{idle-ee}$ = the iIdle power of the new unit in kilowatts

$\%HOURS_{consteam}$ = pPercentage 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.

$HOURS_{op}$ = tTotal operating hours per day

` $HOURS_{pre}$ = dDaily hours spent preheating the steam cooker

$CAPY_b$	= ~~the p~~Production capacity per pan of the baseline unit in pounds per hour of the baseline unit
$CAPY_{ee}$	= ~~the p~~Production capacity per pan of the new unit in pounds per hour
Qty_{pans}	= ~~the q~~Quantity of pans in the unit
EFLH	= ~~the e~~Equivalent full load hours per year
CF	= Demand Coincidence Factor (See Section 1.4)~~Demand coincidence factor~~
1000	= ~~c~~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
Eff_{ee}	Variable	Nameplate	EDC Data Gathering
		Default values in Table 3-70	Table 3-70
Eff_b	Fixed	See Table 3-70	Table 3-70
$Power_{idle\text{-}b}$	Variable	See Table 3-70	Table 3-70
$Power_{idle\text{-}ee}$	Variable	Nameplate	EDC Data Gathering
		Default values in Table 3-70	Table 3-70
$HOURS_{op}$	Variable	Nameplate	EDC Data Gathering
		12 hours	1
$HOURS_{pre}$	Fixed	0.25	1
$\%HOURS_{consteam}$	Fixed	40%	1
$CAPY_b$	Fixed	See Table 3-70	Table 3-70
$CAPY_{ee}$	Fixed	See Table 3-70	Table 3-70
Qty_{pans}	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[232]

# of Pans	Parameter	Baseline Model	Efficient Model	Savings
3	$Power_{idle}$ (kW)[233]	1.000	0.27	
	CAPY (lb/h)	23.3	16.7	
	lbsfood	100	100	
	Eff[234]	2630%	59%	
	ΔkWh			2,813
	ΔkW_{peak}			0.54
4	$Power_{idle}$ (kW)	1.325	0.30	
	CAPY (lb/h)	21.8	16.8	
	lbsfood	128	128	
	Eff	2630%	57%	
	ΔkWh			3,902
	ΔkW_{peak}			0.75

[232] 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.
[233] Efficient values calculated from a list of ENERGY STAR qualified products.
[234] Ibid.

# of Pans	Parameter	Baseline Model	Efficient Model	Savings
5	$Power_{idle}$ (kW)	1.675	0.31	
	CAPY (lb/h)	20.6	16.6	
	lbsfood	160	160	
	Eff	2630%	70%	
	ΔkWh			5,134
	ΔkW_{peak}			0.98
6	$Power_{idle}$ (kW)	2.000	0.31	
	CAPY (lb/h)	20.0	16.7	
	lbsfood	192	192	
	Eff	2630%	65%	
	ΔkWh			6,311
	ΔkW_{peak}			1.21

3.20.3 Measure Life

According to Food Service Technology Center (FSTC) data provided to ENERGY STAR, the lifetime of a steam cooker is 12 years[235].

3.20.4 Evaluation Protocols

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

[235] http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=COC

3.21 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[236] and between 0°F to 30°F for medium-temperature and between 35°F to 55°F for high-temperature display cases[237]. 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.

3.21.1 Algorithms

The energy savings and demand reduction are obtained through the following calculations[238].

$$\Delta kWh = W \times SF \times HOU$$

There are no demand savings for this measure because the covers will not be in use during the peak period[239].

3.21.2 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*

[236] http://www.smud.org/en/business/rebates/Pages/express-refrigeration.aspx
[237] Massachusetts 2011 Technical Reference Manual
[238] "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.
[239] 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.

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[240]	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.

3.21.3 Measure Life

The expected measure life is 5 years[241,242].

[240] 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

[241] 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Effective/Remaining Useful Life Values", California Public Utilities Commission, December 16, 2008.

[242] The Measure Life Report for Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc., June 2007

3.22 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.

3.22.1 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

3.22.2 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).

3.23 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.

3.23.1 Eligibility[243]

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.

3.23.2 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

$\Delta kWh = \Delta kWh_{cooler}$

$\Delta kW_{peak} = \Delta kW_{cooler}$

Main Freezer Doors

$\Delta kWh = \Delta kWh_{freezer}$

$\Delta kW_{peak} = \Delta kW_{freezer}$

3.23.3 Definition of Terms

$\Delta kWh_{cooler,}$ = Annual kWh savings for main cooler doors

[243] http://energysmartonline.org/documents/EnergySmart_BPA_T&Cs.pdf

ΔkW_{cooler} = Summer peak kW savings for main cooler doors

$\Delta kWh_{freezer}$, = Annual kWh savings for main freezer doors

$\Delta kW_{freezer}$ = 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		
		kWh_{cooler}	kW_{cooler}	$kWh_{freezer}$	$kW_{freezer}$	
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/

3.23.4 Measure Life

The expected measure life is **8 years**[244].

[244] http://energysmartonline.org/documents/EnergySmart_BPA_T&Cs.pdf

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

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

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

3.24.1 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.

3.24.2 Algorithms

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

$$\Delta kWh = \Delta kWh/ft \times L$$

$$\Delta kW_{peak} = \Delta kW/ft \times L$$

3.24.3 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[245] 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

[245] http://www.calmac.org/publications/ComFac_Evaluation_V1_Final_Report_02-18-2010.pdf

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

3.24.4 Measure Life

The expected measure life is 4 years[246].

[246] http://www.calmac.org/publications/ComFac_Evaluation_V1_Final_Report_02-18-2010.pdf

3.25 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.

3.25.1 Eligibility

This protocol documents the energy savings attributed to insulation of bare refrigeration suction pipes. The following are the eligibility requirements[247]:

- 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)

3.25.2 Algorithms

The demand and energy savings assumptions are based on analysis performed by Southern California Edison (SCE)[248]. – 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. According to a survey carried out in the study, approximately 70% of refrigerated cases in audited grocery stores are medium temperature cases and 30% are low temperature cases[249]. As a result, the energy savings shown in this report are the weighted average energy savings (70% medium temperature, 30% low temperature). Table 3-82 below

[247] http://www.energysmartgrocer.org/pdfs/PGE/2010_2012%20External%20Equipment%20SpecificationTandCs%20v3.pdf

[248] Work papers developed by SCE filed with the CA PUC in support of its 2006 – 2008 energy efficiency program plans

[249] Final Evaluation, Monitoring, and Verification (EM&V) Report for 2004-2005 EnergySmart Grocer Program. 2006. PWP, Inc., p. 39, Exhibit 17

lists the "deemed" savings for the associated California Climate zones and their respective Pennsylvania city.

