# Technical Reference Manual

June 2014 ~~(DRAFT)~~

## 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

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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 annualized energy savings and peak demand savings for the energy efficiency 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.

For an Act 129 program, EDCs may, as an alternative to using the energy and demand savings values for standard measures contained in the TRM, use alternative methods to calculate *ex ante* savings and/or ask their evaluation contractor to use a custom method to verify *ex post* savings. The EDCs, however, must track savings estimated from the TRM protocols and alternative methods and report both sets of values in the quarterly and/or annual EDC reports. The EDCs must justify the deviation from the TRM *ex ante* and *ex post* protocols in the quarterly and/or annual reports in which they report the deviations. EDCs should be aware that use of a custom method as an alternative to the approved TRM protocol increases the risk that the PA PUC may challenge their reported savings. The alternative measurement methods are subject to review and approval by the Commission to ensure their accuracy after the reports are filed to the Commission.

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

## 1.2 Using the TRM

This section provides a consistent framework for EDC Implementation Conservation Service Providers (ICSPs) to estimate *ex ante* (claimed) savings and for EDC evaluation contractors to estimate *ex post* (verified) savings for Act 129 Energy Efficiency & Conservation (EE&C) programs.

### 1.2.1 Measure Categories

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The TRM categorizes all ~~prescriptive~~non-custom measures into two categories: deemed measures and partially deemed measures. Methods used to estimate *ex ante* and/or *ex post* savings differ for deemed measures and partially deemed measures.

- ***Deemed measure protocols*** have specified “deemed energy and demand savings values” [2]; no additional measurement or calculation is required to determine deemed savings. These protocols also may contain an algorithm with “stipulated variables”[3] to provide transparency into deemed savings values and to facilitate the updating of deemed savings values in future TRMs. Stipulated variables should not be adjusted using customer-specific or program-specific information for calculating *ex ante* and/or *ex post* savings.
- ***Partially deemed measure protocols*** have algorithms with stipulated[4] and “open variables”[5], that require ~~measurement~~customer-specific input of certain parameters to calculate the energy and demand savings. Customer-specific or program-specific information is used for each open variable, resulting in multiple savings values for the same measure. Some open variables may have a default value to use when the open variable cannot be collected. Only variables specifically identified as open variables may be adjusted using customer-specific or program-specific information.

Note that **Custom measures**[6] are considered too complex or unique to be included in the list of standard measures provided in the TRM and so are outside the scope of this TRM. Custom measures are determined through a custom-measure-specific process, which is described in Section 1.16 in this TRM.

### 1.2.2 Customer and Program Specific Data

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The EDCs and their contractors (ICSPs and ECs) are encouraged to collect and apply customer-specific or program-specific data in the *ex ante* and/or *ex post* savings calculations for as many open variables as possible to reflect most accurate savings values. Site-specific data or

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[2] A stipulated value for a variable refers to a single input value to an algorithm, while a deemed savings estimate is the result of calculating the end result of all of the stipulated values in the savings algorithm.

[3] A stipulated value for a variable refers to a single input value to an algorithm.

[4] Ibid

[5] Open variables are listed with a “default value” and an option for “EDC Data Gathering” in the TRM. When a measure indicates that an input to a prescriptive saving algorithm may take on a range of values, an average value is also provided in many cases. This value is considered the default input to the algorithm, and should be used when customer-specific information is not available.

[6] This TRM does not provide calculations or algorithms for custom measures since the category covers a wide range of equipment, approaches, and measures. Where custom measures are discussed, the TRM requires site specific equipment, operating schedules, baseline and installed efficiencies, and calculation methodologies to estimate energy and demand savings.

information should be used for measures with important variations in one or more input values (e.g. delta watts, efficiency level, equipment capacity, operating hours). Customer-specific data comes directly from the measure application form or application process and/or EDC data gathering, such as, facility staff interviews, posted schedules, building monitoring systems (BMS), panel data, or metered data. In addition, standard input values for stipulated variables and default values for some open variables provided in this TRM are to be based on evaluations completed in Pennsylvania or best available measured or industry data, available from other jurisdictions or industry associations. The EDCs may use default values for open variables in the TRM if customer-specific or program-specific information is unreliable or the EDCs cannot obtain the information.

Values for exact variables that should be determined using customer-specific information are clearly described in the measure protocols in this TRM. This methodology will provide the EDCs with more flexibility to use customer-specific data, when available obtained from their application process and evaluations to improve the accuracy and reliability of savings.

### 1.2.3 End-use Categories & Thresholds for Using Default Values

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The determination of when to use default values for open variables provided in the TRM in the *ex ante* and/or *ex post* savings calculations is a function of the savings impact and uncertainty associated with the measure[7]. The default values are appropriate for low-impact and low-uncertainty measures such as lighting retrofits in a small business facility. In contrast, customer-specific values are appropriate for high-impact and high-uncertainty measures, such as HVAC or lighting retrofits in universities or hospitals that have diverse facilities, and where those types of projects represent a significant share of program savings for a year.

The TRM ~~puts~~organizes all measures[8] into various end-use categories[9] (e.g. lighting, HVAC, motors & VFDs). ~~The~~ kWh savings thresholds are established at the end-use category level and should be used to determine whether customer-specific information is ~~necessary~~required for estimating *ex ante* and/or *ex post* savings. If a project involves multiple measures/technology[10] types that fall under the same end-use category, the savings for all those measures/technology types should be grouped together to determine if the project falls below or above a particular

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[7] While the EDCs are required to collect and apply customer specific or program specific data for projects with savings at or above the established kWh thresholds in the TRM, they are allowed to use either default values or customer specific or program specific data for projects with savings below the thresholds.

[8] ~~A measure is defined as an efficient technology or precoedure that results in energy savings as compared to the baseline efficiency.~~ A measure is defined as a new installation, the replacement of an existing installation, or the retrofitting/modification of an existing installation of a building, of a system or process component, or of an energy using device in order to reduce energy consumption. e.g., the installation of a 14W CFL is one measure, and the installation of a 21W CFL is a separate measure; the installation of wall insulation, or the modification of an existing building to reduce air infiltration are two other measures..

[9] ~~An end-use category describes the categories of equipment that provide a service to an individual or building.~~ An end-use is defined as the grouping of related technology types all associated with a similar application or primary function. E.g., CFLs, LEDs, fluorescent lamps, and lighting controls are all within the lighting end-use category; efficient water heaters, water heater blankets, water heater setback, and faucet aerators are all within the domestic hot water end-use category.

[10] A technology is defined as the grouping of related measures in order to differentiate one type of measure from another. Each technology type may consist of multiple measures. e.g., CFLs, LEDs, and VFDs are all different technology types. A 14W CFL and a 21W CFL are different measures within the CFL technology type.

threshold[11]. ~~Table 1-1~~ lists all the end-use categories and the sections for measures within a particular end-use category.

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[11] For example, linear fluorescent lighting, CFL lighting and LED lighting are individual measures within the Lighting end-use category.

~~Table 1-1: End-Use Categories and Measures in the TRM~~[12]

Table 1-1: End-Use Categories and Measures in the TRM[13]

| End-Use Categories | List of Measures (Sections) |
|---|---|
| **Residential Market Sector** | |
| Lighting | 2.4, 2.7, 2.29, 2.35, 2.36 |
| HVAC | 2.1, 2.5, 2.10, 2.15, 2.16, 2.19, 2.28 |
| Domestic Hot Water | 2.3, 2.6, 2.8, 2.9, 2.13, 2.14, 2.17, 2.18, 2.37, 2.41 |
| Appliances | 2.2, 2.11, 2.21, 2.23, 2.24, 2.25, 2.26, 2.27, 2.42 |
| Building Shell | 2.20, 2.22, 2.30, 2.40 |
| Electronics | 2.12, 2.33, 2.34 |
| Miscellaneous | 2.31, 2.32, 2.38, 2.39 |
| **Commercial & Industrial Market Sector** | |
| Lighting | 3.2, 3.29 |
| HVAC | 3.5, 3.6, 3.17, 3.18, 3.32, 3.34, 3.39 |
| Motors & VFDs | 3.3, 3.4 |
| Domestic Hot Water | 3.27, 3.28, 3.30, 3.31, 3.37, 3.38 |
| Refrigeration | 3.7, 3.8, 3.9, 3.10, 3.16, 3.20, 3.22, 3.23, 3.24, 3.25, 3.33, 3.35, 3.36 |
| Appliances | 3.26 |
| Food Service Equipment | 3.13, 3.14, 3.19 |
| Building Shell | 3.15 |
| Electronics | 3.11, 3.12, 3.21 |
| **Agricultural Sector** | |
| Agricultural Equipment | 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8 |

| ~~End-Use Categories~~ | ~~List of Measures (Sections)~~ |
|---|---|
| ~~**Residential Market Sector**~~ | |
| ~~Lighting~~ | ~~2.4, 2.7, 2.29, 2.35, 2.36, 2.37~~ |
| ~~HVAC~~ | ~~2.1, 2.5, 2.10, 2.11, 2.15, 2.16, 2.19, 2.22, 2.28~~ |
| ~~Domestic Hot Water~~ | ~~2.3, 2.8, 2.9, 2.13, 2.14, 2.17, 2.18, 2.42~~ |
| ~~Appliances~~ | ~~2.2, 2.21, 2.23, 2.24, 2.25, 2.26, 2.27, 2.33, 2.43~~ |
| ~~Building Shell~~ | ~~2.2, 2.22, 2.30, 2.41~~ |
| ~~Office EquipmentElectronics~~ | ~~2.12, 2.34~~ |
| ~~Agricultural Equipment~~ | ~~4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8~~ |
| ~~Miscellaneous~~ | ~~2.31, 2.32, 2.39, 2.40~~ |
| ~~**Commercial & Industrial Market Sector**~~ | |
| ~~Lighting~~ | ~~3.2, 3.29~~ |

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~~[12] Please note that this is not an exhaustive list of end-uses and that others may be included in future TRM updates.~~

[13] Please note that this is not an exhaustive list of end-uses and that others may be included in future TRM updates.

| | |
|---|---|
| ~~HVAC~~ | ~~3.5, 3.6, 3.717, 3.18, 3.19, 3.3332, 3.3534, 3.4039~~ |
| ~~Motors & VFDs~~ | ~~3.3, 3.4, 3.5~~ |
| ~~Domestic Hot Water~~ | ~~3.27, 3.28, 3.2930, 3.31, 3.3237, 3.38, 3.39~~ |
| ~~Refrigeration~~ | ~~3.7, 3.8, 3.9, 3.10, 3.11, 3.1716, 3.2120, 3.22, 3.23, 3.24, 3.25, 3.2633, 3.3435, 3.36, 3.37~~ |
| ~~Appliances~~ | ~~3.2726~~ |
| ~~Food Service Equipment~~ | ~~3.13, 3.14, 3.15, 3.2019~~ |
| ~~Building Shell~~ | ~~3.1615~~ |
| ~~Office EquipmentElectronics~~ | ~~3.11, 3.12, 3.13, 3.2221~~ |
| ~~**Agricultural Sector**~~ | |
| ~~Agricultural Equipment~~ | ~~4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8~~ |

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Table 1-2 shows the kWh thresholds[14] for various end-use categories. For projects with savings of established kWh thresholds or higher, the EDCs are required to collect site-specific information for open variables used in the calculation of energy and demand savings. If savings for individual end-use categories within projects fall below the threshold, the EDCs may gather customer-specific data, or may use the default stipulated value for each open variable. The thresholds below are subject to review and adjustment by the EDC ECs in coordination with SWE to minimize the uncertainty of estimates. End-use metering is the preferred method of data collection for projects above the threshold, but trend data from BMS or panel data and billing analysis[15] are acceptable substitutes. The EDCs are encouraged to meter projects with savings below the thresholds that have high uncertainty but are not required ~~i.e.~~ where data is unknown, variable, or difficult to verify. Exact conditions of “high uncertainty” are to be determined by the EDCs to appropriately manage variance. Metering completed by the ICSP may be leveraged by the evaluation contractor, subject to a reasonableness review[16]. This approach is intended to determine values for key variables and verify savings at a high level of rigor for projects that account for majority of the programs expected savings.

**Table 1-2~~1-2~~: kWh Savings Thresholds**

| End-Use Category | Expected kWh/yr Savings Threshold[17] |
|---|---|
| C&I Lighting | >= 500,000 ~~kWh~~ |
| C&I HVAC | >= 250,000 ~~kWh~~ |

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[14] These end-use specific thresholds were developed by the SWE based on review of methods used by other jurisdictions. In addition, the SWE also performed a sensitivity analyses using different threholds based on all the energy efficiency projects (partially deemed/non-custom) implemented in Phase I (PY1 through PY4) of Act 129 Programs among all the EDCs.

[15] Billing analysis should be conducted using at least 12 months of billing data (pre- and post-retrofit).

[16] EDC evaluation contractors must verify the project-specific M&V data (including pre and post metering results) obtained by the CSPs, as practicable, for projects in the evaluation sample. If the evaluation contractor determines that data collected by the CSPs are not reasonably valid, then the evaluator must perform measurements consistent with IPMVP options to collect post-retrofit information for projects that have estimated end-use savings above a threshold kWh/year level. The SWE reserves the right to audit and review claimed and verified impacts of any project selected in the evaluation sample.

[17] In situations where an ICSP meters a project because the expected kWh savings are above the established threshold and then realizes that the actual savings are below the threshold, metered results should be used for reporting claimed and verified savings.

| | |
|---|---|
| C&I Motors & VFDs | >= 250,000 ~~kWh~~ |
| C&I Building Shell | >= 250,000 ~~kWh~~ |
| Agricultural Equipment | >= 250,000 |

### 1.2.4Applicability of the TRM for estimating *Ex Ante* (Claimed) savings

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For replacements and retrofits, the applicable date for determining which TRM version to use to estimate EDC claimed savings is the "in-service date" (ISD) or "commercial date of operation" (CDO) – the date at which the measure is "installed and commercially operable,"[18] and when savings actually start to occur. This is analogous to when a commercial customer's meter "sees" the savings under expected and designed-for operation. For most projects, this is obvious. For projects with commissioning, the CDO occurs after the commissioning is completed. For incented measures that have been installed, but are not being used because there is no occupant, or will not be used until another, unrelated installation/project is completed; the equipment is not "commercially operable." For these projects, the CDO is the date at which the customer begins using the incented equipment, not the date at which the equipment is energized. For new construction, the appropriate TRM must be based on the date when the building/construction permit was issued (or the date construction starts if no permit is required) because that aligns with codes and standards that define the baseline. Savings begin to accrue at the project's ISD.

## 1.3 Definitions

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

- Administrator/Program Administrator (PA) – The Credit Administrator of the AEPS program that receives and processes, and approves AEPS Credit applications.

- AEPS application forms – application forms submitted to qualify and register alternative energy facilities for alternative energy credits.

- Application worksheets – part of the AEPS application forms.

- Alternative Energy Credits (AECs) – A tradable instrument used to establish, verify, and measure compliance with the AEPS. One credit is earned for each 1000kWh of electricity generated (or saved from energy efficiency or conservation measures) at a qualified alternative energy facility.

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- ~~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.~~

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[18] Pennsylvania Public Utility Commission Act 129 Phase II Order, Docket Number: M-2012-2289411 and M-2008-2069887, Adopted August 2, 2012, language in Section K.1.b.

- Direct Install (DI) Measure – A prescriptive measure implemented on site during an energy audit or other initial visit without the requirement of a diagnostic testing component. Examples of these DI measures that can be installed directly include the changing of an incandescent bulb to a CFL or LED or the installation of faucet aerators.

- Early Retirement (ERET) Measure – The removal of equipment from service that is not scheduled to be replaced by either a more efficient option or a less efficient option and is deemed to be eligible for savings due to the nature of reduction in energy use by taking the equipment out of service.

- EDC Reported Gross Savings – Also known as “EDC Claimed Savings” or “*Ex Ante* 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~~.~~ or Site Specific M&V Protocols (SSMVP). The savings calculations/estimates follow algorithms prescribed by the TRM or ~~CMP~~Site Specific M&V Protocols (SSMVP) and are based non-verified, estimated, stipulated, EDC gathered or measured values of key variables.

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- ~~Retrofit~~Efficiency Kits (KIT) – A collection of energy efficient upgrade measure materials that can be delivered to and installed by the end-user. Examples of these items are CFL light bulbs, LED nightlights, or faucet aerators.

- Replace on Burnout (ROB) 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 ~~retrofit~~replace on burnout measures is the applicable code, standard or industry standard practice~~.~~ in the absence of applicable code or standards. The incremental cost for ~~retrofit~~replacement on burnout 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, or imminent failure, as judged by a competent service specialist, 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, (Substantial Renovation Measure) – The substitution of efficient equipment for standard baseline equipment which the customer does not yet own~~. –~~ or during the course of a major renovation project which removes existing, but operationally functional equipment. 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~~or industry standard practice in the absence of applicable code or standards in place at the time of construction/installation~~.~~/substantial renovation. The incremental cost for a new construction or substantial renovation 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~~.~~

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~~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~~Realization Rate – The ratio of "Verified Savings" to "EDC Reported Gross Savings".
- Retrofit Measure (RET) – Measures which modify or add on to existing equipment with technology to make the system more energy efficient. 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, or industry standard practice expected to be in place at the time the unit would have been naturally replaced or retrofit. If there are no known or expected changes to the baseline standards, the standard in effect at the time of the retrofit is to be used. Incremental cost is the full cost of equipment retrofit. In practice, in order to avoid the uncertainty surrounding the determination of "remaining useful life" retrofit measure savings and costs sometimes follow replace on burnout baseline and incremental cost definitions. Examples of projects which fit this category include installation of a VFD on an existing HVAC system, or installation of wall or ceiling insulation.
- Early Replacement Measure (EREP) – 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. Early replacement 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, or industry 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 the early replacement is to be used. 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 replace on burnout baseline and incremental cost definitions. Examples of projects which fit this category include upgrade of an existing production line to gain efficiency, upgrade an existing, but functional, lighting or HVAC system that is not part of a renovation/remodeling project, or replacement of an operational chiller with a more efficient unit.

- Time of Sale (TOS) Measure – A measure implemented, usually incentivized at the retail level, that provides a financial incentive to the buyer or end user in order to promote the higher efficiency of the measure product over a standard efficiency product. Examples include the low-flow pre-rinse sprayers available to commercial kitchens and their applicable incentives to be purchased over standard flow sprayers.
- Verified Gross 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~~.~~ or Site Specific M&V Protocols (SSMVP). The savings calculations/estimates follow algorithms prescribed by the TRM or ~~CMP~~Site Specific M&V Protocols (SSMVP) and are based on verified values of stipulated variables, EDC or evaluator gathered data, or measured key variables.
- Lifetime – The number of years (or hours) that the new high efficiency equipment is expected to function. These are generally based on engineering lives, but sometimes adjusted based on expectations about frequency of removal, remodeling or demolition. Two important distinctions fall under this definition; Effective Useful Life and Remaining Useful Life.
- Effective Useful Life (EUL) – EUL is based on the manufacturers rating of the effective useful life; how long the equipment will last. For example, a CFL that operates x hours per year will typically have an EUL of y. A house boiler may have a lifetime of 20 years but the EUL is only 15 years since after that time it may be operating at a non-efficient point. It is an estimate of the median number of years that the measures installed under a program are still in place and operable.
- Remaining Useful Life (RUL) – It applies to retrofit or early replacement measures. For example, if an existing working refrigerator is replaced with a high efficiency unit, the RUL is an assumption of how many more years the existing unit would have lasted.

## 1.4 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:

The application form that the customer or customer's agent submits with basic information.

Application worksheets and field tools with more detailed, site-specific data, input values and calculations.

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.

## 1.5 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.

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

$$\Delta kW_{peak} = \Delta kW \text{ X } CF$$

$$\Delta kWh = \Delta kW \text{ X } EFLH$$

Where**:**

$\Delta kW$ = *Demand Savings*

$\Delta kW_{peak}$ = *Coincident Peak Demand Savings*

$\Delta kWh$ = *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, defined as~~ Factors represent the fraction of ~~the total technology demand that is~~connected load expected to be coincident with the ~~utility system summer~~PJM peak~~,~~ demand period as defined ~~by Act 129.~~ in Section 1.10~~1.10~~.

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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.

## 1.6 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.

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.

## 1.7 Baseline Estimates

The savings methods and assumptions can differ substantially based on the program delivery mechanism for each measure type. Within each of the measure protocols in the TRM, there is a definition for the measure's baseline efficiency, a critical input into the savings calculations. For most measures there will be at least two baselines that are most commonly used:

- One for market-driven choices -- often called "lost opportunity" and either replacing equipment that has failed (retrofit on burnout) or new installations (new construction)
- One for discretionary installations – often called early replacement

For all new construction (NC) and ~~retrofit~~ replace on burnout (ROB) scenarios, the baseline may be a jurisdictional code, a national standard, or the prevailing level of efficiency in the marketplace. The ∆kW and ∆kWh savings calculations are based on standard efficiency equipment versus new high-efficiency equipment. For all early replacement (EREP) scenarios, the baseline may be the existing equipment efficiency, but at some point the ∆kW and ∆kWh savings calculations must incorporate changes to the baseline for new installations, e.g. code or market changes. 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, and will be handled in future versions of the TRM by describing the choice of and reasoning behind a shifting baseline assumption.

## 1.8 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.

## 1.9 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.

## 1.10 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.

**Table 1-3~~1-3~~: Periods for Energy Savings and Coincident Peak Demand Savings**

| Period | Energy Savings | Coincident Peak Demand Savings |
|---|---|---|
| Summer | May through September | June through August (excluding weekends and holidays) |
| Winter | October through April | N/A |
| Peak | 8:00 a.m. to 8:00 p.m. Mon.-Fri. | 2:00 p.m. to 6:00 p.m. |
| Off-Peak | 8:00 p.m. to 8:00 a.m. Mon.-Fri.,<br>12 a.m. to 12 a.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 definition of summer peak is adopted from PJM which is applied statewide in this TRM. Only the summer peak period is defined for the purpose of this TRM. The coincident summer peak period is defined as the period between the hour ending 15:00 Eastern Prevailing

Time[19] (EPT) and the hour ending 18:00 EPT during all days from June 1 through August 31, inclusive, that is not a weekend or federal holiday[20].

## 1.11 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.

## 1.12 Adjustments to Energy and Resource Savings

### 1.12.1 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 system peak period.

### 1.12.2 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. 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).

It is important to note that the Commission's Phase II Implementation Order, dated August 2, 2012, provides clarification on the accumulation and reporting of savings from Act 129 programs in Phase II. This order states on page 26 that "Savings reduction targets can be considered cumulative in two different ways - at the end of a phase and among phases. The Act 129 programs are cumulative at the end of a phase such that the savings at the end of a phase must show that the total savings from measures installed during the phase are equal to or greater than the established reduction target. Therefore, if any measures are installed whose useful life expires before the end of the phase, another measure must be installed or implemented during that phase which replenishes the savings from the expired measure." This means that reported savings for Phase II must take into account the useful life of measures. For example, savings for a measure with a useful life of two years installed in the first program year of Phase II cannot be counted towards the established reduction target unless another measure is installed or implemented to replenish the savings form the expired measures.

It is also important to note that the 2008 Pennsylvania Act 129 legislation states that the Total Resource Cost test shall be used to determine program cost effectiveness, and defines the TRC test as " A STANDARD TEST THAT IS MET IF,OVER THE EFFECTIVE LIFE OF EACH PLAN NOT TO EXCEED 15 YEARS, THE NET PRESENT VALUE OF THE AVOIDED MONETARY COST OF SUPPLYING ELECTRICITY IS GREATER THAN THE NET PRESENT VALUE OF THE MONETARY COST OF ENERGY EFFICIENCY CONSERVATION MEASURES." Thus

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[19] This is same as the Daylight Savings Time (DST)

[20] PJM Manual 18B for Energy Efficiency Measurement & Verification

when TRC ratios are calculated for Act 129 programs, the life for any measure cannot be longer than 15 years.

### 1.12.3 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 lighting, the energy and peak demand savings is increased by an amount specified in the algorithm to account for HVAC interaction depending on the presence of air conditioning.

For Residential New Construction, the interaction of energy and peak demand 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 and peak demand savings is increased by an amount specified in the algorithm to account for HVAC interaction depending on the presence of air ~~conditiong~~conditioning.

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

### 1.12.4 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).

## 1.13 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)*

Please refer to the 2013 TRC Order[21] for a more detailed discussion of other resource savings.

## 1.14 Transmission and Distribution System Losses

The electric energy consumption reduction compliance targets for Phase II of Act 129 are established at the retail level i.e. based on forecasts of sales. The energy savings must be reported to the Commission at the customer meter level, which is used to determine if EDCs have met their statutory targets for Phase II. For the purpose of calculating cost-effectiveness of Act 129 programs, the value of both energy and demand savings shall be calculated at the system level. 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. The electric line loss factors multiplied by the savings calculated from the algorithms will result in savings at the system level.

The EDC specific electric line loss factors filed in its Commission approved EE&C Plans, or other official reports filed with the Commission should be applied to gross up energy savings from the customer meter level to the system level. The EDCs are allowed to use alternate loss factors calculated to reflect system losses at peaking conditions when available to gross up demand savings to the system level. The Commissions encourages the use of the most recent and accurate values for line loss factors for energy and demand known to the EDCs, regardless of what was filed in the original Phase II EE&C Plans.

## 1.15 Measure Lives

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

In general, avoided cost savings for programs where measures replace units before the end of their useful life are measured from the efficient unit versus the replaced unit for the remaining life of the existing unit, then from the efficient unit versus a new standard unit for the remaining efficient measure's life. Specific guidance is provided through the 2013 TRC Order.

## 1.16 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.

While TRM measures are reviewed and approved by the PA PUC through the TRM update process, custom measures do not undergo the same approval process. The EDCs are not

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[21] See 2012 PA Total Resource Cost (TRC) Test; 2009 PA Total Resource Cost Test Final Order, at Docket Nos. M-2012-2300653 and M-2009-2108601, (2013 TRC Test Final Order), entered August 30, 2012.

required to submit savings protocols for C&I custom measures to the Commission or the SWE for each measure/technology type prior to implementing the custom measure~~. The~~, however, the Commission recommends that ~~these~~site-specific custom measure protocols be established in general conformity to the International Performance Measurement and Verification Protocol (IPMVP)[22] or Federal Energy Management Program[23] M&V Guidelines. All evaluation sampled custom projects require a Site-Specific Measurement and Verification Plan (SSMVP) developed or approved for use by the EDC evaluator which must be available for SWE review. During Phase I of Act 129, the TWG developed custom measure protocols (CMPs) for calculating the energy and demand savings for several custom measures. CMPs approved during Phase I are considered available for use in Phase II by EDCs[24]. The qualification for and availability of AEPS Credits and energy efficiency and demand response savings are determined on a case-by-case basis.

In addition, certain mass market programs in the residential sector are a subset of custom measures. These programs offer measures, or groups of measures, which are not included in the TRM. As with the C&I CMPs, during Phase I of Act 129, the TWG developed mass market protocols ("MMPs") for calculating the energy and demand savings associated with residential behavioral modification and low-income weatherization programs. MMPs approved during Phase I are considered available for use in Phase II by the EDCs.

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: Relationship between Program Savings and Evaluation Savings~~Appendix B: Relationship between Program Savings and Evaluation Savings~~.

## 1.17 Impact of Weather

To account for weather differences within Pennsylvania, the Equivalent Full Load Hours (ELFH) for C&I HVAC measures are calculated based on the degree day scaling methodology. The EFLH values reported in the 2012 Connecticut Program Savings Documentation were adjusted using full load hours (FLH) from the US Department of Energy's ENERGY STAR Calculator[25]. Degree day scaling ratios were calculated using heating degree day and cooling degree day values for seven Pennsylvania cities: Allentown, Erie, Harrisburg, Philadelphia, Pittsburgh, Scranton, and

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[22] http://www.evo-world.org/index.php?option=com_content&task=view&id=272&Itemid=279

[23] www1.eere.energy.gov/femp/pdfs/mv_guidelines.pdf

[24] If the CMPs use a top 100 hours approach for calculating peak demand savings, the protocol must be revised to address the new peak demand window definition prior to use.

[25] http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/ASHP_Sav_Calc.xls

Williamsport. These reference cities provide a representative sample of the various climate and utility regions in Pennsylvania.

In addition, several protocols in this TRM rely on the work and analysis completed in California, where savings values are adjusted for climate. These measures include Refrigeration – Auto Closers (Section 3.22~~3.23~~22~~), Refrigeration – Door Gaskets for Walk-in Coolers and Freezers (Section 3.24),~~) and Refrigeration – Suction Pipes Insulation (Section 3.24~~3.25~~24). There are sixteen California climate zones and seven Pennsylvania cities. Each of the seven reference cities are mapped to a California climate zone as shown in Table 1-4: California CZ Mapping Table~~Table 1-4: California CZ Mapping Table~~ based on comparable number of cooling degree hours and average wet bulb temperatures. Section 3.22~~3.23~~22~~, 3.24 and 3.25~~ and 3.24 will follow this mapping table.

**Table 1-4~~1-4~~: California CZ Mapping Table**

| Reference City | California Climate Zone |
|---|---|
| Allentown | 15 |
| Erie | 9 |
| Harrisburg | 15 |
| Philadelphia | 15 |
| Pittsburgh | 4 |
| Scranton | 4 |
| Williamsport | 15 |

Furthermore, all the Pennsylvania zip codes are mapped to a reference city as shown in Appendix G: Zip Code Mapping~~Appendix G: 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.

## 1.18 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.

Measure Applicability Based on Sector

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). In addition, air sealing, duct sealing and ceiling/attic and wall insulation protocols and standards for residential measures should be used to estimate savings in two to four ~~untis~~units multifamily complexes whereas air sealing and insulation protocols and standards for C&I measures should be applied in multifamily complexes with more than four units.

## 1.19 Algorithms for Energy Efficient Measures

The following sections present measure-specific algorithms. Section 2 addresses residential sector measures and Section 3 addresses commercial and industrial sector measures. Section 4 addresses agricultural measures for both residential and commercial and industrial market sectors.

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# 2 RESIDENTIAL MEASURES

The following section of the TRM contains savings protocols for residential measures. This TRM does include an updated energy-to-demand factor for residential energy efficiency measures affecting the electric water heating end use. Due to time constraints, energy-to-demand factors for all other residential energy efficiency measures will be reviewed and updated in future TRMs.

## 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 or heat pump's cooling/heating energy use and peak demand contribution. Input data is based both on fixed assumptions and data supplied from the high efficiency equipment AEPS application form or EDC data gathering.

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

Larger commercial air conditioning and heat pump applications are dealt with in Section 3.5~~3.65~~.

### 2.1.1 Eligibility

This measure requires the purchase of an ENERGY STAR Air Conditioner, Air Source Heat Pump, or Ground Source Heat Pump, proper sizing of a central air conditioner, central air conditioner or air source heat pump maintenance, installation of a desuperheater on an existing Ground Source Heat Pump, or installation of a new high efficiency fan on an exisiting furnace. The baseline condition is an exisiting standard efficiency electric heating system, a gas or lectric furnace with a standard efficiency furnace fan, or a ground source heat pump without a desuperheater.

The following sections detail how this measure's energy and demand savings were determined.

### ~~2.1.1~~2.1.2 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.

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

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

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

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

**Central A/C (Proper Sizing[26])**

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

$\Delta kWh = (CAPY_{cool}/(SEER_q \times 1000)) \times EFLH_{cool} \times PSF$

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

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

This algorithm is used for measures providing services to maintain, service or tune-up central A/C and ASHP units. The tuneup must include the following at a minimum:

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

- Check refrigerant charge level and correct as necessary
- Clean filters as needed
- Inspect and lubricate bearings
- Inspect and clean condenser and, if accessible, eveaporator coil

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

$\Delta kWh_{cool} \quad = ((CAPY_{cool}/(1000 X SEER_m)) X EFLH_{cool}) X MF_{cool}$

$\Delta kWh_{heat}$ (ASHP Only) $\quad = ((CAPY_{heat}/(1000 X HSPF_m)) X EFLH_{heat}) X MF_{heat}$

$\Delta kW_{peak} \quad = ((CAPY_{cool}/(1000 X EER_m)) X CF) X MF_{cool}$

~~**Central A/C and ASHP (Duct Sealing)**~~

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

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

~~$\Delta kWh_{cool} \quad = (CAPY_{cool}/(1000 X SEER_e)) X EFLH_{cool} X DuctSF$~~

~~$\Delta kWh_{heat}$ (ASHP Only) $\quad = (CAPY_{heat}/(1000 X HSPF_e)) X EFLH_{heat} X DuctSF$~~

~~$\Delta kW_{peak} \quad = ((CAPY_{cool}/(1000 X EER_e)) X CF) X DuctSF$~~

**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 3.5.1~~3.65.1~~.

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

$COP_{sys} \quad = COP_g x GSHPDF$

$EER_{sys} \quad = EER_g x GSHPDF$

$\Delta kWh_{cool} \quad = CAPY_{cool}/1000 X (1/SEER_b – (1/(EER_{sys} X GSER))) X EFLH_{cool}$

$\Delta kWh_{heat} \quad = CAPY_{heat}/1000 X (1/HSPF_b – (1/(COP_{sys} X GSOP))) X EFLH_{heat}$

$\Delta kW \quad = CAPY_{cool}/1000 X (1/EER_b – (1/(EER_{sys} X GSPK))) X CF$

**GSHP Desuperheater**

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

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

$= 576 kWh$

$\Delta kW$ = *EDSH x Energy to Demand Factor*

**Furnace High Efficiency Fan**

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

$\Delta kWh_{heat}$ = *HFS*

$\Delta kWh_{cool}$ = *CFS*

$\Delta kW_{peak}$ = *PDFS*

### ~~2.1.2~~2.1.3 Definition of Terms

$CAPY_{cool}$ = *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.*

$CAPY_{heat}$ = *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*

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

$SEER_e$ = *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.*

$EER_e$ = *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.*

$EER_{sys}$ =*Ground Source Heat Pump effective system EER.*

$GSER$ = *Factor used to determine the SEER of a GSHP based on its EERg.*

$EFLH_{cool}$ = *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.*

*PSF* = *Proper Sizing Factor or the assumed saving due to proper sizing and proper installation.*

$MF_{cool}$ = *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 1.5~~1.4~~)*

$HSPF_b$ = *Heating Seasonal Performance Factor of the Baseline Unit.*

$HSPF_e$ = *Heating Seasonal Performance Factor of the unit being installed. This data is obtained from the AEPS Application Form or EDC's data gathering.*

$HSPF_m$ = *Heating Seasonal Performance Factor of the unit receiving maintenance.*

$COP_g$ = *Coefficient of Performance. This is a measure of the efficiency of a heat pump.*

*GSHPDF* =*Ground Source Heat Pump De-rate Factor*

$COP_{sys}$ =*Ground Source Heat Pump effective system COP.*

*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.*

*EFDSH* = *Energy Factor per desuperheater.*

$EF_{base}$ = *Energy Factor of Electric Water Heater*

*HW* = *Daily Hot Water Use*

$T_h$ = *Hot Water Temperature*

$T_c$ = *Cold Water Temperature*

*EDSH* = *Fixed savings per desuperheater.*[27]

*Energy to Demand Factor* = *Fixed factor per desuperheater*

*PDSH* = *Assumed peak-demand savings per desuperheater.*

*HSF* = *Assumed heating season savings per furnace high efficiency fan*

*CFS* = *Assumed cooling season savings per furnace high efficiency fan*

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

*1000* = *Conversion from watts to kilowatts.*

**Table 2-1~~2-1~~: Residential Electric HVAC - References**

| Component | Type | Value | Sources |
|---|---|---|---|
| $CAPY_{cool}$<br>$CAPY_{heat}$ | Variable | EDC Data Gathering | AEPS Application; EDC Data Gathering |
| $SEER_b$ | Fixed | Replace on Burnout: 13 SEER | 1 |
| | Variable | Early Retirement: Default 10 SEER or EDC Data Gathering | 13; EDC Data Gathering |
| $SEER_e$ | Variable | EDC Data Gathering | AEPS Application; EDC Data Gathering |
| $SEER_m$ | Variable | Default 10 SEER or EDC Data Gathering | 13; EDC Data Gathering |
| $EER_b$ | Fixed | Replace on Burnout: 11.3 | 2 |
| | Variable | Early Retirement: Default 8.69 EER or EDC Data Gathering | 14; EDC Data Gathering |
| $EER_e$ | Fixed | (11.3/13) X $SEER_e$ | 2 |
| $EER_g$ | Variable | EDC Data Gathering | AEPS Application; EDC's Data Gathering |
| $EER_{sys}$ | Variable | Calculated | Calculated |
| $EER_m$ | Variable | Default 8.69 SEER or EDC Data Gathering | 14; EDC Data Gathering |
| GSER | Fixed | 1.02 | 3 |

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[27] 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.

| Component | Type | Value | Sources |
|---|---|---|---|
| $EFLH_{cool}$ | Default | Allentown Cooling = 487 Hours<br>Erie Cooling = 389 Hours<br>Harrisburg Cooling = 551 Hours<br>Philadelphia Cooling = 591 Hours<br>Pittsburgh Cooling = 432 Hours<br>Scranton Cooling = 417 Hours<br>Williamsport Cooling = 422 Hours | 4 |
| | Optional | An EDC can either use the Alternate EFLH Table or estimate its own EFLH based on customer billing data analysis. | Alternate EFLH Table (See Section 2.1.4)~~ 2.1.3Error! Reference source not found.)~~; EDC Data Gathering |
| $EFLH_{heat}$ | Default | Allentown Heating = 1,193 Hours<br>Erie Heating = 1,349 Hours<br>Harrisburg Heating = 1,103 Hours<br>Philadelphia Heating = 1,060 Hours<br>Pittsburgh Heating = 1,209 Hours<br>Scranton Heating = 1,296 Hours<br>Williamsport Heating = 1,251 Hours | 4 |
| | Optional | An EDC can either use the Alternate EFLH Table or estimate its own EFLH based on customer billing data analysis. | Alternate EFLH Table (See Section 2.1.4)~~2.1.3Error! Reference source not found.)~~; EDC Data Gathering |
| PSF | Fixed | 5% | 5 |
| $MF_{cool}$ | Fixed | 5% | 15 |
| $MF_{heat}$ | Fixed | 5% | 15 |
| CF | Fixed | 70% | 6 |
| $HSPF_b$ | Fixed | Replace on Burnout: 7.7 | 7 |
| | Variable | Early Retirement: EDC Data Gathering | EDC Data Gathering |
| $HSPF_e$ | Variable | EDC Data Gathering | AEPS Application; EDC's Data Gathering |
| $HSPF_m$ | Fixed | 6.8 | 13 |
| $COP_g$ | Variable | EDC Data Gathering | AEPS Application; EDC's Data Gathering |

| Component | Type | Value | Sources |
|---|---|---|---|
| ~~GSHPDR~~GSHPDF | Fixed | 0.885 | 19<br>(Engineering Estimate - See 2.1.5~~2.1.5~~~~2.1.4Error! Reference source not found.~~) |
| $COP_{sys}$ | Variable | Calculated | Calculated |
| GSOP | Fixed | 3.413 | 8 |
| GSPK | Fixed | 0.8416 | 9 |
| EFDSH | Fixed | 17% | 10, 11 |
| EDSH | Fixed | 576 kWh | Calculated |
| $EF_{base}$ | Fixed | 0.904 | Table 2-4~~Table 2-4Error! Reference source not found.~~ |
| HW | Fixed | 50 | Table 2-4~~Table 2-4Error! Reference source not found.~~ |
| ~~$T_{hot}$~~$T_h$ | Fixed | ~~124~~123 | Table 2-4~~Table 2-4Error! Reference source not found.~~ |
| ~~$T_{cold}$~~$T_c$ | Fixed | 55 | Table 2-4~~Table 2-4Error! Reference source not found.~~ |
| Energy To Demand Factor | Fixed | 0.~~00009172~~00008294 | Table 2-4~~Table 2-4Error! Reference source not found.~~ |
| PDSH | Fixed | 0.05 kW | Calculated |
| HFS | Fixed | 311 kWh | 16 |
| CFS | Fixed | 135 kWh | 17 |
| PDFS | Fixed | 0.114 kW | 18 |

### ~~2.1.3~~2.1.4 Alternate Equivalent Full Load Hour (EFLH) Tables

Table 2-2 and Table 2-3 below show cooling EFLH and heating EFLH, respectively, by city and for each EDC's housing demographics. EFLH values are only shown for cities that are close to customers in each EDC's service territory. In order to determine the most appropriate EFLH value to use for a project, first select the appropriate EDC, then, from that column, pick the closest city to the project location. The value shown in that cell will be the EFLH value to use for the project.

Table 2-2~~2-2~~: Alternate Cooling ~~EFLH~~EFLH[20]

| | PPL | Penelec | Met Ed | West Penn | Duquesne | Penn Power | PECO |
|---|---|---|---|---|---|---|---|
| **Allentown** | **431** | **528** | **453** | N/A | N/A | N/A | **523** |
| **Erie** | N/A | **418** | N/A | **413** | N/A | **397** | N/A |
| **Harrisburg** | **487** | N/A | **506** | **580** | N/A | N/A | N/A |
| **Philadelphia** | N/A | N/A | **536** | N/A | N/A | N/A | **651** |
| **Pittsburgh** | N/A | **468** | N/A | **458** | **417** | **448** | N/A |
| **Scranton** | **376** | **454** | N/A | N/A | N/A | N/A | N/A |
| **Williamsport** | N/A | N/A | N/A | **447** | N/A | N/A | N/A |

Table 2-3~~2-3~~: Alternate Heating ~~EFLH~~EFLH[20]

| | PPL | Penelec | Met Ed | West Penn | Duquesne | Penn Power | PECO |
|---|---|---|---|---|---|---|---|
| **Allentown** | **1112** | **1057** | **1122** | N/A | N/A | N/A | **1320** |
| **Erie** | N/A | **1204** | N/A | **1317** | N/A | **1376** | N/A |
| **Harrisburg** | **1028** | N/A | **1035** | **1077** | N/A | N/A | N/A |
| **Philadelphia** | N/A | N/A | **1001** | N/A | N/A | N/A | **1165** |
| **Pittsburgh** | N/A | **1068** | N/A | **1175** | **1274** | **1234** | N/A |
| **Scranton** | **1203** | **1151** | N/A | N/A | N/A | N/A | N/A |
| **Williamsport** | N/A | N/A | N/A | **1218** | N/A | N/A | N/A |

| | PPL | Penelec | Met Ed | West Penn | Duquesne | Penn Power | PECO |
|---|---|---|---|---|---|---|---|
| **Allentown** | **1112** | **1057** | **1122** | N/A | N/A | N/A | **1320** |
| **Erie** | N/A | **1204** | N/A | **1317** | N/A | **1376** | N/A |
| **Harrisburg** | **1028** | N/A | **1035** | **1077** | N/A | N/A | N/A |
| **Philadelphia** | N/A | N/A | **1001** | N/A | N/A | N/A | **1165** |
| **Pittsburgh** | N/A | **1068** | N/A | **1175** | **1274** | **1234** | N/A |
| **Scranton** | **1203** | **1151** | N/A | N/A | N/A | N/A | N/A |
| **Williamsport** | N/A | N/A | N/A | **1218** | N/A | N/A | N/A |

**Field Code Changed**

### ~~2.1.4~~2.1.5 System Performance of Ground Source Heat Pumps

Ground Source heat pump nameplate AHRI ratings do not include auxiliary pumping energy for ground loop water distribution. Based on McQuay heat pump design guidelines, it is estimated that approximately a 1/3 HP pump would be required to be paired with a 2.5 ton Ground Source Heat Pump (assuming 3 GPM//ton design flow and 200 ft./ton of 1-inch tubing). At 7.5 GPM, a 1/3 HP pump would consume approximately 0.23 kW (7.5 GPM @ 30 ft. head). Assuming a 2 kW load for the heat pump itself, this would amount to a roughly 11.5% increase in system energy. The system COP de-rate factor would then be 0.885.

**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 as calculated by EER = -0.02 × SEER² + 1.12 × SEER based on U.S. DOE Building America House Simulation Protocol, Revised 2010.
3. VEIC estimate. Extrapolation of manufacturer data.

4. Based on REM/Rate modeling using models from the PA 2012 Potential Study. EFLH calculated from kWh consumption for cooling and heating. Models assume 50% over-sizing of air conditioners28 and 40% oversizing of heat pumps.[29]
5. Northeast Energy Efficiency Partnerships, Inc., “Strategies to Increase Residential HVAC Efficiency in the Northeast”, (February 2006): Appendix C Benefits of HVAC Contractor Training: Field Research Results 03-STAC-01, page 46.
6. Based on an analysis of six different utilities by Proctor Engineering.
7. Federal Register, Vol. 66, No. 14, Monday, January 22, 2001/Rules and Regulations, p. 7170-7200.
8. Engineering calculation, HSPF/COP=3.413.
9. VEIC Estimate. Extrapolation of manufacturer data.
10. ”Residential Ground Source Heat Pumps with Integrated Domestic Hot Water Generation: Performance Results from Long-Term Monitoring”, U.S. Department of Energy, November 2012.
11. Desuperheater Study, New England Electric System, 1998 42 U.S.C.A 6295(i) (West Supp. 2011) and 10 C.F.R. 430.32 (x) (2011).
12. Northeast Energy Efficiency Partnerships, Inc., “Benefits of HVAC Contractor Training”, (February 2006): Appendix C Benefits of HVAC Contractor Training: Field Research Results 03-STAC-01.
13. Minimum Federal Standards for new Central Air Conditioners and Air Source Heat Pumps between 1990 and 2006 based on VEIC estimates.
14. The same EER to SEER ratio used for SEER 13 units applied to SEER 10 units. EERm = (11.3/13) * 10.
15. 2013 Illinois Statewide TRM (Central Air Conditioning in Wisconsin, Energy Center of Wisconsin, May 2008)
16. Scott Pigg (Energy Center of Wisconsin), “Electricity Use by New Furnaces: A Wisconsin Field Study”, Technical Report 230-1, October 2003, page 20. The average heating-mode savings of 400 kWh multiplied by the ratio of average heating degree days in PA compared to Madison, WI (5568/7172).
17. Ibid, page 34. The average cooling-mode savings of 88 kWh multiplied by the ratio of average EFLH in PA compared to Madison, WI (749/487).
18. Ibid, page 34. The average kW savings of 0.1625 multiplied by the coincidence factor from Table 2-1.
19. McQuay Application Guide 31-008, Geothermal Heat Pump Design Manual, 2002.
20. Based on building energy model simulations and residential baseline characteristics determined from the Residential End-use Study

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[28] Neme, Proctor, Nadal, “National Energy Savings Potential From Addressing Residential HVAC Installation Problems. ACEEE, February 1, 1999. Confirmed also by *Central Air Conditioning in Wisconsin, a compilation of recent field research.* Energy Center of Wisconsin. May 2008, emended December 15, 2010

[29] ACCA, “Verifying ACCA Manual S Procedures,” http://www.acca.org/Files/?id=67.

## 2.2 Electric Clothes Dryer with Moisture Sensor

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| **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** | 13 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

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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

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**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:

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

The annual consumption of a standard unit without a moisture sensor (905 kWh) was based on 2008 estimates from Natural Resources Canada.[30]

The annual consumption of a standard unit with a moisture sensor (769 kWh) was based on estimates from EPRI[31] and the Consumer Energy Center[32] that units equipped with moisture sensors (and energy efficient motors, EPRI) are about 15% more efficient than units without.

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

**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

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[30] Natural Resources Canada Report.pdf

[31] EPRI Electric Clothes Dryer Report.pdf

[32] Natural Living Guide.pdf

annual hours of use was based on 392[33] loads per year with a 1 hour dry cycle. This calculation is shown below:

$$\Delta kW \quad = 136 / 392 \quad = 0.346\ kW$$

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:

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

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

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

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

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Based on information developed by the National Association of Homebuilders and ENERGY STAR, we have assumed the measure life of an electric clothes dryer to be 13 years.

### 2.2.4 Evaluation Protocol

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

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[33] Energy Star Clothes Washer Calculator Assumptions.pdf

[5] NAHB, Study of Life Expectancy of Home Components, Feb. 2007, p. 7.

[6] ENERGY STAR Market & Industry Scoping Report – Residential Clothes Dryers, Nov. 2011, p. 4.

## 2.3 Efficient Electric Water Heaters

| Measure Name | Efficient Electric Water Heaters |
|---|---|
| **Target Sector** | Residential Establishments |
| **Measure Unit** | Water Heater |
| **Unit Energy Savings** | Varies with Energy Factor of New Unit |
| **Unit Peak Demand Reduction** | Varies with Energy Factor of New Unit |
| **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.

### 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:

$$\Delta kWh = \cancel{\frac{\left\{\left(\frac{1}{EF_{Base}} - \frac{1}{EF_{Proposed}}\right)\times\left(HW\times365\times8.3\frac{lb}{gal}\times(T_{hot}-T_{cold})\right)\right\}}{3413\frac{Btu}{kWh}}}\frac{\left\{\left(\frac{1}{EF_{Base}} - \frac{1}{EF_{Proposed}}\right)\times\left(HW\times365x1\ Btu/lb\text{-}f\times8.3\frac{lb}{gal}\times(T\right.\right.}{3413\frac{Btu}{kWh}}$$

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~~2 PM to 6 PM on summer weekdays to the total annual energy usage.

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

The Energy to Demand Factor is defined below:

$$EnergyToDemandFactor = \frac{Average\ Usage_{Summer\ WD\ \cancel{Noon\text{-}8}2\text{-}6\ PM}}{Annual\ Energy\ Usage}$$

The ratio of the average energy usage during ~~noon and 8~~2 PM to 6 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[34]. The factor is constructed as follows:

1) Obtain the average kW, as monitored for 82 water heaters in PJM territory[35], 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~~2 PM to ~~8~~6 PM on summer days from the same data.

3) The average ~~noon~~2 PM to ~~8~~6 PM demand is converted to average *weekday* ~~noon~~2 PM to ~~8~~6 PM demand through comparison of weekday and weekend monitored loads from the same PJM study[36].

4) The ratio of the average ~~weekday noon~~weekday2 PM to ~~8~~6 PM energy demand to the annual energy usage obtained in step 1. The resulting number, 0.~~00009172~~00008294, 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~~Figure 2-1~~ below.

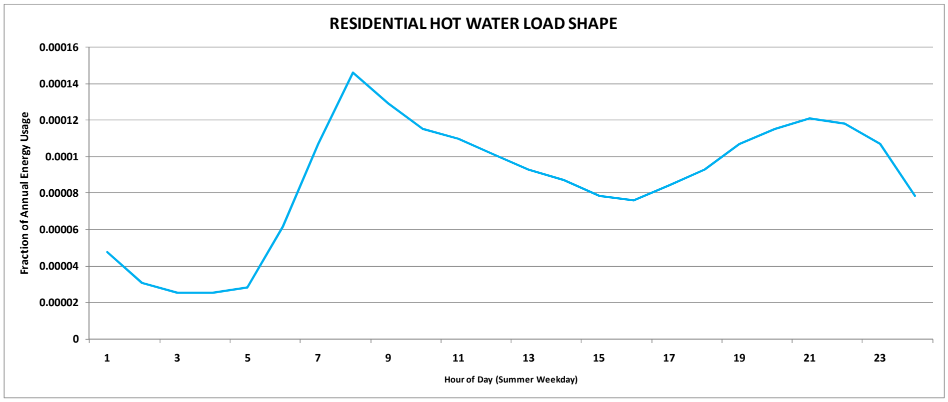

**Figure 2-1: Load shapes for hot water in residential buildings taken from a PJM study.**

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[34] Deemed Savings Estimates for Legacy Air Conditioning and Water Heating Direct Load Control Programs in PJM Region. The report can be accessed online: http://www.pjm.com/~/media/committees-groups/working-groups/lrwg/20070301/20070301-pjm-deemed-savings-report.ashx

[35] 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

[36] 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~~2 PM to ~~8~~6 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 2-4 below.

**Table 2-4~~2-4~~: Efficient Electric Water Heater Calculation Assumptions**

| Component | Type | Values | Source |
|---|---|---|---|
| $EF_{base}$, Energy Factor of baseline water heater | Fixed | See Table 2-5 | 1 |
| $EF_{proposed}$, Energy Factor of proposed efficient water heater | Variable | 0.93 (default) or EDC Data Gathering | Program Design; EDC Data Gathering |
| HW , Hot water used per day in gallons | Fixed | 50 gallon/day | 2 |
| $T_{hot}$, Temperature of hot water | Fixed | 123°F | 3 |
| $T_{cold}$, Temperature of cold water supply | Fixed | 55 °F | 43 |
| Energy To Demand Factor | Fixed | 0.~~00009172~~00008294 | 1-4 |

### 2.3.4 Energy Factors based on Tank Size

Federal Standards for Energy Facotrs are equal to 0.97 -0.00132 x Rated Storage in Gallons. The following table shows the Energy Factors for various tank sizes.

**Table 2-5~~2-5~~: Minimum Baseline Energy Factors based on Tank Size**

| Tank Size (gallons) | Energy Factor |
|---|---|
| 40 | 0.9172 |
| 50 | 0.9040 |
| 65 | 0.8842 |
| 80 | 0.8644 |
| 120 | 0.8116 |

**Sources:**

1. Federal Standards are 0.97 -0.00132 x Rated Storage in Gallons. For a 50-gallon tank this is 0.904. “Energy Conservation Program: Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters” US Dept of Energy Docket Number: EE–2006–BT-STD–0129, p. 30
2. Residential Energy Consumption Survey, EIA, 2009.2012 SWE Residential Baseline Study ~~Mid-Atlantic TRM, footnote #24~~
3. ~~Deemed~~2012 SWE Residential Baseline Study
4. The performance curve is adapted from Table 1 in http://wescorhvac.com/HPWH%20design%20details.htm#Single-stage%20HPWHs

5. 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.

### 2.3.5 Default Savings

Savings for the installation of efficient electric water heaters are calculated using the formula below:

$$\cancel{\Delta}\Delta kWh \;\cancel{= (2{,}671.58 - \frac{2{,}449.87}{EF_{Proposed}})} = \left(\frac{1}{EF_{Base}} - \frac{1}{EF_{Proposed}}\right) * 3018.0$$

$$\Delta kW_{peak} = \Delta kWh \text{ X } 0.\cancel{0000917}200008294$$

### 2.3.6 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**[37]

### 2.3.7 Evaluation Protocols

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

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

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## 2.4 Electroluminescent Nightlight

| **Measure Name** | **Electroluminescent Nightlight** |
|---|---|
| **Target Sector** | Residential Establishments |
| **Measure Unit** | Nightlight |
| **Unit Energy Savings** | ~~26~~29.49 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* = ((~~$W_{inc}$ * $h_{inc}$~~$W_{base}$ * $h_{base}$) – (WNL * $h_{NL}$)) * 365 / 1000 * ISRNL

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

*Deemed Energy Savings* = ((7*12)–(0.03*24))*365/1000*0.~~84 = 25.53~~97 = 29.49 kWh

~~(Rounded to 26 kWh)~~

### 2.4.2 Definition of Terms

$W_{NL}$ = Watts per electroluminescent nightlight

$W_{inc}$ = Watts per ~~incandescent~~baseline nightlight

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

~~$h_{inc}$~~$h_{base}$ = Average hours of use per day incandescent nightlight

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

**Table 2-6~~2-6~~: Electroluminescent Nightlight - References**

| Component | Type | Value | Sources |
|---|---|---|---|
| $W_{NL}$ | Variable | 0.03 or EDC Data Gathering | 1 |
| ~~Winc~~Wbase | ~~Fixed~~Variable | ~~7~~7 (for incandescent bulbs) or EDC Data Gathering | 2 |
| $h_{NL}$ | Fixed | 24 | 3 |
| $h_{inc}$ | Fixed | 12 | 2 |
| $ISR_{NL}$ | Variable | ~~See ISR for CFLs~~0.97 or EDC Data Gathering | 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** | Varies |
| **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

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$$\Delta kWh = \Delta kWh_{heating} + \Delta kWh_{cooling}$$

$$\Delta kWh_{heating} = MkW \text{ X } EFLH_{heating} \text{ X } EI \text{ X } ISR$$

$$\Delta kWh_{cooling} = MkW \text{ X } EFLH_{cooling} \text{ X } EI \text{ X } ISR$$

$$\Delta kW_{peak} = \Delta kWh_{cooling} / EFLH_{cooling} \text{ X } CF$$

### 2.5.2 Definition of Terms

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$MkW$ = Average motor full load electric demand (kW)

~~EFLH~~$EFLH_{Heating}$ = Estimated Full Load Hours (Heating ~~and~~ ) for the EDC region.

$EFLH_{Cooling}$ = Estimated Full Load Hours (Cooling) for the EDC region.

$EI$ = Efficiency Improvement

$ISR$ = In-service Rate

**Table 2-7~~2-7~~: Furnace Whistle - References**

| Component | Type | Value | Sources |
|---|---|---|---|
| MkW | Fixed | 0.5 kW | 1, 2 |
| ~~EFLH~~$EFLH_{Heating}$ | Fixed | Variable. See **Error! Reference source not found.**~~Table 2-8~~ | TRM **Error! Reference source not found.**~~Table 2-1~~ |
| $EFLH_{Cooling}$ | Fixed | Variable. See **Error! Reference source not found.**~~Table 2-8~~~~**Error! Reference source not found.**~~ | TRM **Error! Reference source not found.**~~Table 2-1~~ ~~**Error! Reference source not found.**~~ |
| EI | Fixed | 15% | 3 |
| ISR | Fixed | 0.474 | 4 |
| CF | Fixed | 70% | TRM Table 2-1 |
| Measure EUL | Fixed | ~~15~~14 | ~~15~~TRM Appendix A (Life assumed to be the life of CAC unit) |

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**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.
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 2-8~~2-8~~: EFLH for various cities in Pennsylvania (TRM Data)

| City | Cooling load hours | Heating load hours | Total load hours |
|---|---|---|---|
| Allentown | 487 | 1,193 | 1,681 |
| Erie | 389 | 1,349 | 1,739 |
| Harrisburg | 551 | 1,103 | 1,654 |
| Philadelphia | 591 | 1,060 | 1,651 |
| Pittsburgh | 432 | 1,209 | 1,641 |
| Scranton | 417 | 1,296 | 1,713 |
| Williamsport | 422 | 1,251 | 1,673 |

### 2.5.3 Deemed Savings

The following table presents the assumptions and the results of the deemed savings calculations for each EDC.

Table 2-9~~2-9~~: Assumptions and Results of Deemed Savings Calculations (Pittsburgh, PA)

| | Blower Motor kW | Pittsburgh EFLH | Clean Annual kWh | Dirty Annual kWh | Furnace Whistle Savings (kWh) | ISR | Estimated Savings (kWh) |
|---|---|---|---|---|---|---|---|
| Heating | 0.5 | 1,209 | 604 | 695 | 91 | 0.474 | 43 |
| Cooling | 0.5 | 432 | 216 | 248 | 32 | 0.474 | 15 |
| Total | | 1,641 | 820 | 944 | 123 | | 58 |

$\Delta kW_{peak}$ = 0.024 kW (Pittsburgh)

Table 2-10~~2-10~~: Assumptions and Results of Deemed Savings Calculations (Philadelphia, PA)

| | Blower Motor kW | Philadelphia EFLH | Clean Annual kWh | Dirty Annual kWh | Furnace Whistle Savings (kWh) | ISR | Estimated Savings (kWh) |
|---|---|---|---|---|---|---|---|
| Heating | 0.5 | 1,060 | 530 | 609 | 79 | 0.474 | 38 |
| Cooling | 0.5 | 591 | 296 | 340 | 44 | 0.474 | 21 |
| Total | | 1,651 | 826 | 949 | 124 | | 59 |

$\Delta kW_{peak}$ = 0.025 kW (Philadelphia)

**Table 2-11~~2-11~~: Assumptions and Results of Deemed Savings Calculations (Harrisburg, PA)**

| | Blower Motor kW | Harrisburg EFLH | Clean Annual kWh | Dirty Annual kWh | Furnace Whistle Savings (kWh) | ISR | Estimated Savings (kWh) |
|---|---|---|---|---|---|---|---|
| Heating | 0.5 | 1,103 | 552 | 634 | 83 | 0.474 | 39 |
| Cooling | 0.5 | 551 | 276 | 317 | 41 | 0.474 | 20 |
| Total | | 1,654 | 827 | 951 | 124 | | 59 |

$\Delta kW_{peak}$ = 0.025 kW (Harrisburg)

**Table 2-12~~2-12~~: Assumptions and Results of Deemed Savings Calculations (Erie, PA)**

| | Blower Motor kW | Erie EFLH | Clean Annual kWh | Dirty Annual kWh | Furnace Whistle Savings (kWh) | ISR | Estimated Savings (kWh) |
|---|---|---|---|---|---|---|---|
| Heating | 0.5 | 1,349 | 675 | 776 | 101 | 0.474 | 48 |
| Cooling | 0.5 | 389 | 195 | 224 | 29 | 0.474 | 14 |
| Total | | 1,739 | 869 | 1,000 | 130 | | 62 |

$\Delta kW_{peak}$ = 0.025 kW (Erie)

**Table 2-13~~2-13~~: Assumptions and Results of Deemed Savings Calculations (Allentown, PA)**

| | Blower Motor kW | Allentown EFLH | Clean Annual kWh | Dirty Annual kWh | Furnace Whistle Savings (kWh) | ISR | Estimated Savings (kWh) |
|---|---|---|---|---|---|---|---|
| Heating | 0.5 | 1,193 | 597 | 686 | 89 | 0.474 | 42 |
| Cooling | 0.5 | 487 | 244 | 280 | 37 | 0.474 | 17 |
| Total | | 1,681 | 840 | 966 | 126 | | 60 |

$\Delta kW_{peak}$ = 0.024 kW (Allentown)

Table 2-14~~2-14~~: Assumptions and Results of Deemed Savings Calculations (Scranton, PA)

| | Blower Motor kW | Scranton EFLH | Clean Annual kWh | Dirty Annual kWh | Furnace Whistle Savings (kWh) | ISR | Estimated Savings (kWh) |
|---|---|---|---|---|---|---|---|
| Heating | 0.5 | 1,296 | 648 | 745 | 97 | 0.474 | 46 |
| Cooling | 0.5 | 417 | 208 | 240 | 31 | 0.474 | 15 |
| Total | | 1,713 | 857 | 985 | 129 | | 61 |

$\Delta kW_{peak}$ = 0.025 kW (Scranton)

Table 2-15~~2-15~~: Assumptions and Results of Deemed Savings Calculations (Williamsport, PA)

| | Blower Motor kW | Williamsport EFLH | Clean Annual kWh | Dirty Annual kWh | Furnace Whistle Savings (kWh) | ISR | Estimated Savings (kWh) |
|---|---|---|---|---|---|---|---|
| Heating | 0.5 | 1,251 | 625 | 719 | 94 | 0.474 | 44 |
| Cooling | 0.5 | 422 | 211 | 243 | 32 | 0.474 | 15 |
| Total | | 1,673 | 836 | 962 | 125 | | 59 |

$\Delta kW_{peak}$ = 0.025 kW (Williamsport)

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## 2.6 Heat Pump Water Heaters

| **Measure Name** | **Heat Pump Water Heaters** |
|---|---|
| **Target Sector** | Residential Establishments |
| **Measure Unit** | Water Heater |
| **Unit Energy Savings** | ~~1,774 kWh for 2.3 Energy Factor~~<br>~~1,542 kWh for 2.0 Energy Factor~~<br>Variable based on energy factosr |
| **Unit Peak Demand Reduction** | ~~0.162 kW for 2.3 Energy Factor~~<br>~~0.141kW for 2.0 Energy Factor~~<br>Variable based on energy factors |
| **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 2.3. 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:

$$\Delta kWh = \cancel{\frac{\left\{\left(\frac{1}{EF_{Base}} - \left(\frac{1}{EF_{Proposed}} \times \frac{1}{F_{Deratest}}\right)\right) \times HW \times 365\ X\ 8.3\ \frac{lb}{gal}\ X\ (Thot - Tcold)\right\}}{3413\ \frac{Btu}{kWh}}} \frac{\left\{\left(\frac{1}{EF_{Base}} - \left(\frac{1}{EF_{Proposed}} \times \frac{1}{F_{Deratest}}\right)\right) \times HW}{341}$$

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~~2 PM to 6 PM on summer weekdays to the total annual energy usage.

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

The Energy to Demand Factor is defined below:

$$EnergyToDemandFactor = \frac{Average\ Usage_{Summer\ WD\ \cancel{Noon-8}2\text{-}6\ PM}}{Annual\ Energy\ Usage}$$

The ratio of the average energy usage during ~~noon and 8~~2 PM to 6 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[38]. The factor is constructed as follows:

1. Obtain the average kW, as monitored for 82 water heaters in PJM territory[39], 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~~2 PM to ~~8~~6 PM on summer days from the same data.
3. The average ~~noon~~2 PM to ~~8~~6 PM demand is converted to average *weekday* ~~noon~~2 PM to ~~8~~6 PM demand through comparison of weekday and weekend monitored loads from the same PJM study[40].
4. The ratio of the average weekday ~~noon~~2 PM to ~~8~~6 PM energy demand to the annual energy usage obtained in step 1. The resulting number,~~-~~0.~~00009172~~00008294, 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~~Figure 2-2~~ below.

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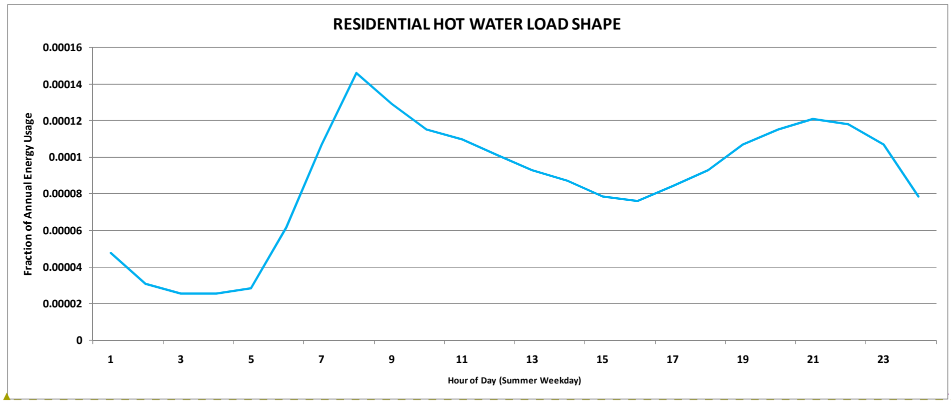
[38] Deemed Savings Estimates for Legacy Air Conditioning and Water Heating Direct Load Control Programs in PJM Region. The report can be accessed online: http://www.pjm.com/~/media/committees-groups/working-groups/lrwg/20070301/20070301-pjm-deemed-savings-report.ashx

[39] 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

[40] 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~~2 PM to ~~8~~6 PM is slightly higher is the weekends than on weekdays



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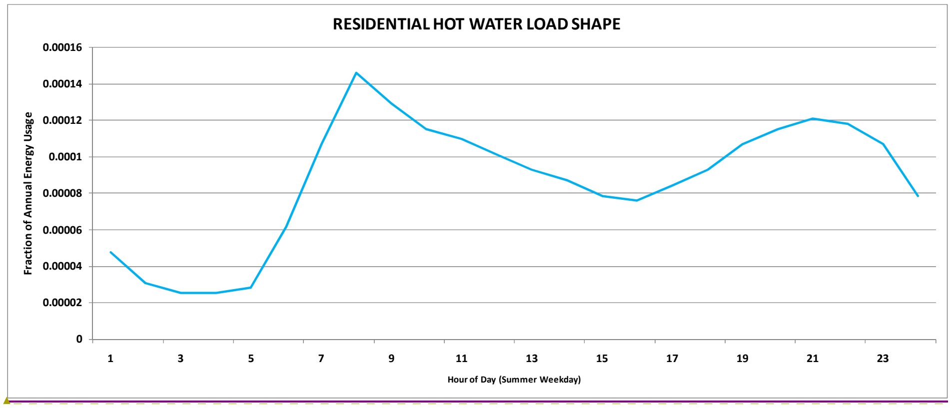

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**Figure 2-2: Load shapes for hot water in residential buildings taken from a PJM study.**

### 2.6.3 Definition of Terms

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

**Table 2-16~~2-16~~: Heat Pump Water Heater Calculation Assumptions**

| Component | Type | Values | Source |
|---|---|---|---|
| EFbase , Energy Factor of baseline water heater | Fixed | See Table 2-17 | 4 |
| EFproposed, Energy Factor of proposed efficient water heater | Variable | >=2.0 or EDC Data Gathering | Program Design;<br>EDC Data Gathering |
| HW , Hot water used per day in gallons | Fixed | 50 gallon/day | 5 |
| Thot , Temperature of hot water | Fixed | 123°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~~00008294 | 1-~~4~~3 |

### 2.6.4 Energy Factors based on Tank Size

Federal Standards for Energy Factors are equal to 0.97 -0.00132 x Rated Storage in Gallons. The following table shows the Energy Factors for various tank sizes.

**Table 2-17~~2-17~~: Minimum Baseline Energy ~~Factor~~Factors Based on Tank Size**

| Tank Size (gallons) | Minimum Energy Factor (EFBase) |
|---|---|
| 40 | 0.9172 |
| 50 | 0.9040 |
| 65 | 0.8842 |
| 80 | 0.8644 |
| 120 | 0.8116 |

**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

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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~~2 PM to ~~8~~6 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. Residential Energy Consumption Survey, EIA, 2009.
6. 2012 SWE Residential Baseline Study ~~Mid-Atlantic TRM, footnote #24~~
7. Mid-Atlantic TRM Version 3.0, March 2013, footnote #314

~~7.~~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.

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### 2.6.5 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[41]. The heat pump performance is temperature dependent. The plot below shows relative coefficient of performance (COP) compared to the COP at rated conditions[42]. 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.

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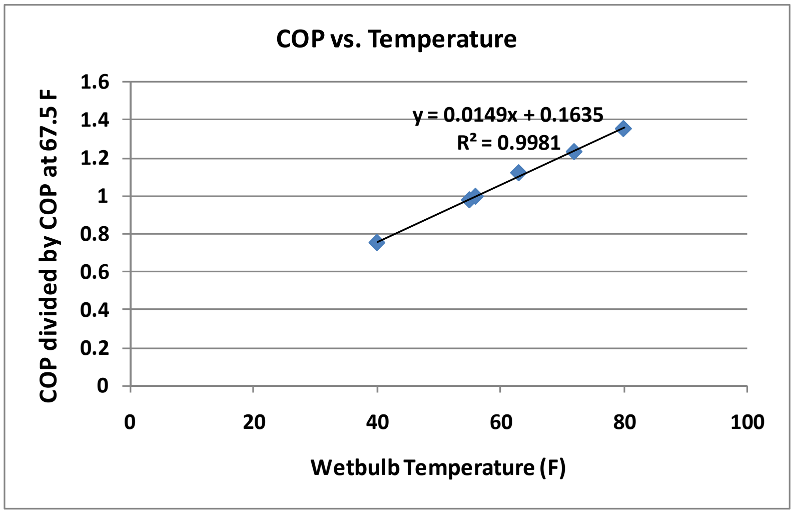
[41] Based on TMY2 weather files from DOE2.com for Erie, Harrisburg, Pittsburgh, Wilkes-Barre, And Williamsport, the average annual wetbulb temperature is 45 □ 1.3 °F. The wetbulb temperature in garages or attics, where the heat pumps are likely to be installed, are likely to be two or three degrees higher, but for simplicity, 45 °F is assumed to be the annual average wetbulb temperature.

[42] 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.



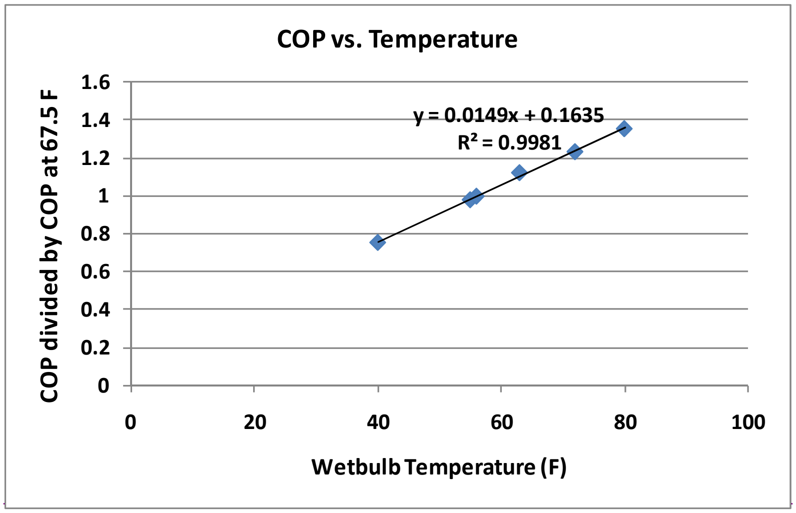


Figure 2-3: Dependence of COP on outdoor wet-bulb temperature.

### 2.6.6 ~~Deemed~~Default Savings

Savings for the installation of efficient electric water heaters are calculated using the formula below ~~Δ~~.

$$\Delta kWh = \cancel{\left(2{,}671.61 - \frac{2{,}916.51}{EF_{Proposed}}\right)} = \left(\frac{1}{EF_{Base}} - \frac{1}{EF_{Proposed} * 0.84}\right) * 3018.0$$

$\Delta kW_{peak}$ = ΔkWh X 0.~~00009172~~00008294

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### 2.6.7 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**[43].

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

## 2.7 LED Nightlight

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| 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.

### 2.7.1 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:

$$\Delta kWh = ((Watts_{base} - Watts_{NL}) \text{ X } (NL_{hours} \text{ X } 365))/1000) \text{ x } ISR$$

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

### 2.7.2 Definition of Terms

$Watts_{base}$ = Wattage of baseline nightlight

$Watts_{NL}$ = Wattage of 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 2-18~~2-18~~: LED Nightlight - References**

| Component | Type | Value | Sources |
|---|---|---|---|
| $Watts_{base}$ | Variable | Default = 7 Watts; EDC Data Gathering | EDC Data Gathering |
| $Watts_{NL}$ | Variable | Default= 1 Watt; EDCData Gathering | EDC Data Gathering |
| $NL_{hours}$ | Fixed | 12 | 1 |
| ISR | Fixed | ~~See ISR for CFLs~~0.97 or EDC Data Gathering | PA CFL ISR value |
| EUL | Fixed | 8 years | 1 |

**Sources:**

~~20.~~1. Southern California Edison Company, “LED, Electroluminescent & Fluorescent Night Lights”, Work Paper WPSCRELG0029 Rev. 1, February 2009, p. 2 & p. 3.

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### 2.7.3 Deemed Savings

The default energy savings is based on a delta watts assumption ($Watts_{base}$ – $Watts_{EE}$) of 6 watts.

*ΔkWh* = *((6 X (12 X 365))/1000) X 0.~~84 = 22.07~~97 = 25.49 kWh*
*(rounded to 22kWh)*

## 2.8 Low Flow Faucet Aerators

| Measure Name | Low Flow Faucet Aerators |
|---|---|
| Target Sector | Residential Establishments |
| Measure Unit | Aerator |
| Unit Energy Savings | ~~27.4 kWh~~ Varies by installation location |
| Unit Peak Demand Reduction | ~~0.0025 kW~~Varies by installation location |
| 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.

### 2.8.1 Algorithms

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

$$\Delta kWh = ISR \times ELEC \times [(\cancel{F_B - F_P}GPM_{Base} - GPM_{Low}) \times T_{Person\text{-}Day} \times N_{Persons} \times 365 \cancel{\times \Delta T_L \times} \times (T_{out} - T_{in}) \times U_H \times U_E \times DF/RE] / (F/home)$$

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

Where:

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

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

$F_{ED}$ = CF / Hours

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CF = [% faucet use during peak[44] × ($T_{Person\text{-}Day}$ × $N_{Person}$) /(F/home)] / 240 (minutes in peak period)

Hours = ($T_{Person\text{-}Day}$ × $N_{Persons}$ × 365) /(F/home) / 60

The ratio of the average energy usage during ~~noon~~2 PM and ~~8~~6 PM on summer weekdays to the total annual energy usage is taken from average daily load shape data collected for ~~a water heater and HVAC demand response~~faucets from an Aquacraft, Inc study~~ for PJM~~.[45]~~.~~ The average daily load shapes (~~fractions~~percentages of ~~annual~~daily energy usage that occur within each hour) ~~during summer week days~~ are plotted ~~for three business types in~~ in **Error! Reference source not found.**~~Figure 2-4~~ below~~.~~ (symbol FAU represents faucets).

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[44] Aquacraft, Inc., Water Engineering and Management. The end use of hot water in single family homes from flow trace analysis. 2001. The percentage of faucet use that takes place during peak hours is determined to be 18.9%. http://www.aquacraft.com/sites/default/files/pub/DeOreo-(2001)-Disaggregated-Hot-Water-Use-in-Single-Family-Homes-Using-Flow-Trace-Analysis.pdf

[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 summer load shapes are taken from tables 14,15, and 16 in pages 5-31 and 5-32, and table 18 in page 5-34 is used to derive an adjustment factor that scales average summer usage to summer weekday usage. The factor is constructed as follows: 1) Obtain the average kW, as monitored for 82 water heaters in PJM territory, for each hour of the typical day summer, winter, and spring/fall days. Weight the results (91 summer days, 91 winter days, 183 spring/fall days) to obtain annual energy usage. 2) Obtain the average kW during noon to 8 PM on summer days from the same data. 3) The average noon to 8 PM demand is converted to average *weekday* noon to 8 PM demand through comparison of weekday and weekend monitored loads from the same PJM study. 4) The ratio of the average weekday noon to 8 PM energy demand to the annual energy usage obtained in step 1. The resulting number, 0.00009172, is the *EnergyToDemandFactor*.~~ Aquacraft, Inc., Water Engineering and Management. The end use of hot water in single family homes from flow trace analysis. 2001. http://www.aquacraft.com/sites/default/files/pub/DeOreo-(2001)-Disaggregated-Hot-Water-Use-in-Single-Family-Homes-Using-Flow-Trace-Analysis.pdf.