$\Delta kWh = \Delta kWh/ft \times L$

$\Delta kW_{peak} = \Delta kW/ft \times L$

3.25.3 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[250]

City	Associated California Climate Zone	CoolersMedium-TemperatureCoolers		FreezersLow-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

[250] 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

3.25.4 Measure Life

The expected measure life is 11 years[251,252].

[251] California Measurement Advisory Committee Public Workpapers on PY 2001 Energy Efficiency Programs. September 2000. Appendix F, P.14

[252] DEER database, EUL/RUL for insulation bare suction pipes

3.26 Refrigeration – Evaporator Fan Controllers

This measure is for the installation of evaporator fan controls[253] 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.~~The controller reduces air flow rather than turning fans off completely when the compressor is not operating because a minimum airflow is required to provide defrosting and prevent the air in the cooler from stratifying into layers of higher and lower temperature.~~ 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.

3.26.1 Eligibility

This protocol documents the energy savings attributed to installation of evaporator fan controls in medium-temperature walk-in coolers~~. These controllers are not applicable to~~ and low temperature walk-in ~~coolers~~freezers~~ because they are incompatible with the operation of the defrost system in those coolers.~~.

3.26.2 Algorithms[254]

$\Delta kWh = \Delta kWh_{Fan} + \Delta kWh_{Heat} + \Delta kWh_{Control}$

$\Delta kWh_{Fan} = kW_{Fan} \times 8760 \times \%Off$

$\Delta kWh_{Heat} = \Delta kWh_{Fan} \times 0.28 \times Eff_{RS}$

$\Delta kWh_{Control} = [kW_{CP} \times Hours_{CP} + kW_{Fan} \times 8760 \times (1 - \%Off)] \times 5\%$

$\Delta kW = \Delta kWh / 8760$

3.26.3 Definition of Terms

ΔkWh_{Fan} = Energy savings due to evaporator being shut off

ΔkWh_{Heat} = Heat energy savings due to reduced heat from evaporator fans

$\Delta kWh_{Control}$ = Control energy savings due to electronic controls on compressor and evaporator

kW_{Fan} = Power demand of evaporator fan calculated from equipment nameplate data and estimated power factor/adjustment. See

[253] 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).

[254] 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

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*

Eff_{RS} = *Efficiency of typical refrigeration system*

kW_{CP} = *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.*

$Hours_{CP}$ = *Equivalent annual full load hours of compressor operation*[255]

5% = *Reduced run-time of compressor and evaporator due to electronic controls*[256]

Table 3-83: Evaporator Fan Controller Calculations Assumptions

Component	**Type**	**Value**	**Source**
Power Factor: kW_{Fan}	Fixed	Default: 0.55	1
%Off	Fixed	Default: 46%	2
Eff_{RS}	Fixed	Default: 1.6 kW/ton	3
Power Factor: kW_{CP}	Fixed	Default: 0.85	4
$Hours_{CP}$	Variable	EDC Data Gathering	EDC Data Gathering
kW_{Fan}	Variable	EDC Data Gathering[257]	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.* Prepared for NSTAR.
3. Estimated average refrigeration efficiency for small business customers, Massachusetts Technical Reference Manual

[255] Conservative value based on 15 years of NRM field observations and experience

[256] 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.

[257] 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

4. This value is an estimate by NRM based on hundreds of downloads of hours of use data from the electronic controller

3.26.4 Measure Life

The expected measure life is 10 years[258].

[258] Energy & Resource Solutions (2005). Measure Life Study. Prepared for The Massachusetts Joint Utilities; Table 1-1.

3.27 ENERGY STAR Clothes Washer (Electric Water Heater, Electric Dryer)

Measure Name	Clothes Washer
Target Sector	Multifamily Common Area Laundry
Measure Unit	Per Washing Machine
Unit Energy Savings	See Table 3-85: Deemed Savings for ENERGY STAR Clothes Washer
Unit Peak Demand Reduction	See Table 3-85: Deemed Savings for ENERGY STAR Clothes Washer
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 (ft^3 ×cycle)/ (kWh). The Federal efficiency standard is >1.26 (ft^3 ×cycle)/ (kWh)[259].

3.27.1 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. To qualify for this rebate, the heating fuel source for both the clothes dryer and water heater must be electricity. Electric savings are substantially lower if the dryer and/or water heater is gas-heated and do not qualify for this protocol.

3.27.2 Algorithms

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

$\Delta kWh = \Delta kWh_{load} \text{ X Loads}$

$\Delta kW_{peak} = \text{kWh Savings X UF}$

$$\Delta kWh = \frac{Loads \times Vol}{MEF_B} - \frac{Loads \times Vol}{MEF_P}$$

$$\Delta kW_{peak} = kWh\ Savings \times UF$$

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

[259] Consortium for Energy Efficiency: http://www.cee1.org/resid/seha/rwsh/reswash_specs.pdf

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 – 1144950 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.

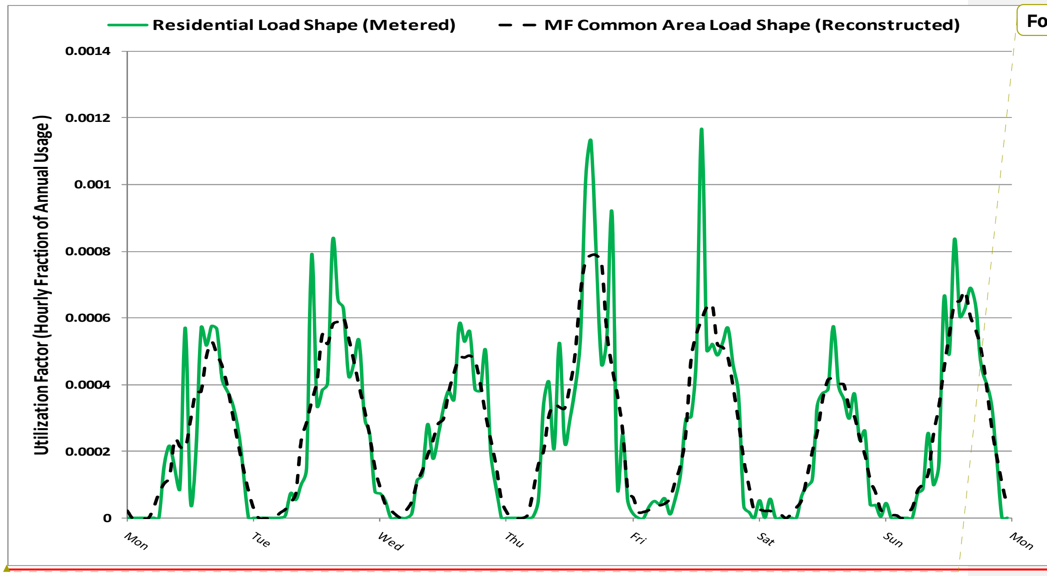

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Figure 3-1: Utilization factor for a sample week in July[260]

[260] 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

3.27.3 Definition of Terms

The parameters in the above equation are listed in Table 3-84: Commercial Clothes Washer Calculation Assumptions below.

Table 3-84: Commercial Clothes Washer Calculation Assumptions

Component	Type	Values	Source
MEF_B, Base Federal Standard Modified Energy Factor	Fixed	1.26[261]	1
MEF_P, Modified Energy Factor of Qualified Washing Machine (Name Plate)	Variable	Nameplate Tier 1: ≥2.00 Tier 2: ≥2.20 Tier 3: ≥2.40	1
ΔkWh_{load}[262], Difference in Electricity Consumption per Load of Laundry between Baseline and Efficient Equipment Vol, Volume of Qualified Washing Machine ft^3	VariableFixed	Nameplate Table 3-85	EDC Data Gathering2
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, OctoberJuly 200911
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

3.27.4 Deemed Savings

The deemed savings for the installation of a washing machine with a MEF of 2.0 or higher, is directly correlated to both the internal volume and MEF specified on the name platedependent on the energy source for washer. The table below shows an example of typical savings for washing machines with a 3.0 ft^3 volume and range of common MEFs.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.

[261] Standard clothes washer that is DOE 2007 compliant
[262] Dependent on energy source for washer

Table 3-85: ExampleDeemed Savings for 3.0 ft³ENERGY STAR Clothes Washing machineer

Volume (ft^3)Fuel Source	Cycles/ Year	ΔkWh$_{load}$ Standard kWh	Energy Savings (kWh)	Demand Reduction (kW)
3 Electric Hot Water Heater, Electric Dryer	950	2,2620.57	541837	0.1290.199
Electric Hot Water Heater, Gas Dryer3	950	2,2620.36	342966	0.0810.230
Electric Hot Water Heater, No Dryer3	950590	2,2620.36	3421,074	0.0810.256
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

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3.27.5 Measure Life

The Database for Energy Efficiency Resources estimates the measure life at 10 years[263].

3.27.6 Evaluation Protocols

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

[263] 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Effective/Remaining Useful Life Values"

3.28 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.

3.28.1 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.

3.28.2 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:

$$\Delta kWh = \frac{\left\{\left(\frac{1}{EF_{Base}} - \frac{1}{EF_{Proposed}}\right) \times Load \times (Thot - Tcold)\right\}}{3413\frac{Btu}{kWh}}$$

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$$\Delta kWh = \frac{\left\{\left(\frac{1}{EF_{Base}} - \frac{1}{EF_{Proposed}}\right) \times Load \times (Thot - Tcold)\right\}}{3413\frac{Btu}{kWh}}$$

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.

$$\Delta kW_{peak} = EnergyToDemandFactor \times Energy\ Savings \times ResistiveDiscountFactor$$

The Energy to Demand Factor is defined below:

$$EnergyToDemandFactor = \frac{Average\ Usage_{Summer\ WD\ Noon-8}}{Annual\ Energy\ Usage}$$

Loads

The annual loads are taken from data from the DEER database[264]. The DEER database has data for gas energy usage for the domestic hot water end use for various small commercial buildings. The actual loads in kBTU per 1000 ft^2 result from dividing by the DEER models' gas water heater energy factor, 0.63. 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. Finally, the loads are multiplied by the typical building sizes in the DEER models to obtain annual kBTU. The loads are summarized in HW

$$(Gallons) = \frac{Load \times EF_{NG,\ Base}\ X\ 1000\ \frac{Btu}{kBtu}\ X\ Typical\ SF}{8.3\ \frac{lb}{gal}\ X\ (Thot - Tcold)\ X\ 1000\ SF}$$

Table 3-86. The loads associated with residential domestic water heating from the PA TRM are also provided for comparison.

$$HW\ (Gallons) = \frac{Load \times EF_{NG,\ Base}\ X\ 1000\ \frac{Btu}{kBtu}\ X\ Typical\ SF}{8.3\ \frac{lb}{gal}\ X\ (Thot - Tcold)\ X\ 1000\ SF}$$

Table 3-86: Typical water heating loads.

Building Type	Typical Square Footage	Average Annual Load In kBTU	SourceAverage Annual Use, Gallons
Motel	30,000	55,9992,963999	97,870DEER
Small Office	10,000	13,9462,214946	24,377DEER
Small Retail	7,000	7,3141,451314	11,183DEER
Residential	2,000	12,672	PA TRM

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[265]. 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,

[264] http://www.deeresources.com/deer0911planning/downloads/DEER2008-CommercialResultsReview-NonUpdatedMeasures.exe
[265] ibid

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[266].

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

[266] 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).