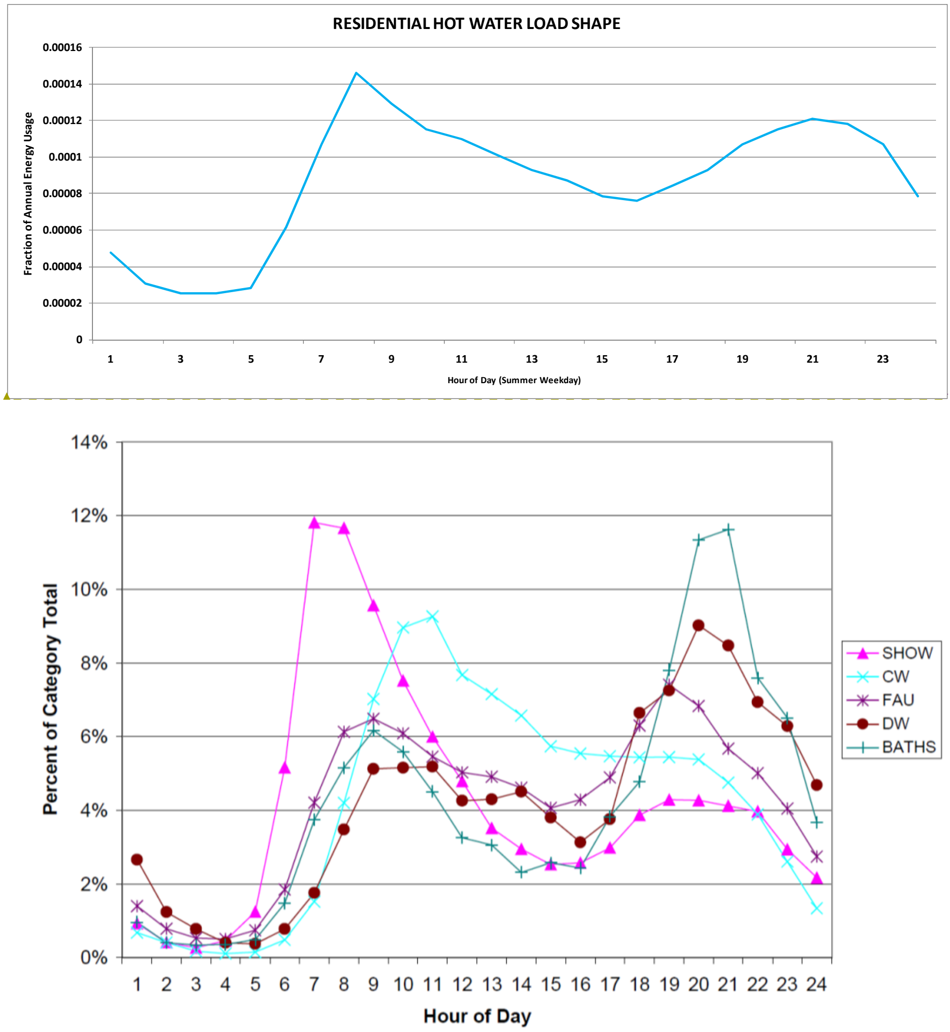

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Figure 2-4: Daily Load ~~shapes for hot water in residential buildings taken from a PJM study.~~Shapes for Hot Water Measurers

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### 2.8.2 Definition of Terms

The parameters in the above equation are defined in Table 2-19.

### Table 2-19~~2-19~~: Low Flow Faucet Aerator Calculation Assumptions

| Parameter | Description | Type | Value | Source |
|---|---|---|---|---|
| ~~$F_B$~~$GPM_{Base}$ | Average ~~Baseline Flow Rate~~baseline flow rate of aerator (GPM) | Variable~~Fixed~~ | ~~1.~~Default =2.2<br>Or EDC Data Gathering | 1 |
| ~~$F_P$~~$GPM_{Low}$ | Average ~~Post Measure Flow Rate~~post measure flow rate of ~~Sprayer~~aerator (GPM) | Variable~~Fixed~~ | ~~0.94~~Default = 1.5<br>Or EDC Data Gathering | 1 |
| $T_{Person\text{-}Day}$ | Average time of hot water usage per person per day (minutes) | Fixed | Kitchen=4.5<br>Bathroom=1.6<br>Unknown=6.1 | 2 |
| ~~$N_{Per}$~~$N_{Persons}$ | Average number of persons per household | Variable | Default SF=2.7<br>Default MF=1.8<br>Default ~~unknown~~Unknown=2.6<br>Or EDC Data Gathering | 3 |
| ~~$\Delta T$~~$T_{out}$ | Average mixed water temperature ~~differential between outgoing mixed faucet water and supply water~~flowing from the facuet (ºF) | Fixed | ~~35~~Kitchen=93<br>Bathroom=86<br>Unknown= 87.8 | 4 |
| $T_{in}$ | Average temperature of water entering the house (ºF) | Fixed | 55 | 5, 6 |
| $U_H$ | Unit Conversion: 8.33BTU/(Gallons-°F) | Fixed | 8.33 | Convention |
| $U_E$ | Unit Conversion: 1 kWh/3413 BTU | Fixed | 1/3413 | Convention |
| RE | Recovery efficiency of electric water heater | Fixed | 0.98 | ~~5~~7 |
| $F_{ED}$ | Energy To Demand Factor | Fixed | 0.~~0000917~~200012913 | ~~6~~8 |
| Days/year | Number of days per year | Fixed | 365 | |
| F/home | Average number of faucets in the home | Fixed | SF:<br>Kitchen=1.0<br>Bathroom=3.0<br>Unknown=4.0<br>MF:<br>Kitchen=1.0<br>Bathroom=1.7 | ~~7~~9 |

| | | | | |
|---|---|---|---|---|
| | | | Unknown=2.7<br>Unknown Home Type:<br>Kitchen=1.0<br>Bathroom=2.8<br>Unknown=3.8 | |
| DF | Percentage of water flowing down drain | Fixed | Kitchen=75%<br>Bathroom=90 %<br>Unknown=79.5 % | ~~8~~10 |
| ISR | In Service Rate | Variable | Variable | EDC Data Gathering |
| ELEC | Percentage of homes with electric water heat | Variable | Default=43%<br>Or EDC Data Gathering | ~~9~~11 |

**Sources:**

1. ~~Illinois TRM Effective June 1, 2013. Maximum rated flowrates of 2.2 gpm and 1.5 gpm are not an accurate measurement of actual average flowrates over a period of time because of throttling. These flowrates represent an average flow consumed over a period of time and take occupant behavior (not always using maximum flow rates) into account. Based on results from various studies.~~~~[46,47,48,49]~~
1. Cadmus and Opinion Dynamics Evaluation Team. Showerhead and Faucet Aerator Meter Study. For Michigan Evaluation Working Group. June 2013. Baseline GPM of replaced aerators is set to the federal minimum GPM of 2.2. The GPM of new aerators is set to the typical rated GPM value of 1.5 GPM. Discounted GPM flow rates were not applied because the "throttle factor" adjustment was found to have been already accounted for in the mixed water temperature variable. Additionally, the $GPM_{Base}$ was set to a default value of 2.2 due to the inability to verify what the GPM flow rate was of the replaced faucet.
2. Cadmus and Opinion Dynamics Evaluation Team. Showerhead and Faucet Aerator Meter Study. For Michigan Evaluation Working Group. June 2013. If aerator location is known, use the corresponding kitchen/bathroom value. If unknown, use 6.1

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~~[46] 2000, Mayer, Peter, William DeOreo, and David Lewis. Seattle Home Water Conservation Study. December 2000.v~~

~~[47] 2003, Mayer, Peter, William DeOreo. Residential Indoor Water Conservation Study. Aquacraft, Inc. Water Engineering and Management. Prepared for East Bay Municipal Utility District and the US EPA. July 2003~~

~~[48] 2011, DeOreo, William. Analysis of Water Use in New Single Family Homes. By Aquacraft. For Salt Lake City Corporation and US EPA. July 20, 2011.~~

~~[49] 2008, Schultdt, Marc, and Debra Tachibana. Energy related Water Fixture Measurements: Securing the Baseline for Northwest Single Family Homes. 2008 ACEEE Summer Study on Energy Efficiency in Buildings.~~

min/person/day as the average length of use value, which is the total for the household: kitchen (4.5 min/person/day) + bathroom (1.6 min/person/day) = 6.1 min/person/day.

3. Table 4-8, section 4.2.4. GDS Associates, Inc. Pennsylvania Statewide Residential End-Use Saturation Study, 2012. For The Pennsylvania Public Utility Commission.

~~4.~~ Table 7. Cadmus and Opinion Dynamics Evaluation Team. Showerhead and Faucet Aerator Meter Study. For Michigan Evaluation Working Group. June 2013. ~~Illinois TRM effective June 1, 2013. Based on a 90F mixed faucet temperature and a 55F supply temperature.~~

4. The study finds that the average mixed water temperature flowing from the kitchen and bathroom faucets is 93ºF and 86ºF, respectively. If the faucet location is unknown, 87.8ºF is the corresponding value to be used, which was calculated by taking a weighted average of faucet type (using the statewide values): ((1*93)+(3*86))/(1+3) = 87.8.

5. Table 9. Cadmus and Opinion Dynamics Evaluation Team. Showerhead and Faucet Aerator Meter Study. For Michigan Evaluation Working Group. June 2013. Inlet water temperatures were measured and a weighted average based upon city populations was used to calculate the value of 55ºF.

6. 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*

~~5.~~7. Mid Atlantic TRM Version 2.0 (updated July 2011) and Ohio TRM updated August 2010.

8. ~~Deemed Savings Estimates for Legacy Air Conditioning and Water Heating Direct Load Control Programs in PJM Region.~~ Aquacraft, Inc., Water Engineering and Management. The end use of hot water in single family homes from flow trace analysis. 2001. http://www.aquacraft.com/sites/default/files/pub/DeOreo-(2001)-Disaggregated-Hot-Water-Use-in-Single-Family-Homes-Using-Flow-Trace-Analysis.pdf. The statewide values were used for inputs in the $F_{ED}$ algorithm components. The CF for faucets is found to be 0.00328: [% faucet use during peak × ($T_{Person-Day}$ × $N_{Person}$) /(F/home)] / 240 (minutes in peak period) = [18.9% × (6.1 x 2.6 / 3.8)] / 240 = 0.00328. The Hours for faucets is found to be 25.4: ($T_{Person-Day}$ × $N_{Persons}$ × 365) /(F/home) / 60 = (6.1 x 2.6 x 365) / 3.8 / 60 = 25.4. The resulting $F_{ED}$ is calculated to be 0.00012913: CF / Hours = 0.00328 / 25.4 = 0.00012913.

~~6. 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.~~

~~7.~~9. Table 4-68, section 4.6.3. GDS Associates, Inc. Pennsylvania Statewide Residential End-Use Saturation Study, 2012. For The Pennsylvania Public Utility Commission.

~~8.~~10. Illinois TRM Effective June 1, 2013. Faucet usages are at times dictated by volume, only ~~usage of the sort that would go straight~~“directly down the drain” usage will provide savings. Due to the lack of a metering study that has determined this specific factor, the Illinois Technical Advisory Group has deemed these values to be 75% for the kitchen and 90% for the bathroom. If the aerator location is unknown an average of 79.5% should be used which is based on the assumption that 70% of household water runs through the kitchen faucet and 30% through the bathroom (0.7*0.75)+(0.3*0.9)=0.795.

~~9.~~11. Table 4-61, Section 4.6.1 GDS Associates, Inc. Pennsylvania Statewide Residential End-Use Saturation Study, 2012. For The Pennsylvania Public Utility Commission. This study finds that only 43% of households statewide have an electric water heater. As such, if the proportion of households with electric water heaters is unknown, deemed savings should only be applied to 43% of the study group.

~~For example, a direct installed (*ISR=1)* kitchen low flow faucet aerator in a single family electric DHW home:~~

~~ΔkWh = 1.0 * 1.0 * (((1.2– 0.94) * 4.5 * 2.7 * 365 * 35 * 8.33 * (1/3413) * .75 / .98) / 1)~~

~~= 75.4 kWh~~

~~For example, a direct installed (*ISR=1)* low flow faucet aerator in unknown faucet in an unknown family type electric DHW home:~~

~~ΔkWh = 1.0 * 1.0 * (((1.2– 0.94) * 6.1 * 2.6 * 365 * 35 * 8.33 * (1/3413) * .795 / .98) / 3.8)~~

~~= 27.4 kWh per faucet~~

### ~~2.8.3 Deemed Savings~~

~~The deemed energy savings for the installation of~~

For example, a direct installed (*ISR=1)* kitchen low flow faucet aerator ~~compared to~~in a ~~standard aerator is **ISR × 27**.~~single family electric DHW home:

ΔkWh = 1.0 * 1.0 * (((2.2 – 1.5) * 4.5 * 2.7 * 365 * (93 – 55) * 8.33 * (1/3413) * 0.75 / 0.98) / 1)

= 220.3 kWh~~/**year** with~~

For example, a ~~demand reduction of~~ direct installed (*ISR* ~~**× 0.0025 kW,** with ISR determined through data collection.~~*=1)* low flow faucet aerator in unknown faucet in an unknown family type electric DHW home:

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$\Delta$kWh = 1.0 * 1.0 * (((2.2 – 1.5) * 6.1 * 2.6 * 365 * (87.8 – 55) * 8.33 * (1/3413) * 0.795 / 0.98) / 4.0)

= 65.8 kWh per faucet

### 2.8.3 Default Savings

| Housing Type | Faucet Location | Unit Energy Savings (kWh) | Unit Demand Savings (kW) |
|---|---|---|---|
| Single Family | Kitchen | 220.3 | 0.0284 |
| | Bathroom | 25.6 | 0.0033 |
| | Unknown | 68.3 | 0.0088 |
| Multifamily | Kitchen | 146.9 | 0.0190 |
| | Bathroom | 30.1 | 0.0039 |
| | Unknown | 67.5 | 0.0087 |
| Statewide (Unknown Housing Type) | Kitchen | 212.2 | 0.0274 |
| | Bathroom | 26.4 | 0.0034 |
| | Unknown | 65.8 | 0.0085 |

### 2.8.4 Measure Life

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

### 2.8.5 Evaluation Protocols

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

## 2.9 Low Flow Showerheads

| **Measure Name** | **Low Flow Showerheads** |
|---|---|
| **Target Sector** | Residential Establishments |
| **Measure Unit** | Water Heater |
| **Unit Energy Savings** | Partially Deemed |
| **Unit Peak Demand Reduction** | Partially Deemed |
| **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.

### 2.9.1 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.

### 2.9.2 Algorithms

The annual energy savings are obtained through the following formula:

$\Delta kWh$ = $ISR$ ~~*~~ × $ELEC$ ~~* ((((GPM<sub></sub>~~ ~~$GPM_{base} - GPM_{low}) / GPM_{base})$ *~~ × $[(GPM_{Base} - GPM_{Low}) \times T_{Person-Day}$ × $N_{Persons}$ ~~* gals/day *~~ × $N_{Showers-Day}$ × 365~~) * $(TEMP_{ft} - TEMP_{in})$ *~~ × $(T_{out} - T_{in})$ × $U_H$ ~~*~~ × $U_E$ / $RE$~~)~~] / (S/home)

$\Delta kW_{peak}$ = $\Delta kWh$ × $F_{ED}$

Where:

$F_{ED}$ = CF / Hours

CF = [% showerhead use during peak[50] × $(T_{Person-Day} \times N_{Person} \times N_{Showers-Day})$ /(S/home)] / 240 (minutes in peak period)

Hours = $(T_{Person-Day} \times N_{Persons} \times N_{Showers-Day} \times 365)$ /(S/home) / 60

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The ratio of the average energy usage during ~~* EnergyToDemandFactor~~ 2 PM and 6 PM on summer weekdays to the total annual energy usage is taken from average daily load shape data

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[50] Aquacraft, Inc., Water Engineering and Management. The end use of hot water in single family homes from flow trace analysis. 2001. The percentage of showerhead use that takes place during peak hours is determined to be 11.7%. http://www.aquacraft.com/sites/default/files/pub/DeOreo-(2001)-Disaggregated-Hot-Water-Use-in-Single-Family-Homes-Using-Flow-Trace-Analysis.pdf

collected for showerheads from an Aquacraft, Inc study.[51] The average daily load shapes (percentages of daily energy usage that occur within each hour) during are plotted in Figure 2-5 below (symbol SHOW represents showerheads).

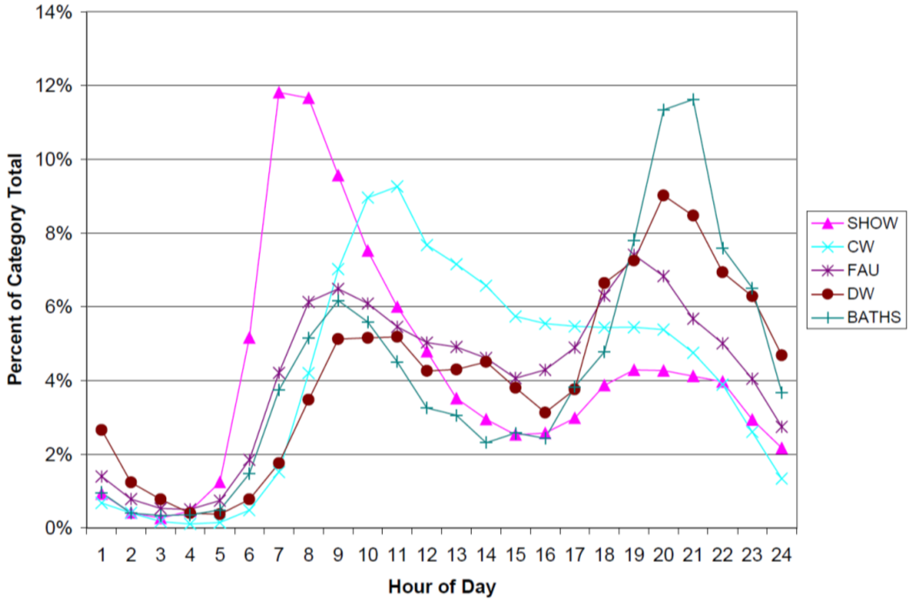

Figure 2-5: Daily Load Shapes for Hot Water Measures

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[51] Aquacraft, Inc., Water Engineering and Management. The end use of hot water in single family homes from flow trace analysis. 2001. http://www.aquacraft.com/sites/default/files/pub/DeOreo-(2001)-Disaggregated-Hot-Water-Use-in-Single-Family-Homes-Using-Flow-Trace-Analysis.pdf.

### 2.9.3 Definition of Terms

**Table 2-20~~2-20~~: Low Flow Showerhead Calculation Assumptions**

| Parameter | Description | Type | Value | Source |
|---|---|---|---|---|
| $GPM_{Base}$ | Gallons per minute of baseline showerhead | Fixed | ~~2.5~~Default value = 2.5 or EDC Data Gathering | 1 |
| $GPM_{Low}$ | Gallons per minute of low flow showerhead | Variable | Default value = 1.5 or EDC Data Gathering | 2 |
| $T_{Person\text{-}Day}$ | Average time of shower usage per person (minutes) | Fixed | 7.8 | 3 |
| ~~People~~$N_{persons}$ | Average number of persons per household | Variable | Default SF=2.7<br>Default MF=1.8<br>Default unknown=2.6<br>Or EDC Data Gathering | ~~3~~4 |
| ~~gals/day~~$N_{Showers\text{-}Day}$ | Average ~~gallons~~number of ~~hot water used for showering~~showers per person per day | Fixed | ~~11.7~~0.6 | ~~4~~5 |
| days/year | Number of days per year | Fixed | 365 | |
| ~~Showers~~S/home | Average number of showers in the home | Variable | Default SF=1.7 (89.6% of homes)<br>Default MF=1.3 (10.4% of homes)<br>Default unknown = 1.6<br>Or EDC Data Gathering | ~~5~~6 |
| ~~$TEMP_{ft}$~~$T_{out}$ | Assumed temperature of water used by showerhead | Fixed | 101° F | ~~6~~7 |
| ~~$TEMP_{in}$~~$T_{in}$ | Assumed temperature of water entering house | Fixed | 55° F | ~~6,~~7,8 |
| $U_H$ | Unit Conversion: 8.33BTU/(Gallons-°F) | Fixed | 8.33 | Convention |
| $U_E$ | Unit Conversion: 1 kWh/3413 BTU | Fixed | 1/3413 | Convention |
| RE | Recovery efficiency of electric water heater | Fixed | 0.98 | ~~8~~9 |
| $F_{ED}$ | Energy To Demand Factor | Fixed | 0.~~00009172~~00008013 | ~~9~~10 |
| ISR | In Service Rate | Variable | Variable | EDC Data Gathering |
| ELEC | Percentage of homes with electric water heat | Variable | Default=43%<br>Or EDC Data | ~~10~~11 |

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| | | | | |
|---|---|---|---|---|
| | | | Gathering | |

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**Sources:**

1. Cadmus and Opinion Dynamics Evaluation Team. Showerhead and Faucet Aerator Meter Study. For Michigan Evaluation Working Group. June 2013. Uses the federal minimum GPM allowed as the baseline for the replaced showerheads, corresponding to 2.5 GPM.

2. Illinois TRM Effective June 1, 2013. Allows for varying flow rate of the low-flow showerhead, most notably values of 2.0 GPM, 1.75 GPM and 1.5 GPM. Custom or actual values are also allowed for.

3. Table 6. Cadmus and Opinion Dynamics Evaluation Team. Showerhead and Faucet Aerator Meter Study. For Michigan Evaluation Working Group. June 2013. The study compared shower length by single-family and multifamily populations, finding no statistical difference in showering times. For the energy-saving analysis, the study used the combined single-family and multifamily average shower length of 7.8 minutes.

~~3.~~4. Table 4-8, section 4.2.4. GDS Associates, Inc. Pennsylvania Statewide Residential End-Use Saturation Study, 2012. For The Pennsylvania Public Utility Commission.

5. Table 8. Cadmus and Opinion Dynamics Evaluation Team. Showerhead and Faucet Aerator Meter Study. For Michigan Evaluation Working Group. June 2013. For each shower fixture metered, the evaluation team knew the total number of showers taken, duration of time meters remained in each home, and total occupants reported to live in the home. From these values average showers taken per day, per person was calculated. The study compared showers per day, per person by single-family and multifamily populations, finding no statistical difference in the values. For the energy-saving analysis, the study used the combined single-family and multifamily average showers per day, per person of 0.6.

~~4. *Cadmus and Opinion Dynamics Evaluation Team. Showerhead and Faucet Aerator Meter Study. For Michigan Evaluation Working Group. June 2013.* Based upon a metering study, this report concludes that the average shower length is 7.8 minutes and the average number of showers per day per person is 0.6. Using the showerhead flow rate of 2.5 GPM, the resulting calculation for gallons per day is as follows: 7.8 min * 2.5 gallons/min * 0.6 showers per day per person = 11.7 gallons per day per person.~~

~~5.~~6. Table 4-69, section 4.6.3. GDS Associates, Inc. Pennsylvania Statewide Residential End-Use Saturation Study, 2012. For The Pennsylvania Public Utility Commission.

~~6.~~7. Cadmus and Opinion Dynamics Evaluation Team. Showerhead and Faucet Aerator Meter Study. For Michigan Evaluation Working Group. June 2013. Temperature sensors provided the mixed water temperature readings resulting in an average of 101ºF. Inlet water temperatures were measured and a weighted average based upon city populations was used to calculate the value of 55ºF.

~~7.~~8. 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*

~~8.~~9. Mid Atlantic TRM Version 2.0 (updated July 2011) and Ohio TRM updated August 2010.

10. Aquacraft, Inc., Water Engineering and Management. The end use of hot water in single family homes from flow trace analysis. 2001. http://www.aquacraft.com/sites/default/files/pub/DeOreo-(2001)-Disaggregated-Hot-Water-Use-in-Single-Family-Homes-Using-Flow-Trace-Analysis.pdf. The statewide values were used for inputs in the $F_{ED}$ algorithm components. The CF for showerheads is found to be 0.00371: [% showerhead use during peak × ($T_{Person\text{-}Day}$× $N_{Person}$) /(S/home)] / 240 (minutes in peak period) = [11.7% × (7.8 x 2.6 x 0.6 / 1.6)] / 240 = 0.00371. The Hours for showerheads is found to be 46.3: ($T_{Person\text{-}Day}$× $N_{Persons}$× 365) /(S/home) / 60 = (7.8 x 2.6 x 0.6 x 365) / 1.6 / 60 = 46.3. The resulting $F_{ED}$ is calculated to be 0.00008013: CF / Hours = 0.00371 / 46.3 = 0.00008013.

9. ~~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.~~

~~10.~~11. Table 4-61, Section 4.6.1 of the 2012 Pennsylvania Statewide Residential End-Use and Saturation Study. This study finds that only 43% of households statewide have an electric water heater. As such, if the proportion of households with electric water heaters is unknown, deemed savings should only be applied to 43% of the study group.

~~For example, a direct-installed (*ISR=1*) 1.5 GPM low flow showerhead in a single family electric DHW home where the number of showers is not known:~~

~~ΔkWh = 1.0 * 1.0 * ((((2.5 – 1.5) / 2.5) * 2.7 * 11.7 * 365) * (101-55) * 8.33 * (1/3413) / 0.98) / 1.7~~

~~310.8 = kWh~~

~~For example, a direct-installed (*ISR=1*) 1.5 GPM low flow showerhead in an unknown family type home with electric DHW where the number of showers is not known:~~

~~ΔkWh = 1.0 * 1.0* ((((2.5 – 1.5) / 2.5) * 2.6 * 11.7 * 365) * (101-55) * 8.33 * (1/3413) / 0.98) / 1.6~~

~~318.0 = kWh~~

~~*EnergyToDemandFactor=Summer peak coincidence factor for measure = 0.00009172*~~~~[52]~~

~~*ΔkWh =Annual kWh savings*~~

~~*ΔkW =Summer peak kW savings*~~

~~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:~~

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

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~~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~~~~[53]~~~~. 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.~~

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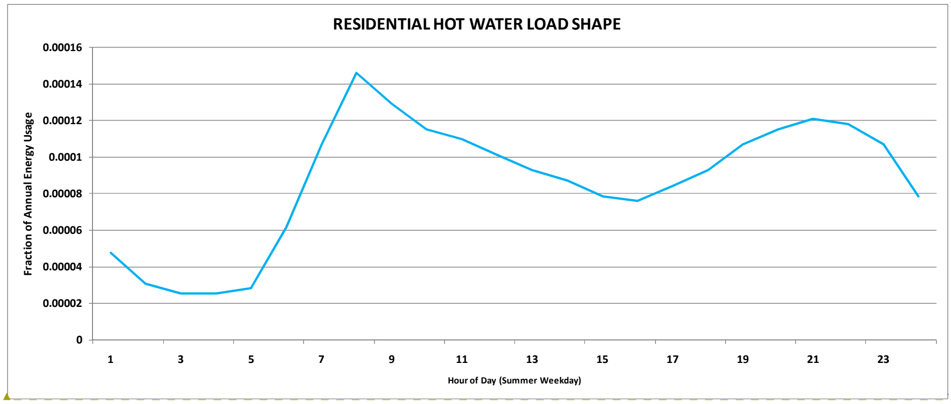
~~[52] Deemed Savings Estimates for Legacy Air Conditioning and Water Heating Direct Load Control Programs in PJM Region. The report can be accessed online: http://www.pjm.com/~/media/committees-groups/working-groups/lrwg/20070301/20070301-pjm-deemed-savings-report.ashx~~

~~[53] Op. cit.~~

~~The load shapes (fractions of annual energy usage that occur within each hour) during summer week days are plotted in Figure 2-5 below.~~



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

~~Deemed~~

For example, a direct-installed (*ISR=1*) 1.5 GPM low flow showerhead in a single family electric DHW home where the number of showers is not known:

ΔkWh = 1.0 * 1.0 * [(2.5 – 1.5) * 7.8 * 0.6 * 2.7 * 365 * (101 - 55) * 8.33 * (1/3413) / 0.98] / 1.7

310.8 = kWh

For example, a direct-installed (*ISR=1*) 1.5 GPM low flow showerhead in an unknown family type home with electric DHW where the number of showers is not known:

ΔkWh = 1.0 * 1.0* [(2.5 – 1.5) * 7.8* 0.6 * 2.6 * 365 * (101 - 55) * 8.33 * (1/3413) / 0.98] / 1.6

318.0 = kWh

### 2.9.4 Default Savings

| Housing Type | Low Flow Rate (gpm) | Unit Energy Savings (kWh) | Unit Demand Savings (kW) |
|---|---|---|---|
| ~~Single Family~~ | ~~2.0~~ | ~~155~~ | ~~0.0142~~ |
| | ~~1.75~~ | ~~233~~ | ~~0.0214~~ |
| | ~~1.5~~ | ~~311~~ | ~~0.0285~~ |
| ~~Multifamily~~ | ~~2.0~~ | ~~135~~ | ~~0.0124~~ |
| | ~~1.75~~ | ~~203~~ | ~~0.0186~~ |
| | ~~1.5~~ | ~~271~~ | ~~0.0249~~ |
| ~~Statewide~~ | ~~2.0~~ | ~~159~~ | ~~0.0146~~ |
| | ~~1.75~~ | ~~239~~ | ~~0.0219~~ |
| | ~~1.5~~ | ~~318~~ | ~~0.0292~~ |

| | | | |
|---|---|---|---|
| Single Family | 2.0 | 155 | 0.0124 |
| | 1.75 | 233 | 0.0187 |
| | 1.5 | 311 | 0.0249 |
| Multifamily | 2.0 | 135 | 0.0108 |
| | 1.75 | 203 | 0.0163 |
| | 1.5 | 271 | 0.0217 |
| Statewide (Unknown Housing Type) | 2.0 | 159 | 0.0127 |
| | 1.75 | 239 | 0.0192 |
| | 1.5 | 318 | 0.0255 |

### 2.9.5 Measure Life

According to the Efficiency Vermont Technical Reference User Manual (TRM), the expected measure life is **9 years**[54].

### 2.9.6 Evaluation Protocols

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

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

## 2.10 Programmable Thermostat

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

Programmable thermostats are used to control heating and/or cooling loads in residential buildings by modifying the temperature set-points during specified unoccupied and nighttime hours. These units are expected to replace a manual thermostat and the savings assume an existing ducted HVAC system with electric resistance heating and DX cooling. A standard programmable thermostat installed on a heat pump can have negative energy consequences. 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.

### 2.10.1 Algorithms

$\Delta kWh = \Delta kWh_{COOL} + \Delta kWh_{HEAT}$

$\Delta kWh_{COOL} = CAP_{COOL}/1000 \text{ X } (1/(SEER \text{ x } Eff_{duct}$~~)~~$)) \text{ X } EFLH_{COOL} \text{ X } ESF_{COOL}$

$\Delta kWh_{HEAT} = CAP_{HEAT}/1000 \text{ X } (1/(HSPF \text{ X } Eff_{duct})) \text{ X } EFLH_{HEAT} \text{ X } ESF_{HEAT}$

$\Delta kW_{peak} = 0$

### 2.10.2 Definition of Terms

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

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

$Eff_{duct}$ = *Duct system efficiency*

$SEER$ = *Seasonal energy efficiency ratio of the cooling unit.*

$HSPF$ = *Heating seasonal performance factor of the heating unit.*

$ESF_{COOL,HEAT}$ = *Energy savings factor for cooling and heating, respectively*

$EFLH_{COOL, HEAT}$ = *Equivalent full load hours for cooling and heating, respectively*

**Table 2-21~~2-21~~: Residential Electric HVAC Calculation Assumptions**

| Component | Type | Value | Sources |
|---|---|---|---|
| $CAP_{COOL}$ | Variable | Nameplate data | EDC Data Gathering |
| | | Default: ~~36~~32,000 BTUh | 1 |
| $CAP_{HEAT}$ | Variable | Nameplate Data | EDC Data Gathering |
| | | Default: ~~36~~32,000 BTUh | 1 |
| SEER | Variable | Nameplate data | EDC Data Gathering |
| | | Default: ~~10~~11.9 SEER | ~~2~~1 |
| 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 |
| $EFLH_{COOL}$ | Default | Allentown Cooling = 487 Hours<br>Erie Cooling = 389 Hours<br>Harrisburg Cooling = 551 Hours<br>Philadelphia Cooling = 591 Hours<br>Pittsburgh Cooling = 432 Hours<br>Scranton Cooling = 417 Hours<br>Williamsport Cooling = 422 Hours | 6 |
| | Optional | Can use the more EDC-specific values in Table 2-2 in Section 2.1.3 | Alternate EFLH Table in Section 2.1.3 |
| | Optional | An EDC can estimate it's own EFLH based on customer billing data analysis. | EDC Data Gathering |
| $EFLH_{HEAT}$ | Default | Allentown Heating = 1,193 Hours<br>Erie Heating = 1,349 Hours<br>Harrisburg Heating = 1,103 Hours<br>Philadelphia Heating = 1,060 Hours<br>Pittsburgh Heating = 1,209 Hours<br>Scranton Heating = 1,296 Hours<br>Williamsport Heating = 1,251 Hours | 6 |
| | Optional | An EDC can use the Alternate EFLH values in Table 2-3 in Section 2.1.3 | Alternate EFLH Table in Section 2.1.3 |
| | Optional | An EDC can estimate it's own EFLH based on customer billing data analysis. | EDC Data Gathering |
| Measure Life (EUL) | Fixed | ~~11~~11years | 7 |

**Sources:**

1. ~~Average size of residential air conditioner or furnace.~~
1. Data set from the 2012 Pennsylvania Residential End-Use and Saturation Study submitted to Pennsylvania PUC by GDS Associates, Nexent, and Mondre: http://www.puc.pa.gov/electric/pdf/Act129/PA_Residential_Baseline_Report2012.pdf
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. Based on REM/Rate modeling using models from the PA 2012 Potential Study. EFLH calculated from kWh consumption for cooling and heating. Models assume 50% over-sizing of air conditioners[55] and 40% oversizing of heat pumps.[56]
7. New York Standard Approach for Estimating Energy Savings from Energy Efficiency Measures in Commercial and Industrial Programs, September 1, 2009, based on DEER.

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[55] Neme, Proctor, Nadal, "National Energy Savings Potential From Addressing Residential HVAC Installation Problems. ACEEE, February 1, 1999. Confirmed also by *Central Air Conditioning in Wisconsin, a compilation of recent field research.* Energy Center of Wisconsin. May 2008, emended December 15, 2010

[56] ACCA, "Verifying ACCA Manual S Procedures," http://www.acca.org/Files/?id=67.

## 2.11 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).

### 2.11.1 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.

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

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

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

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

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

### 2.11.2 Definition of Terms

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$EFLH_{RAC}$ = *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~~, however, the current (July 2010) ES Room AC calculator EFLHs ~~are too~~ appear unreasonably high ~~because they~~and are in the ~~same as~~range of those typically used for the Central AC calculator~~, whereas~~ . In reality, RAC full load hours should be much lower than for a CAC system~~. As~~ , and as such, the ~~ES~~$EFLH_{RAC}$ values were calculated from CAC EFLH values ~~were corrected~~ as follows:

$EFLH_{RAC}$ = ~~$EFLH_{ES-RAC}$~~$EFLH_{cool}$ * AF

~~Where:~~

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**Where:**

$EFLH$ ~~$_{ES-RAC}$~~$_{cool}$ = *Full load hours from ~~the ENERGY STAR Room AC Calculator~~REM/Rate modeling (Source 1)*

$AF$ = *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 $EFLH_{ES-RAC}$ 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 2-22~~2-22~~: Room AC Retirement Calculation Assumptions**

| Component | Type | Value | Sources |
|---|---|---|---|
| $EFLH_{RAC}$ | Varies | Table 2-23 | 1 |
| ~~$EFLH_{ES\text{-}RAC}$~~$EFLH_{cool}$ | Varies | Table 2-23 | 1 |
| | Optional | The Alternate $EFLH_{COOL}$ values in Table 2-1 may be used | Table 2-1 in Section 2.1.3 |
| AF | Fixed | 0.31 | 2 |
| CAPY (RAC capacity, Btuh) | Variable | Default :10,000; or EDC Data Gathering | 3 |
| $EER_{RetRAC}$ | Variable | Default: 9.07; or EDC Data Gathering | 4 |
| $EER_b$ (for a 10,000 Btuh unit) | Fixed | 9.8 | 5 |
| $EER_{ES}$ (for a 10,000 Btuh unit) | Variable | Default: 10.8; or EDC Data Gathering | 5 |
| $CF_{RAC}$ | Default~~Fixed~~ | 0.58 | 6 |
| | Variable | EDC data gathering | EDC data gathering |
| RAC Time Period Allocation Factors | Fixed | 65.1%, 34.9%, 0.0%, 0.0% | 6 |
| Measure Life (EUL) | Fixed | 4 | See source notes |

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**Table 2-23~~2-23~~: RAC Retirement-Only EFLH and Energy Savings by City**[57]

| City | Original Hours (~~$EFLH_{ES\ RAC}$~~$EFLH_{cool}$) | Corrected Hours ($EFLH_{RAC}$) | Energy Impact (kWh) | Demand Impact (kW) |
|---|---|---|---|---|
| Allentown | ~~784~~ 487 | ~~243~~ 151 | ~~268~~ 166 | 0.6395 |
| Erie | ~~482~~ 389 | ~~149~~ 121 | ~~164~~ 133 | |
| Harrisburg | ~~929~~ 551 | ~~288~~ 171 | ~~318~~ 188 | |
| Philadelphia | ~~1032~~ 591 | ~~320~~ 183 | ~~353~~ 202 | |
| Pittsburgh | ~~737~~ 432 | ~~228~~ 134 | ~~251~~ 148 | |
| Scranton | ~~621~~ 417 | ~~193~~ 129 | ~~213~~ 143 | |
| Williamsport | ~~659~~ 422 | ~~204~~ 131 | ~~225~~ 144 | |

**Sources:**

~~1. Full load hours for Pennsylvania cities from the ENERGY STAR Room AC Calculator[58] spreadsheet, Assumptions tab. Note that the EFLH values currently used in the ES Room AC calculator are incorrect and too high because they are the same as those used for the Central AC calculator, but should be much less.~~

1. ~~For reference, EIA-RECS for the Northeast, Middle Atlantic region shows the per-household energy use for an RAC = 577 kWh and an average of 2.04 units per home, so the adjusted RAC use = 283 kWh per unit. This more closely aligns with the energy consumption for room AC using the adjusted EFLH values than without adjustment.~~Based on REM/Rate modeling using models from the PA 2012 Potential Study. EFLH calculated from kWh consumption for cooling and heating. Models assume 50% over-sizing of air conditioners59 and 40% oversizing of heat pumps.[60]

   ~~a.~~

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. The average ratio of EFLH for Room AC provided in RLW

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57
Table 2-23
~~Table 2-21~~ 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.

~~[58] 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 .~~

[59] Neme, Proctor, Nadal, "National Energy Savings Potential From Addressing Residential HVAC Installation Problems. ACEEE, February 1, 1999. Confirmed also by *Central Air Conditioning in Wisconsin, a compilation of recent field research.* Energy Center of Wisconsin. May 2008, emended December 15, 2010

[60] ACCA, "Verifying ACCA Manual S Procedures," http://www.acca.org/Files/?id=67.

Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008[61] to FLH for Central Cooling for the same location (provided by AHRI: <http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls> is 31%. This factor was applied to the EFLH for Central Cooling provided for PA cities and averaged to come up with the assumption for EFLH for Room AC."

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 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.

### 2.11.3 Measure Life

*Room Air Conditioner Retirement = 4 years*

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[61] Accessed: <http://www.puc.nh.gov/Electric/Monitoring%20and%20Evaluation%20Reports/National%20Grid/117_RLW_CF%20Res%20RAC.pdf>

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 2-24, the results from a recent evaluation of ComEd's appliance recycling program[62] 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.

**Table 2-24~~2-24~~: 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.

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

## 2.12 Smart Strip Plug Outlets

| **Measure Name** | **Smart Strip Plug Outlets** |
|---|---|
| **Target Sector** | Residential |
| **Measure Unit** | Per Smart Strip |
| **Unit Energy Savings** | 48.9 kWh (5-plug, unspecified use or multiple purchased)<br>58.7 kWh (7-plug, unspecified use or multiple purchased)<br>62.1 kWh (5-plug, Entertainment Center)<br>74.5 kWh (7-plug, Entertainment Center) |
| **Unit Peak Demand Reduction** | 0.0054 kW (5-plug, unspecified use or multiple purchased)<br>0.0064 kW (7-plug, unspecified use or multiple purchased)<br>0.0068 kW (5-plug, Entertainment Center)<br>0.0082 kW (7-plug, Entertainment Center) |
| **Measure Life** | 4 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~~2.12.1 Eligibility

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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 office systems and home entertainment systems. Power strips used with entertainment systems typically save more energy than power strips used with home office components. It is expected that approximately three to five items will be plugged into each 5-plug power strip, and that five to six items will be plugged into a 7-plug power strip.

### ~~2.13.2~~2.12.2 Algorithms

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The energy savings and demand reduction were obtained through the following calculations using standard standby or low power wattages for typical entertainment center and home office components. If the intended use of the power strip is not specified, or if multiple power strips are purchased, the algorithm for “unspecified use should be applied”. If it is known that the power strip is intended to be used for an entertainment center, the “entertainment center” algorithm should be applied:

$$\Delta kWh_{unspecified\ use} = \frac{(kW_{comp} \times Hr_{comp}) + (kW_{TV} \times Hr_{TV})}{2} \times 365 = 48.9\ kWh\ \ (5\text{-plug});\ 58.7\ kWh\ \ (7\text{-plug})$$

$$\Delta kWh_{entertainment\ center} = kW_{TV} \times Hr_{Tv} \times 365 = 62.1\ kWh\ \ (5\text{-plug});\ 74.5\ kWh\ \ (7\text{-plug})$$

$$\Delta kW_{peak}\ \textit{unspecified use} \quad = \frac{CF\times(kW_{comp}+kW_{TV})}{2} \quad = 0.0054\ kW\ \ (5\text{-plug});\ 0.0064\ kW\ (7\text{-plug})$$

$$\Delta kW_{peak}\ \textit{entertainment center} \quad = \quad CF\times\ kW_{TV} \quad = 0.0068\ kW\ \ (5\text{-plug});\ 0.0082\ kW\ \ (7\text{-plug})$$

### ~~2.13.3~~2.12.3 Definition of Terms

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The parameters in the above equation are listed in ~~Table 2-25.~~Table 2-25.

**Table 2-25~~2-25~~: Smart Strip Plug Outlet Calculation Assumptions**

| Parameter | Component | Type | Value | Source |
|---|---|---|---|---|
| $kW_{comp}$ | Idle kW of computer system | Fixed | 0.0049 (5-plug)<br>0.00588 (7-plug) | 1,2,4 |
| $Hr_{comp}$ | Daily hours of computer idle time | Fixed | 20 | 1 |
| $kW_{TV}$ | Idle kW of TV system | Fixed | 0.0085 (5-plug)<br>0.0102 (7-plug) | 1,4 |
| $Hr_{TV}$ | Daily hours of TV idle time | Fixed | 20 | 1 |
| CF | Coincidence Factor | Fixed | 0.80 | 3 |

**Sources:**

1. "Electricity Savings Opportunities for Home Electronics and Other Plug-In Devices in Minnesota Homes", Energy Center of Wisconsin, May 2010.
2. "Smart Plug Strips", ECOS, July 2009.
3. Efficiency Vermont coincidence factor for smart strip measure – in the absence of empirical evaluation data, this was based on the assumptions of the typical run pattern for televisions and computers in homes.
4. "Advanced Power Strip Research Report", NYSERDA, August 2011.

### ~~2.13.4~~2.12.4 Deemed Savings

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$\Delta kWh$ = *48.9 kWh (5-plug power strip, unspecified use or multiple purchsed)*

*58.7 kWh (7-plug power strip, unspecified use or multiple purchased)*

*62.1 kWh (5-plug power strip, entertainment center)*

*74.5 kWh (7-plug power strip, entertainment center)*

$\Delta kW_{peak}$ = *0.0054 kW (5-plug power strip, unspecified use or multiple purchase)*

*0.0064 kW (7-plug power strip, unspecified use, or multiple purchased)*

*0.0068 kW (5-plug power strip, entertainment center)*

*0.82 ~~0.0082~~ kW (7 plug power strip, entertainment center)*

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### ~~2.13.5~~2.12.5 Measure Life

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4 years[63].

### ~~2.13.6~~2.12.6 Evaluation Protocols

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

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[63] "Smart Strip Electrical Savings and Usability", David Rogers, Power Smart Engineering, October 2008.

## 2.13 Solar Water Heaters

| **Measure Name** | **Solar Water Heaters** |
|---|---|
| **Target Sector** | Residential Establishments |
| **Measure Unit** | Water Heater |
| **Default Unit Energy Savings** | 1,698 kWh |
| **Default Unit Peak Demand Reduction** | 0.~~306~~277 kW |
| **Measure Life** | 15 years |

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

### 2.13.1 Eligibility

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

### 2.13.2 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:

$$\Delta kWh = \frac{\cancel{\left\{\left(\frac{1}{EF_{Base}} - \frac{1}{EF_{Proposed}}\right) \times \left(HW \times 365 \times 8.3\frac{lb}{gal} \times (T_{hot} - T_{cold})\right)\right\}}}{\cancel{3413\frac{Btu}{kWh}}} \frac{\left\{\left(\frac{1}{EF_{Base}} - \frac{1}{EF_{Proposed}}\right) \times \left(HW \times \left(365\frac{days}{year}\right) \times (8.3\frac{lb}{gal}) x (1\right.\right.}{3413\frac{Btu}{kWh}}$$

The energy factor used in the above equation represents an average energy factor of market available solar water heaters[64]. 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~~2PM to 6PM on summer weekdays to the total annual energy usage. Note that this is a different formulation than the demand savings calculations for other water heaters. This modification of the formula reflects the fact that a solar water heater's capacity is subject to seasonal variation, and that during the peak summer season~~ (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:

$$EnergyToDemandFactor = \frac{Average\ Usage_{Summer\ WD\ \cancel{Noon-8}2\ PM-\ 6\ PM}}{Annual\ Energy\ Usage}$$

---

[64] 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~~6 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[65]. The factor is constructed as follows:

1. Obtain the average kW, as monitored for 82 water heaters in PJM territory[66], 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~~the 2 PM to 6 PM time period on summer ~~days~~weekdays from the same data. ~~Noon to 8 PM is used because most of the top 100~~These are the hours ~~(over 80%) occur during noon and 8 PM~~[67]that PJM has defined as peak hours .
3. The average ~~noon~~weekday 2 PM to ~~8~~6 PM demand is converted to average *weekday* ~~noon~~2 PM to ~~8~~6 PM demand through comparison of weekday and weekend monitored loads from the same PJM study[68].
4. The ratio of the average weekday ~~noon~~2 PM to ~~8~~6 PM energy demand to the annual energy usage obtained in step 1. The resulting number, 0.~~00009172~~00008294, is the *~~EnergyToDemandFactor~~EnergyTo Demand Factor*.

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

---

[65] 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

[66] 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

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

[68] 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~~2 PM to ~~8~~6 PM is slightly higher is the weekends than on weekdays.

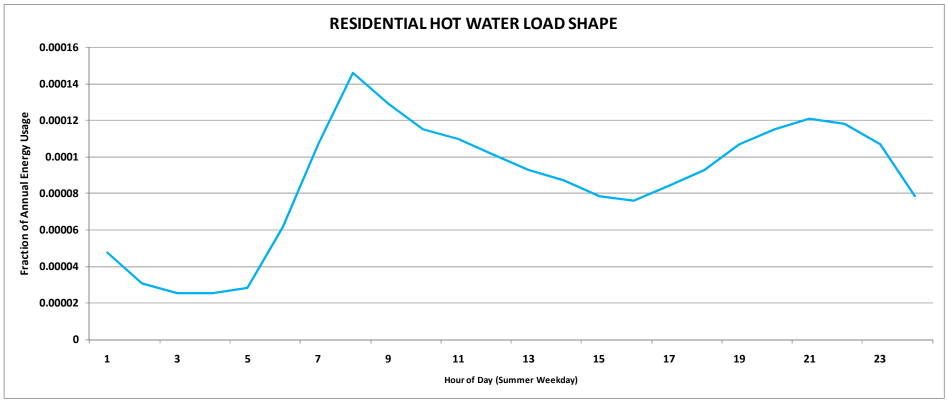

Figure 2-6: Load shapes for hot water in residential buildings taken from a PJM study.

### 2.13.3 Definition of Terms

The parameters in the above equation are listed in **Error! Reference source not found.**~~Table 2-26~~.

Table 2-26~~2-26~~: Solar Water Heater Calculation Assumptions

| Component | Type | Values | Source |
|---|---|---|---|
| $EF_{base}$ , Energy Factor of baseline electric water heater | Variable | See Table 2-27 | 6 |
| | | Default: .904<br>(50 gallon) | 6 |
| $EF_{proposed}$, Year-round average Energy Factor of proposed solar water heater | Variable | EDC Data Gathering | EDC Data Gathering |
| | | Default: 1.84 | 1 |
| HW , Hot water used per day in gallons | Fixed | 50 gallon/day | 7 |
| $T_{hot}$ , Temperature of hot water | Fixed | 123 F | 8 |
| $T_{cold}$ , Temperature of cold water supply | Fixed | 55 F | 9 |
| Default Baseline Energy Usage for an electric water heater without a solar water heater (kWh) | Calculated | 3,338 | |
| ~~EnergyToDemandFactor~~EnergyToDemand Factor: Ratio of average ~~Noon~~2 to ~~8~~6 PM usage during summer peak hours (on weekdays) to annual energy usage | Fixed | ~~0.00009172~~.00008294 | 2-5 |

### 2.13.4 Energy Factors based on Tank Size

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

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**Table 2-27~~2-27~~: Minimum Baseline Energy Factors Based on Tank Size**

| Tank Size (gallons) | Minimum Energy ~~Factor~~Factors |
|---|---|
| 40 | 0.9172 |
| 50 | 0.9040 |
| 65 | 0.8842 |
| 80 | 0.8644 |
| 120 | 0.8116 |

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**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 calculated 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.~~
4. PJM peak load hours are from 2 pm to 6 pm on summer weekdays.
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 ia approximately .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, pp. 26005-26006.
8. Pennsylvania Statewide Residential End-Use and Saturation Study. 2012.
9. Mid-Atlantic TRM Version 3.0, March 2013, footnote #~~24~~314

### ~~2.13.5 Deemed Savings (based on default values)~~

~~$\Delta kWh = 1,698\ kWh$~~

~~$\Delta kW_{peak}$ = 0.306 kW~~

### ~~2.13.6 Measure Life~~

~~The expected useful life is 15[69] years, according to ENERGY STAR[70].~~

### ~~2.13.7 Evaluation Protocols~~

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

---

[69] ~~The actual measure life for the Solar Water Heater measure is 20 years according to ENERGY STAR, but is reduced to 15 years per Act 129.~~

[70] ~~http://www.energystar.gov/index.cfm?c=solar_wheat.pr_savings_benefits~~

## 2.14 ~~Electric Water~~ Heater Pipe Insulation

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| **Measure Name** | **Electric Water Heater Pipe Insulation** |
|---|---|
| **Target Sector** | Residential Establishments |
| **Measure Unit** | Water Heater |
| **Unit Energy Savings** | Default: ~~9.6~~10 kWh per foot of installed insulation |
| **Unit Peak Demand Reduction** | 0.~~0008~~00083 kW per foot of installed insulation |
| **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=0.904) with an annual energy usage of 3~~,191~~.338 kWh.[71]

### 2.14.1 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.

### 2.14.2 Algorithms

The annual energy savings are assumed to be 3% of the annual energy use of an electric water heater (3,~~191~~338 kWh), or ~~96~~100.14 kWh based on 10 feet of insulation. This estimate is based on a recent report prepared by the ACEEE for the State of Pennsylvania.[72] On a per foot basis, this is equivalent to ~~9.6~~10 kWh.

*ΔkWh* = ~~*9.6*~~*10 kWh per foot of installed insulation*

The summer coincident peak kW savings are calculated as follows:

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

### 2.14.3 Definition of Terms

*ΔkWh* = *Annual kWh savings =* ~~*9,6*~~*10 kWh per foot of installed insulation*

---

[71] See Section 2.3 for assumptions used to calculate annual energy usage.

[72] 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.

*EnergyToDemandFactor*= *Summer peak coincidence factor for measure = 0.~~000091720~~0008294* [73]

$\Delta kW_{peak}$ =*Summer peak kW savings =* ~~.00088~~*0.00083 kW per foot of installed insulation*

The demand reduction is taken as the annual energy savings multiplied by the ratio of the average energy usage during ~~noon and 8PM~~2 PM to 6 PM on summer weekdays to the total annual energy usage. The Energy to Demand Factor is defined as:

$$EnergyToDemandFactor \cancel{=} = \cancel{\frac{Average\ Usage_{Summer\ WD\ Noon-8}}{Annual\ Energy\ Usage}} \frac{Average\ Usage_{Summer\ WD\ 2PM\text{-}6PM}}{Annual\ Energy\ Usage}$$

The ratio of the average energy usage during ~~noon and 8~~2 PM ~~on summer weekdays~~ to 6 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[74]. The factor is constructed as follows:

~~5.~~2. 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.

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~~the total annual energy usage is taken from load shape data collected for a water heater and HVAC demand response study for PJM[75]. 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.~~3. Obtain the average kW during ~~noon~~2 PM to ~~8~~6 PM on summer days from the same data.

~~3.~~4. The average ~~noon~~2 PM to ~~8~~6 PM demand is converted to average *weekday* ~~noon~~2 PM to ~~8~~6 PM demand through comparison of weekday and weekend monitored loads from the same PJM study,

~~4.~~5. The ratio of the average weekday ~~noon~~2 PM to ~~8~~6 PM energy demand to the annual energy usage obtained in step 1. The resulting number, 0.~~000091720~~0008294, is the Energy to Demand Factor, or Coincidence Factor.

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

---

[73] 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

[74] Op. cit.

~~[75] Op. cit.~~

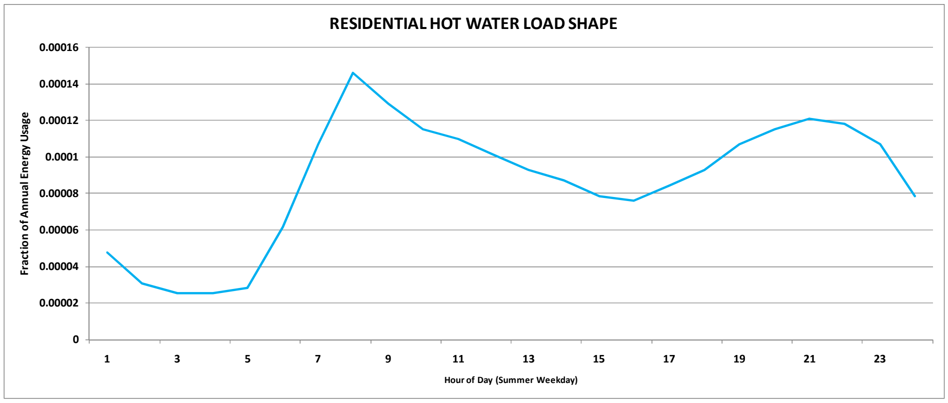

**Figure 2-7: Load shapes for hot water in residential buildings taken from a PJM study.**

### 2.14.4 Measure Life

According to the Efficiency Vermont Technical Reference User Manual (TRM), the expected measure life is **13 years**[76].

### 2.14.5 Evaluation Protocols

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

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

## 2.15 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.

### 2.15.1 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.[77] Energy savings for this measure are based on whole house fan energy savings values reported by the energy modeling software, REM/Rate[78].

### 2.15.2 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.[79]

---

[77] *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

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

[79] 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 2-28~~2-28~~: 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.

### 2.15.3 Measure Life

Measure life = 20 years[80] (15 year maximum for PA TRM)

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

## 2.16 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 years |

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.

### 2.16.1 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.[81] 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.

### 2.16.2 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:**

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

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

$\Delta kWh_{cool} = CAPY_{cool}/1000 \text{ X } (1/SEER_b – 1/SEER_e) \text{ X } EFLH_{cool} \text{ X } LF$

---

[81] 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.

$\Delta kW_{peak}$ = $CAPY_{cool}/1000 \text{ X } (1/EER_b – 1/EER_e) \text{ X } CF$

**Multi-Zone:**

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

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

$\Delta kWh_{cool}$ = $[CAPY_{cool}/1000 \text{ X } (1/SEER_b – 1/SEER_e) \text{ X } EFLH_{cool} \text{ X } LF]_{ZONE1}$
$+ [CAPY_{cool}/1000 \text{ X } (1/SEER_b – 1/SEER_e) \text{ X } EFLH_{cool} \text{ X } LF]_{ZONE2}$
$+ [CAPY_{cool}/1000 \text{ X } (1/SEER_b – 1/SEER_e) \text{ X } EFLH_{cool} \text{ X } LF]_{ZONEn}$

$\Delta kW_{peak}$ = $[CAPY_{cool}/1000 \text{ X } (1/EER_b – 1/EER_e) \text{ X } CF]_{ZONE1} +$
$[CAPY_{cool}/1000 \text{ X } (1/EER_b – 1/EER_e) \text{ X } CF]_{ZONE2} +$
$[CAPY_{cool}/1000 \text{ X } (1/EER_b – 1/EER_e) \text{ X } CF]_{ZONEn}$

### 2.16.3 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 2-27, the EFLH will use the EFLH primary hours listed in Table 2-26. If the unit is installed as a secondary heating or cooling system, the EFLH will use the EFLH secondary hours listed in Table 2-26.*

$HSPF_b$ = *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 2-29~~2-29~~: DHP – Values and References**

| Component | Type | Values | Sources |
|---|---|---|---|
| $CAPY_{cool}$<br>$CAPY_{heat}$ | Variable | EDC Data Gathering | AEPS Application;<br>EDC Data Gathering |
| EFLH primary | Fixed | Allentown Cooling = 487 Hours<br>Allentown Heating = 1,193 Hours<br>Erie Cooling = 389 Hours<br>Erie Heating = 1,349 Hours<br>Harrisburg Cooling = 551  Hours<br>Harrisburg Heating = 1,103 Hours<br>Philadelphia Cooling = 591 Hours<br>Philadelphia Heating = 1,060 Hours<br>Pittsburgh Cooling = 432 Hours<br>Pittsburgh Heating = 1,209 Hours<br>Scranton Cooling = 417 Hours<br>Scranton Heating = 1,296 Hours<br>Williamsport Cooling = 422 Hours<br>Williamsport Heating = 1,251 Hours | 1 |
|  | Optional | An EDC can either use the Alternate EFLH Table 2-3 or estimate ~~it's~~its own EFLH based on customer billing data analysis~~.~~ | EDC Data Gathering |
| EFLH secondary | Fixed | Allentown Cooling = 243 Hours<br>Allentown Heating = 800 Hours<br>Erie Cooling = 149 Hours<br>Erie Heating = 994 Hours<br>Harrisburg Cooling = 288 Hours<br>Harrisburg Heating = 782 Hours<br>Philadelphia Cooling = 320 Hours<br>Philadelphia Heating = 712 Hours<br>Pittsburgh Cooling = 228 Hours<br>Pittsburgh Heating = 848 Hours<br>Scranton Cooling = 193 Hours<br>Scranton Heating = 925 Hours<br>Williamsport Cooling = 204 Hours<br>Williamsport Heating = 875 hours | 2, 3 |

| Component | Type | Values | Sources |
|---|---|---|---|
| $HSPF_b$ | Fixed | Standard DHP: 7.7<br>Electric resistance: 3.413<br>ASHP: 7.7<br>Electric furnace: 3.242<br>No existing or non-electric heating: use standard DHP: 7.7 | 4, 6 |
| $SEER_b$ | Fixed | DHP, ASHP, or central AC: 13<br>Room AC: 11.3<br>No existing cooling for primary space: use DHP, ASHP, or central AC: 13<br>No existing cooling for secondary space: use Room AC: 11.3 | 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<br>= 9.8 room AC | 5,9 |
| $EER_e$ | Variable | = (11.3/13) X $SEER_e$<br>Based on nameplate information. Should be at least ENERGY STAR. | AEPS Application; EDC Data Gathering |
| LF | Fixed | 25% | 10 |

**Sources:**

1. Based on REM/Rate modeling using models from the PA 2012 Potential Study. EFLH calculated from kWh consumption for cooling and heating. Models assume 50% over-sizing of air conditioners[82] and 40% oversizing of heat pumps.[83]
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.

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[82] Neme, Proctor, Nadal, “National Energy Savings Potential From Addressing Residential HVAC Installation Problems. ACEEE, February 1, 1999. Confirmed also by *Central Air Conditioning in Wisconsin, a compilation of recent field research.* Energy Center of Wisconsin. May 2008, emended December 15, 2010

[83] ACCA, “Verifying ACCA Manual S Procedures,” http://www.acca.org/Files/?id=67.

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.

### 2.16.4 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 2-30.

**Table 2-30~~2-30~~: DHP – Heating Zones**

| Component | Definition |
|---|---|
| Primary Heating Zone | Living room<br>Dining room<br>House hallway<br>Kitchen areas<br>Family Room<br>Recreation Room |
| Secondary Heating Zone | Bedroom<br>Bathroom<br>Basement<br>Storage Room<br>Office/Study<br>Laundry/Mudroom<br>Sunroom/Seasonal Room |

### 2.16.5 Measure Life

According to an October 2008 report for the CA Database for Energy Efficiency Resources, a heat pump's lifespan is **15 years.**[84]

### 2.16.6 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 but billing analysis will be accepted as a proper form of savings verification and evaluation.

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[84] 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

## 2.17 Fuel Switching: ~~Domestic Hot Water~~ DHW Electric to ~~Gas, Oil, or Propane~~Fossil Fuel Water Heater

| Measure Name | Fuel Switching: DHW Electric ~~to Gas~~toFossible Fuel Water Heater |
|---|---|
| Target Sector | Residential |
| Measure Unit | Water Heater |
| Unit Energy Savings | 3,338 kWh |
| Unit Peak Demand Reduction | 0.~~306~~277 kW |
| Gas, Fossil FuelConsumption Increase | Gas: 15.38 MMBtu<br>Propane: 15.38 MMBtu<br>Oil: 20.04 MMBtu |
| Measure Life | Gas:13 years<br>Propane: 13 years<br>Oil: 8 years |

Natural gas, propane and oil water heaters generally offer the customer lower costs compared to standard electric water heaters. Additionally, they typically see an overall energy savings when looking at the source energy of the electric unit versus the fossil fuel-fired unit. Federal standard electric water heaters have energy factors of 0.904 for a 50 gal unit and a an ENERGY STAR gas and propane-fired water heater have an energy factor of 0.67 for a 40gal unit and 0.514 for an oil-fired 40 gal unit[85].

### 2.17.1 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 an ENERGY STAR natural gas or propane water heater with Energy Factor of 0.67 or greater and 0.514 for oil water heater. If a customer submits a rebate for a product that has applied for ENERGY STAR Certification but has not yet been certified, the savings will be counted for that product contingent upon its eventual certification as an ENERGY STAR measure. If at any point the product is rejected by ENERGY STAR, the product is then ineligible for the program and savings will not be counted.

The target sector primarily consists of single-family residences.

### 2.17.2 Algorithms

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

---

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

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

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

$$\text{Fuel Consumption (MMBtu)} = \frac{\left\{\left(\frac{1}{EF_{fuel,inst}}\right)\times\left(HW\times 365\,\frac{days}{yr}\times 1\,\frac{BTU}{lb-F}\times 8.3\,\frac{lb}{gal}\times\left(T_{hot}\text{-}T_{cold}\right)\right)\right\}}{1{,}000{,}000\,\frac{Btu}{MMBtu}}$$

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~~2 PM to 6 PM on summer weekdays to the total annual energy usage.

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

The Energy to Demand Factor is defined below:

~~$\Delta kW_{peak}$ = EnergyToDemandFactor × Energy Savings~~

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

$$EnergyToDemandFactor = \cancel{\frac{Average\ Usage_{Summer\ WD\ Noon-8}}{Annual\ Energy\ Usage}}\ \frac{Average\ Usage_{Summer\ WD\ 2PM-\ 6\ PM}}{Annual\ Energy\ Usage}$$

The ratio of the average energy usage during ~~noon~~2 PM to 6 PM on summer weekdays to the total annual energy usage is taken from load shape data collected for a water heater 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[86]. The factor is constructed as follows:~~

1. ~~Obtain the average kW, as monitored for 82 water heaters in PJM territory[87], 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.~~

HVAC demand response study for PJM[88]. The factor is constructed as follows:

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~~[86] 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~~

~~[87] 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~~

1. Obtain the average kW, as monitored for 82 water heaters in PJM territory[89], 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~~2 PM to ~~8~~6 PM on summer days from the same data.
3. The average ~~noon~~2 PM to ~~8~~6 PM demand is converted to average *weekday* ~~noon~~2 PM to ~~8~~6 PM demand through comparison of weekday and weekend monitored loads from the same PJM study[90].
4. The ratio of the average weekday ~~noon~~2 PM to ~~8~~6 PM energy demand to the annual energy usage obtained in step 1. The resulting number, 0.~~00009172~~00008294, is the *EnergyToDemandFactor.*

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

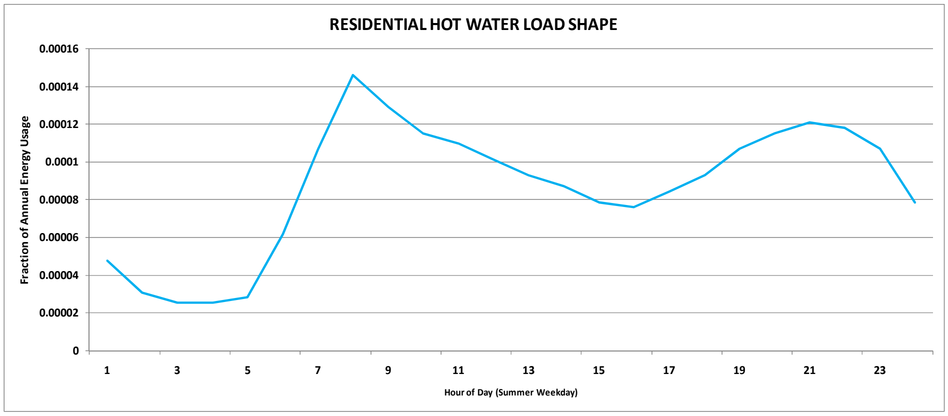

**Figure 2-8: Load shapes for hot water in residential buildings taken from a PJM.**

### 2.17.3 Definition of Terms

The parameters in the above equation are listed in Table 2-31 below.

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[88] 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

[89] 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

[90] 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~~2PM to ~~8~~6 PM is slightly higher is the weekends than on weekdays.

**Table 2-31~~2-31~~: Calculation Assumptions for Fuel Switching~~, Domestic Hot Water~~ DHW Electric to ~~Gas~~Fossil Fuel Water Heater**

| Component | Type | Values | Source |
|---|---|---|---|
| $EF_{elect,bl}$, Energy Factor of baseline water heater | Variable | 0.904 or EDC Data Gathering | 4 |
| $EF_{NG,inst}$, Energy Factor of installed natural gas water heater* | Variable | >=0.67 | 5 |
| $EF_{Propane,inst}$, Energy Factor of installed propane water heater* | Variable | >=0.67 | 5 |
| $EF_{Tankless\ Water\ Heater}$, Energy Factor of installed tankless water heater | Variable | >=0.82 | 5 |
| $EF_{Oil,inst}$, Energy Factor of installed oil water heater* | Variable | >=0.514 | 6 |
| HW, Hot water used per day in gallons | Fixed | 50 gallon/day | 7 |
| $T_{hot}$, Temperature of hot water | Fixed | 123 °F | ~~7~~8 |
| $T_{cold}$, Temperature of cold water supply | Fixed | 55 °F | ~~8~~9 |
| EnergyToDemandFactor | Fixed | 0.~~00009172~~00008294 | 1-3 |

~~* For tankless water heaters, the EF should be at least 0.82~~

### ~~2.17.4 Energy Factors based on Tank Size~~

~~Federal Standards for Energy Facotrs are equal to 0.97 -0.00132 x Rated Storage in Gallons. The following table shows the Energy Factors for various tank sizes.~~

**~~Table 2-32: Energy Factors based on Tank Size~~**

| ~~Tank Size (gallons)~~ | ~~Energy Factor~~ |
|---|---|
| ~~40~~ | ~~0.9172~~ |
| ~~50~~ | ~~0.9040~~ |
| ~~65~~ | ~~0.8842~~ |
| ~~80~~ | ~~0.8644~~ |
| ~~120~~ | ~~0.8116~~ |

**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

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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~~0008294.

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. Commission Order[91] requires fuel switching to ENERGY STAR measures, not standard efficiency measures. The Energy Factor has therefore been updated to reflect the EnergyStar standard for Gas Storage Water Heaters beginning September 1, 2010. From Residential Water Heaters Key Product Criteria. http://www.energystar.gov/index.cfm?c=water_heat.pr_crit_water_heaters Accessed June 2013

6. Federal Standards are 0.67 -0.0019 x Rated Storage in Gallons for oil-fired storage water heater. For a 40-gallon tank this 0.514. "Energy Conservation Program: Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters" US Dept of Energy Docket Number: EE–2006–BT-STD–0129, p. 307. "Energy Conservation Program for Consumer Products: Test Procedure for Water Heaters", Federal Register / Vol. 63, No. 90, p. 26005-26006.

~~1.~~7. "Energy Conservation Program for Consumer Products: Test Procedure for Water Heaters", Federal Register / Vol. 63, No. 90, p. 26005-26006.

8. Pennsylvania Statewide Residential End-Use and Saturation Study, 2012, page 42.~~8. Many states have plumbing codes that limit shower and bathtub water temperature to 120 °F. Pennsylvania Statewide Residential End-Use and Saturation Study, 2012, page 42.~~9.

~~7.~~9. Mid-Atlantic TRM Version 3.0, March 2013, footnote #~~24~~314

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### ~~2.17.5~~2.17.4 Energy Factors based on Tank Size

Federal Standards for Energy Facotrs are equal to 0.97 -0.00132 x Rated Storage in Gallons. The following table shows the Energy Factors for various tank sizes.

---

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

**Table 2-32~~2-32~~: Minimum Baseline Energy Factors based on Tank Size**

| Tank Size (gallons) | Minimum Energy Factors (EFbase) |
|---|---|
| 40 | 0.9172 |
| 50 | 0.9040 |
| 65 | 0.8842 |
| 80 | 0.8644 |
| 120 | 0.8116 |

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~~Deemed~~

### ~~2.17.6~~2.17.5 Default Savings

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

$$\Delta kWh = (1/EFelect,bl)*3018.0$$

The default savings for the installation of a natural gas/ propane/oil water heater in place of a standard electric water heater are listed in Table 2-33~~Table 2-33~~ below.

**Table 2-33~~2-33~~: Energy Savings and Demand Reductions for Fuel Switching, Domestic Hot Water Electric to Fossil Fuel**

| Electric unit Energy Factor | Energy Savings (kWh) | Demand Reduction (kW) |
|---|---|---|
| 0.904 | 3338 | 0.~~306~~277 |

The ~~deemed~~default fossil fuel consumption for the installation of a standard efficiency natural gas/ propane/oil water heater in place of a standard electric water heater is listed in Table 2-34~~Table 2-34~~ below.

**Table 2-34~~2-34~~: Fuel Consumption for Fuel Switching, Domestic Hot Water Electric to Fossil Fuel**

| Fuel Type | Energy Factor | Fossil Fuel Consumption (MMBtu) |
|---|---|---|
| Gas | 0.67 | 15.37 |
| Propane | 0.67 | 15.37 |
| OIl | 0.514 | 20.04 |

Note that 1 MMBtu of propane is equivalent to 10.87 gals of propane, and 1 MMBtu of oil is equivalent to 7.19 gals of oil[92].

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

### ~~2.17.7~~2.17.6 Measure Life

According to an October 2008 report for the CA Database for Energy Efficiency Resources, gas and propane water heaters' lifespans are **13 years.** An oil water heater's lifespand is 8 years.[93].

### ~~2.17.8~~2.17.7 Evaluation Protocols

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

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

## 2.18 Fuel Switching: Heat Pump Water Heater to ~~Gas, Oil or Propane~~Fossil Fuel Water Heater

| **Measure Name** | **Fuel Switching: Heat Pump Water Heater to ~~Gas Water~~Fossil Fuel Heater** |
|---|---|
| Target Sector | Residential |
| Measure Unit | Water Heater |
| Unit Energy Savings | 1,793 kWh (for EF = 2.0) |
| Unit Peak Demand Reduction | 0.~~164~~150 kW |
| Gas, Fossil Fuel Consumption Increase | Gas: 15.38 MMBtu<br>Propane: 15.38 MMBtu<br>Oil: 20.04 MMBtu |
| Measure Life | Gas:13 years<br>Propane: 13 years<br>Oil: 8 years |

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

### 2.18.1 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 an ENERGY STAR natural gas or propane water heater with Energy Factor of 0.67 or greater and 0.514 for an oil water heater. If a customer submits a rebate for a product that has applied for ENERGY STAR Certification but has not yet been certified, the savings will be counted for that product contingent upon its eventual certification as an ENERGY STAR measure. If at any point the product is rejected by ENERGY STAR, the product is then ineligible for the program and savings will not be counted.

The target sector primarily consists of single-family residences.

### 2.18.2 Algorithms

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

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

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

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

~~*Fossil*~~

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

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

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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~~2 PM to 6 PM on summer weekdays to the total annual energy usage.

*Demand Savings* =*EnergyToDemandFactor* × *Energy Savings*

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

The Energy to Demand Factor is defined below:

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

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

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The ratio of the average energy usage during 2 PM to 6 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[94]. The factor is constructed as follows:

~~5.~~2. Obtain the average kW, as monitored for 82 water heaters in PJM territory[95], 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.

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[94] 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

[95] 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

~~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[96]. The factor is constructed as follows:~~

~~1. Obtain the average kW, as monitored for 82 water heaters in PJM territory[97], 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.~~3. Obtain the average kW during ~~noon~~2 PM to ~~8~~6 PM on summer days from the same data.

~~3.~~4. The average ~~noon~~2 PM to ~~8~~6 PM demand is converted to average *weekday* ~~noon~~2 PM to ~~8~~6 PM demand through comparison of weekday and weekend monitored loads from the same PJM study[98].

~~4.~~5. The ratio of the average weekday ~~noon~~2 PM to ~~8~~6 PM energy demand to the annual energy usage obtained in step 1. The resulting number, 0.~~00009172~~00008294, is the *EnergyToDemandFactor.*

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

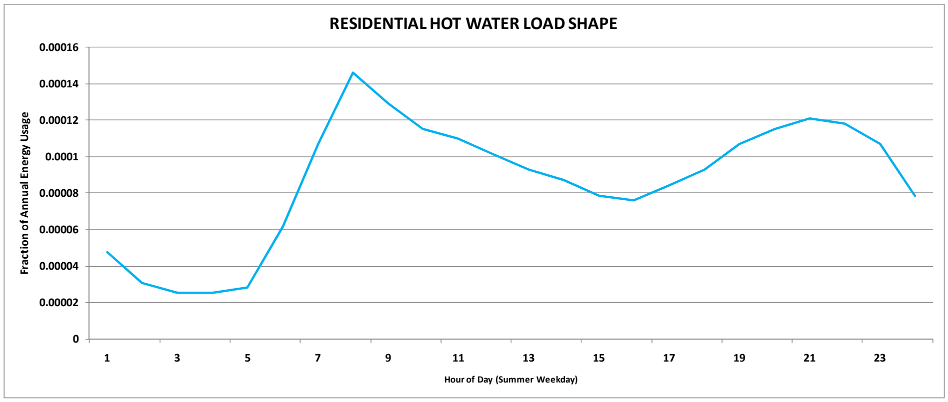

**Figure 2-9: Load shapes for hot water in residential buildings taken from a PJM.**

### 2.18.3 Definition of Terms

The parameters in the above equation are listed in Table 2-35~~Table 2-35~~.

---

~~[96] 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.ashxhttp://www.pjm.com/~/media/committees-groups/working-groups/lrwg/20070301/20070301-pjm-deemed-savings-report.ashx~~

~~[97] 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~~

[98] 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.

**Table 2-35~~2-35~~: Calculation Assumptions for Heat Pump Water Heater to Fossil Fuel Water Heaters**

| Component | Type | Values | Source |
|---|---|---|---|
| $EF_{HP,bl}$ , Energy Factor of baseline heat pump water heater | Variable | Default ≥ 2.0; or EDC Data Gathering | 4 |
| $EF_{NG,inst}$ . Energy Factor of installed natural gas water heater | Variable | ≥ 0.67 or EDC Data Gathering | 5 |
| $EF_{Propane,inst}$, Energy Factor of installed propane water heater | Variable | >=0.67 or EDC Data Gathering | 5 |
| $EF_{Tankless\ Water\ Heater}$ , Energy Factor of installed tankless water heater | Variable | >=0.82 | 5 |
| $EF_{Oil,inst}$, Energy Factor of installed oil water heater | Variable | >=0.514 or EDC Data Gathering | 6 |
| HW, Hot water used per day in gallons | Fixed | 50 gallon/day | ~~6~~7 |
| $T_{hot}$, Temperature of hot water | Fixed | 123 °F | ~~7~~8 |
| $T_{cold}$, Temperature of cold water supply | Fixed | 55 °F | ~~8~~9 |
| $F_{Derate}$, COP De-rating factor | Fixed | 0.84 | ~~9~~10, and discussion below |
| EnergyToDemandFactor | Fixed | 0.~~0000917~~200008294 | 1-3 |

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**Sources:**

~~2.~~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

~~3.~~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

~~4.~~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~~2 PM to ~~8~~6 PM is slightly higher is the weekends than on weekdays.

~~5.~~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**.

~~6.~~5. Commission Order[99] requires fuel switching to ENERGY STAR measures, not standard efficiency measures. The Energy Factor has therefore been updated to reflect the EnergyStar standard for Gas Storage Water Heaters beginning September 1, 2010. From Residential Water Heaters Key Product Criteria. http://www.energystar.gov/index.cfm?c=water_heat.pr_crit_water_heaters Accessed June 2013 ederal Standards are 0.67 -0.0019 x Rated Storage in Gallons. ederal 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. Federal Standards are 0.67 -0.0019 x Rated Storage in Gallons for oil-fired storage water heater. For a 40-gallon tank this 0.514. “Energy Conservation Program: Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters” US Dept of Energy Docket Number: EE–2006–BT-STD–0129, p. 307. “Energy Conservation Program for Consumer Products: Test Procedure for Water Heaters”, Federal Register / Vol. 63, No. 90, p. 26005-26006.

7. “Energy Conservation Program for Consumer Products: Test Procedure for Water Heaters”, **Federal Register** / Vol. 63, No. 90, p. 26005-26006.

8. Pennsylvania Statewide Residential End-Use and Saturation Study, 2012, page 42.

9. Mid-Atlantic TRM Version 3.0, March 2013, footnote #314

10. 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.

~~7.~~10. ~~“Energy Conservation Program for Consumer Products: Test Procedure for Water Heaters”, Federal Register / Vol. 63, No. 90, p. 26005-26006.~~

~~8. Pennsylvania Statewide Residential End-Use and Saturation Study, 2012, page 42.~~

~~9.~~2. ~~Mid-Atlantic TRM, footnote #24~~

11. 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.

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

### 2.18.4 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[100]. 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[101]. According to the linear regression shown on the plot, the COP of a heat pump water heater at 45 °F is 0.84 of the COP at nominal rating conditions. As such, a de-rating factor of 0.84 is applied to the nominal Energy Factor of the Heat Pump water heaters.

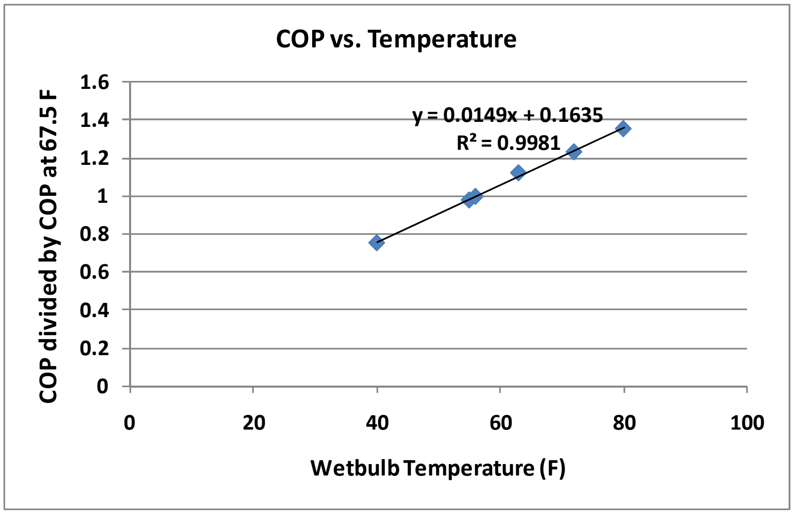

Figure 2-10: Dependence of COP on Outdoor Wet-Bulb Temperature

### ~~2.18.5 Deemed Savings~~

### 2.18.5 ~~The deemed~~DefaultSavings

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

ΔkWh = (1/ [EFHP,BI*Fderate])*3018.0The fossil fuel consumption should be calculated using the deemed algorithm below.