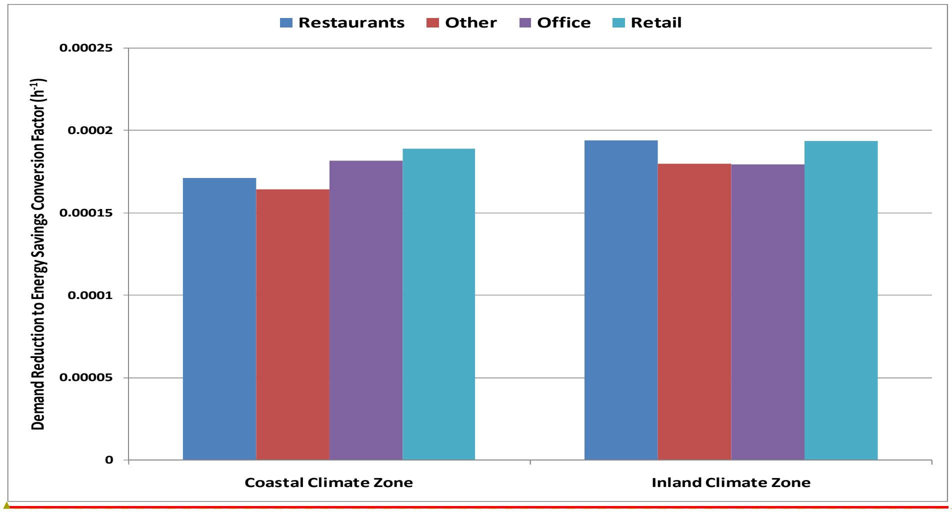

Figure 3-3: Energy to demand factors for four commercial building types

3.28.3 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
EF_{base}, Energy Factor of baseline water heater	Fixed	0.90490	1
$EF_{proposed}$, Energy Factor of proposed efficient water heater	Variable	≥0.93	Program Design
Load, Average annual Load in -kBTU	Fixed	Varies	DEER Database
T_{hot}, Temperature of hot water	Fixed	120 °F	2
T_{cold}, 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
$EF_{NG, base}$, 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.

3.28.4 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, GallonsAnnual Load In kBTU**	**EF**	**Energy Savings (kWh)**	**Demand Reduction (kW)**
Motel	97,87055,999	0.95	960829	0.180.16
Small Office	24,37713,946	0.95	239207	0.054
Small Retail	11,1837,314	0.95	12595	0.02

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3.28.5 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[267].

3.28.6 Evaluation Protocols

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

[267] DEER values, updated October 10, 2008 http://www.deeresources.com/deer0911planning/downloads/EUL_Summary_10-1-08.xls

3.29 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.

3.29.1 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.

3.29.2 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:

$$\Delta kWh = \frac{\left\{\left(\frac{1}{EF_{Base}} - \left(\frac{1}{EF_{Proposed}} \times \frac{1}{F_{Adjust}}\right)\right) \times Load \times (Thot - Tcold)\right\}}{3413\frac{Btu}{kWh}}$$

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$$\Delta kWh = \frac{\left\{\left(\frac{1}{EF_{Base}} - \left(\frac{1}{EF_{Proposed}} \times \frac{1}{F_{Adjust}}\right)\right) \times Load \times (Thot - Tcold)\right\}}{3413\frac{Btu}{kWh}}$$

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.

ΔkW_{peak} = *EnergyToDemandFactor × Energy Savings × ResistiveDiscountFactor*

The Energy to Demand Factor is defined below:

$$EnergyToDemandFactor = \frac{Average\ Usage_{Summer\ WD\ Noon\text{-}8}}{Annual\ Energy\ Usage}$$

Loads

The annual loads are taken from data from the DEER database[268]. The DEER database has data for gas energy usage for the domestic hot water end use for various small commercial buildings. The actual loads in kBTU per 1000 ft^2 result from dividing by the DEER models' gas water heater energy factor, 0.63. 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. Finally, the loads are multiplied by the typical building sizes in the DEER models to obtain annual kBTU. The loads are summarized in

$$HW\,(Gallons) = \frac{Load \times EF_{NG,\ Base}\ X\ 1000\ \frac{Btu}{kBtu}\ X\ Typical\ SF}{8.3\ \frac{lb}{gal}\ X\ (Thot - Tcold)\ X\ 1000\ SF}$$

Table 3-86 below. The loads associated with residential domestic water heating from the PA TRM are also provided for comparison.

$$HW\,(Gallons) = \frac{Load \times EF_{NG,\ Base}\ X\ 1000\ \frac{Btu}{kBtu}\ X\ Typical\ SF}{8.3\ \frac{lb}{gal}\ X\ (Thot - Tcold)\ X\ 1000\ SF}$$

Table 3-89: Typical water heating loads

Building Type	**Typical Square Footage**	**Average Annual Load In kBTUAnnual Load In kBTU**	**Average Annual Use, GallonsSource**
Motel	30,000	2,96355,999	97,870DEER
Small Office	10,000	2,21413,946	24,377DEER
Small Retail	7,000	1,4517,314	11,183DEER
Residential	2,000	12,672	PA TRM

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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[269]. 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

[268] http://www.deeresources.com/deer0911planning/downloads/DEER2008-CommercialResultsReview-NonUpdatedMeasures.exe
[269] ibid

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[270].

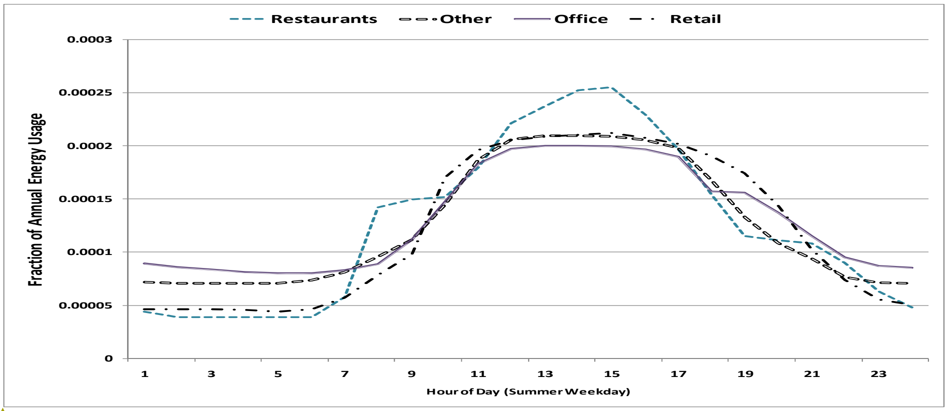

Figure 3-4: Load shapes for hot water in four commercial building types

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[270] 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).