---

[100] 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.

[101] 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.

Fossil Fuel Consumption (MMBtu) = (1/EFNG,Inst)*10.3

The default savings for the installation of a fossil fuel-fired water heater in place of a standard heat pump water heater are listed in Table 2-36 below.

**Table 2-36~~2-36~~: Energy Savings and Demand Reductions for Heat Pump Water Heater to Fossil Fuel Water Heater**

| Heat Pump unit Energy Factor | Energy Savings (kWh) | Demand Reduction (kW) |
|---|---|---|
| **2.0** | 1,796 | 0.~~164~~150 |

The ~~deemed gas~~defaultgas consumption for the installation of an ENERGY STAR natural gas, propane or oilwater heater in place of a standard heat pump water heater is listed in Table 2-37~~Table 2-37~~ below.

**Table 2-37~~2-37~~: Gas, Oil, Propane Consumption for Heat Pump Water Heater ~~to Gas Water~~toFossil FuelWater Heater**

| Fuel Type | Energy Factor | Gas Consumption (MMBtu) |
|---|---|---|
| Gas | 0.67 | 15.37 |
| Propane | 0.67 | 15.37 |
| OIl | 0.514 | 20.04 |

### 2.18.6 Measure Life

According to an October 2008 report for the CA Database for Energy Efficiency Resources, gas and propane water heaters' lifespan are**13 years**[102]**.** An oil water heater's lifespand is 8 years.[103]..

### 2.18.7 Evaluation Protocols

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

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

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

## 2.19 Fuel Switching: Electric Heat to Gas/Propane/Oil Heat

This protocol documents the energy savings attributed to converting from an existing electric heating system to a new natural gas, propane, or oil furnace or boiler in a residential home. The 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, propane, or oil furnace or boiler. To encourage adoption of the highest efficiency units, older units which meet outdated ENERGY STAR standards may be incented up through the given sunset dates (see table below).

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| ENERGY STAR Product Criteria Version | ENERGY STAR Effective Manufacture Date | Act 129 Sunset Date[a] |
|---|---|---|
| ENERGY STAR Furnaces Version 4.0 | February 1, 2013 | N/A |
| ENERGY STAR Furnaces Version 3.0 | February 1, 2012 | May 31, 2014 |
| ENERGY STAR Furnaces Version 2.0, Tier II units | October 1, 2008 | May 31, 2013 |

[a] Date after which Act 129 programs may no longer offer incentives for products meeting the criteria for the listed ENERGY STAR version."

EDCs may provide incentives for equipment with efficiencies greater than or equal to the applicable ENERGY STAR requirement per the following table.

| Equipment | Energy Star Requirements[104] |
|---|---|
| Gas Furnace | • AFUE rating of 95% or greater<br>• Less than or equal to 2.0% furnace fan efficiency<br>• Less than or equal to 2.0% air leakage |
| Oil Furnace | • AFUE rating of 85% or greater<br>• Less than or equal to 2.0% furnace fan efficiency<br>• Less than or equal to 2.0% air leakage |
| Boiler | • AFUE rating of 85% or greater |

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[104] Residential Furnace and Boiler Energy Star product criteria. http://www.energystar.gov/index.cfm?c=furnaces.pr_crit_furnaces and http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=BO

### 2.19.1 Algorithms

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

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

Energy Impact:

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

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

Energy Impact:

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

For boilers, the annual pump energy consumption is negligible (<50 kWh per year) and not included in this calculation.[105]

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 fossil fuel energy is obtained through the following formulas:

**Gas consumption with ~~natural gas~~ fossil fuel furnace:**

$$Gas\ Consumption\ (MMBtu) = \cancel{\frac{CAPY_{Fuel\ Heat} \times EFLH_{fuel\ furnace}}{AFUE_{Fuelheat} \times 1{,}000{,}000\frac{Btu}{MMBtu}}} \frac{CAPY_{fuel\ heat} \times EFLH_{fuel\ furnace}}{AFUE_{fuel\ heat} \times 1{,}000{,}000\frac{Btu}{MMBtu}}$$

### 2.19.2 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)*

$CAPY_{fuel\ heat}$ = *Total heating capacity of new natural gas furnace (BtuH)*

$EFLH_{ASHP}$ = *Equivalent Full Load Heating hours for Air Source Heat Pumps*

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[105] Pump motors are typically 1/25 HP. With 1,000 hour runtime and 80% assumed efficiency, this translates to 37 kWh.

$EFLH_{elec\ furnace}$ = *Equivalent Full Load Heating hours for Electric Forced Air Furnaces*

$EFLH_{elec\ bb}$ = *Equivalent Full Load Heating hours for Electric Baseboard systems*

$EFLH_{fuel\ furnace}$ = *Equivalent Full Load Heating hours for Fossil Fuel Furnace systems*

$HSPF_{ASHP}$ = *Heating Seasonal Performance Factor for existing heat pump (Btu/W▪hr)*

$AFUE_{fuel\ heat}$ = *Annual Fuel Utilization Efficiency for the new gas furnace (%)*

$HP_{motor}$ = *Gas furnace blower motor horsepower (hp)*

$\eta_{motor}$ = *Efficiency of furnace blower motor*

The default values for each term are shown in Table 2-38.

**Field Code Changed**

**Table 2-38~~2-38~~: 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 |
| $CAPY_{fuel\ heat}$ | Variable | Nameplate | EDC Data Gathering |
| $EFLH_{ASHP}$ | Default | Allentown = 1,193<br>Erie = 1,349<br>Harrisburg = 1,103<br>Philadelphia = 1,060<br>Pittsburgh = 1,209<br>Scranton = 1,296<br>Williamsport = 1,251 | 2014 PA TRM Table 2-1, in Electric HVAC section |
| | Optional | An EDC can either use the Alternate EFLH Table or estimate it's own EFLH based on customer billing data analysis. | Alternate EFLH Table (See Section 2.19.3) or EDC Data Gathering |
| $EFLH_{elec\ furnace}$ | Default | Allentown = 1,000<br>Erie = 1,075<br>Harrisburg = 947<br>Philadelphia = 934<br>Pittsburgh = 964<br>Scranton = 1,034<br>Williamsport = 1,011 | 1 |
| | Optional | An EDC can either use the Alternate EFLH Table or estimate it's own EFLH based on customer billing data analysis. | Alternate EFLH Table (See Section 2.19.3) or EDC Data Gathering |
| $EFLH_{elec\ bb}$ | Default | Allentown = 1,321<br>Erie = 1,396<br>Harrisburg = 1,265<br>Philadelphia = 1,236<br>Pittsburgh = 1,273<br>Scranton = 1,357<br>Williamsport = 1,354 | 1 |
| | Optional | An EDC can either use the Alternate EFLH Table or estimate it's own EFLH based on customer billing data analysis. | Alternate EFLH Table (See Section 2.19.3) or EDC Data Gathering |

| | | | |
|---|---|---|---|
| $EFLH_{fuel\_furnace}$ | Default | Allentown = 1,022<br>Erie = 1,098<br>Harrisburg = 969<br>Philadelphia = 955<br>Pittsburgh = 985<br>Scranton = 1,056<br>Williamsport = 1,033 | 1 |
| | Optional | An EDC can either use the Alternate EFLH Table or estimate it's own EFLH based on customer billing data analysis. | Alternate EFLH Table (See Section 2.19.3) or EDC Data Gathering |
| $EFLH_{fuel\_boiler}$ | Default | Allentown = 1,334<br>Erie = 1,411<br>Harrisburg = 1,279<br>Philadelphia = 1,249<br>Pittsburgh = 1,283<br>Scranton = 1,371<br>Williamsport = 1,354 | 1 |
| | Optional | An EDC can either use the Alternate EFLH Table or estimate it's own EFLH based on customer billing data analysis. | Alternate EFLH Table (See Section 2.19.3) or EDC Data Gathering |
| $HSPF_{ASHP}$ | Variable | Default = 7.7 | 2010 PA TRM Table 2-1 |
| | | Nameplate | EDC Data Gathering |
| $AFUE_{fuel\ heat}$ | Variable | Default = ~~90~~95% (natural gas/propane furnace)<br>~~80~~95% (natural gas/propane steam boiler)<br>~~82~~95% (natural gas/propane hot water boiler)<br>85% (oil furnace)<br>~~82~~85% (oil steam boiler)<br>~~84~~85% (oil hot water boiler) | ~~NAECA Code Effective May 1, 2013[106]~~ ENERGY STAR requirement |
| | | Nameplate | EDC Data Gathering |

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~~[106] *Energy Conservation Program: Energy Conservation Standards for Residential Furnaces and Residential Central Air Conditioners and Heat Pumps*. Federal Register, Vol. 76, No. 123, Monday, June 27, 2011. 10 CFR Part 430.~~

| | | | |
|---|---|---|---|
| $HP_{motor}$ | Variable | Default = ½ hp | Average blower motor capacity for gas furnace (typical range = ¼ hp to ¾ hp) |
| | | Nameplate | EDC Data Gathering |
| $\eta_{motor}$ | Variable | Default = 0.50 | Typical efficiency of ½ hp blower motor |
| | | Nameplate | EDC Data Gathering |

### 2.19.3 Alternate Equivalent Full Load Hour (EFLH) Tables

Table 2-39 through Table 2-43Table 2-43~~Table 2-43~~ below, show heating EFLH by city and for each EDC's housing demographics. In order to determine the most appropriate EFLH value to use for a project, first select the type of electric heating equipment being replaced, then the appropriate EDC. Next, from the column, pick the closest city to the project location. The value shown in that cell will be the EFLH value to use for the project.

**Table 2-39~~2-39~~: Alternate Heating EFLH for Air Source Heat Pumps**

| | PPL | Penelec | Met Ed | West Penn | Duquesne | Penn Power | PECO |
|---|---|---|---|---|---|---|---|
| Allentown | 1112 | 1057 | 1122 | 1165 | 1265 | 1226 | 1320 |
| Erie | 1255 | 1204 | 1273 | 1317 | 1420 | 1376 | 1494 |
| Harrisburg | 1028 | 974 | 1035 | 1077 | 1174 | 1138 | 1219 |
| Philadelphia | 986 | 940 | 1001 | 1039 | 1134 | 1098 | 1165 |
| Pittsburgh | 1124 | 1068 | 1133 | 1175 | 1274 | 1234 | 1347 |
| Scranton | 1203 | 1151 | 1218 | 1261 | 1365 | 1321 | 1445 |
| Williamsport | 1161 | 1110 | 1175 | 1218 | 1320 | 1278 | 1392 |

**Table 2-40~~2-40~~: Alternate Heating EFLH for Electric Furnaces**

| | PPL | Penelec | Met Ed | West Penn | Duquesne | Penn Power | PECO |
|---|---|---|---|---|---|---|---|
| Allentown | 914 | 890 | 952 | 991 | 1079 | 1037 | 1100 |
| Erie | 986 | 964 | 1027 | 1064 | 1150 | 1108 | 1183 |
| Harrisburg | 866 | 837 | 900 | 940 | 1027 | 986 | 1041 |
| Philadelphia | 854 | 827 | 893 | 931 | 1018 | 976 | 1021 |
| Pittsburgh | 882 | 854 | 914 | 950 | 1033 | 994 | 1068 |
| Scranton | 945 | 922 | 983 | 1020 | 1107 | 1064 | 1144 |
| Williamsport | 924 | 902 | 961 | 998 | 1085 | 1043 | 1118 |

**Table 2-41~~2-41~~: Alternate Heating EFLH for Electric Baseboard Heating**

| | PPL | Penelec | Met Ed | West Penn | Duquesne | Penn Power | PECO |
|---|---|---|---|---|---|---|---|
| Allentown | 1355 | 1204 | 1280 | 1334 | 1351 | 1355 | 1326 |
| Erie | 1432 | 1287 | 1360 | 1408 | 1426 | 1430 | 1395 |
| Harrisburg | 1300 | 1144 | 1224 | 1280 | 1298 | 1299 | 1271 |
| Philadelphia | 1272 | 1115 | 1194 | 1247 | 1268 | 1269 | 1242 |
| Pittsburgh | 1301 | 1158 | 1230 | 1281 | 1297 | 1431 | 1277 |
| Scranton | 1389 | 1245 | 1317 | 1369 | 1385 | 1385 | 1366 |
| Williamsport | 1373 | 1230 | 1303 | 1351 | 1371 | 1371 | 1394 |

**Table 2-42~~2-42~~: Alternate Heating EFLH for Fossil Fuel Furnaces**

| | PPL | Penelec | Met Ed | West Penn | Duquesne | Penn Power | PECO |
|---|---|---|---|---|---|---|---|
| Allentown | 934 | 919 | 985 | 1023 | 1116 | 1071 | 1106 |
| Erie | 1007 | 995 | 1060 | 1098 | 1188 | 1144 | 1190 |
| Harrisburg | 887 | 865 | 931 | 973 | 1064 | 1018 | 1048 |
| Philadelphia | 873 | 855 | 922 | 962 | 1055 | 1007 | 1027 |
| Pittsburgh | 900 | 882 | 945 | 982 | 1067 | 1024 | 1075 |
| Scranton | 965 | 951 | 1016 | 1053 | 1144 | 1099 | 1149 |
| Williamsport | 944 | 931 | 993 | 1031 | 1121 | 1078 | 1124 |

**Table 2-43~~2-43~~: Alternate Heating EFLH for Fossil Fuel Boilers**

| | PPL | Penelec | Met Ed | West Penn | Duquesne | Penn Power | PECO |
|---|---|---|---|---|---|---|---|
| Allentown | 1366 | 1214 | 1289 | 1346 | 1363 | 1364 | 1347 |
| Erie | 1445 | 1299 | 1370 | 1422 | 1440 | 1440 | 1417 |
| Harrisburg | 1312 | 1155 | 1234 | 1290 | 1308 | 1309 | 1291 |
| Philadelphia | 1281 | 1125 | 1205 | 1261 | 1278 | 1280 | 1260 |
| Pittsburgh | 1315 | 1169 | 1240 | 1294 | 1311 | 1311 | 1292 |
| Scranton | 1400 | 1256 | 1330 | 1378 | 1399 | 1397 | 1386 |
| Williamsport | 1384 | 1238 | 1313 | 1365 | 1382 | 1383 | 1364 |

### 2.19.4 Measure Life

Measure life = 20 years[107]

**Sources:**

1. Based on REM/Rate modeling using models from the PA 2012 Potential Study. EFLH calculated from kWh consumption for cooling and heating. Models 40% oversizing of heat systems.

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

## 2.20 Ceiling / Attic and Wall Insulation

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This measure applies to installation/retrofit of new or additional insulation in a ceiling/attic, or walls of existing residential homes or apartment units in multifamily complexes with a primary electric heating and/or cooling source. The installation must achieve a finished ceiling/attic insulation rating of R-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~~2.20.1 Algorithms

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The savings values are based on the following algorithms.

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

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

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

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

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

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

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

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

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

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

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

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

**Heading 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~~2.20.2 Definition of Terms

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*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.*

*AHF* = *Attic Heating Factor increases cooling load to home due to attic temperatures being warmer than ambient outdoor air temperature on sunny days.*

$A_{roof}$ = *Area of the ceiling/attic with upgraded insulation* ($ft^2$)

$A_{wall}$ = *Area of the wall with upgraded insulation* ($ft^2$)

$R_{roof,bl}$ = *Assembly R-value of ceiling/attic before retrofit* ($ft^2$*°F*hr/Btu)

$R_{roof,ee}$ = *Assembly R-value of ceiling/attic after retrofit* ($ft^2$*°F*hr/Btu)

$R_{wall,bl}$ = *Assembly R-value of wall before retrofit* ($ft^2$*°F*hr/Btu)

$R_{wall,ee}$ = *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)*

$\overline{EER}_{RAC}$ = *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*

$EFLH_{cool\ RAC}$ = *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 2-43.~~ Table 2-44. The default values for heating and cooling days and hours are given in Table 2-44Table 2-45~~Table 2-45Table 2-43~~.

**Table 2-44~~2-44~~: 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[108] |
| AHF | Fixed | 1.056 | 13,14 |
| $R_{roof,bl}$[109]<br>Variable | ~~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 |
| | | Existing Assembly R-value | EDC Data Gathering |
| $R_{roof,ee}$[110]<br>Variable | ~~Variable~~ | 38 | Retrofit to R-38 total attic insulation |
| | | 49 | Retrofit to R-49 total attic insulation |
| | | Retrofit Assembly R-value | EDC Data Gathering |
| $R_{wall,bl}$[111] | Variable | Default = 5.0 | 15 Assumes existing, un-insulated wall with 2x4 studs @ |

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[108] “State of Ohio Energy Efficiency Technical Reference Manual,” prepared for the Public Utilities Commission of Ohio by Vermont Energy Investment Corporation. August 6, 2010.

[109] 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.

[110] 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.

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

| | | | |
|---|---|---|---|
| | | | 16” o.c., w/ wood/vinyl siding |
| | | Existing Assembly R-value | EDC Data Gathering |
| $R_{wall,ee}$[112] | Variable | Default = ~~9~~11.0 | Assumes adding R-6 per DOE recommendations[113] |
| | | Retrofit Assembly R-value | EDC Data Gathering |
| $SEER_{CAC}$ | Variable | Default for equipment installed before 1/23/2006 = 10<br>Default for equipment installed after 1/23/2006 = 13 | Minimum Federal Standard for new Central Air Conditioners/Heat Pumps between 1990 and 2006<br>ASHRAE 90.1-2007 |
| | | Nameplate | EDC Data Gathering |
| $\overline{EER}_{RAC}$ | 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<br>Default for equipment installed after 1/23/2006 = 13 | Minimum Federal Standard for new Central Air Conditioners/Heat Pumps between 1990 and 2006<br>ASHRAE 90.1-2007 |
| | | Nameplate | EDC Data Gathering |
| $HSPF_{ASHP}$ | Variable | Default for equipment installed before 1/23/2006 = 6.8<br>Default for equipment installed after 1/23/2006 = 7.7 | Minimum Federal Standard for new Central Air Conditioners/Heat Pumps between 1990 and 2006<br>ASHRAE 90.1-2007 |
| | | Nameplate | EDC Data Gathering |
| $CF_{CAC}$ | Fixed | 0.70 | Table 2-1 |
| $CF_{RAC}$ | Fixed | 0.58 | See Section 2.29 |
| $CF_{ASHP}$ | Fixed | 0.70 | Table 2-1 |
| $F_{Room,AC}$ | Fixed | 0.38 | Calculated[114] |

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[112] 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.

[113] 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

**Table 2-45~~2-45~~: EFLH, CDD and HDD by City**

| City | $EFLH_{cool}$ (Hours)[115] | $EFLH_{cool\ RAC}$ (Hours)[116] | CDD (Base 65)[117] | HDD (Base 65)[118] |
|---|---|---|---|---|
| Allentown | 487 | 243 | 787 | 5830 |
| Erie | 389 | 149 | 620 | 6243 |
| Harrisburg | 551 | 288 | 955 | 5201 |
| Philadelphia | 591 | 320 | 1235 | 4759 |
| Pittsburgh | 432 | 228 | 726 | 5829 |
| Scranton | 417 | 193 | 611 | 6234 |
| Williamsport | 422 | 204 | 709 | 6063 |

Alternate EFLH values from Table 2-2Table 2-2~~Table 2-2 **Error! Reference source not found.**~~ and Table 2-3~~**Error! Reference source not found.**~~ in Section 2.1 may also be used for central airc conditioners and air source heat pumps. The tables show cooling EFLH and heating EFLH, respectively, by city and for each EDC's housing demographics. EFLH values are only shown for cities that are close to customers in each EDC's service territory. In order to determine the most appropriate EFLH value to use for a project, first select the appropriate EDC, then, from that column, pick the closest city to the project location. The value shown in that cell will be the EFLH value to use for the project.

### ~~2.21.3~~2.20.3 Measure Life

Measure life = 25 years[119].

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[114] 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

[115] PA TRM Table 2-1.

[116] PA TRM Section 2.12 Room AC Retirement

[117] 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

[118] Ibid.

[119] *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.

[13] "Improving Attic Thermal Performance", Home Energy, November 2004.

[14] NOAA Climatic Data for Pennsylvania cities- Cloudiness (mean number of days Sunny, Partly Cloudy, and Cloudy), http://ols.nndc.noaa.gov/plolstore/plsql/olstore.prodspecific?prodnum=C00095-PUB-A0001.

[15] 2013 Illinois Statewide TRM - An estimate based on review of Madison Gas and Electric, Exterior Wall Insulation, R-value for no insulation in walls, and NREL's Building Energy Simulation Test for Existing Homes (BESTEST-EX).

### ~~2.21.4~~2.20.4 Attic Heating Effect on Cooling Loads

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On sunny days, attic temperatures can be 20%-35% higher than ambient outdoor air temperatures during the 7 hours between 9 AM and 4 PM and 6%-8% higher for the 4 hours from 7 AM to 9 AM and 4 PM to 6 PM.[13] The remaining 13 hours of the day there was no significant difference seen between attic temperature and outdoor air temperature; this results in an average hourly temperature difference between the attic and outdoor air of approximately +9% over the course of a 24 hour period, but only on sunny days. According to NOAA climatic data for Pennsylvania cities (Allentown, Erie, Harrisburg, Philadelphia, and Pittsburgh) for June through August, it is sunny or partly cloudy an average of 62% of the days.[14] It is assumed that there is an attic heating effect on both sunny and partly cloudy days, but not on cloudy days; therefore, an appropriate attic heating factor would be 1.056 based on the fact that the average hourly difference between attic temperature and outdoor air temperature is approximately +5.6% (9% x 62%).

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## 2.21 Refrigerator / Freezer Recycling with and without Replacement

| Measure Name | Refrigerator/Freezer Recycling and Replacement |
|---|---|
| Target Sector | Residential Establishments |
| Measure Unit | Refrigerator or Freezer |
| ~~Deemed~~Default Unit Annual Energy Savings- Refrigerators | Varies by EDC |
| ~~Deemed~~Default Unit Peak Demand Reduction- Refrigerators | Varies by EDC |
| ~~Deemed~~Default Unit Annual Energy Savings- Freezers | Varies by EDC |
| ~~Deemed~~Default Unit Peak Demand Reduction- Freezers | Varies by EDC |
| Measure Life (no replacement) | 8 years[120] |
| Measure Life (with replacement) | 7 years (see measure life discussion below) |

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This measure is (1) the retirement of a refrigerator or freezer with no replacement or (2) the recycling and replacement before end of life of an existing refrigerator or freezer with a new refrigerator or freezer. This protocol quantifies savings where the replacement refrigerator or freezer is ENERGY STAR ~~and~~or non-ENERGY STAR qualified. This protocol applies to both residential and non-residential sectors, as refrigerator and freezer usage and energy usage are assumed to be independent of customer rate class[121]. The partially deemed savings ~~value is~~algorithms are based on regression analysis of metered data on kWh consumption from other States. The partially deemed savings ~~values~~algorithms for this measure can be applied to refrigerator and freezer retirements or early replacements meeting the following criteria:

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

EDCs can use the default savings values listed for each EDC in this protocol or an EDC can calculate program savings using the partially deemed savings algorithms, the deemed regression equation coefficients, and actual program year recycled refrigerator/freezer data. An EDC's use of actual program year data can provide a more accurate annual ex ante savings estimate due to the changing mix of recycled appliance models from year-to-year.

### 2.21.1 Partially Deemed Savings Algorithms

*Equation 1:*

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[120] Vermont Energy Investment Corporation (VEIC) for NEEP, Mid Atlantic TRM Version 2.0. July 2011. Pg.36.

[121] 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.

*DEEMED_kWhsaved Per Unit* = *EXISTING_UEC * PART_USE*

*Equation 2:*

*NET_kWhsaved Per Unit* = *DEEMED kWhsaved Per Unit – (REPLACEMENTUEC * PART_USE)*

### 2.21.2 Definition of Terms

*~~DEEMED~~DEFAULT_kWhsaved* = Annual electricity savings measured in kilowatt hours.

*EXISTING_UEC* = The average annual unit energy consumption of participating refrigerators~~. The PY3 value is 1059 for refrigerators and 1188 for freezers~~ and freezers for Program year 4. Tables 2-46 to 2-49 below provide the equation inputs needed to calculate the UEC for removed refrigerators and freezers respectively as well as the calculation of the default Unit Energy Consumption value for refrigerators or freezers for each EDC.

*PART_USE* = The portion of the year the average refrigerator or freezer would likely have operated if not recycled through the program. For PY3, the average refrigerator was plugged in 96.9% of the year and the average freezer was plugged in 98.5% of the year.

*REPLACEMENTUEC* = The annual unit energy consumption of the average replacement unit. ~~This comes from the Energy Star calculator and is equal to 417 kWh for a new Energy Star refrigerator, and 537 for a new non Energy Star refrigerator. It is equal to 423 kWh for a new Energy Star freezer, and 510 for a new non Energy Star freezer.~~The appropriate UEC values for replacement refrigerator and freezer units were obtained from the Energy Star calculator.

### 2.21.3 ~~Deemed~~Default Savings Calculations

For removed refrigerators, the annual Unit Energy Consumption (UEC) is based upon regression analyses of data from refrigerators metered and recycled through five utilities. The UEC for removed refrigerators was calculated specifically for each utility using data collected from each utility's Program Year Four (PY4) Appliance Removal programs. Therefore, each UEC represents the average ages, sizes, etc of the fleet of refrigerators removed removed in Program Year Four.

$$
\begin{aligned}
&Existing\ Refrigerator\ UEC \\
&\quad = 365.25*(0.582 + 0.027*(average\ age\ of\ \cancel{appliance27.036}appliance) \\
&\quad + 1.055*(\%\ of\ appliances\ manufactured\ before\ 1990) + 0.067 \\
&\quad *(number\ of\ \ cubic\ feet) - 1.977*(\ \%\ of\ single\ door\ units) + 1.071 \\
&\quad *(\%\ of\ side-by-side) + 0.605*(\%\ of\ primary\ usage) + 0.02 \\
&\quad *(unconditioned\ space\ CDDs) - 0.045*(unconditioned\ HDDs)) = kWh
\end{aligned}
$$

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

| Refrigerator Unit Energy Consumption Equation | |
|---|---|
| **Equation Intercept and Independent Variables** | **Estimate Coefficient (Daily kWh)** |
| Intercept | 0.582 |
| Appliance Age (years) | 0.027 |
| Dummy: Manufactured Pre-1990 | 1.055 |
| Appliance Size (square feet) | 0.067 |
| Dummy: Single-Door Configuration | -1.977 |
| Dummy: Side-by-Side Configuration | 1.071 |
| Dummy: Primary Usage Type (in absence of the program) | 0.6054 |
| Interaction: Located in Unconditioned Space x CDDs | 0.02 |
| Interaction: Located in Unconditioned Space x HDDs | -0.045 |

**Refrigerator Savings - No Replacement:**

*~~DEEMED~~DEFAULT_kWhsaved Per Unit$_{NO\ REP}$= EXISTING_UEC * PART_USE = kWh*

**Refrigerator Savings - Replacement with Energy Star Unit:**

*~~NET~~DEFAULT_kWhsaved Per Unit ~~= DEEMED~~$_{WITH\ ES\ REP}$ = DEFAULT kWhsaved Per Unit ~~– (REPLACEMENTUEC~~$_{NO\ REP}$ – (REPLACEMENTUEC$_{ES}$ * PART_USE) = kWh*

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**Refrigerator Savings - Replacement with non-Energy Star Unit:**

*~~NET~~DEFAULT_kWhsaved Per ~~Unit = DEEMED~~Unit$_{WITH\ NON\ ES\ REP}$ = kWhsaved Per Unit$_{NO\ REP}$ – (REPLACEMENTUEC$_{NON\ ES}$ * PART_USE) = kWh*

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$$\begin{aligned} Existing\ Freezer\ UEC \\ &= 365.25\ days \\ &* (-2.297 + 0.067 * [average\ age\ of\ appliance\ ] + 0.401 \\ &* [8\%\ of\ appliances\ manufactured\ pre - 1993] + 0.150 \\ &* [average\ number\ of\ \ cubic\ feet] + 0.854 \\ &* [\%\ of\ appliances\ that\ are\ chest\ freezers] + 0.1046 * [CDDs]) = kWh \end{aligned}$$

Source for freezer UEC equation: ~~US DOE Uniform Method Project,~~Cadmus memo to Michigan Public Service Commission (August 2012)

| Freezer Unit Energy Consumption Equation | |
|---|---|
| Equation Intercept and Independent Variables | Estimate Coefficient (Daily kWh) |
| Intercept | 365.25 |
| Appliance Age (years) | 0.401 |
| Dummy: Manufactured Pre-1993 | 0.067 |
| Appliance Size (cubic feet) | 0.15 |
| % of appliances that are chest freezers | 0.854 |
| Cooling Degree Days (CDD) | 0.1046 |

**Freezer Savings** ~~Protocol for Refrigerator Retirement.[122]~~

**- No Replacement:**

*~~DEEMED~~DEFAULT_kWhsaved Per Unit*$_{NO\ REP}$*= EXISTING_UEC * PART_USE =kWh*

**Freezer Savings - Replacement with Energy Star Unit:**

*~~NET~~DEFAULT_kWhsaved Per ~~Unit = DEEMED~~Unit*$_{WITH\ ES\ REP}$ *= DEFAULT kWhsaved Per Unit*$_{NO\ REP}$ *– (REPLACEMENTUEC*$_{ES}$ ** PART_USE) = kWh*

**Freezer Savings - Replacement with non-Energy Star Unit:**

*~~NET~~DEFAULT_kWhsaved Per ~~Unit = DEEMED~~Unit*$_{WITH\ NON\ ES\ REP}$ *= kWhsaved Per Unit*$_{NO\ REP}$ *– (REPLACEMENTUEC*$_{NON\ ES}$ ** PART_USE) = kWh*

The Commission has computed the EDC-specific values that are needed for input to the ~~regressions equation~~regression equations for determining the Unit Energy Consumption based on Act 129 ~~Program Year 4~~PY4 data provided by each EDC for ~~removed~~ refrigerators and freezers removed in PY4. Once these input values were determined, they were substituted into the above equation in order to estimate the UEC for removed refrigerators and freezers for each EDC. ~~Tabe 2-45 below provides the equation inputs needed to calculate the UEC for removed refrigerators and freezers respectively.~~

Tables 2-46 to Table 2-49~~2-49~~ below provide the equation inputs needed to calculate the UEC for removed refrigerators and freezers respectively as well as the calculation of the default Unit Energy Consumption value for refrigerators or freezers for each EDC. Note that equation inputs in Table 2-46 to Table 2-49~~2-49~~ are provided for each appliance (refrigerators, then freezers) depending on whether the units were or were not replaced with a new unit.

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~~[122] On page 7-27 of the Uniform Method Protocol, the text states "While differences exist between the evaluation approach for each appliance type (for example, all stand-alone freezers are secondary units, while refrigerators may be primary or secondary units), this protocol can also be used to evaluate the savings for freezers."~~

**Table 2-46~~2-46~~: ~~Deemed~~Default Savings values for ~~Residentail~~Residential Refrigerator Recycling Without Replacement With a New Refrigerator**

| Variable Name | Duquesne Light | Met Ed | PECO | PennElec | PennPower | PPL | West Penn Power |
|---|---|---|---|---|---|---|---|
| Age of appliance | 32.67 | 27.96 | 25.55 | 22.88 | 29.06 | 30.06 | 30.94 |
| % manufactured pre 1990 | 68.18% | 61.83% | 49.86% | 61.84% | 60.56% | 60.43% | 64.98% |
| Appliance size (volume in square feet) | 16.03 | 18.47 | 18.65 | 16.11 | 16.25 | 18.07 | 16.57 |
| Dummy: percent that are single-door appliances | 12.13% | 4.39% | 8.12% | 8.56% | 7.71% | 7.03% | 8.27% |
| Dummy: percent that are side by side configuration | 12.40% | 21.43% | 19.89% | 10.78% | 12.96% | 18.31% | 13.71% |
| Dummy: primary usage type (in absence of the program) | 18.45% | 10.12% | 24.74% | 17.22% | 16.76% | 26.01% | 14.03% |
| Located in unconditioned space X CDD | 0.98 | 1.78 | 2.47 | 1.07 | 1.22 | 0.92 | 1.20 |
| Located in unconditioned space X HDD | 7.90 | 10.86 | 9.51 | 9.93 | 10.17 | 9.85 | 9.42 |
| ESTIMATED UEC Savings (Annual kWh per year) for a removed refrigerator that is not replaced | 1068.9 | 1087.3 | 1048.5 | 933.8 | 1003.9 | 1107.2 | 1052.4 |

| Variable Name | Duquesne Light | Met Ed | PECO | PennElec | PennPower | PPL | West Penn Power |
|---|---|---|---|---|---|---|---|
| Age of appliance | 32.67 | 27.96 | 25.55 | 22.88 | 29.06 | 30.06 | 30.94 |
| % manufactured pre 1990 | 68.18% | 61.83% | 49.86% | 61.84% | 60.56% | 60.43% | 64.98% |
| Appliance size (volume in square feet) | 16.03 | 18.47 | 18.65 | 16.11 | 16.25 | 18.07 | 16.57 |
| Dummy: percent that are single-door appliances | 12.13% | 4.39% | 8.12% | 8.56% | 7.71% | 7.03% | 8.27% |
| Dummy: percent that are side by side configuration | 12.40% | 21.43% | 19.89% | 10.78% | 12.96% | 18.31% | 13.71% |
| Dummy: primary usage type (in absence of the program) | 18.45% | 10.12% | 24.74% | 17.22% | 16.76% | 26.01% | 14.03% |
| Located in unconditioned space X CDD | 0.98 | 1.78 | 2.47 | 1.07 | 1.22 | 0.92 | 1.20 |
| Located in unconditioned space X HDD | 7.90 | 10.86 | 9.51 | 9.93 | 10.17 | 9.85 | 9.42 |
| ESTIMATED UEC Savings (Annual kWh per year) for a removed refrigerator that is not replaced | 1068.9 | 1087.3 | 1048.5 | 933.8 | 1003.9 | 1107.2 | 1052.4 |

### Table 2-47~~2-47~~: ~~Deemed~~Default Savings values for ~~Residentail~~Residential Freezer Recycling Without Replacement With a New Freezer

| Variable Name | Duquesne Light | Met Ed | PECO | PennElec | PennPower | PPL | West Penn Power |
|---|---|---|---|---|---|---|---|
| Age of appliance | 35.51 | 32.21 | 29.05 | 32.88 | 34.17 | 32.68 | 33.21 |
| % manufactured pre 1993 | 89.41% | 87.03% | 76.60% | 86.94% | 88.55% | 88.20% | 86.85% |
| Appliance size (volume in square feet) | 15.40 | 15.44 | 15.59 | 15.70 | 15.80 | 15.65 | 15.74 |
| Dummy: percent that are chest appliances | 27.45% | 36.47% | 22.70% | 34.83% | 37.89% | 30.14% | 33.45% |
| Located in unconditioned space X CDD | 0.78 | 1.55 | 1.97 | 0.88 | 0.99 | 0.88 | 1.08 |
| ESTIMATED UEC Savings (Annual kWh per year) for a removed refrigerator that is not replaced | 1120.3 | 1095.4 | 983.9 | 1095.6 | 1148.7 | 1074.9 | 1109.1 |

| Variable Name | Duquesne Light | Met Ed | PECO | PennElec | PennPower | PPL | West Penn Power |
|---|---|---|---|---|---|---|---|
| Age of appliance | 35.51 | 32.21 | 29.05 | 32.88 | 34.17 | 32.68 | 33.21 |
| % manufactured pre 1993 | 89.41% | 87.03% | 76.60% | 86.94% | 88.55% | 88.20% | 86.85% |
| Appliance size (volume in square feet) | 15.40 | 15.44 | 15.59 | 15.70 | 15.80 | 15.65 | 15.74 |
| Dummy: percent that are chest appliances | 27.45% | 36.47% | 22.70% | 34.83% | 37.89% | 30.14% | 33.45% |
| Located in unconditioned space X CDD | 0.78 | 1.55 | 1.97 | 0.88 | 0.99 | 0.88 | 1.08 |
| ESTIMATED UEC Savings (Annual kWh per year) for a removed refrigerator that is not replaced | 1120.3 | 1095.4 | 983.9 | 1095.6 | 1148.7 | 1074.9 | 1109.1 |

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

In Program Year 3, the Commission determined that the average removed refrigerator was plugged in and used 96.9% of the year and the average freezer was plugged in and used 98.5% of the year. Thus, the ~~deemed~~default value for the part-use factor is 96.9% (and 98.5%) based on program year 3 data for all EDCs. EDCs may elect to calculate an EDC specific part-use factor~~.~~ for a specific program year. In the event an EDC desires to calculate an EDC specific part-use factor, EDCs should use the following methodology. Using participant surveys, evaluators should determine the amount of time a removed refrigerator is plugged in.

Table 2-48 and Table 2-49 below shows the basis for the calculation of default per unit savings for ~~units~~refrigerators and freezers that are removed but then replaced.

### Table 2-48~~2-48~~: ~~Deemed~~Default Savings values for ~~Residentail~~Residential Refrigerator Recycling With Replacement With a New Energy Star Refrigerator[123]

| Variable Name | Duquesne Light | Met Ed | PECO | PennElec | PennPower | PPL | West Penn Power |
|---|---|---|---|---|---|---|---|
| Age of appliance | 25.97 | 19.39 | 22.47 | 22.54 | 23.21 | 30.06 | 25.50 |
| % manufactured pre 1990 | 44.70% | 30.88% | 37.85% | 41.57% | 41.52% | 60.43% | 42.54% |
| Appliance size (volume in square feet) | 18.39 | 20.65 | 19.57 | 18.45 | 18.73 | 18.07 | 18.82 |
| Dummy: percent that are single-door appliances | 2.62% | 0.61% | 3.72% | 3.01% | 2.29% | 7.03% | 2.25% |
| Dummy: percent that are side by side configuration | 15.44% | 35.79% | 24.51% | 19.83% | 18.67% | 18.31% | 22.15% |
| Dummy: primary usage type (in absence of the program) | 58.73% | 88.55% | 43.53% | 67.13% | 62.86% | 26.01% | 61.83% |
| Located in unconditioned space X CDD | 0.55 | 0.18 | 2.40 | 0.47 | 0.54 | 0.92 | 0.52 |
| Located in unconditioned space X HDD | 4.41 | 1.11 | 9.25 | 4.15 | 4.50 | 9.85 | 4.27 |
| ESTIMATED UEC Savings (Annual kWh per year) for a removed refrigerator that is replaced | 1193.7 | 1342.5 | 1089.5 | 1186.0 | 1185.1 | 1107.2 | 1229.2 |
| kWh Use of new refrigerator | 475.12 | 475.12 | 475.12 | 475.12 | 475.12 | 475.12 | 475.12 |

| Variable Name | Duquesne Light | Met Ed | PECO | PennElec | PennPower | PPL | West Penn Power |
|---|---|---|---|---|---|---|---|
| Age of appliance | 25.97 | 19.39 | 22.47 | 22.54 | 23.21 | 30.06 | 25.50 |
| % manufactured pre 1990 | 44.70% | 30.88% | 37.85% | 41.57% | 41.52% | 60.43% | 42.54% |
| Appliance Size (volume in square feet) | 18.39 | 20.65 | 19.57 | 18.45 | 18.73 | 18.07 | 18.82 |
| Dummy: percent that are single-door appliances | 2.62% | 61.00% | 3.72% | 3.01% | 2.29% | 7.03% | 2.25% |
| Dummy: percent that are side-by-side configuration | 15.44% | 35.79% | 24.51% | 19.83% | 18.67% | 18.31% | 22.15% |
| Dummy: primary usage type (in absence of the program) | 58.73% | 88.55% | 43.53% | 67.13% | 62.86% | 26.01% | 61.83% |
| Located in unconditioned space X CDD | 0.55 | 0.18 | 2.40 | 0.47 | 0.54 | 0.92 | 0.52 |
| Located in unconditioned space X HDD | 4.41 | 1.11 | 9.25 | 4.15 | 4.50 | 9.85 | 4.27 |
| ESTIMATED UEC Savings (Annual kWh per year) for a removed refrigerator that is replaced | 11193.70 | 1342.50 | 1089.50 | 1186.00 | 1185.10 | 1107.20 | 1229.20 |
| kWh Use of new refrigerator | 431.22 | 431.22 | 431.22 | 431.22 | 431.22 | 431.22 | 431.22 |

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[123] kWh use of new refrigerator is average consumption of all ENERGY STAR qualifying models by configuration from ENERGY STAR Residential Refrigerators Qualified Products List. July 5, 2013.

### Table 2-49~~2-49~~: ~~Deemed~~Default Savings values for ~~Residentail~~Residential Freezer Recycling With Replacement With a New Energy Star Freezer[124]

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| Variable Name | Duquesne Light | Met Ed | PECO | PennElec | PennPower | PPL | West Penn Power |
|---|---|---|---|---|---|---|---|
| Age of appliance | 31.28 | 28.20 | 28.23 | 29.22 | 33.21 | 32.68 | 31.15 |
| % manufactured pre 1993 | 80.90% | 86.67% | 70.42% | 80.60% | 91.43% | 88.20% | 77.95% |
| Appliance size (volume in square feet) | 16.12 | 16.67 | 16.15 | 16.41 | 16.29 | 15.65 | 16.97 |
| Dummy: percent that are chest appliances | 31.46% | 33.33% | 14.79% | 35.78% | 42.86% | 30.14% | 41.03% |
| Located in unconditioned space X CDD | 0.87 | 0.64 | 2.33 | 0.69 | 0.95 | 0.88 | 0.72 |
| ESTIMATED UEC Savings (Annual kWh per year) for a removed refrigerator that is replaced | 1059.8 | 1019.6 | 974.9 | 1031.1 | 1169.8 | 1074.9 | 1123.1 |
| kWh Use of new freezer* | 391 | 391 | 391 | 391 | 391 | 391 | 391 |

| Variable Name | Duquesne Light | Met Ed | PECO | PennElec | PennPower | PPL | West Penn Power |
|---|---|---|---|---|---|---|---|
| Age of appliance | 31.28 | 28.20 | 28.23 | 29.22 | 33.21 | 32.68 | 31.15 |
| % manufactured pre 1990 | 80.90% | 86.67% | 70.42% | 80.60% | 91.43% | 88.20% | 77.95% |
| Appliance Size (volume in square feet) | 16.12 | 16.67 | 16.15 | 16.41 | 16.29 | 15.65 | 16.97 |
| Dummy: percent that are chest appliances | 31.46 | 33.33 | 14.79 | 35.78 | 42.86 | 30.14 | 410.03 |
| Located in unconditioned space X CDD | 0.87 | 0.64 | 2.33 | 0.69 | 0.95 | 0.88 | 0.72 |
| ESTIMATED UEC Savings (Annual kWh per year) for a removed freezer that is replaced | 1059.80 | 1019.60 | 974.90 | 1031.10 | 1169.80 | 1074.90 | 1123.10 |
| kWh Use of new freezer | 351.00 | 351.00 | 351.00 | 351.00 | 351.00 | 351.00 | 351.00 |

Per unit kW demand savings are based upon annual hours of use of 5,000 and a peak coincidence factor of 62%.

### 2.21.4 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)[125] 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

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[124] kWh use of new freezer is average consumption of all ENERGY STAR qualifying models by configuration from ENERGY STAR Residential Freezer Qualified Products List. July 5, 2013.

[125] 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

Refrigerator Replacement measure which reflects the less frequent replacement cycle among low-income households. The PA TRM limits measure savings to a maximum of 15 yrs.

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

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

*Example Measure savings over lifetime*

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

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

*Example Measure savings over lifetime*

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

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

*Example Measure savings over lifetime*

*= 1205 kWh/yr * 7 yrs = 8435 kWh/measure lifetime*

**Sources:**

1. U.S. Department of Energy, draft Uniform Methods Project protocol titled “Refrigerator Recycling Evaluation Protocol”, prepared by Doug Bruchs of the Cadmus Group, July 2012
2. Cadmus Memo - August 20, 2012 Technical Memo from the Cadmus Group to the Michigan Evaluation Working Group on the topic of Appliance Recycling Measure Savings Study. This memo summarizes research on the energy savings of recycled refrigerators and freezers conducted by The Cadmus Group, Inc. and Opinion Dynamics (together known as the evaluation team) on behalf Consumers Energy (Consumers) and DTE Energy (DTE). This memo provides an overview of the research conducted and

Cadmus' recommendations for deemed per-unit energy and demand savings values for affected measures in the Michigan Energy Measures Database (MEMD).

3. 2009-2010 Pacific Power/Rocky Mountain Power Impact Evaluations - PacifiCorp has impact evaluations for CA, ID, UT, WA, and WY that contain an earlier version of the multi-state Appliance Recycling Program regression models for both refrigerators and freezers. The Statewide Evaluator reviewed the report for the State of Washington, but all states include the same models and are publicly available online. The model coefficients can be found on pages 16 and 17 of the Washington document. http://www.pacificorp.com/content/dam/pacificorp/doc/Energy_Sources/Demand_Side_Management/WA_2011_SYLR_Final_Report.pdf
4. 2010 Ontario Power Authority Impact Evaluation - This evaluation report contains a regression equation for annual consumption for refrigerators only (the freezer sample was too small). That equation can be found on page 10 of the OPA evaluation report. See http://www.powerauthority.on.ca/sites/default/files/new_files/2010/2010%20Residential%20Great%20Refrigerator%20Roundup%20Program%20Evaluation.pdf
5. Efficiency Vermont; Technical Reference User Manual (TRM). 2008. TRM User Manual No. 2008-53. Burlington, VT 05401. July 18, 2008.
6. Mid Atlantic TRM Version 2.0. July 2011. Prepared by Vermont Energy Investment Corporation. Facilitated and managed by Northeast Energy Efficiency Partnerships.

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## 2.22 Residential New Construction

### 2.22.1 Algorithms

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

Energy and peak demand savings due to improvements in the above measures in Residential New Construction programs will be a direct output of accredited Home Energy Ratings (HERS) software that meets the applicable Mortgage Industry National Home Energy Rating System Standards. REM/Rate[126] is cited here as an example of an accredited software which can be used to estimate savings for this program. REM/Rate has a module that compares the energy characteristics of the energy efficient home to the baseline/reference home and calculates savings. For residential new construction, the baseline building thermal envelope and/or system characteristics shall be based on the current state adopted 2009 International Residential Code (IRC 2009).

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

*Energy savings of the qualified home (kWh)*

$$= (\text{Heating kWh}_b – \text{Heating kWh}_q) + (\text{Cooling kWh}_b – \text{Cooling kWh}_q)$$

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

*Peak demand of the baseline home*

$$= (PLb) / EER_b$$

*Peak demand of the qualifying home*

$$= (PLq) / EER_q$$

*Coincident system peak electric demand savings*

$$= (\text{Peak demand of the baseline home} – \text{Peak demand of the qualifying home}) \text{ X } CF.$$

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

Quantification of additional energy and peak demand savings due to the installation of high-efficiency electric water heaters, lighting and other appliances will be based on the algorithms presented for these measures in Section 2 (Residential Measures) of this Manual. Where the TRM algorithms involve deemed savings, e.g. lighting, the savings in the baseline and qualifying homes should be compared to determine the actual savings of the qualifying home above the baseline.

In instances where REM/Rate calculated parameters or model inputs do not match TRM algorithm inputs, additional data collection is necessary to use the TRM algorithms. One such

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

example is lighting. REM/Rate requires an input of percent of lighting fixtures that are energy efficient whereas the TRM requires an exact fixture count. Another example is refrigerators, where REM/Rate requires projected kWh consumed and the TRM deems savings based on the type of refrigerator.

It is also possible to have increases in consumption or coincident peak demand instead of savings for some non-weather sensitive measures. For example, if the amount of efficient lighting in a new home is less than the amount assumed in the baseline (IRC 2009), the home will have higher energy consumption and coincident peak demand for lighting, even though it still qualifies for the program.

According to Architectural Energy Corporation, the developer of the REM/Rate model, this model does account for the interaction of energy savings due to the installation of high efficiency lighting or appliances with the energy used in a home for space conditioning. Architectural Energy Corporation staff explained to the Statewide Evaluator that lighting and appliance energy usage is accounted for in the REM/Rate model, and the model does adjust energy use due to the installation of high efficiency lighting and appliances.[127]

### 2.22.2 Definition of Terms

| | |
|---|---|
| *Heating* $kWh_b$ | *= Annual heating energy consumption of the baseline home in kWh, from software.* |
| *Heating* $kWh_q$ | *= Annual heating energy consumption of the qualifying home in kWh, from software.* |
| *Cooling* $kWh_b$ | *= Annual cooling energy consumption of the baseline home in kWh, from software.* |
| *Cooling* $kWh_q$ | *= Annual cooling energy consumption of the qualifying home in kWh, from software.* |
| *PLb* | *= Estimated peak cooling load of the baseline home in kbtuh, from software.* |
| $EER_b$ | *= Energy Efficiency Ratio of the baseline unit.* |
| $EER_q$ | *= Energy Efficiency Ratio of the qualifying unit.* |
| *SEERb* | *= Seasonal Energy Efficiency Ratio of the baseline unit.* |
| *BLEER* | *= Factor to convert baseline SEERb to EERb.* |
| *PLq* | *= Estimated peak cooling loadfor the qualifying home constructed, in kbtuh, from software.* |

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[127] Email from V. Robert Salcido, P.E., LEED AP, Director of Products at Architectural Energy Corporation to Josh Duckwall, Project Manager at GDS Associates, November 21, 2013.

*SEERq* = *SEER 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 2-50~~2-50~~: Residential New Construction – References**

| Component | Type | Value | Sources |
|---|---|---|---|
| Heating $kWh_b$ | Variable | Software Calculated | 1 |
| Heating $kWh_q$ | Variable | Software Calculated | 2 |
| Cooling $kWh_b$ | Variable | Software Calculated | 1 |
| Cooling $kWh_q$ | Variable | Software Calculated | 2 |
| PLb | Variable | Software Calculated | 3 |
| $EER_b$ | Variable | EDC Data Gathering or $SEER_b$ * BLEER | 4 |
| $EER_q$ | Variable | EDC Data Gathering or $SEER_q$ * BLEER | 4 |
| SEER*b* | Fixed | 13 | 5 |
| BLEER | Fixed | (11.3/13) | 6 |
| PL*q* | Variable | Software Calculated | 7 |
| SEER*q* | Variable | EDC Data Gathering | 8 |
| CF | Fixed | 0.70 | 9 |

**Sources**:

1. Calculation of annual energy consumption of a baseline home from the home energy rating tool based on the reference home energy characteristics.
2. Calculation of annual energy consumption of an energy efficient home from the home energy rating tool based on the qualifying home energy characteristics
3. Calculation of peak load of baseline home from the home energy rating tool based on the reference home energy characteristics.
4. If the EER of the unit is know, use the EER. If only the SEER is known, then use SEER * BLEER to estimate the EER.
5. Federal Register, Vol. 66, No. 14, Monday, January 22, 2001/Rules and Regulations, p. 7170-7200.
6. Ratio to calculate EER from SEER based average EER for SEER 13 units.
7. Calculation of peak load of energy efficient home from the home energy rating tool based on the qualifying home energy characteristics.

8. SEER of HVAC unit in energy efficient qualifying home.
9. Based on an analysis of six different utilities by Proctor Engineering.

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

**Table 2-51~~2-51~~: Baseline Insulation and Fenestration Requirements by Component (Equivalent U-Factors)**

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

**Sources:**

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

**Table 2-52~~2-52~~: Energy Star Homes - User Defined Reference Home**

| Data Point | Value[128] | Source |
|---|---|---|
| Air Infiltration Rate | 0.30 ACH for windows, skylights, sliding glass doors<br>0.50 ACH for swinging doors | 1 |
| Duct Leakage | 12 cfm25 (12 cubic feet per minute per 100 square feet of conditioned space when tested at 25 pascals) | 1 |
| Duct Insulation | Supply ducts in attics shall be insulated to a minimum of R-8. All other ducts insulated to a minimum of R-6. | 1 |
| Duct Location | 50% in conditioned space, 50% unconditioned space | Program Design |
| Mechanical Ventilation | None | 1 |
| Lighting Systems | Minimum 50% of permanent installed fixtures to be high-efficacy lamps | 1 |
| Appliances | Use Default | |
| Setback Thermostat | Maintain zone temperature down to 55 $^{o}$F (13 $^{o}$C) or up to 85 $^{o}$F (29 $^{o}$C) | 1 |

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[128] Single and multiple family as noted.

| Data Point | Value[128] | Source |
|---|---|---|
| Temperature Set Points | Heating: 70°F<br>Cooling: 78°F | 1 |
| Heating Efficiency | | |
| Furnace | 80% AFUE | 2 |
| Boiler | 80% AFUE | 2 |
| Combo Water Heater | 76% AFUE (recovery efficiency) | 2 |
| Air Source Heat Pump | 7.7 HSPF | 1 |
| Geothermal Heat Pump | 7.7 HSPF | 1 |
| PTAC / PTHP | Not differentiated from air source HP | 1 |
| Cooling Efficiency | | |
| Central Air Conditioning | 13.0 SEER | 1 |
| Air Source Heat Pump | 13.0 SEER | 1 |
| Geothermal Heat Pump | 13 SEER (11.2 EER) | 1 |
| PTAC / PTHP | Not differentiated from central AC | 1 |
| Window Air Conditioners | Not differentiated from central AC | 1 |
| Domestic WH Efficiency | | |
| Electric | EF = 0.97 - (0.00132 * gallons) | 3 |
| Natural Gas | EF = 0.67 - (0.0019 * gallons) | 3 |
| Additional Water Heater Tank Insulation | None | |

**Sources:**

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

## 2.23 ENERGY STAR Refrigerators

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| **Measure Name** | **Refrigerators** |
|---|---|
| **Target Sector** | Residential Establishments |
| **Measure Unit** | Refrigerator |
| **Unit Energy Savings** | Varies by Configuration |
| **Unit Peak Demand Reduction** | Varies by Configuration |
| **Measure Life** | 12 years |

This measure is for the purchase and installation of a new refrigerator meeting ENERGY STAR or ENERGY STAR Most Efficient criteria. An ENERGY STAR refrigerator must be at least 20 percent more efficient than the minimum federal government standard. The ENERGY STAR Most Efficient is a new certification that identifies the most efficient products among those that qualify for ENERGY STAR. ENERGY STAR Most Efficient refrigerators must be at least 30 percent more efficient than the minimum federal standard.

### 2.23.1 Algorithms

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

*Total Savings* =*Number of Refrigerators x Savings per Refrigerator*

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

If the volume and configuration of the refrigerator is known, the ~~federal minimum efficiency and ENERGY STAR qualified~~baseline models' annual energy consumption (kWhbase) may be are determined using Table 2-53.

The efficient models' annual energy ~~and demand savings are~~ consumption (kWhEE or kWhME) may be determined using manufacturers' test data for the given ~~by the following~~model. Where test data is not available the algorithms~~:~~ in Table 2-53~~Tables 2-53~~ and Table 2-55~~Table 2-552-55~~ for "ENERGY STAR and ENERGY STAR Most Efficient maximum energy usage in kWh/year" may be used to determine the efficient energy consumption for a conservative savings estimate.

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**ENERGY STAR Refrigerator**

$\Delta kWh \quad = kWh_{base} - kWh_{EE}$

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

**ENERGY STAR Most Efficient Refrigerator**

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

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

### 2.23.2 Definition of Terms

$kWh_{base}$ = *Annual energy consumption of baseline unit*

$kWh_{EE}$ = *Annual energy consumption of ENERGY STAR qualified unit*

$kWh_{ME}$ = *Annual energy consumption of ENERGY STAR Most Efficient qualified unit*

*CF* =*Demand coincidence factor*

*Hours* =*Hours of operation per year*

**Where**:

*CF* = *1*

*Hours* =*8,760*[129]

Refrigerator energy use is characterized by configuration (top freezer, bottom freezer, etc.), volume, whether defrost is manual or automatic and whether there is through-the-door ice. If this information is known, annual energy ~~usage~~ consumption ($kWh_{base}$) of the ~~ENERGY STAR model and~~ federal standard model ~~can~~may be ~~calculated~~determined using Table 2-53~~Table 2-53~~. The efficient models' annual energy consumption (kWhEE or kWhME) may be determined using manufacturers' test data for the given model. Where test data is not available, the algorithms in Table 2-53~~tables 2-53~~ and

Table 2-55~~Table 2-552-55~~ for “ENERGY STAR and ENERGY STAR Most Efficient maximum energy usage in kWh/year” may be used to determine efficient energy consumption for a conservative savings estimate. The term “AV” in the equations refers to “Adjusted Volume,” which is AV = (Fresh Volume) + 1.63 x (Freezer Volume). Note, ENERGY STAR algorithms are not given for the categories “bottom mount freezer with through-the-door ice”, “refrigerator only-single door without ice” and “refrigerator/freezer- single door.” Refer to Table 2-54~~Table 2-54~~ for default values for these categories. Table 2-53~~Table 2-53~~ is also provided for planning purposes to compare to the changing federal standards detailed in Table 2-57~~Table 2-57~~.

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[129] ENERGY STAR Residential Refrigerators Savings Calculator. Accessed July 2013

**Table 2-53~~2-53~~: Federal Standard and ENERGY STAR Refrigerators Maximum Annual Energy Consumption if Configuration and Volume Known[130]**

| Refrigerator Category | Federal Standard Maximim Usage in kWh/year | ENERGY STAR Maximum Energy Usage in kWh/year |
|---|---|---|
| **Standard Size Models: 7.75 cubic feet or greater** | | |
| Manual Defrost and Partial Automatic Defrost | 8.82*AV+248.4 | 7.056*AV+198.72 |
| Automatic defrost with top-mounted freezer without through-the-door ice service and all-refrigerators--automatic defrost | 9.80*AV+276 | 7.84*AV+220.8 |
| Automatic defrost with side-mounted freezer without through-the-door ice service | 4.91*AV+507.5 | 3.928*AV+406 |
| Automatic defrost with bottom-mounted freezer without through-the-door ice service | 4.60*AV+459 | 3.68*AV+367.2 |
| Automatic defrost with top-mounted freezer with through-the-door ice service | 10.20*AV+356 | 8.16*AV+284.8 |
| Automatic defrost with side-mounted freezer with through-the-door ice service | 10.10*AV+406 | 8.08*AV+324.8 |
| **Compact Size Models: Less than 7.75 cubic feet and 36 inches or less in height** | | |
| Compact Refrigerator-Freezer--partial automatic defrost | 7.00*AV+398 | 5.6*AV+318.4 |
| Compact Refrigerator-Freezers--automatic defrost with top-mounted freezer and compact all-refrigerators--automatic defrost | 12.70*AV+355 | 10.16*AV+284 |
| Compact Refrigerator-Freezers--automatic defrost with side-mounted freezer | 7.60*AV+501 | 6.08*AV+400.8 |
| Compact Refrigerator-Freezers--automatic defrost with bottom-mounted freezer | 13.10*AV+367 | 10.48*AV+293.6 |

The default values for each configuration are given in Table 2-54

**Table 2-54~~2-54~~: Default Savings Values for ENERGY STAR Refrigerators[131]**

| Refrigerator Category | Assumed Volume of Unit (cubic feet)[132] | Conventional Unit Energy Usage in kWh/yr[133] | ENERGY STAR Energy Usage in kWh/yr[134] | ΔkWh | ΔkW |
|---|---|---|---|---|---|
| Manual Defrost and Partial Automatic Defrost | 12.2 | 311 | 230 | 80 | 0.0092 |
| Top mount freezer without door ice | 17.9 | 475 | 369 | 111 | 0.0126 |
| Side mount freezer without door ice | 22.7 | 713 | 557 | 156 | 0.0178 |
| Bottom mount freezer without door ice | 20.0 | 692 | 538 | 154 | 0.0176 |

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[130] ENERGY STAR Refrigerators and Freezers Key Product Criteria. http://www.energystar.gov/index.cfm?c=refrig.pr_crit_refrigerators Access July 2013

[132] ENERGY STAR Appliances Calculator. Accessed November 2013.

[133] ENERGY STAR Residential Refrigerators Qualified Products List. July 5, 2013. Average federal standard consumption of all qualifying models by configuration.

[134] Ibid. Average consumption of all ENERGY STAR qualifying models by configuration.

| | | | | | |
|---|---|---|---|---|---|
| Side mount freezer with door ice | 24.6 | 629 | 490 | 139 | 0.0159 |
| Bottom mount freezer with door ice | 25.4 | 569 | 447 | 122 | 0.0139 |
| Refrigerator only - single door without ice | 12.2 | 381 | 292 | 89 | 0.0102 |
| Refrigerator/Freezer – single door | 12.2 | 450 | 348 | 102 | 0.0116 |
| **Compact Size Models: Less than 7.75 cubic feet and 36 inches or less in height** | | | | | |
| Manual Defrost and Partial Automatic Defrost | 3.3 | 362 | 276 | 86 | 0.0098 |
| Top Mount and Refrigerator Only | 4.5 | 417 | 306 | 111 | 0.0126 |
| Bottom mount freezer | 5.1 | 452 | 362 | 90 | 0.0103 |

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ENERGY STAR Most Efficient annual energy ~~**usage can**~~consumption (kWhME) may be ~~**calculated**~~determined using ~~Table 2-55.[135]~~ manufacturers' test data for the given model. Where test data is not available, the algorithms in

Table **2-55**~~Table 2-55Table 2-55~~ for "ENERGY STAR Most Efficient maximum energy usage in kWh/year" may be used to determine efficient energy consumption for a conservative savings estimate. Baseline annual energy usage ~~**can be calculated**~~consumption (kWhbase) of the federal standard model may be determined using Table 2-53.

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**Table 2-55~~2-55~~: ENERGY STAR Most Efficient Annual Energy Usage if Configuration and Volume Known**

| Refrigerator Category | ENERGY STAR Most Efficient Maximum Energy Usage in kWh/yr |
|---|---|
| Manual Defrost and Automatic Defrost | AV ≤ 49.8, Eann ≤ 6.17*AV + 173.9<br>AV > 49.8, Eann ≤ 481 |
| Top mount freezer without door ice | AV ≤ 42.0, Eann ≤ 6.86*AV + 193.2<br>AV > 42.0, Eann ≤ 481 |
| Side mount freezer without door ice | AV ≤ 36.5, Eann ≤ 3.44*AV + 355.3<br>AV > 36.5, Eann ≤ 481 |
| Bottom mount freezer without door ice | AV ≤ 49.6, Eann ≤ 3.22*AV + 321.3<br>AV > 49.6, Eann ≤ 481 |
| Bottom mount freezer with door ice | AV ≤ 29.6, Eann ≤ 3.50*AV + 377.3<br>AV > 29.6, Eann ≤ 481 |
| Top mount freezer with door ice | AV ≤ 32.5, Eann ≤ 7.14*AV + 249.2<br>AV > 32.5, Eann ≤ 481 |
| Side mount freezer with door ice | AV ≤ 27.8, Eann ≤ 7.07*AV + 284.2<br>AV > 27.8, Eann ≤ 481 |

The default values for each ENERGY STAR Most Efficient configuration are given in Table 2-56.

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~~[135] ENERGY STAR Most Efficient 2012 Eligibility Criteria for Recognition Refrigerator-Freezers. http://www.energystar.gov/ia/partners/downloads/Ref_Freezer_Criteria_ME_2012.pdf?ff08-8680~~

**Table 2-56~~2-56~~: Default Savings Values for ENERGY STAR Most Efficient Refrigerators**[136]

| Refrigerator Category | Conventional Unit Energy Usage in kWh/yr[137] | ENERGY STAR Most Efficient Consumption in kWh/yr[138] | ΔkWh | ΔkW |
|---|---|---|---|---|
| Top mount freezer without door ice | 475 | 350 | 125 | 0.0149 |
| Bottom mount freezer without door ice | 692 | 403 | 228 | 0.0192 |
| Bottom mount freezer with door ice | 569 | 502 | 167 | 0.026 |

### 2.23.3 Measure Life

ENERGY STAR and ENERGY STAR Most Efficient Refrigerators: Measure Life = ~~13~~12 years.[139]

### 2.23.4 Future Standards Changes

As of September 15, 2014 new federal minimum efficiency standards for refrigerators and refrigerators-freezers will take effect. The maximum allowable energy usage by refrigerator configuration is listed in Table 2-57~~Table 2-57~~. These standards will take effect beginning with the 2015 TRM.

**Table 2-57~~2-57~~: Federal Refrigerator Standards Effective as of the 2015 TRM**[140]

| Refrigerator Category | Federal Standard Maximim Usage in kWh/year (Effective 2015 TRM) |
|---|---|
| **Standard Size Models: 7.75 cubic feet or greater** | |
| Refrigerators-freezers and refrigerators other than all-refrigerators with manual defrost (including partial automatic defrost) | 7.99*AV + 225.0 |
| All-refrigerators – manual defrost | 6.79*AV + 193.6 |
| Automatic defrost with top-mounted freezer without through-the-door ice service | 8.07*AV + 233.7 |
| Automatic defrost with side-mounted freezer without through-the-door ice service | 8.51*AV + 297.8 |
| Automatic defrost with bottom-mounted freezer without through-the-door ice service | 8.85*AV + 317.0 |
| Automatic defrost with top-mounted freezer with through-the-door ice service | 8.40*AV + 385.4 |
| Automatic defrost with side-mounted freezer with through-the-door ice service | 8.54*AV + 432.8 |

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[136] Configurations of qualified models as of July 5, 2013.

[137] ENERGY STAR Residential Refrigerators Qualified Products List. July 5, 2013. Average federal standard consumption of all qualifying models by configuration.

[138] Average consumption of all qualified units as of July 5, 2013. Qualified units list from http://www.energystar.gov/index.cfm?c=most_efficient.me_medium_fridges_freezers

[139] ENERGY STAR Appliances.~~ February 2008~~November 2013. U.S. Environmental Protection Agency and U.S. Department of Enegy. ENERGY STAR. http://www.energystar.gov/.

[140] U.S. Department of Energy. *Federal Register*. 179th ed. Vol. 76. September 15, 2011. https://www1.eere.energy.gov/buildings/appliance_standards/pdfs/refrig_finalrule_frnotice.pdf

| Compact Size Models: Less than 7.75 cubic feet and 36 inches or less in height | |
|---|---|
| Compact refrigerator-freezers and refrigerators other than all-refrigerators with manual defrost | 9.03*AV + 252.3 |
| Compact refrigerator-freezers – manual defrost | 7.84*AV + 219.1 |
| Compact refrigerator-freezer – partial automatic defrost | 5.91*AV + 335.8 |
| Compact refrigerator-freezers--automatic defrost with top-mounted freezer | 11.80*AV + 339.2 |
| Compact Refrigerator-Freezers--automatic defrost with side-mounted freezer | 6.82*AV + 456.9 |
| Compact Refrigerator-Freezers--automatic defrost with bottom-mounted freezer | 11.80*AV + 339.2 |

## 2.24 ENERGY STAR Freezers

| **Measure Name** | **Freezers** |
|---|---|
| **Target Sector** | Residential Establishments |
| **Measure Unit** | Freezer |
| **Unit Energy Savings** | Varies by Configuration |
| **Unit Peak Demand Reduction** | Varies by Configuration |
| **Measure Life** | 12 years |

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

### 2.24.1 Algorithms

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

*Total Savings* =*Number of Freezers x Savings per Freezer*

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

If the volume and configuration of the freezer is known, the ~~federal minimum efficiency and ENERGY STAR qualified~~baseline models' annual energy consumption (kWhbase) may be are determined using Table 2-58.

The efficient models' annual energy ~~and demand savings are~~ consumption (kWhEE) may be determined using manufacturers' test data for the given ~~by the following~~model. Where test data is not available the algorithms~~:~~ in Table 2-58~~Table 2-58~~ for “ENERGY STAR Maximum Energy Usage in kWh/year” may be used to determine the efficient energy consumption for a conservative savings estimate

**ENERGY STAR Freezer**

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

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

### 2.24.2 Definition of Terms

$kWh_{base}$ = *Annual energy consumption of baseline unit*

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*$kWh_{EE}$* = *Annual energy consumption of ENERGY STAR qualified unit*

*Hours* =*Hours of operation per year*

*CF* =*Demand coincidence factor*

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**Where**:

*CF* = *1*

*Hours* =*8,760*[141]

Freezer energy use is characterized by configuration (upright, chest or compact), volume and whether defrost is manual or automatic and whether. If this information is known, annual energy ~~usage~~consumption of the ~~ENERGY STAR model and~~ federal minimum efficiency standard model ~~can~~may be ~~calculated~~determined using Table 2-58~~Table 2-58~~. The efficient models' annual energy consumption (kWhEE) may be determined using manufacturers' test data for the given model. Where test data is not available, the algorithms in Table 2-58~~Table 2-58~~ for "ENERGY STAR maximum energy usage in kWh/year" may be used to determine efficient energy consumption for a conservative savings estimate. The term "AV" in the equations refers to "Adjusted Volume," which is AV = 1.73 x Total Volume. Note this table is also provided for planning purposes to compare to the changing federal standards detailed in Table 2-60~~Table 2-60~~.

**Table 2-58~~2-58~~: Federal Standard and ENERGY STAR Freezers Maximum Annual Energy Consumption if Configuration and Volume Known**[142]

| Freezer Category | Federal Standard Maximim Usage in kWh/year | ENERGY STAR Maximum Energy Usage in kWh/year |
|---|---|---|
| Upright with manual defrost | 7.55*AV+258.3 | < 6.795*AV + 232.47 |
| Upright with automatic defrost | 12.43*AV+326.1 | < 11.187*AV + 293.49 |
| Chest Freezer | 9.88*AV+143.7 | < 8.892*AV + 129.33 |
| Compact Upright with manual defrost | 9.78*AV+250.8 | < 7.824*AV + 200.64 |
| Compact Upright with automatic defrost | 11.40*AV+391 | < 9.120*AV + 312.8 |
| Compact Chest Freezer | 10.45*AV+152 | < 8.360*AV + 121.6 |

The default values for each configuration are given in Table 2-59. Note that a compact freezer is defined as a freezer that has a volume less than 7.75 cubic feet and is 36 inches or less in height.

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[141] ENERGY STAR Freezers Savings Calculator. Accessed June 24, 2012.

[142] ENERGY STAR Refrigerators and Freezers Key Product Criteria. http://www.energystar.gov/index.cfm?c=refrig.pr_crit_refrigerators

**Table 2-59~~2-59~~: Default Savings Values for ENERGY STAR Freezers**

| Freezer Category | Conventional Unit Energy Usage in kWh/yr[143] | ENERGY STAR Energy Usage in kWh/yr[144] | ΔkWh | ΔkW |
|---|---|---|---|---|
| Upright with manual defrost | 405 | 347 | 58 | 0.0066 |
| Upright with automatic defrost | 681 | 599 | 82 | 0.0094 |
| Chest Freezer | 392 | 351 | 41 | 0.0047 |
| Compact Upright with manual defrost | 301 | 235 | 66 | 0.0076 |
| Compact Upright with automatic defrost | 495 | 355 | 140 | 0.0160 |
| Compact Chest Freezer | 257 | 204 | 54 | 0.0061 |

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### 2.24.3 Measure Life

ENERGY STAR Freezers: Measure Life = 12 years.[145]

### 2.24.4 Future Standards Changes

As of September 15, 2014 new federal minimum efficiency standards for freezers will take effect. The maximum allowable energy usage by freezer configuration is listed in Table 2-60~~Table 2-60~~. These standards will take effect beginning with the 2015 TRM.

**Table 2-60~~2-60~~: Federal Freezer Standards Effective as of the 2015 TRM[146]**

| Freezer Category | Federal Standard Maximim Usage in kWh/year (Effective 2015 TRM) |
|---|---|
| Upright with manual defrost | 5.57*AV + 193.7 |
| Upright with automatic defrost | 8.62*AV + 228.3 |
| Chest Freezer | 7.29*AV + 107.8 |
| Compact Upright with manual defrost | 8.65*AV + 225.7 |
| Compact Upright with automatic defrost | 10.17*AV + 351.9 |
| Compact Chest Freezer | 9.25*AV + 136.8 |

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[143] ENERGY STAR Residential Freezers Qualified Products List. July 10, 2013. Average federal standard consumption of all qualifying models by configuration.

[144] Ibid. Average ENERGY STAR consumption of all qualifying models by configuration.

[145] ENERGY STAR Appliances Savings Calculator. Accessed July 10, 2013.

[146] U.S. Department of Energy. *Federal Register*. 179th ed. Vol. 76. September 15, 2011. https://www1.eere.energy.gov/buildings/appliance_standards/pdfs/refrig_finalrule_frnotice.pdf

## 2.25 ENERGY STAR Clothes Washers

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| **Measure Name** | **Clothes Washers** |
|---|---|
| **Target Sector** | Residential Establishments |
| **Measure Unit** | Clothes Washer |
| **Unit Energy Savings** | Varies by Fuel Mix |
| **Unit Peak Demand Reduction** | 0.0147 kW |
| **Measure Life** | 11 years |

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

### 2.25.1 Algorithms

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

*Total Savings* =*Number of Clothes Washers x Savings per Clothes Washer*

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

Per unit energy and demand savings are given by the following algorithms:

$$\Delta kWh = [((CAPY_{base} / MEF_{base}) X (CW_{base} + (DHW_{base} X \underline{\%}Electric\ DHW) + (Dryer_{base} X \underline{\%}Electric\ Dryer))) – ((CAPY_{EE} / MEF_{EE}) X (CW_{EE} + ( DHW_{EE} X \underline{\%}Electric\ DHW) + (Dryer_{EE} X \underline{\%}Electric\ Dryer)))] X Cycles$$

$$\Delta kW = DSav_{CW} X CF$$

Where MEFis the Modified Energy Factor, which is the energy performance ~~meteric~~metric for clothes washers. MEF is defined as:

> *MEF is the quotient of the capacity of the clothes container, C, divided by the total clothes washer energy consumption per cycle, with such energy consumption expressed as the sum of the machine electrical energy consumption, M, the hot water energy consumption,*

*E, and the energy required for removal of the remaining moisture in the wash load, D. The higher the value, the more efficient the clothes washer is.*[147]

MEF = C / (M + E + D)

### 2.25.2 Definition of Terms

$CAPY_{base}$ = *Capactiy of baseline clothes washer in cubic feet*

$CAPY_{EE}$ = *Capacity of ENERGY STAR clothes washer in cubic feet*

$MEF_{base}$ = *Modified Energy Factor of baseline clothes washer*

$MEF_{EE}$ = *Modified Energy Factor of ENERGY STAR clothes washer*

*Cycles* = *Number of clothes washer cycles per year*

~~%~~$CW_{base}$ =~~*Percentage of total*~~*Total energy consumption for baseline clothes washer operation*

~~%~~$CW_{EE}$ =~~*Percentage of total*~~ *Total energy consumption for ENERGY STAR clothes washer operation*

~~%~~$DHW_{base}$ = ~~*Percentage of total*~~*Total energy consumption for baseline clothes* ~~*washer water*~~*washerwater heating*

~~%~~$DHW_{EE}$ = ~~*Percentage of total*~~*Total energy consumption for ENERGY STAR clothes washer water heating*

*%ElectricDWH* = *Percentage of clothes washers that utilize electrically heated hot water*

~~%~~$Dyer_{base}$ = ~~*Percentage of total*~~*Total energy consumption for dryer operation with baseline clothes washer*

~~%~~$Dyer_{EE}$ = ~~*Percentage of total*~~*Total energy consumption for dryer operation with ENERGY STAR clothes washer*

*%Electric Dryer* = *Percentage of dryers that are electric*

*DSavCW* = *Summer demand savings per purchased ENERGY STAR clothes washer.*[148]

*CF* =*Demand Coincidence Factor. The coincidence of average clothes washer demand to summer system peak*

As of February 1, 2013 a clothes washer must have a MEF ≥ 2.0 and a WF ≤ 6.0 to meet ENERGY STAR standards. WF is the Water Factor, which is the measure of water efficiency of a

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[147] Definition provided on ENERGY STAR Clothes Washers Key Product Criteria website: ~~http://www.energystar.gov/index.cfm?c=clotheswash.pr_crit_clothes_washers~~http://www.energystar.gov/index.cfm?c=clotheswash.pr_crit_clothes_washers.

[148] Further research to update this value and CF is planned for 2015 TRM update.

clothes washer, expressed in gallons per cubic feet. WF is the quotient of the total weighted per-cycle water consumption ~~dividied by~~dividedby the capacity of the clothes washer.[149]

The federal standard for a clothes washer must have a MEF ≥ 1.26 and WF ≤ 9.5.[150]

The default values for the terms in the algorithms are listed in Table 2-61.  If unit information is known (such as capacity, MEF, fuel mix) then actual values should be used.

**Table 2-61~~2-61~~: ENERGY STAR Clothes Washers - References**

| Term | Type | Value | Source |
|---|---|---|---|
| $CAPY_{base}$ | Fixed | 3.10 $ft^3$ | 1 |
| $CAPY_{EE}$ | Variable | EDC Data Gathering | EDC Data Gathering |
| | | Default: 3.10 $ft^3$ | 2 |
| $MEF_{base}$ | Fixed | 1.26 | 1 |
| $MEF_{EE}$ | Variable | EDC Data Gathering | EDC Data Gathering |
| | | Default: 2.00 | 2 |
| Cycles | Fixed | 265 | 3 |
| ~~%~~$CW_{base}$ | Fixed | 9% | 4 |
| ~~%~~$CW_{EE}$ | Fixed | 9% | 4 |
| ~~%~~$DHW_{base}$ | Fixed | 37% | 4 |
| ~~%~~$DHW_{EE}$ | Fixed | 22% | 4 |
| %Electric DHW | Variable | EDC Data Gathering | Appliance Saturation Studies |
| | | Default: 43% | 3 |
| ~~%~~$Dryer_{base}$ | Fixed | 54% | 4 |

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[149] Based on ENERGY STAR Version 6.~~0~~1 requirements, *ENERGY STAR Program Requirements Product Specification for ~~Cltohes~~Clothes Washers*, *Eligibility Criteria Version 6.~~0. Accessed August 2012~~1. Updated February 15,2013*. http://www.energystar.gov/ia/partners/prod_development/revisions/downloads/commercial_clothes_washers/ENERGY_STAR_Final_Version_6_Clothes_Washer_Specification.pdf

[150] ~~ENERGY STAR Clothes Washers Key Product Criteria website: http://www.energystar.gov/index.cfm?c=clotheswash.pr_crit_clothes_washers~~ U.S. Department of Energy, Energy Efficiency and Renewable Energy Building Technologies Office, Residential Clothes Washers. Accessed November 2013. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/39

| | | | |
|---|---|---|---|
| ~~%~~$\text{Dryer}_{EE}$ | Fixed | 69% | 4 |
| %Electric Dryer | Variable | EDC Data Gathering | Appliance Saturation Studies |
| | | Default: 64% | ~~6~~5 |
| $\text{DSav}_{CW}$ | Fixed | 0.0147 | ~~7~~6 |
| CF | Fixed | 1 | ~~8~~7 |

**Sources:**

1. Energy Star Calculator, EPA research on available models. Accessed June 2013
2. EnergyStar Calculator, Average MEF and capacity of all ENERGY STAR qualified clothes washers. Accessed June 2013

3. ~~3.~~ Statewide average for all housing types from Pennsylvania Statewide Residential End-Use and Saturation Study, 2012~~,~~.