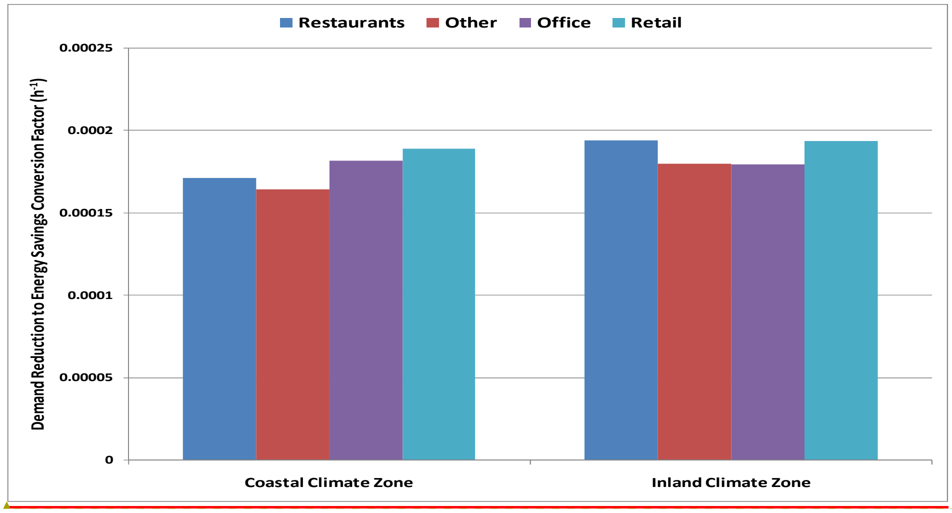

Figure 3-5: Energy to demand factors for four commercial building types

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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[271], while the average wetbulb temperature in conditioned typically ranges from 50 °F to 80 °F. The heat

[271] 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.

pump performance is temperature dependent. Figure 3-6 below shows relative coefficient of performance (COP) compared to the COP at rated conditions[272]. 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

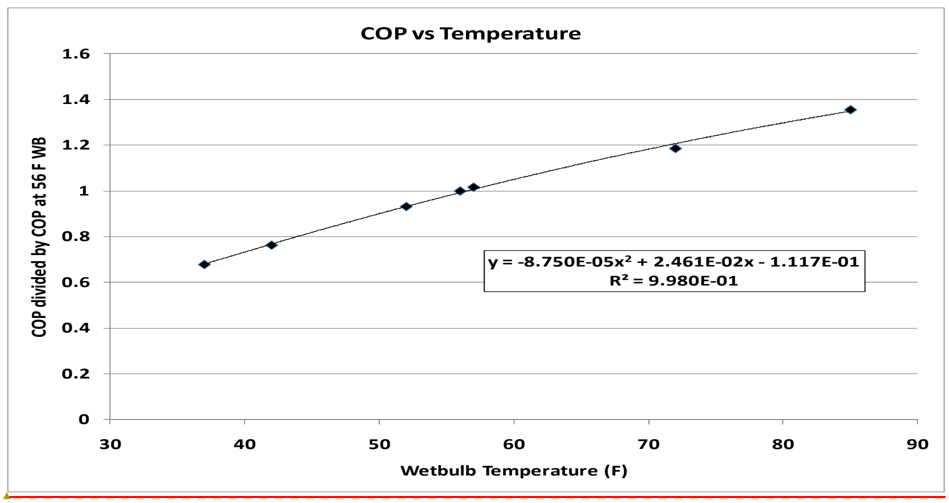

Figure 3-6: Dependence of COP on outdoor wetbulb temperature.

3.29.3 Definition of Terms

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

[272] 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.

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Table 3-91: Electric Resistance Water Heater Calculation Assumptions

Component	Type	Values	Source
EF_{base}, Energy Factor of baseline water heater	Fixed	0.904	1
$EF_{proposed}$, Energy Factor of proposed efficient water heater	Variable	Nameplate	EDC Data Gathering
Load, Average annual Load in kBTULoad, Annual Load in BTU	Fixed	Varies	5
T_{hot}, Temperature of hot water	Fixed	120 °F	2
T_{cold}, Temperature of cold water supply	Fixed	55 °F	3
EnergyToDemandFactor	Fixed	0.0001916	8, and discussion above4
F_{Adjust}, 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
$EF_{NG, base}$, 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

3.29.4 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~~Annual Load In kBTU~~	EF	COP Adjustment Factor	Energy Savings (kWh)	Demand Reduction (kW)
Motel	Unconditioned Space	97,870~~55,999~~	2.2	0.80	8,324~~8,908~~	1.44~~1.54~~
Motel	Conditioned Space	97,870~~55,999~~	2.2	1.09	10,662~~11,388~~	1.84~~1.96~~
Motel	Kitchen	97,870~~55,999~~	2.2	1.30	11,704~~12,494~~	2.02~~2.15~~
Small Office	Unconditioned Space	24,377~~13,946~~	2.2	0.80	2,073~~2,218~~	0.36~~0.38~~
Small Office	Conditioned Space	24,377~~13,946~~	2.2	1.09	2,656~~2,836~~	0.46~~0.49~~
Small Office	Kitchen	24,377~~13,946~~	2.2	1.30	2,915~~3,111~~	0.50~~0.54~~
Small Retail	Unconditioned Space	11,183~~7,314~~	2.2	0.80	951~~1,163~~	0.16~~0.20~~
Small Retail	Conditioned Space	11,183~~7,314~~	2.2	1.09	1,218~~1,487~~	0.21~~0.26~~
Small Retail	Kitchen	11,183~~7,314~~	2.2	1.30	1,338~~1,632~~	0.23~~0.28~~

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3.29.5 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[273].

3.29.6 Evaluation Protocols

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

[273] DEER values, updated October 10, 2008. http://www.deeresources.com/deer0911planning/downloads/EUL_Summary_10-1-08.xls

3.30 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.

3.30.1 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%[274] 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.

3.30.2 Algorithms

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

$\Delta kW = kW_{base} - kW_{ee}$

$kW_{base} = kW_N/ft \times Q \times N$

$kW_{ee} = kW_{LED}/ft \times Q \times N$

$\Delta kW_{peak} = \Delta kW \times CF \times (1+IF\ demand)$

$\Delta kWh = [kW_{base} \times (1+IF\ energy) \times EFLH] – [kW_{ee} \times (1+IF\ energy) \times EFLH \times (1 – SVG)]$

3.30.3 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)

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

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

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[274] http://www.aepohio.com/global/utilities/lib/docs/save/programs/Application_Steps_Incentive_Process.pdf

L = length of the sign (feet)

Q[275] = 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)~~Demand Coincidence Factor~~

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).