~~3.~~4. The percentage of total consumption that is used for the machine, water heating and dryer varies with efficiency. Perecentages were developed using the above parameters and using the U.S. Department of Energy's Life-Cycle Cost and Payback Period tool, available at: http://www1.eere.energy.gov/buildings/appliance_standards/residential/clothes_washers_support_stakeholder_negotiations.html

~~4.~~5. EIA 2009 Residential Energy Consumption Survey (RECS) appliance data for the state of Pennsylvania. http://www.eia.gov/consumption/residential/index.cfm

~~5.~~6. 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.

~~6.~~7. Coincidence factor already embedded in summer peak demand reduction estimate

The default values for various fuel mixes are given in Table 2-62.

**Table 2-62~~2-62~~: Default Clothes Washer Savings**

| Fuel Mix | ΔkWh |
|---|---|
| Electric DHW/Electric Dryer | 215 |
| Electric DHW/Gas Dryer | 159 |
| Gas DHW/Electric Dryer | 55 |

| | |
|---|---|
| Gas DHW/Gas Dryer | 19 |
| Default (17% Electric DHW 64% Electric Dryer) | 79 |

### 2.25.3 Measure Life

ENERGY STAR Clothes Washer: Measure Life = 11 years.[151]

### 2.25.4 Future Standards Changes

As of March 7, 2015 new federal minimum efficiency standards for clothes washers will take effect. Further efficiency standards for top-loading clothes washers go into effect beginning January 1, 2018. The 2015 efficiency standards for front-loading clothes washers will continue to be effective in 2018. The efficiency standards and the effective TRM ~~that these~~in which these standards become the baseline are detailed in Table 2-63.

Note that the current standards are based on the MEF and WF, but beginning in 2015 the standards will be based on the Integrated Modified Energy Factor (IMEF) and Integrated Water Factor (IWF). The IMEF incorporates energy use in standby and off modes and includes updates to the provisions of per-cycle measurements. The IWF more accurately represents consumer usage patterns as compared to the current metric. [152]

These standards are effective for both compact- and standard-size clothes washers. A compact clothes washer is defined to have a capacity of less than 1.6 ft3 and a standard-size clothes washer has a capacity of 1.6 ft3 or greater.[153]

**Table 2-63~~2-63~~: Future Federal Standards for Clothes Washers[154]**

| | 2015 TRM | | 2018 TRM | |
|---|---|---|---|---|
| | Minimum IMEF | Maximum IWF | Minimum IMEF | Maximum IWF |
| Top-loading, Compact | 0.86 | 14.4 | 1.15 | 12.0 |
| Top-loading, Standard | 1.29 | 8.4 | 1.57 | 6.5 |
| Front-loading, Compact | 1.13 | 8.3 | N/A | |
| Front-loading, Standard | 1.84 | 4.7 | N/A | |

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[151] ENERGY STAR Calculator . Accessed July 10, 2013.

[152] Ibid.

[153] U.S. Department of Energy. 10 CFR Parts 429 and 430. *Energy Conservation Program: Energy Conservation Standards for Residential Clothes Washers*. Direct Final Rule.

[154] U.S. Department of Energy. 10 CFR Parts 429 and 430. *Energy Conservation Program: Energy Conservation Standards for Residential Clothes Washers*. Direct Final Rule.

## 2.26 ENERGY STAR Dishwashers

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| **Measure Name** | **Dishwashers** |
|---|---|
| **Target Sector** | Residential Establishments |
| **Measure Unit** | Dishwasher |
| **Unit Energy Savings** | Varies by Water Heating Fuel Mix |
| **Unit Peak Demand Reduction** | 0.0225 kW |
| **Measure Life** | ~~11~~10 years |

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

### 2.26.1 Algorithms

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

*Total Savings* =*Number of Dishwashers x Savings per Dishwasher*

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

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

$$\Delta kWh = ((kWh_{base} - kWh_{EE}) \times (\%kWh_{op} + (\%kWh_{heat} \times \%Electric_{DHW})))$$

$$\Delta kW = DSav_{DW} \times CF$$

### 2.26.2 Definition of Terms

$kWh_{base}$ = *Annual anergy consumption of baseline dishwasher*

$kWh_{EE}$ = *Annual energy consumption of ENERGY STAR qualified unit*

$\%kWh_{op}$ = *Percentage of unit dishwasher energy consumption used for operation*

$\%kWh_{heat}$ = *Percentage of dishwasher unit energy consumption used for water heating*

$\%Electric_{DHW}$ = *Percentage of dishwashers assumed to utilize electrically heated hot water.*

$DSav_{DW}$ = *Summer demand savings per purchased ENERGY STAR dishwasher.*

*CF* = *Demand Coincidence Factor. The coincidence of average dishwasher demand to summer system peak*

ENERGY STAR qualified dishwashers must use less than or equal to the water and energy consumption values given in Table 2-64. Note, as of May 30, 2013, ENERGY STAR compact dishwashers have the same maximum water and energy consumption requirements as the federal standard and therefore are not included in the TRM since there is not energy savings to be calculated for installation of an ENERGY STAR compact dishwasher. A standard sized dishwasher is defined as any dishwasher that can hold 8 or more place settings and at least six serving pieces.[155]

**Table 2-64~~2-64~~: Federal Standard and ENERGY STAR v 5.0 Residential ~~Dishwaster~~Dishwasher Standard**

| Product Type | Federal Standard[156] | | ENERGY STAR v 5.0[157] | |
|---|---|---|---|---|
| | Water (gallons per cycle) | Energy (kWh per year) | Water (gallons per cycle) | Energy (kWh per year) |
| Standard | ≤ 6.50 | ≤ 355 | ≤ 4.25 | ≤ 295 |

**Table 2-65~~2-65~~: ENERGY STAR Dishwashers - References**

| Component | Type | Value | Source |
|---|---|---|---|
| $\text{kWh}_{base}$ | Fixed | ~~151~~355 kWh/yr | 1 |
| $\text{kWh}_{EE}$ | Fixed | ~~126~~295 kWh/yr | 1 |
| $\%\text{kWh}_{op}$ | Fixed | 44% | 1 |
| $\%\text{kWh}_{heat}$ | Fixed | 56% | 1 |
| $\%\text{Electric}_{DHW}$ | Variable | Default: 43%; or EDC Data Gathering | 2 |
| $\text{DSav}_{DW}$ | Fixed | 0.0225~~[158]~~ | 3 |
| CF | Fixed | 1[159] | 43 |

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[155] Dishwashers Key Product Criteria. http://www.energystar.gov/index.cfm?c=dishwash.pr_crit_dishwashers

[156] Ibid.

[157] *ENERGY STAR Program Requirements Product Specification for Residential Dishwashers*. http://www.energystar.gov/ia/partners/prod_development/revisions/downloads/res_dishwashers/ES_V5_Dishwashers_Specification.pdf

~~[158] Further research to update this value and CF is planned for 2015 TRM update.~~

[159] Further research to update this value and CF is planned for 2015 TRM update.

**Sources:**

1. ENERGY STAR Appliances Calculator. Accessed July 2013.
2. ~~3.~~ Statewide average for all housing types from Pennsylvania Statewide Residential End-Use and Saturation Study, 2012,Demand savings derived using dishwasher load shape.
3. Coincidence factor already embedded in summer peak demand reduction estimate

The default values for electric and non-electric water heating and the default fuel mix from **Error! Reference source not found.** Table 2-64 ~~is given~~are given in Table 2-66.

**Table 2-66~~2-66~~: Default Dishwasher Energy ~~and Demand~~ Savings**

| Water Heating | ΔkWh/yr |
|---|---|
| Electric (%Electric$_{DHW}$ = 100%) | 25 |
| Non-Electric (%Electric$_{DHW}$ = 0%) | 11 |
| Default Fuel Mix (%Electric$_{DHW}$ = ~~42~~43%) | 17 |

### 2.26.3 Measure Life

ENERGY STAR Dishwashers: Measure Life = 10 years[160]

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[160] EnergyStar Calculator. Accessed July 2013.

## 2.27 ENERGY STAR ~~Dehumidifiers~~Dehumidiers

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| Measure Name | Dehumidifiers |
|---|---|
| **Target Sector** | Residential Establishments |
| **Measure Unit** | Dehumidifier |
| **Unit Energy Savings** | Varies based on capacity |
| **Unit Peak Demand Reduction** | 0.0098 kW |
| **Measure Life** | 12 years |

ENERGY STAR qualified dehumidifiers are 15 percent more efficient than non-qualified models due to more efficient refrigeration coils, compressors and fans.

### 2.27.1 Algorithms

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

*Total Savings* =*Number of Dehumidifiers x Savings per Dehumidifier*

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

$$\Delta kWh = ((Avg\ Capacity\ *0.473) / 24) * Hours) * (1/ (L/kWh_{base}) – 1/ (L/kWh_{EE}))$$

$$\Delta kW_{peak} = DSav_{DH}\ X\ CF$$

### 2.27.2 Definition of Terms

*Avg Capacity* = *Average capacity of the unit (pints/day)*
*0.473* = *Conversion factor from pints to liters*
*24* =*Conversion factor from liters/day to liters/hour*
*Hours* =*Annual hours of operation*
=*1632*[161]
$L/kWh_{base}$ =*Baseline unit liters of water per kWh consumed*
$L/kWh_{EE}$ =*ENERGY STAR qualified unit liters of water per kWh consumed*

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[161] ENERGY STAR Calculator. Accessed July 2013.

*$DSav_{DH}$* = *Summer demand savings per purchased ENERGY STAR dehumidifier*
*=0.0098 kW*[162] [163]

*CF* = *Demand Coincidence Factor. The coincidence of average dehumidifier demand to summer system peak*
*=1*[164]

Table 2-67 shows the federal standard minimum efficiency and ENERGY STAR standards, effective October 1, 2012. Federal standards do not limit residential dehumidifier capacity, but since ENERGY STAR standards do limit the capacity to 185 pints per day, Table 2-59 only presents standards for the range of dehumidifier capacities that savings can be claimed.

**Table 2-67~~2-67~~: Dehumidifier Minimum Federal Efficiency and ENERGY STAR Standards**

| Capacity (pints/day) | Federal Standard[165] (L/kWh) | ENERGY STAR[166] (L/kWh) |
|---|---|---|
| ≤ 35 | 1.35 | ≥ 1.85 |
| > 35 ≤ 45 | 1.50 | |
| >45 ≤ 54 | 1.60 | |
| >54 < 75 | 1.70 | |
| 75 ≤ 185 | 2.5 | ≥ 2.80 |

The annual energy usage and savings of an ENERGY STAR unit over the federal minimum standard are presented in ~~Table 2-68~~Table 2-68 for each capacity range.

**Table 2-68~~2-68~~: Dehumidifier Default Energy Savings**[167]

| Capacity Range (pints/day) | Default Capacity (pints/day) | Federal Standard (kWh/yr) | ENERGY STAR (kWh/yr) | ΔkWh |
|---|---|---|---|---|
| ≤ 35 | 35 | ~~686~~ 834 | ~~500~~ 609 | ~~186~~ 225 |
| > 35 ≤ 45 | 45 | ~~905~~ 965 | ~~733~~ 782 | ~~172~~ 183 |
| >45 ≤ 54 | 54 | ~~988~~ 1086 | ~~854~~ 939 | ~~134~~ 147 |
| >54 < 75 | 74 | 1,~~211~~400 | 1,~~113~~287 | ~~98~~ 113 |
| 75 ≤ 185 | 130 | 1,~~660~~673 | 1,~~482~~493 | ~~178~~ 180 |

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[162] Conservatively assumes same kW/kWh ratio as Refrigerators.

[163] Further research to update this value and CF is planned for 2015 TRM update.

[164] Coincidence factor already embedded in summer peak demand reduction estimate.

[165] EnergyStar Calculator Accessed July 2013 using U.S. Department of Energy. *Federal Register*. 66th ed. Vol. 74. April 8, 2009. https://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/74fr16040.pdf;

[166] EnergyS tar Calculator Accessed July 2013 using ENERGY STAR Program Requirements Product Specification for Dehumidifiers, Eligibility Criteria Version 3.0. http://www.energystar.gov/ia/partners/prod_development/revisions/downloads/dehumid/ES_Dehumidifiers_Final_V3.0_Eligibility_Criteria.pdf?3cbf-7a48;

[167] Derived from equations in section 2.27, matching values generated by Energy Star Appliance Savings Calculator: http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/appliance_calculator.xlsx

### 2.27.3 Measure Life

### ~~2.27.4 Measure Life~~

ENERGY STAR Dehumidifiers: Measure Life = 12 years.[168]

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

## 2.28 ENERGY STAR Room Air Conditioners

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| **Measure Name** | **Room Air Conditioners** |
|---|---|
| **Target Sector** | Residential Establishments |
| **Measure Unit** | Room Air Conditioner |
| **Unit Energy Savings** | Varies |
| **Unit Peak Demand Reduction** | 0.059 kW |
| **Measure Life** | 9 years |

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

### 2.28.1 Algorithms

The general form of the equation for the ENERGY STAR Room Air Conditioners (RAC) measure savings algorithm is:

*Total Savings* =*Number of Room Air Conditioner x Savings per Room Air Conditioner*

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

$\Delta kWh = CAPY_{RAC}/1000 \text{ X } (1/EER_b – 1/EER_{ee}) * EFLH_{RAC}$

$\Delta kW = DSav_{RAC} \text{ X } CF$

### 2.28.2 Definition of Terms

$CAPY_{RAC}$ =*The cooling capacity (output in Btuh) of the room air conditioner (RAC) being installed*

$EER_b$ =*Energy efficiency ratio of the baseline unit*

$EER_{ee}$ =*Energy efficiency ratio of the RAC being installed*

$EFLH_{RAC}$ =*Equivalent full load hours of the RAC being installed*

$DSav_{RAC}$ = *Summer demand savings per purchased ENERGY STAR room AC* =*0.1018 kW*[169, 170]

*CF* =*Demand coincidence factor*

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[169] Average demand savings based on engineering estimate.

[170] Further research to update this value and CF is planned for 2015 TRM update.

*=0.58*[171]

*=Optional CF from EDC data gathering*

Table 2-69~~Table 2-69~~Table 2-69 lists the minimum federal efficiency standards as of June 2014 and minimum ENERGY STAR efficiency standards for RAC units of various capacity ranges and with and without louvered sides. Units without louvered sides are also referred to as “through the wall” units or “built-in” units. Note that the new federal standards are based on the Combined Energy Efficiency Ratio Metric (CEER), which is a metric that incorporates energy use in all modes, including standby and off modes.[172]

Also, as of October 1, 2013 ENERGY STAR Room Air Conditioner Version 3.0 will take effect. The new eligibility criteria are given in Table 2-69~~Table 2-69~~, Table 2-70~~Table 2-70~~ and Table 2-71.

**Table 2-69~~2-69~~: RAC Federal Minimum Efficiency and ENERGY STAR Version 3.0 Standards** [173]

| Capacity (Btu/h) | Federal Standard CEER, with louvered sides | ENERGY STAR EER, with louvered sides | Federal Standard EER, without louvered sides | ENERGY STAR CEER, without louvered sides |
|---|---|---|---|---|
| < 6,000 | ≥11.0 | 11.2 | 10.0 | 10.4 |
| 6,000 to 7,999 | | | | |
| 8,000 to 10,999 | ≥10.9 | 11.3 | 9.6 | 9.8 |
| 11,000 to 13,999 | | | 9.5 | |
| 14,000 to 19,999 | ≥10.7 | 11.2 | 9.3 | |
| 20,000 to 24,999 | ≥9.4 | 9.8 | 9.4 | |
| ≥25,000 | ≥9.0 | | | |

~~Table 2-70~~ Table 2-70 lists the minimum federal efficiency standards and minimum ENERGY STAR efficiency standards for casement-only and casement-slider RAC units. Casement-only refers to a RAC designed for mounting in a casement window with an encased assembly with a width of 14.8 inches or less and a height of 11.2 inches or less. Casement-slider refers to a RAC with an encased assembly designed for mounting in a sliding or casement window with a width of 15.5 inches or less.

**Table 2-70~~2-70~~: Casement-Only and Casement-Slider RAC Federal Minimum Efficiency and ENERGY STAR Version 3.0 Standards (effective 2014 TRM)**

| Casement | Federal Standard CEER | ENERGY STAR EER |
|---|---|---|
| Casement-only | ≥ 9.5 | ≥ 10.0 |
| Casement-slider | ≥ 10.4 | ≥ 10.9 |

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[171] Based on data from PEPCO.

[172] Federal stanards: U.S. Department of Energy. *Federal Register*. 164th ed. Vol. 76, August 24, 2011.

[173] Federal stanards: U.S. Department of Energy. *Federal Register*. 164th ed. Vol. 76, August 24, 2011.
ENERGY STAR standards: *ENERGY STAR Program Requirements Product Specification for Room Air Conditioners, Eligibility Criteria Version 3.0*. June 22, 2012.

Table 2-71Table 2-71 lists the minimum federal efficiency standards and minimum ENERGY STAR efficiency standards for reverse-cycle RAC units.

Field Code Changed

**Table 2-712~~-71~~: Reverse-Cycle RAC Federal Minimum Efficiency Standards and ENERGY STAR Version 3.0 Standards (effective 2014 TRM)**

| Capacity (Btu/h) | Federal Standard CEER, with louvered sides | ENERGY STAR EER, with louvered sides | Federal Standard CEER, without louvered sides | ENERGY STAR EER, without louvered sides |
|---|---|---|---|---|
| < 14,000 | n/a | n/a | ≥ 9.3 | ≥ 9.8 |
| ≥ 14,000 | | | ≥ 8.7 | ≥ 9.2 |
| < 20,000 | ≥ 9.8 | ≥ 10.4 | n/a | n/a |
| ≥ 20,000 | ≥ 9.3 | ≥ 9.8 | | |

Table 2-72

~~Table 2-72~~ provides deemed EFLH by city and default energy savings values if efficiency and capacity information is unknown. Alternate $EFLH_{cool}$ values from Table 2-2 in Section 2.1 may be used in conjunction with the Adjustment Factor (AF) in Section 2.11 to find $EFLH_{RAC}$ if desired.

**Table 2-722~~-72~~: Deemed EFLH and Default Energy Savings[174, 175]**

| City | $EFLH_{RAC}$ | ΔkWh |
|---|---|---|
| Allentown | ~~243~~ 151 | ~~23~~ 14 |
| Erie | ~~149~~ 121 | ~~14~~ 11 |
| Harrisburg | ~~288~~ 171 | ~~27~~ 16 |
| Philadelphia | ~~320~~ 183 | ~~30~~ 17 |
| Pittsburgh | ~~228~~ 134 | ~~22~~ 13 |
| Scranton | ~~193~~ 129 | ~~18~~ 12 |
| Williamsport | ~~204~~ 131 | ~~19~~ 12 |

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### 2.28.3 Measure Life

ENERGY STAR Room Air Conditioners: Measure Life = ~~10~~ 9 years[176]

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[174] Values taken from ENERGY STAR calculator except for EFLH estimates, which can be found in Section 2.~~12~~11 (Room AC Retirement~~).~~), Table 2-23.

[175] Assumes 10,000 Btu/h capacity and 9.8 EER for baseline unit and 10.8 EER for ENERGY S TAR unit.

[176] ~~ENERGY STAR Appliances. February 2008. U.S. Environmental Protection Agency and U.S. Department of Enegy. ENERGY STAR. http://www.energystar.gov/.~~
Appliance Magazine, 2008.

## 2.29 ENERGY STAR Lighting

### ~~2.29.1 Algorithms~~

Savings ~~from installation of screw-in ENERGY STAR CFLs, ENERGY STAR fluorescent torchieres, ENERGY STAR indoor fixtures and ENERGY STAR outdoor fixtures~~for residential energy efficient lighting products are based on a straightforward algorithm that calculates the difference between ~~existing~~baseline 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 parameter estimates in this section are for residential use only. If the split between residential and non-residential installations is unknown (e.g., an upstream program), EDCs can conduct data gathering to determine the percentage of bulbs sold and installed in various types of non-residential applications. EDCs should use the CF and hours of use by business type present in Section **Error! Reference source not found.** for non-residential bulb savings estimates.

### ~~2.41.1~~2.29.1 Eligibility

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**Definition of Efficient Equipment**

In order for this measure protocol to apply, the high-efficiency equipment must be a screw-in ENERGY STAR CFL (general service or specialty bulb), screw-in ENERGY STAR LED bulb (general service or specialty bulb), LED fixture, ENERGY STAR fluorescent torchiere, ENERGY STAR indoor fluorescent fixture, ENERGY STAR outdoor fluorescent fixture, or an ENERGY STAR ceiling fan with a fluorescent light fixture.[177]

**Definition of Baseline Equipment**

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

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

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For upstream buy-down, retail (time of sale), or efficiency kit programs, baseline wattages can be determined using the tables included in this protocol below. For direct install programs where wattage of the existing bulb is known, and the existing bulb was in working condition, wattage of the existing lamp removed by the program may be used in lieu of the tables below.

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

### 2.29.2 Algorithms

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

*Total Savings* = *Number of Units X Savings per Unit*

**ENERGY STAR CFL Bulbs (screw-in):**

~~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*~~

~~**ENERGY STAR CFL Bulbs (screw-in):**~~

$\Delta kWh$ = $(Watts_{base} - Watts_{CFL}$~~)~~)/1000 X $CFL_{hours}$ X $(1+IE_{kWh})$ X 365 ~~/ 1000~~ X $ISR_{CFL}$

$\Delta kW_{peak}$ = $(Watts_{base} - Watts_{CFL}$~~) /~~)/1000 X CF X $(1+IE_{kW})$ X ~~CF X~~ $ISR_{CFL}$

**ENERGY STAR LED Bulbs (screw-in):**

$\Delta kWh$ = $(Watts_{base} - Watts_{LED})/1000$ X $CFL_{hours}$ X $(1+IE_{kWh-LED})$ X 365 X $ISR_{CFL}$

$\Delta kW_{peak}$ = $(Watts_{base} - Watts_{LED})/1000$ X CF X $(1+IE_{kW-LED})$ X $ISR_{CFL}$

**ENERGY STAR Torchieres:**

~~**ENERGY STAR Torchieres:**~~

$\Delta kWh$ = $(Watts_{base} - Watts_{Torch}$~~)~~)/1000 X $Torch_{hours}$ X $(1+IE_{kWh})$ X 365 ~~/ 1000~~ X $ISR_{Torch}$

$\Delta kW_{peak}$ = $(Watts_{base} - Watts_{Torch}$~~) /~~)/1000 X CF X $(1+IE_{kW})$ X ~~CF X~~ $ISR_{Torch}$

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

$\Delta kWh$ = $(Watts_{base} - Watts_{IF}$~~)~~)/1000 X $IF_{hours}$ X $(1+IE_{kWh-LED})$ X 365 ~~/ 1000~~ X $ISR_{IF}$

$\Delta kW_{peak}$ = $(Watts_{base} - Watts_{IF}$~~) /~~)/1000 X CF X $(1+IE_{kW-LED})$ X ~~CF X~~ $ISR_{IF}$

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

$\Delta kWh$ = $(Watts_{base} - Watts_{IF})/1000$ X $IF_{hours}$ X $(1+IE_{kWh})$ X 365 X $ISR_{IF}$

$\Delta kW_{peak}$ = $(Watts_{base} - Watts_{IF})/1000$ X CF X $(1+IE_{kW})$ X $ISR_{IF}$

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

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

$\Delta kWh$ = $(Watts_{base} - Watts_{OF}$~~)~~)/1000 X $OF_{hours}$ X 365 ~~/ 1000~~ X $ISR_{OF}$

$\Delta kW_{peak}$ = $(Watts_{base} - Watts_{OF}$~~) /~~)/1000 X CF X $ISR_{OF}$

**Ceiling Fan with ENERGY STAR Light Fixture:**

~~**Ceiling Fan with ENERGY STAR Light Fixture:**~~

$\Delta kWh$ = $(Watts_{base} – Watts_{Fan}$~~)~~)/1000 X $Fan_{hours}$ X (1~~-~~+$IE_{kWh}$) X 365~~/1000~~ X $ISR_{Fan}$

$\Delta kW_{peak}$ = $(Watts_{base} - Watts_{Fan}$~~) /~~)/1000 X CF X (1~~-~~+$IE_{kW}$) X ~~CF X~~ $ISR_{Fan}$

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### ~~2.29.2~~2.29.3 Definition of Terms

### ~~2.29.3 Definition of Terms~~

$Watts_{base}$ = Wattage of baseline case lamp/fixture. ~~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. SeeTable 2-79.~~

$Watts_{CFL}$ = Wattage of CFL

~~$Watts_{CFL}$ = Wattage of CFL~~

$CFL_{hours}$ = Average hours of use per day per CFL

$IE_{kWh}$ =HVAC Interactive Effect for CFL energy

$IE_{kW}$ =HVAC Interactive Effect for CFL demand

$ISR_{CFL}$ = In-service rate per CFL.

$Watts_{LED}$ =Wattage of LED

$IE_{kWh-LED}$ =HVAC Interactive Effect for LED energy

$IE_{kW-LED}$ =HVAC Interactive Effect for LED demand

$Watts_{Torch}$ = Wattage of ENERGY STAR torchiere

$Torch_{hours}$ = Average hours of use per day per torchiere

$ISR_{Torch}$ = In-service rate per Torchiere

$Watts_{IF}$ = Wattage of ENERGY STAR Indoor Fixture

$IF_{hours}$ = Average hours of use per day per Indoor Fixture

$ISR_{IF}$ = In-service rate per Indoor Fixture

$Watts_{OF}$ = Wattage of 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)~~*

$Watts_{Fan}$ = *Wattage of ENERGY STAR Ceiling Fan light fixture*

$Fan_{hours}$ = *Average hours of use per day per Ceiling Fan light fixture*

$ISR_{Fan}$ = *In-service rate per Ceiling Fan fixture*

### Table 2-73~~2-73~~: ENERGY STAR Lighting - References

| Component | Type | Value | Sources |
|---|---|---|---|
| $Watts_{base}$ | Variable | ~~See Table 2-74~~Data Gathering[178] or Table 2-74~~Table Table 2-74~~, Table 2-75, & Table 2-76~~Table 2-76~~ | ~~Table 2-74~~7 |
| $Watts_{CFL}$ | Variable | Data Gathering | Data Gathering |
| $CFL_{hours}$ | Fixed | 2.8 | 5 |
| $IE_{kWh}$ | Variable | ~~See~~ Data Gathering or Table 2-77~~Table 2-77~~~~Table 2-76~~ | 6 |
| $IE_{kW}$ | Variable | ~~See Table 2-76~~Data Gathering or Table 2-77~~Table 2-77~~ | 6 |
| $ISR_{CFL}$ | Fixed | ~~96~~97%[179] | 2 |
| $Watts_{LED}$ | Variable | Data Gathering | Data Gathering |
| $IE_{kWh\text{-}LED}$ | Variable | Data Gathering or Table 2-78~~Table 2-78~~ | 6 |
| $IE_{kW\text{-}LED}$ | Variable | Data Gathering or Table 2-78~~Table 2-78~~ | 6 |
| $Watts_{Torch}$ | Variable | Data Gathering | Data Gathering |
| $Torch_{hours}$ | Fixed | 3.0 | 1 |
| $ISR_{Torch}$ | Fixed | 83% | 2 |
| $Watts_{IF}$ | Variable | Data Gathering | Data Gathering |
| $IF_{hours}$ | Fixed | 2.6 | 1 |
| $ISR_{IF}$ | Fixed | 95% | 2 |
| $Watts_{OF}$ | Variable | Data Gathering | Data Gathering |
| $OF_{hours}$ | Fixed | 4.5 | 1 |
| $ISR_{OF}$ | Fixed | 87% | 2 |
| CF | Fixed | 9.1% | 3 |
| $Watts_{Fan}$ | Variable | Data Gathering | Data Gathering |
| $Fan_{hours}$ | Fixed | 3.5 | 4 |
| $ISR_{Fan}$ | Fixed | 95% | 4 |

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**Sources:**

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[178] EDCs may use the wattage of the replaced bulb for directly installed program bulbs

[179] ~~Subject to verification through evaluation. The value can be updated if evaluation findings reveal a value that differs from the default.~~ For direct install program bulbs, EDCs have the option to use an evaluated ISR when verified through PA program primary research.

1. Nexus Market Research, “Impact Evaluation of the Massachusetts, Rhode Island and Vermont 2003 Residential Lighting Programs”, Final Report, October 1, 2004,. 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.

2. The ISR is based on an installation rate “trajectory” and includes savings for all program bulbs that are believed to ultimately be installed. Evaluations of the PECO Smart Lighting Discounts program determined a first year ISR of 78% for customers that purchased a bulb through a retailer or were provided a CFL through a give-a-way program[180]. For future installations, the recommendations of the Uniform Methods Project (“UMP”) can be incorporated. The UMP recommends using the findings from the evaluation of the 2006-2008 California Residential Upstream Lighting Programs, which estimated that 99% of program bulbs get installed within three years, including the program year. Discounting the future savings back to the current program year reduces the ISR to 97%.

3. EmPOWER Maryland 2012 Final Evaluation Report: Residential Lighting Program, Prepared by Navigant Consulting and the Cadmus Group, Inc., March 2013, Table 50.

4. ENERGY STAR Ceiling Fan Savings Calculator (Calculator updated April 2009). Hours based on ENERGY STAR calculator for the Mid-Atlantic region – defer to this value since it is recognized that ceiling fans are generally installed in high-use areas such as kitchens, living rooms and dining rooms. Ceiling fans are also installed in bedrooms, but the overall average HOU for this measure is higher than the average of all CFLs (2.8) and indoor fixtures (2.6) since these values incorporate usage in low-use areas such as bathrooms and hallways where ceiling fans are generally not installed.

5. Nexus Market Research, "Residential Lighting Markdown Impact Evaluation", Final Report, January 20, 2009. Table 6-1.

   Additionally, the following studies were reviewed and analyzed to support the “Residential Lighting Markdown Inpact Evaluation”:

   - Nexus Market Research, “Impact Evaluation of the Massachusetts, Rhode Island and Vermont 2003 Residential Lighting Programs”, Final Report, October 1, 2004. Table 9-7.
   - CFL Metering Study, Final Report. Prepared for PG&E, SDG&E, and SCE by KEMA, Inc. February 25, 2005. Table 4-1.
   - Nexus Market Research, ""Process and Impact Evaluation of the Efficiency Maine Lighting Program"", April 2007. Table 1-7."
   - Nexus Market Research, "Residential Lighting Markdown Impact Evaluation", Final Report, January 20, 2009. Table 6-1.
   - KEMA, Inc., "Final Evaluation Report: Upstream Lighting Program." Prepared from the California Public Utilities Commission, Febuary 8, 2010. Table 18.

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[180] Evaluation Research Report: PECO Smart Lighting Discounts Program, Navigant Consulting, September 20, 2012

- Itron, Inc. "Verification of Reported Energy and Peak Savings from the EmPOWER Maryland Energy Efficiency Programs." Prepared for the Maryland Public Service Commission, April 21, 2011. Table 3-6.
- TecMarket Works, "Duke Energy Residential Smart Saver CFL Program in North Carolina and South Carolina", February 2011. Table 29.
- Glacier Consulting Group, LLC. “Adjustments to CFL Operating Hours-Residential.” Memo to Oscar Bloch, Wisconsin DOA. June 27, 2005.
- New Jersey’s Clean Energy Program Residential CFL Impact Evaluation and Protocol Review. KEMA, Inc. September 28, 2008. pg. 21.

~~4.~~1. ~~GDS simulation modeling.~~

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~~**Table 2-74: Baseline Wattage by Lumen Output for General Service Lamps (GSL)[181]**~~

6. GDS Simulation Modeling, September-November 2013.
7. Lumen bins and Pre-EISA baselines are consistent with ENERGY STAR lamp labeling requirements, Version 1.0. Post-EISA baselines are the maximum EISA complaint equivalent incandescent wattages based on EISA lumen bins.

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[181] ~~Lumen bins and incadescent equivalent wattages from ENERGY STAR labeling requirements, Version 1.0 http://www.energystar.gov/products/specs/sites/products/files/ENERGY%20STAR%20Lamps%20V1.0%20Final%20Draft%20Specification.pdf. EISA Standards from: United States Department of Energy. *Impact of EISA 2007 on General Service Incandescent Lamps: FACT SHEET.* http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/general_service_incandescent_factsheet.pdf~~

### 2.29.4 Variable Input Values

**Baseline Wattage Values – General Service Lamps**

| ~~Baseline wattage is dependent on lumens, shape of bulb, and EISA qualifications. Commonly used EISA exempt bulbs include 3-way bulbs, globes with ≥5" diameter or ≤749 lumens, and candelabra base bulbs with ≤1049 lumens.~~ ~~Minimum Lumens (a)~~ | ~~Maximum Lumens (b)~~ | ~~Incandescent Equivalent $\text{Watts}_{\text{Base}}$ (Pre-EISA 2007) (c)~~ | ~~$\text{Watts}_{\text{Base}}$ (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~~ | ~~2014 TRM~~ |
| ~~310~~ | ~~749~~ | ~~40~~ | ~~29~~ | ~~2014 TRM~~ |

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

For direct installation programs where the removed bulb is known, and the bulb is in working condition, EDCs may use the wattage of the replaced bulb in lieu of the tables below.[182] For bulbs

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[182] **Bulb that are not installed during the home visit do not qualify for this exemption. This includes bulbs that are left for homeowners to install. In these instances, baseline wattages should be estimated using Table 2-74~~Table Table 2-72~~, Table 2-75~~Table 2-73~~, & Table 2-76. Default Baseline Wattage for Reflector Bulbs**

| **Bulb Type (a)** | **Incandescent Equivalent (Pre-EISA) (b)** | **$\text{Watts}_{\text{Base}}$ (Post-EISA) (c)** |
|---|---|---|
| PAR20 | 50 | 35 |
| PAR30 | 50 | 35 |
| R20 | 50 | 45 |
| PAR38 | 60 | 55 |

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

To determine the $\text{Watts}_{\text{Base}}$ for ~~GSLs~~General Service Lamps[183] , follow these steps:

1. Identify the ~~ENERGY STAR CFL, Torchiere,~~ rated ~~Indoor Fixture or Outdoor Fixture's rated~~ lumen output of the energy efficient lighting product
2. ~~In Table 2-74~~Identify if the bulb is EISA exempt[184]
~~2.~~3. In Table 2-74~~Table Table 2-74~~, find the lumen range into which the lamp falls (see columns (a) and (b).
~~5.~~4. Find the baseline wattage ($\text{Watts}_{\text{Base}}$) in column (c) or column (d). ~~Values in~~ If the bulb is exempt from EISA legislation, use column (c), else, use column (d).

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| | | |
|---|---|---|
| BR30 | 65 | EXEMPT |
| BR40 | 65 | EXEMPT |
| ER40 | 65 | EXEMPT |
| BR40 | 75 | 65 |
| BR30 | 75 | 65 |
| PAR30 | 75 | 55 |
| PAR38 | 75 | 55 |
| R30 | 75 | 65 |
| R40 | 75 | 65 |
| PAR38 | 90 | 70 |
| PAR38 | 120 | 70 |
| R20 | ≤ 45 | EXEMPT |
| BR30 | ≤ 50 | EXEMPT |
| BR40 | ≤ 50 | EXEMPT |
| ER30 | ≤ 50 | EXEMPT |
| ER40 | ≤ 50 | EXEMPT |

~~Default Baseline Wattage for Reflector Bulbs~~~~**Bulb Type(a)Incandescent Equivalent (Pre-EISA)(b)WattsBase(Post-EISA)(c)**~~~~PAR205035PAR305035R205045PAR386055BR3065EXEMPTBR4065EXEMPTER4065EXEMPTBR407565BR307565PAR307555PAR387555R307565R407565PAR389070PAR3812070R20≤ 45EXEMPTBR30≤ 50EXEMPTBR40≤ 50EXEMPTER30≤ 50EXEMPTER40≤ 50EXEMPT~~Table 2-76~~Table 2-74~~.

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[183] General Service Lamps are medium screw based bulbs that are not globe, bullet, candle,flood, reflector, or decorative shaped. These bulbs do encompass both twist/spiral and a-lamp shaped bulbs.

[184] The EISA 2007 standards apply to general service incandescent lamps. 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.* http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/general_service_incandescent_factsheet.pdf

**Table 2-742-74: Baseline Wattage by Lumen Output for General Service Lamps (GSL)[185]**

~~**) are used for $\text{Watts}_{\text{Base}}$ until the TRM listed under column (e) is effective. Afterwards,**~~

| Minimum Lumens (a) | Maximum Lumens (b) | Incandescent Equivalent $\text{Watts}_{\text{Base}}$ (Pre-EISA 2007) (c) | $\text{Watts}_{\text{Base}}$ (Post-EISA 2007) (d) | $\text{Watts}_{\text{base}}$ post 2020[186] (e) |
|---|---|---|---|---|
| 2000 | 2600 | 150 | 72 | 23 |
| 1600 | 1999 | 100 | 72 | 23 |
| 1100 | 1599 | 75 | 53 | 18 |
| 800 | 1099 | 60 | 43 | 15 |
| 450 | 799 | 40 | 29 | 9 |
| 310 | 449 | 25 | 25 | 25 |

~~1.~~ Baseline values in Table 2-74~~Table Table 2-74~~ column (e), $\text{Watts}_{\text{base}}$ post 2020, should only be used in cost-effectiveness calculations for bulbs expected to be in use past 2020, such as LEDs. For these bulbs, $\text{Watts}_{\text{base}}$ column (d) should be used for the savings calculations until 2020, followed by the values in column (e) for the remainder of the measure life.~~column (d) are used for $\text{Watts}_{\text{Base}}$.the savings calculations until 2020, followed by the values in column (e) for the remainder of the measure life.~~

#### ~~For EISA exempt[187] GSL~~Baseline Wattage Values – Specialty Bulbs

ENERGY STAR provides separate equivelant incandescent wattages for specialty and decorative bulb shapes. These shapes include candelabra base, globe, bullet, and shapes other than A-lamp bulbs.[188] For these bulbs, use the $\text{Watts}_{\text{Base}}$ from Table 2-75.

For EISA exempt specialty bulbs, use the $\text{Watts}_{\text{base}}$ value in column (c) in ~~Table 2-74, above.~~Table 2-75. Commonly used EISA exempt bulbs include 3-way bulbs, globes with ≥5" diameter or ≤749 lumens, and candelabra base bulbs with ≤1049 lumens. See the EISA legislation for the full list of exemptions.

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[185] Lumen bins and incadescent equivalent wattages from ENERGY STAR labeling requirements, Version 1.0 http://www.energystar.gov/products/specs/sites/products/files/ENERGY%20STAR%20Lamps%20V1.0%20Final%20Draft%20Specification.pdf. EISA Standards from: United States Department of Energy. *Impact of EISA 2007 on General Service Incandescent Lamps: FACT SHEET.* http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/general_service_incandescent_factsheet.pdf

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

~~[187] The EISA 2007 standards apply to general service incandescent lamps. 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*.~~

[188] ANSI Shapes for decorative bulbs: B, BA, C, CA, DC, F, and G

To determine the $\text{Watts}_{\text{Base}}$ for specialty/decorative lamps , follow these steps:

1. Identify the rated lumen output of the energy efficient lighting product
2. Identify if the bulb is EISA exempt
3. In Table 2-75, fine the lamp shape of the bulb (see columns (a) or (b)).
4. In Table 2-75, find the lumen range into which the lamp falls (see columns (a) or (b)).
5. Find the baseline wattage ($\text{Watts}_{\text{Base}}$) in column (c) or column (d). If the bulb is exempt from EISA legislation, use column (c), else, use column (d).

Table 2-75~~2-75~~: Baseline Wattage by Lumen Output for Specialty Lamps [189]

| Lumen Bins (decorative) (a) | Lumen Bins (globe) (b) | Incandescent Equivalent $\text{Watts}_{\text{Base}}$ (Pre-EISA 2007) (c) | $\text{Watts}_{\text{Base}}$ (Post-EISA 2007) (d) |
|---|---|---|---|
|  | 1100-1300 | 150 | 72 |
|  | 650-1099 | 100 | 72 |
|  | 575-649 | 75 | 53 |
| 500-699 | 500-574 | 60 | 43 |
| 300-499 | 350-499 | 40 | 29 |
| 150-299 | 250-349 | 25 | 25 |
| 90-149 |  | 15 | 15 |
| 70-89 |  | 10 | 10 |

## Baseline Wattage Values – Reflector or Flood Lamps

**Reflector (directional) bulbs fall under legislation different from GSL and other specialty bulbs. For these bulbs, EDCs can use the manufacturer rated equivalent wattage as printed on the retail packaging, or use the default WattsBase (column (c)) in Table 2-76. Default Baseline Wattage for Reflector Bulbs**

| Bulb Type (a) | Incandescent Equivalent (Pre-EISA) (b) | $\text{Watts}_{\text{Base}}$ (Post-EISA) (c) |
|---|---|---|
| PAR20 | 50 | 35 |
| PAR30 | 50 | 35 |
| R20 | 50 | 45 |
| PAR38 | 60 | 55 |

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[189] Lumen bins and incadescent equivalent wattages from ENERGY STAR labeling requirements, Version 1.0 http://www.energystar.gov/products/specs/sites/products/files/ENERGY%20STAR%20Lamps%20V1.0%20Final%20Draft%20Specification.pdf. EISA Standards from: United States Department of Energy. *Impact of EISA 2007 on General Service Incandescent Lamps: FACT SHEET.*

| | | |
|---|---|---|
| BR30 | 65 | EXEMPT |
| BR40 | 65 | EXEMPT |
| ER40 | 65 | EXEMPT |
| BR40 | 75 | 65 |
| BR30 | 75 | 65 |
| PAR30 | 75 | 55 |
| PAR38 | 75 | 55 |
| R30 | 75 | 65 |
| R40 | 75 | 65 |
| PAR38 | 90 | 70 |
| PAR38 | 120 | 70 |
| R20 | ≤ 45 | EXEMPT |
| BR30 | ≤ 50 | EXEMPT |
| BR40 | ≤ 50 | EXEMPT |
| ER30 | ≤ 50 | EXEMPT |
| ER40 | ≤ 50 | EXEMPT |

~~Default Baseline Wattage for Reflector Bulbs**Bulb Type(a)Incandescent Equivalent (Pre-EISA)(b)Watts$_{Base}$(Post-EISA)(c)**PAR205035PAR305035R205045PAR386055BR3065EXEMPTBR4065EXEMPTER4065EXEMPTBR407565BR307565PAR307555PAR387555R307565R407565PAR389070PAR3812070R20≤ 45EXEMPTBR30≤ 50EXEMPTBR40≤ 50EXEMPTER30≤ 50EXEMPTER40≤ 50EXEMPTTable 2-75~~ below.

**Table 2-76~~2-76~~. Default Baseline Wattage for Reflector Bulbs[190]**

| **Bulb Type (a)** | **Incandescent Equivalent (Pre-EISA) (b)** | **Watts$_{Base}$ (Post-EISA) (c)** |
|---|---|---|
| PAR20 | 50 | 35 |
| PAR30 | 50 | 35 |
| R20 | 50 | 45 |
| PAR38 | 60 | 55 |
| BR30 | 65 | EXEMPT |
| BR40 | 65 | EXEMPT |
| ER40 | 65 | EXEMPT |
| BR40 | 75 | 65 |

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[190] Based on manufacturer recommended replacements for EISA affected lamps. Manufacturer ratings may differ from the list above, in which case EDCs should default to the manufacturer equivalent rating.

| | | |
|---|---|---|
| BR30 | 75 | 65 |
| PAR30 | 75 | 55 |
| PAR38 | 75 | 55 |
| R30 | 75 | 65 |
| R40 | 75 | 65 |
| PAR38 | 90 | 70 |
| PAR38 | 120 | 70 |
| R20 | ≤ 45 | EXEMPT |
| BR30 | ≤ 50 | EXEMPT |
| BR40 | ≤ 50 | EXEMPT |
| ER30 | ≤ 50 | EXEMPT |
| ER40 | ≤ 50 | EXEMPT |

~~75. Default Baseline Wattage for Reflector Bulbs~~[191]

| ~~Bulb Type (a)~~ | ~~Incandescent Equivalent (Pre-EISA) (b)~~ | Watts$_{Base}$ ~~(Post-EISA) (c)~~ |
|---|---|---|
| ~~PAR20~~ | ~~50~~ | ~~35~~ |
| ~~PAR30~~ | ~~50~~ | ~~35~~ |
| ~~R20~~ | ~~50~~ | ~~45~~ |
| ~~PAR38~~ | ~~60~~ | ~~55~~ |
| ~~BR30~~ | ~~65~~ | ~~EXEMPT~~ |
| ~~BR40~~ | ~~65~~ | ~~EXEMPT~~ |
| ~~ER40~~ | ~~65~~ | ~~EXEMPT~~ |
| ~~BR40~~ | ~~75~~ | ~~65~~ |
| ~~BR30~~ | ~~75~~ | ~~65~~ |
| ~~PAR30~~ | ~~75~~ | ~~55~~ |
| ~~PAR38~~ | ~~75~~ | ~~55~~ |
| ~~R30~~ | ~~75~~ | ~~65~~ |
| ~~R40~~ | ~~75~~ | ~~65~~ |
| ~~PAR38~~ | ~~90~~ | ~~70~~ |
| ~~PAR38~~ | ~~120~~ | ~~70~~ |
| ~~R20~~ | ~~≤ 45~~ | ~~EXEMPT~~ |
| ~~BR30~~ | ~~≤ 50~~ | ~~EXEMPT~~ |
| ~~BR40~~ | ~~≤ 50~~ | ~~EXEMPT~~ |
| ~~ER30~~ | ~~≤ 50~~ | ~~EXEMPT~~ |

---

[191] ~~Based on manufacturer recommended replacements for EISA affected lamps. Manufacturer ratings may differ from the list above, in which case EDCs should default to the manufacturer equivalent rating.~~

| ~~ER40~~ | ~~≤ 50~~ | ~~EXEMPT~~ |
|---|---|---|

### Interactive Effects Values

In the absence of EDC data gathering and analysis, the default values for Energy and Demand HVAC Interactive Effects are below. Due to the differences between LED and CFL technologies, these bulb types have separate interactive effects values.

**Table 2-77~~2-76~~77. CFL Energy and Demand HVAC Interactive Effects by EDC**[192]

| – | ~~$IE_{kWh}$~~ | ~~$IE_{kW}$~~ |
|---|---|---|
| **EDC** | **$IE_{kWh}$** | **$IE_{kW}$** |
| Duquesne | 8% | 13% |
| FE (MetEd) | -8% | 13% |
| FE (Penn Elec) | 1% | 10% |
| FE (Penn Power) | 0% | 20% |
| FE (WPP) | -2% | 30% |
| PPL | -6% | 12% |
| PECO | 9% | 14% |

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~~In the absence of EDC data gathering, the default savings for ENERGY STAR Torchieres, Indoor Fixtures and Outdoor Fixtures are listed in the Table 2-77.~~

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**Table 2-78~~2-77~~78~~: Default Savings for ENERGY STAR Indoor Fixtures, ENERGY STAR~~. LED Energy and Demand HVAC Interactive Effects by~~Outdoor Fixtures and ENERGY STAR Torchieres (per fixture)~~**~~[193]~~

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| | ~~Torchiere~~ | ~~Indoor Fixture~~ | ~~Outdoor Fixture~~ |
|---|---|---|---|
| ~~ΔkWh~~ | ~~65.0~~ | ~~27.1~~ | ~~83.6~~ |
| ~~$\Delta kW_{peak}$~~ | ~~0.0030~~ | ~~0.0014~~ | ~~0.0025~~ |

---

[192] HVAC Interactive Effects modeled through REM/Rate models, using EDC specific inputs. Values were weighted to the saturation of HVAC equipment and housing types present in each EDC service territory as reported in the Pennsylvania Statewide Residential End-Use and Saturation Study, 2012.

~~[193] Source of change in watts(before adjusting for EISA 2007) between the baseline and efficient case is 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). Adjustment to account for EISA 2007 standards based on Mid-Atlantic TRM, version 2.0. Prepared by Vermont Energy Investment Corporation. Facilitated and managed by the Northeast Energy Efficiency Partnerships. July 2011.~~

~~Adjustment made by calculating an average adjustment factor (61.77%) for all incandescent bulbs that EISA affectsand applying at the midpoint of the three year EISA phase-in (2013). As an example of an adjustment factor, the 100 W incandescent the baseline is 72 watts post-EISA and the CFL equivalent assumption is a 25.3 watt CFL. Therefore the adjustment factor is calculated as follows(72-25.3)/(100-25.3)*100= 62.5%.~~

~~The "Equivalent CFL Wattage" is calculated using a ratio of 3.95. This is calculated assuming that the average wattage of a CFL is 15.5W and the replacement incandescent bulb is 61.2W (ratio of 3.95 to 1), RLW Analytics, New England Residential Lighting Markdown Impact Evaluation, January 20, 2009.~~

~~In the absence of~~ EDC ~~data gathering, the deemed savings for ENERGY STAR Ceiling Fans are listed in Table 2-78.~~ ~~[194]~~[195]

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| EDC | $IE_{kWh-LED}$ | $IE_{kW-LED}$ |
|---|---|---|
| Duquesne | 8% | 10% |
| FE (MetEd) | -7% | 11% |
| FE (Penn Elec) | 1% | 10% |
| FE (Penn Power) | 0% | 16% |
| FE (WPP) | -3% | 27% |
| PPL | -6% | 17% |
| PECO | 9% | 24% |

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~~Table 2-78: Default Savings for ENERGY STAR Ceiling Fans Light Fixtures (per fixture)~~

| ~~ΔkWh~~ | ~~$\Delta kW_{peak}$~~ | ~~Effective Date~~ |
|---|---|---|
| ~~146~~ | ~~0.0057~~ | ~~2013 TRM~~ |
| ~~84~~ | ~~0.0033~~ | ~~2014 TRM~~ |

## 2.29.5 Measure Life

Residential CFL Measure Life is 5.2 years[196], [197]

Residential LED Measure Life is 14.7 years[198].

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~~[194] Effective date is the date when EISA 2007 standards are incorporated. The baseline assumption is three 60 watt (ENERGY STAR Ceiling Fans Savings Calculator) incandescent lamps and therefore the EISA 2007 affects this measure beginning 2014.~~

[195] HVAC Interactive Effects modeled through REM/Rate models, using EDC specific inputs. Values were weighted to the saturation of HVAC equipment and housing types present in each EDC service territory as reported in the Pennsylvania Statewide Residential End-Use and Saturation Study, 2012.

[196] Jump et al "Welcome to the Dark Side: The Effect of Switching on CFL Measure Life" indicates that the "observed life" of CFLs with an average rated life of 8,000 hours is 5.2 years due to increased on/off switching.

[197] Since the replacement baseline bulb from 2020 on will be equivalent to a CFL, no additional savings should be claimed from that point. Due to expected delay in clearing stock from retail outlets, this shift is assumed not to occur unitl mid-2020. Measure life is reduced to 5 years for CFLs installed June 2015 – May 2016. For every subsequent year, CFL measure life should be reduced by one year.

[198] All LED bulbs listed on the qualified ENERGY STAR product list have a lifetime of at least 15,000 hours. Assuming 2.8 hours per day usage, this equates to 14.7 years .

## 2.30 ENERGY STAR Windows

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### 2.30.1 Algorithms

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

$$\text{Total Savings} = \text{Square Feet of Window Area X Savings per Square Foot}$$

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.[199] 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:**

$$\Delta kWh = ESav_{HP}$$

$$\Delta kW_{peak} = DSav_{HP} \text{ X } CF$$

**Electric Heat/Central Air Conditioning:**

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

$$\Delta kW_{peak} = DSav_{CAC} \text{ X } CF$$

**Electric Heat/No Central Air Conditioning:**

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

$$\Delta kW_{peak} = DSav_{NOCAC} \text{ X } CF$$

### 2.30.2 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.

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[199] 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 2-79~~2-79~~: 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%<br>Summer/Off-Peak 7%<br>Winter/On-Peak 40%<br>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%<br>Summer/Off-Peak 7%<br>Winter/On-Peak 40%<br>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%<br>Summer/Off-Peak 3%<br>Winter/On-Peak 45%<br>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.

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## 2.31 ENERGY STAR Audit

### 2.31.1 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.

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## 2.32 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:

- A software tool whose performance has passed testing according to the National Renewable Energy Laboratory's HERS BESTEST software energy simulation testing protocol.[200]
- Software approved by the US Department of Energy's Weatherization Assistance Program.[201]
- RESNET approved rating software.[202]

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.

### 2.32.1 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)[203]. 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

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[200] A new standard for BESTEST-EX for existing homes is currently being deveoped - status is found at http://www.nrel.gov/buildings/bestest_Ex.html. The existing 1995 standard can be found at http://www.nrel.gov/docs/legosti/fy96/7332a.pdf.

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

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

[203] 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.

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).

### 2.32.2 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.

### 2.32.3 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.

### 2.32.4 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.

### 2.32.5 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.

### 2.32.6 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.

### 2.32.7 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.

### 2.32.8 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.

### 2.32.9 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.

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## 2.33 ENERGY STAR Televisions

This measure applies to the purchase of an ENERGY STAR TV meeting Version 6.0 standards. Version 6.0 standards are effective as of June 1, 2013. Additionally, in 2012 ENERGY STAR introduced the ENERGY STAR Most Efficient designation, which recognizes the most efficient of the ENERGY STAR qualified televisions.

The baseline equipment is a TV meeting ENERGY STAR Version 5.3~~.0~~ requirements[204].

### 2.33.1 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.

### 2.33.2 Definition of Terms

| | |
|---|---|
| $W_{base,on}$ | = *power use (in Watts) of baseline TV while in on mode (i.e. active mode turned on and operating).* |
| $W_{ES,on}$ | = *power use (in Watts) of ENERGY STAR Version ~~5.3~~6.0 or ENERGY STAR Most Efficient TV while in on mode (i.e. active mode turned on and operating).* |
| $HOURS_{on}$ | = *number of hours per day that a typical TV is on (active mode turned on and in use).* |
| *CF* | = *Demand Coincidence Factor (See Section 1.4)* |
| *365* | = *days per year.* |

---

[204] This updated baseline ~~assumption is made because there is no federal standard~~takes into account the fact that ~~specifies minimum~~84% of national TV ~~efficiencies.~~shipments were ENERGY STAR ~~Version~~ compliant in 2012 to the v5.3~~.0 predates Version 6.0 standards.~~ specification according to the recent report "Business & Consumer Electronics: A Strategy for the Northeast" Northeast Energy Efficiency Partnerships, August 2013

**Table 2-80~~2-80~~: ENERGY STAR TVs - References**

| Component | Type | Value | Source |
|---|---|---|---|
| CF | Fixed | 0.28 | 1 |
| $HOURS_{on}$ | Fixed | 5 | 2 |

**Sources**:

1. Deemed Savings Technical Assumptions, Program: ENERGY STAR Retailer Incentive Pilot Program, accessedJune 2013, http://www.xcelenergy.com/staticfiles/xe/Regulatory/Regulatory%20PDFs/ES_RetailerIncentiveFile.pdf
2. Calculations assume TV is in on mode (or turned on) for 5 hours per day and sleep/standby mode for 19 hours per day. Based on assumptions from ENERGY STAR Calculator, *'EPA Research on Available Models, 2012*, accessed June 2013, http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_Televisions_Bulk.xls http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&ved=0CDAQFjAA&url=http%3A%2F%2Fwww.energystar.gov%2Fia%2Fbusiness%2Fbulk_purchasing%2Fbpsavings_calc%2FConsumer_Electronics_Calculator.xlsx&ei=bzWyUbb0H4Xx0wHw4oBw&usg=AFQjCNGPH4-NaXM_-1IM4J29-of6Plpx5g&sig2=Xau5mB6YjLf3r81hOgmWAQ&bvm=bv.47534661,d.dmQ

### 2.33.3 On Mode Power Consumption Requirements:

$$P_{ON\ MAX} = 100 \times TAHN(0.00085 \times (A - 140) + 0.052) + 14.1$$

Where:

- PON_MAX is the maximum allowable On Mode Power consumption in Watts. All ENERGY STAR Televisions must use 1.0 watts or less while in Sleep Mode (i.e. standby mode).[205]
- A is the viewable screen area of the product in sq. inches, calculated by multiplying the viewable image width by the viewable image height
- tanh is the hyperbolic tangent function

ENERGY STAR Most Efficient Televisions must meet all of the program requirments of ENERGY STAR Version ~~5.3~~6.0 as well as the following additional requirement:[206]

$$P_{ON\ MAX} = 82 * TANH(0.00084(A-150)+0.05)+12.75$$

Where TANH is the hyperbolic tangent function.

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[205] *ENERGY STAR Program Requirements for Televisions, Partner Commitments Versions 6.0*, accessed June 2013.

[206] *ENERGY STAR Most Efficient Eligibility Criteria for Recognition Televisions*, accessed August 2012. http://www.energystar.gov/ia/partners/downloads/Televisions_Criteria_ME_2012.pdf

**Table 2-81~~2-81~~: TV power consumption**

| Diagonal Screen Size (inches)[207] | Baseline Active Power Consumption [$W_{base,active}$][208] | ENERGY STAR V. 6.0 Active Power Consumption [$W_{ES,active}$][209] | ENERGY STAR Most Efficient Power Consumption [$W_{ES,active}$] |
|---|---|---|---|
| < 20 | ~~51~~17 | 16 | 13 |
| 20 < 30 | ~~85~~40 | 30 | 20 |
| 30 < 40 | ~~137~~62 | 50 | 31 |
| 40 < 50 | ~~235~~91 | 72 | 43 |
| 50 < 60 | ~~353~~108* | 92 | 54 |
| ≥ 60 | ~~391~~108* | 99 | 58 |

### 2.33.4 Deemed Savings

Deemed annual energy savings for ENERGY STAR 6.0 and ENERGY STAR Most Efficient TVs are given in Table 2-82~~Table 2-82~~.

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[207] 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".

[208] Based on ENERGY STAR Version 5.3~~.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~~November 2013, http://www.energystar.gov/ia/partners/prod_development/revisions/downloads/television/V5.3_Program_Requirements.pdf?db43-0cc6

[209] ~~Ibid.~~ Based on ENERGY STAR Version 6.0 requirements, from *ENERGY STAR Program Requirements for Televisions, Partner Commitments*, accessed November 2013, http://www.energystar.gov/ia/partners/prod_development/revisions/downloads/television/Fina_lDraft_Version_6_TVs_Specification.pdf?94ce-893a

**Table 2-82~~2-82~~: Deemed energy savings for ENERGY STAR Version ~~5.3 and~~6.0and ENERGY STAR Most Efficient TVs.**

| Diagonal Screen Size (inches)[210] | Energy Savings ENERGY STAR V. ~~5.3~~6.0 TVs (kWh/year) | Energy Savings ENERGY STAR Most Efficient TVs (kWh/yr) |
|---|---|---|
| < 20 | ~~64~~2 | ~~69~~7 |
| 20 < 30 | ~~100~~18 | ~~119~~37 |
| 30 < 40 | ~~159~~22 | ~~193~~57 |
| 40 < 50 | ~~297~~35 | ~~350~~88 |
| 50 < 60 | ~~476~~29 | ~~546~~99 |
| ≥ 60 | ~~533~~16 | ~~608~~91 |

Coincident demand savings are given in the Table 2-83: Deemed coincident demand savings for ENERGY STAR Version 6.0 and ENERGY STAR Most Efficient TVs.Table 2-83~~Table 2-83Table 2-83: Deemed coincident demand savings for ENERGY STAR Version 6.0 and ENERGY STAR Most Efficient TVs.~~.

**Table 2-83~~2-83~~: Deemed coincident demand savings for ENERGY STAR Version ~~5.3~~6.0 and ENERGY STAR Most Efficient TVs.**

| Diagonal Screen Size (inches)[211] | Coincident Demand Savings ENERGY STAR V. ~~5.3~~6.0 (kW) | Coincident Demand Savings ENERGY STAR Most Efficient (kW) |
|---|---|---|
| < 20 | 0.~~010~~00028 | 0.~~011~~0011 |
| 20 < 30 | 0.~~0154~~0028 | 0.~~018~~0056 |
| 30 < 40 | 0.~~024~~0034 | 0.~~030~~0087 |
| 40 < 50 | 0.~~046~~0053 | 0.~~054~~0134 |
| 50 < 60 | 0.~~073~~0045 | 0.~~084~~0151 |
| ≥ 60 | 0.~~082~~0025 | 0.~~093~~0140 |

### 2.33.5 Measure Life

Measure life = 6 years[212]

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[210] 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". 60" was used to compute the value for sizes ≥ 60"

[211] Ibid.

[212] *ENERGY STAR Program Requirements for Televisions, Partner Commitments Versions 6.0*, accessed June 2013.

## 2.34 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.

### 2.34.1 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~~December 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**

$\Delta kWh = ESav_{MON}$

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

### 2.34.2 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 1.18 for demand impacts for all office equipment reflecting embedded coincidence in the DSav factor. |

Table 2-84~~2-84~~: ENERGY STAR Office Equipment - References

| Component | Type | Value | Sources |
|---|---|---|---|
| $ESav_{COM}$<br>$ESav_{FAX}$<br>$ESav_{COP}$<br>$ESav_{PRI}$<br>$ESav_{MUL}$<br>$ESav_{MON}$ | Fixed | see Table 2-85 | 1 |
| $DSav_{COM}$<br>$DSav_{FAX}$<br>$DSav_{COP}$<br>$DSav_{PRI}$<br>$DSav_{MUL}$<br>$DSav_{MON}$ | Fixed | see Table 2-85 | 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~~1.18 | 3 |

**Sources:**

1. ENERGY STAR Office Equipment Savings Calculator (Calculator updated: ~~June~~December 2010). Default values were used.
2. Using a ~~residential~~commercial office equipment load shape, the percentage of total savings that occur during the ~~top 100 system hours~~PJM peak demand period was calculated and multiplied by the energy savings. The coincidence factor, defined as (kW * 8760) / kWh, used for all office equipment is 1.18 as calculated by doing a covariance between the load shape and peak hours.

~~1.~~3. Coincidence factors already embedded in summer peak demand reduction estimates.

~~3. Coincidence factors already embedded in summer peak demand reduction estimates.~~

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### 2.34.3 Default Savings

Table 2-85~~2-85~~: ENERGY STAR Office Equipment Energy and Demand Savings Values

| Measure | Energy Savings (ESav) | Demand Savings (DSav) | Source |
|---|---|---|---|
| Computer | ~~77~~133 kWh | 0.~~0100~~018 kW | 1 |
| Fax Machine (laser) | 78 kWh | 0.0105 kW | 1 |
| Copier (monochrome) | | | |
| 1-25 images/min | 73 kWh | 0.0098 kW | 1 |
| 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 | 1 |
| 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 | 1 |
| 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~~ 15 kWh | 0.~~0019~~0020 kW | 1 |

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**Sources:**

1. ENERGYSTAR Office Equipment Calculator (Calculator updated: December 2010)

~~1. ENERGYSTAR office equipment calculators~~

## ~~2.35 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/or fixtures. LEDs provide an efficient alternative to incandescent lighting. The ENERGY STAR program began labeling qualified LED products in the latter half of 2010.~~

### ~~2.35.1~~ Office~~Eligibility Requirements~~

~~In order for this measure protocol to apply, the high-efficiency equipment must be a screw-in LED bulb (general service or specialty bulb), LED fixture, or efficiency kit with LED bulb with the following qualifications:~~

- ~~**ENERGY STAR qualified**[213] – 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**[214] – 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.~~

1. ~~**Definition of Baseline**~~ **Equipment** Calculator (Calculator updated: December 2010)

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~~The baseline equipment is assumed to be a socket or fixture with a standard general service incandescent light bulb(s) or specialty incandescent light bulb.~~

~~An adjustment to the baseline wattage for general service screw-in LEDs is made to account for the Energy Independence and Security Act of 2007 (EISA 2007), which requires that all general service lamps between 40 W and 100 W meet minimum efficiency standards in terms of amount of light delivered per unit of energy consumed. The standard is phased in over two years, between January 1, 2012 and January 1, 2014. This adjustment affects the baseline for ENERGY STAR LEDs, and may affect the baseline for ENERGY STAR LED Torchieres, ENERGY STAR Indoor LED Fixtures, ENERGY STAR Outdoor LED Fixtures and ENERGY STAR Ceiling Fans with LEDs, where the baseline condition is assumed to be a general service, standard screw-in incandescent light bulb.~~

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~~For upstream buy-down, retail (time of sale), or efficiency kit programs, baseline wattages can be determined using the tables included in this protocol below. For direct install programs, wattage of the existing lamp removed may be used in lieu of the tables below.~~

### ~~2.35.2 Algorithms~~

~~The LED measure savings are based on the following algorithms:~~

---

~~[213] http://www.energystar.gov/ia/partners/product_specs/program_reqs/SSL_Key_Product_Criteria.pdf~~

~~[214] http://www.lightingfacts.com/~~

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

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

### ~~2.35.3 Definition of Terms~~

~~$Watts_{base}$ = Wattage of baseline case lamp/fixture. 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.~~

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

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

~~$IE_{kWh}$ =HVAC Interactive Effect for energy~~

~~$IE_{kW}$ =HVAC Interactive Effect for demand~~

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

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

~~Table 2-86: Residential LED Variables~~

| ~~Variable~~ | ~~Type~~ | ~~Value~~ | ~~Source~~ |
|---|---|---|---|
| ~~$Watts_{Base}$~~ | ~~Fixed~~ | ~~See Table 2-87~~ | ~~Table 2-87~~ |
| ~~$Watts_{LED}$~~ | ~~Fixed~~ | ~~Variable~~ | ~~Data Gathering~~ |
| ~~$Hours_{LED}$~~ | ~~Fixed~~ | ~~2.8~~ | ~~1~~ |
| ~~CF~~ | ~~Fixed~~ | ~~9.1%~~ | ~~2~~ |
| ~~$ISR_{LED}$~~ | ~~Fixed~~ | ~~95%~~[215] | ~~3~~ |
| ~~$IE_{kWh}$~~ | ~~Variable~~ | ~~See Table 2-89~~ | ~~4~~ |
| ~~$IE_{kW}$~~ | ~~Variable~~ | ~~See Table 2-89~~ | ~~4~~ |

**~~Sources:~~**

1. ~~Nexus Market Research, "Residential Lighting Markdown Impact Evaluation", Final Report, January 20, 2009. Table 6-1. Reference Section 2.30: ENERGY STAR Lighting for full citation.~~

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

2. ~~EmPOWER Maryland 2012 Final Evaluation Report: Residential Lighting Program, Prepared by Navigant Consulting and the Cadmus Group, Inc., March 2013, Table 50.~~
3. ~~Mid-Atlantic TRM, version 2.0. Prepared by Vermont Energy Investment Corporation. Facilitated and managed by the Northeast Energy Efficiency Partnerships. July 2011.~~

### ~~2.35.4 GDS simulation modeling~~

~~Table 2-87: Baseline Wattage by Lumen Output for General Service Lamps (GSL)~~[216]

| ~~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~~ | ~~2014 TRM~~ |
| ~~310~~ | ~~749~~ | ~~40~~ | ~~29~~ | ~~2014 TRM~~ |

~~To determine the Watts$_{Base}$ for GSLs, follow these steps:~~

1. ~~Identify the ENERGY STAR LED's rated lumen output~~
2. ~~In Table 2-87, find the lumen range into which the lamp falls (see columns (a) and (b).~~
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$_{Base}$.~~

~~For EISA exempt~~[217] ~~GSL bulbs, use the Watts$_{Base}$ value in column (c) in Table 2-87 above. Commonly used EISA exempt bulbs include 3-way bulbs, globes with ≥5" diameter or ≤749 lumens, and candelabra base bulbs with ≤1049 lumens. See EISA legislation for full list of exemptions.~~

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~~Reflector (directional) bulbs fall under legislation different from GSL bulbs. For these bulbs, EDCs can use the manufacturer rated equivalent wattage as printed on the retail packaging, or use the default Watts$_{Base}$ (column (c)) in Table 2-88, below.~~

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[216] ~~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~~

[217] ~~The EISA 2007 standards apply to general service incandescent lamps. 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*.~~

~~Table 2-88: Default Baseline Wattage for Reflector Bulbs~~[218]

| ~~Bulb Type (a)~~ | ~~Incandescent Equivalent (Pre-EISA) (b)~~ | ~~$\text{Watts}_{\text{Base}}$ (Post-EISA) (c)~~ |
|---|---|---|
| ~~PAR20~~ | ~~50~~ | ~~35~~ |
| ~~PAR30~~ | ~~50~~ | ~~35~~ |
| ~~R20~~ | ~~50~~ | ~~45~~ |
| ~~PAR38~~ | ~~60~~ | ~~55~~ |
| ~~BR30~~ | ~~65~~ | ~~EXEMPT~~ |
| ~~BR40~~ | ~~65~~ | ~~EXEMPT~~ |
| ~~ER40~~ | ~~65~~ | ~~EXEMPT~~ |
| ~~BR40~~ | ~~75~~ | ~~65~~ |
| ~~BR30~~ | ~~75~~ | ~~65~~ |
| ~~PAR30~~ | ~~75~~ | ~~55~~ |
| ~~PAR38~~ | ~~75~~ | ~~55~~ |
| ~~R30~~ | ~~75~~ | ~~65~~ |
| ~~R40~~ | ~~75~~ | ~~65~~ |
| ~~PAR38~~ | ~~90~~ | ~~70~~ |
| ~~PAR38~~ | ~~120~~ | ~~70~~ |
| ~~R20~~ | ~~≤ 45~~ | ~~EXEMPT~~ |
| ~~BR30~~ | ~~≤ 50~~ | ~~EXEMPT~~ |
| ~~BR40~~ | ~~≤ 50~~ | ~~EXEMPT~~ |
| ~~ER30~~ | ~~≤ 50~~ | ~~EXEMPT~~ |
| ~~ER40~~ | ~~≤ 50~~ | ~~EXEMPT~~ |

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[218] ~~Based on manufacturer recommended replacements for EISA affected lamps. Manufacturer ratings may differ from the list above, in which case EDCs should default to the manufacturer equivalent rating.~~

~~In the absence of EDC data gathering, the default values for Energy and Demand HVAC Interactive Effects are in Table 2-89 below.~~

**~~Table 2-89: Energy and Demand HVAC Interactive Effects by EDC~~[219]**

| - | ~~$IE_{kWh}$~~ | ~~$IE_{kW}$~~ |
|---|---|---|
| ~~Duquesne~~ | ~~8%~~ | ~~13%~~ |
| ~~FE (MetEd)~~ | ~~-8%~~ | ~~13%~~ |
| ~~FE (Penn Elec)~~ | ~~1%~~ | ~~10%~~ |
| ~~FE (Penn Power)~~ | ~~0%~~ | ~~20%~~ |
| ~~FE (WPP)~~ | ~~-2%~~ | ~~30%~~ |
| ~~PPL~~ | ~~-6%~~ | ~~12%~~ |
| ~~PECO~~ | ~~9%~~ | ~~14%~~ |

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### ~~2.35.5 Measure Life~~

~~Residential LED Measure Life is 14.7 yrs~~[220]~~.~~

---

[219] ~~HVAC Interactive Effects modeled through REM/Rate models, using EDC specific inputs. Values were weighted to the saturation of HVAC equipment and housing types present in each EDC service territory as reported in the Pennsylvania Statewide Residential End-Use and Saturation Study, 2012.~~

[220] ~~All LED bulbs listed on the qualified ENERGY STAR product list have a lifetime of at least 15,000 hours. Assuming 2.8 hours per day usage, this equates to 14.7 years.~~

## ~~2.36~~2.35 Residential Occupancy Sensors

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

### ~~2.36.1~~2.35.1 Algorithms

$\Delta kWh$ = ~~$kW_{controlled}$ x 365~~ $Watts_{controlled}/1000$ x ($RH_{old}$ – $RH_{new}$) x 365

$\Delta kW_{peak}$ = 0

### ~~2.36.2~~2.35.2 Definition of Terms

~~$kW_{controlled}$~~ $Watts_{controlled}$ = 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 2-86~~2-90~~86: Residential Occupancy Sensors Calculations Assumptions**

| Component | Type | Value | Source |
|---|---|---|---|
| ~~$kW_{controlled}$~~$Watts_{controlled}$ | Variable | EDC's Data Gathering | AEPS Application;<br>EDC's Data Gathering |
| $RH_{old}$ | Fixed | 2.8 | 1 |
| $RH_{new}$ | Fixed | 2.0 (70% of $RH_{old}$) | 2 |

**Sources:**

1. Nexus Market Research, "Residential Lighting Markdown Impact Evaluation", Final Report, January 20, 2009. Table 6-1. Reference Section 0: ENERGY STAR Lighting for full citation.
2. Lighting control savings fractions consistent with current programs offered by National Grid, Northeast Utilities, Long Island Power Authority, NYSERDA, and Energy Efficient Vermont

### ~~2.36.3~~2.35.3 Measure Life

The expected measure life is 10 years[221].

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

## ~~2.37~~2.36 Holiday Lights

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| **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.

### ~~2.37.1~~2.36.1 Eligibility

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

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

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

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

**Key assumptions**

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

### ~~2.37.2~~2.36.2 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*

*#Bulbs* = *Number of bulbs per strand*

*#Strands* = *Number of strands of lights per package*

*Hr* = *Annual hours of operation*

**Table 2-87~~2-9187~~: 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 |
| | | Default: 25 per strand | Section 2.38.1: Key Assumptions |
| $\#_{Strands}$ | Variable | Variable | EDC Data Gathering |
| | | Default: 1 strand | Section 2.38.1: Key Assumptions |
| Hr | Fixed | 150 | 1 |

**Sources:**

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

### ~~2.37.3~~2.36.3 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.

### ~~2.37.4~~2.36.4 Measure Life

Measure life is 10 years[222,223].

### ~~2.37.5~~2.36.5 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.

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[222] 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"

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

## ~~2.38~~2.37 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.

### ~~2.38.1~~2.37.1 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.

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

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

### ~~2.38.2~~2.37.2 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$^2$).

~~R = 1/U~~

R = R-value is a measure of resistance to heat flow and is equal to 1/U (Hr-F-ft$^2$/Btu)

$A_{base}$ = Surface area of storage tank prior to adding tank wrap (square feet)[224]

$A_{insul}$ = Surface area of storage tank after addition of tank wrap (square feet)[225].

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[224] Area includes tank sides and top to account for typical wrap coverage.

$\eta_{Elec}$ = *Thermal efficiency of electric heater element*

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

$T_{ambient}$ = *Temperature of ambient air (F).*

*HOU* = *Annual hours of use for water heater tank.*

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

*3412* = *Conversion factor (Btu/kWh)*

The U.S. Department of Energy recommends adding a water heater wrap of at least R-8 to any water heater with an existing R-value less than R-24[226]. The default inputs for the savings algorithms are given in Table 2-88~~Table 2-88Table 2-92~~. 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 2-88~~2-92~~88: Water Heater Tank Wrap – Default Values**

| Component | Type | Value | Source |
|---|---|---|---|
| $R_{base}$ | Variable | Default: ~~12~~8.33; or EDC Data Gathering | 1 |
| $R_{insul}$ | Variable | Default: 20; or EDC Data Gathering | 2 |
| $\eta_{Elec}$ | Fixed | 0.97 | 3 |
| $T_{hot}$ | Fixed | 123 | 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.~~

1. Results and Methodology of the Engineering Analysis for Residential Water Heater Efficiency Standards, PNNL, 1998.
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.

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[225] Ibid.

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

5. 2012 Residential SWE Baseline Study

**Table 2-89~~2-93~~89: Deemed savings by water heater capacity.**

| Capacity (gal) | $R_{base}$ | $R_{insul}$ | $A_{base}$ ($ft^2$)[227] | $A_{insul}$ ($ft^2$)[228] | 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 |

### ~~2.38.3~~2.37.3 Measure Life

The measure life is 7 years[229].

---

[227] 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.

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

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

## ~~2.39~~2.38 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~~2 PM to ~~8~~6 PM peak period.

### 2.38.1 Eligibility

### ~~2.41.2 Eligibility~~

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This protocol documents the energy savings attributed to schedule residential single speed pool pumps to avoid run during the peak hours from ~~noon~~2 PM to ~~8~~6 PM. 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.

### ~~2.41.3~~2.38.2 Algorithms

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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~~of 2 PM to ~~8PM~~6 PM.

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

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

The peak coincident factor, CF, is defined as the average coincident factor during ~~noon and 8~~2 PM to 6 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~~2 PM and ~~8~~6 PM, divided by ~~8~~4.

### ~~2.41.4~~2.38.3 Definition of Terms

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$\Delta hours/day$ = *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 2-90~~Table 2-90Table 2-94~~*

$CF_{pre}$ = *Peak coincident factor of single speed pump from ~~noon~~2 PM to ~~8PM~~6 PM in summer weekday prior to pump rescheduling. This quantity should be inferred from the timer settings*

$CF_{post}$ = *Peak coincident factor of single speed pump from ~~noon~~2 PM to ~~8PM~~6 PM 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 2-90~~2-94~~90: Pool Pump Load Shifting Assumptions**

| Component | Type | Value | Source |
|---|---|---|---|
| ∆hours/day | Fixed | 0 | 2 |
| $kW_{pump}$ | Fixed | Default 1.364 kW or<br>See Table 2-91~~Table 2-91Table 2-95~~ | Table 2-91~~Table 2-91Table 2-95~~ |
| $CF_{pre}$ | Fixed | 0.235 | 3 |
| $CF_{post}$ | Fixed | 0 | 2 |
| $Days_{Operating}$ | Fixed | 100 | 1 |

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**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 2-94~~Table 2-91 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[230]. 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.

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[230] "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>

**Table 2-91~~2-959~~1: Single Speed Pool Pump Specification[231]**

| 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 |

### ~~2.41.5~~2.38.4 Measure Life

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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.

### ~~2.41.6~~2.38.5 Evaluation Protocol

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The most appropriate evaluation protocol for this measure is verification of pool pump run time as well as verification of hours of operation coincident with peak demand.

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[231] 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.

## ~~2.40~~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~~.~~ to replace an existing constant speed pool pump. Second, the variable speed pool pump may be commissioned such that it does not operate in the ~~noon~~2 PM to ~~8~~6 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.

### ~~2.43.1~~2.39.1 Eligibility

To qualify for the load shifting rebate, the pumps are required to be off during the hours of ~~noon~~2 PM to ~~8~~6 PM weekdays. This practice results in additional demand reductions.