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[275] 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.

Table 3-93: LED Channel Signage Calculation Assumptions

Component	Type	Value	Source
kW_N/ft	Variable	EDC Data Gathering Default: 0.00457[276]	EDC Data Gathering
kW_{LED}/ft	Variable	EDC Data Gathering Default: 0.00136[277]	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
IF_{demand}	Fixed	See Table 3-7	Table 3-7
IF_{energy}	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.

3.30.4 Measure Life

Expected measure life is 15 years[278].

[276] 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.

[277] ibid

[278] 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.

3.31 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: 152151152 kWh; Non-Groceries: 1,2271,222227 kWh
Unit Peak Demand Reduction	Groceries: 0.03kW; Non-Groceries: 0.220.2322 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.

3.31.1 Algorithms

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

ΔkWh *for Non-Groceries* $= (((F_{BNG} \times U_{BNG})-(F_{PNG} \times U_{PNG})) \times 365) \times 8.33 \text{ x } (T_{MHNG}) \times (T_{MNG}-T_C) \times C_H \times C_E \times / \times Eff^{-1} \text{ (EF x 3413 Btu/kWh)}$

ΔkWh *for Groceries* $= (((F_{BG} \times U_{BG})-(F_{PG} \times U_{PG})) \times 365) \times 8.33 \text{ x } -(T_{MHG}) \times (T_{MG}-T_C) / \text{(EF x 3413 Btu/kWh)} \times \times C_H \times C_E \times Eff^{-1}$

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.

$\Delta kW_{peak} = EnergyToDemandFactor \times Energy\ Savings$

The Energy to Demand Factor is defined below:

$$EnergyToDemandFactor = \frac{\text{Average Usage}_{\text{Summer WD Noon-8}}}{\text{Annual Energy Usage}}$$

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[279].

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

[279] 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).

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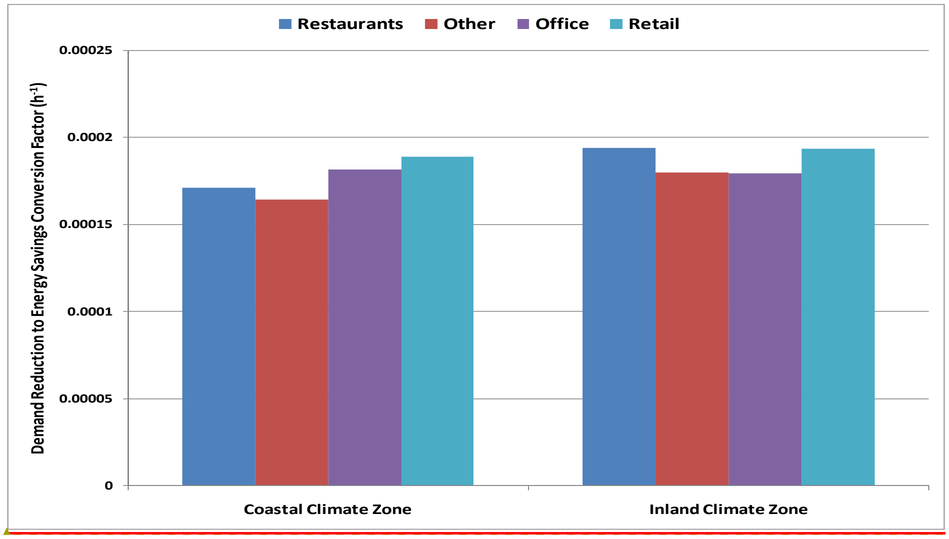

Figure 3-8: Energy to demand factors for four commercial building types.

3.31.2 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.

F_{BNG} = Baseline Flow Rate of Sprayer for Non-Grocery Applications

F_{PNG} = Post Measure Flow Rate of Sprayer for Non-Grocery Applications

U_{BNG} = Baseline Water Usage Duration for Non-Grocery Applications

U_{PNG} = Post Measure Water Usage Duration for Non-Grocery Applications

F_{BG} = Baseline Flow Rate of Sprayer for Grocery Applications

F_{PG} = Post Measure Flow Rate of Sprayer for Grocery Applications

U_{BG} = Baseline Water Usage Duration for Grocery Applications

U_{PG} = Post Measure Water Usage Duration for Grocery Applications

T_{HNG} = Hot water Temperature of hot water coming from the spray nozzle for Non-Grocery Application

T_C = Cold Incoming cold water Ttemperature for Grocery and Non-Grocery Application

T_{HG} = Hot water Temperature of hot water coming from the spray nozzle for Grocery Application

T_C = Cold water Temperature for Grocery Application

C_H = Unit Conversion: 8.33BTU/(Gallons-°F)

C_E = Unit Conversion: 1 kWh/3413 BTU

EffEF = Efficiencynergy of existingEnergy Factor of existing Electric Water Heater System

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

Description	Type	Value	Source
F_{BNG}	Fixed	2.25 gpm	1
F_{PNG}	Fixed	1.12 gpm	1
U_{BNG}	Fixed	32.4min/day	2
U_{PNG}	Fixed	43.8 min/day	2
F_{BG}	Fixed	2.15 gpm	1
F_{PG}	Fixed	1.12 gpm	1
U_{BG}	Fixed	4.8 min/day	2
U_{PG}	Fixed	6 min/day	2
T_{HNG}	Fixed	127.5107ºF	3
T_C	Fixed	72.855ºF	363
T_{HG}	Fixed	118.597.6ºF	3
T_C	Fixed	70.7ºF	3
C_H	Fixed	8.33	Conversion
C_E	Fixed	1/3413	Conversion
EffEFEff	Fixed	0.90490	545
EnergyToDemandFactor	Fixed	0.00019160.000193885	656

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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

3.31.3 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 types such 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.

3.31.4 Measure Life

The effective life for this measure is 5 years[280].

3.31.5 Evaluation Protocol

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

[280] *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

3.32 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.

3.32.1 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.