### ~~2.43.2~~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:

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

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

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

The peak coincident factor, CF, is defined as the average coincident factor during ~~noon and 8~~2 PM to 6 PM on summer weekdays. Ideally, the demand coincidence factor for the supplanted

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### ~~2.43.3~~2.39.3 Definition of Terms

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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.*

$kW_{SS}$ = *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.*

$kW_{basepeak}$ = *Peak demand of single speed pump*

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

$kW_{VFD\ peak}$ = *Peak demand of VFD pump.*

$CF_{SS}$ = *Peak coincident factor of single speed pump from ~~noon~~2 PM to ~~8~~6 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~~2 PM to ~~8~~6 PM in summer weekday. This quantity should be inferred from the new timer settings.*

**Table 2-92~~2-96~~92: 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 |
| $kW_{SS}$ | Variable | EDC Data Gathering<br>Default: 1.364 W or See Table 2-93~~Table 2-93~~~~Table 2-97~~ | 1 and ~~Table 2-95~~Table 2-91 or Table 2-93~~Table 2-93~~~~Table 2-97~~ |
| $kW_{VFD}$ | Variable | EDC Data Gathering | EDC Data Gathering |

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|---|---|---|---|
| $CF_{SS}$ | Variable | Default: 0.235 | 3 |
| $CF_{VFD}$ | 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 2-93~~Table 2-93Table 2-97~~ 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[232]. 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 2-93~~2-97~~93: Single Speed Pool Pump Specification[233]

| 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 |

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[232] "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>

[233] 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.

**Electric Demand and Pump Flow Rate**

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

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

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 Default Savings

~~2.43.4~~ The energy savings and demand reductions are prescriptive according to the above formulae. ~~Deemed Savings~~

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

### ~~2.43.5~~2.39.5 Measure Life

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According to an October 2008 report for the CA Database for Energy Efficiency Resources[234], a variable speed drive's lifespan is 10 years.

### ~~2.43.6~~2.39.6 Evaluation Protocol

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

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

## ~~2.41~~2.40 Duct Insulation and Sealing

This measure describes evaluating the savings associated with performing duct sealing using mastic sealant or metal tape to the distribution system of homes with either central air conditioning or a ducted heating system.

Two methodologies for estimating the savings ~~associate from~~associated with sealing ~~the~~ ducts are provided. The first (preferred method) requires the use of a blower door and the second requires careful inspection of the duct work.

1. ***Modified Blower Door Subtraction*** – this technique is described in detail on p.44 of the Energy Conservatory Blower Door Manual; http://www.energyconservatory.com/~~download/bdmanual~~sites/default/files/documents/mod_3-4_dg700_-_new_flow_rings_-_cr_-_tpt_-_no_fr_switch_manual_ce_0.pdf
2. ***Evaluation of Distribution Efficiency*** – this methodology requires the evaluation of three duct characteristics below, and use of the Building Performance Institutes 'Distribution Efficiency Look-Up Table; http://www.bpi.org/files/pdf/DistributionEfficiencyTable-BlueSheet.pdf
    a. Percentage of duct work found within the conditioned space
    b. Duct leakage evaluation
    c. Duct insulation evaluation

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### ~~2.41.1~~2.40.1 Eligibility

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

### ~~2.41.2~~2.40.2 Algorithms

***Methodology 1: Modified Blower Door Subtraction***

a) Determine Duct Leakage rate before and after performing duct sealing

$$CFM50DL = (CFM50Whole\ House – CFM50Envelope\ Only) \times SCF$$

b) Calculate duct leakage reduction, convert to CFM25DL and factor in Supply and Return Loss Factors

$$\Delta CFM25DL = (Pre\ CFM50DL – Post\ CFM50DL) \times Conv \times (SLF + RLF)$$

c) Calculate Energy Savings

$$\Delta kWhcooling = ((\Delta CFM25DL)/ ((Capcool/12,000) \times TCFM)) \times EFLHcool \times Capcool) / 1000 / SEER$$

$$\Delta kWhheating = (((\Delta CFM25DL / ((Capheat/12,000) \times TCFM)) \times EFLHheat \times Capheat) / COP / 3412$$

***Methodology 2: Evaluation of Distribution Efficiency***

Determine Distribution Efficiency by evaluating duct system before and after duct sealing using Building Performance Institute "Distribution Efficiency Look-Up Table"

$$\Delta kWhcooling = ((DEafter - DEbefore)/ DEafter)) \times EFLHcool \times Capcool)/1000 / SEER$$

$$\Delta kWhheating = ((DEafter - DEbefore)/ DEafter)) \times EFLHheat \times Capheat ) / COP / 3412$$

**Summer Coincident Peak Demand Savings**

$$\Delta kW = \Delta kWhcooling/ EFLHcool \times CF$$

### ~~2.41.3~~2.40.3 Definition of Terms

*CF* = *Demand Coincidence Factor (See Section 1.4) for central AC systems*

*CFM50DL* = *Duct leakage at 50 Pascal pressure differential*

*ΔCFM25DL* = *Duct Leakage Reduction in CFM25*

$CFM_{50Whole\ House}$ = *Standard Blower Door test result finding Cubic Feet per Minute at 50 Pascal pressure differential*

$CFM_{50Envelope\ Only}$ = *Blower Door test result finding Cubic Feet per Minute at 50 Pascal pressure differential with all supply and return registers sealed.*

*SCF* = *Subtraction Correction Factor to account for underestimation of duct leakage due to connections between the duct system and the home. Determined by measuring pressure in duct system with registers sealed, and using look up table provided by Energy Conservatory.*

*Conv* = *Conversion factor from CFM50 to CFM25*

*SLF* = *Supply Loss Factor (% leaks sealed located in Supply ducts x 1)*

*RLF* = *Return Loss Factor (Portion of % leaks sealed located in Return ducts x 0.5)*

$\Delta kWh_{cooling}$ = *Cooling Energy Savings*

$\Delta kWh_{heating}$ = *Heating Energy Savings*

*ΔkW* = *Summer Coincident Peak Demand Savings*

$Cap_{cool}$ = *Capacity of Air Cooling System (Btuh)*

$Cap_{heat}$ = *Capacity of heating system (Btuh)*

$EFLH_{cool}$ = *Cooling equivalent full load hours*

$SEER$ = *Efficiency of cooling equipment*

$EFLH_{heat}$ = *Heating equivalent full load hours*

$TCFM$ = *Conversion from tons of cooling to CFM*

$COP$ = *Efficiency of Heating Equipment*

$DE_{after}$ = *Distribution energy after duct sealing*

$DE_{before}$ = *Distribution energy before duct sealing*

**Table 2-94~~2-98~~94: Duct Sealing – Values and References**

| Term | Type | Value | Source |
|---|---|---|---|
| CF | Fixed | 0.70 | Table 2-1 |
| $CFM50_{Whole\ House}$ | Variable | EDC Data Gathering | EDC Data Gathering |
| $CFM50_{Envelope\ Only}$ | Variable | EDC Data Gathering | EDC Data Gathering |
| SCF | Variable | Variable | ~~5, 8~~ 7, 10 |
| Conv | Fixed | 0.64 | 2 |
| SLF | Variable | Default = 0.5 or EDC Data Gathering | ~~3~~4, EDC Data Gathering |
| RLF | Variable | Default = 0.25 or EDC Data Gathering | ~~4~~6, EDC Data Gathering |
| Cap | Variable | EDC Data Gathering | EDC Data Gathering |
| TCFM | Fixed | 400 | ~~5~~7 |
| SEER | Variable | Default 10 SEER or EDC Data Gathering | ~~6~~8, EDC Data Gathering |
| COP | Variable | Default 2.0 COP or EDC Data Gathering | ~~6~~8, EDC Data Gathering |
| $EFLH_{cool}$ | Default | Allentown Cooling = 487 Hours<br>Erie Cooling = 389 Hours<br>Harrisburg Cooling = 551 Hours<br>Philadelphia Cooling = 591 Hours<br>Pittsburgh Cooling = 432 Hours<br>Scranton Cooling = 417 Hours<br>Williamsport Cooling = 422 | Table 2-1 |

| Term | Type | Value | Source |
|---|---|---|---|
| | | Hours | |
| | Optional | An EDC can either use the Alternate EFLH Table or estimate its own EFLH based on customer billing data analysis. | Alternate EFLH Table (See Section 2.1.3, Table 2-2), EDC Data Gathering |
| $EFLH_{heat}$ | Default | Allentown Heating = 1,193 Hours<br>Erie Heating = 1,349 Hours<br>Harrisburg Heating = 1,103 Hours<br>Philadelphia Heating = 1,060 Hours<br>Pittsburgh Heating = 1,209 Hours<br>Scranton Heating = 1,296 Hours<br>Williamsport Heating = 1,251 Hours | Table 2-1 |
| | Optional | An EDC can either use the Alternate EFLH Table or estimate its own EFLH based on customer billing data analysis. | Alternate EFLH Table (See Section 2.1.3, Table 2-3), EDC Data Gathering |
| $DE_{after}$ | Variable | Variable | ~~5,~~ 7, 9 |
| $DE_{before}$ | Variable | Variable | ~~5,~~ 7, 9 |

### Sources

1. Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007. ~~http://neep.org/uploads/EMV%20Forum/EMV%20Studies/measure_life_GDS%5B1%5D.pdf~~http://www.neep.org/Assets/uploads/files/emv/emv-library/measure_life_GDS%5B1%5D.pdf
2. 25 Pascals is the standard assumption for typical pressures experienced in the duct system under normal operating conditions. To convert CFM50 to CFM25 you multiply by 0.64 (inverse of the “Can’t Reach Fifty” factor for CFM25; see Energy Conservatory Blower Door Manual).
3. Assumes that for each percent of supply air loss there is one percent annual energy penalty. This assumes supply side leaks are direct losses to the outside and are not recaptured back to the house. This could be adjusted downward to reflect regain of usable energy to the house from duct leaks. For example, during the winter some of the

energy lost from supply leaks in a crawlspace will probably be regained back to the house (sometimes 1/2 or more may be regained). More information provided in "Appendix E Estimating HVAC System Loss From Duct Airtightness Measurements" from http://www.energyconservatory.com/download/dbmanual.pdf ~~Assumes 50% of leaks are in supply ducts.~~

~~4~~4. Assumes 50% of leaks are in supply ducts (Illinois Statewide TRM 2013).

5. Assumes that for each percent of return air loss there is a half percent annual energy penalty. Note that this assumes that return leaks contribute less to energy losses than do supply leaks. This value could be adjusted upward if there was reason to suspect that the return leaks contribute significantly more energy loss than "average" (e.g. pulling return air from a super-heated attic), or can be adjusted downward to represent significantly less energy loss (e.g. pulling return air from a moderate temperature crawl space) . More information provided in "Appendix E Estimating HVAC System Loss from Duct Airtightness Measurements" from http://www.energyconservatory.com/download/dbmanual.pdf ~~Assumes 50% of leaks are in return ducts.~~

~~5~~6. Assumes 50% of leaks are in return ducts (Illinois Statewide TRM 2013).

7. Illinois Statewide TRM, 2013, Section 5.3.4

~~6~~8. Minimum Federal Standards for new Central Air Conditioners and Air Source Heat Pumps between 1990 and 2006 based on VEIC estimates.

~~7~~9. Building Performance Institute, Distribution Efficiency Table, http://www.bpi.org/files/pdf/DistributionEfficiencyTable-BlueSheet.pdf

~~7~~10. http://www.bpi.org/files/pdf/DistributionEfficiencyTable-BlueSheet.pdf~~http://www.energyconservatory.com/download/bdmanual.pdf~~

http://www.energyconservatory.com/sites/default/files/documents/mod_3-4_dg700_-_new_flow_rings_-_cr_-_tpt_-_no_fr_switch_manual_ce_0.pdf

### ~~2.41.4~~2.40.4 Measure Life

The assumed lifetime of this measure is 20 years[235]. The actual duct sealing measure cost should be used.

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[235] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007. ~~http://neep.org/uploads/EMV%20Forum/EMV%20Studies/measure_life_GDS%5B1%5D.pdf~~http://www.neep.org/Assets/uploads/files/emv/emv-library/measure_life_GDS%5B1%5D.pdf

## ~~2.42~~2.41 Water Heater Temperature Setback

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| **Measure Name** | **Water Heater Temperature Setback** |
|---|---|
| **Target Sector** | Residential Establishments |
| **Measure Unit** | Water Heater Temperature |
| **Unit Energy Savings** | ~~105 kWh/yr for storage water heater~~<br>~~48 kWh/yr for heat pump water heater~~<br>Variable |
| **Unit Peak Demand Reduction** | ~~0.010 kW for storage water heater~~<br>~~0.0044kW for heat pump water heater~~<br>Variable |
| **Measure Life** | 4 years |

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

### ~~2.42.1~~2.41.1 Eligibility

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This protocol documents the energy savings attributed to ~~turning down~~ reducing the electric or heat pump water heater temperature ~~to 120ºF.~~setpoint. The target sector primarily consists of single-family residences.

### ~~2.42.2~~2.41.2 Algorithms

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

~~$\Delta kWh/yr = \frac{1}{EF\_} x\ 0.6\ x\ CAP + \frac{\left\{\left(\frac{1}{EF\_}\right)\times\left(HW\times 365\times 8.3\frac{lb}{gal}\times(T_{hot\_i}-T_{hot\_f})\right)\right\}}{3413\frac{Btu}{kWh}}$~~

$$\Delta\, kWh/yr \; = \frac{A_{tank} \times \left(T_{hot\ i} - T_{hot\ f}\right) \times 8760\frac{hrs}{yr}}{R_{tank} \times \eta_{elec} \times 3412\frac{Btu}{kWh}} + \frac{V_{HW} \times \left(8.3\frac{lb}{gal}\right) \times \left(365\frac{days}{yr}\right) \times \left(1\frac{Btu}{°F \cdot lb}\right) \times \left(T_{hot\ i} - T_{hot\ f}\right)}{\left(3412\frac{Btu}{kWh}\right) \times EF_{WH}}$$

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~~2 PM to 6 PM on summer weekdays to the total annual energy usage.

~~$\Delta kW_{peak}$ = EnergyToDemandFactor × Energy Savings~~

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

$\Delta kW_{peak}$ = *EnergyToDemandFactor × Energy Savings*

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The Energy to Demand Factor is defined below:

$$EnergyToDemandFactor \quad = \frac{Average\ Usage_{Summer\ WD\ \cancel{Noon-8}2PM-\ 6\ PM}}{Annual\ Energy\ Usage}$$

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The ratio of the average energy usage during ~~noon and 8~~2 PM ~~on summer weekdays~~ to 6 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[236]. The factor is constructed as follows:

~~the total annual energy usage is taken from load shape data collected for a water heater and HVAC demand response study for PJM[237]. The factor is constructed as follows:~~

1) Obtain the average kW, as monitored for 82 water heaters in PJM territory[238], 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~~2 PM to ~~8~~6 PM on summer days from the same data.

3) The average ~~noon~~2 PM to ~~8~~6 PM demand is converted to average *weekday* ~~noon~~2 PM to ~~8~~6 PM demand through comparison of weekday and weekend monitored loads from the same PJM study[239].

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[236] 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.ashxhttp://www.pjm.com/~/media/committees-groups/working-groups/lrwg/20070301/20070301-pjm-deemed-savings-report.ashx

~~[237] 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~~

[238] 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) The ratio of the average weekday ~~noon~~2 PM to ~~8~~6 PM energy demand to the annual energy usage obtained in step 1. The resulting number~~,~~ 0.~~00009172~~00008294, is the *EnergyToDemandFactor*.

The load shapes (fractions of annual energy usage that occur within each hour) during summer week days are plotted in ~~Figure 2-11~~Figure 2-11 below.

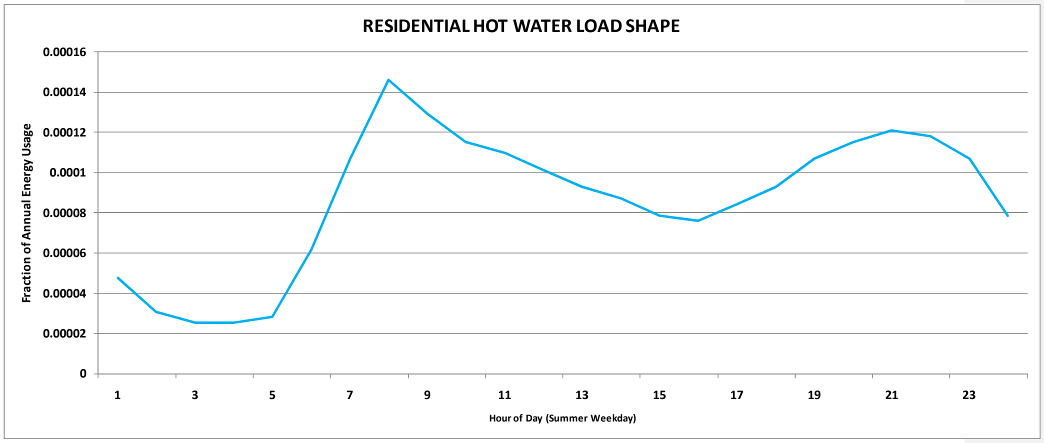

**Figure 2-11: Load shapes for hot water in residential buildings taken from a PJM study.**

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[239] 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.

### ~~2.42.3~~2.41.3 Definition of Terms

The parameters in the above equation are listed in ~~Table 2-99 below. Reduced tank losses are based on heat loss calculation for a 50 gallon water heater[240] dimensions[241] and average of base (R-8.33) and most efficient (R-24) tank insulation levels[242,243]. Estimated tank loss default is 30 kWh for a 50 gallon electric hot water heater~~Table 2-95 below. .

**Table 2-95~~2-99~~95~~: Efficient Electric~~: Water Heater ~~Calculation~~Temperature Setback Assumptions**

| Component | Type | Values | Source |
|---|---|---|---|
| ~~EF,~~ $EF_{WH}$, Energy Factor of water heater | Variable | EDC data collection | 1 |
| | Default: ~~Variable~~ | Electric Storage – 0.904<br>HPWH – 2.0 | |
| ~~CAP, Hot~~$R_{tank}$, R value of water heater ~~capacity~~tank, $\frac{hr\cdot°F\cdot ft^2}{Btu}$ | Variable | EDC ~~Data Gathering~~data collection | |
| | | Default: 8.33[244] | |
| $A_{tank}$, Surface Area of water heater tank, $ft^2$ | Variable | EDC data collection | |
| | | Default: ~~50 gallon~~24.99 $ft^2$ | ~~10~~ 50 gal. value in Table 2-93, Section 2.38 |
| $\eta_{elec}$, Thermal efficiency of electric heater element (equiv. to COP for HPWH) | Fixed | Electric Storage- 0.97<br>HPWH- 2.1 | 2, 3 |
| ~~HW , Hot~~ $V_{HW}$ , Volume of hot water used per day, in gallons | Fixed | 7.32 ~~gallon~~gallons/day | ~~2,~~ 4, 5, 6, 7, 8~~, 9~~ |
| $T_{hot\_i}$, Temperature setpoint of ~~hot~~ water heater initially | Variable | EDC data collection | ~~3~~ 9 |
| | | Default: 130°F | |
| $T_{hot\_f}$, Temperature ~~of hot~~setpoint water heater after setback | ~~Fixed~~ Variable | ~~120 °F~~EDC data collection | ~~4~~ 10 |
| | | Default: 123 °F | |
| Energy To Demand Factor | Fixed | 0.~~00009172~~00008294 | ~~5~~ 11-13 |

**Sources:**

1. Federal Standards are 0.97 -0.00132 x Rated Storage in Gallons. For a 50-gallon tank this is 0.904. "Energy Conservation Program: Energy Conservation Standards for

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~~[240] Section 2.3, Efficient Electric Water Heaters~~

~~[241] Lowes, 50 gallon electric water heater tank dimensions~~

~~[242] Results and Methodology of the Engineering Analysis for Residential Water Heater Efficiency Standards, PNNL, 1998~~

~~[243] Energy Star Appliance Calculator~~

[244] Results and Methodology of the Engineering Analysis for Residential Water Heater Efficiency Standards, PNNL, 1998

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Residential Water Heaters, Direct Heating Equipment, and Pool Heaters" US Dept of Energy Docket Number: EE–2006–BT-STD–0129, p. 30

2. New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs. October 15, 2010. Prepared by New York Advisory Contractor Team.

3. NEEA Heat Pump Water Heater Field Study Report. Prepared by Fluid Market Strategies. October 22, 2013. http://neea.org/docs/default-source/reports/heat-pump-water-heater-field-study-report.pdf?sfvrsn=5

~~2.~~4. Daily Usage based on AWWA Research Foundation, 1998, Residential End Uses of Water, found in EPA's Water Sense guide: http://www.epa.gov/WaterSense/docs/home_suppstat508.pdf Clothes washer hot water use per capita per day adjusted for current water use per load and using PA Census Data. Hot water comprises 28% of total water in clothes washer load.

~~3. Engineering assumption~~

~~4. Many states have plumbing codes that limit shower and bathtub water temperature to 120 °F.~~

~~5.~~2. ~~Mid-Atlantic TRM, footnote #24~~

~~6.~~5. Federal minimum Water Factor standards (9.5) and Energy Star minimum Water Factor standards (6.0) for clothes washers, Section 2.26, "Energy Star Clothes Washers".

~~7.~~6. Average capacity of base (3.19 cu. ft.) and energy efficient (3.64 cu. ft.) clothes washers, Table 2-52, Section 2.26.

~~8.~~7. Households with Energy Star Clothes Washers 2009 (36%), "Energy Star Product Retrospective: Clothes Washers", 2012. Used to determine current weighted average gallons per load (27.3 gal)

~~9.~~8. 2007-2011 U.S. Census Data for Pennsylvania (2.47 persons per household average).

9. Engineering assumption

10. Pennsylvania Statewide Residential End-Use and Saturation Study, 2012, page 42.9.

11. 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

12. 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

13. 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.

### ~~2.43.7~~2.41.4 Deemed Savings

~~10.~~ The energy savings and demand reductions are prescriptive according to the above formulae. ~~Section 2.3, Efficient Electric Water Heaters~~

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### ~~2.42.4 Deemed Savings~~

~~The deemed savings for the setback of water heater temperature with is listed below, based on Energy Factor.~~

However, some values for common configurations are provided in table 2-100 below.

**Table 2-96~~2-100~~96: Energy Savings and Demand Reductions**

| ~~EF~~ | ~~Energy Savings (kWh/yr)~~ | ~~Demand Reduction (kW)~~ |
|---|---|---|
| ~~0.904~~ | ~~105~~ | ~~0.010~~ |
| ~~2.0~~ | ~~48~~ | ~~0.0044~~ |

| Type | Tank Size (gallons) | $R_{tank}$ | $A_{tank}$ | $T_{hot\ i} - T_{hot\ f}$ (˚F) | $\eta_{elec}$ | $EF_{WH}$ | Energy Savings ($\Delta$ kWh/yr) | Demand Reduction ($\Delta KW_{peak}$) |
|---|---|---|---|---|---|---|---|---|
| Electric Storage | 50 | 8.33 | 24.99 | 10 | 0.97 | 0.904 | 151 | 0.0125 |
| Electric Storage | 50 | 8.33 | 24.99 | 5 | 0.97 | 0.904 | 76 | 0.0063 |
| HPWH | 50 | 8.33 | 24.99 | 10 | 2.1 | 2.0 | 69 | 0.0057 |
| HPWH | 50 | 8.33 | 24.99 | 5 | 2.1 | 2.0 | 35 | 0.0029 |

### ~~2.42.5~~2.41.5 Measure Life

According to an October 2008 report for the CA Database for Energy Efficiency Resources, an electric water heater's lifespan is **4 years**[245]

### ~~2.42.6~~2.41.6 Evaluation Protocols

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

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[245] GDS Associates, Inc., Measure Life Report Prepared for The New England State program Working Group (SPWG), June 2007

## 2.42 ENERGY STAR Water Coolers

| **Measure Name** | **ENERGY STAR Water Coolers** |
|---|---|
| **Target Sector** | Residential Establishments |
| **Measure Unit** | Water Cooler |
| **Unit Energy Savings** | Cold Water Only: 47 kWh<br>Hot/Cold Water: 361 kWh |
| **Unit Peak Demand Reduction** | 0.0232 kW |
| **Measure Life** | 10 years |

## ~~2.43~~

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

### 2.42.1 Eligibility

In order for this measure protocol to apply, the high-efficiency equipment must meet the ENERGY STAR efficiency criteria: Cold Only & Cook & Cold Units ≤0.16 kW-hours/day, Hot & Cold Units ≤1.20 kW-hours/day.

### ~~2.43.1~~2.42.2 Algorithms

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

*Total Savings* =*Number of Water Coolers x Savings per Water Cooler*

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

Per unit energy and demand savings algorithms:

$$\Delta kWh = ESav_{WC}$$

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

### ~~2.43.2~~2.42.3 Definition of Terms

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$ESav_{WC}$ = *Electricity savings per purchased ENERGY STAR water cooler.*

$DSav_{WC}$ = *Summer demand savings per purchased ENERGY STAR water cooler.*

$CF_{WC}$ = *The coincidence of average water cooler demand to summer system peak*

**Table 2-97~~2-10197~~: ENERGY STAR Water Coolers – References**

| Component | Type | Value | Sources |
|---|---|---|---|
| $ESav_{WC}$ | Fixed | Water Cooler – Cold Water Only: 47 kWh<br>Water Cooler – Hot/Cold Water~~ Only~~: 361 kWh | 1 |
| $DSav_{WC}$ | Fixed | ~~0.0232 kW~~0.0232 kW (Note, this demand reduction number is the demand savings at the time of the system pleak load) | 2 |
| ~~$CF_{WC}$~~ | ~~Fixed~~ | ~~1.0~~ | ~~3~~ |

**Sources:**

1. ENERGY STAR Water Coolers Savings Calculator (Calculator updated: May 2012). Default values were used.
2. Average demand savings are estimated by taking an average of the energy savings values for both types of water coolers and dividing it by 8,760 hours usage.

~~3.~~1. ~~Coincidence factors already embedded in summer peak demand reduction estimates.~~

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### ~~2.43.3~~2.42.4 Measure Life

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The measure life for an ENERGY STAR Water Coolers is 10 years[246].

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

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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. 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 Residential 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

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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 annualized energy savings and peak demand savings is based on algorithms through the stipulation of key variables (i.e. Coincidence Factor, Interactive Factor and Hours of Use) 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 Appendix F: Eligibility Requirements for Solid State Lighting Products in Commercial and Industrial Applications~~Appendix F~~~~Appendix F: Eligibility Requirements for Solid State Lighting Products in Commercial and Industrial Applications~~ for specific eligibility requirements.

### 3.2.2 Algorithms

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For all lighting fixture improvements (without control improvements), the following algorithms apply:

$\Delta kWh$ = $(kW_{base} - kW_{EE}) * [HOU * (1 - SVG_{base}) * (1+IF_{energy})]$

$\Delta kW_{peak}$ = $(kW_{base} - kW_{EE}) * [CF * (1 - SVG_{base}) * (1+IF_{demand})]$ ~~* CF~~

For all lighting control improvements (without fixture improvements), the following algorithms apply:

$\Delta kWh$ = $kW_{controlled} * HOU * (SVG_{EE} - SVG_{base}) * (1+IF_{energy})$

$\Delta kW_{peak}$ = $kW_{controlled} * (SVG_{EE} - SVG_{base}) * (1+IF_{demand}) * CF$

For new construction and facility renovation projects, annualized energy savings and peak demand 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.

### 3.2.3 Definition of Terms

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$\Delta kW$ = 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.

$kW_{controlled}$ = *Total lighting load connected to the new control in kilowatts*[247]*. Savings is per control. The total connected load per control should be collected from the customer or the default values*[248] *shown in Table 3-8 should be used.*

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

*HOU* = *Hours of Use – the average annual operating hours of the baseline lighting equipment (before the lighting controls are in place), 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.*

$SVG_{EE}$ = *Savings factor for new lighting control (percent of time the lights are off).*

$SVG_{base}$ = *Savings factor for existing lighting control (percent of time the lights are off), typically manual switch.*

### 3.2.4 Baseline Assumptions

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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

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[247] Connected load is calculated by multiplying fixture wattage with total number of fixtures foreach control.

[248] Note that the PA TRM contains savings factors for thirteen lighting control technologies (Table 3-7); however, default values are presented only for occupancy sensor control type. Default values for other control technologies will be added in the future TRM updates if information is available.

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

### 3.2.5 Detailed Inventory Form

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

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

For projects having less than 20kW in connected load savings, a detailed inventory is not required but information sufficient to validate savings according to the algorithm in Section 3.2.2 must be included in the documentation. This includes identification of baseline equipment utilized for quantifying kW base. Appendix C contains a prescriptive lighting table, which can estimate savings for small, simple projects under 20kW in savings provided that the user self-certifies the baseline condition, and information on pre-installation conditions include, at a minimum, lamp type, lamp wattage, ballast type and fixture configuration (2 lamp, 4 lamp, etc.).

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

For projects having a connected load savings of 20 kW or higher, a detailed inventory is required. Using the algorithms in Section 3.2.2, ∆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 (HOU), 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, HOU, CF and IF values for each line entry. The inventory will also specify the location and number of fixtures for reference and validation.

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

Baseline and retrofit fixture wattages are determined by selecting the appropriate fixture code from the "Wattage Table" sheet. The "Fixture Code Locator" sheet can be used to find the appropriate code for a particular lamp-ballast combination[249]. Actual wattages of fixtures determined by manufacturer's equipment specification sheets or other independent sources may not be used unless (1) the manufacturer's cut sheet indicates that the difference in delta-watts of fixture

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[249] 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.

wattages (i.e. difference in delta watts of baseline and “actual” installed efficient fixture wattage and delta watts of baseline and nearest matching efficient fixture in standard wattage table of appendix C) is more than 10%[250] or (2) the corresponding fixture code is not listed in the Standard Wattage Table. In these cases, alternate wattages for lamp-ballast combinations can be inputted using the “User Input” sheet of Appendix C. Documentation supporting the alternate wattages must be provided in the form of manufacturer provided specification sheets or other industry accepted sources (e.g. ENERGY STAR listing, Design Lights Consortium listing). It must cite test data performed under standard ANSI procedures. These exceptions will be used as the basis for periodically updating the Standard Wattage Table to better reflect market conditions and more accurately represent savings.

Some lighting contractors may have developed in-house lighting inventory forms that are used to determine preliminary estimates of projects. In order to ensure standardization of all lighting projects, Appendix C must still be used. However, if a third-party lighting inventory form is provided, entries to Appendix C may be condensed into groups sharing common baseline fixtures, retrofit fixtures, space type, building type, and controls. Whereas Appendix C separates fixtures by location to facilitate evaluation and audit activities, third-party forms can serve that specific function if provided.

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

### 3.2.6 Quantifying Annual Hours of Operation

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- **Usage Groups and Annual Hours of Use**

**Projects with connected load savings less than 20 kW**
For whole facility lighting projects with connected load savings less than 20 kW, apply stipulated whole building hours shown in Table 3-6. If the project cannot be described by the categories listed in Table 3-6, or the project retrofitted only a portion of a facility’s lighting system for which whole building hours of use would not be appropriate, select the “other” category and determine hours using facility staff interviews, posted schedules, or metered data.

For whole facility lighting projects where the facility’s actual lighting hours deviates by more than 10% from Table 3-4 hours for the appropriate building type, use of the “other” category may be used at the discretion of the EDC’s implementation and evaluation contractors. If this option is chosen, EDC implementation and evaluation contractors should apply this methodology consistently throughout a program year for all projects to which it pertains.

For projects using the “other” category, “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. Where usage groups are used, fixtures should be separated into "usage groups" that exhibit similar usage patterns. Use of usage groups may be subject to SWE review. Annual hours of use values should be estimated for each group using facility staff interviews, posted schedules, building monitoring system (BMS), or metered data.

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

**Projects with connected load savings of 20 kW or higher**
For projects with connected load savings of 20 kW or higher, "usage groups" must be considered and used in place of stipulated whole building hours where possible. Fixtures should be separated into "usage groups" that exhibit similar usage patterns. Annual hours of use values should be estimated for each group using facility staff interviews, posted schedules, building monitoring system (BMS), or metered data.

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

- **Metering**[251]

**Projects with savings below 500,000 kWh**
Metering is encouraged for projects with expected savings below 500,000 kWh but have 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 completed by the implementation contractor maybe leveraged by the evaluation contractor, subject to a reasonableness review. Sampling methodologies within a site are to be either discerned by the EDC evaluation contractor based on the characteristics of the facility in question or performed consistent with guidance the EDC EM&V contractor provides.

**Projects with savings of 500,000 kWh or higher**
For projects with expected savings of 500,000 kWh or higher, metering is required[252] but trend data from BMS is an acceptable substitute. 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 either discerned by the EDC evaluation contractor and communicated to implementation contractors based on the characteristics of the facility in question~~.~~ or performed consistent with guidance the EDC EM&V contractor provides.

When BMS data is used as a method of obtaining customer-specific data in lieu of metering, the following guidelines should be followed:

- Care should be taken with respect to BMS data, since the programmed schedule may not reflect regular hours of long unscheduled overrides of the lighting system, such as nightly cleaning in office buildings, and may not reflect how the lights were actually used, but only the times of day the common area lighting is commanded on and off by the BMS.
- The BMS trends should represent the actual status of the lights (not just the command sent to the lights), and the ICSP and EC are required to demonstrate that the BMS system is functioning as expected, prior to relying on the data for evaluation purposes.
- The BMS data utilized should be specific to the lighting systems, and should be required to be representative of the building areas included in the lighting project.

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[251] The exact variables that should be determined using metering is shown in Table 3-8 of this 2014 TRM.

[252] The Commission allows the EDCs to use alternative methods for obtaining customer-sepcific data where customer processes do not support metering. The EDCs are required to provide supporting documentation to the SWE for review if there are any such exceptions.

### 3.2.7 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 baseline demand (kWbase) and the new fixtures' wattages as the post-installation demand (kWee). Pursuant to ASHRAE 90.1-2007, the interior lighting baseline is calculated using either the Building Area Method~~[253]~~[254] as shown in Table 3-1, or the Space-by-Space Method~~[255]~~[256] as shown in Table 3-2~~Table 3-2~~. For exterior lighting, the baseline is calculated using the Baseline Exterior Lighting Power Densities~~257~~[258] as shown in

Table 3-3~~Table 3-3~~. The new fixture wattages are specified in the Lighting Audit and Design Tool shown in Appendix C.

CF and IF values are the same as those shown in Table 3-6 and Table 3-7. HOU shall be determined in accordance with Section 3.2.6.

HOU and CF values for dusk-to-dawn lighting are the same as those shown in Table 3-6 unless shorter hours are required by ASHRAE or the fixtures are demonstrated to operate longer hours (e.g. for signage or shading in a parking garage).

Appendix E, a Microsoft Excel inventory form was developed to automate the calculation of energy and demand impacts for new construction lighting projects, based on a series of entries by the user defining key characteristics of the new construction project. The EDCs' implementation and evaluation contractors are allowed to use this tool as an option to simplify their lighting application forms. Appendix C must be used separately to calculate savings for measures other than lighting fixture installs such as control measures for NC lighting projects.

The calculator contains separate "Lighting Forms" for interior and exterior applications. Each lighting form, contains several tables with detailed line-by-line inventory incorporating variables required to calculate savings. The key variables required to calculate savings include building/space type, building size (gross lighted area), lighting power density (LPD), quantity and type of fixtures installed, hours of use (HOU), coincidence factors (CF) or interactive factors (IF).

The 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[259]. Actual wattages of fixtures determined by manufacturer's equipment specification sheets or other independent sources may not be used unless (1) the manufacturer's cut sheet indicates that the difference in delta-watts of fixture wattages (i.e. difference in delta watts of baseline and "actual" installed efficient fixture wattage and delta watts of baseline and nearest matching efficient fixture in standard wattage table of appendix C) is more

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~~[253] ASHRAE 90.1-2007, Table 9.5.1 – Building Area Method~~

[254] ASHRAE 90.1-2007, Table 9.5.1 – Building Area Method

~~[255] ASHRAE 90.1-2007, Table 9.6.1 – Space-by-Space Method~~

[256] ASHRAE 90.1-2007, Table 9.6.1 – Space-by-Space Method

~~[257] ASHRAE 90.1-2007, Table 9.4.5 – Baseline Exterior Lighting Power Densities~~

[258] ASHRAE 90.1-2007, Table 9.4.5 – Baseline Exterior Lighting Power Densities

[259] 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.

than 10%[260] 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 separate “User Input” sheets for interior and exterior applications. 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.

Appendix E 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 the Appendix E.

**Table 3-13~~-1~~: Lighting Power Densities from ASHRAE 90.1-2007 Building Area Method[261]**

| Building Area Type[262] | LPD (W/ft2) | Building Area Type | LPD (W/ft2) |
|---|---|---|---|
| Automotive facility | 0.9 | Multifamily | 0.7 |
| Convention center | 1.2 | Museum | 1.1 |
| Courthouse | 1.2 | Office | 1.0 |
| Dining: bar lounge/leisure | 1.3 | Parking garage | 0.3 |
| Dining: cafeteria/fast food | 1.4 | Penitentiary | 1.0 |
| Dining: family | 1.6 | Performing arts theater | 1.6 |
| Dormitory | 1.0 | Police/fire station | 1.0 |
| Exercise center | 1.0 | Post office | 1.1 |
| Gymnasium | 1.1 | Religious building | 1.3 |
| Health-care clinic | 1.0 | Retail | 1.5 |
| Hospital | 1.2 | School/university | 1.2 |
| Hotel | 1.0 | Sports arena | 1.1 |
| Library | 1.3 | Town hall | 1.1 |
| Manufacturing facility | 1.3 | Transportation | 1.0 |
| Motel | 1.0 | Warehouse | 0.8 |
| Motion picture theater | 1.2 | Workshop | 1.4 |

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[260] This value was agreed upon by the Technical Working Group convened to discuss updates to the TRM. This value is subject to adjustment based on implementation feedback during ~~PY3 and PY4~~PY1 in Phase II.

[261] ASHRAE 90.1-2007, “Table 9.5.1 Lighting Power Densities Using the Building Area Method.”

[262] In cases where both a common space type and a building specific type are listed, the building specific space type shall apply.

### Table 3-2~~3-2~~: Lighting Power Densities from ASHRAE 90.1-2007 Space-by-Space Method[263]

| **Common Space Type[264]** | **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 |

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[263] ASHRAE 90.1-2007, "Table 9.6.1 Lighting Power Densities Using the Space-by-Space Method."

[264] In cases where both a common space type and a building specific type are listed, the building specific space type shall apply.

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| **Common Space Type**[264] | **LPD (W/ft2)** | **Building Specific Space Types** | **LPD (W/ft2)** |
|---|---|---|---|
| For Family Dining | 2.1 | Laundry—Washing | 0.6 |
| Food Preparation | 1.2 | Automotive—Service/Repair | 0.7 |
| Laboratory | 1.4 | Manufacturing | |
| Restrooms | 0.9 | Low (<25 ft Floor to Ceiling Height) | 1.2 |
| Dressing/Locker/Fitting Room | 0.6 | High (>25 ft Floor to Ceiling Height) | 1.7 |
| Corridor/Transition | 0.5 | Detailed Manufacturing | 2.1 |
| For Hospital | 1.0 | Equipment Room | 1.2 |
| For Manufacturing Facility | 0.5 | Control Room | 0.5 |
| Stairs—Active | 0.6 | Hotel/Motel Guest Rooms | 1.1 |
| Active Storage | 0.8 | Dormitory—Living Quarters | 1.1 |
| For Hospital | 0.9 | Museum | |
| Inactive Storage | 0.3 | General Exhibition | 1.0 |
| For Museum | 0.8 | Restoration | 1.7 |
| Electrical/Mechanical | 1.5 | Bank/Office—Banking Activity Area | 1.5 |
| Workshop | 1.9 | Religious Buildings | |
| Sales Area | 1.7 | Worship Pulpit, Choir | 2.4 |
| | | Fellowship Hall | 0.9 |
| | | Retail ~~[For accent lighting, see 9.3.1.2.1(c)]~~ | |
| | | Sales Area [For accent lighting, see 9.3.1.2.1(c)] | 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 |

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| Common Space Type[264] | LPD (W/ft2) | Building Specific Space Types | LPD (W/ft2) |
|---|---|---|---|
| | | Terminal—Ticket Counter | 1.5 |

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**Table 3-3~~3-3~~: Baseline Exterior Lighting Power Densities**[265]

| 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 |

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[265] ASHRAE 90.1-2007 Table 9.4.5

| Building Exterior | Space Description | LPD |
|---|---|---|
| Parking near 24-hour retail entrances | | 800 W per main entry |

**Prescriptive Lighting Improvements**

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

Note that the Energy Policy Act of 2005 ("EPACT 2005") and Energy Independence and Security Act ("EISA") 2007 standards introduced new efficacy standards for linear fluorescent bulbs and ballasts, effectively phasing out magnetic ballasts (effective October 1, 2010) and most T-12 bulbs (effective July 14, 2012). This induces a shift in what a participant would have purchased in the absence of the program because T-12 bulbs on magnetic ballasts are no longer viable options and, therefore, adjusts the baseline assumption. The baseline for a lighting retrofit project will continue to be the existing lighting system (fixtures, lamps, ballast) for the entirety of Phase II[266]. This is to reflect the time required for the market to adjust to the new code standards, taking into account the fact that end-users may have an existing stock of T-12 lamps and do not need to purchase new replacement lamps for several years.

With this understanding, these new code standards will not impact the EDCs' first year savings (which will be used to determine EDC compliance). However, these regulatory changes affect the TRC Test valuation for T-12 replacements as the energy savings and useful life are reduced each year due to the changing lighting baseline values as such lighting becomes unavailable. This section describes a methodology to calculate lifetime savings for linear fluorescent measures that replace T-12s in Program Years 6 (June 1, 2014 – May 31, 2015) and 7 (June 1, 2015 – May 31, 2016) (PY6 and PY7). Standard T-8s become the baseline for all T-12 linear fluorescent retrofits beginning June 1, 2016, should the Commission implement a Phase III of the Act 129 EE&C Programs. Therefore, measures installed in PY6 and PY7 will claim full savings until June 1, 2016. Savings adjustment factors[267] would be applied to the full savings for savings starting June 1, 2016, and for the remainder of the measure life. Savings adjustments are developed for different combinations of retrofits from T-12s to T-8 or T-5 lighting. In TRC Test calculations, the EDCs may adjust lifetime savings either by applying savings adjustment factors or by reducing the effective useful life[268] (EUL) to adjust lifetime savings. Savings adjustment factors and reduced EULs for HPT8 and T5 measures are in Table 3-4 and Table 3-5, below.

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[266] The PEG will continue to monitor the market's activity and that the baseline for lighting retrofit projects be reconsidered during the first TRM update that would be effective during a potential Phase III.

[267] Savings adjustment is defined as the ratio between the wattage reduction from the T-8 baseline to HPT-8 or T-5 lighting and the wattage reduction from the T-12 fixture.

[268] EUL adjustments are calculated by applying the savings adjustment factor to the remaining useful life of the measure and reducing the EUL accordingly. The savings adjustment factor methodology and the adjusted EUL methodology will produce the same lifetime savings.

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**Table 3-4~~3-4~~: 2016 Savings Adjustment Factors and Adjusted EULs for HPT8 Measures**[269]

| Fixture Type | Savings Adjustment Factor | | | Adjusted EUL | | |
|---|---|---|---|---|---|---|
| | T12 EEmag ballast and 34 w lamps | T12 EEmag ballast and 40 w lamps | T12 mag ballast and 40 w lamps | T12 EEmag ballast and 34 w lamps | T12 EEmag ballast and 40 w lamps | T12 mag ballast and 40 w lamps |
| 1-Lamp Relamp/Reballast | 53% | 70% | 80% | 8.9 | 11.1 | 12.4 |
| 2-Lamp Relamp/Reballast | 47% | 70% | 78% | 8.1 | 11.1 | 12.1 |
| 3-Lamp Relamp/Reballast | 58% | 62% | 79% | 9.5 | 10.1 | 12.3 |
| 4-Lamp Relamp/Reballast | 56% | 71% | 77% | 9.3 | 11.2 | 12.0 |

**Table 3-5~~3-5~~: 2016 Savings Adjustment Factors and Adjusted EULs for T5 Measures**

| Fixture Type | Savings Adjustment Factor | | | Adjusted EUL | | |
|---|---|---|---|---|---|---|
| | T12 EEmag ballast and 34 w lamps | T12 EEmag ballast and 40 w lamps | T12 mag ballast and 40 w lamps | T12 EEmag ballast and 34 w lamps | T12 EEmag ballast and 40 w lamps | T12 mag ballast and 40 w lamps |
| 1-Lamp T5 Industrial/Strip | 58% | 71% | 76% | 9.5 | 11.2 | 11.9 |
| 2-Lamp T5 Industrial/Strip | 39% | 60% | 66% | 7.1 | 9.8 | 10.6 |
| 3-Lamp T5 Industrial/Strip | 49% | 60% | 69% | 8.4 | 9.8 | 11.0 |
| 4-Lamp T5 Industrial/Strip | 40% | 59% | 49% | 7.2 | 9.7 | 8.4 |

Other factors required to calculate savings are shown in Table 3-6 and Table 3-7. Note that if HOU is stated and verified by logging lighting hours of use groupings, actual hours should be applied. The IF factors shown in Table 3-7 are to be used only when the facilities are air conditioned and only for fixtures in conditioned or refrigerated space. The HOU for refrigerated spaces are to be estimated or logged separately. To the extent that operating schedules are known based on metered data, site-specific coincidence factors may be calculated in place of the default coincidence factors provided in Table 3-6.

**Table 3-6~~3-6~~: Lighting HOU and CF by Building Type or Function**

| Building Type | HOU | CF[270] | Source |
|---|---|---|---|

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[269] The savings adjustment is equal to the ratio between wattage reduction from T8 baseline to HPT8 ot T5 lighting and wattage reduction  from T12 fixture. These factors are taken from the 2013 IL TRM.

| Building Type | HOU | CF[270] | Source |
|---|---|---|---|
| Auto Related | 4,056 | 0.62* | 7 |
| Daycare | 2,590 | 0.62* | 8 |
| Dusk-to-Dawn / Exterior Lighting | 3,833 | 0.00 | 2 |
| Education – School | 1,632 | 0.31 | 1 |
| Education – College/University | 2,348 | 0.76 | 1 |
| Grocery | 4,660 | 0.87 | 1 |
| Health/Medical – Clinic | 3,213 | 0.73 | 1 |
| Hospitals | 5,182 | 0.80 | 1 |
| Industrial Manufacturing – 1 Shift | 2,857 | 0.57 | 6 |
| Industrial Manufacturing – 2 Shift | 4,730 | 0.57 | 6 |
| Industrial Manufacturing – 3 Shift | 6,631 | 0.57 | 6 |
| Libraries | 2,566 | 0.62* | 9 |
| Lodging – Guest Rooms | 914 | 0.09 | 1 |
| Lodging – Common Spaces | 7,884 | 0.90 | 1 |
| Multi-Family (Common Areas) - High-rise & Low-rise | 5,950 | 0.62* | 3 |
| Nursing Home | 4,160 | 0.62* | 4 |
| Office | 2,567 | 0.61 | 1 |
| Parking Garages | 6,552 | 0.62* | 10 |
| Public Order and Safety | 5,366 | 0.62* | 11 |
| Public Assembly (one shift) | 2,610 | 0.62* | 4 |
| Public Services (nonfood) | 3,425 | 0.62* | 5 |
| Restaurant | 3,613 | 0.65 | 1 |
| Retail | 2,829 | 0.73 | 1 |
| Religious Worship/Church | 1,810 | 0.62* | 12 |
| Storage Conditioned/Unconditioned | 3,420 | 0.62* | 4 |
| Warehouse | 2,316 | 0.54 | 1 |
| 24/7 Facilities or Spaces | 8,760 | 1.00 | N/A |
| Other[271] | Varies | Varies | 1 |

* 0.62 represents the simple average of all coincidence factors listed in the 2011 Mid-Atlantic TRM

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[270] Coincidence Factor values are taken from the 2011 Mid-Atlantic TRM. For the building types where CF values are not available in the Mid-Atlantic TRM, an average of CF values available for all building types in the Mid-Atlantic TRM is reported.Subject to revision based on detailed measurement or additional research in subsequent TRM Updates.

[271] To be used only when no other category is applicable. Hours of operation must be documented by facility staff interviews, posted schedules, or metered data.

**Sources:**

1. The Mid-Atlantic TRM – Northeast Energy Efficiency Partnerships, Mid-Atlantic Technical Reference Manual, Version 2.0, submitted by Vermont Energy Investment Corporation, July, 2011.
    a. Development of Interior Lighting Hours of Use and Coincidence Factor Values for EmPOWER Maryland Commercial Lighting Program Evaluations, Itron, 2010.
    b. California Public Utility Commission. *Database for Energy Efficiency Resources,* 2008
    c. Small Commercial Contract Group Direct Impact Evaluation Report prepared by Itron for the California Public Utilities Commission Energy Division, February 9, 2010
2. State of Ohio Energy Efficiency Technical Reference Manual, Vermont Energy Investment Corporation, August 6, 2010. Exterior lighting 3,833 hours per year assumes 10.5 hours per day; typical average for photocell control.
3. Illinois Energy Efficiency Technical Reference Manual, Vermont Energy Investment Corporation, 2012. Multi-family common area value based on Focus on Energy Evaluation, ACES Deemed Savings Desk Review, November 2010.
4. California Public Utility Commission. Database for Energy Efficiency Resources, 2011
5. State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0", KEMA, March, 2010.
6. UI and CL&P Program Savings Documentation for 2012 Program Year, United Illuminating Company, September 2011.
7. California Public Utility Commission. Database for Energy Efficiency Resources, 2011; available at www.deeresources.com
8. 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.
9. 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.

10. 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).
11. 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.
12. 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.

**Table 3-7~~3-7~~: Interactive Factors and Other Lighting Variables**

| Component | Type | Value | Source |
|---|---|---|---|
| $IF_{demand}$ | Fixed | Cooled space (60 °F – 79 °F) = 0.34<br>Freezer spaces (-35 °F – 20 °F) = 0.50<br>Medium-temperature refrigerated spaces (20 °F – 40 °F) = 0.29<br>High-temperature refrigerated spaces (40 °F – 60 °F) = 0.18<br>Un-cooled space = 0 | 1 |
| $IF_{energy}$ | Fixed | Cooled space (60 °F – 79 °F) = 0.12<br>Freezer spaces (-35 °F – 20 °F) = 0.50<br>Medium-temperature refrigerated spaces (20 °F – 40 °F) = 0.29<br>High-temperature refrigerated spaces (40 °F – 60 °F) = 0.18<br>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. The measurement of energy savings is based on algorithms with key variables (e.g. coincidence factor, hours of use) provided through existing end-use metering of a sample of facilities or from other utility programs with experience with these measures (i.e., % of annual lighting energy saved by lighting control). These key variables are listed in Table 3-8.

If a lighting improvement consists of solely lighting controls, the lighting fixture baseline is the existing fixtures with the existing lamps and ballasts or, if retrofitted, new fixtures with new lamps and ballasts as defined in Lighting Audit and Design Tool shown in Appendix C. In either case, the $kW_{EE}$ 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 3-8~~3-8~~: Lighting Controls Assumptions**

| Component | Type | Value | Source |
|---|---|---|---|
| $kW_{controlled}$ | Variable | Lighting Audit and Design Tool in Appendix C | EDC Data Gathering |
| | | Default:<br>Wall mounted occupancy sensor: 0.350<br>Remote mounted occupancy sensor: 0.587<br>Fixture mounted occupancy sensor: 0.073 | 2, 3 |
| ~~SVG~~$SVG_{base}$ and $SVG_{EE}$ | Variable | Default: See Table 3-9<br>~~Table 3-9 : Savings Control Factors Assumptions~~ | 1 |
| | | Based on metering | EDC Data Gathering |
| CF | Variable | By building type and size | See Table 3-6 |
| | | Based on metering | EDC Data Gathering |
| HOU | Variable | By building type and size | See Table 3-6 |
| | | See Section 3.2.6 | EDC Data Gathering |
| IF | Variable | By building type and size | See Table 3-7 |

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**Table 3-9~~3-9~~: Savings Control Factors Assumptions**[272]

| Strategy | Definition | Technology | Savings % |
|---|---|---|---|
| Switch | Manual On/Off Switch | Light Switch | 0% |
| Occupancy | Adjusting light levels according to the presence of occupants | Occupancy Sensors | 24% |
| | | Time Clocks | 24% |
| | | Energy Management System | 24% |
| Daylighting | Adjusting light levels automatically in response to the presence of natural light | Photosensors | 28% |
| | | Time Clocks | 28% |
| Personal Tuning | Adjusting individual light levels by occupants according to their personal preferences; applies, for example, to private offices, workstation-specific lighting in open-plan offices, and classrooms | Dimmers | 31% |
| | | Wireless on-off switches | 31% |
| | | Bi-level switches | 31% |
| | | Computer based controls | 31% |
| | | Pre-set scene selection | 31% |
| Institutional Tuning | Adjustment of light levels through commissioning and technology to meet location specific needs or building policies; or provision of switches or controls for areas or groups of occupants; examples of the former include high-end trim dimming (also known as ballast tuning or reduction of ballast factor), task tuning and lumen maintenance | Dimmable ballasts | 36% |
| | | On-off or dimmer switches for non-personal tuning | 36% |
| Multiple Types | Includes combination of any of the types described above. Occupancy and personal tuning, daylighting and occupancy are most common. | Occupancy and personal tuning/ daylighting and occupancy | 38% |

**Sources:**

1. Williams, A., Atkinson, B., Garbesi, K., Rubinstein, F., "A Meta-Analysis of Energy Savings from Lighting Controls in Commercial Buildings", Lawrence Berkeley National Laboratory, September 2011.
2. Goldberg et al, State of Wisconsin Public Service Commission of Wisconsin, Focus on Energy Evaluation, Business Programs, Incremental Cost Study, KEMA, October 28, 2009
3. 2011 Efficiency Vermont TRM

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[272] 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 3-10~~3-10~~: Assumptions for LED Traffic Signals**

| Component | Type | Value | Source |
|---|---|---|---|
| ∆kW | Variable | See Table 3-11 | PECO |
| CF | Red Round | 55% | PECO |
|  | Yellow Round | 2% |  |
|  | Round Green | 43% |  |
|  | Turn Yellow | 8% |  |
|  | Turn Green | 8% |  |
|  | Pedestrian | 100% |  |
| HOU | Variable | See Table 3-11 | PECO |
| IF | Fixed | 0 |  |

**Table 3-113~~-11~~: LED Traffic Signals**[273]

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

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

**Table 3-12~~3-12~~: 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 3-13, 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 algorithms in Section 3.2.2 with assumptions in Table 3-13.

**Table 3-13~~3-13~~: LED Exit Signs**

| Component | Type | Value | Source |
|---|---|---|---|
| $kW_{base}$ | Variable | Single-Sided Incandescent: 20W<br>Dual-Sided Incandescent: 40W<br>Single-Sided Fluorescent: 9W<br>Dual-Sided Fluorescent: 20W | Appendix C: Standard Wattage Table |
| | | Actual Wattage | EDC Data Gathering |
| $kW_{inst}$ | Variable | Single-Sided: 2W<br>Dual-Sided: 4W | Appendix C: Standard Wattage Table |
| | | Actual Wattage | EDC Data Gathering |
| CF | Fixed | 1.0 | 1 |
| HOU | Fixed | 8760 | 1 |
| $IF_{energy}$ | Fixed | Cooled Space: 0.12 | ~~Table 3-8: Lighting Controls Assumptions~~Table 3-8 |
| $IF_{demand}$ | Fixed | Cooled Space: 0.34 | Table 3-8~~Table 3-8: Lighting Controls Assumptions~~ |

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

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

### 3.3.1 Algorithms

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

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

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

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

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

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

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

### 3.3.2 Definition of Terms

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

*LF* = *Load Factor. Ratio between the actual load and the rated load. Motor efficiency curves typically result in motors being most efficient at approximately 75% of the rated load. The default value is 0.75. Variable loaded motors should use custom measure protocols.; LF = Measured motor kW / (Rated motor HP x 0.746 /nameplate efficiency)*[274]

$\eta_{base}$ = *Efficiency of the baseline motor*

$\eta_{ee}$ = *Efficiency of the energy-efficient motor*

*RHRS* = *Annual run hours of the motor*

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

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[274] 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.

### 3.3.3 Description of Calculation Method

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

**Table 3-14~~3-14~~: Building Mechanical System Variables for Premium Efficiency Motor Calculations**

| Component | Type | Value | Source |
|---|---|---|---|
| HP | Variable | Nameplate | EDC Data Gathering |
| RHRS[275] | Variable | Based on logging, panel data or modeling[276] | EDC Data Gathering |
| | | Default Table 3-17 | From Table 3-17 |
| LF[277] | Variable | Based on spot metering [278] and nameplate | EDC Data Gathering |
| | | Default 75% | 1 |
| $\eta_{base}$ | Variable | Early Replacement: Nameplate | EDC Data Gathering |
| | | New Construction or Replace on Burnout: Default comparable standard motor.<br>~~For PY1 and PY2, EPACT Standard (See Table 3-13). For PY3 and PY3,~~ NEMA Premium (See ~~Table 3-14)~~Table 3-15 and<br>Table 3-16<br>~~Table 3-16~~) | ~~From Table 3-15 for PY1 and PY2.~~<br>~~From Table 3-16 for PY3 and PY4.~~Table 3-15 and<br>Table 3-16<br>~~Table 3-16~~ |
| $\eta_{ee}$ | Variable | Nameplate | EDC Data Gathering |
| CF[279] | Variable | Single Motor Configuration: 74%<br>Duplex Motor Configuration: 37% | 1 |

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**Sources:**

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[275] Default Value can be used by EDC but is subject to metering and adjustment by evaluators or SWE

[276] Modeling is an acceptable substitute to metering and panel data if modeing is conducted using building- and equipment-specific information at the site and the facility consumption is calibrated using 12 months of billing data (pre-retrofit).

[277] Default Value can be used by EDC but is subject to metering and adjustment by evaluators or SWE

[278] See definition in section 3.3.2 for specific algorithm to be used when performing spot metering analysis to determine alternate load factor.

[279] Need to confirm source through TWG

1. California Public Utility Commission. *Database for Energy Efficiency Resources* 2005. The coincident peak demand period is 12:00 p.m. to 6:00 p.m., weekdays, May – October.

Note that the Energy Independence and Security Act of 2007[280] restates the definition of General Purpose Electric Motors and classifies them as Subtype I or Subtype II.

The term 'General Purpose electric motor (Subtype I)' means any motor that meets the definition of 'General Purpose' as established in the final rule issued by the Department of Energy titled "Energy Efficiency Program for Certain Commercial and Industrial Equipment: Test Procedures, Labeling, and Certification Requirements for Electric Motors" (10 CFR 431), as in effect on the date of enactment of the Energy Independence and Security Act of 2007.

The term 'General Purpose electric motor (Subtype II)' means motors incorporating the design elements of a general purpose electric motor (Subtype I) that are configured as one of the following:

- A U-Frame Motor
- A Design C Motor
- A close-coupled pump motor
- A Footless motor
- A vertical solid shaft normal thrust motor (as tested in a horizontal configuration)
- An 8-pole motor (900 rpm)
- A poly-phase motor with voltage of not more than 600 volts (other than 230 or 460 volts)

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[280] US Congress, Energy Independence and Security Act of 2007 (EISA), January 4, 2007

**Table 3-15~~3-15~~: Baseline Motor Nominal Efficiencies for General Purpose Electric Motors (Subtype I)~~PY1 and PY2[281]~~**

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

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~~[281] 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 3-16: Baseline Motor Nominal Efficiencies for PY3 and PY4~~[282]

| | **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% |

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[282] 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 3-16~~3-16~~: Baseline Motor Nominal Efficiencies for General Purpose Electric Motors (Subtype II)[283]**

| | 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% | N/A | 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% |
| 250 | 94.5% | 95.4% | 94.5% | 95.0% | 95.0% | 95.4% |
| 300 | 94.5% | 95.4% | 95.0% | 95.0% | 95.4% | 95.4% |
| 350 | 94.5% | 95.4% | 95.0% | 95.0% | 95.4% | 95.4% |
| 400 | N/A | 95.4% | 95.4% | N/A | 95.4% | 95.4% |
| 450 | N/A | 95.8% | 95.8% | N/A | 95.4% | 95.4% |
| 500 | N/A | 95.8% | 95.8% | N/A | 95.8% | 95.4% |

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[283] Table is based on NEMA premium efficiency motor standards.

**Table 3-17~~3-17~~: Stipulated Hours of Use for Motors in Commercial Buildings**[284]

| Facility Type | Fan Motor | Chilled Water Pumps/Cooling Tower Fan | Heating Pumps |
|---|---|---|---|
| Auto Related | 4,056 | 1,878 | 6,000 |
| Bakery | 2,854 | 1,445 | 6,000 |
| Banks, Financial Centers | 3,748 | 1,767 | 6,000 |
| Church | 1,955 | 1,121 | 6,000 |
| College – Cafeteria | 6,376 | 2,713 | 6,000 |
| College - Classes/Administrative | 2,586 | 1,348 | 6,000 |
| College - Dormitory | 3,066 | 1,521 | 6,000 |
| Commercial Condos | 4,055 | 1,877 | 6,000 |
| Convenience Stores | 6,376 | 2,713 | 6,000 |
| Convention Center | 1,954 | 1,121 | 6,000 |
| Court House | 3,748 | 1,767 | 6,000 |
| Dining: Bar Lounge/Leisure | 4,182 | 1,923 | 6,000 |
| Dining: Cafeteria / Fast Food | 6,456 | 2,742 | 6,000 |
| Dining: Family | 4,182 | 1,923 | 6,000 |
| Entertainment | 1,952 | 1,120 | 6,000 |
| Exercise Center | 5,836 | 2,518 | 6,000 |
| Fast Food Restaurants | 6,376 | 2,713 | 6,000 |
| Fire Station (Unmanned) | 1,953 | 1,121 | 6,000 |
| Food Stores | 4,055 | 1,877 | 6,000 |
| Gymnasium | 2,586 | 1,348 | 6,000 |
| Hospitals | 7,674 | 3,180 | 6,000 |
| Hospitals / Health Care | 7,666 | 3,177 | 6,000 |
| Industrial - 1 Shift | 2,857 | 1,446 | 6,000 |
| Industrial - 2 Shift | 4,730 | 2,120 | 6,000 |
| Industrial - 3 Shift | 6,631 | 2,805 | 6,000 |
| Laundromats | 4,056 | 1,878 | 6,000 |
| Library | 3,748 | 1,767 | 6,000 |
| Light Manufacturers | 2,857 | 1,446 | 6,000 |
| Lodging (Hotels/Motels) | 3,064 | 1,521 | 6,000 |
| Mall Concourse | 4,833 | 2,157 | 6,000 |
| Manufacturing Facility | 2,857 | 1,446 | 6,000 |
| Medical Offices | 3,748 | 1,767 | 6,000 |

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

| | | | |
|---|---|---|---|
| Motion Picture Theatre | 1,954 | 1,121 | 6,000 |
| Multi-Family (Common Areas) | 7,665 | 3,177 | 6,000 |
| Museum | 3,748 | 1,767 | 6,000 |
| Nursing Homes | 5,840 | 2,520 | 6,000 |
| Office (General Office Types) | 3,748 | 1,767 | 6,000 |
| Office/Retail | 3,748 | 1,767 | 6,000 |
| Parking Garages & Lots | 4,368 | 1,990 | 6,000 |
| Penitentiary | 5,477 | 2,389 | 6,000 |
| Performing Arts Theatre | 2,586 | 1,348 | 6,000 |
| Police / Fire Stations (24 Hr) | 7,665 | 3,177 | 6,000 |
| Post Office | 3,748 | 1,767 | 6,000 |
| Pump Stations | 1,949 | 1,119 | 6,000 |
| Refrigerated Warehouse | 2,602 | 1,354 | 6,000 |
| Religious Building | 1,955 | 1,121 | 6,000 |
| Residential (Except Nursing Homes) | 3,066 | 1,521 | 6,000 |
| Restaurants | 4,182 | 1,923 | 6,000 |
| Retail | 4,057 | 1,878 | 6,000 |
| School / University | 2,187 | 1,205 | 6,000 |
| Schools (Jr./Sr. High) | 2,187 | 1,205 | 6,000 |
| Schools (Preschool/Elementary) | 2,187 | 1,205 | 6,000 |
| Schools (Technical/Vocational) | 2,187 | 1,205 | 6,000 |
| Small Services | 3,750 | 1,768 | 6,000 |
| Sports Arena | 1,954 | 1,121 | 6,000 |
| Town Hall | 3,748 | 1,767 | 6,000 |
| Transportation | 6,456 | 2,742 | 6,000 |
| Warehouse (Not Refrigerated) | 2,602 | 1,354 | 6,000 |
| Waste Water Treatment Plant | 6,631 | 2,805 | 6,000 |
| Workshop | 3,750 | 1,768 | 6,000 |
| Other[285] | 3,985 | 1,852 | 6,000 |

**Sources:**

1. UI and CL&P Program Savings Documentation for 2012 Program Year, United Illuminating Company, September 2011
2. Other category calculated based on simple averages.

### 3.3.4 Evaluation Protocol

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Motor projects achieving expected kWh savings of 250,000 kWh or higher must[286] be metered to calculate *ex ante* and/or *ex post* savings. In addition, if any motor within a sampled project uses

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[285] To be used only when no other category is applicable.

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.

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[286] The Commission allows the EDCs to use alternative methods for obtaining customer-sepcific data where customer processes do not support metering. The EDCs are required to provide supporting documentation to the SWE for review if there are any such exceptions.

## 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 3-19. The baseline condition is a motor without a VFD control. The efficient condition is a motor with a VFD control.

### 3.4.1 Algorithms

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

$$\Delta kW_{peak} = HP\ X\ LF / \eta_{motor}\ X\ CF\ X\ DSF$$

### 3.4.2 Definitions of Terms

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$HP$ = *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.* [287]

$\eta_{motor}$ = *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. Percent of baseline energy consumption saved by installing VFD.*

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

### 3.4.3 Description of Calculation Method

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

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[287] 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.

**Table 3-18~~3-18~~: Variables for VFD Calculations**

| Component | Type | Value | Source |
|---|---|---|---|
| Motor HP | Variable | Nameplate | EDC Data Gathering |
| RHRS[288] | Variable | Based on logging, panel data or modeling | EDC Data Gathering |
| | | Default Table 3-17 | See Table 3-17 |
| LF[289] | Variable | Based on spot metering and nameplate | EDC Data Gathering |
| | | Default 75% | 1 |
| ESF | Variable | Default See Table 3-19~~Table 3-19~~ | See Table 3-19~~Table 3-19~~ |
| | | Based on logging and panel data | EDC Data Gathering |
| DSF | Variable | Default See Table 3-19~~Table 3-19~~ | See Table 3-19~~Table 3-19~~ |
| | | Based on logging and panel data | EDC Data Gathering |
| Efficiency - $\eta_{base}$ | Variable | Nameplate | EDC Data Gathering |
| CF[290] | Fixed | 74% | 1 |

**Sources:**

1. California Public Utility Commission. *Database for Energy Efficiency Resources* 2005. The coincident peak demand period is 12:00 p.m. to 6:00 p.m., weekdays, May – October.

**Table 3-19~~3-19~~: ESF and DSF for Typical Commercial VFD Installations[291, 292]**

| HVAC Fan VFD Savings Factors | | |
|---|---|---|
| **Baseline** | **ESF** | **DSF** |
| Constant Volume[293] | 0.534 | 0.347 |
| Air Foil/Backward Incline | 0.354 | 0.26 |
| Air Foil/Backward Incline with Inlet Guide Vanes | 0.227 | 0.13 |
| Forward Curved | 0.179 | 0.136 |

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[288] Default Value can be used by EDC but is subject to metering and adjustment by evaluators or SWE

[289] Default Value can be used by EDC but is subject to metering and adjustment by evaluators or SWE

[290] Need to confirm source through TWG

[291] UI and CL&P Program Savings Documentation for 2012 Program Year, United Illuminating Company, September 2011. Page 45.

[292] UI and CL&P Program Savings Documentation for 2011 Program Year, United Illuminating Company, September 2010. Page 44.

[293] The ESF and DSF values for the constant volume baseline condition are taken from the 2011 Connecticut TRM whereas 2012 Connecticut TRM was used to report values for all other baseline conditions. This is because the 2012 Connecticut TRM does not report values for constant volume condition. Note that the values for all baseline conditions for HVAC fans are same in both versions of the Connecticut TRM. The values were only updated for the HVAC pump baseline conditions.

| | | |
|---|---|---|
| Forward Curved with Inlet Guide Vanes | 0.092 | 0.029 |
| **HVAC Pump VFD Savings Factors** | | |
| **System** | **ESF** | **DSF** |
| Chilled Water Pump | 0.411 | 0.299 |
| Hot Water Pump | 0.424 | 0 |

### 3.4.4 Evaluation Protocol

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VFD projects achieving expected kWh savings of 250,000 kWh or higher must[294] be metered to calculate *ex ante* and/or *ex post* 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.

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[294] The Commission allows the EDCs to use alternative methods for obtaining customer-sepcific data where customer processes do not support metering. The EDCs are required to provide supporting documentation to the SWE for review if there are any such exceptions.

## 3.5 HVAC Systems~~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~~

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

~~$\Delta kW = 0.129 X HP$~~

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

### ~~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.*[295]~~

~~$\eta_{base}$ = *Efficiency of the baseline motor*~~

~~$RHRS$ = *Annual run hours of the motor*~~

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

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~~[295] 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 3-20: Variables for Industrial Air Compressor Calculation~~

| ~~Component~~ | ~~Type~~ | ~~Value~~ | ~~Source~~ |
|---|---|---|---|
| ~~Motor HP~~ | ~~Variable~~ | ~~Nameplate~~ | ~~EDC Data Gathering~~ |
| ~~RHRS~~ | ~~Variable~~ | ~~Based on logging, panel data or 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 and 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.~~[296]

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[296] ~~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 systems is determined from the algorithms listed ~~in~~ below. This protocol excludes water source, ground source, and groundwater source heat pumps~~.~~ measures that are covered in Section 3.17.

### ~~3.6.1~~3.5.1 Algorithms

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**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 $\Delta$kWh and convert SEER to EER to calculate $\Delta kW_{peak}$ using 11.3/13 as the conversion factor.

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

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

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

**Air Source and Packaged Terminal Heat Pump**

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

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

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

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

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

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

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

### ~~3.6.2~~3.5.2 Definition of Terms

**Formatted:** Indent: Left: 0", Tab stops: 0.25", List tab + Not at 0.44"

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

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

$EER_{base}$ = *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 3-20~~3-2120~~: 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 3-21~~Table 3-2221~~ | See Table 3-21~~Table 3-2221~~ |
| $EER_{ee}$ | 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 3-21~~Table 3-2221~~ | See Table 3-21~~Table 3-2221~~ |
| $SEER_{ee}$ | 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 3-21~~Table 3-2221~~ | See Table 3-21~~Table 3-2221~~ |
| $COP_{ee}$ | 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 3-21~~Table 3-2221~~ | See Table 3-21~~Table 3-2221~~ |
| $HSPF_{ee}$ | Variable | Nameplate data (AHRI or AHAM) | EDC's Data Gathering |
| CF | Fixed | ~~80~~55% | 2 |
| $EFLH_{cool}$ | Variable | Based on Logging, BMS data or Modeling[297] | EDC's Data Gathering |
| | | Default values from Note:<br>• For air-source air conditioners and air-source heat pumps, subtract 0.2 from the required baseline efficiency rating value if unit has heating section other than electric resistance.<br>• Integrated Energy Efficiency Ratios | See Note:<br>• For air-source air conditioners and air-source heat pumps, subtract 0.2 from the required baseline efficiency rating value if unit has heating section other than electric resistance.<br>• Integrated Energy |

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[297] Modeling is an acceptable substitute to metering and BMS data if modeing is conducted using building- and equipment-specific information at the site and the facility consumption is calibrated using 12 months of billing data (pre-retrofit).

| Component | Type | Value | Source |
|---|---|---|---|
| | | (IEERs) are only applicable to equipment with capacity modulation.<br>Table 3-22~~Table 3-23~~22 | Efficiency Ratios (IEERs) are only applicable to equipment with capacity modulation.<br>Table 3-22~~Table 3-23~~22 |
| $EFLH_{heat}$ | Variable | Based on Logging, BMS data or Modeling[298] | EDC's Data Gathering |
| | | Default values from Table 3-23~~Table 3-24~~23 | See Table 3-23~~Table 3-24~~23 |

**Sources:**

1. The Equivalent Full Load Hours (ELFH) for Pennsylvania are calculated based on the degree day scaling methodology. The EFLH values reported in the Connecticut Program Savings Documentation were adjusted using full load hours (FLH) from the US DOE ENERGY STAR Calculator to account for differences in weather conditions. Degree day scaling ratios were calculated using heating degree day and cooling degree day values for seven Pennsylvania cities: Allentown, Erie, Harrisburg, Philadelphia, Pittsburgh, Scranton, and Williamsport.
    a. US Department of Energy. ENERGY STAR Calculator and Bin Analysis Models
    b. UI and CL&P Program Savings Documentation for 2012 Program Year, United Illuminating Company, September 2011, Pages 219-220.

~~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)~~

2. C&I Unitary HVAC Load Shape Project Final Report, KEMA, 2011. The study reports CF values in the range of 44% to 63% depending on the size of the unit for the Mid Atlantic PJM hours. The study, therefore, assumes an average CF value of 55% for the PJM peak demand period that is applied to all units.

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[298] Ibid

Table 3-21~~3-22~~21: HVAC Baseline Efficiencies[299]

| 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 / 11.4 IEER | N/A |
| ≥ 135,000 BtuH and < 240,000 BtuH | 11.0 EER / 11.2 IEER | N/A |
| ≥ 240,000 BtuH and < 760,000 BtuH<br>(IPLV for units with capacity-modulation only) | 10.0 EER / ~~9.7 IPLV~~10.1 IEER | N/A |
| ≥ 760,000 BtuH<br>(IPLV for units with capacity-modulation only) | 9.7 EER / 9.~~4 IPLV~~8 IEER | N/A |
| Air-Source Heat Pumps | | |
| < 65,000 BtuH | 13 SEER | 7.7 HSPF |
| ≥ 65,000 BtuH and <135,000 BtuH | 11.0 EER / 11.2 IEER | 3.3 COP |
| ≥ 135,000 BtuH and < 240,000 BtuH | 10.6 EER / 10.7 IEER | 3.2 COP |
| ≥ 240,000 BtuH<br>(IPLV for units with capacity-modulation only) | 9.5 EER / 9.~~2 IPLV~~6 IEER | 3.2 COP |
| Packaged Terminal Systems (~~Replacements)~~~~[300]~~Nonstandard Size) [301, 302] | | |
| PTAC (cooling) | 10.9 - (0.213 x Cap / 1000) EER | N/A |
| PTHP | 10.8 - (0.213 x Cap / 1000) EER | 2.9 - (0.026 x Cap / 1000) COP |
| Packaged Terminal Systems (~~New Construction)~~~~[303]~~Standard Size) [304, 305] | | |
| PTAC (cooling) | 12.5 - (0.213 x Cap / 1000) EER | N/A |
| PTHP | 12.3 - (0.213 x Cap / 1000) EER | 3.2 - (0.026 x Cap / 1000) COP |

**Note:**

- For air-source air conditioners and air-source heat pumps, subtract 0.2 from the required baseline efficiency rating value if unit has heating section other than electric resistance.
- Integrated Energy Efficiency Ratios (IEERs) are only applicable to equipment with capacity modulation.

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[299] Baseline values from IECC 2009, after Jan 1, 2010 or Jan 23, 2010 as applicable. Integrated Energy Efficiency Ratio (IEER) requirements have been incorporated from ASHRAE 90.1-2007, "Energy Standard for Buildings Except Low-Rise Residential Buildings", 2008 Supplement (Addendum S: (Tables 6.8.1A and 6.8.1B). IECC 2009 does not present IEER requirements.

~~[300] 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.~~

[301] Nonstandard size packaged terminal air conditioners and heat pumps with existing sleeves having an external wall opening of less than 16 in. high or less than 42 in. wide and having a cross-sectional area less than 670 in. Shall be factory labeled as follows: Manufactured for nonstandard size applications only: not to be installed in new construction projects.

[302] 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.

~~[303] 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.~~

[304] This is intended for applications with standard size exterior wall openings.

[305] 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.

**Table 3-22~~3-23~~22: Cooling EFLH for Pennsylvania Cities**[306, 307]

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

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

[307] The Equivalent Full Load Hours (ELFH) for Pennsylvania are calculated based on the degree day scaling methodology. The EFLH values reported in the Connecticut Program Savings Documentation were adjusted using full load hours (FLH) from the US DOE ENERGY STAR Calculator to account for differences in weather conditions.

**Table 3-23~~3-2423~~: Heating EFLH for Pennsylvania Cities**[308, 309]

| 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 | 701 | 573 | 576 | 605 | 563 | 612 |
| Dining: Bar Lounge/Leisure | 1,156 | 1,346 | 1,100 | 1,104 | 1,161 | 1,080 | 1,175 |
| Dining: Cafeteria / Fast Food | 582 | 678 | 554 | 556 | 585 | 544 | 592 |
| 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 | 258 | 280 |
| Industrial: 1 Shift/Light Manufacturing | 1,491 | 1,737 | 1,420 | 1,425 | 1,498 | 1,394 | 1,516 |
| Industrial: 2 Shift | 1,017 | 1,184 | 968 | 972 | 1,022 | 951 | 1,034 |
| Industrial: 3 Shift | 538 | 626 | 512 | 513 | 540 | 502 | 546 |
| Lodging: Hotels/Motels/Dormitories | 1,438 | 1,675 | 1,369 | 1,374 | 1,444 | 1,344 | 1,462 |
| Lodging: Residential | 1,438 | 1,675 | 1,369 | 1,374 | 1,444 | 1,344 | 1,462 |
| Multi-Family (Common Areas) | 277 | 322 | 263 | 264 | 278 | 259 | 281 |
| Museum/Library | 1,266 | 1,474 | 1,205 | 1,209 | 1,271 | 1,183 | 1,286 |
| Nursing Homes | 738 | 859 | 702 | 704 | 740 | 689 | 749 |
| Office: General/Retail | 1,266 | 1,474 | 1,205 | 1,209 | 1,271 | 1,183 | 1,286 |
| 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 | 965 | 789 | 792 | 832 | 774 | 842 |
| Police/Fire Stations (24 Hr) | 277 | 322 | 263 | 264 | 278 | 259 | 281 |
| 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 | 1,933 | 1,580 | 1,586 | 1,667 | 1,551 | 1,687 |
| Warehouses (Not Refrigerated) | 1,555 | 1,810 | 1,480 | 1,485 | 1,561 | 1,453 | 1,580 |
| Warehouses (Refrigerated) | 1,555 | 1,810 | 1,480 | 1,485 | 1,561 | 1,453 | 1,580 |
| Waste Water Treatment Plant | 538 | 626 | 512 | 513 | 540 | 502 | 546 |

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

[309] The Equivalent Full Load Hours (ELFH) for Pennsylvania are calculated based on the degree day scaling methodology. The EFLH values reported in the Connecticut Program Savings Documentation were adjusted using full load hours (FLH) from the US DOE ENERGY STAR Calculator to account for differences in weather conditions.

## ~~3.7~~3.6 Electric Chillers

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

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

### ~~3.7.1~~3.6.1 Algorithms

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**Efficiency ratings in EER**

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

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

**Efficiency ratings in kW/ton**

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

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

### ~~3.7.2~~3.6.2 Definition of Terms

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$Tons_{ee}$ = *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 3-24~~Table 3-25~~24 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 3-24~~3-25~~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 3-25~~Table 3-26~~25 | See Table 3-25~~Table 3-26~~25 |
| | | 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 3-25~~Table 3-26~~25 | EDC Data Gathering |
| $EER_{base}$ | Variable | New Construction or Replace on Burnout: Default value from Table 3-25~~Table 3-26~~25 | See Table 3-25~~Table 3-26~~25 |
| | | Early Replacement: Nameplate Data | EDC Data Gathering |
| $EER_{ee}$ | Variable | Nameplate Data (ARI Standards 550/590). At minimum, must satisfy standard listed in Table 3-25~~Table 3-26~~25 | EDC Data Gathering |
| CF | Fixed | 80% | 1 |
| EFLH | Variable | Default value from Table 3-26~~Table 3-27~~26 | See Table 3-26~~Table 3-27~~26 |
| | | Based on Logging, BMS data or Modeling[310] | EDC Data Gathering |

**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)

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[310] Modeling is an acceptable substitute to metering and BMS data if modeing is conducted using building- and equipment-specific information at the site and the facility consumption is calibrated using 12 months of billing data (pre-retrofit).

### Table 3-25~~3-26~~25: Electric Chiller Baseline Efficiencies (IECC 2009)[311]

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

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[311] IECC 2009 – Table 503.2.3(7). Chillers must satisfy efficiency requirements for both full load and IPLV efficiencies for either Path A or Path B. The table shows the efficiency ratings to be used for the baseline chiller efficiency in the savings estimation algorithm, which must be consistent with the expected operating conditions of the efficient chiller. For example, if the efficient chiller satisfies Path A and generally performs at part load, the appropriate baseline chiller efficiency is the IPLV value under Path A for energy savings. If the efficient chiller satisfies Path B and generally performs at full load, the appropriate baseline chiller efficiency is the full load value under Path B for energy savings. Generally, chillers operating above 70 percent load for a majority (50% or more) of operating hours should use Path A and chillers below 70% load for a majority of operating hours should use Path B. The “full load” efficiency from the appropriate Path A or B should be used to calculate the Peak Demand Savings as it is expected that the chillers would be under full load during the peak demand periods.

**Table 3-26~~3-27~~26: Chiller Cooling EFLH by Location[312, 313]**

| 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 | 1,251 | 690 | 1,330 | 1,055 | 944 | 1,478 | 889 |

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

[313] The Equivalent Full Load Hours (ELFH) for Pennsylvania are calculated based on the degree day scaling methodology. The EFLH values reported in the Connecticut Program Savings Documentation were adjusted using full load hours (FLH) from the US DOE ENERGY STAR Calculator to account for differences in weather conditions.

## ~~3.8~~3.7 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~~3.7.1 Algorithms

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**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~~3.7.2 Definition of Terms

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*$N$ = 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 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 of performance of cooler*

*$COP_{Freeze}$ = Coefficient of performance of freezer*

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

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

**Table 3-27~~3-2827~~ 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<br>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 3-28~~3-2928~~ 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~~3.7.3 Measure Life

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12 Years (DEER 2008, Regional Technical Forum)

## ~~3.9~~3.8 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~~3.8.1 Algorithms

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**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~~3.8.2 Definition of Terms

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$kWh_{base}$ = *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 3-29~~3-30~~29: Refrigeration Cases - References**

| Component | Type | Value | Sources |
|---|---|---|---|
| $kWh_{base}$ | Calculated | See Table 3-30~~Table 3-31~~30 and Table 3-31~~Table 3-32~~31 | 1 |
| $kWh_{ee}$ | Calculated | See Table 3-30~~Table 3-31~~30 and Table 3-31~~Table 3-32~~31 | 1 |
| V | Variable | EDC data gathering | EDC data gathering |
| Days/year | Fixed | 365 | 1 |
| CF | Fixed | ~~1.~~0.772 | 2 |

**Sources:**

~~2.~~1. ENERGY STAR calculator, March, 2010 update.

~~Load shape for commercial refrigeration equipment~~

2. Northeast Energy Efficiency Partnerships, Mid Atlantic TRM Version 3.0. March 2013. Calculated from Itron eShapes, which is 8760 hourly data by end use for Upstate New York.

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**Table 3-30~~3-3130~~: 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 3-31~~3-3231~~: 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 3-32~~3-3332~~: 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 3-33~~3-34~~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~~3.8.3 Measure Life

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12 years

**Sources:**

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

## ~~3.10~~3.9 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~~3.9.1 Algorithms

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**Cooler**

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

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

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

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

**Freezer**

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

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

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

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

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

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

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

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

$\Delta kWh = N * kWh_{default}/motor$

### ~~3.10.2~~3.9.2 Definition of Terms

**Formatted:** Indent: Left: 0", Tab stops: 0.25", List tab + Not at 0.44"

$N$ = *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 3-34~~3-35~~34: Variables for High-Efficiency Evaporator Fan Motor**

| Variable | Type | Value | Source |
|---|---|---|---|
| $W_{base}$ | Variable | Default | Table 3-35~~Table 3-36~~35 |
| | | Nameplate Input Wattage | EDC Data Gathering |
| $W_{ee}$ | Variable | Default | Table 3-35~~Table 3-36~~35 |
| | | 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 3-35~~3-36~~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 3-36~~3-37~~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 3-37~~3-38~~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 3-38~~3-39~~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:<br>1-14 Watt | 50 | 14 | 0.9 | 100% | 0.98 | 2.5 | 0.0461 | 404 |
| Cooler: Shaded Pole to ECM:<br>16-23 Watt | 93 | 30 | 0.9 | 100% | 0.98 | 2.5 | 0.0802 | 703 |
| Cooler: Shaded Pole to ECM:<br>1/20 HP (37 Watt) | 142 | 56 | 0.9 | 100% | 0.98 | 2.5 | 0.1093 | 958 |
| Freezer: Shaded Pole to ECM:<br>1-14 Watt | 50 | 14 | 0.9 | 94.4% | 0.98 | 1.3 | 0.0551 | 483 |
| Freezer: Shaded Pole to ECM:<br>16-23 Watt | 93 | 30 | 0.9 | 94.4% | 0.98 | 1.3 | 0.0960 | 841 |
| Freezer: Shaded Pole to ECM:<br>1/20 HP (37 Watt) | 142 | 56 | 0.9 | 94.4% | 0.98 | 1.3 | 0.1308 | 1146 |

**Table 3-39~~3-40~~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~~3.9.3 Measure Life

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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~~3.10 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~~3.10.1 Algorithms

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**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)**

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

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

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

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

### ~~3.11.2~~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 walk-in coolers in stores vs. total of freezers and coolers*

*HR* = *Operating hours per year*

**Table 3-40~~3-4140~~: Variables for High-Efficiency Evaporator Fan Motor**

| Variable | Type | Value | Source |
|---|---|---|---|
| $W_{base}$ | Variable | Default | Table 3-41~~Table 3-4241~~ |
| | | Nameplate Input Wattage | EDC Data Gathering |
| $W_{ee}$ | Variable | Default | Table 3-41~~Table 3-4241~~ |
| | | 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.

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

**Table 3-41~~3-4241~~: 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 3-42~~3-43~~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 3-43~~3-4443~~: 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:<br>1/40 HP (16-23 Watt) | 93 | 30 | 0.9 | 100% | 0.98 | 2.5 | 0.0798 | 661 |
| Cooler: Shaded Pole to ECM:<br>1/20 HP (37 Watt) | 142 | 56 | 0.9 | 100% | 0.98 | 2.5 | 0.1090 | 902 |
| Cooler: Shaded Pole to ECM:<br>1/15 HP (49 Watt) | 191 | 75 | 0.9 | 100% | 0.98 | 2.5 | 0.1470 | 1,216 |
| Freezer: Shaded Pole to ECM:<br>1/40 HP (16-23 Watt) | 93 | 30 | 0.9 | 94.4% | 0.98 | 1.3 | 0.0955 | 790 |
| Freezer: Shaded Pole to ECM:<br>1/20 HP (37 Watt) | 142 | 56 | 0.9 | 94.4% | 0.98 | 1.3 | 0.1304 | 1,079 |
| Freezer: Shaded Pole to ECM:<br>1/15 HP (49 Watt) | 191 | 75 | 0.9 | 94.4% | 0.98 | 1.3 | 0.1759 | 1,455 |

**Table 3-44~~3-4544~~: 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~~3.10.3 Measure Life

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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~~3.11 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~~3.11.1 Algorithms

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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~~December 2010 release of the ENERGY STAR calculator for office equipment.

**ENERGY STAR Computer**

$\Delta kWh = ESav_{COM}$

$\Delta kW_{peak} = DSav_{COM}$ ~~$x\ CF_{COM}$~~

**ENERGY STAR Fax Machine**

$\Delta kWh = ESav_{FAX}$

$\Delta kW_{peak} = DSav_{FAX}$ ~~$x\ CF_{FAX}$~~

**ENERGY STAR Copier**

$\Delta kWh = ESav_{COP}$

$\Delta kW_{peak} = DSav_{COP}$ ~~$x\ CF_{COP}$~~

**ENERGY STAR Printer**

$\Delta kWh = ESav_{PRI}$

$\Delta kW_{peak} = DSav_{PRI}$ ~~$x\ CF_{PRI}$~~

**ENERGY STAR Multifunction**

$\Delta kWh = ESav_{MUL}$

$\Delta kW_{peak} = DSav_{MUL}$ ~~$x\ CF_{MUL}$~~

**ENERGY STAR Monitor**

$\Delta kWh = ESav_{MON}$

$\Delta kW_{peak} = DSav_{MON}$ ~~$x\ CF_{MON}$~~

### ~~3.12.2~~3.11.2 Definition of Terms

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$ESav_{COM}$ = 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 1.18 for demand impacts for all office equipment reflecting embedded coincidence in the DSav factor.

**Table 3-45~~3-46~~45: ENERGY STAR Office Equipment - References**

| Component | Type | Value | Sources |
|---|---|---|---|
| $ESav_{COM}$<br>$ESav_{FAX}$<br>$ESav_{COP}$<br>$ESav_{PRI}$<br>$ESav_{MUL}$<br>$ESav_{MON}$ | Fixed | See Table 3-46~~Table 3-47~~46 | 1 |
| $DSav_{COM}$<br>$DSav_{FAX}$<br>$DSav_{COP}$<br>$DSav_{PRI}$<br>$DSav_{MUL}$<br>$DSav_{MON}$ | Fixed | See Table 3-46~~Table 3-47~~46 | 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~~1.18 | 3 |

**Sources:**

2. ENERGY STAR Office Equipment Savings Calculator (Calculator updated: ~~June~~December 2010). Default values were used.
3. Using a commercial office equipment load shape, the percentage of total savings that occur during the ~~top 100 system hours~~PJM peak demand period was calculated and multiplied by the energy savings. The coincidence factor, defined as (kW * 8760) / kWh, used for all office equipment is 1.18 as calculated by doing a covariance between the load shape and peak hours.
4. ~~Coincidence factors already embedded in summer peak demand reduction estimates.~~
4. Coincidence factors already embedded in summer peak demand reduction estimates.

### 3.11.3 Default Savings

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**Table 3-46~~3-47~~46: ENERGY STAR Office Equipment Energy and Demand Savings Values**

| Measure | Energy Savings (ESav) | Demand Savings (DSav) | Source |
|---|---|---|---|
| Computer | 133 kWh | 0.018 –kW | 1 |
| Fax Machine (laser) | 78 kWh | 0.0105 kW | 1 |
| Copier (monochrome) | | | |
| 1-25 images/min | 73 kWh | 0.0098 kW | 1 |
| 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 | 1 |
| 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 | 1 |
| 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 | 1 |

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**Sources:**

1. ENERGYSTAR ~~office equipment calculators~~Office Equipment Calculator (Calculator updated: December 2010).

### ~~3.12.3~~3.11.4 Measure Life

**Table 3-47~~3-48~~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~~Office Equipment Calculator (Calculator updated: December 2010).

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## ~~3.13~~3.12 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~~3.12.1 Eligibility

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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~~3.12.2 Algorithms

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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:

$$\Delta kWh \qquad = \left(kW_{comp} \times Hr_{comp}\right) \times 365 = \mathbf{123.69}\boldsymbol{kWh}\ (\boldsymbol{rounded\ to\ 124kWh})$$

$$\Delta kWpeak \qquad = CF \times kW_{comp} = \mathbf{0.0101}\ \boldsymbol{kW}$$

### ~~3.13.3~~3.12.3 Definition of Terms

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The parameters in the above equation are listed below.

**Table 3-48~~3-49~~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~~3.12.4 Deemed Savings

$\Delta kWh$ = 124 kWh

$\Delta kW_{peak}$ = 0.0101 kW

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### ~~3.13.5~~3.12.5 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.

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### ~~3.13.6~~3.12.6 Evaluation Protocols

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

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## ~~3.14~~3.13 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~~3.13.1 Algorithms

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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~~3.13.2 Definition of Terms

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$kWh_{base}$ = 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~~3.13.3 Energy Savings Calculations

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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%[314,315,316,317]. It should be noted that

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[314] 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 3-49~~Table 3-50~~49. 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 3-49~~3-50~~49: Beverage Machine Controls Energy Savings**[318]

| 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~~3.13.4 Measure Life

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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

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[315] 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

[316] *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

[317] *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

[318] 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~~3.14 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[319]. 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~~3.14.1 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.

$$\Delta kWh = \frac{(kWh_{base}\text{-}kWh_{he})}{100} \times H \times 365 \times D$$

$$\Delta kW_{peak} = \frac{\Delta kWh}{8760 * D} \times CF$$

### ~~3.15.2~~3.14.2 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 3-50~~Table 3-51~~50. 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.

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[319] *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

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Table 3-50~~3-51~~50: Ice Machine Reference values for algorithm components

| Term | Type | Value | Source |
|---|---|---|---|
| $kWh_{base}$ | Variable | Table 3-51~~Table 3-5251~~ | 1 |
| $kWh_{he}$ | Variable | Table 3-51~~Table 3-5251~~ | 2 |
| H | Variable | Manufacturer Specs | EDC Data Gathering |
| D | Variable | Default = 0.4[320] | 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~~3.14.3 Energy Savings Calculations

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Ice machine energy usage levels are dependent on the ice harvest rate (H), and are calculated using CEE specifications as shown in Table 3-51~~Table 3-5251~~. 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[321]. The two energy consumption values are then applied to the energy savings algorithm above.

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[320] *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.

[321] *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 3-51~~3-52~~51: Ice Machine Energy Usage**[322]

| 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~~3.14.4 Measure Life

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Measure life = 10 years[323].

**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

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[322] 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.

[323] *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~~3.15 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~~3.15.1 Eligibility

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This measure applies to non-residential buildings or common areas in multifamily complexes 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~~3.15.2 Algorithms

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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~~3.15.3 Definition of Terms

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*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* = *equivalent full load hours*

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

*EER* = *efficiency of the cooling system*

*COP* = *efficiency of the heating system*

**Table 3-52~~3-53~~52: Non-Residential Insulation – Values and References**

| Component | Type | Values | Sources |
|---|---|---|---|
| A | Variable | Application | AEPS Application;<br>EDC Data Gathering |
| HDD | Fixed | Allentown = 5318<br>Erie = 6353<br>Harrisburg = 4997<br>Philadelphia = 4709<br>Pittsburgh = 5429<br>Scranton = 6176<br>Williamsport = 5651 | 1 |
| CDD | Fixed | Allentown = 787<br>Erie = 620<br>Harrisburg = 955<br>Philadelphia = 1235<br>Pittsburgh = 726<br>Scranton = 611<br>Williamsport = 709 | 1 |
| 24 | Fixed | 24 | n/a |

| Component | Type | Values | Sources |
|---|---|---|---|
| 1000 | Fixed | 1000 | n/a |
| Ceiling $R_i$ | Existing: Variable<br>New Construction: Fixed | For new construction buildings and when variable is unknown for existing buildings: See Table 3-53~~Table 3-54~~53 and Table 3-54~~Table 3-55~~54 for values by building type | AEPS Application; EDC Data Gathering; 2, 4 |
| Wall $R_i$ | Existing: Variable<br>New Construction: Fixed | For new construction buildings and when variable is unknown for existing buildings: See Table 3-53~~Table 3-54~~53 and Table 3-54~~Table 3-55~~54 for values by building type | AEPS Application; EDC Data Gathering; 3, 4 |
| $R_f$ | Variable | EDC Data Gathering | AEPS Application; EDC Data Gathering; |
| $EFLH_{cool}$ | Variable | Default: See Table 3-56~~Table 3-57~~56 | 5 |
| | | Based on Logging, BMS data or Modeling[324] | EDC Data Gathering |
| CF | Fixed | ~~67~~55% | 5 |
| EER | Variable | Default: See Table 3-55~~Table 3-56~~55 | 6~~, 7~~ |
| | | Nameplate | EDC Data Gathering |
| COP | Variable | Default: See Table 3-55~~Table 3-56~~55 | 6~~, 7~~ |
| | | Nameplate | EDC Data Gathering |

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**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

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[324] Modeling is an acceptable substitute to metering and BMS data if modeing is conducted using building- and equipment-specific information at the site and the facility consumption is calibrated using 12 months of billing data (pre-retrofit).

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~~C&I Unitary HVAC Load Shape Project Final Report, KEMA, 2011. The study reports CF values ~~and coincidence factors~~in the range of 44% to 63% depending on the size of the unit for ~~HVAC~~ the Mid Atlantic PJM hours. The study, therefore, assumes an average CF value of 55% for the PJM peak demand ~~savings calculations come from the Pennsylvania Technical Reference Manual. June 2010.~~period that is applied to all units.
6. Baseline values from ~~ASHRAE 90.1-2004 for existing buildings.~~ IECC 2009, Tables 503.2.3(1), 503.2.3(2), and 503.2.3(3). after Jan 1, 2010 or Jan 23, 2010 as applicable. Integrated Energy Efficiency Ratio (IEER) requirements have been incorporated from ASHRAE 90.1-2007, "Energy Standard for Buildings Except Low-Rise Residential Buildings", 2008 Supplement (Addendum S: (Tables 6.8.1A and 6.8.1B). IECC 2009 does not present IEER requirements.
7. ~~Baseline values from IECC 2009 for new construction buildings.~~

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**Table 3-53~~3-54~~53: Ceiling R-Values by Building Type**

| Building Type | Ceiling $R_i$-Value (New Construction) | Ceiling $R_i$-Value (Existing) |
|---|---|---|
| Large Office<br>Large Retail<br>Lodging<br>Health<br>Education<br>Grocery | 20 | 9 |
| Small Office<br>Warehouse | 24.4 | 13.4 |
| Small Retail<br>Restaurant<br>Convenience Store | 20 | 9 |

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**Table 3-54~~3-55~~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<br>Large Retail | 14 | 3.0 |

| | | |
|---|---|---|
| Small Retail<br>Convenience Store | | |
| Lodging<br>Health<br>Education<br>Grocery | 13 | 2.0 |
| Restaurant | 14 | 3.2 |
| Warehouse | 14 | 2.5 |

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### Table 3-55~~3-56~~55: HVAC Baseline Efficiencies for Non-Residential Buildings[325]

| | | | ~~Existing Building~~[326] | ~~New Construction~~[327] | | |
|---|---|---|---|---|---|---|
| **Equipment Type and Capacity** | | | **Cooling Efficiency** | **Heating Efficiency** | ~~**Cooling Efficiency**~~ | ~~**Heating Efficiency**~~ |
| Air-Source Air Conditioners | | | | | | |
| < 65,000 BtuH | ~~10.0 SEER~~ | ~~N/A~~ | 13.0 SEER | N/A | | |
| > 65,000 BtuH and <135,000 BtuH | ~~10.3 EER~~ | ~~N/A~~ | 11.2 EER / 11.4 IEER | N/A | | |
| > 135,000 BtuH and < 240,000 BtuH | ~~9.7 EER~~ | ~~N/A~~ | 11.0 EER / 11.2 IEER | N/A | | |
| > 240,000 BtuH and < 760,000 BtuH<br>(IPLV for units with capacity-modulation only) | ~~9.5 EER~~ | ~~N/A~~ | 10.0 EER / ~~9.7 IPLV~~10.1 IEER | N/A | | |
| > 760,000 BtuH<br>(IPLV for units with capacity-modulation only) | ~~9.2 EER~~ | ~~N/A~~ | 9.7 EER / 9.~~4 IPLV~~8 IEER | N/A | | |
| Water-Source and Evaporatively-Cooled Air Conditioners | | | | | | |
| < 65,000 BtuH | | | 12.1 EER / 12.3 IEER | N/A | ~~12.1 EER~~ | ~~N/A~~ |
| > 65,000 BtuH and <135,000 BtuH | | | 11.5 EER / 11.7 IEER | N/A | ~~11.5 EER~~ | ~~N/A~~ |
| > 135,000 BtuH and < 240,000 BtuH | | | 11.0 EER / 11.2 IEER | N/A | ~~11.0 EER~~ | ~~N/A~~ |
| > 240,000 BtuH | | | 11.0 EER / 11.1 IEER | N/A | ~~11.5 EER~~ | ~~N/A~~ |
| Air-Source Heat Pumps | | | | | | |
| < 65,000 BtuH | ~~10.0 SEER~~ | ~~6.8 HSPF~~ | 13 SEER | 7.7 HSPF | | |
| > 65,000 BtuH and <135,000 BtuH | ~~10.1 EER~~ | ~~3.2 COP~~ | 11.0 EER / 11.2 IEER | 3.3 COP | | |
| > 135,000 BtuH and < 240,000 BtuH | ~~9.3 EER~~ | ~~3.1 COP~~ | 10.6 EER / 10.7 IEER | 3.2 COP | | |
| > 240,000 BtuH (IPLV for units with capacity-modulation only) | ~~9.0 EER~~ | ~~3.1 COP~~ | 9.5 EER / 9.~~2 IPLV~~6 IEER | 3.2 COP | | |
| Water-Source Heat Pumps | | | | | | |
| < 17,000 BtuH | | | 11.2 EER | 4.2 COP | ~~11.2 EER~~ | ~~4.2 COP~~ |
| > 17,000 BtuH and < 65,000 BtuH | | | 12.0 EER | 4.2 COP | ~~12.0 EER~~ | ~~4.2 COP~~ |

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[325] Baseline values from IECC 2009, Tables 503.2.3(1), 503.2.3(2), and 503.2.3(3). after Jan 1, 2010 or Jan 23, 2010 as applicable. Integrated Energy Efficiency Ratio (IEER) requirements have been incorporated from ASHRAE 90.1-2007, "Energy Standard for Buildings Except Low-Rise Residential Buildings", 2008 Supplement (Addendum S: (Tables 6.8.1A and 6.8.1B). IECC 2009 does not present IEER requirements.

~~[326] ASHRAE 90.1-2004, Tables 6.8.1A, 6.8.1B, and 6.8.1D~~

~~[327] IECC 2009, Tables 503.2.3(1), 503.2.3(2), and 503.2.3(3)~~

| | | | ~~Existing Building~~[326] | ~~New Construction~~[327] | | |
|---|---|---|---|---|---|---|
| Ground Water Source Heat Pumps | | | | | | |
| < 135,000 BtuH | | | 16.2 EER | 3.6 COP | ~~16.2 EER~~ | ~~3.6 COP~~ |
| Ground Source Heat Pumps | | | | | | |
| < 135,000 BtuH | | | 13.4 EER | 3.1 COP | ~~13.4 EER~~ | ~~3.1 COP~~ |
| Packaged Terminal Systems | | | | | | |
| PTAC (cooling) | ~~10.9 - (0.213 x Cap / 1000) EER~~ | ~~N/A~~ | 12.5 - (0.213 x Cap / 1000) EER | N/A | | |
| PTHP | ~~10.8 - (0.213 x Cap / 1000) EER~~ | ~~2.9 - (0.026 x Cap / 1000) COP~~ | 12.3 - (0.213 x Cap / 1000) EER | 3.2 - (0.026 x Cap / 1000) COP | | |

**Note:**

- For air-source air conditioners, water-source and evaporatively-cooled air conditioners and air-source heat pumps, subtract 0.2 from the required baseline efficiency rating value if unit has heating section other than electric resistance.
- Integrated Energy Efficiency Ratios (IEERs) are only applicable to equipment with capacity modulation.

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**Table 3-56~~3-575~~6: Cooling EFLH for Key PA Cities**[328]

| 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 |

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[328] US Department of Energy. ENERGY STAR Calculator and Bin Analysis Models

| **Space and/or Building Type** | **Allentown** | **Erie** | **Harrisburg** | **Pittsburgh** | **Williamsport** | **Philadelphia** | **Scranton** |
|---|---|---|---|---|---|---|---|
| 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 | 1,251 | 690 | 1,330 | 1,055 | 944 | 1,478 | 889 |

### ~~3.16.4~~3.15.4 Measure Life

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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~~3.16 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[329], 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[330].

### ~~3.17.1~~3.16.1 Eligibility

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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[331].

### ~~3.17.2~~3.16.2 Algorithms

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$\Delta kWh = \Delta kWh/sqft \times A$

$\Delta kW_{peak} = \Delta kW/sqft \times A$

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[329] 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.

[330] See source 1 for Table 3-14.

[331] 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[332] (an application of Bernoulli's equation) and the ASHRAE handbook[333]. To the extent that evaluation findings are able to provide more reliable site specific inputs assumptions, they may be used in place of the default per square foot savings using the following equation.

~~$\Delta kWh = 365 \text{ x } t_{open} \text{ x } (\eta_{new} - \eta_{old}) \text{ x } 20C_D \text{ x } A \text{ x } \{[(T_i - T_r)/T_i]gH\}^{0.5} \text{ x } (\rho_i h_i - \rho_r h_r) / (3413 \text{ x } COP_{adj})$~~

$$\Delta kWh = \frac{365 \text{ x t open x } (\eta \text{ new} - \eta \text{ old}) \text{ x } 20 \text{ x CD x A x } \{[(\text{Ti} - \text{Tr}) / \text{Ti}] \text{ x g x H}\}^{0.5} \text{x } (\rho \text{i x hi} - \rho \text{r x hr})}{3413 \frac{Btu}{kWh} x\ COP\ adj \text{ x A}}$$

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[334] in the study of strip curtains in supermarkets, convenience stores, and restaurants.

### ~~3.17.3~~3.16.3 Definition of Terms

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The variables in the main equations are defined below:

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

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

*A* = *Doorway area, ft2*

The variables in the source equation are defined below:

$t_{open}$ = *Minutes walk-in door is open per day*

$\eta_{new}$ = *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.*

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[332] *Kalterveluste durch kuhlraumoffnungen*. Tamm W,.Kaltetechnik-Klimatisierung 1966;18;142-144

[333] American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE). 2006. *ASHRAE Handbook,* Refrigeration: 13.4, 13.6

[334] http://www.calmac.org/publications/ComFac_Evaluation_V1_Final_Report_02-18-2010.pdf

$\eta_{old}$ = *Efficacy of the old strip curtain*

*20* = *Product of 60 minutes per hour and an integration factor of 1/3*[335]

$C_D$ = *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*

= *Farenheit + 459.67*

$T_r$ = *Dry-bulb temperature of refrigerated air, Rankine*

= *Farenheit + 459.67*

*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.*

$\rho_i$ = *Density of the infiltration air, lb/ft3. Based on 55% RH.*

$\rho_r$ = *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 3-57~~Table 3-58~~57. Default parameters used in the source equations are listed in Table 3-58~~Table 3-59~~58, Table 3-59~~Table 3-60~~59, Table 3-60~~Table~~

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[335] 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 $\Delta H_{NPL}$ }^0.5 where $\Delta H_{NPL}$ 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 $\Delta H_{NPL}$ ) 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.

~~3-61~~60, and Table 3-61~~Table 3-62~~61. 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[336]. The original work included 8760-hourly bin calculations. The values used herein represent annual average values. For example, the differences in the temperature between the refrigerated and infiltrating airs are averaged over all times that the door to the walk-in unit is open. Recommendations made by the evaluation team have been adopted to correct for errors observed in the *ex ante* savings calculation.

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As for the verified savings for all strip curtains installed in the refrigerated warehouses, the study found several issues that resulted in low realization rates despite the relatively high savings if the curtains are found to be installed in an actual warehouse. The main factor was the misclassification of buildings with different end-use descriptions as refrigerated warehouses. For example, the EM&C contractor found that sometimes the facilities where the curtains were installed were not warehouses at all, and sometimes the strip curtain installations were not verified. The Commission, therefore, believes that the savings for strip curtains installed at an actual refrigerated warehouse should be much higher. To accurately estimate savings for this measure, the Commission encourages the EDCs to use billing analysis for refrigerated warehouses for projects selected in the evaluation sample.

**Table 3-57~~3-58~~57: 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 |

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[336] 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.

| | | | |
|---|---|---|---|
| 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 3-58~~3-59~~58: Strip Curtain Calculation Assumptions for Supermarkets**

| Component | Type | Value | | Source |
|---|---|---|---|---|
| | | Cooler | Freezer | |
| $\eta_{new}$ | Fixed | 0.88 | 0.88 | 1 |
| $\eta_{old}$<br>with Pre-existing curtain<br>with no Pre-existing curtain<br>unknown | Fixed | <br>0.58<br>0.00<br>0.00 | <br>0.58<br>0.00<br>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 |
| $\rho_i$ | Fixed | 0.074 | 0.074 | 3 |
| $h_i$ | Fixed | 26.935 | 24.678 | 3 |
| $\rho_r$ | 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 3-59~~3-60~~59: Strip Curtain Calculation Assumptions for Convenience Stores**

| Component | Type | Value | | Source |
|---|---|---|---|---|
| | | Cooler | Freezer | |
| $\eta_{new}$ | Fixed | 0.79 | 0.83 | 1 |

| Component | Type | Value | | Source |
|---|---|---|---|---|
| | | Cooler | Freezer | |
| $\eta_{old}$<br>with Pre-existing curtain<br>with no Pre-existing curtain<br>unknown | Fixed | <br>0.58<br>0.00<br>0.34 | <br>0.58<br>0.00<br>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 |
| $\rho_i$ | Fixed | 0.074 | 0.075 | 3 |
| $h_i$ | Fixed | 25.227 | 23.087 | 3 |
| $\rho_r$ | 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 3-60~~3-61~~60: Strip Curtain Calculation Assumptions for Restaurant**

| Component | Type | Value | | Source |
|---|---|---|---|---|
| | | Cooler | Freezer | |
| $\eta_{new}$ | Fixed | 0.80 | 0.81 | 1 |
| $\eta_{old}$<br>with Pre-existing curtain<br>with no Pre-existing curtain<br>unknown | Fixed | <br>0.58<br>0.00<br>0.33 | <br>0.58<br>0.00<br>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 |
| $\rho_i$ | Fixed | 0.074 | 0.074 | 3 |
| $h_i$ | Fixed | 26.356 | 24.678 | 3 |

| | | | | |
|---|---|---|---|---|
| $\rho_r$ | 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 3-61~~3-62~~61: Strip Curtain Calculation Assumptions for Refrigerated Warehouse**

| Component | Type | Value | Source |
|---|---|---|---|
| $\eta_{new}$ | Fixed | 0.89 | 1 |
| $\eta_{old}$<br>with Pre-existing curtain<br>with no Pre-existing curtain<br>unknown | Fixed | <br>0.58<br>0.00<br>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 |
| $\rho_i$ | Fixed | 0.076 | 3 |
| $h_i$ | Fixed | 20.609 | 3 |
| $\rho_r$ | 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~~3.16.4 Measure Life

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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~~3.16.5 Evaluation Protocols

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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~~3.17 Water Source and Geothermal Heat Pumps

This protocol shall apply to ground source, groundwater source, water source heat pumps, and water source and evaporatively cooled air conditioners 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~~3.17.1 Eligibility

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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.

This protocol does not apply to heat pump systems coupled with non-heat pump systems such as chillers, rooftop AC units, boilers, or cooling towers. Projects that use unique, combined systems such as these 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 3-62~~3-6362~~: Water Source or 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~~3.17.2 Algorithms

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There are three primary components that must be accounted for in the energy and demand calculations. The first component is the heat pump unit energy and power, the second is the circulating pump in the ground/water loop system energy and power, and the third is the well 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:**

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

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

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

$\Delta kWh_{pump}$ $= \{(HP_{basemotor} \times LF_{base} \times 0.746 \times (1/\eta_{basemotor}) \times (1/\eta_{basepump}) \times (HOURS_{basepump})\} - \{(HP_{eemotor} \times LF_{ee} \times 0.746 \times (1/\eta_{eemotor}) * (1/\eta_{eepump}) \times (HOURS_{eepump})\}$

$\Delta kW_{peak}$ $= \Delta kW_{peak\ cool} + \Delta kW_{peak\ pump}$

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

$\Delta kW_{peak\ pump}$ $= \{HP_{basemotor} \times LF_{base} \times 0.746 \times (1/\eta_{basemotor}) \times (1/\eta_{basepump}) \times CF_{pump}\} - \{HP_{eemotor} \times LF_{ee} \times 0.746 \times (1/\eta_{eemotor}) \times (1/\eta_{eepump})] \times CF_{pump}\}$

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

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

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

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

$\Delta kWh_{pump} = \{(HP_{basemotor} \text{ X } LF_{base} \text{ X } 0.746 \text{ X } (1/\eta_{basemotor}) \text{ X } (1/\eta_{basepump}) \text{ X } (HOURS_{basepump})\} - \{(HP_{eemotor} \text{ X } LF_{ee} \text{ X } 0.746 \text{ X } (1/\eta_{eemotor}) * (1/\eta_{eepump}) \text{ X } (HOURS_{eepump})\}$

$\Delta kW_{peak} = \Delta kW_{peak\ cool} + \Delta kW_{peak\ pump}$

$\Delta kW_{peak\ cool} = \{(BtuH_{cool} / 1000) \text{ X } [(1/EER_{base})] \text{ X } CF_{cool}\} - \{(BtuH_{cool} / 1000) \text{ X } [(1/EER_{ee})] \text{ X } CF_{cool}\}$

$\Delta kW_{peak\ pump} = \{HP_{basemotor} \text{ X } LF_{base} \text{ X } 0.746 \text{ X } (1/\eta_{basemotor}) \text{ X } (1/\eta_{basepump}) \text{ X } CF_{pump}\} - \{HP_{eemotor} \text{ X } LF_{ee} \text{ X } 0.746 \text{ X } (1/\eta_{eemotor}) \text{ X } (1/\eta_{eepump})] \text{ X } CF_{pump}\}$

### ~~3.18.3~~3.17.3 Definition of Terms[337]

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$BtuH_{cool}$ = 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

$EER_{ee}$ = the cooling EER of the new ground source, groundwater source, or water source heat pumpground being installed

$COP_{ee}$ = Coefficient of Performance of the new ground source, groundwater source, or water source heat pump being installed

$EFLH_{cool}$ = Cooling annual Equivalent Full Load Hours EFLH for Commercial HVAC for different occupancies

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[337] The cooling efficiency ratings of the baseline and efficient units should be used not including pumps where appropriate.

$EFLH_{heat}$ = *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*

$\eta_{eepump}$ = *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 3-63~~3-6463~~: 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)<br>Use $BtuH_{cool}$ 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 3-66~~Table 3-6766~~ | See Table 3-66~~Table 3-6766~~ |
| $EER_{base}$ | Fixed | Early Replacement: Nameplate data<br>= $SEER_{base}$ X (11.3/13) if EER not available[338] | EDC Data Gathering |
| | | New Construction or Replace on Burnout: Default values from Table 3-66~~Table 3-6766~~ | See Table 3-66~~Table 3-6766~~ |
| $HSPF_{base}$ | Fixed | Early Replacement: Nameplate data | EDC Data Gathering |
| | | New Construction or Replace on Burnout: Default values from Table 3-66~~Table 3-6766~~ | See Table 3-66~~Table 3-6766~~ |
| $COP_{base}$ | Fixed | Early Replacement: Nameplate data | EDC Data Gathering |
| | | New Construction or Replace on Burnout: Default values from Table 3-66~~Table 3-6766~~ | See Table 3-66~~Table 3-6766~~ |
| $EER_{ee}$ | Variable | Nameplate data (ARI or AHAM)<br>= $SEER_{ee}$ X (11.3/13) if EER not available[339] | EDC Data Gathering |
| $COP_{ee}$ | Variable | Nameplate data (ARI or AHAM) | EDC Data Gathering |
| $EFLH_{cool}$ | Variable | Based on Logging, BMS data or Modeling[340] | EDC Data Gathering |

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[338] 11.3/13 = Conversion factor from SEER to EER, based on average EER of a SEER 13 unit.

[339] 11.3/13 = Conversion factor from SEER to EER, based on average EER of a SEER 13 unit.

[340] Modeling is an acceptable substitute to metering and BMS data if modeing is conducted using building- and equipment-specific information at the site and the facility consumption is calibrated using 12 months of billing data (pre-retrofit).

| Component | Type | Values | Sources |
|---|---|---|---|
| | | Default values from Note:<br>- For air-source air conditioners and air-source heat pumps, subtract 0.2 from the required baseline efficiency rating value if unit has heating section other than electric resistance.<br>- Integrated Energy Efficiency Ratios (IEERs) are only applicable to equipment with capacity modulation.<br>Table 3-22~~Table 3-23~~22 and Table 3-23~~Table 3-24~~23 | See Note:<br>- For air-source air conditioners and air-source heat pumps, subtract 0.2 from the required baseline efficiency rating value if unit has heating section other than electric resistance.<br>- Integrated Energy Efficiency Ratios (IEERs) are only applicable to equipment with capacity modulation.<br>Table 3-22~~Table 3-23~~22 and Table 3-23~~Table 3-24~~23 |
| $EFLH_{heat}$ | Variable | Based on Logging, BMS data or Modeling[341] | EDC Data Gathering |

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[341] Ibid

| Component | Type | Values | Sources |
|---|---|---|---|
| | | Default values from Note:<br>• For air-source air conditioners and air-source heat pumps, subtract 0.2 from the required baseline efficiency rating value if unit has heating section other than electric resistance.<br>• Integrated Energy Efficiency Ratios (IEERs) are only applicable to equipment with capacity modulation.<br>Table 3-22~~Table 3-23~~22 and Table 3-23~~Table 3-24~~23 | See Note:<br>• For air-source air conditioners and air-source heat pumps, subtract 0.2 from the required baseline efficiency rating value if unit has heating section other than electric resistance.<br>• Integrated Energy Efficiency Ratios (IEERs) are only applicable to equipment with capacity modulation.<br>Table 3-22~~Table 3-23~~22 and Table 3-23~~Table 3-24~~23 |
| $CF_{cool}$ | Fixed | Default = ~~0.80~~55% | 3 |
| $CF_{pump}$ | Fixed | If unit runs 24/7/365, default = 1.0;<br>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 and nameplate | EDC Data Gathering |
| | | Default 75% | 1 |
| $\eta_{basemotor}$ | Variable | Nameplate | EDC's Data Gathering |
| | | If unknown, assume the federal minimum efficiency requirements in Table 3-64~~Table 3-65~~64 | See Table 3-64~~Table 3-65~~64 |
| $\eta_{basepump}$ | Variable | Nameplate | EDC's Data Gathering |
| | | If unknown, assume program compliance efficiency in Table 3-65~~Table 3-66~~65 | See Table 3-65~~Table 3-66~~65 |

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| Component | Type | Values | Sources |
|---|---|---|---|
| $HOURS_{basepump}$ | Fixed | Based on Logging, BMS data or Modeling[342] | EDC's Data Gathering |
| | | $EFLH_{cool}$ + $EFLH_{heat}$ [343]<br>Default values from Note:<br>- For air-source air conditioners and air-source heat pumps, subtract 0.2 from the required baseline efficiency rating value if unit has heating section other than electric resistance.<br>- Integrated Energy Efficiency Ratios (IEERs) are only applicable to equipment with capacity modulation.<br>Table 3-22~~Table 3-23~~22 and Table 3-23~~Table 3-24~~23 | 2 |
| $HP_{eemotor}$ | Variable | Nameplate | EDC's Data Gathering |
| $LF_{ee}$ | Variable | Based on spot metering and nameplate | EDC Data Gathering |
| | | Default 75% | 1 |
| $\eta_{eemotor}$ | Variable | Nameplate | EDC's Data Gathering |
| | | If unknown, assume the federal minimum efficiency requirements in Table 3-64~~Table 3-65~~64 | Table 3-64~~Table 3-65~~64 |
| $\eta_{eepump}$ | Variable | Nameplate | EDC's Data Gathering |
| | | If unknown, assume program compliance efficiency in Table 3-65~~Table 3-66~~65 | See Table 3-65~~Table 3-66~~65 |
| $HOURS_{eepump}$ | Variable | Based on Logging, BMS data or Modeling[344] | EDC Data Gathering |
| | | $EFLH_{cool}$ + $EFLH_{heat}$ [345]<br>Default values from Note:<br>- For air-source air conditioners and air-source heat pumps, subtract 0.2 from the required baseline efficiency rating value if unit has heating section other than electric resistance.<br>- Integrated Energy Efficiency Ratios (IEERs) are only applicable to equipment with capacity modulation.<br>Table 3-22~~Table 3-23~~22 and Table 3-23~~Table 3-24~~23 | 2 |

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[342] Ibid

[343] $EFLH_{cool}$ + $EFLH_{heat}$ represent the addition of cooling and heating annual equivalent full load hours for commercial HVAC for different occupancies, respectively.

[344] Ibid

[345] $EFLH_{cool}$ + $EFLH_{heat}$ represent the addition of cooling and heating annual equivalent full load hours for commercial HVAC for different occupancies, respectively.

**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)~~
3. C&I Unitary HVAC Load Shape Project Final Report, KEMA, 2011. The study reports CF values in the range of 44% to 63% depending on the size of the unit for the Mid Atlantic PJM hours. The study, therefore, assumes an average CF value of 55% for the PJM peak demand period that is applied to all units.
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 3-64~~3-65~~64: Federal Minimum Efficiency Requirements for Motors**[346]

| Size HP | Open Drip Proof (ODP) # of Poles | | | Totally Enclosed Fan-Cooled (TEFC) | | |
|---|---|---|---|---|---|---|
| | *6* | *4* | *2* | *6* | *4* | *2* |
| | **Speed (RPM)** | | | **Speed (RPM)** | | |
| | *1200* | *1800* | *3600* | *1200* | *1800* | *3600* |
| 1 | 82.50% | 85.50% | 77.00% | 82.50% | 85.50% | 77.00% |
| 1.5 | 86.50% | 86.50% | 84.00% | 87.50% | 86.50% | 84.00% |
| 2 | 87.50% | 86.50% | 85.50% | 88.50% | 86.50% | 85.50% |
| 3 | 88.50% | 89.50% | 85.50% | 89.50% | 89.50% | 86.50% |
| 5 | 89.50% | 89.50% | 86.50% | 89.50% | 89.50% | 88.50% |
| 7.5 | 90.20% | 91.00% | 88.50% | 91.00% | 91.70% | 89.50% |
| 10 | 91.70% | 91.70% | 89.50% | 91.00% | 91.70% | 90.20% |
| 15 | 91.70% | 93.00% | 90.20% | 91.70% | 92.40% | 91.00% |
| 20 | 92.40% | 93.00% | 91.00% | 91.70% | 93.00% | 91.00% |

**Table 3-65~~3-66~~65: Ground/Water Loop Pump and Circulating Pump Efficiency**[347]

| HP | Minimum Pump Efficiency at Design Point ($\eta_{pump}$) |
|---|---|
| 1.5 | 65% |
| 2 | 65% |

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[346] 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~~

[347] Based on program requirements submitted during protocol review.

| | |
|---|---|
| 3 | 67% |
| 5 | 70% |
| 7.5 | 73% |
| 10 | 75% |
| 15 | 77% |
| 20 | 77% |

**Table 3-66~~3-67~~66: Default Baseline Equipment Efficiencies**

| Equipment Type and Capacity | Cooling Baseline | Heating Baseline |
|---|---|---|
| Water-Source and Evaporatively-Cooled Air Conditioners | | |
| < 65,000 BtuH | 12.1 EER / 12.3 IEER | N/A |
| ≥ 65,000 BtuH and <135,000 BtuH | 11.5 EER / 11.7 IEER | N/A |
| ≥ 135,000 BtuH and < 240,000 BtuH | 11.0 EER / 11.2 IEER | N/A |
| ≥ 240,000 BtuH | 11.~~5~~0 EER / 11.1 IEER | N/A |
| Water-Source Heat Pumps | | |
| < 17,000 BtuH | 11.2 EER | 4.2 COP |
| ≥ 17,000 BtuH and ≤ 65,000 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 |

**Note:**

- For water-source and evaporatively-cooled air conditioners, subtract 0.2 from the required baseline efficiency rating value if unit has heating section other than electric resistance.
- Integrated Energy Efficiency Ratios (IEERs) are only applicable to equipment with capacity modulation.

### ~~3.18.4~~3.17.4 Measure Life

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The expected measure life is assumed to be 15 years.[348]

### ~~3.18.5~~3.17.5 Evaluation Protocols

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

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[348] Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc., June 2007.

## ~~3.19~~3.18 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 years |

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~~3.18.1 Eligibility

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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.[349] 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). In addition, the old systems should be de energized, completely uninstalled and removed in order to ensure that the full savings is realized.

### ~~3.19.2~~3.18.2 Algorithms

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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:

For Heat Pump units < 65,000 BtuH, use SEER to calculate $\Delta kWh_{cool}$ and HSPF to calculate $\Delta kWh_{heat}$. Convert SEER to EER to calculate $\Delta kW_{peak}$ using 11.3/13 as the conversion factor.

**Single Zone:**

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

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

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[349] 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.

$\Delta kWh_{cool} = CAPY_{cool} / 1000 \text{ X } (1/SEER_b – 1/SEER_e) \text{ X } EFLH_{cool} \text{ X } LF$

$\Delta kW_{peak} = CAPY_{cool} / 1000 \text{ X } (1/EER_b – 1/EER_e) \text{ X } CF$

**Multi-Zone:**

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

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

$\Delta kWh_{cool} = [CAPY_{cool} / 1000 \text{ X } (1/SEER_b – 1/SEER_e) \text{ X } EFLH_{cool} \text{ X } LF]_{ZONE1} + [CAPY_{cool} / 1000 \text{ X } (1/SEER_b – 1/SEER_e) \text{ X } EFLH_{cool} \text{ X } LF]_{ZONE2} + [CAPY_{cool} / 1000 \text{ X } (1/SEER_b – 1/SEER_e) \text{ X } EFLH_{cool} \text{ X } LF]_{ZONEn}$

$\Delta kW_{peak} = [CAPY_{cool} / 1000 \text{ X } (1/EER_b – 1/EER_e) \text{ X } CF]_{ZONE1} + [CAPY_{cool} / 1000 \text{ X } (1/EER_b – 1/EER_e) \text{ X } CF]_{ZONE2} + [CAPY_{cool} / 1000 \text{ X } (1/EER_b – 1/EER_e) \text{ X } CF]_{ZONEn}$

### ~~3.19.3~~3.18.3 Definition of Terms

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$CAPY_{cool}$ =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

$HSPF_b$ = Heating Seasonal Performance Factor, heating efficiency of baseline unit

$HSPF_e$ = Heating Seasonal Performance Factor, heating efficiency of the installed DHP

$SEER_b$ = Seasonal Energy Efficiency Ratio cooling efficiency of baseline unit

$SEER_e$ = Seasonal Energy Efficiency Ratio cooling efficiency of the installed DHP

$LF$ = Load factor

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

**Table 3-67~~3-6867~~: DHP – Values and References**

| Component | Type | Values | Sources |
|---|---|---|---|
| $CAPY_{cool}$<br>$CAPY_{heat}$ | Variable | Nameplate | AEPS Application; EDC Data Gathering |
| $EFLH_{cool}$<br>$EFLH_{heat}$ | Variable | Default: See Table 3-68: ~~Table 3-6968:~~ and Table 3-69: ~~Table 3-7069:~~ | 1 |
| | | Based on Logging, BMS data or Modeling[350] | EDC Data Gathering |
| $HSPF_b$ | Fixed | Standard DHP: 7.7<br>Electric resistance: 3.413<br>ASHP: 7.7<br>PTHP[351] (Replacements): 2.9 - (0.026 x Cap / 1000) COP<br>PTHP (New Construction): 3.2 - (0.026 x Cap / 1000) COP<br>Electric furnace: 3.242<br>For new space, no heat in an existing space, or non-electric heating in an existing space: use standard DHP: 7.7 | 2, 4,9 |
| $SEER_b$ | Fixed | DHP, ASHP, or central AC: 13<br>Room AC: 11.3<br>PTAC[352] (Replacements): 10.9 - (0.213 x Cap / 1000) EER<br>PTAC (New Construction): 12.5 - (0.213 x Cap / 1000) EER<br>PTHP (Replacements): 10.8 - (0.213 x Cap / 1000) EER<br>PTHP (New Construction): 12.3 - (0.213 x Cap / 1000) EER<br>For new space or no cooling in an existing space: use Central AC: 13 | 3,4,5,7,9 |
| $HSPF_e$ | 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% | 6 |

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[350] Ibid

[351] Cap represents the rated cooling capacity of the product in Btu/h. If the unit's capacity is less than 7,000 Btu/h, 7,000 Btu/h is used in the calculation. If the unit's capacity is greater than 15,000 Btu/h, 15,000 Btu/h is used in the calculation. Use HSPF = COP X 3.413.

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

| Component | Type | Values | Sources |
|---|---|---|---|
| LF | Variable | 25% | 8 |
| | | Based on spot metering and nameplate | EDC Data Gathering |

**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 3-68~~3-69~~68: Cooling EFLH for Pennsylvania Cities[353, 354, 355]

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

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

[354] A zip code mapping table is located in Appendix F. This table should be used to identify the reference Pennsylvania city for all zip codes in Pennsylvania

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

Table 3-69~~3-7069~~: Heating EFLH for Pennsylvania Cities[356, 357, 358]

| 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 | 701 | 573 | 576 | 605 | 563 | 612 |
| Dining: Bar Lounge/Leisure | 1,156 | 1,346 | 1,100 | 1,104 | 1,161 | 1,080 | 1,175 |
| Dining: Cafeteria / Fast Food | 582 | 678 | 554 | 556 | 585 | 544 | 592 |
| 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 | 258 | 280 |
| Industrial: 1 Shift/Light Manufacturing | 1,491 | 1,737 | 1,420 | 1,425 | 1,498 | 1,394 | 1,516 |
| Industrial: 2 Shift | 1,017 | 1,184 | 968 | 972 | 1,022 | 951 | 1,034 |
| Industrial: 3 Shift | 538 | 626 | 512 | 513 | 540 | 502 | 546 |
| Lodging: Hotels/Motels/Dormitories | 1,438 | 1,675 | 1,369 | 1,374 | 1,444 | 1,344 | 1,462 |
| Lodging: Residential | 1,438 | 1,675 | 1,369 | 1,374 | 1,444 | 1,344 | 1,462 |
| Multi-Family (Common Areas) | 277 | 322 | 263 | 264 | 278 | 259 | 281 |
| Museum/Library | 1,266 | 1,474 | 1,205 | 1,209 | 1,271 | 1,183 | 1,286 |
| Nursing Homes | 738 | 859 | 702 | 704 | 740 | 689 | 749 |
| Office: General/Retail | 1,266 | 1,474 | 1,205 | 1,209 | 1,271 | 1,183 | 1,286 |
| 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 | 965 | 789 | 792 | 832 | 774 | 842 |
| Police/Fire Stations (24 Hr) | 277 | 322 | 263 | 264 | 278 | 259 | 281 |
| 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 | 1,933 | 1,580 | 1,586 | 1,667 | 1,551 | 1,687 |
| Warehouses (Not Refrigerated) | 1,555 | 1,810 | 1,480 | 1,485 | 1,561 | 1,453 | 1,580 |
| Warehouses (Refrigerated) | 1,555 | 1,810 | 1,480 | 1,485 | 1,561 | 1,453 | 1,580 |
| Waste Water Treatment Plant | 538 | 626 | 512 | 513 | 540 | 502 | 546 |

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

[357] 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

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

### ~~3.19.4~~3.18.4 Measure Life

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According to an October 2008 report for the CA Database for Energy Efficiency Resources, a heat pump's lifespan is 15 years.[359]

### ~~3.19.5~~3.18.5 Evaluation Protocols

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

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[359] 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~~3.19 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~~3.19.1 Algorithms

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

$$\Delta kWh = \Delta kWh_{cooking} + \Delta kWh_{idle}$$

$$\Delta kWh_{cooking} = lbsfood \times EnergyToFood \times (1/Eff_{b} - 1/Eff_{ee})$$

$$\Delta kWh_{idle} = [(Power_{idle\text{-}b} \times (1 - \%HOURS_{consteam}) + \%HOURS_{consteam} \times CAPY_{b} \times Qty_{pans} \times (EnergyToFood/Eff_{b}) \times (HOURS_{op} - lbsfood/(CAPY_{b} \times Qty_{pans}) - HOURS_{pre})] -$$

$$[(Power_{idle\text{-}ee} \times (1 - \%HOURS_{consteam}) + \%HOURS_{consteam} \times CAPY_{ee} \times Qty_{pans} \times (EnergyToFood/Eff_{ee}) \times (HOURS_{op} - lbsfood/(CAPY_{ee} \times Qty_{pans}) - HOURS_{pre})]$$

$$\Delta kW_{peak} = (\Delta kWh / EFLH) \times CF$$

### ~~3.20.2~~3.19.2 Definition of Terms

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

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

$Eff_{ee}$ = *Cooking energy efficiency of the new unit*

$Eff_{b}$ = *Cooking energy efficiency of the baseline unit*

$Power_{idle\text{-}b}$ = *Idle power of the baseline unit in kilowatts*

$Power_{idle\text{-}ee}$ = *Idle power of the new unit in kilowatts*

$\%HOURS_{consteam}$ = *Percentage of idle time per day the steamer is in continuous steam mode instead of timed cooking. The power used in this mode is the same as the power in cooking mode.*

$HOURS_{op}$ = *Total operating hours per day*

$HOURS_{pre}$ = *Daily hours spent preheating the steam cooker*

*$CAPY_b$* = *Production capacity per pan of the baseline unit in pounds per hour of the baseline unit*

*$CAPY_{ee}$* = *Production capacity per pan of the new unit in pounds per hour*

*$Qty_{pans}$* = *Quantity of pans in the unit*

*EFLH* = *Equivalent full load hours per year*

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

*1000* = *Conversion from watts to kilowatts*

**Table 3-70~~3-71~~70: Steam Cooker - Values and References**

| **Component** | **Type** | **Values** | **Sources** |
|---|---|---|---|
| Lbsfood | Variable | Nameplate | EDC Data Gathering |
| | | Default values in Table 3-71~~Table 3-7271~~ | Table 3-71~~Table 3-7271~~ |
| EnergyToFood | Fixed | 0.0308 kWh/pound | 1 |
| $Eff_{ee}$ | Variable | Nameplate | EDC Data Gathering |
| | | Default values in Table 3-71~~Table 3-7271~~ | Table 3-71~~Table 3-7271~~ |
| $Eff_b$ | Fixed | See Table 3-71~~Table 3-7271~~ | Table 3-71~~Table 3-7271~~ |
| $Power_{idle\text{-}b}$ | Variable | See Table 3-71~~Table 3-7271~~ | Table 3-71~~Table 3-7271~~ |
| $Power_{idle\text{-}ee}$ | Variable | Nameplate | EDC Data Gathering |
| | | Default values in Table 3-71~~Table 3-7271~~ | Table 3-71~~Table 3-7271~~ |
| $HOURS_{op}$ | Variable | Nameplate | EDC Data Gathering |
| | | 12 hours | 1 |
| $HOURS_{pre}$ | Fixed | 0.25 | 1 |
| $\%HOURS_{consteam}$ | Fixed | 40% | 1 |
| $CAPY_b$ | Fixed | See Table 3-71~~Table 3-7271~~ | Table 3-71~~Table 3-7271~~ |
| $CAPY_{ee}$ | Fixed | See Table 3-71~~Table 3-7271~~ | Table 3-71~~Table 3-7271~~ |
| $Qty_{pans}$ | Variable | Nameplate | EDC Data Gathering |
| EFLH | Fixed | 4380 | 2 |
| CF | Fixed | 0.84 | 4, 5 |

**Sources:**

~~2.~~1. US Department of Energy. ENERGY STAR Calculator.

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~~10.~~2. Food Service Technology Center (FSTC), based on an assumption that the restaurant is open 12 hours a day, 365 days a year.

~~11.~~3. FSTC (2002). *Commercial Cooking Appliance Technology Assessment*. Chapter 8: Steamers.

~~12.~~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.

~~13.~~5. RLW Analytics. Coincidence Factor Study – Residential and Commercial Industrial Lighting Measures. Spring 2007. The peak demand period used to estimate the CF value is 1PM-5PM, weekday, non-holiday, June-August.

**Table 3-71~~3-72~~71: Default Values for Electric Steam Cookers by Number of Pans[360]**

| # of Pans | Parameter | Baseline Model | Efficient Model | Savings |
|---|---|---|---|---|
| 3 | $Power_{idle}$ (kW)[361] | 1.000 | 0.27 | |
| | CAPY (lb/h) | 23.3 | 16.7 | |
| | lbsfood | 100 | 100 | |
| | Eff[362] | 30% | 59% | |
| | $\Delta$kWh | | | 2,813 |
| | $\Delta kW_{peak}$ | | | 0.54 |
| 4 | $Power_{idle}$ (kW) | 1.325 | 0.30 | |
| | CAPY (lb/h) | 21.8 | 16.8 | |
| | lbsfood | 128 | 128 | |
| | Eff | 30% | 57% | |
| | $\Delta$kWh | | | 3,902 |
| | $\Delta kW_{peak}$ | | | 0.75 |

---

[360] 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.

[361] Efficient values calculated from a list of ENERGY STAR qualified products.

[362] 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 | 30% | 70% | |
| | ΔkWh | | | 5,134 |
| | $\Delta kW_{peak}$ | | | 0.98 |
| 6 | $Power_{idle}$ (kW) | 2.000 | 0.31 | |
| | CAPY (lb/h) | 20.0 | 16.7 | |
| | lbsfood | 192 | 192 | |
| | Eff | 30% | 65% | |
| | ΔkWh | | | 6,311 |
| | $\Delta kW_{peak}$ | | | 1.21 |

### ~~3.20.3~~3.19.3 Measure Life

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According to Food Service Technology Center (FSTC) data provided to ENERGY STAR, the lifetime of a steam cooker is 12 years[363].

### ~~3.20.4~~3.19.4 Evaluation Protocols

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

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[363] http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=COC

## ~~3.21~~3.20 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[364] and between 0°F to 30°F for medium-temperature and between 35°F to 55°F for high-temperature display cases[365]. 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~~3.20.1 Algorithms

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The energy savings and demand reduction are obtained through the following calculations[366].

$\Delta kWh = W \times SF \times HOU$

There are no demand savings for this measure because the covers will not be in use during the peak period[367].

### ~~3.21.2~~3.20.2 Definition of Terms

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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*

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[364] http://www.smud.org/en/business/rebates/Pages/express-refrigeration.aspx

[365] Massachusetts 2011 Technical Reference Manual

[366] "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.

[367] 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 3-72~~3-73~~72: Night Covers Calculations Assumptions**

| Component | Type | Value | Source |
|---|---|---|---|
| W | Variable | EDC's Data Gathering | EDC's Data Gathering |
| SF | Fixed | Default values in Table 3-73: Savings Factors~~Table 3-7473: Savings Factors~~ | 1 |
| HOU | Variable | EDC's Data Gathering<br>Default: 2190[368] | 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 3-73~~3-74~~73: 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~~3.20.3 Measure Life

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The expected measure life is 5 years[369,370].

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[368] 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

[369] 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Effective/Remaining Useful Life Values", California Public Utilities Commission, December 16, 2008.

[370] The Measure Life Report for Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc., June 2007

## ~~3.22~~3.21 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~~3.21.1 Eligibility Requirements

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The deemed savings reported in Table 3-74: Network Power Controls, Per Unit Summary Table~~Table 3-7574: Network Power Controls, Per Unit Summary Table~~ are applicable to any software that meets the following Pacific Northwest Regional Technical Forum's ("RTF") Networked Computer Power Management Control Software Specifications[371]:

- Workstation is defined as the computer monitor and the PC box.
- The software shall have wake-on-LAN capability to allow networked workstations to be remotely wakened from or placed into any power-saving mode and to remotely boot or shut down ACPI-compliant workstations.
- The software shall give the IT administrator easily-accessible central control over the power management settings of networked workstations that optionally overrides settings made by users.
- The software shall be capable of applying specific power management policies to network groups, utilizing existing network grouping capabilities.
- The software shall be compatible with multiple operating systems and hardware configurations on the same network.
- The software shall monitor workstation keyboard, mouse, CPU and disk activity in determining workstation idleness.

### ~~3.22.2~~3.21.2 Deemed Savings

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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

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[371] Network PC Power Management Presentation, Regional Technical Forum, May 4, 2010.

on a research study conducted by Regional Technical Forum which involves actual field measurements of the Verdiem Surveyor product. The study reports deemed energy and demand savings for three different building types (schools, large office and small office) in combination with different HVAC systems types (electric heat, gas heat, and heat pumps). The deemed savings values in Table 3-74: Network Power Controls, Per Unit Summary Table~~Table 3-75~~74~~: Network Power Controls, Per Unit Summary Table~~ also take into account the HVAC interactive effects. A simple average is reported for Pennsylvania.

**Table 3-74~~3-75~~74: 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 |
|---|---|---|---|---|
| Network PC Plug Load Power Management Software | One copy of licensed software installed on a PC workstation | 0.0078[372] | 135[373] | 5 |

### ~~3.22.3~~3.21.3 Effective Useful Life

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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. Regional Technical Forum (RTF) as part of the Northwest Power & Conservation Council, Deemed Measures List. Network Computer Power Management, v3.0.
    a. Office Plug Load Field Monitoring Report, Laura Moorefield et al, Ecos Consulting, Dec, 2008.
    b. PSE PC Power Management Results, Cadmus Group, Feb, 2011.
    c. Non-Residential Network Computer Power Management, Avista, Feb, 2011.
    d. After-hours Power Status of Office Equipment and Inventory of Miscellaneous Plug-Load Equipment, LBNL, Jan 2004.
    e. Ecos Commercial Field Research Report, 2008.
2. 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

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[372] http://www.nwcouncil.org/energy/rtf/measures/measure.asp?id=95&decisionid=117

[373] ibid

3. 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
4. Greenberg, D. (2004). *Network Power Management Software: Saving Energy by Remote Control* (E source report No. ER-04-15). Boulder, CO: Platts Research & Consulting.
5. 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

## ~~3.23~~3.22 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~~3.22.1 Eligibility~~[374]~~[375]

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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~~3.22.2 Algorithms

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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 hours (CDHs) and wet bulb temperatures. 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***

$$\Delta kWh = \Delta kWh_{freezer}$$

$$\Delta kW_{peak} = \Delta kW_{freezer}$$

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~~[374] http://energysmartonline.org/documents/EnergySmart_BPA_T&Cs.pdf~~

[375] http://energysmartonline.org/documents/EnergySmart_BPA_T&Cs.pdf

### ~~3.23.3~~3.22.3 Definition of Terms

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$\Delta kWh_{cooler,}$ = Annual kWh savings for main cooler doors

$\Delta kW_{cooler}$ = 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 3-75~~3-7675~~: Refrigeration Auto Closers Calculations Assumptions**

| Reference City | Associated California Climate Zone[376] | Value | | | | Source |
|---|---|---|---|---|---|---|
| | | Cooler | | Freezer | | |
| | | $kWh_{cooler}$ | $kW_{cooler}$ | $kWh_{freezer}$ | $kW_{freezer}$ | |
| Allentown | 15 | 882 | 0.061 | 2351 | 0.142 | 1 |
| Williamstown | 15 | 882 | 0.061 | 2351 | 0.142 | 1 |
| Pittsburgh | 4 | 961 | 0.135 | 2319 | 0.327 | 1 |
| Philadelphia | 15 | 882 | 0.061 | 2351 | 0.142 | 1 |
| Erie | 9 | 989 | 0.175 | 2369 | 0.395 | 1 |
| Harrisburg | 15 | 882 | 0.061 | 2351 | 0.142 | 1 |
| Scranton | 4 | 961 | 0.135 | 2319 | 0.327 | 1 |

**Sources:**

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

### ~~3.23.4~~3.22.4 Measure Life

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The expected measure life is **8 years**[377].

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[376] The deemed savings values were adopted from the California region and are adjusted to account for differences in weather conditions in Pennsylvania based on cooling degree hours and wet bulb temperatures.The Refrigeration – Auto Closers measure protocol follows the weather mapping table shown in Section 1.17.

[377] http://energysmartonline.org/documents/EnergySmart_BPA_T&Cs.pdf

## ~~3.24~~3.23 Refrigeration – Door Gaskets for Walk-in and Reach-in Coolers and Freezers

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

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

### ~~3.24.1~~3.23.1 Eligibility

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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~~3.23.2 Algorithms

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

$$\Delta kWh = \Delta kWh/ft \ X \ L$$

$$\Delta kW_{peak} = \Delta kW/ft \ X \ L$$

### ~~3.24.3~~3.23.3 Definition of Terms

**Formatted:** Indent: Left: 0", Tab stops: 0.25", List tab + Not at 0.44"

*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 3-76~~3-777~~6: Door Gasket Assumptions**

| Component | Type | Value | Source |
|---|---|---|---|
| ΔkWh/ft | Variable | ~~From Table 3-78 to Table 3-83~~Table 3-77 | 1, 2 |
| ΔkW/ft | Variable | ~~From Table 3-78 to Table 3-83~~Table 3-77 | 1, 2 |
| L | Variable | As Measured | EDC Data Gathering |

**Sources:**

2. ~~Southern California Edison Company, Design & Engineering Services, Work Paper WPSCNRRN0001, Door Gaskets for Main Door of Walk-in Coolers and Freezers, 2006 – 2008 Program Planning Cycle.~~
3. ~~Southern California Edison Company, Design & Engineering Services, Work Paper WPSCNRRN00013, Revision 0, Door Gaskets for Glass Doors of Medium and Low Temp Reach-in Display Cases & Solid Doors of Reach-in Coolers and Freezers, October 15, 2007.~~

~~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[378] ~~prepared for the~~, California Public ~~Utilities~~Utility 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.~~

1. ~~Walk-in Coolers and Freezers[379]:~~February 2010. http://www.calmac.org/publications/ComFac_Evaluation_V1_Final_Report_02-18-2010.pdf.

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**Table 3-~~77~~3-~~78~~77: Door Gasket Savings ~~per~~Per Linear Foot for Walk-in and Reach-in Coolers and Freezers ~~(CZ 4 Pittsburgh, Scranton)~~**

| Building Type | Coolers | | Freezers | |
|---|---|---|---|---|
| | ΔkW/ft | ΔkWh/ft | ΔkW/ft | ΔkW/ft |
| Restaurant | 0.~~000886~~00005 | ~~18~~0.4 | 0.~~001871~~00044 | ~~63~~3.3 |
| Small Grocery Store/ Convenience Store | ~~0.000658~~ | ~~15~~ | ~~0.00162~~ | ~~64~~ |
| Medium/Large Grocery Store/ Supermarkets | ~~0.000647~~ | ~~15~~ | ~~0.001593~~ | ~~91~~ |

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**~~Table 3-79: Door Gasket Savings per Linear Foot for Walk-in Coolers and Freezers (CZ 15 Allentown, Harrisburg, Philadelphia, Williamstown)~~**

| ~~Building Type~~ | ~~Coolers~~ | | ~~Freezers~~ | |
|---|---|---|---|---|
| | ~~ΔkW/ft~~ | ~~ΔkWh/ft~~ | ~~ΔkW/ft~~ | ~~ΔkWh/ft~~ |
| ~~Restaurant~~ | ~~0.001589~~ | ~~31~~ | ~~0.003551~~ | ~~105~~ |
| ~~Small Grocery Store/ Convenience Store~~ | ~~0.001185~~ | ~~24~~ | ~~0.003089~~ | ~~106~~ |
| ~~Medium/Large Grocery Store/ Supermarkets~~ | ~~0.001158~~ | ~~24~~ | ~~0.003054~~ | ~~150~~ |

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[378] ~~http://www.calmac.org/publications/ComFac_Evaluation_V1_Final_Report_02-18-2010.pdf~~

[379] ~~The deemed savings values were adopted from the California region and are adjusted to account for differences in weather conditions in Pennsylvania based on cooling degree hours and wet bulb temperatures.The Refrigeration – Door Gaskets measure protocol follows the weather mapping table shown in Section 1.17.~~

~~Table 3-80: Door Gasket Savings per Linear Foot for Walk-in Coolers and Freezers (CZ 9 Erie)~~

| ~~Building Type~~ | ~~Coolers~~ | | ~~Freezers~~ | |
|---|---|---|---|---|
| | ~~ΔkW/ft~~ | ~~ΔkWh/ft~~ | ~~ΔkW/ft~~ | ~~ΔkWh/ft~~ |
| ~~Restaurant~~ | ~~0.001028~~ | ~~20~~ | ~~0.002235~~ | ~~71~~ |
| ~~Small Grocery Store/ Convenience Store~~ | ~~0.000765~~ | ~~16~~ | ~~0.001937~~ | ~~72~~ |
| ~~Medium/Large Grocery Store/ Supermarkets~~ | ~~0.000747~~ | ~~16~~ | ~~0.001907~~ | ~~102~~ |

~~Reach-in Coolers and Freezers~~[380]~~:~~

~~Table 3-81: Door Gasket Savings per Linear Foot for Reach-in Coolers and Freezers (CZ 4 Pittsburgh, Scranton)~~

| ~~Building Type~~ | ~~Coolers~~ | | ~~Freezers~~ | |
|---|---|---|---|---|
| | ~~ΔkW/ft~~ | ~~ΔkWh/ft~~ | ~~ΔkW/ft~~ | ~~ΔkW/ft~~ |
| ~~Grocery/Restaurant~~ | ~~0.001788~~ | ~~9~~ | ~~0.003783~~ | ~~19~~ |

~~Table 3-82: Door Gasket Savings per Linear Foot for Reach-in Coolers and Freezers (CZ 15 Allentown, Harrisburg, Philadelphia, Williamstown)~~

| ~~Building Type~~ | ~~Coolers~~ | | ~~Freezers~~ | |
|---|---|---|---|---|
| | ~~ΔkW/ft~~ | ~~ΔkWh/ft~~ | ~~ΔkW/ft~~ | ~~ΔkWh/ft~~ |
| ~~Grocery/Restaurant~~ | ~~0.002597~~ | ~~13~~ | ~~0.005526~~ | ~~28~~ |

~~Table 3-83: Door Gasket Savings per Linear Foot for Reach-in Coolers and Freezers (CZ 9 Erie)~~

| ~~Building Type~~ | ~~Coolers~~ | | ~~Freezers~~ | |
|---|---|---|---|---|
| | ~~ΔkW/ft~~ | ~~ΔkWh/ft~~ | ~~ΔkW/ft~~ | ~~ΔkWh/ft~~ |
| ~~Grocery/Restaurant~~ | ~~0.001959~~ | ~~10~~ | ~~0.004167~~ | ~~21~~ |

### ~~3.24.4~~3.23.4 Measure Life

The expected measure life is 4 years[381].

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[380] ~~The deemed savings values were adopted from the California region and are adjusted to account for differences in weather conditions in Pennsylvania based on cooling degree hours and wet bulb temperatures.The Refrigeration – Door Gaskets measure protocol follows the weather mapping table shown in Section 1.17.~~

[381] http://www.calmac.org/publications/ComFac_Evaluation_V1_Final_Report_02-18-2010.pdf

## ~~3.25~~3.24 Refrigeration – Suction Pipes Insulation for Walk-in Coolers and Freezers

| 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 the 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 for Walk-in Coolers and Freezers. 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~~3.24.1 Eligibility

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This protocol documents the energy savings attributed to insulation of bare refrigeration suction pipes. The following are the eligibility requirements[382]:

- 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~~3.24.2 Algorithms

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The demand and energy savings assumptions are based on analysis performed by Southern California Edison (SCE)[383]. Measure savings per linear foot of insulation installed on bare suction lines in Restaurants and Grocery Stores is provided in Table 3-78: Insulate Bare Refrigeration Suction Pipes Calculations AssumptionsTable 3-78~~Table 3-84~~~~Table 3-78: Insulate Bare Refrigeration Suction Pipes Calculations Assumptions~~ Table 3-79~~Table 3-85~~79 below lists the “deemed” savings for the associated California Climate zones and their respective Pennsylvania city.

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[382] http://www.energysmartgrocer.org/pdfs/PGE/2010_2012%20External%20Equipment%20SpecificationTandCs%20v3.pdf

[383] Work papers developed by SCE filed with the CA PUC in support of its 2006 – 2008 energy efficiency program plans

$\Delta kWh \quad = \Delta kWh/ft \times L$

$\Delta kW_{peak} \quad = \Delta kW/ft \times L$

### ~~3.25.3~~3.24.3 Definition of Terms

**Formatted:** Indent: Left: 0", Tab stops: 0.25", List tab + Not at 0.44"

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 3-78~~3-84~~78: Insulate Bare Refrigeration Suction Pipes Calculations Assumptions**

| Component | Type | Value | Source |
|---|---|---|---|
| ΔkW/ft | Variable | Table 3-79~~Table 3-85~~79 | 1 |
| ΔkWh/ft | Variable | Table 3-79~~Table 3-85~~79 | 1 |
| L | Variable | As Measured | EDC Data Gathering |

**Table 3-79~~3-85~~79: Insulate Bare Refrigeration Suction Pipes Savings per Linear Foot for Walk-in Coolers and Freezers of Restaurants and Grocery Stores[384]**

| City | Associated California Climate Zone[385] | Medium-Temperature Walk-in Coolers | | Low-Temperature Walk-in Freezers | |
|---|---|---|---|---|---|
| | | ΔkW/ft | ΔkWh/ft | ΔkW/ft | ΔkWh/ft |
| Allentown | 15 | 0.002488 | 14.5 | 0.002861 | 17.6 |
| Williamstown | 15 | 0.002488 | 14.5 | 0.002861 | 17.6 |
| Pittsburgh | 4 | 0.001507 | 8 | 0.0023 | 13 |
| Philadelphia | 15 | 0.002488 | 14.5 | 0.002861 | 17.6 |
| Erie | 9 | 0.001757 | 9.5 | 0.00246 | 14 |
| Harrisburg | 15 | 0.002488 | 14.5 | 0.002861 | 17.6 |
| Scranton | 4 | 0.001507 | 8 | 0.0023 | 13 |

**Sources:**

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

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[384] 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

[385] The deemed savings values were adopted from the California region and are adjusted to account for differences in weather conditions in Pennsylvania based on cooling degree hours and wet bulb temperatures.The Refrigeration – Suction Pipes Insulation measure protocol follows the weather mapping table shown in Section 1.17.

### ~~3.25.4~~3.24.4 Measure Life

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The expected measure life is 11 years[386,387].

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[386] California Measurement Advisory Committee Public Workpapers on PY 2001 Energy Efficiency Programs. September 2000. Appendix F, P.14

[387] DEER database, EUL/RUL for insulation bare suction pipes

## ~~3.26~~3.25 Refrigeration – Evaporator Fan Controllers

This measure is for the installation of evaporator fan controls[388] in medium-temperature walk-in coolers with no pre-existing controls. Evaporator fans run constantly to provide cooling when the compressor is running, and to provide air circulation when the compressor is not running. The equations specified in the Algorithms section are for fans that are turned off and/or cycled.A fan controller saves energy by reducing fan usage, by reducing the refrigeration load resulting from the heat given off by the fan and by reducing compressor energy resulting from the electronic temperature control. This protocol documents the energy savings attributed to evaporator fan controls.

### ~~3.26.1~~3.25.1 Eligibility

**Formatted:** Indent: Left: 0", Tab stops: 0.25", List tab + Not at 0.44"

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

### ~~3.26.2~~3.25.2 Algorithms~~[389]~~[390]

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$$\Delta kWh = \Delta kWh_{Fan} + \Delta kWh_{Heat} + \Delta kWh_{Control}$$

$$\Delta kWh_{Fan} = kW_{Fan} \text{ X } 8760 \text{ X } \%Off$$

$$\Delta kWh_{Heat} = \Delta kWh_{Fan} \text{ X } 0.28 \text{ X } Eff_{RS}$$

$$\Delta kWh_{Control} = [kW_{CP} \text{ X } Hours_{CP} + kW_{Fan} \text{ X } 8760 \text{ X } (1 - \%Off)] \text{ X } 5\%$$

$$\Delta kW = \Delta kWh / 8760$$

Determine $kW_{Fan}$ and $kW_{CP}$ variables using any of the following methods:

1. Calculate using the nameplate horsepower and load factor.

   $kW_{Fan}$ or $kW_{CP}$ = $[(HP \text{ X } LF \text{ X } 0.746) / \eta]$

2. Calculate using the nameplate amperage and voltage and a power factor.

   $kW_{Fan}$ or $kW_{CP}$ = $[V \text{ X } A \text{ X } PF\ motor \text{ X } LF]$

3. Measure the input kW fan using a power meter reading true RMS power.

### ~~3.26.3~~3.25.3 Definition of Terms

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$\Delta kWh_{Fan}$ = Energy savings due to evaporator being shut off

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[388] 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).

~~[389] 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~~

[390] 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

$\Delta kWh_{Heat}$ = *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 any of the methods described above*

$kW_{CP}$ = *Power demand of compressor motor and condenser fan calculated from any of the methods described above*

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

$HP$ = *Rated horsepower of the motor*

$\eta_{eemotor}$ = *efficiency of the motor*

$LF$ = *Load factor of motor*

$Voltage$ = *Voltage of the motor*

$Amperage$ = *Rated amperage of the motor*

$PF$ = *Power factor of the motor*

$Eff_{RS}$ = *Efficiency of typical refrigeration system*

$Hours_{CP}$ = *Equivalent annual full load hours of compressor operation*

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

5% = *Reduced run-time of compressor and evaporator due to electronic controls*[391]

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

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[391] 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.

**Table 3-80~~3-8680~~: Evaporator Fan Controller Calculations Assumptions**

| Component | Type | Value | Source |
|---|---|---|---|
| PF | Fixed | Fan motor: 0.75<br>Compressor motor: 0.9 | 1, 7, 8 |
| %Off | Fixed | 46% | 2 |
| $Eff_{RS}$ | Fixed | 1.6 kW/ton | 3 |
| $Hours_{CP}$ | Variable | 4,072 | 1, 6 |
| | | EDC Data Gathering | EDC Data Gathering |
| Motor HP | Variable | EDC Data Gathering | EDC Data Gathering |
| Motor Eff | Variable | EDC Data Gathering | EDC Data Gathering |
| LF | Fixed | 0.9 | Section 3.10 |
| Voltage | Variable | EDC Data Gathering | EDC Data Gathering |
| Amperage | Variable | EDC Data Gathering | EDC Data Gathering |

**Sources:**

1. Conservative value based on 15 years of NRM field observations and experience
2. Select Energy (2004). *Analysis of Cooler Control Energy Conservation Measures. Pre*pared for NSTAR.
3. Estimated average refrigeration efficiency for small business customers, Massachusetts Technical Reference Manual
4. Southern California Edison. Non-Residential Express 2003 Refrigeration Work Paper. Pg. 27
5. PSC of Wisconsin, Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0, p. 4-103 to 4-106.
6. 2012 Program Year Rhode Island Technical Reference Manual for Estimating Savings from Energy Efficiency Measures
7. ESource Customer Direct to Touchstone Energy for Evaporator Fan Controllers, 2005
8. LBNL 57651 Energy Savings in Refrigerated Walk-in Boxes, 1998

### ~~3.26.4~~3.25.4 Measure Life

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The expected measure life is 10 years[392].