3.32.2 Algorithms

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

For Cooling:

$\Delta kWh = (EFLH_C \times CAPY_C CAP_C/1000) \times (1/[EER \times RCF] - 1/EER)$

$\Delta kW_{peak} = (CF \times CAPY_C CAP_C/1000) \times (1/[EER \times RCF] - 1/EER)$

Additional Heating Savings for Heat Pumps:

$\Delta kWh = (EFLH_{MH} \times CAPY_H CAP_H/1000) \times (1/[HSPF \times RCF] - 1/HSPF)$

3.32.3 Definition of Terms

$CAPY_C$ = Unit Capacity, in Btu/h for cooling

$CAPY_H$ ~~CAPY:~~ = Unit Capacity, in Btu/h for heating

EER = Energy Efficiency Ratio

HSPF = Heating Seasonal Performance Factor

$EFLH_C$ = Equivalent Full-Load Hours for Mechanical Cooling

$EFLH_{HMMH}$ = Equivalent Full-Load Hours for Mechanical Heating[281]

RCF = COP Degradation Factor for Cooling

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

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

Table 3-95: Refrigerant Charge Correction Calculations Assumptions

Component	Type	Value	Source
$CAPY_C$	Variable	Nameplate	EDC Data Gathering
$CAPY_H$	Variable	Nameplate	EDC Data Gathering
EER	Variable	Nameplate Default: 9.0	EDC Data Gathering
HSPF	Variable	Default: 7.0	EDC Data Gathering
$EFLH_C$	Variable	Table 3-22 and Table 3-23 in 2011 PA TRM	2011 PA TRM
$EFLH_{HMMH}$	Variable	Take $EFLH_{HM}$ as 870% of the listed $EFLH_H$ 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

[281] 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.

Table 3-96: Refrigerant charge correction COP degradation factor (RCF) for various relative charge adjustments for both TXV metered and non-TXV units.[282].

% 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%

[282] CA 2003 RTU Survey

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%

3.32.4 Measure Life

According to the 2008 Database for Energy Efficiency Resources (DEER) EUL listing, the measure life for refrigerant charging is **10 years**[283].

[283] http://www.deeresources.com/deer0911planning/downloads/EUL_Summary_10-1-08.xls

3.33 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.

3.33.1 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[284] amps per linear foot for low temperature display cases. Rebate is based on the door width (not including case frame).

3.33.2 Algorithms

The energy savings and demand reduction are obtained through the following calculations adopted from California's Southern California Edison[285].

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

[284] http://www.energysmartgrocer.org/pdfs/PGE/BridgeEquipment%20SpecificationTandCs.pdf

[285] Southern California Edison. Non-Residential Express 2003 Refrigeration Work Paper. Pg. 27.

Compressor Savings (excluding condenser):

$\Delta\ kW_{compressor}$ = [$Q\text{-}cooling_{svg}$/EER/1000]

$\Delta\ kWh_{compressor}$ = Δ kW x EFLH

$Q\text{-}cooling_{svg}$ = Q-cooling x K-ASH

Anti-Sweat Heater Savings:

$\Delta\ kW_{ASH}$ = Δ ASH / 1000

$\Delta\ kWh_{ASH}$ = $\Delta\ kW_{ASH}$ x t

3.33.3 Definition of Terms

The variables in the above equation are defined below:

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

$Q\text{-}cooling_{svg}$ = Cooling savings (Btu/hr/door)

$\Delta\ kW_{compressor}$ = Compressor power savings (kW/door)

$\Delta\ kW_{ASH}$ = 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)

$\Delta\ kWh_{compressor}$ = Annual compressor energy savings (excluding condenser energy), (kWh/door)

$\Delta\ kWh_{ASH}$ = 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[286]	1
Δ ASH	Fixed	83[287]	1
t	Fixed	8,760	1

Sources:

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

3.33.4 Measure Life

The expected measure life is 15 years[288].

[286] 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.

[287] From Actual Test: 0.250 kW per 3 doors

[288] http://energysmartonline.org/documents/EnergySmart_BPA_T&Cs.pdf

3.34 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.

3.34.1 Algorithms

ΔkWh = $(BtuH_{cool} / 1000) \times (1/EER_{base} - 1/EER_{ee}) \times EFLH_{cool}$

ΔkW_{peak} = $(BtuH_{cool} / 1000) \times (1/EER_{base} - 1/EER_{ee}) \times CF$

3.34.2 Definition of Terms

$BtuH_{cool}$ = Rated cooling capacity of the energy efficient unit in $BtuH_{cool}$

EER_{base} = Efficiency rating of the baseline unit.

EER_{ee} = Efficiency rating of the energy efficiency unit.

CF = Demand Coincidence Factor (See Section 1.4)

$EFLH_{cool}$ = 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
EER_{base}	Variable	~~Early Replacement: Nameplate data~~ Default values from Table 3-99	~~EDC's Data Gathering~~ See Table 3-99
EER_{ee}	Variable	Nameplate data (AHRI or AHAM)	EDC's Data Gathering
CF	Fixed	80%	2
$EFLH_{cool}$	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[289]

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[290]

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

[289] Baseline values from IECC 2009, after Jan 1, 2010 or Jan 23, 2010 as applicable.
[290] US Department of Energy. Energy Star Calculator and Bin Analysis Models

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4 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.

4.1 Determination of Act 129 Peak Load Reductions

4.1.1 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[291] 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,

4.1.2 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.*

4.1.3 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

[291] See the Secretarial Letter issued by the Commission on January 12, 2011, at Docket No. M-2008-2069887.

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.

4.1.4 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[292] + Constant Load Reductions from non-dispatchable measures (i.e., peak load reductions from EE measures + peak load reductions from CPP programs + 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.

4.2 Determine the "Top 100 Hours" (100 hours of highest peak load)

4.2.1 Step 2a

The EDC will record actual system load data for every hour from June 1, 2012, through September 30, 2012.

4.2.2 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.[293] 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.[294]
- 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

[292] This will be 0 MW if there was not a curtailment event in that hour.
[293] 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.
[294] 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.

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.

4.2.3 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).

4.2.4 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.

4.2.5 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.

4.3 Determine the Act 129 Average Peak Load Reduction During the 100 Peak Hours

4.3.1 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.

4.3.2 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.