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[392] Energy & Resource Solutions (2005). Measure Life Study. Prepared for The Massachusetts Joint Utilities; Table 1-1.

## ~~3.27~~3.26 ENERGY STAR Clothes Washer

| Measure Name | Clothes Washer |
|---|---|
| Target Sector | Multifamily Common Area Laundry and Laundromats |
| Measure Unit | Per Washing Machine |
| Unit Energy Savings | See Table 3-82~~Table 3-88~~82 to Table 3-85: Deemed Savings Front Loading ENERGY STAR Clothes Washer for Laundromats Table 3-85~~Table 3-91 Table 3-85: Deemed Savings Front Loading ENERGY STAR Clothes Washer for Laundromats~~ |
| Unit Peak Demand Reduction | See Table 3-82~~Table 3-88~~82 to Table 3-85: Deemed Savings Front Loading ENERGY STAR Clothes Washer for Laundromats Table 3-85~~Table 3-91 Table 3-85: Deemed Savings Front Loading ENERGY STAR Clothes Washer for Laundromats~~ |
| Measure Life | 11.3 years for Multifamily and 7.1 years for Laundromats |

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 $\geq$2.2 ($ft^3$ ×cycle)/ (kWh). The Federal efficiency standard is $\geq$1.60 ($ft^3$ ×cycle)/ (kWh) for Top Loading washers and $\geq$2.0 ($ft^3$ ×cycle)/ (kWh) for Front Loading washers[393].

### ~~3.27.1~~3.26.1 Eligibility

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This protocol documents the energy savings attributed to efficient clothes washers meeting ENERGY STAR or better in small commercial applications. This protocol is limited to clothes washers in laundry rooms of multifamily complexes and commercial Laundromats.

### ~~3.27.2~~3.26.2 Algorithms

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

*Total Savings =Number of Clothes Washers x Savings per Clothes Washer*

To determine resource savings, the per-unit estimates in the algorithms will be multiplied by the number of clothes washers.

Per unit energy and demand savings are obtained through the following calculations:

$$\Delta kWh = [(HE_{T,\,base} + ME_{T,\,base} + D_{E,\,base}) - (HE_{T,\,new} + ME_{T,\,new} + D_{E,\,new})] \times N$$

*Where:*

---

[393] DOE Technical Support Document, 2009. Web address: http://www1.eere.energy.gov/buildings/appliance_standards/commercial/clothes_washers.html

$D_E$ $= LAF \times WGHT_{max} \times DEF \times DUF \times (RMC$[394] $– 4\%)$

$RMC$ $= (-0.156 \times MEF) + 0.734$

$HE_T$ $= (Cap/MEF) – ME_T - D_E$

$\Delta kW_{peak}$ $= kWh\ Savings \times UF$

The algorithms used to calculate energy savings are taken from the U.S. Department of Energy's Life-Cycle Cost and Payback Period tool.[395] DOE adopted the algorithms for commercial clothes washers in a final rule published on October 18, 2005. Commercial clothes washer per-cycle energy consumption is composed of three components: water-heating energy, machine energy, and drying energy. DOE established the annual energy consumption of commercial clothes washers by multiplying the per-cycle energy and water use by the number of cycles per year.

In the above equations, MEF is the Modified Energy Factor, which is the energy performance metric for clothes washers. MEF is defined as:

> *MEF is the quotient of the capacity of the clothes container, C, divided by the total clothes washer energy consumption per cycle, with such energy consumption expressed as the sum of the machine electrical energy consumption, M, the hot water energy consumption, E, and the energy required for removal of the remaining moisture in the wash load, D. The higher the value, the more efficient the clothes washer is.*[396]
>
> $MEF = C / (M + E + D)$

The following steps should be taken to determine per-cycle energy consumption for top-loading and front-loading commercial clothes washers for both old and new clothes washers. Per-cycle energy use is disaggregated into water heating, machine, and clothes drying.

1. Calculate the remaining moisture content (RMC) based on the relationship between RMC and MEF.
2. Calculate the per-cycle clothes-drying energy use using the equation that determines the per-cycle energy consumption for the removal of moisture.
3. Use the per-cycle machine energy use value of 0.133kWh/cycle for MEFs up to 1.40 and 0.114kWh/cycle for MEFs greater than 1.40. These values are estimated from 2000 TSD for residential clothes washers' database.
4. With the per-cycle clothes dryer and machine energy known, determine the per-cycle water-heating energy use by first determining the total per-cycle energy use (the clothes container volume divided by the MEF) and then subtracting from it the per-cycle clothes-drying and machine energy.

---

[394] DOE used its residential clothes washer analysis from the year 2000 to determine a relationship between remaining moisture content (RMC) and modified energy factor (MEF) for the purpose of calculating the dryer energy for commercial clothes washers. RMC was determined using the dryer energy, the clothes container volume, and the resulting maximum test-load weight

[395] http://www1.eere.energy.gov/buildings/appliance_standards/commercial/clothes_washers_snopr_spreadsheets.html

[396] Definition provided on ENERGY STAR Clothes Washers Key Product Criteria website: http://www.energystar.gov/index.cfm?c=clotheswash.pr_crit_clothes_washers

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

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

The value is the June-September, weekday noon to 8 PM 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 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), it is important to check that the resulting minutes of usage per hour is significantly smaller than 60. If the minutes of usage per hour approach 60, then it should be assumed that the load shape for multi-family laundry room clothes washers must be different than the load shape for in-house clothes washers. The maximum utilization per hour is 36.2 minutes.

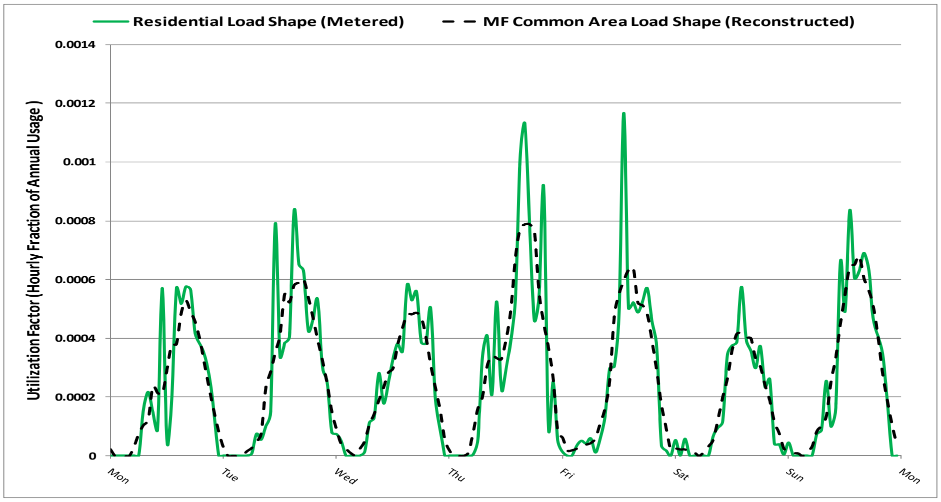

Figure 3-1: Utilization factor for a sample week in July[397]

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[397] 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~~3.26.3 Definition of Terms

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The parameters in the above equation are listed in Table 3-81: Commercial Clothes Washer Calculation AssumptionsTable 3-81~~Table 3-87Table 3-81: Commercial Clothes Washer Calculation Assumptions~~ below.

**Table 3-81~~3-87~~81: Commercial Clothes Washer Calculation Assumptions**

| Component | Type | Values | Source |
|---|---|---|---|
| $MEF_B$, Base Federal Standard Modified Energy Factor | Fixed | Top loading: 1.6<br>Front loading: 2.0 | 4 |
| $MEF_P$, Modified Energy Factor of ENERGY STAR Qualified Washing Machine | Variable | Nameplate | EDC Data Gathering |
| | Default | 2.2 | 4 |
| $HE_T$ , Per-cycle water heating consumption (kWh/cycle) | Variable | Calculation | Calculation |
| $D_E$ , Per-cycle energy consumption for removal of moisture i.e. dryer energy consumption (kWh/cycle) | Variable | Calculation | Calculation |
| $ME_T$ , Per-cycle machine electrical energy consumption (kWh/cycle) | Fixed | 0.114[398] | 1 |
| $Cap_{base}$, Capacity of baseline clothes washer (Cu. Ft) | Variable | Nameplate | EDC Data Gathering |
| | Default | Front Loading: 2.84<br>Top Loading: 2.95 | 5 |
| $Cap_{EE}$, Capacity of efficient clothes washer (Cu. Ft) | Variable | Nameplate | EDC Data Gathering |
| | Default | Front Loading: 2.84<br>Top Loading: 2.84 | 5 |
| LAF, Load adjustment factor | Fixed | 0.52 | 1, 2 |
| DEF, Nominal energy required for clothes dryer to remove moisture from clothes (kWh/lb.) | Fixed | 0.5 | 1, 2 |
| DUF, Dryer usage factor, percentage of washer loads dried in a clothes dryer | Fixed | 0.84 | 1, 2 |
| $WGHT_{max}$ , Maximum test-load weight (lbs./cycle) | Fixed | 11.7 | 1, 2 |
| RMC, Remaining moisture content (lbs.) | Variable | Calculation[399] | Calculation |
| N, Number of cycles per year | Fixed | Multifamily: 1,241<br>Laundromats: 2,190 | 1, 2 |
| UF, Utilization Factor | Fixed | 0.0002382 | 3 |

---

[398] Based on residential clothes washer data from DOE 2000 TSD

[399] Based on the relationship: RMC = -0.156* MEF + 0.734

**Sources:**

1. http://www1.eere.energy.gov/buildings/appliance_standards/commercial/pdfs/ccw_snopr_chap6.pdf
2. U.S. Department of Energy's Life-Cycle Cost and Payback Period tool, available at: http://www1.eere.energy.gov/buildings/appliance_standards/commercial/clothes_washers_snopr_spreadsheets.html
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
4. http://www1.eere.energy.gov/buildings/appliance_standards/commercial/clothes_washers.html
5. California Energy Commission ("CEC") Appliance Efficiency database, http://www.appliances.energy.ca.gov/QuickSearch.aspx

### ~~3.27.4~~3.26.4 Deemed Savings

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The deemed savings for the installation of a washing machine with a MEF of 2.2 or higher, is dependent on the energy source for washer. The table below shows savings for washing machines for different combinations of water heater and dryer types. The values are based on the difference between the baseline clothes washer with MEF Federal efficiency standard of >1.60 ($ft^3$ ×cycle)/ (kWh) for Top Loading washers and >2.0 ($ft^3$ ×cycle)/ (kWh) for Front Loading washers and minimum ENERGY STAR qualified front loading[400] clothes washer of >2.2 ($ft^3$ ×cycle)/ (kWh).

For clothes washers where fuel mix is unknown, calculate default savings using the algorithms below and EDC specific saturation values. For EDCs where saturation information is not accessible, use "Default values" described in tables below.

$$ESav_{CW} = kWh_{GWH\text{-}GD} \times \%GWH\text{-}GD_{CW} + kWh_{GWH\text{-}ED} \times \%GWH\text{-}ED_{CW} + kWh_{EWH\text{-}GD} \times \%EWH\text{-}GD_{CW} + KWh_{EWH\text{-}ED} \times \%EWH\text{-}ED_{CW}$$

Where:

$kWh_{GWH\text{-}GD}$ = *Energy savings for clothes washers with gas water heater and non-electric dryer fuel from tables below.*

$kWh_{GWH\text{-}ED}$ = *Energy savings for clothes washers with gas water heater and electric dryer fuel from tables below.*

$kWh_{EWH\text{-}GD}$ = *Energy savings for clothes washers with electric water heater and non-electric dryer fuel from tables below.*

---

[400] ENERGY STAR-qualified commercial clothes washers in 2013 are likely to be front-loading units because there are no top-loading commercial clothes washers at this time which have been certified by DOE as meeting the 2013 standards

$KWh_{EWH\text{-}ED}$ = *Energy savings for clothes washers with electric water heater and electric dryer fuel from tables below.*

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

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

**Table 3-82~~3-8882~~: Deemed Savings for Top Loading ENERGY STAR Clothes Washer for Laundry in Multifamily Buildings**[401]

| Fuel Source | Cycles/ Year | Energy Savings (kWh) | Demand Reduction (kW) |
|---|---|---|---|
| Electric Hot Water Heater, Electric Dryer | 1,241 | 686 | 0.163 |
| Electric Hot Water Heater, Gas Dryer | 1,241 | 341 | 0.081 |
| Gas Hot Water Heater, Electric Dryer | 1,241 | 345 | 0.082 |
| Gas Hot Water Heater, Gas Dryer | 1,241 | 0 | 0 |
| Default (20% Electric DHW 40% Electric Dryer)[402] | 1,241 | 206 | 0.049 |

**Table 3-83~~3-8983~~: Deemed Savings for Front Loading ENERGY STAR Clothes Washer for Laundry in Multifamily Buildings** [403]

| Fuel Source | Cycles/ Year | Energy Savings (kWh) | Demand Reduction (kW) |
|---|---|---|---|
| Electric Hot Water Heater, Electric Dryer | 1,241 | 160 | 0.038 |
| Electric Hot Water Heater, Gas Dryer | 1,241 | 61 | 0.015 |
| Gas Hot Water Heater, Electric Dryer | 1,241 | 99 | 0.024 |
| Gas Hot Water Heater, Gas Dryer | 1,241 | 0 | 0 |
| Default (20% Electric DHW 40% Electric Dryer)[404] | 1,241 | 52 | 0.012 |

---

[401] Based on a container volume of 2.8 cu. ft., maximum test-load weight of 11.7 lb./cycle and electric water heater at 100% efficiency.

[402] http://www1.eere.energy.gov/buildings/appliance_standards/commercial/clothes_washers_snopr_spreadsheets.html

[403] ibid

[404] ibid

**Table 3-84~~3-90~~84: Deemed Savings for Top Loading ENERGY STAR Clothes Washer for Laundromats** [405]

| Fuel Source | Cycles/ Year | Energy Savings (kWh) | Demand Reduction (kW) |
|---|---|---|---|
| Electric Hot Water Heater, Electric Dryer | 2,190 | 1,211 | 0.288 |
| Electric Hot Water Heater, Gas Dryer | 2,190 | 602 | 0.143 |
| Gas Hot Water Heater, Electric Dryer | 2,190 | 609 | 0.145 |
| Gas Hot Water Heater, Gas Dryer | 2,190 | 0 | 0 |
| Default (0% Electric DHW 0% Electric Dryer)[406] | 2,190 | 0 | 0 |

**Table 3-85~~3-91~~85: Deemed Savings Front Loading ENERGY STAR Clothes Washer for Laundromats** [407]

| Fuel Source | Cycles/ Year | Energy Savings (kWh) | Demand Reduction (kW) |
|---|---|---|---|
| Electric Hot Water Heater, Electric Dryer | 2,190 | 283 | 0.067 |
| Electric Hot Water Heater, Gas Dryer | 2,190 | 108 | 0.026 |
| Gas Hot Water Heater, Electric Dryer | 2,190 | 175 | 0.042 |
| Gas Hot Water Heater, Gas Dryer | 2,190 | 0 | 0 |
| Default (0% Electric DHW 0% Electric Dryer)[408] | 2,190 | 0 | 0 |

### ~~3.27.5~~3.26.5 Measure Life

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The measure life is 11.3 years for Multifamily and 7.1 years for Laundromats[409].

### ~~3.27.6~~3.26.6 Evaluation Protocols

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

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[405] ibid

[406] ibid

[407] Ibid

[408] ibid

[409] http://www1.eere.energy.gov/buildings/appliance_standards/commercial/clothes_washers_snopr_spreadsheets.html

## ~~3.28~~3.27 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~~3.27.1 Eligibility

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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~~3.27.2 Algorithms

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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:

$$\Delta kWh = \frac{\left\{\left(\frac{1}{EF_{Base}} - \frac{1}{EF_{Proposed}}\right) \times HW \ X \ 8.3 \ \frac{lb}{gal} \ X \ 1.0 \ \frac{Btu}{lb-F} \ X \ (Thot - Tcold)\right\}}{3413 \frac{Btu}{kWh}}$$

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~~between 2 PM to 6 PM on summer weekdays to the total annual energy usage.

$\Delta kW_{peak}$ = *EnergyToDemandFactor × Energy Savings × ResistiveDiscountFactor*

The Energy to Demand Factor is defined below:

$$EnergyToDemandFactor = \cancel{\frac{Average\ Usage_{Summer\ WD\ Noon-8}}{Annual\ Energy\ Usage}}\ \frac{Average\ Usage_{Summer\ WD\ 2-6\ PM}}{Annual\ Energy\ Usage}$$

### Loads

The annual loads are taken from data from the DEER database[410]. The DEER database has data for gas energy usage for the domestic hot water end use for various small commercial buildings. The loads are averaged over all 16 climate zones and all six vintage types in the DEER database. Finally, the loads are converted to average annual gallons of use using the algorithm below. The loads are summarized in Table 3-86: Typical water heating loads.~~Table 3-9286: Typical water heating loads.~~ below.

$$HW\,(Gallons) = \frac{Load \times EF_{NG,\ Base}\ X\ 1000\ \frac{Btu}{kBtu}\ X\ Typical\ SF}{8.3\ \frac{lb}{gal}\ X\ (Thot - Tcold)\ X\ 1000\ SF}$$

**Table 3-86~~3-9286~~: Typical water heating loads.**

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

### Energy to Demand Factor

The ratio of the average energy usage ~~during noon and 8~~between 2 PM to 6 PM on summer weekdays to the total annual energy usage is taken from usage profile data collected for commercial water heaters in CA[411]. The usage profiles are shown in Figure 3-2. To ensure that the load shape data derived from observations in CA can be applied to PA, we compared the annual energy usage to peak demand factors for two disparate climate zones in CA. The results, shown in Figure 3-3, indicate that the ratio of peak demand to annual energy usage is not strongly influenced by climate. Also, though the actual usage profiles may be different, the average usage between ~~noon and 8~~2 PM to 6 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[412].

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[410] http://www.deeresources.com/deer0911planning/downloads/DEER2008-CommercialResultsReview-NonUpdatedMeasures.exe

[411] ibid

[412] 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 3-2: Load shapes for hot water in four commercial building types

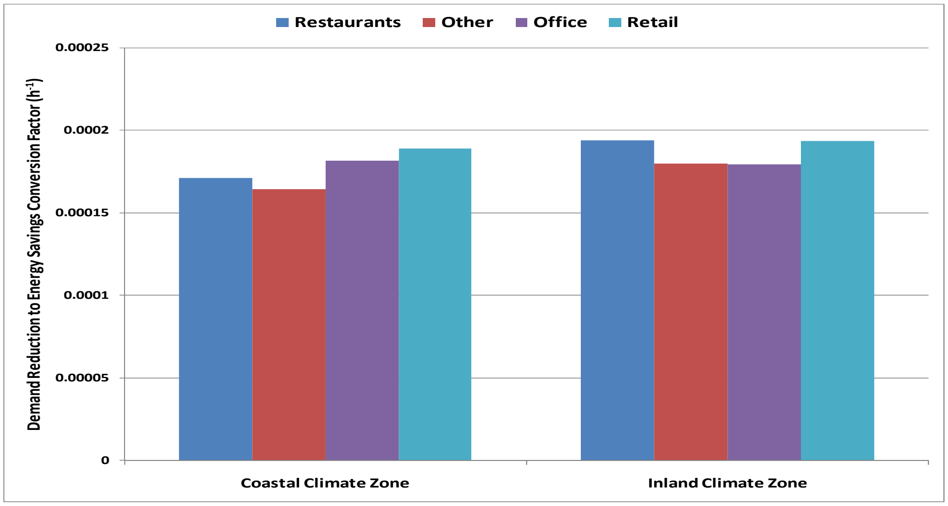

Figure 3-3: Energy to demand factors for four commercial building types

### ~~3.28.3~~3.27.3 Definition of Terms

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The parameters in the above equation are listed in Table 3-87~~Table 3-93~~87.

Table 3-87~~3-87~~: Electric Resistance Water Heater Calculation Assumptions

| Component | Type | Values | Source |
|---|---|---|---|

~~93~~

~~: Electric Resistance Water Heater Calculation Assumptions~~

| ~~Component~~ | ~~Type~~ | ~~Values~~ | ~~Source~~ |
|---|---|---|---|
| ~~$EF_{base}$, Energy Factor of baseline water heater~~ | ~~Variable~~ | ~~See Table 3-94~~ | ~~1~~ |
| ~~$EF_{proposed}$, Energy Factor of proposed efficient water heater~~ | ~~Variable~~ | ~~Default: 0.93~~ | ~~Program Design~~ |
| $EF_{base}$, Energy Factor of baseline water heater | Variable | See Table 3-88 | 1 |
| $EF_{proposed}$, Energy Factor of proposed efficient water heater | Variable | Default: 0.93 | Program Design |
| | | Nameplate | EDC Data Gathering |
| Load, Average annual Load in kBTU | Fixed | Varies | DEER Database |
| $T_{hot}$, Temperature of hot water | Fixed | ~~120~~123 °F | 2 |
| $T_{cold}$, Temperature of cold water supply | Fixed | 55 °F | 3 |
| EnergyToDemandFactor | Fixed | 0.~~0001916~~000178 | 4 |
| HW, Average annual gallons of Use | Variable | Default: See Table 3-86~~Table 3-92~~86 | Calculation |
| | | EDC Data Gathering | EDC Data Gathering |
| $EF_{NG, base}$, Energy Factor of baseline gas water heater | Fixed | 0.594 | 5 |
| ResistiveDiscountFactor | Fixed | 1.0 | 6 |

### ~~3.28.4~~3.27.4 Energy Factors based on Tank Size

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Federal Standards for Energy ~~Facotrs~~Factors are equal to 0.97 -0.00132 x Rated Storage in Gallons. The following table shows the Energy Factors for various tank sizes.

Table 3-88~~3-94~~88~~:~~: Minimum Baseline Energy Factors based on Tank Size

| Tank Size (gallons) | Minimum Energy ~~Factor~~Factors ($E_{base}$) |
|---|---|
| 40 | 0.9172 |
| 50 | 0.9040 |
| 65 | 0.8842 |
| 80 | 0.8644 |
| 120 | 0.8116 |

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**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

~~40~~ ~~0.9172~~

~~50~~ ~~0.9040~~

~~65~~ ~~0.8842~~

~~80~~ ~~0.8644~~

~~120~~ ~~0.8116~~

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~~1.~~2. ~~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~~

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~~3. Many states have plumbing codes that limit shower and bathtub water temperature to 120 °F.~~

~~14.~~3. 2012 SWE Residential Baseline Study Mid-Atlantic TRM~~, footnote #24.~~

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~~15.~~4. Mid-Atlantic TRM, footnote #24

~~16.~~5. The EnergyToDemandFactor is estimated using the California load shapes and reflects PJM’s peak demand period. The load shapes can be accessed online: http://www.ethree.com/CPUC/PG&ENonResViewer.zip

~~17.~~6. 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

~~18.~~7. Engineering Estimate. No discount factor is needed because this measure is already an electric resisitance water heater system.

### 3.27.5 ~~Deemed~~ DefaultSavings

### ~~3.28.5~~ Savings

~~As an example, the deemed savings~~ for the installation of efficient electric resitance water heaters ~~with an energy factor of 0.95~~ in ~~various applications~~different building types are ~~listed~~calculated using the formula below~~.~~:

Table ~~3-95:~~3-95: Energy Savings ~~and Demand Reductions~~Algorithms

| Building Type | ~~Average Annual Use, Gallons~~Default Algorithms | ~~EF~~ | ~~Energy Savings (kWh)~~ | ~~Demand Reduction (kW)~~ |
|---|---|---|---|---|
| Motel | ~~97,870~~ $\Delta kWh = 16{,}185\,(\frac{1}{EF_{base}} - \frac{1}{EF_{proposed}})$ | ~~0.95~~ | ~~829~~ | ~~0.16~~ |
| Small Office | ~~24,377~~ $\Delta kWh = 4{,}031\,(\frac{1}{EF_{base}} - \frac{1}{EF_{proposed}})$ | ~~0.95~~ | ~~207~~ | ~~0.04~~ |
| Small Retail | ~~11,183~~ $\Delta kWh = 1{,}849\,(\frac{1}{EF_{base}} - \frac{1}{EF_{proposed}})$ | ~~0.95~~ | ~~95~~ | ~~0.02~~ |

### ~~3.28.6~~3.27.6 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[413].

### ~~3.28.7~~3.27.7 Evaluation Protocols

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

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

## ~~3.29~~3.28 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~~3.28.1 Eligibility

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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~~3.28.2 Algorithms

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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:

$$\Delta kWh = \frac{\left\{\left(\frac{1}{EF_{Base}} - \left(\frac{1}{EF_{Proposed}} \times \frac{1}{F_{Adjust}}\right)\right) \times HW\ X\ 8.3\ \frac{lb}{gal}\ X\ 1.0\ \frac{Btu}{lb-F}\ X(Thot - Tcold)\right\}}{3413\,\frac{Btu}{kWh}}$$

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~~between 2 PM to 6 PM on summer weekdays to the total annual energy usage.

$\Delta kW_{peak}$ = *EnergyToDemandFactor × Energy Savings × ResistiveDiscountFactor*

The Energy to Demand Factor is defined below:

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

~~**Loads**~~

~~*The annual loads are taken from data from the DEER database[414]. The DEER database has data for gas energy usage for the domestic hot water end use for various small commercial buildings. The loads are averaged over all 16 climate zones and all six vintage types in the DEER database. Finally, the loads are converted to average annual gallons of use using the algorithm below.*~~ $\frac{\cancel{Average\ Usage_{Summer\ WD\ 2\text{-}6\ PM}}}{\cancel{Annual\ Energy\ Usage}}$

**Loads**

The annual loads are taken from data from the DEER database[415]. The DEER database has data for gas energy usage for the domestic hot water end use for various small commercial buildings. The loads are averaged over all 16 climate zones and all six vintage types in the DEER database. Finally, the loads are converted to average annual gallons of use using the algorithm below. The loads are summarized in Table 3-89: Typical water heating loads~~Table 3-9689: Typical water heating loads~~ below.

$$HW\,(Gallons) = \frac{Load \times EF_{NG,\ Base}\ X\ 1000\ \frac{Btu}{kBtu}\ X\ Typical\ SF}{8.3\ \frac{lb}{gal}\ X\ (Thot - Tcold)\ X\ 1000\ SF}$$

**Table 3-89~~3-9689~~: Typical water heating loads**

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

**Energy to Demand Factor**

The ratio of the average energy usage ~~during noon and 8~~between 2 PM to 6 PM on summer weekdays to the total annual energy usage is taken from usage profile data collected for commercial water heaters in CA[416]. The usage profiles are shown in Figure 3-4. To ensure that the load shape data derived from observations in CA can be applied to PA, we compared the annual energy usage to peak demand factors for two disparate climate zones in CA. The results, shown in Figure 3-5, indicate that the ratio of peak demand to annual energy usage is not strongly influenced by climate. Also, though the actual usage profiles may be different, the average usage between ~~noon and 8~~2 PM to 6 PM on summer weekdays is quite similar for al

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~~[414] http://www.deeresources.com/deer0911planning/downloads/DEER2008-CommercialResultsReview-NonUpdatedMeasures.exe~~

[415] http://www.deeresources.com/deer0911planning/downloads/DEER2008-CommercialResultsReview-NonUpdatedMeasures.exe

[416] ibid

building types. The close level of agreement between disparate climate zones and building types suggest that the results will carry over to Pennsylvania[417].

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

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[417] 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).

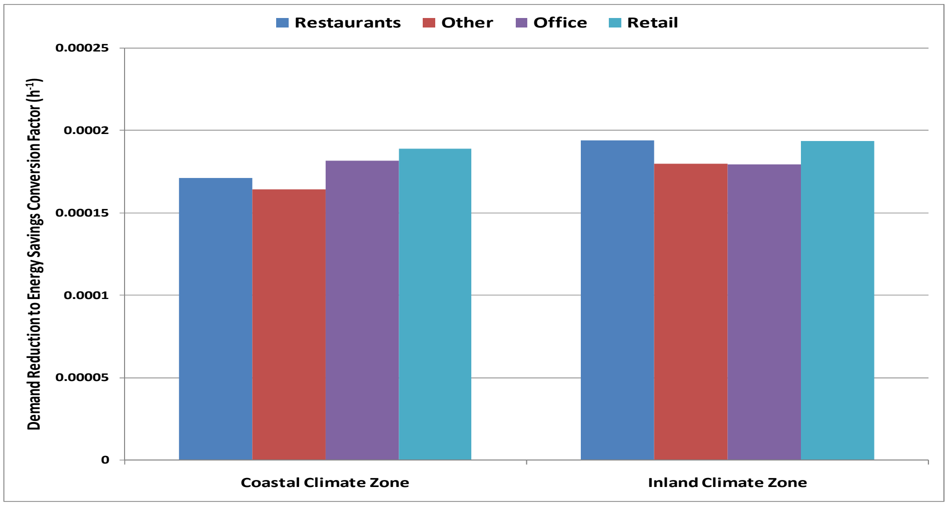

**Figure 3-5: Energy to demand factors for four commercial building types**

**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~~123 °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[418], while the average wetbulb temperature in conditioned typically ranges from 50 °F to 80 °F. The heat pump performance is temperature dependent. Figure 3-6 below shows relative coefficient of

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[418] 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.

performance (COP) compared to the COP at rated conditions[419]. According to the plotted profile, the following adjustments are recommended.

**Table 3-90~~3-9790~~: 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 |

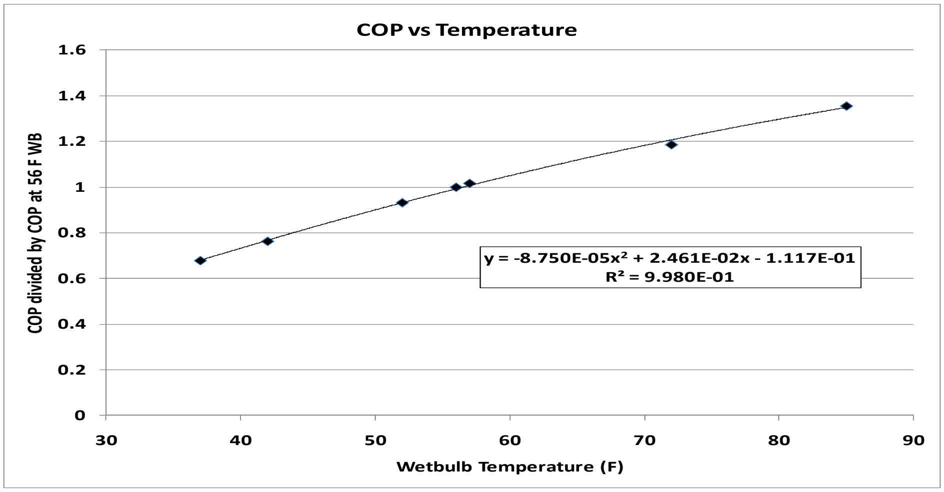

Figure 3-6: Dependence of COP on outdoor wetbulb temperature.

### ~~3.29.3~~3.28.3 Definition of Terms

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The parameters in the above equation are listed in Table 3-91~~Table 3-9791~~.

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[419] 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.

**Table 3-91~~3-91~~: ~~Electric Resistance~~Heat Pump Water Heater Calculation Assumptions**

| Component | Type | Values | Source |
|---|---|---|---|

~~98~~

**~~: Electric Resistance Water Heater Calculation Assumptions~~**

| ~~Component~~ | ~~Type~~ | ~~Values~~ | ~~Source~~ |
|---|---|---|---|
| ~~$EF_{base}$, Energy Factor of baseline water heater~~ | ~~Variable~~ | ~~See Table 3-99~~ | ~~1~~ |
| $EF_{base}$, Energy Factor of baseline water heater | Variable | See Table 3-92 | 1 |
| $EF_{proposed}$, Energy Factor of proposed efficient water heater | Variable | Default: 2.2 | Program Design |
| | | Nameplate | EDC Data Gathering |
| Load, Average annual Load in kBTU | Fixed | Varies | 5 |
| $T_{hot}$, Temperature of hot water | Fixed | ~~120~~123 °F | 2 |
| $T_{cold}$, Temperature of cold water supply | Fixed | 55 °F | 3 |
| EnergyToDemandFactor | Fixed | 0.~~0001916~~000178 | 4 |
| $F_{Adjust}$, COP Adjustment factor | Fixed | 0.80 if outdoor<br>1.09 if indoor<br>1.30 if in kitchen | 4 |
| ResistiveDiscountFactor | Fixed | 0.90 | 6 |
| HW, Average annual gallons of Use | Variable | Default: See Table 3-89: Typical water heating loadsTable 3-89~~Table 3-96 Table 3-89: Typical water heating loads~~ | Calculation |
| | | EDC Data Gathering | EDC Data Gathering |
| $EF_{NG, base}$, Energy Factor of baseline gas water heater | Fixed | 0.594 | 7 |

### ~~3.29.4~~3.28.4 Energy Factors based on Tank Size

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Federal Standards for Energy ~~Facotrs~~Factors are equal to 0.97 -0.00132 x Rated Storage in Gallons. The following table shows the Energy Factors for various tank sizes.

**Table 3-92~~3-99~~92~~:~~: Minimum Baseline Energy Factor Based on Tank Size**

| Tank Size (gallons) | Minimum Energy ~~Factor~~Factors ($E_{base}$) |
|---|---|
| 40 | 0.9172 |
| 50 | 0.9040 |
| 65 | 0.8842 |
| 80 | 0.8644 |
| 120 | 0.8116 |

**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

| | |
|---|---|
| ~~40~~ | ~~0.9172~~ |
| ~~50~~ | ~~0.9040~~ |
| ~~65~~ | ~~0.8842~~ |
| ~~80~~ | ~~0.8644~~ |
| ~~120~~ | ~~0.8116~~ |

~~**Sources:**~~

2. ~~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~~

~~4. Many states have plumbing codes that limit shower and bathtub water temperature to 120 °F.~~

~~19.~~3. 2012 SWE Residential Baseline Study Mid-Atlantic TRM~~, footnote #24.~~

~~11.~~4. Mid-Atlantic TRM, footnote #24

~~20.~~5. The EnergyToDemandFactor is estimated using the California load shapes and reflects PJM’s peak demand period. The load shapes can be accessed online: http://www.ethree.com/CPUC/PG&ENonResViewer.zip

~~21.~~6. DEER Database

~~22.~~7. Engineering Estimate

~~23.~~8. 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

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Residential Water Heaters, Direct Heating Equipment, and Pool Heaters” US Dept of Energy Docket Number: **EE–2006–BT-STD–0129,** p. 30

### ~~3.29.5~~3.28.5 ~~Deemed~~Default Savings

~~Asn~~As an example, the ~~deemed savings~~defaultsavings for the installation of heat pump electric water heaters with energy factor of 2.2 in various applications are ~~listed~~Calculated using the algorithms below~~.~~:

~~**Table 3-100: Energy Savings and Demand Reductions**~~

| **Building Type** | **Location Installed** | **~~Average Annual Use, Gallons~~Algorithm** | **~~EF~~** | **~~COP Adjustment Factor~~** | **~~Energy Savings (kWh)~~** | **~~Demand Reduction (kW)~~** |
|---|---|---|---|---|---|---|
| Motel | ~~Unconditioned Space~~Outdoor | ~~97,870~~$\Delta kWh = \left(\frac{16{,}184.54}{EF_{base}} - \frac{20{,}230.67}{EF_{proposed}}\right)$ | ~~2.2~~ | ~~0.80~~ | ~~8,324~~ | ~~1.44~~ |
| Motel | Indoor~~Conditioned Space~~ | ~~97,870~~$\Delta kWh = \left(\frac{16{,}184.54}{EF_{base}} - \frac{14{,}848.20}{EF_{proposed}}\right)$ | ~~2.2~~ | ~~1.09~~ | ~~10,662~~ | ~~1.84~~ |
| Motel | Kitchen | ~~97,870~~$\Delta kWh = \left(\frac{16{,}184.54}{EF_{base}} - \frac{12{,}449.64}{EF_{proposed}}\right)$ | ~~2.2~~ | ~~1.30~~ | ~~11,704~~ | ~~2.02~~ |
| Small Office | Outdoor~~Unconditioned Space~~ | ~~24,377~~$\Delta kWh = \left(\frac{4{,}031.17}{EF_{base}} - \frac{5{,}038.96}{EF_{proposed}}\right)$ | ~~2.2~~ | ~~0.80~~ | ~~2,073~~ | ~~0.36~~ |
| Small Office | Indoor~~Conditioned Space~~ | ~~24,377~~$\Delta kWh = \left(\frac{4{,}031.17}{EF_{base}} - \frac{3{,}698.32}{EF_{proposed}}\right)$ | ~~2.2~~ | ~~1.09~~ | ~~2,656~~ | ~~0.46~~ |
| Small Office | Kitchen | ~~24,377~~$\Delta kWh = \left(\frac{4{,}031.17}{EF_{base}} - \frac{3{,}100.90}{EF_{proposed}}\right)$ | ~~2.2~~ | ~~1.30~~ | ~~2,915~~ | ~~0.50~~ |
| Small Retail | Outdoor~~Unconditioned Space~~ | ~~11,183~~$\Delta kWh = \left(\frac{1{,}849.31}{EF_{base}} - \frac{2{,}311.63}{EF_{proposed}}\right)$ | ~~2.2~~ | ~~0.80~~ | ~~951~~ | ~~0.16~~ |
| Small Retail | Indoor~~Conditioned Space~~ | ~~11,183~~$\Delta kWh = \left(\frac{1{,}849.31}{EF_{base}} - \frac{1{,}696.6}{EF_{proposed}}\right)$ | ~~2.2~~ | ~~1.09~~ | ~~1,218~~ | ~~0.21~~ |
| Small Retail | Kitchen | ~~11,183~~$\Delta kWh = \left(\frac{1{,}849.31}{EF_{base}} - \frac{1{,}422.54}{EF_{proposed}}\right)$ | ~~2.2~~ | ~~1.30~~ | ~~1,338~~ | ~~0.23~~ |

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### ~~3.29.6~~3.28.6 Measure Life

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According to an October 2008 report for the CA Database for Energy Efficiency Resources, an electric water heater's lifespan is 10 years[420].

### ~~3.29.7~~3.28.7 Evaluation Protocols

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

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

## ~~3.30~~3.29 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~~3.29.1 Eligibility Requirements

This measure must replace inefficient argon-mercury or neon channel letter signs with efficient LED channel letter signs. Retrofit kits or complete replacement LED signs are eligible. ~~Neon lamps are used for red signage and argon-mercury lamps for white signage.~~ Replacement signs cannot use more than 20%[421] 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~~3.29.2 Algorithms

The savings are calculated using the equations below and the assumptions in Table 3-93~~Table 3-101~~93.

***Indoor applications***:

$$\Delta kWh = [kW_{base}\ X(1+IF_{energy})\ X\ HOU\cancel{]}\ X\ (1-SVG_{base})] – [kW_{ee}\ X(1+IF_{energy})\ X\ HOU\ X\ (1 – \cancel{SVG}SVG_{EE})]$$

$$\Delta kW_{peak} = [kW_{base}\ X(1+\ IF\ demand)\ X\ CF\cancel{]}\ X\ (1-SVG_{base})] – [kW_{ee}\ X(1+\ IF\ demand)\ X\ CF\ X\ (1 – \cancel{SVG}SVG_{EE})]$$

***Outdoor applications***:

$$\Delta kWh^{422} = [kW_{base}\ X\ HOU\cancel{]}\ X\ (1-SVG_{base})] – [kW_{ee}\ X\ HOU\ X\ (1 – \cancel{SVG}SVG_{EE})]$$

$$\Delta kW_{peak} = \cancel{0^{423}} = [kW_{base}\ X\ CF\ X\ (1-SVG_{base})] – [kW_{ee}\ X\ CF\ X\ (1 – SVG_{EE})]$$

### ~~3.30.3~~3.29.3 Definition of Terms

ΔkWh = *Annual energy savings (kWh/letter)*

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[421] http://www.aepohio.com/global/utilities/lib/docs/save/programs/Application_Steps_Incentive_Process.pdf

[422] For exterior measures, energy interactive effects are not included in the energy savings calculations.

~~[423] The peak demand reduction is zero, as the exterior lighting applications are assumed to be in operation during off-peak hours and have a peak coincidence factor of 0.0.~~

$\Delta kW_{base}$ = Change in connected load from baseline (pre-retrofit) to installed (post-retrofit) lighting level (kW/letter)

$kW_{ee}$ = kW of post-retrofit or energy-efficient lighting system (LED) lighting per letter

CF = Demand Coincidence Factor (See Section □~~1.4□~~)

HOU = Hours of 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~~

$SVG_{EE}$ = Savings factor for new lighting control (percent of time ~~that~~the lights are off ~~due to~~).

$SVG_{base}$ = Savings factor for existing lighting ~~controls relative to~~control (percent of time the ~~baseline controls system (~~lights are off), typically manual switch~~)~~.

Table 3-93~~3-10193~~: LED Channel Signage Calculation Assumptions

| Component | Type | Value | Source |
|---|---|---|---|
| $kW_{base}$ | Variable | EDC Data Gathering<br>Default: See Table 3-94~~Table 3-10294~~[424] | EDC Data Gathering |
| $kW_{ee}$ | Variable | EDC Data Gathering<br>Default: See Table 3-94~~Table 3-10294~~[425] | EDC Data Gathering |
| CF | ~~Fixed~~Variable | EDC Data Gathering<br>Default for Indoor Applications: See Table 3-6<br>Default for Outdoor Applications: 0[426] | EDC Data Gathering<br>Table 3-6 |
| ~~EFLH~~HOU | Variable | EDC Data Gathering<br>Default: See Table 3-6 | EDC Data Gathering<br>Table 3-6 |
| $IF_{demand}$ | Fixed | See Table 3-7 | Table 3-7 |
| $IF_{energy}$ | Fixed | See Table 3-7 | Table 3-7 |
| ~~SVG~~$SVG_{base}$ and $SVG_{EE}$ | ~~Fixed~~Variable | ~~See Table 3-8~~Default: See<br>Table 3-9: Savings Control Factors Assumptions<br>~~Table 3-9: Savings Control Factors Assumptions~~ | ~~See Table 3-8~~<br>Table 3-9: Savings Control Factors Assumptions<br>~~Table 3-9: Savings Control Factors Assumptions~~ |

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Table 3-94~~3-10294~~: Power demand of baseline (neon and argon-mercury) and energy-efficient (LED) signs

| | Power Demand (kW/letter) | | Power Demand (kW/letter) | |
|---|---|---|---|---|
| **Sign Height** | **Neon** | **Red LED** | **Argon-mercury** | **White LED** |
| ≤ 2 ft | 0.043 | 0.006 | 0.034 | 0.004 |
| > 2 ft | 0.108 | 0.014 | 0.086 | 0.008 |

### ~~3.30.4~~3.29.4 Measure Life

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Expected measure life is 15 years[427].

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[424] Average values were estimated based on wattages data obtained from major channel letter lighting product manufacturers. San Diego Gas & Electric, LED Channel Letter Signs, Work Paper WPSDGENRLG0021, Revision #1, August 25, 2010.

[425] ibid

[426] The peak demand reduction is zero, as the exterior lighting applications are assumed to be in operation during off-peak hours and have a peak coincidence factor of 0.0.

[427] Southern California Edison Company, LED Channel Letter Signage (Red), Work

## ~~3.31~~3.30 Low Flow Pre-Rinse Sprayers for Retrofit Programs

| Measure Name | Low Flow Pre-Rinse Sprayers for Retrofit Programs |
|---|---|
| Target Sector | Commercial Kitchens |
| Measure Unit | Pre Rinse Sprayer |
| Unit Energy Savings | Groceries: 151 kWh; Non-Groceries: 1,222 kWh |
| Unit Peak Demand Reduction | Groceries: 0.03kW; Non-Groceries: 0.~~23~~22 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. In addition, the replacement pre-rinse spray nozzle must use less than 1.6 gallons per minute with a cleanability performance of 26 seconds per plate or less. Low flow pre-rinse sprayers reduce hot water usage and save energy associated with water heating.

This protocol is applicable to Retrofit programs only. The baseline for Retrofit Program is assumed to be an 2.25 GPM[428] and 2.15 GPM[429] for non-grocery and grocery applications respectively.

### ~~3.31.1~~3.30.1 Algorithms

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

$\Delta kWh$ for Non-Groceries $= ((F_{BNG} \times U_{BNG})-(F_{PNG} \times U_{PNG})) \times 365 \times 8.33 \text{ x } (T_{HNG}-T_C) / \times (EF \text{ x } 3413 \text{ Btu/kWh})$

$\Delta kWh$ for Groceries $= ((F_{BG} \times U_{BG})-(F_{PG} \times U_{PG})) \times 365 \times 8.33 \text{ x } (T_{HG}-T_C) / (EF \text{ x } 3413 \text{ Btu/kWh})$

The demand reduction is taken as the annual energy savings multiplied by the ratio of the average energy usage ~~during noon and 8PM~~between 2 PM to 6 PM on summer weekdays to the total annual energy usage.

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

The Energy to Demand Factor is defined below:

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Paper SCE13LG052, Revision, April 6, 2012. DEER only includes an LED Exit Sign measure which was used to estimate the effective useful life of the LED Channel Letter Signage. The Work Paper assumes 16 years for interior and exterior applications. The measure life is capped at 15 years per Act 129.

[428] 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

[429] ibid

$$\text{EnergyToDemandFactor} = \frac{\text{Average Usage}_{\text{Summer WD }\cancel{\text{Noon-8}}\text{2-6 PM}}}{\text{Annual Energy Usage}}$$

The ratio of the average energy usage ~~during noon and 8~~between 2 PM to 6 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~~2 PM to 6 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[430].

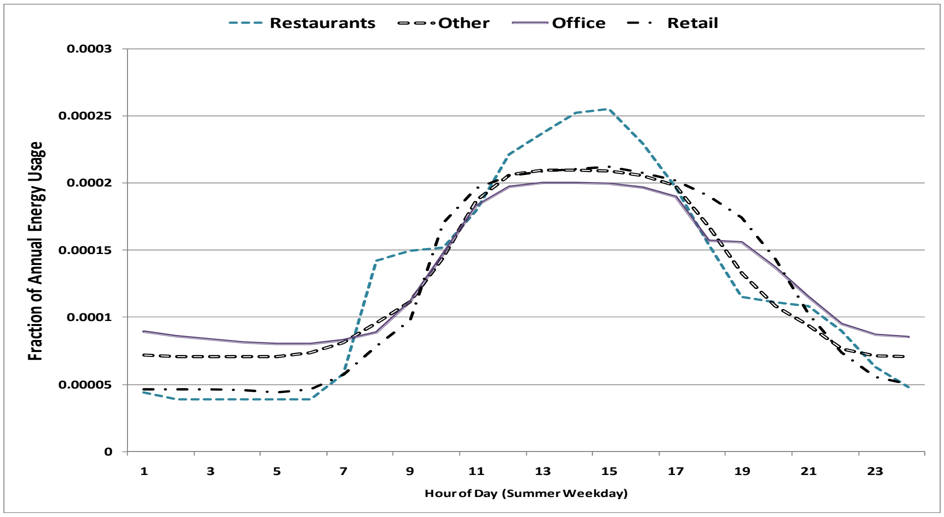

**Figure 3-7: Load shapes for hot water in four commercial building types**

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[430] 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).

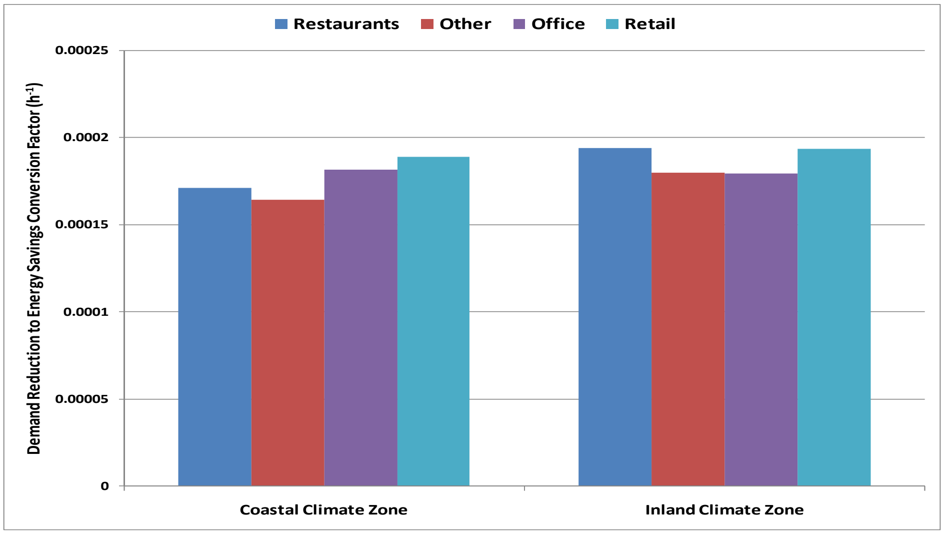

**Figure 3-8: Energy to demand factors for four commercial building types.**

### ~~3.31.2~~3.30.2 Definition of Terms

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The parameters in the above equation are listed in Table 3-95~~Table 3-101~~95 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*

$T_{HNG}$ = *Temperature of hot water coming from the spray nozzle for Non-Grocery Application*

$T_C$ = *Incoming cold water temperature for Grocery and Non-Grocery Application*

$T_{HG}$ = *Temperature of hot water coming from the spray nozzle for Grocery Application*

$EF_{electric}$ = *Energy Factor of existing Electric Water Heater System*

**Table 3-95~~3-103~~95: Low Flow Pre-Rinse Sprayer Calculations Assumptions**

| Description | Type | Value | Source |
|---|---|---|---|
| $F_{BNG}$ | Fixed | Retrofit: 2.25 gpm | 1, 7 |
| $F_{PNG}$ | Variable | Default: 1.12 gpm | 1 |
| | | EDC Data Gathering | EDC Data Gathering |
| $U_{BNG}$ | Fixed | 32.4min/day | 2 |
| $U_{PNG}$ | Fixed | 43.8 min/day | 2 |
| $F_{BG}$ | Fixed | Retrofit: 2.15 gpm | 1, 7 |
| $F_{PG}$ | Variable | 1.12 gpm | 1 |
| | | EDC Data Gathering | EDC Data Gathering |
| $U_{BG}$ | Fixed | 4.8 min/day | 2 |
| $U_{PG}$ | Fixed | 6 min/day | 2 |
| $T_{HNG}$ | Fixed | 107ºF | 3 |
| $T_C$ | Fixed | 55ºF | 6 |
| $T_{HG}$ | Fixed | 97.6ºF | 3 |
| $EF_{electric}$ | Variable | 0.904 | 4 |
| | | EDC Data Gathering | EDC Data Gathering |
| EnergyToDemandFactor | Fixed | 0.~~0001916~~000178 | 5 |

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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 EnergyToDemandFactor is estimated using the California load shapes and reflects PJM’s peak demand period. The load shapes can be accessed online: http://www.ethree.com/CPUC/PG&ENonResViewer.zip
6. Mid-Atlantic TRM, footnote #24
7. The Energy Policy Act (EPAct) of 2005 sets the maximum flow rate for pre-rinse spray valves at 1.6 GPM at 60 pounds per square inch of water pressure when tested in accordance with ASTM F2324-03. This performance standard went into effect January 1, 2006.

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### ~~3.31.3~~3.30.3 ~~Deemed~~Default Savings

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The deemed savings for the installation of a low flow pre-rinse sprayer compared to a standard efficiency sprayer is 151 kWh/year for pre-rinse sprayers installed in grocery stores and 1,222 kWh/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 0.03 kW for pre-rinse sprayers installed in grocery stores and 0.~~23~~22 kW for pre-rinse sprayers installed in non-groceries building types such as restaurants.

### ~~3.31.4~~3.30.4 Measure Life

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The effective life for this measure is 5 years[431].

### ~~3.31.5~~3.30.5 Evaluation Protocol

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

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[431] *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~~3.31 Low Flow Pre-Rinse Sprayers for Time of Sale / Retail Programs

| **Measure Name** | **Low Flow Pre-Rinse Sprayers for Time of Sale / Retail Programs** |
|---|---|
| Target Sector | Commercial Kitchens |
| Measure Unit | Pre Rinse Sprayer |
| Unit Energy Savings | See Table 3-97: Low Flow Pre-Rinse Sprayer Default Savings~~Table 3-10597: Low Flow Pre-Rinse Sprayer Default Savings~~ |
| Unit Peak Demand Reduction | See Table 3-97: Low Flow Pre-Rinse Sprayer Default Savings~~Table 3-10597: Low Flow Pre-Rinse Sprayer Default Savings~~ |
| Measure Life | 5 years |

This protocol documents the energy savings and demand reductions attributed to efficient low flow pre-rinse sprayers in small quick service restaurants, medium-sized casual dining restaurants, and large institutional establishments with cafeteria. Low flow pre-rinse sprayers reduce hot water usage and save energy associated with water heating. Only premises with electric water heating may qualify for this incentive. In addition, the new pre-rinse spray nozzle must have a cleanability performance of 26 seconds per plate or less.

This protocol is applicable to Time of Sale/Retail programs only. The baseline for Time of Sale / Retail programs is assumed to be 1.52 GPM[432].

### ~~3.32.1~~3.31.1 Algorithms

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

$$\Delta kWh = (F_B - F_P) \times U \times 60 \times 312 \times 8.33 \text{ x } 1 \text{ x } (T_H - T_C)\ /\ (EF \text{ x } 3413\ Btu/kWh)$$

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

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

---

[432] The Energy Policy Act (EPAct) of 2005 sets the maximum flow rate for pre-rinse spray valves at 1.6 GPM at 60 pounds per square inch of water pressure when tested in accordance with ASTM F2324-03. This performance standard went into effect January 1, 2006. The federal baseline is adjusted using a baseline adjustment factor of 0.95 to arrive at 1.52 GPM i.e. 1.6 GPM X 0.95 = 1.52 GPM. This value is derived based on the performance rating results of 29 models listed on the Food Service Technology Center Website which showed that the highest rated flow was 1.51 GPM.
Web address: http://www.fishnick.com/equipment/sprayvalves/, Accessed September 21, 2012. Sprayer by T&S Brass Model JetSpray B-0108 was rated at 1.48 GPM, and tested at 1.51 GPM.

The Energy to Demand Factor is defined below:

$$\text{EnergyToDemandFactor} = \frac{\text{Average Usage}_{\text{Summer WD } \cancel{\text{Noon-8}}\text{2-6 PM}}}{\text{Annual Energy Usage}}$$

The ratio of the average energy usage ~~during noon and 8~~between 2 PM to 6 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 3-9: Load shapes for hot water in four commercial building types~~Figure 3-9: Load shapes for hot water in four commercial building types~~. 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 3-10: Energy to demand factors for four commercial building types.~~Figure 3-10: Energy to demand factors for four commercial building types.~~ 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~~2 PM to 6 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[433].

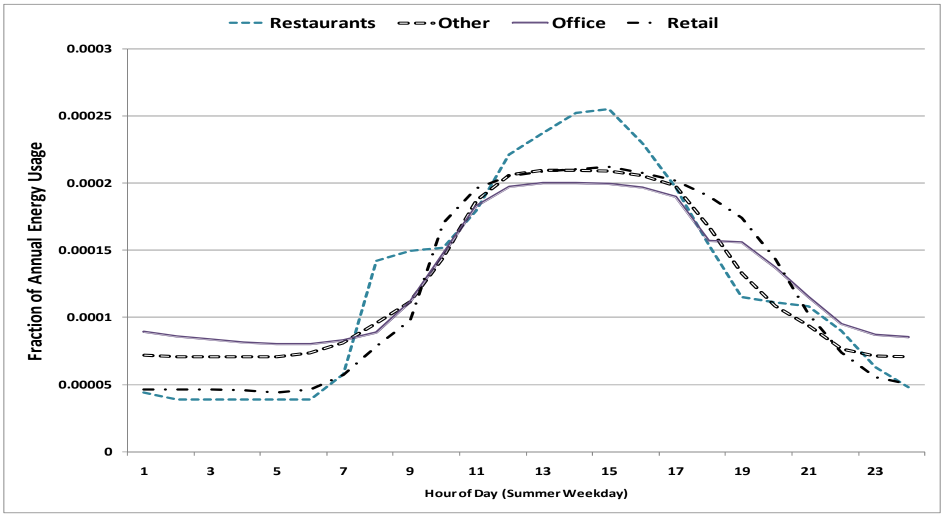

Figure 3-9: Load shapes for hot water in four commercial building types

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[433] 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).

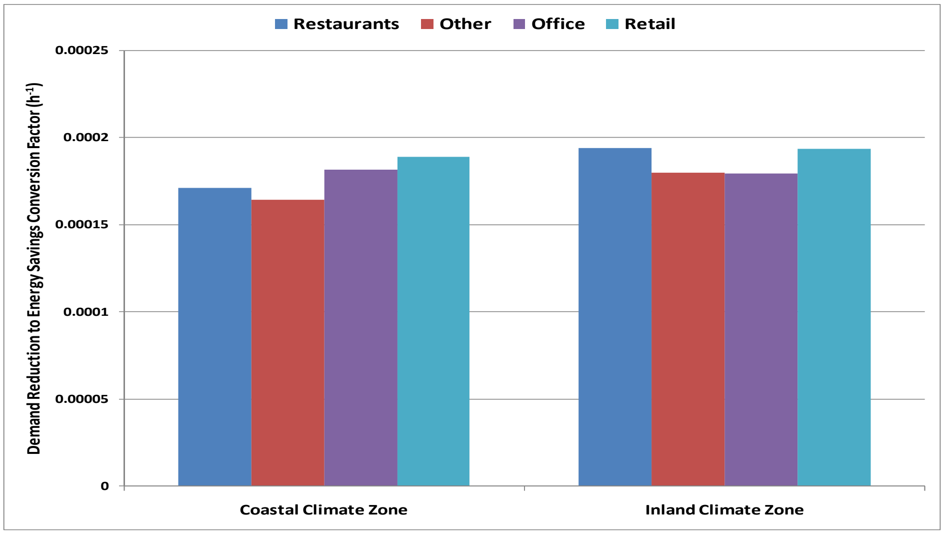

Figure 3-10: Energy to demand factors for four commercial building types.

### ~~3.32.2~~3.31.2 Definition of Terms

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The parameters in the above equation are listed in Table 3-95~~Table 3-103~~95 below.

*$F_B$* = *Baseline Flow Rate of Sprayer*

*$F_P$* = *Post Measure Flow Rate of Sprayer*

*U* = *Baseline and Post Measure Water Usage Duration based on application.*

$T_H$ = Temperature of hot water coming from the spray nozzle

*$T_C$* = *Incoming cold water temperature*

*$EF_{electric}$* = *Energy Factor of existing Electric Water Heater System*

*8.33 lbm/gal* = *specific mass in pounds of one gallon of water*

*1 Btu/lbm°F* = *Specific heat of water: 1 Btu/lbm/°F*

*312*[434] = *Days per year pre-rinse spray valve is used at the site*

*60* = *Minutes per hour pre-rinse spray valve is used at the site*

---

[434] Days per year pre-rinse spray valve is used at the site is assumed to be 312 days/yr derived based on 6 days/wk x 52 wk/yr.

### Table 3-96~~3-104~~96: Low Flow Pre-Rinse Sprayer Calculations Assumptions

| Description | Type | Value | Source |
|---|---|---|---|
| $F_B$ | Fixed | Time of Sale/Retail: 1.52 GPM | 1, 2 |
| $F_P$ | Fixed | Default: Time of Sale/Retail: 1.06 GPM | 3 |
| | Variable | EDC Data Gathering | EDC Data Gathering |
| U (hours/day) | Fixed | Default:<br>Small, quick- service restaurants: 0.5<br>\Medium-sized casual dining restaurants: 1.5<br>Large institutional establishments with cafeteria: 3 | 4 |
| $T_H$ | Fixed | 120°F | 5 |
| $T_C$ | Fixed | 55°F | 6 |
| $EF_{electric}$ | Fixed | Default: 0.904 | 7 |
| | Variable | EDC Data Gathering | EDC Data Gathering |
| EnergyToDemandFactor | Fixed | 0.~~0001916~~000178 | 8 |

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**Sources:**

1. Verification measurements taken at 195 installations showed average pre and post flowrates of 2.23 and 1.12 gallon per minute, respectively.” from Impact and Process Evaluation Final Report for California Urban Water Conservation Council 2004-5 Pre-Rinse Spray Valve Installation Program (Phase 2) (PG&E Program # 1198-04; SoCalGas Program 1200-04) (“CUWCC Report”, Feb 2007)
2. The Energy Policy Act (EPAct) of 2005 sets the maximum flow rate for pre-rinse spray valves at 1.6 GPM at 60 pounds per square inch of water pressure when tested in accordance with ASTM F2324-03. This performance standard went into effect January 1, 2006. The federal baseline is adjusted using a baseline adjustment factor of 0.95. This value is derived based on the performance rating results of 29 models listed on the Food Service Technology Center Website showed that the highest rated flow was 1.51 GPM. Web address: http://www.fishnick.com/equipment/sprayvalves/, Accessed September 21, 2012. Sprayer by T&S Brass Model JetSpray B-0108 was rated at 1.48 GPM, and tested at 1.51 GPM.
3. 1.6 gallons per minute used to be the high efficiency flow, but more efficient spray valves are available ranging down to 0.64 gallons per minute per Federal Energy Management Program which references the Food Services Technology Center web site with the added note that even more efficient models may be available since publishing the data. The average of the nozzles listed on the FSTC website is 1.06.

4. Hours primarily based on PG& E savings estimates, algorithms, sources (2005), Food Service Pre-Rinse Spray Valves with review of 2010 Ohio Technical Reference Manual and Act on Energy Business Program Technical Resource Manual Rev05.
5. Food Service Technology Center calculator assumptions to account for variations in mixing and water heater efficiencies. In the algorithm, T h = Tc + 70° F temperature rise from Tc.
6. Mid-Atlantic TRM, footnote #24
7. 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

~~8.~~1. ~~The load shapes can be accessed online: http://www.ethree.com/CPUC/PG&ENonResViewer.zip~~

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8. The EnergyToDemandFactor is estimated using the California load shapes and reflects PJM's peak demand period. The load shapes can be accessed online: http://www.ethree.com/CPUC/PG&ENonResViewer.zip ~~Deemed~~

### ~~3.32.3~~3.31.3 Default Savings

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The deemed savings for the installation of a low flow pre-rinse sprayer compared to a standard efficiency sprayer for retail programs are listed in Table 3-97: Low Flow Pre-Rinse Sprayer Default Savings~~Table 3-10597: Low Flow Pre-Rinse Sprayer Default Savings~~ below.

**Table 3-97~~3-10597~~: Low Flow Pre-Rinse Sprayer ~~Deemed~~Default Savings**

| Application | Retail | |
|---|---|---|
| | kWh | kW |
| Small quick service restaurants | 814 | 0.~~156~~145 |
| Medium-sized casual dining restaurants | 2,441 | 0.~~468~~434 |
| Large institutional establishments with cafeteria | 4,882 | 0~~.935~~ |

### ~~3.32.4~~3.31.4 Measure Life

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The effective life for this measure is 5 years[435].

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[435] *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

### ~~3.32.5~~3.31.5 Evaluation Protocol

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

## ~~3.33~~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.

### ~~3.33.1~~3.32.1 Eligibility

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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.

### ~~3.33.2~~3.32.2 Algorithms

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

**Air Conditioning:**

For A/C units < 65,000 BtuH, use SEER instead of EER to calculate ΔkWh and convert SEER to EER to calculate $\Delta kW_{peak}$ using 11.3/13 as the conversion factor.

$$\Delta kWh = (EFLH_C \times CAPY_C/1000) \times (1/[EER \times RCF] - 1/EER)$$

$$= (EFLH_C \times CAPY_C/1000) \times (1/[SEER \times RCF] - 1/SEER)$$

$$\Delta kW_{peak} = (CF \times CAPY_C/1000) \times (1/[EER \times RCF] - 1/EER)$$

**Heat Pumps:**

For Heat Pump units < 65,000 BtuH, use SEER instead of EER to calculate $\Delta kWh_{cool}$ and HSPF instead of COP to calculate $\Delta kWh_{heat}$. Convert SEER to EER to calculate $\Delta kW_{peak}$ using 11.3/13 as the conversion factor.

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

$$\Delta kWh_{cool} = (EFLH_C \times CAPY_C/1000) \times (1/[EER \times RCF] - 1/EER)$$

$$= (EFLH_C \times CAPY_C/1000) \times (1/[SEER \times RCF] - 1/SEER)$$

$$\Delta kWh_{heat} = (EFLH_{MH} \times CAPY_H/1000) / 3.412 \times (1/[COP \times RCF] - 1/COP)$$

$$= (EFLH_{MH} \times CAPY_H/1000) \times (1/[HSPF \times RCF] - 1/HSPF)$$

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

### ~~3.33.3~~3.32.3 Definition of Terms

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$CAPY_C$ = *Unit Capacity, in Btu/h for cooling*

$CAPY_H$ = *Unit Capacity, in Btu/h for heating*

*EER* = *Energy Efficiency Ratio. For A/C and heat pump units < 65,000 BtuH, SEER should be used for cooling savings.*

*SEER* = *Seasonal Energy Efficiency Ratio. For A/C and heat pump units > 65,000 BtuH, EER should be used for cooling savings.*

*HSPF* = *Heating Seasonal Performance Factor. For heat pump units > 65,000 BtuH, COP should be used for heating savings.*

*COP* = *Coefficient of Performance. For heat pump units < 65,000 BtuH, HSPF should be used for heating savings.*

$EFLH_C$ = *Equivalent Full-Load Hours for Mechanical Cooling*

$EFLH_{MH}$ = *Equivalent Full-Load Hours for Mechanical Heating*[436]

*RCF* = *COP Degradation Factor for Cooling*

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

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

The values and sources are listed in Table 3-98~~Table 3-10698~~.

**Table 3-98~~3-10698~~: 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 | EDC Data Gathering |
| | | Default: See Table 3-21~~Table 3-2221~~ in 2014 PA TRM | 2014 PA TRM |
| HSPF | Variable | Nameplate | EDC Data Gathering |

---

[436] 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.

| | | | |
|---|---|---|---|
| | | Default: See Table 3-21~~Table 3-22~~21 in 2014 PA TRM | 2014 PA TRM |
| $EFLH_C$ | Variable | Note:<br>• For air-source air conditioners and air-source heat pumps, subtract 0.2 from the required baseline efficiency rating value if unit has heating section other than electric resistance.<br>• Integrated Energy Efficiency Ratios (IEERs) are only applicable to equipment with capacity modulation.<br>Table 3-22~~Table 3-23~~22 in 2014 PA TRM | 2014 PA TRM |
| | | Based on Logging, BMS data or Modeling[437] | EDC's Data Gathering |
| $EFLH_{MH}$ | Variable | Take $EFLH_{HM}$ as 70% of the listed $EFLH_H$ in Table 3-23~~Table 3-24~~23 in 2014 PA TRM | 2 |
| RCF | Variable | See Table 3-99~~Table 3-107~~99 | 1 |
| CF | Fixed | ~~80~~55% | ~~Table 3-21 in 2014 PA TRM~~3 |

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**Sources:**

1. CA 2003 RTU Survey
2. Assumes 70% of heating is done by compressor, 30% by fan and supplemental resistive heat
3. C&I Unitary HVAC Load Shape Project Final Report, KEMA, 2011. The study reports CF values in the range of 44% to 63% depending on the size of the unit for the Mid Atlantic PJM hours. The study, therefore, assumes an average CF value of 55% for the PJM peak demand period that is applied to all units.

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[437] Modeling is an acceptable substitute to metering and BMS data if modeing is conducted using building- and equipment-specific information at the site and the facility consumption is calibrated using 12 months of billing data (pre-retrofit).

**Table 3-99~~3-107~~99: Refrigerant charge correction COP degradation factor (RCF) for various relative charge adjustments for both TXV metered and non-TXV units.[438].**

| % 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% |

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[438] 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% |

### ~~3.33.4~~3.32.4 Measure Life

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According to the 2008 Database for Energy Efficiency Resources (DEER) EUL listing, the measure life for refrigerant charging is **10 years**[439].

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[439] http://www.deeresources.com/deer0911planning/downloads/EUL_Summary_10-1-08.xls

## ~~3.34~~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.

### ~~3.34.1~~3.33.1 Eligibility

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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[440] amps per linear foot for low temperature display cases. Rebate is based on the door width (not including case frame).

### ~~3.34.2~~3.33.2 Algorithms

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The energy savings and demand reduction are obtained through the following calculations adopted from California's Southern California Edison[441].

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

---

[440] http://www.energysmartgrocer.org/pdfs/PGE/BridgeEquipment%20SpecificationTandCs.pdf

[441] Southern California Edison. Non-Residential Express 2003 Refrigeration Work Paper. Pg. 27.

**Compressor Savings (excluding condenser):**

$\Delta\ kW_{compressor} = [Q\text{-}cooling_{svg}/EER/1000]$

$\Delta\ kWh_{compressor} = \Delta\ kW \times EFLH$

$Q\text{-}cooling_{svg} = Q\text{-}cooling \times K\text{-}ASH$

**Anti-Sweat Heater Savings:**

$\Delta\ kW_{ASH} = \Delta\ ASH / 1000$

$\Delta\ kWh_{ASH} = \Delta\ kW_{ASH} \times t$

### ~~3.34.3~~3.33.3 Definition of Terms

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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)*

$\Delta\ ASH$ = *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 3-100~~3-108~~100: 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 | Variable | Default: 5,700[442] | 1 |
| | | Based on Logging, BMS data or Modeling[443] | EDC's Data Gathering |
| Δ ASH | Fixed | 83[444] | 1 |
| t | Fixed | 8,760 | 1 |

**Sources:**

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

### ~~3.34.4~~3.33.4 Measure Life

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The expected measure life is 15 years[445].

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[442] 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.

[443] Modeling is an acceptable substitute to metering and BMS data if modeing is conducted using building- and equipment-specific information at the site and the facility consumption is calibrated using 12 months of billing data (pre-retrofit).

[444] From Actual Test: 0.250 kW per 3 doors

[445] http://energysmartonline.org/documents/EnergySmart_BPA_T&Cs.pdf

## ~~3.35~~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.

### ~~3.35.1~~3.34.1 Algorithms

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

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

### ~~3.35.2~~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 3-101~~3-109~~101: Variables for HVAC Systems**

| Component | Type | Value | Source |
|---|---|---|---|
| BtuH | Variable | Nameplate data (AHRI or AHAM) | EDC's Data Gathering |
| $EER_{base}$ | Variable | New Construction or Replace on Burnout: Default values from Table 3-110 to Table 3-112 ~~Table 3-110~~ | See Table 3-110 to Table 3-112 ~~Table 3-110~~ |
| | | Early Replacement: Nameplate data | EDC's Data Gathering |
| $EER_{ee}$ | Variable | Nameplate data (AHRI or AHAM) | EDC's Data Gathering |
| CF | Fixed | ~~80~~55% | ~~2~~1 |
| $EFLH_{cool}$ | Variable | Based on Logging, BMS data or Modeling[446] | EDC's Data Gathering |
| | | Default values from Table 3-102~~Table 3-111~~102 | See Table 3-102~~Table 3-111~~102 |

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[446] Modeling is an acceptable substitute to metering and BMS data if modeing is conducted using building- and equipment-specific information at the site and the facility consumption is calibrated using 12 months of billing data (pre-retrofit).

**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 3-110: Room Air Conditioner Baseline Efficiencies[447]**~~

1. C&I Unitary HVAC Load Shape Project Final Report, KEMA, 2011. The study reports CF values in the range of 44% to 63% depending on the size of the unit for the Mid Atlantic PJM hours. The study, therefore, assumes an average CF value of 55% for the PJM peak demand period that is applied to all units.

Table 3-110 lists the minimum federal efficiency standards for room air conditioners (effective as of June 1, 2014) and minimum ENERGY STAR efficiency standards for RAC units of various capacity ranges and with and without louvered sides. Units without louvered sides are also referred to as "through the wall" units or "built-in" units. Note that the new federal standards are based on the Combined Energy Efficiency Ratio Metric (CEER), which is a metric that incorporates energy use in all modes, including standby and off modes.[448]

Also, as of October 1, 2013 ENERGY STAR Room Air Conditioner Version 3.0 will take effect.

**Table 3-110: RAC Federal Minimum Efficiency and ENERGY STAR Version 3.0 Standards [449]**

| ~~Equipment Type and~~ Capacity (Btu/h) | ~~Cooling Baseline~~Federal Standard CEER, with louvered sides | ~~Heating Baseline~~ENERGY STAR EER, with louvered sides | Federal Standard EER, without louvered sides | ENERGY STAR CEER, without louvered sides |
|---|---|---|---|---|
| ~~Room AC<~~< 6,000 | ≥11.0 | 11.2 | 10.0 | 10.4 |
| ~~< 8~~6,000 ~~BtuH~~to 7,999 | ~~9.7 EER~~ | ~~N/A~~ | | |
| ~~≥ ~~8,000 ~~BtuH and <14,000 BtuH~~to 10,999 | ≥10.9 | 11.3 | 9.6 | 9.8~~ EER~~<br>~~N/A~~ |
| 11,000 to 13,999 | | | 9.5 | |
| ~~≥ ~~14,000 ~~BtuH and < 20,000 BtuH~~to | ~~9~~≥10.7~~ EER~~ | ~~N/A~~11.2 | 9.3 | |

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~~[447] Baseline values from IECC 2009, after Jan 1, 2010 or Jan 23, 2010 as applicable.~~

[448] Federal stanards: U.S. Department of Energy. *Federal Register*. 164th ed. Vol. 76, August 24, 2011.

[449] Federal stanards: U.S. Department of Energy. *Federal Register*. 164th ed. Vol. 76, August 24, 2011. ENERGY STAR standards: *ENERGY STAR Program Requirements Product Specification for Room Air Conditioners, Eligibility Criteria Version 3.0*. June 22, 2012.

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| | | | | |
|---|---|---|---|---|
| 19,999 | | | | |
| ≥ 20,000 ~~BtuH~~to 24,999 | ≥9.4 | 9.8~~.5 EER~~ | ~~N/A~~9.4 | |
| ≥25,000 | ≥9.0 | | | |

Table 3-111 lists the minimum federal efficiency standards and minimum ENERGY STAR efficiency standards for casement-only and casement-slider RAC units. Casement-only refers to a RAC designed for mounting in a casement window with an encased assembly with a width of 14.8 inches or less and a height of 11.2 inches or less. Casement-slider refers to a RAC with an encased assembly designed for mounting in a sliding or casement window with a width of 15.5 inches or less.

Table 3-111: Casement-Only and Casement-Slider RAC Federal Minimum Efficiency and ENERGY STAR Version 3.0 Standards (effective 2014 TRM)

| Casement | Federal Standard CEER | ENERGY STAR EER |
|---|---|---|
| Casement-only | ≥ 9.5 | ≥ 10.0 |
| Casement-slider | ≥ 10.4 | ≥ 10.9 |

Table 3-112 lists the minimum federal efficiency standards and minimum ENERGY STAR efficiency standards for reverse-cycle RAC units.

Table 3-112: Reverse-Cycle RAC Federal Minimum Efficiency Standards and ENERGY STAR Version 3.0 Standards (effective 2014 TRM)

| Capacity (Btu/h) | Federal Standard CEER, with louvered sides | ENERGY STAR EER, with louvered sides | Federal Standard CEER, without louvered sides | ENERGY STAR EER, without louvered sides |
|---|---|---|---|---|
| < 14,000 | n/a | n/a | ≥ 9.3 | ≥ 9.8 |
| ≥ 14,000 | | | ≥ 8.7 | ≥ 9.2 |
| < 20,000 | ≥ 9.8 | ≥ 10.4 | n/a | n/a |
| ≥ 20,000 | ≥ 9.3 | ≥ 9.8 | | |

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Table 3-102~~3-111~~102: Cooling EFLH for Pennsylvania Cities[450]

| 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 |

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

## ~~3.36~~3.35 Refrigeration – Floating Head Pressure Controls

| **Measure Name** | **Floating Head Pressure Control** |
|---|---|
| **Target Sector** | Commercial Refrigeration |
| **Measure Unit** | Floating Head Pressure Controls |
| **Unit Energy Savings** | Deemed by location, kWh |
| **Unit Peak Demand Reduction** | 0 kW |
| **Measure Life** | 15 |

Installers conventionally design a refrigeration system to condense at a set pressure-temperature setpoint, typically 90º F. By installing a floating head pressure control[451] (FHPCs) condenser system, the refrigeration system can change condensing temperatures in response to different outdoor temperatures. This means that the minimum condensing head pressure from a fixed setting (180 psig for R-22) is lowered to a saturated pressure equivalent at 70º F or less. Either a balanced-port or electronic expansion valve that is sized to meet the load requirement at a 70º F condensing temperature must be installed. Alternatively, a device may be installed to supplement the refrigeration feed to each evaporator attached to a condenser that is reducing head pressure.

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### ~~3.36.1~~3.35.1 Eligibility

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This protocol documents the energy savings attributed to FHPCs applied to a single-compressor refrigeration system in commercial applications. The baseline case is a refrigeration system without FHPC whereas the efficient case is a refrigeration system with FHPC. FHPCs must have a minimum Saturated Condensing Temperature (SCT) programmed for the floating head pressure control of ≤ 70ºF. The use of FHPC would require balanced-port expansion valves, allowing satisfactory refrigerant flow over a range of head pressures. Compressor must be 1HP or larger.

### ~~3.36.2~~3.35.2 Algorithms

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The savings are primarily dependent on the following factors:

- Load factor of compressor motor horsepower (HP)
- Climate zone
- Refrigeration system temperature application

The savings algorithm is as follows:

$$\Delta kWh = HP_{compressor} \text{ x } kWh/HP$$

*If the refrigeration system is rated in tonnage:*

$$\Delta kWh = (4.715 / COP) \text{ x } Tons \text{ x } kWh/HP$$

---

[451] Also called as flood back control

$\Delta kW_{peak}$ = 0

### ~~3.36.3~~3.35.3 Definition of Terms

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$HP_{compressor}$ = *Rated horsepower (HP) per compressor*

*kWh/HP* = *Annual savings per HP*

*COP* = *Coefficient of Performance*

*Tons* = *Refrigeration tonnage of the system*

*4.715* = *Conversion factor to convert from tons to HP*

**Table 3-103~~3-112~~103: Floating Head Pressure Controls – Values and References**

| Component | Type | Values | Sources |
|---|---|---|---|
| $HP_{compressor}$ | Variable | EDC Data Gathering | EDC Data Gathering |
| kWh/HP | Fixed | Table 3-104~~Table 3-113~~104 | 1 |
| COP | Variable | Based on design conditions | EDC Data Gathering |
| | | Default:<br>Condensing Unit;<br>Refrigerator (Medium Temp: 28 °F – 40 °F): 2.55 COP<br>Freezer (Low Temp: -20 °F – 0 °F): 1.32 COP<br>Remote Condenser;<br>Refrigerator (Medium Temp: 28 °F – 40 °F): 2.49 COP<br>Freezer (Low Temp: -20 °F – 0 °F): 1.45 COP | 2 |
| Tons | Variable | EDC Data Gathering | EDC Data Gathering |
| 4.715 | Fixed | Engineering Estimate | 3 |

**Sources:**

1. The deemed savings values were derived from the Regional Technical Forum (RTF) as part of the Northwest Power & Conservation Council, Deemed Measures List. Grocery Floating Head Pressure Controls for Single Compressor Systems, FY2010, V1. Using RTF Deemed saving estimates for the NW climate zone, data was extrapolated to Pennsylvania climate zones by using cooling degree days comparison based on the locale.
2. The given COP values are averaged based on the data from: Regional Technical Forum (RTF) as part of the Northwest Power & Conservation Council, Deemed Measures List. Grocery Floating Head Pressure Controls for Single Compressor Systems, FY2010, V1.