4.3.3 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)

Definitions	
Actual Load: Total metered load	
Constant Load Reductions: Reductions from CVR, energy efficiency, time-based pricing, etc.	
Event-Driven Load Reductions: Reductions from load curtailment, direct load control, etc.	
Calculations	**Section**
Hourly Load Reductions = **Constant Load Reductions** + **Event-Driven Load Reductions**	1d
Hourly Reconstructed Load = **Actual Load** + **Hourly Load Reductions** (minus pre-cooling and snapback if applicable for EDC)	2b
Top 100 Hours = 100 hours with highest **Hourly Reconstructed Loads**	2c
Total Top 100 Peak Load Reductions = Sum of **Hourly Load Reductions** during **Top 100 Hours**	3a
Average Peak Load Reductions = **Total Top 100 Peak Load Reductions** / 100	3b

Figure 4-1: Demand Response Definitions and Calculations

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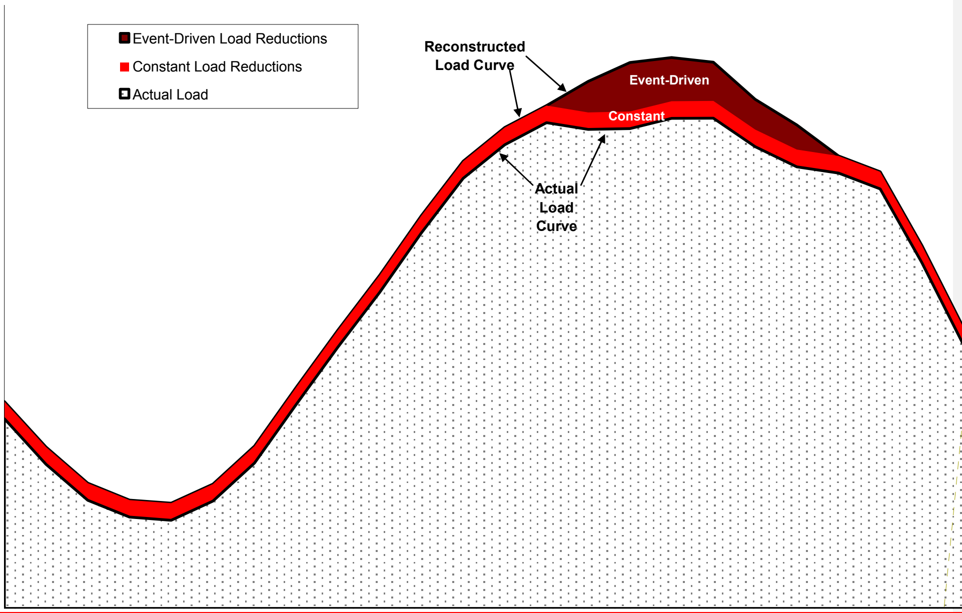

Figure 4-2: EDC Example Daily Load Curve

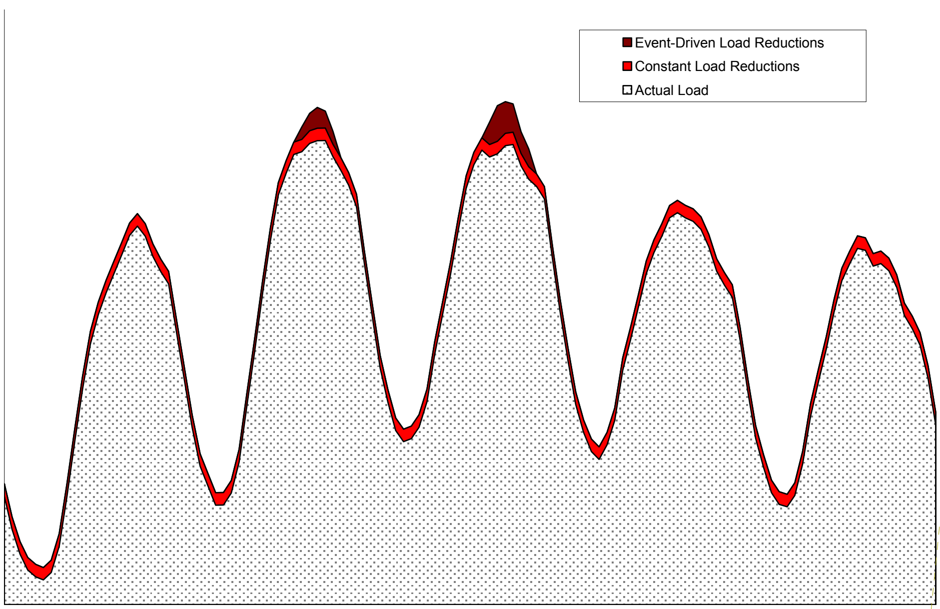

Figure 4-3: 5 Daily Load Curve Example

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45 APPENDICES

4.15.1 Appendix A: Measure Lives

Measure Lives Used in Cost-Effectiveness Screening
February 2008[295]

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

295 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/>.

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

4.25.2 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.

4.35.3 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

4.45.4 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.

5.5 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.

5.5.1 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[296], the product shall meet the minimum ENERGY STAR requirements[297] [298] for the given product category. Products are not required to be on the ENERGY STAR Qualified Product List[299], 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

[296] ENERGY STAR website for Commercial LED Lighting: http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=LTG

[297] "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

[298] "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

[299] ENERGY STAR Qualified LED Lighting list http://www.energystar.gov/index.cfm?fuseaction=ssl.display_products_res_html

For SSL products for which there is not an ENERGY STAR commercial product category, but for which there is a DLC commercial product category[300], the product shall meet the minimum DLC requirements[301] for the given product category. Products are not required to be on the DLC Qualified Product List[302], 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)

[300] 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
[301] Ibid.
[302] 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."

    - Correlated color temperature (CCT)
    - LED lumen maintenance at 6000 hrs
    - Manufacturer's estimated lifetime for L_{70} (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.

5.6 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
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15049	Pittsburgh
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15052	Pittsburgh
15053	Pittsburgh

Zip	Reference City
15054	Pittsburgh
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15061	Pittsburgh
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Zip	Reference City
15116	Pittsburgh
15120	Pittsburgh
15122	Pittsburgh
15123	Pittsburgh
15126	Pittsburgh
15127	Pittsburgh
15129	Pittsburgh
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Zip	Reference City
15218	Pittsburgh
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Zip	Reference City
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Zip	Reference City
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Zip	Reference City
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15488	Pittsburgh

Zip	Reference City
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Zip	Reference City	Zip	Reference City	Zip	Reference City
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