3. Conversion factor for compressor horsepower per ton: http://www.engineeringtoolbox.com/refrigeration-formulas-d_1695.html

**Table 3-104~~3-113104~~: Annual Savings kWh/HP by Location**

| Climate Zone | Condensing Unit (kWh/HP) | | | Remote Condenser (kWh/HP) | | |
|---|---|---|---|---|---|---|
| | Refrigerator (Medium Temp) | Freezer (Low Temp) | Default[452] (Temp Unknown) | Refrigerator (Medium Temp) | Freezer (Low Temp) | Default[453] (Temp Unknown) |
| Allentown | 630 | 767 | 674 | 380 | 639 | 463 |
| Erie | 681 | 802 | 720 | 438 | 657 | 508 |
| Harrisburg | 585 | 737 | 634 | 330 | 623 | 424 |
| Philadelphia | 546 | 710 | 598 | 286 | 609 | 390 |
| Pittsburgh | 617 | 759 | 662 | 366 | 634 | 452 |
| Scranton | 686 | 806 | 724 | 443 | 659 | 512 |
| Williamsport | 663 | 790 | 703 | 417 | 651 | 492 |

**Table 3-105~~3-114105~~: Default Condenser Type Annual Savings kWh/HP by Location**

| Climate Zone | Unknown Condenser Type Default[454] (kWh/HP) | | |
|---|---|---|---|
| | Refrigerator (Medium Temp) | Freezer (Low Temp) | Temp Unknown |
| Allentown | 505 | 703 | 568 |
| Erie | 559 | 730 | 614 |
| Harrisburg | 458 | 680 | 529 |
| Philadelphia | 416 | 660 | 494 |
| Pittsburgh | 491 | 697 | 557 |
| Scranton | 564 | 732 | 618 |
| Williamsport | 540 | 720 | 598 |

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[452] Default based on: 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."

[453] Ibid.

[454] No data available to predict if condensing units or remote condensers will be more prevalent, assumed 50/50 split, based on discussion with Portland Energy Conservation, Inc. (PECI) GrocerySmart staff.

### ~~3.36.4~~3.35.4 Measure Life

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The measure life is 15 years[455] as per the Regional Technical Forum (RTF) of the Northwest Power & Conservation Council.

### ~~3.36.5~~3.35.5 Evaluation Protocols

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The most appropriate evaluation protocol for this measure is verification of installed refrigeration capacity coupled with EDC data gathering or assignment of stipulated energy savings.

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[455] Grocery Floating Head Pressure Controls for Single Compressor Systems, FY2010, V1. Accessed from RTF website http://www.nwcouncil.org/rtf/measures/Default.asp on September 06, 2011.

## ~~3.37~~3.36 Variable Speed Refrigeration Compressor

| Measure Name | VSD Refrigeration Compressor |
|---|---|
| Target Sector | Commercial Refrigeration Establishments |
| Measure Unit | VSD Refrigeration Compressor |
| Unit Energy Savings | Variable |
| Unit Peak Demand Reduction | Variable |
| Measure Life | 10 |

Variable speed drive (VSD) compressors are used to control and reduce the speed of the compressor during times when the refrigeration system does not require the motor to run at full capacity. VSD control is an economical and efficient retrofit option for existing compressor installations. The performance of variable speed compressors can more closely match the variable refrigeration load requirements thus minimizing energy consumption.

### ~~3.37.1~~3.36.1 Eligibility

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This measure, VSD control for refrigeration systems and its eligibility targets applies to retrofit construction in the commercial and industrial building sectors; it is most applicable to grocery stores or food processing applications with refrigeration systems. This protocol is for a VSD control system replacing a slide valve control system.

### ~~3.37.2~~3.36.2 Algorithms

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The savings algorithm is as follows:

*If the refrigeration system is rated in tonnage:*

$$\Delta kWh = Tons \times ES_{Value}$$

$$\Delta kW_{peak} = Tons \times DS_{Value}$$

*If the refrigeration system is rated in horsepower:*

$$\Delta kWh = 0.445 * HP_{compressor} \times ES_{Value}$$

$$\Delta kW_{peak} = 0.445 * HP_{compressor} \times DS_{Value}$$

### ~~3.37.3~~3.36.3 Definition of Terms

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$HP_{compressor}$ = *Rated horsepower per compressor*

$ES_{Value}$ = *Energy savings value in kWh per compressor HP*

$DS_{Value}$ = *Demand savings value in kW per compressor HP*

*Tons* = *Refrigeration tonnage of the system*

*0.445* = *Conversion factor to convert from tons to HP*

**Table 3-1063~~-115~~106: VSD Compressor – Values and References**

| Component | Type | Values | Sources |
|---|---|---|---|
| Tons | Variable | EDC Data Gathering | EDC Data Gathering |
| $HP_{compressor}$ | Variable | EDC Data Gathering | EDC Data Gathering |
| $ES_{Value}$ | Fixed | 1,696 kWh/ton | 1 |
| $DS_{Value}$ | Fixed | 0.22 kW/ton | 1 |
| 0.445 | Fixed | Engineering Estimate | 2,3 |

**Sources:**

1. Deemed savings values of 1696 kWh/ton and 0.22 kW/ton were obtained from the 2005 DEER (Database for Energy Efficiency Resources). This measure considered the associated savings by vintage and by climate zone for compressors. The deemed value was an average across all climate zones[456] and all vintages (excluding new construction).
2. PSC of Wisconsin, Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0, p. 4-103 to 4-106. Where refrigerator (medium temp: 28 °F – 40 °F) COP equals 2.5 and freezer COP (low temp: -20 °F – 0 °F) equals 1.3. The weighted average COP equals 2.1, based on 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.”
3. Conversion factor for compressor horsepower per ton is HP/ton = 4.715/COP, using weighted average COP of 2.1. From http://www.engineeringtoolbox.com/refrigeration-formulas-d_1695.html

### ~~3.37.4~~3.36.4 Measure Life

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According to the 2005 DEER, a VFD compressor has a measure life of 10 years.

### ~~3.37.5~~3.36.5 Evaluation Protocols

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The most appropriate evaluation protocol for this measure is verification of installed refrigeration capacity affected by the retrofit coupled with EDC data gathering or assignment of stipulated energy savings.

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[456] The deemed savings was averaged across all climate zones since the variance between all cases was less than 5%.

## ~~3.38~~3.37 Fuel Switching: Domestic Hot Water Electric to Gas / Oil / Propane

| Measure Name | Fuel Switching: DHW Electric to Gas/Oil/Propane |
|---|---|
| **Target Sector** | Small Commercial |
| **Measure Unit** | Water Heater |
| **Unit Energy Savings** | Varies |
| **Unit Peak Demand Reduction** | Varies |
| **Fossil Fuel Consumption Increase** | Varies |
| **Measure Life** | 13 years for natural gas or propane<br>8 years for oil |

Natural gas, propane, and oil water heaters generally offer the customer lower costs compared to standard electric water heaters. Additionally, they typically see an overall energy savings when looking at the source energy of the electric unit versus the fossil fuel unit. Federal standard electric water heaters have energy factors of >=0.904 and ~~a federal standard efficiency~~an ENERGY STAR gas and propane-fired water heater have an energy factor of 0.~~575~~67 for a 50 gal unit and 0.495 for an oil-fired 50 gal unit. This protocol does not apply for units >55 gal.

### ~~3.38.1~~3.37.1 Eligibility

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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~~ an Energy Star natural gas/propane-fired water heater with Energy Factor of 0.~~575~~67 or greater and 0.495 or greater for ~~an~~a standard oil-fired water heater. The target sector primarily consists of motels, small office, and small retail establishments. If a customer submits a rebate for a product that has applied for ENERGY STAR Certification but has not yet been certified, the savings will be counted for that product contingent upon its eventual certification as an ENERGY STAR measure. If at any point the product is rejected by ENERGY STAR, the product is then ineligible for the program and savings will not be counted.

### ~~3.38.2~~3.37.2 Algorithms

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The energy savings calculation utilizes average performance data for available small commercial standard electric and natural gas water heaters and typical water usage. Because there is little electric energy associated with a natural gas or propane water heater, the energy savings are the full energy utilization of the electric water heater. The energy savings are obtained through the following formula:

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

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

$$\text{Fuel Consumption (MMBtu)} = \cancel{\frac{\left\{\left(\frac{1}{EF_{fuel,inst}}\right)\times\left(HW\times 1\,\frac{BTU}{lb-F}\times 8.3\,\frac{lb}{gal}\times(T_{hot}-T_{cold})\right)\right\}}{1{,}000{,}000\,\frac{Btu}{MMBtu}}}\;\frac{\left\{\left(\frac{1}{EF_{fuel,inst}}\times\frac{1}{DF_{fuel,adjust}}\right)\times\left(HW\times 1\,\frac{BTU}{lb-F}\times 8.3\,\frac{lb}{gal}\times(T_{hot}-T_{co}\right.\right.}{1{,}000{,}000\,\frac{Btu}{MMBtu}}$$

Where $EF_{fuel}$ changes depending on the fossil fuel used by the water heater.

For resistive water heaters, the demand reduction is taken as the annual energy savings multiplied by the ratio of the average energy usage ~~during noon and 8~~between 2 PM to 6 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:

$$EnergyToDemandFactor = \frac{Average\ Usage_{Summer\ WD\ \cancel{Noon-8}2\text{-}6\ PM}}{Annual\ Energy\ Usage}$$

**Loads**

The annual loads are taken from data from the DEER database[457]. The DEER database has data for gas energy usage for the domestic hot water end use for various small commercial buildings. The loads are averaged over all 16 climate zones and all six vintage types in the DEER database. Finally, the loads are converted to average annual gallons of use using the algorithm below. The loads are summarized in Table 3-107~~Table 3-116~~107 below, assuming a 40 gal natural gas water heater with a standard efficiency of 0.594.

$$HW\,(Gallons) = \frac{Load \times EF_{NG,\,Base}\ X\ 1000\,\frac{Btu}{kBtu}\ X\ Typical\ SF}{1\,\frac{BTU}{lb-F}\times 8.3\,\frac{lb}{gal}\ X\ (Thot - Tcold)\ X\ 1000\ SF}$$

**Table 3-107~~3-116~~107: Typical water heating loads.**

| Building Type | Typical Square Footage | Average Annual Load In kBTU/1000 sq ft | Average Annual Use, Gallons |
|---|---|---|---|
| Motel | 30,000 | 2,963 | 97,870 |
| Small Office | 10,000 | 2,214 | 24,377 |
| Small Retail | 7,000 | 1,451 | 11,183 |

**Energy to Demand Factor**

The ratio of the average energy usage ~~during noon and 8~~between 2 PM to 6 PM on summer weekdays to the total annual energy usage is taken from usage profile data collected for

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[457] http://www.deeresources.com/deer0911planning/downloads/DEER2008-CommercialResultsReview-NonUpdatedMeasures.exe

commercial water heaters in CA[458]. The usage profiles are shown in Figure 3-11. 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 3-12, 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~~2 PM to 6 PM on summer weekdays is quite similar for all building types. The close level of agreement between disparate climate zones and building types suggest that the results will carry over to Pennsylvania[459].

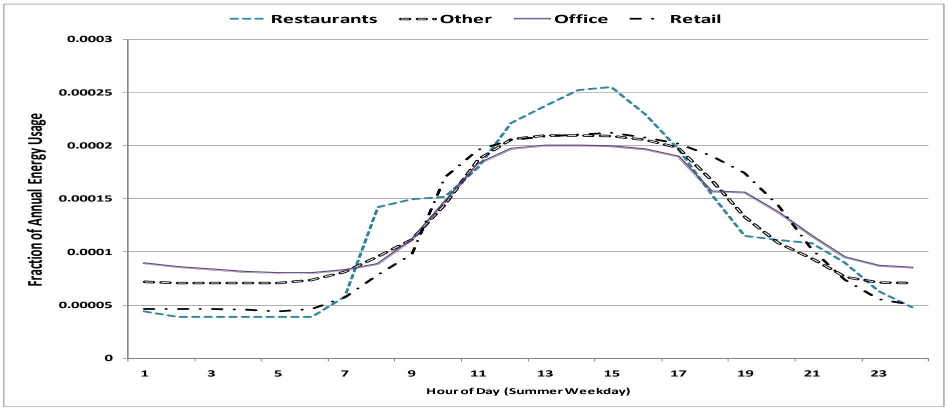

Figure 3-11: Load shapes for hot water in four commercial building types

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[458] ibid

[459] 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).

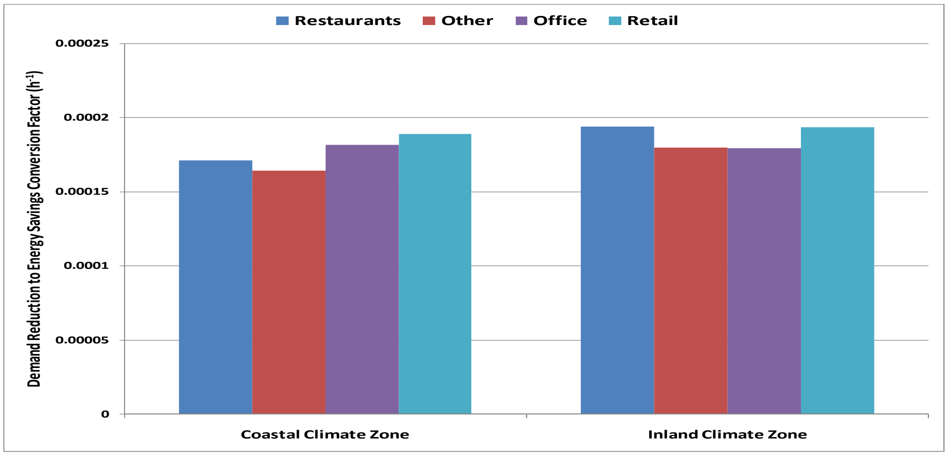

**Figure 3-12: Energy to demand factors for four commercial building types**

### ~~3.38.3~~3.37.3 Definition of Terms

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The parameters in the above equation are listed in Table 3-108~~Table 3-117~~108.

**Table 3-108~~3-117~~108: Commercial Water Heater Fuel Switch Calculation Assumptions**

| Component | Type | Values | Source |
|---|---|---|---|
| $EF_{base}$, Energy Factor of baseline water heater | Variable | Default: 0.904 | 1 |
| | | Nameplate | EDC Data Gathering |
| $EF_{fuel}$[460], Energy Factor of installed fossil fuel water heater* | Variable | >=0.~~575~~67 for Natural Gas and Propane<br>>=0.495 for Oil | 5, EDC Data Gathering |
| $EF_{Tankless\ Water\ Heater}$, Energy Factor of installed tankless water heater | Variable | >=0.82 | 5 |
| $DF_{fuel,\ adjust}$, Fossil Fuel Water Heaters Derating Adjustment factor | Fixed | Storage Water Heaters: 1.0<br>Tankless Water Heaters: 0.91 | 7 |
| Load, Average annual Load in kBTU | Fixed | Varies | DEER Database |
| $T_{hot}$, Temperature of hot water | Fixed | ~~120~~123 °F | 2 |
| $T_{cold}$, Temperature of cold water supply | Fixed | 55 °F | 3 |
| HW, Average annual gallons of Use | Variable | Default: See Table 3-107~~Table 3-116~~107 | Calculation |

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[460] Note that the federal minimum energy efficiency standards for electric and fossil fuel water heaters will increase starting April 16, 2015. These new standards will be included in the 2015 TRM.

| | | EDC Data Gathering | EDC Data Gathering |
|---|---|---|---|
| EnergyToDemandFactor | Fixed | 0.~~0001916~~000178 | 4 |
| [461]$EF_{NG,\ base}$, Energy Factor of baseline gas water heater | Fixed | 0.594 | 5 |
| ResistiveDiscountFactor | Fixed | 1.0 | 6 |

### 3.37.4 ~~* For tankless water heaters, the EF should be at least 0.82~~Energy Factors based on Tank Size

Federal Standards for Energy Factors are equal to 0.97 -0.00132 x Rated Storage in Gallons. The following table shows the Energy Factors for various tank sizes.

**Table 3-109~~3-109~~: Minimum Baseline Energy Factors based on Tank Size**

| Tank Size (gallons) | Minimum Energy Factors ($E_{base}$) |
|---|---|
| 40 | 0.9172 |
| 50 | 0.9040 |
| 65 | 0.8842 |
| 80 | 0.8644 |
| 120 | 0.8116 |

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**Sources:**

~~1.~~2. 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. 2012 SWE Residential Baseline Study Mid-Atlantic TRM.

~~3.~~4. Mid-Atlantic TRM, footnote #24

~~9.~~5. The EnergyToDemandFactor is estimated using the California load shapes and reflects PJM's peak demand period. The load shapes can be accessed online: http://www.ethree.com/CPUC/PG&ENonResViewer.zip

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~~4.~~ Commission Order[462] requires fuel switching to ENERGY STAR measures, not standard efficiency measures. The Energy Factor has therefore been updated to reflect the EnergyStar standard for natural gas or propane storage water heaters beginning

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[461] The protocol assumes a 40 gal natural gas water heater with a standard efficiency of 0.594 to calculate the loads summarized in Table 3-86: Typical water heating loads.~~Table 3-92~~91~~: Typical water heating loads.~~

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

September 1, 2010. From Residential Water Heaters Key Product Criteria. http://www.energystar.gov/index.cfm?c=water_heat.pr_crit_water_heaters Accessed June 2013. ~~The load shapes can be accessed online: http://www.ethree.com/CPUC/PG&ENonResViewer.zip~~

~~5.~~6. Federal Standards are 0.~~67 -0.0019 x Rated Storage in Gallons for natural gas/propane and 0.~~59 – 0.0019 x Rated Storage in Gallons for oil. For a 50-gallon tank this is 0.~~575 for natural gas/propane and 0.~~495 for oil. For a 40-gallon tank, this is 0.594 for natural gas. "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.~~7. Engineering Estimate. No discount factor is needed because the baseline is already an electric resistance water heater system.

8. ~~Deemed~~The disconnect between rated energy factor and in-situ energy consumption is markedly different for tankless units due to significantly higher contributions to overall household hot water usage from short draws. In tankless units the large burner and unit heat exchanger must fire and heat up for each draw. The additional energy losses incurred when the mass of the unit cools to the surrounding space in-between shorter draws was found to be 9% in a study prepared for Lawrence Berkeley National Laboratory by Davis Energy Group, 2006. "Field and Laboratory Testing of Tankless Gas Water Heater Performance" Due to the similarity (storage) between the other categories and the baseline, this derating factor is applied only to the tankless category.

### ~~3.38.4~~3.37.5 Default Savings

The ~~deemed savings~~defaultsavings for the replacement of 50 gal electric water heater with a 50 gal fossil fuel units in various applications are listed below.

**Table 3-1103-~~118~~110: Water Heating Fuel Switch Energy Savings ~~and Demand Reductions~~Algorithms**

| Building Type | ~~Average Annual Use, Gallons~~ | ~~Energy Savings (~~ΔkWh~~)~~ | ~~Demand Reduction (kW)~~ | ~~Natural Gas/Propane Usage~~Fuel Consumption (MMBtu) | ~~Oil Usage (MMBtu)~~ | | |
|---|---|---|---|---|---|---|---|
| Motel | | ~~97,870~~$\frac{16,184.54}{EF_{Elec,bl}}$ | | ~~17,113~~ $\frac{55.24}{EF_{fuel,inst}} \times \frac{1}{DF_{fuel,adjust}}$ | ~~3.28~~ | ~~91.8~~ | ~~106.7~~ |
| Small Office | | ~~24,377~~$\frac{4,031.17}{EF_{Elec,bl}}$ | | ~~4,263~~ $\frac{13.76}{EF_{fuel,inst}} \times \frac{1}{DF_{fuel,adjust}}$ | ~~0.82~~ | ~~22.9~~ | ~~26.6~~ |
| Small Retail | | ~~11,183~~$\frac{1,849.31}{EF_{Elec,bl}}$ | | ~~1,955~~ $\frac{6.31}{EF_{fuel,inst}} \times \frac{1}{DF_{fuel,adjust}}$ | ~~0.37~~ | ~~10.5~~ | ~~12.2~~ |

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### ~~3.38.5~~3.37.6 Measure Life

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A natural gas or propane water heater's lifespan is 13 years[463] and an oil-fired water heater has an 8 year lifetime.[464]

### ~~3.38.6~~3.37.7 Evaluation Protocols

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

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[463] From ENERGY STAR https://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=WGS

[464] http://www.aceee.org/consumer/water-heating

## ~~3.39~~3.38 Fuel Switching: Heat Pump Water Heaters to Gas / Oil / Propane

| Measure Name | Heat Pump Water Heaters |
|---|---|
| Target Sector | Commercial Establishments |
| Measure Unit | Water Heater |
| Unit Energy Savings | Varies |
| Unit Peak Demand Reduction | Varies |
| Fossil Fuel Consumption Increase | Varies |
| Measure Life | 13 years for natural gas/propane<br>8 years for oil |

Natural gas, propane, and oil water heaters generally offer the customer lower costs compared to heat pump water heaters. Additionally, they typically see an overall energy savings when looking at the source energy of the electric unit versus the gas unit. Heat pump water heaters have energy factors of 2 or greater and ~~a federal standard efficiency~~an ENERGY STAR gas and propane water heater have an energy factor of 0.~~575~~67 for a 50 gal unit and 0.495 for an oil-fired 50 gal unit. This protocol does not apply for units >55 gal.

### ~~3.39.1~~3.38.1 Eligibility

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This protocol documents the energy savings attributed to converting heat pump water heaters with Energy Factors of 2 or greater to fossil fuel water heaters. 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 heat pump water heater with a fossil fuel water heater. It does not cover systems where the heat pump is a pre-heater or is combined with other water heating sources. If a customer submits a rebate for a product that has applied for ENERGY STAR Certification but has not yet been certified, the savings will be counted for that product contingent upon its eventual certification as an ENERGY STAR measure. If at any point the product is rejected by ENERGY STAR, the product is then ineligible for the program and savings will not be counted. More complicated installations can be treated as custom projects.

### ~~3.39.2~~3.38.2 Algorithms

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

$$\Delta kWh = \frac{\left\{\left(\left(\frac{1}{EF_{base}} \times \frac{1}{F_{Adjust}}\right)\right) \times HW\ X\ 8.3\ \frac{lb}{gal}\ X\ 1.0\ \frac{Btu}{lb-F}\ X(Thot - Tcold)\right\}}{3413\,\frac{Btu}{kWh}}$$

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

Fuel Consumption (MMBtu) = ~~$\frac{\left\{\left(\frac{1}{EF_{fuel,inst}}\right) \times \left(HW \times 1\frac{BTU}{lb-F} \times 8.3\frac{lb}{gal} \times (T_{hot} - T_{cold})\right)\right\}}{1{,}000{,}000\frac{Btu}{MMBtu}}$~~ $\frac{\left\{\left(\frac{1}{EF_{fuel,inst}} \times \frac{1}{DF_{fuel,adjust}}\right) \times \left(HW \times 1\frac{BTU}{lb-F} \times 8.3\frac{lb}{gal} \times (T_{hot}\text{-}T_{co}\right.\right.}{1{,}000{,}000\frac{Btu}{MMBtu}}$

Where $EF_{fuel}$ changes depending on the fossil fuel used by the water heater.

For replacement of heat pump water heaters with fossil fuel units, 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~~between 2 PM to 6 PM on summer weekdays to the total annual energy usage.

$\Delta kW_{peak}$ = *EnergyToDemandFactor × Energy Savings × ResistiveDiscountFactor*

The Energy to Demand Factor is defined below:

*EnergyToDemandFactor* = ~~$\frac{Average\ Usage_{Summer\ WD\ Noon\text{-}8}}{Annual\ Energy\ Usage}$~~ $\frac{Average\ Usage_{Summer\ WD\ 2\text{-}6\ PM}}{Annual\ Energy\ Usage}$

~~**Loads**~~

~~*The annual loads are taken from data from the DEER database[465]. The DEER database has data for gas energy usage for the domestic hot water end use for various small commercial buildings. The loads are averaged over all 16 climate zones and all six vintage types in the DEER database. Finally, the loads are converted to average annual gallons of use using the algorithm below. The loads are summarized in Table 3-119*~~

**Loads**

The annual loads are taken from data from the DEER database[466]. The DEER database has data for gas energy usage for the domestic hot water end use for various small commercial buildings. The loads are averaged over all 16 climate zones and all six vintage types in the DEER database. Finally, the loads are converted to average annual gallons of use using the algorithm below. The loads are summarized in Table 3-89: Typical water heating loads~~Table 3-89: Typical water heating loads~~ below, assuming a 40 gal natural gas water heater with a standard efficiency of 0.594.

$$HW\ (Gallons) = \frac{Load \times EF_{NG,\ Base}\ X\ 1000\ \frac{Btu}{kBtu}\ X\ Typical\ SF}{1\ \frac{BTU}{lb-F} \times 8.3\ \frac{lb}{gal}\ X\ (Thot - Tcold)\ X\ 1000\ SF}$$

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~~[465] http://www.deeresources.com/deer0911planning/downloads/DEER2008-CommercialResultsReview-NonUpdatedMeasures.exe~~

[466] http://www.deeresources.com/deer0911planning/downloads/DEER2008-CommercialResultsReview-NonUpdatedMeasures.exe

**Table 3-111~~3-119111~~: Typical water heating loads**

| Building Type | Typical Square Footage | Average Annual Load In kBTU/1000 sq ft | Average Annual Use, Gallons |
|---|---|---|---|
| Motel | 30,000 | 2,963 | 97,870 |
| Small Office | 10,000 | 2,214 | 24,377 |
| Small Retail | 7,000 | 1,451 | 11,183 |

**Energy to Demand Factor**

The ratio of the average energy usage ~~during noon and 8~~between 2 PM to 6 PM on summer weekdays to the total annual energy usage is taken from usage profile data collected for commercial water heaters in CA[467]. The usage profiles are shown in Figure 3-13. 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 3-14, 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~~2 PM to 6 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[468].

Figure 3-13: Load shapes for hot water in four commercial building types

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[467] ibid

[468] 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).

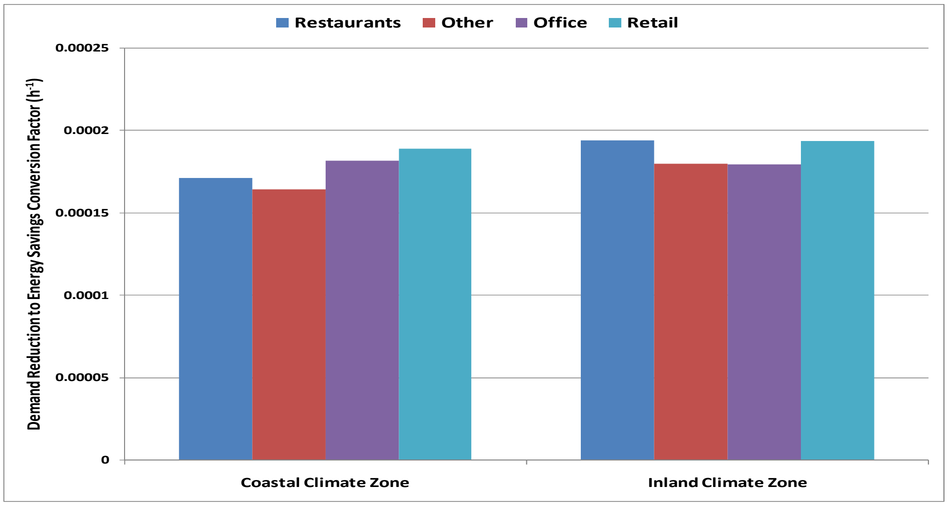

Figure 3-14: Energy to demand factors for four commercial building types

**Resistive Heating Discount Factor**

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

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

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

**Heat Pump COP Adjustment Factor**

The Energy Factors are determined from a DOE testing procedure that is carried out at 56 °F wetbulb temperature. However, the average wetbulb temperature in PA is closer to 45 °F[469], while the average wetbulb temperature in conditioned typically ranges from 50 °F to 80 °F. The heat pump performance is temperature dependent. Figure 3-15 below shows relative coefficient of

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[469] 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.

performance (COP) compared to the COP at rated conditions[470]. According to the plotted profile, the following adjustments are recommended.

**Table 3-112~~3-120112~~: 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 |

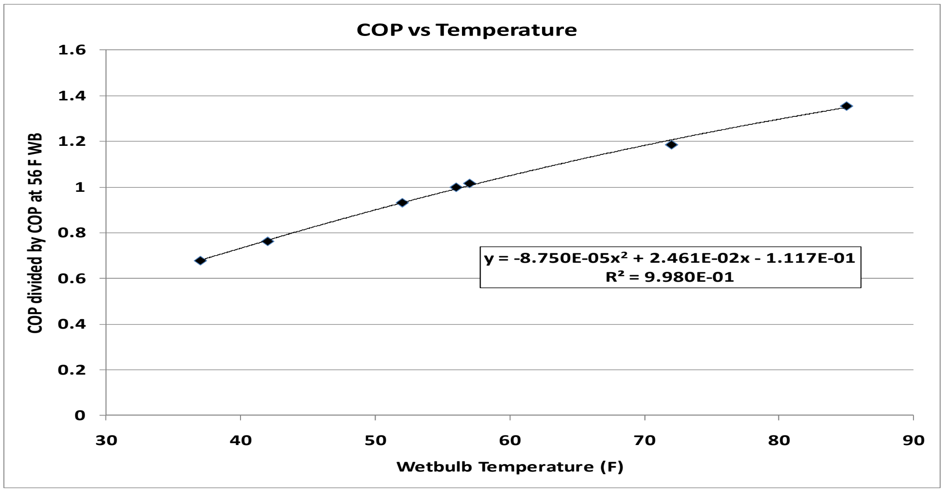

**Figure 3-15: Dependence of COP on outdoor wetbulb temperature.**

### ~~3.39.3~~3.38.3 Definition of Terms

The parameters in the above equation are listed in Table 3-113~~Table 3-121113~~.

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[470] 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.

**Table 3-113~~3-121~~113: Heat Pump Water Heater Fuel Switch Calculation Assumptions**

| Component | Type | Values | Source |
|---|---|---|---|
| $EF_{base}$, Energy Factor of baseline water heater | Variable | Default: >= 2 | 1 |
| | | Nameplate | EDC Data Gathering |
| $EF_{fuel}$[471], Energy Factor of installed fossil fuel water heater* | Variable | >=0.~~575~~67 for Natural Gas and Propane<br>>=0.495 for Oil | 7, EDC Data Gathering |
| $EF_{Tankless\ Water\ Heater}$, Energy Factor of installed tankless water heater | Variable | >=0.82 | 7 |
| $DF_{fuel,\ adjust}$, Fossil Fuel Water Heaters Derating Adjustment factor | Fixed | Storage Water Heaters: 1.0<br>Tankless Water Heaters: 0.91 | 8 |
| Load, Average annual Load in kBTU | Fixed | Varies | 5 |
| $T_{hot}$, Temperature of hot water | Fixed | ~~120~~123 °F | 2 |
| $T_{cold}$, Temperature of cold water supply | Fixed | 55 °F | 3 |
| EnergyToDemandFactor | Fixed | 0.~~0001916~~000178 | 4 |
| $F_{Adjust}$, COP Adjustment factor | Fixed | 0.80 if outdoor<br>1.09 if indoor<br>1.30 if in kitchen | 4 |
| HW, Average annual gallons of Use | Variable | Default: See Table 3-111~~Table 3-119~~111 | Calculation |
| | | EDC Data Gathering | EDC Data Gathering |
| ResistiveDiscountFactor | Fixed | 0.90 | 6 |
| [472]$EF_{NG,\ base}$, Energy Factor of baseline gas water heater | Fixed | 0.594 | 7 |

~~* For tankless water heaters, the EF should be at least 0.82~~

~~**Sources:**~~

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[471] Note that the federal minimum energy efficiency standards for electric and fossil fuel water heaters will increase starting April 16, 2015. These new standards will be included in the 2015 TRM.

[472] The protocol assumes a 40 gal natural gas water heater with a standard efficiency of 0.594 to calculate the loads summarized in Table 3-89: Typical water heating loads~~Table 3-95~~94~~: Typical water heating loads~~,

### 3.38.4 Energy Factors based on Tank Size

Federal Standards ~~are~~for Energy Factors are equal to 0.97 -0.00132 x Rated Storage in Gallons. The following table shows the Energy Factors for various tank sizes.

**Table 3-114~~3-114~~: Minimum Baseline Energy Factors based on Tank Size**

| Tank Size (gallons) | Minimum Energy Factors ($E_{base}$) |
|---|---|
| 40 | 0.9172 |
| 50 | 0.9040 |
| 65 | 0.8842 |
| 80 | 0.8644 |
| 120 | 0.8116 |

**Sources:**

1. ~~-~~Heat pump water heater efficiencies have not been set in a Federal Standard. However, the Federal Standard for water heaters ~~require an EF of at least~~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, p. 30.
2. ~~Many states have plumbing codes that limit shower and bathtub water temperature to 120 °F.~~2012 SWE Residential Baseline Study Mid-Atlantic TRM.
3. Mid-Atlantic TRM, footnote #24
4. The EnergyToDemandFactor is estimated using the California load shapes and reflects PJM's peak demand period. The load shapes can be accessed online: http://www.ethree.com/CPUC/PG&ENonResViewer.zip
5. DEER Database
6. Engineering Estimate
7. Commission Order[473] requires fuel switching to ENERGY STAR measures, not standard efficiency measures. The Energy Factor has therefore been updated to reflect the EnergyStar standard for natural gas or propane storage water heaters beginning September 1, 2010. From Residential Water Heaters Key Product Criteria. http://www.energystar.gov/index.cfm?c=water_heat.pr_crit_water_heaters Accessed June 2013.Federal Standards are 0.~~67 -~~59 – 0.0019 x Rated Storage in Gallons for oil. For a 50-gallon tank this is 0.~~575 for natural gas/propane and 0.~~495 for oil. For a 40-gallon tank this is 0.594 for natural gas. "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.

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

8. The disconnect between rated energy factor and in-situ energy consumption is markedly different for tankless units due to significantly higher contributions to overall household hot water usage from short draws. In tankless units the large burner and unit heat exchanger must fire and heat up for each draw. The additional energy losses incurred when the mass of the unit cools to the surrounding space in-between shorter draws was found to be 9% in a study prepared for Lawrence Berkeley National Laboratory by Davis Energy Group, 2006. "Field and Laboratory Testing of Tankless Gas Water Heater Performance" Due to the similarity (storage) between the other categories and the baseline, this derating factor is applied only to the tankless category.

### ~~3.39.4~~3.38.5 ~~Deemed~~ Default Savings

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The deemed savings for the replacement of heat pump electric water heaters with fossil fuel units in various applications are listed below.

Table 3-115~~3-122~~115: Energy Savings ~~and Demand Reductions~~Algorithms

| ~~Building Type~~ | ~~Location Installed~~ | ~~Average Annual Use, Gallons~~~~ΔkWh~~ | ~~EF~~ | ~~COP Adjustment Factor~~ | ~~Energy Savings (kWh)~~ | ~~Demand Reduction (kW)~~ | ~~Natural Gas/Propane Usage~~~~Fuel Consumption (MMBtu)~~ | ~~Oil Usage~~ |
|---|---|---|---|---|---|---|---|---|
| ~~Motel~~ | Outdoor~~Unconditioned Space~~ | ~~97,870~~ ~~$\frac{20,230.67}{EF_{base}}$~~ | ~~2~~ | ~~0.8~~ | ~~9,669~~ | ~~1.85~~ | ~~$\frac{55.24}{EF_{fuel,inst}} \times \frac{1}{DF_{fuel,adjust}}$~~ | |
| ~~Motel~~ | ~~Conditioned Space~~Indoor | ~~97,870~~ ~~$\frac{14,848.20}{EF_{base}}$~~ | ~~2~~ | ~~1.09~~ | ~~7,097~~ | ~~1.36~~ | | |
| ~~Motel~~ | ~~Kitchen~~ | ~~97,870~~ ~~$\frac{12,449.64}{EF_{base}}$~~ | ~~2~~ | ~~1.3~~ | ~~5,950~~ | ~~1.14~~ | | |
| ~~Small Office~~ | ~~Unconditioned Space~~Outdoor | ~~24,377~~ ~~$\frac{5,038.96}{EF_{base}}$~~ | ~~2~~ | ~~0.8~~ | ~~2,408~~ | ~~0.46~~ | ~~$\frac{13.76}{EF_{fuel,inst}} \times \frac{1}{DF_{fuel,adjust}}$~~ | |
| ~~Small Office~~ | Indoor~~Conditioned Space~~ | ~~24,377~~ ~~$\frac{3,698.32}{EF_{base}}$~~ | ~~2~~ | ~~1.09~~ | ~~1,768~~ | ~~0.34~~ | | |
| ~~Small Office~~ | ~~Kitchen~~ | ~~24,377~~ ~~$\frac{3,100.90}{EF_{base}}$~~ | ~~2~~ | ~~1.3~~ | ~~1,482~~ | ~~0.28~~ | | |
| ~~Small Retail~~ | Outdoor~~Unconditioned Space~~ | ~~11,183~~ ~~$\frac{2,311.63}{EF_{base}}$~~ | ~~2~~ | ~~0.8~~ | ~~1,105~~ | ~~0.21~~ | ~~$\frac{6.31}{EF_{fuel,inst}} \times \frac{1}{DF_{fuel,adjust}}$~~ | |
| ~~Small Retail~~ | ~~Conditioned Space~~Indoor | ~~11,183~~ ~~$\frac{1,696.61}{EF_{base}}$~~ | ~~2~~ | ~~1.09~~ | ~~811~~ | ~~0.16~~ | | |
| ~~Small Retail~~ | ~~Kitchen~~ | ~~11,183~~ ~~$\frac{1,422.54}{EF_{base}}$~~ | ~~2~~ | ~~1.3~~ | ~~680~~ | ~~0.13~~ | | |

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| Building Type | Location Installed | ΔkWh | Fuel Consumption (MMBtu) |
|---|---|---|---|
| Motel | Outdoor | $\frac{20{,}230.67}{EF_{base}}$ | $\frac{55.24}{EF_{fuel,inst}} \times \frac{1}{DF_{fuel,adjust}}$ |
| Motel | Indoor | $\frac{14{,}848.20}{EF_{base}}$ | |
| Motel | Kitchen | $\frac{12{,}449.64}{EF_{base}}$ | |
| Small Office | Outdoor | $\frac{5{,}038.96}{EF_{base}}$ | $\frac{13.76}{EF_{fuel,inst}} \times \frac{1}{DF_{fuel,adjust}}$ |
| Small Office | Indoor | $\frac{3{,}698.32}{EF_{base}}$ | |
| Small Office | Kitchen | $\frac{3{,}100.90}{EF_{base}}$ | |
| Small Retail | Outdoor | $\frac{2{,}311.63}{EF_{base}}$ | $\frac{6.31}{EF_{fuel,inst}} \times \frac{1}{DF_{fuel,adjust}}$ |
| Small Retail | Indoor | $\frac{1{,}696.61}{EF_{base}}$ | |
| Small Retail | Kitchen | $\frac{1{,}422.54}{EF_{base}}$ | |

### ~~3.39.5~~3.38.6 Measure Life

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A natural gas or propane water heater's lifespan is 13 years[474] and an oil-fired water heater has an 8 year lifetime.[475]

### ~~3.39.6~~3.38.7 Evaluation Protocols

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

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[474] From ENERGY STAR https://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=WGS

[475] http://www.aceee.org/consumer/water-heating

## ~~3.40~~3.39 Fuel Switching: Small Commercial Electric Heat to Natural gas / Propane / Oil Heat

The energy and demand savings for ~~Commercial~~small commercial fuel switching for heating systems is determined from the algorithms listed below. This protocol excludes water source, ground source, and groundwater source heat pumps.

The baseline for this measure is an existing commercial facility with an electric primary heating source. The heating source can be electric baseboards, packaged terminal heat pump (PTHP) units, electric furnace, or electric air source heat pump. The retrofit condition for this measure is the installation of a new standard efficiency natural gas, propane, or oil furnace or boiler. This algorithm does not apply to combination space and water heating units. This protocol applies to measures with input rating of less than 225,000 Btu/hr.

To encourage adoption of the highest efficiency units, older units which meet outdated ENERGY STAR standards may be incented up through the given sunset dates (see table below).

| **ENERGY STAR Product Criteria Version** | **ENERGY STAR Effective Manufacture Date** | **Act 129 Sunset Date[a]** |
|---|---|---|
| ENERGY STAR Furnaces Version 4.0 | February 1, 2013 | N/A |
| ENERGY STAR Furnaces Version 3.0 | February 1, 2012 | May 31, 2014 |
| ENERGY STAR Furnaces Version 2.0, Tier II units | October 1, 2008 | May 31, 2013 |

[a] Date after which Act 129 programs may no longer offer incentives for products meeting the criteria for the listed ENERGY STAR version.”

EDCs may provide incentives for equipment with efficiencies greater than or equal to the applicable ENERGY STAR requirement per the following table.

| **Equipment** | **Energy Star Requirements[476]** |
|---|---|
| Gas Furnace | AFUE rating of 95% or greater<br>Less than or equal to 2.0% furnace fan efficiency<br>Less than or equal to 2.0% air leakage |
| Oil Furnace | AFUE rating of 85% or greater<br>Less than or equal to 2.0% furnace fan efficiency<br>Less than or equal to 2.0% air leakage |

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[476] Residential Furnace and Boiler Energy Star product criteria. http://www.energystar.gov/index.cfm?c=furnaces.pr_crit_furnaces and http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=BO

| | |
|---|---|
| Boiler | ● AFUE rating of 85% or greater |

### ~~3.40.1~~3.39.1 Algorithms[477]

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

***Electric furnace or air source heat pump***

For ASHP units < 65,000 BtuH, use HSPF instead of COP to calculate $\Delta kWh_{heat}$.

$$\Delta kWh_{heat} = (BtuH_{heat} / 1000) / 3.412 \text{ X } 1/COP_{base} \text{ X } EFLH_{heat}$$

$$= (BtuH_{heat} / 1000) \text{ X } 1/HSPF_{base} \text{ X } EFLH_{heat}$$

***Baseboard heating, packaged terminal heat pump***

$$\Delta kWh_{heat} = \frac{BtuH_{heat} X\ EFLH_{heat}}{3413\frac{Btu}{kWh} * COP_{base}} - \frac{HP_{motor} \times \left(746\frac{W}{HP}\right) \times EFLH_{heat}}{\eta_{\ motor} \times 1000\frac{W}{kW}}$$

The motor consumption of a gas furnace is subtracted from the savings for a baseboard or PTHP heating system, as these existing systems do not require a fan motor while the replacement furnace does (the electric furnace and air source heat pumps require fan motors with similar consumption as a gas furnace and thus there is no significant change in motor load). For boilers, the annual pump energy consumption is negligible (<50 kWh per year) and not included in this calculation.[478]

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

**Fuel consumption with fossil fuel furnace or boiler:**

$$Fuel\ Consumption\ (MMBtu) = \frac{BtuH_{fuel} X EFLH_{heat}}{AFUE_{Fuel} X1{,}000{,}000\frac{Btu}{MMBtu}}$$

### ~~3.40.2~~3.39.2 Definition of Terms

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$BtuH_{heat}$ = Rated heating capacity of the existing electric unit in $BtuH_{heat}$

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[477] EDC's may use billing analysis using program participant data to claim measure savings, in lieu of using the defaults provided in this measure protocol. Billing analysis should be conducted using at least 12 months of billing data (pre- and post-retrofit).

[478] Pump motors are typically 1/25 HP. With 1,000 hour runtime and 80% assumed efficiency, this translates to 37 kWh.

$BtuH_{fuel}$ = *Rated heating capacity of the new fossil fuel unit in* $BtuH_{fuel}$

$COP_{base}$ = *Efficiency rating of the baseline 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.*

$AFUE_{fuel}$ = *Annual Fuel Utilization Efficiency rating of the fossil fuel unit.*

$EFLH_{heat}$ = *Equivalent Full Load Hours for the heating season – The kWh during the entire operating season divided by the kW at design conditions.*

$HP_{motor}$ = *Gas furnace blower motor horsepower (hp)*

$\eta_{motor}$ = *Efficiency of furnace blower motor*

**Table 3-116~~3-123116~~: Variables for HVAC Systems**

| Component | Type | Value | Source |
|---|---|---|---|
| $BtuH_{fuel}$ | Variable | Nameplate data (AHRI or AHAM) | EDC Data Gathering |
| $BtuH_{heat}$ | Variable | Nameplate data (AHRI or AHAM)<br>Default: set equal to $BtuH_{fuel}$ | EDC Data Gathering |
| $COP_{base}$ | Variable | Early Replacement: Nameplate data | EDC Data Gathering |
| | | New Construction or Replace on Burnout: Default values from Table 3-117~~Table 3-124~~117 | See Table 3-117~~Table 3-124~~117 |
| $HSPF_{base}$ | Variable | Early Replacement: Nameplate data | EDC Data Gathering |
| | | New Construction or Replace on Burnout: Default values from Table 3-117~~Table 3-124~~117 | See Table 3-117~~Table 3-124~~117 |
| $AFUE_{fuel}$ | Variable | Default = ~~80~~>= 95% (natural gas/propane furnace)<br>~~79~~>= 95% (natural gas/propane steam boiler)<br>~~80~~>= 95% (natural gas/propane hot water boiler)<br>~~81~~>= 85% (oil furnace)<br>~~81~~>= 85% (oil steam boiler)<br>~~82~~>= 85% (oil hot water boiler) | ~~Code of Federal Regulations 10 CFR 431.87, for Less than 2,500,000 Btu/h~~ENERGY STAR requirement |
| | | Nameplate data (AHRI or AHAM) | EDC Data Gathering |
| $EFLH_{heat}$ | Variable | Based on Logging, EMS data or Modeling[479] | EDC Data Gathering |
| | | Default values from ~~**Table 3-125**~~<br>Table **3-118**~~Table 3-118~~ | ~~**See Table 3-125**~~See<br>Table **3-118**~~Table 3-118~~ |
| $HP_{motor}$ | Variable | Default = ½ hp for furnace | Average blower motor capacity for gas furnace (typical range = ¼ hp to ¾ hp) |
| | | Nameplate | EDC Data Gathering |
| $\eta_{motor}$ | Variable | Default = 0.50 for furnace | Typical efficiency of ½ hp blower motor for gas furnace |
| | | Nameplate | EDC Data Gathering |

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[479] Modeling is an acceptable substitute to metering and BMS data if ~~modeing~~modeling is conducted using building- and equipment-specific information at the site and the facility consumption is calibrated using 12 months of billing data (pre-retrofit).

**Sources:**

1. The Equivalent Full Load Hours (ELFH) for Pennsylvania are calculated based on the degree day scaling methodology. The EFLH values reported in the Connecticut Program Savings Documentation were adjusted using full load hours (FLH) from the US DOE ENERGY STAR Calculator to account for differences in weather conditions. Degree day scaling ratios were calculated using heating degree day and cooling degree day values for seven Pennsylvania cities: Allentown, Erie, Harrisburg, Philadelphia, Pittsburgh, Scranton, and Williamsport.
    a. US Department of Energy. ENERGY STAR Calculator and Bin Analysis Models
    b. UI and CL&P Program Savings Documentation for 2012 Program Year, United Illuminating Company, September 2011, Pages 219-220.

**Table 3-117~~3-124117~~: HVAC Baseline Efficiencies**[480]

| Equipment Type and Capacity | Heating Baseline |
|---|---|
| Air-Source Heat Pumps | |
| < 65,000 BtuH | 7.7 HSPF |
| ≥ 65,000 BtuH and <135,000 BtuH | 3.3 COP |
| ≥ 135,000 BtuH and < 240,000 BtuH | 3.2 COP |
| ≥ 240,000 BtuH<br>(IPLV for units with capacity-modulation only) | 3.2 COP |
| Electric Resistance Heat (Electric Furnace or Baseboard) | |
| All sizes | 1.0 COP |
| Packaged Terminal Systems (Replacements)[481] | |
| PTHP | 2.9 - (0.026 x Cap / 1000) COP |

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

[481] 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.

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Table 3-118~~3-125~~118: Heating EFLH for Pennsylvania Cities[482, 483]

| 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 | 701 | 573 | 576 | 605 | 563 | 612 |
| Dining: Bar Lounge/Leisure | 1,156 | 1,346 | 1,100 | 1,104 | 1,161 | 1,080 | 1,175 |
| Dining: Cafeteria / Fast Food | 582 | 678 | 554 | 556 | 585 | 544 | 592 |
| 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 | 258 | 280 |
| Industrial: 1 Shift/Light Manufacturing | 1,491 | 1,737 | 1,420 | 1,425 | 1,498 | 1,394 | 1,516 |
| Industrial: 2 Shift | 1,017 | 1,184 | 968 | 972 | 1,022 | 951 | 1,034 |
| Industrial: 3 Shift | 538 | 626 | 512 | 513 | 540 | 502 | 546 |
| Lodging: Hotels/Motels/Dormitories | 1,438 | 1,675 | 1,369 | 1,374 | 1,444 | 1,344 | 1,462 |
| Lodging: Residential | 1,438 | 1,675 | 1,369 | 1,374 | 1,444 | 1,344 | 1,462 |
| Multi-Family (Common Areas) | 277 | 322 | 263 | 264 | 278 | 259 | 281 |
| Museum/Library | 1,266 | 1,474 | 1,205 | 1,209 | 1,271 | 1,183 | 1,286 |
| Nursing Homes | 738 | 859 | 702 | 704 | 740 | 689 | 749 |
| Office: General/Retail | 1,266 | 1,474 | 1,205 | 1,209 | 1,271 | 1,183 | 1,286 |
| 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 | 965 | 789 | 792 | 832 | 774 | 842 |
| Police/Fire Stations (24 Hr) | 277 | 322 | 263 | 264 | 278 | 259 | 281 |
| 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 | 1,933 | 1,580 | 1,586 | 1,667 | 1,551 | 1,687 |
| Warehouses (Not Refrigerated) | 1,555 | 1,810 | 1,480 | 1,485 | 1,561 | 1,453 | 1,580 |
| Warehouses (Refrigerated) | 1,555 | 1,810 | 1,480 | 1,485 | 1,561 | 1,453 | 1,580 |
| Waste Water Treatment Plant | 538 | 626 | 512 | 513 | 540 | 502 | 546 |

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

[483] The Equivalent Full Load Hours (ELFH) for Pennsylvania are calculated based on the degree day scaling methodology. The EFLH values reported in the Connecticut Program Savings Documentation were adjusted using full load hours (FLH) from the US DOE ENERGY STAR Calculator to account for differences in weather conditions.

### ~~3.40.3~~3.39.3 Measure Life

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Measure life = 20 years[484]

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[484] DEER 2008 for nonresidential high efficiency furnace (http://www.deeresources.com/deer0911planning/downloads/EUL_Summary_10-1-08.xls) PA 2013 TRM Appendix A: Measure Lives. Note that PA Act 129 savings can be claimed for no more than 15 years.

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# 4 AGRICULTURAL MEASURES

The following section of the TRM contains savings protocols for agricultural measures that apply to both residential and commercial & industrial sector.

## 4.1 Automatic Milker Takeoffs

| **Measure Name** | **Automatic Milker Takeoffs** |
|---|---|
| **Target Sector** | Agriculture (includes Small Commercial, Residential) |
| **Measure Unit** | Per project |
| **Unit Energy Savings** | Varies, partially deemed |
| **Unit Peak Demand Reduction** | Varies, partially deemed |
| **Measure Life** | 10 |

The following protocol for the calculation of energy and demand savings applies to the installation of automatic milker takeoffs on dairy milking vacuum pump systems. Automatic milker takeoffs shut off the suction on teats once a minimum flow rate is achieved. This reduces the load on the vacuum pump.

### 4.1.1 Eligibility

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This measure requires the installation of automatic milker takeoffs to replace pre-existing manual takeoffs on dairy milking vacuum pump systems. Equipment with existing automatic milker takeoffs is not eligible. In addition, the vacuum pump system serving the ~~affected~~impacted milking units must be equipped with a variable speed drive (VSD) to qualify for incentives. Without a VSD, little or no savings will be realized.

### 4.1.2 Algorithms

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The annual energy savings are obtained through the following formula:

$$\Delta kWh/yr = COWS \times \frac{MPD}{2\frac{avg.milkings}{day}} \times ESC$$

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

### 4.1.3 Definition of Terms

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$COWS$ = *Number of cows milked per day*

$MPD$ = *Number of milkings per day per cow*

$ESC$ = *Energy Savings per cow per year.*

$CF$ = *Demand Coincidence factor*

### 4.1.4 Description of Calculation Method

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**Table 4-14~~-1~~: Variables for Automatic Milker Takeoffs**

| Component | Type | Value | Source |
|---|---|---|---|
| COWS | Variable | Based on customer application | EDC Data Gathering |
| MPD | Variable | Based on customer application | EDC Data Gathering |
| | | Default = 2 | 1 |
| ESC | Fixed | 7.5 kWh/cow/yr | 1, 2, 3, 4, 5,6 |
| CF | Fixed | 0.00014 | ~~2~~6 |

***Sources:***

1. The ESC was calculated based on the following assumptions:
    - Average herd size is 75 cows in PA (Source 2)
    - The typical dairy vacuum pump size for the average herd size is 10 horsepower
    - Based on the herd size, average pump operating hours are estimated at 8 hours per day (Source 4)
    - A 12.5% annual energy saving factor (Source 5)
2. Average Pennsylvania Herd Size information came from: Hoard's Dairyman: The National Dairy Farm Magazine, March 2013. U.S. Industry Dairy Statistics, 2007-2013
3. Average dairy vacuum pump size was estimated based on the Minnesota Dairy Project literature. http://www.mnproject.org/resourcecenter/Vacuum%20System%20options.pdf
4. Annual pump operating hours were based on the assumption that 15-20 cows are milked per hour and two milkings occur per day.
5. Savings are based on the assumption that automatic milker take-offs eliminate open vacuum pump time associated with milker take-offs separating from the cow or falling off during the milking process. The following conservative assumptions were made to determine energy savings associated with the automatic milker take-offs:
    - There is 30 seconds of open vacuum pump time for every 8 cows milked
    - The vacuum pump has the ability to turn down during these open-vacuum pump times from a 90% VFD speed to a 40% VFD speed

    Additionally, several case studies from the Minnesota Dairy Project include dairy pump VFD and automatic milker take-off energy savings and are estimated at 50-70% pump savings. It is assumed that the pump VFD savings are 46% (see Section 4.1: Variable Speed Drive (VSD) Controller on Dairy Vacuum ~~Pump VFD IMP~~Pumps), therefore the average remaining savings can be attributed to automatic milker take-offs.

    http://www.mnproject.org/resourcecenter/Vacuum%20System%20options.pdf

6. Because this measure results in vacuum pump energy savings, the load profile and coincidence factor described in the VSD Controller on Dairy Vacuum Pump TRM protocol also apply to this measure.

### 4.1.5 Measure Life

The measure life for automatic milker takeoffs is 10 years.[485]

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[485] Idaho Power Demand Side Management Potential Study – Volume II Appendices, Nexant, 2009.

## 4.2 Dairy Scroll Compressors

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| **Measure Name** | **Dairy Scroll Compressors** |
|---|---|
| **Target Sector** | Agriculture (includes Small Commercial, Residential) |
| **Measure Unit** | Per compressor |
| **Unit Energy Savings** | Varies |
| **Unit Peak Demand Reduction** | Varies |
| **Measure Life** | 15 years |

The following protocol for the calculation of energy and demand savings applies to the installation of a scroll compressor to replace an existing reciprocating compressor or the installation of a scroll compressor in a new construction application. ~~The milk cooling equipment can consume 20 percent to 25 percent of all electrical energy use on a dairy farm.~~ The compressor is used to cool milk for preservation and packaging. The energy and demand savings per cow will depend on the installed scroll compressor energy efficiency ratio (EER), operating days per year and the presence of a precooler in the refrigeration system.

### 4.2.1 Eligibility

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This measure requires the installation of a scroll compressor to replace an existing reciprocating compressor or to be installed in a new construction application. Existing farms replacing scroll compressors are not eligible.

### 4.2.2 Algorithms

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The energy and peak demand savings are dependent on the presence of a precooler in the system, and are obtained through the following formulas:

*Annual Savings without a Precooler*

$$\Delta \text{kWh}_{\text{no precool}}\ /\text{yr} = \left(\frac{CBTU_{\text{no precool}}}{\text{EER}_{\text{base}}} - \frac{CBTU_{\text{no precool}}}{\text{EER}_{\text{eff}}}\right) \times \frac{1\ kW}{1000\ W} \times HRS \times DAYS \times COWS$$

$$\Delta \text{kW}_{peak,\ no\ precool} = \Delta kWh_{no\ precool} \times CF$$

*Annual Savings with a Precooler*

$$\Delta \text{kWh}_{\text{precool}}\ /\text{yr} = \left(\frac{CBTU_{\text{precool}}}{\text{EER}_{\text{base}}} - \frac{CBTU\ _{\text{precool}}}{\text{EER}_{\text{eff}}}\right) \times \frac{1\ kW}{1000\ W} \times HRS \times DAYS \times COWS$$

$$\Delta \text{kW}_{peak,precool} = \Delta kWh_{precool} \times CF$$

### 4.2.3 Definition of Terms

**Formatted:** Indent: Left: 0", Tab stops: 0.25", List tab + Not at 0.44"

$EER_{base}$ = *Baseline compressor efficiency*

$EER_{eff}$ = *Installed compressor efficiency*

$CBTU_{no\ precool}$ = *Heat load of milk per cow per day for a refrigeration system with no precooler in Btu/Cow/day.*

$CBTU_{precool}$ = *Heat load of milk per cow per day for a refrigeration system with a precooler in Btu/Cow/day.*

*DAYS* = *Milking days per year*

*HRS* = *Operating hours per day*

*COWS* = *Average number of cows milked per day*

*CF* = *Demand Coincidence factor*

### 4.2.4 Description of Calculation Method

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**Table 4-2~~4-2~~: Variables for Dairy Scroll Compressors**

| Component | Type | Value | Source |
|---|---|---|---|
| $EER_{base}$ | Variable | Baseline compressor ~~nameplate,~~manufacturers data based upon customer application | EDC Data Gathering |
| | Default | 5.85 | 1 |
| $EER_{eff}$ | Variable | Nameplate | EDC Data Gathering |
| $CBTU_{no\ precool}$ | Fixed | 2,864 Btu/Cow/day | 2, 3 |
| $CBTU_{precool}$ | Fixed | 922 Btu/Cow/day | 2, 3 |
| HRS | Variable | Customer application | EDC Data Gathering |
| | Default | 8 hours | 4 |
| DAYS | Variable | Based on customer application | EDC Data Gathering |
| | Default | 365 days/year | 3, 4 |
| COWS | Variable | Based on customer application | EDC Data Gathering |
| CF | Fixed | 0.00014 | 5 |

***Sources:***

1. Based on the average EER data for a variety of reciprocating compressors from Emerson Climate Technologies. http://www.emersonclimate.com/en-us/Pages/default.aspx
2. Based on a specific heat value of 0.93 Btu/lb deg F and density of 8.7 lb/gallon for whole milk. American Society of Heating Refrigeration and Air-conditioning Engineers Refrigeration Handbook, 2010, Ch.19.5.
3. Based on delta T (~~between cow~~ temperature difference between the milk ~~cooled milk~~leaving the cow and the colledmilk in tank sorage) of 59°F for a system with no pre-cooler and 19°F for a system with a pre-cooler. It was also assumed that an average

cow produces 6 gallons of milk per day. Evaluation of Alliant Energy Agriculture Program, Appendix F, 2008.

4. Based on typical dairy parlor operating hours referenced for agriculture measures in California. California Public Utility Commission. Database for Energy Efficiency Resources (DEER) 2005. The DEER database assumes 20 hours of operation per day, but is based on much larger dairy farms (e.g. herd sizes > 300 cows). Therefore, the DEER default value was lowered to 8 hours per day, as the average ~~heard~~herd size ~~in~~is 75 cows in Pennsylvania.
5. Because the scroll compressor operates on the same operating schedule as the dairy vacuum pump equipment, the load profile and coincidence factor described in the VSD Controller on Dairy Vacuum Pump TRM protocol can be applied to this measure. However, it should be noted that the compressor and refrigeration system are thermostatically controlled and will cycle on and off during the peak demand period.

### 4.2.5 Measure Life

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The measure life for dairy scroll compressors is 15 years[486].

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[486] PA Consulting Group for the State of Wisconsin Public Service Commission, Focus on Energy Evaluation. Business Programs: Measure Life Study. August 25, 2009. Appendix B

## 4.3 High Efficiency Ventilation Fans with and without Thermostats

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| **Measure Name** | **High Efficiency Ventilation Fans** |
|---|---|
| **Target Sector** | Agriculture, Large Commercial, Small Commercial, Residential |
| **Measure Unit** | Per fan |
| **Unit Energy Savings** | Varies |
| **Unit Peak Demand Reduction** | Varies |
| **Measure Life** | 10 years |

The following protocol for the calculation of energy and demand savings applies to the installation of ventilation fans to replace standard efficiency ventilation fans or in new construction. The high efficiency fans move more cubic feet of air per watt than compared to standard efficiency ventilation fans. Adding a thermostat control will reduce the number of hours that the ventilation fans operate.

This protocol does not apply to circulation fans.

### 4.3.1 Eligibility

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This protocol applies to: (1) the installation of high efficiency ventilation fans in either new construction or retrofit applications where standard efficiency ventilation fans are replaced, and/or (2) the installation of a thermostat controlling either new efficient fans or existing fans. Default values are provided for dairy and swine applications. Other facility types are eligible, however, data must be collected for all default values.

### 4.3.2 Algorithms

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The annual energy savings are obtained through the following formula:

$$\Delta kWh_{fan}/yr \quad = Qty_{std}\left(\frac{1}{Eff_{std}}\right)\times CFM \times hours \times \frac{1}{1000} - Qty_{high}\left(\frac{1}{Eff_{high}}\right)\times CFM \times hours \times \frac{1}{1000}$$

$$\Delta kWh_{tstat}/yr \quad = \left(\frac{1}{Eff_{installeds}}\right)\times CFM \times hours_{tstat} \times 1/1000$$

$$\Delta kWh_{total}/yr \quad = \Delta kWh_{fan} + \Delta kWh_{tstat}$$

$$\Delta kW_{peak} \quad = \Delta kWh_{fan} \times CF$$

### 4.3.3 Definition of Terms

**Formatted:** Indent: Left: 0", Tab stops: 0.25", List tab + Not at 0.44"

$Qty_{std}$ = *Quantity of the baseline standard efficiency fans*

$Qty_{high}$ = *Quantity of high efficiency fans that were installed*

$Eff_{high}$ = *Efficiency in cfm/W of the high efficiency fan at a static pressure of 0.1 inches water*

| | |
|---|---|
| $Eff_{std}$ | = Efficiency in cfm/W of the standard efficiency fan at a static pressure of 0.1 inches water |
| $Eff_{installed}$ | = Efficiency in cfm/W at a static pressure of 0.1 inches water for the installed fans controlled by the thermostat |
| CFM | = cubic feet per minute of air movement |
| hours | = operating hours per year of the fan without thermostat |
| $hours_{tstat}$ | = reduction in operating hours of the fan due to the thermostat |
| 1000 | = conversion of watts to kilowatts |
| CF | = demand coincidence factor |

### 4.3.4 Description of Calculation Method

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**Table 4-3~~4-3~~: Variables for Ventilation Fans**

| Component | Type | Value | Source |
|---|---|---|---|
| $Qty_{std}$ | Variable | Based on customer application | EDC Data Gathering |
| $Qty_{high}$ | Variable | Based on customer application | EDC Data Gathering |
| $Eff_{std}$ | Variable | Based on customer application | EDC Data Gathering |
| | Variable | Default values in Table 4-4~~Table 4-4~~ | 1 |
| $Eff_{high}$ | Variable | Based on customer application. Collect the efficiency at static pressure of 0.1 inches water | EDC Data Gathering, 2, 3 |
| | | Default values in Table 4-4~~Table 4-4~~ | 1, 2, 3 |
| $Eff_{installed}$ | Variable | Based on customer application. Collect the efficiency at 0.1 inches water | EDC Data Gathering, 2, 3 |
| | | Default values in Table 4-4~~Table 4-4~~. If fans were not replaced, use the default values for $Eff_{std}$. If fans were replaced, use the default values for $Eff_{high}$. | 1, 2, 3 |
| hours | Variable | Based on customer application | EDC Data Gathering |
| | | Default use values in Table 4-5 | 1, 4 |
| CFM | Variable | Based on customer application. This can vary for pre- and post-installation if the information is known for the pre-installation case. | EDC Data Gathering |
| | Variable | Default values in Table 4-4~~Table 4-4~~ | 1 |
| $hours_{tstat}$ | Variable | Default values in Table 4-6 | 4 |
| CF | Fixed | 0.000197 | 5 |

***Sources:***

~~10.~~1. KEMA Evaluation of Alliant Energy Agriculture Program, Appendix F, 2008. See Table H-5.

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~~1.~~2. Pennsylvania State University. Tunnel Ventilation for Tie Stall Dairy Barns. 2004. Downloaded from http://pubs.cas.psu.edu/freepubs/pdfs/g78.pdf. Static pressure reference point for dairy barns comes from page 3. The recommended static pressure is 0.125 to 0.1 inches water

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~~2.~~3. Iowa State University. Mechanical Ventilation Design Worksheet for Swine Housing. 1999. Downloaded from http://www.extension.iastate.edu/Publications/PM1780.pdf. Static pressure reference point for swine housing comes from page 2. The

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recommended static pressure is 0.125 to 0.1 inches water for winter fans and 0.05 to 0.08 inches water for summer fans. A static pressure of 0.1 inches water was assumed for dairy barns and swine houses as it is a midpoint for the recommended values.

~~3.~~4. Based on the methodology in KEMA's evaluation of the Alliant Energy Agriculture Program (reference 1). Updated the hours for dairies and thermostats using TMY3 temperature data for PA, as fan run time is dependent on ambient dry-bulb temperature. For a stall barn, it was assumed 33% of fans are on 8,760 hours per year, 67% of fans are on when the temperature is above 50 degrees Fahrenheit, and 100% of the fans are on when the temperature is above 70 degrees Fahrenheit. For a cross-ventilated or free-stall barn, it was assumed 10% of fans are on 8,760 hours per year, 40% of fans are on when the temperature is above 50 degrees Fahrenheit, and 100% of the fans are on when the temperature is above 70 degrees Fahrenheit. The hours for hog facilities are based on humidity. These hours were not updated as the methodology and temperatures for determining these hours was not described in KEMA's evaluation report and could not be found elsewhere. However, Pennsylvania and Iowa are in the same ASHRAE climate zone (5A) and so the Iowa hours provide a good estimate for hog facilities in Pennsylvania.

~~4.~~5. The coincident peak demand factor was calculated by dividing the average peak coincident demand kW reduction by ∆kWh savings for the fans. There are no peak demand savings for thermostats.

**Table 4-4~~4-4~~: Default values for standard and high efficiency ventilation fans for dairy and swine facilities**

| Fan Size (inches) | High Efficiency Fan (cfm/W at 0.1 inches water) | Standard Efficiency Fan (cfm/W at 0.1 inches water) | CFM |
|---|---|---|---|
| 14-23 | 12.4 | 9.2 | 3,600 |
| 24-35 | 15.3 | 11.2 | 6,274 |
| 36-47 | 19.2 | 15.0 | 10,837 |
| 48 - 61 | 22.7 | 17.8 | 22,626 |

**Table 4-5~~4-5~~. Default Hours for Ventilation Fans by Facility Type by Location (No Thermostat)**

| Facility Type | Allentown | Erie | Harrisburg | Philadelphia | Pittsburgh | Scranton | Williamsport |
|---|---|---|---|---|---|---|---|
| Dairy - Stall Barn | 5,071 | 4,807 | 5,163 | 5,390 | 5,010 | 4,843 | 5,020 |
| Dairy – Free-Stall or Cross-Ventilated Barn | 3,299 | 2,984 | 3,436 | 3,732 | 3,231 | 2,985 | 3,241 |
| Hog Nursery or Sow House | 5,864 | | | | | | |
| Hog Finishing House | 4,729 | | | | | | |

**Table 4-6~~4-6~~. Default Hours Reduced by Thermostats by Facility Type and Location**

| Facility Type | Allentown | Erie | Harrisburg | Philadelphia | Pittsburgh | Scranton | Williamsport |
|---|---|---|---|---|---|---|---|
| Dairy - Stall Barn | 3,457 | 3,458 | 3,367 | 3,285 | 3,441 | 3,594 | 3,448 |
| Dairy – Free-Stall or Cross-Ventilated Barn | 1,685 | 1,635 | 1,640 | 1,627 | 1,662 | 1,736 | 1,669 |
| Hog Nursery or Sow House | 2,629 | 2,985 | 2,323 | 2,179 | 2,732 | 2,885 | 2,666 |
| Hog Finishing House* | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

*Hog finishing houses base ventilation needs on humidity, therefore a thermostat will not reduce the number of hours the fans operate.

### 4.3.5 Measure Life

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The measure life for high efficiency ventilation fans is 10 years. The measure life for the thermostat is 11 years.[487]

### 4.3.6 Evaluation Protocols

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The most appropriate evaluation protocol for this measure is verification of installation coupled with assignment of stipulated energy savings. For building types which are not covered under this protocol, operating hours should also be verified.

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[487] New York Standard Approach for Estimating Energy Savings from Energy Efficiency Measures in Commercial and Industrial Programs, September 1, 2009, based on DEER.

## 4.4 Heat Reclaimers

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| **Measure Name** | **Heat Reclaimers** |
|---|---|
| **Target Sector** | Agriculture (includes Small Commercial, Residential) |
| **Measure Unit** | Per heat reclaimer |
| **Unit Energy Savings** | Varies |
| **Unit Peak Demand Reduction** | Varies |
| **Measure Life** | 15 years |

The following protocol for the calculation of energy and demand savings applies to the installation of heat recovery equipment on dairy parlor milk refrigeration systems. The heat reclaimers recover heat from the refrigeration system and use it to pre-heat water used for sanitation, sterilization and cow washing.

### 4.4.1 Eligibility

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This measure requires the installation of heat recovery equipment on dairy parlor milk refrigeration systems to heat hot water. This measure only applies to dairy parlors with electric water heating equipment.

The equipment installed must be one of the following pre-approved brands or equivalent: Century-Therm, Fre-Heater, Heat Bank, Sunset, Superheater and Therma- Stor.

### 4.4.2 Algorithms

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The energy and peak demand savings are dependent on the presence of a precooler in the refrigeration system, and are obtained through the following formulas:

*Annual Savings without a precooler*

$$\Delta \mathrm{kWh}_{\mathrm{no\ precool}}\ /\mathrm{yr} = \frac{\mathrm{ES}_{\mathrm{no\ precool}}}{\eta_{\mathrm{water\ heater}}} \times DAYS \times COWS \times HEF$$

$$\Delta \mathrm{kW}_{peak,\ no\ precool} = \Delta kWh_{\mathrm{no\ precool}} \times CF$$

*Annual Savings with a precooler*

$$\Delta \mathrm{kWh}_{\mathrm{precool}}\ /\mathrm{yr} = \frac{\mathrm{ES}_{\mathrm{precool}}}{\eta_{\mathrm{water\ heater}}} \times DAYS \times COWS \times HEF$$

$$\Delta \mathrm{kW}_{\mathrm{peak,\ precool}} = \Delta \mathrm{kWh}_{\mathrm{precool}} \times \mathrm{CF}$$

### 4.4.3 Definition of Terms

**Formatted:** Indent: Left: 0", Tab stops: 0.25", List tab + Not at 0.44"

$ES_{no\ precool}$ = *Energy savings for systems with no precooler in kWh/cow/day.*

$ES_{precool}$ = *Energy savings for systems with a precooler in kWh/cow/day.*

*DAYS* = *Milking days per year*

*$\eta_{water\ heater}$ = Electric water heater efficiency*

*COWS = Average number of cows milked per day*

*HEF = Heating element factor*

*CF = Demand Coincidence factor*

### 4.4.4 Description of Calculation Method

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**Table 4-7~~4-7~~: Variables for Heat Reclaimers**

| Component | Type | Value | Source |
|---|---|---|---|
| ES $_{no\ precool}$ | Fixed | 0.38 kWh/cow/day | 1,2 |
| ES $_{precool}$ | Fixed | 0.29 kWh/cow/day | 1,2 |
| DAYS | Variable | Based on customer application | EDC Data Gathering |
|  | Default | 365 days/year | 2 |
| COWS | Variable | Based on customer application | EDC Data Gathering |
| HEF | Variable | Heat reclaimers with no back-up heat = 1.0<br>Heat reclaimers with back-up heating elements = 0.50 | 3 |
| $\eta_{water\ heater}$ | Variable | Standard electric tank water heater = 0.908<br>High efficiency electric tank water heater = 0.93<br>Heat pump water heater = 2.0 | 4, 5 |
| CF | Fixed | 0.00014 | 6 |

***Sources:***

1. Based on a specific heat value of 0.93 Btu/lb deg F and density of 8.7 lb/gallon for whole milk. American Society of Heating Refrigeration and Air-conditioning Engineers Refrigeration Handbook, 2010, Ch.19.5.
2. Based on a delta T (~~between cow~~ temperature difference between the milk leaving the cow and ~~cooled milk~~the colledmilk in tank sorage) of 59°F for a system without a pre-cooler and 19°F for a system with a pre-cooler. It was also assumed that a cow produces 6~~.5~~ gallons of milk per day (based on two milkings per day), requires 2.2 gallons of hot water per day, and the water heater delta T (between ground water and hot water) is 70°F. Evaluation of Alliant Energy Agriculture Program, Appendix F, 2008.
3. Some smaller dairy farms may not have enough space for an additional water storage tank, and will opt to install a heat reclaimer with a back-up electric resistance element. The HEF used in the savings algorithm is a conservative savings de-ration factor to account for the presence of back-up electric resistance heat. The HEF is based on the assumption that the electric resistance element in a heat reclaimer will increase the

incoming ground water temperature by 40-50 °F before the water is heated by the heat reclaim coil.

4. Standard water heater based on minimum electric water heater efficiencies defined in Table 504.2 of the 2009 International Energy Efficiency Code (IEEC). High efficiency water heater based on water heater efficiencies defined in Table 3-90 of the TRM.
5. Based on minimum heat pump water efficiencies defined by ENERGY STAR, 2009. https://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=WHH
6. Because the water heater operates on the same operating schedule as the dairy vacuum pump equipment and refrigeration equipment, the load profile and coincidence factor described in the VSD Controller on Dairy Vacuum Pump TRM protocol can be applied to this measure.

### 4.4.5 Measure Life

The measure life for a heat reclaimer is ~~14~~15[488] years.

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[488] California Public Utility Commission. Database for Energy Efficiency Resources 2008.

## 4.5 High Volume Low Speed Fans

| **Measure Name** | **High Volume Low Speed Fans** |
|---|---|
| **Target Sector** | Agriculture, Large Commercial, Small Commercial, Residential |
| **Measure Unit** | Per fan |
| **Unit Energy Savings** | Varies |
| **Unit Peak Demand Reduction** | Varies |
| **Measure Life** | 15 years |

The following protocol for the calculation of energy and demand savings applies to the installation of High Volume Low Speed (HVLS) fans to replace conventional circulating fans. HVLS fans are a minimum of 16 feet long in diameter and move more cubic feet of air per watt than conventional circulating fans. Default values are provided for dairy, poultry, and swine applications. Other facility types are eligible, however, the operating hours assumptions should be reviewed and modified as appropriate.

### 4.5.1 Eligibility

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This measure requires the installation of HVLS fans in either new construction or retrofit applications where conventional circulating fans are replaced.

### 4.5.2 Algorithms

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The annual energy savings are obtained through the following formula:

$\Delta kWh/yr$ = $(W_{conventional} - W_{HVLS})/1000 \times hours$

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

$CF$ = $(W_{conventional} - W_{HVLS}) / 1000$ (or use default CF value in Table 4-8)

### 4.5.3 Definition of Terms

**Formatted:** Indent: Left: 0", Tab stops: 0.25", List tab + Not at 0.44"

$W_{conventional}$ = Watts of the conventional fans

$W_{HVLS}$ = Watts of the HVLS fan

*hours* = operating hours per year of the fans

*1000* = conversion of watts to kilowatts

*CF* = Demand coincidence factor

### 4.5.4 Description of Calculation Method

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**Table 4-8~~4-8~~: Variables for HVLS Fans**

| Component | Type | Value | Source |
|---|---|---|---|
| $W_{conventional}$ | Variable | Based on customer application | EDC Data Gathering |
| | Variable | Default values in ~~Table 4-4~~Table 4-9~~Table 4-9~~ | 1, 2 |
| $W_{HVLS}$ | Variable | Based on customer application | EDC Data Gathering |
| | | Default values in Table 4-4~~Table 4-4~~ | 2 |
| hours | Variable | Based on customer application | EDC Data Gathering |
| | | Default values in ~~Table 4-10~~Table 4-10~~Table 4-10~~ | 3 |
| CF | Variable | $(W_{conventional} – W_{HVLS}) / 1000$ | EDC Data Gathering, Engineering calculations |
| | Fixed | Default value is 0.000500 | 4 |

***Sources:***

1. Bioenvironmental and Structural Systems Laboratory database for circulating fans.
2. KEMA. 2009 Evaluation of IPL Energy Efficiency Programs, Appendix F Group I Programs Volume 2. See Table H-17.
3. Number of hours above 65 degrees Fahrenheit. Based on TMY3 data.
4. The coincident peak demand factor is calculated by dividing the peak coincident demand kW reduction by ΔkWh savings. The peak coincident demand kW reduction is calculated by $(W_{conventional} – W_{HVLS}) / 1000$.

**Table 4-9~~4-9~~: Default Values for Conventional and HVLS Fan Wattages**

| Fan Size (ft) | $W_{HVLS}$ | $W_{conventional}$ |
|---|---|---|
| ≥ 16 and < 18 | 761 | 4,497 |
| ≥ 18 and < 20 | 850 | 5,026 |
| ≥ 20 and < 24 | 940 | 5,555 |
| ≥ 24 | 1,119 | 6,613 |

**Table 4-10~~4-10~~. Default Hours by Location for Dairy/Poultry/Swine Applications**

| Location | Hours/year |
|---|---|
| Allentown | 2,446 |
| Erie | 2,107 |
| Harrisburg | 2,717 |
| Philadelphia | 2,914 |
| Pittsburgh | 2,292 |
| Scranton | 2,145 |
| Williamsport | 2,371 |

### 4.5.5 Measure Life

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The measure life for HVLS fans is 15 years.

## 4.6 Livestock Waterer

| **Measure Name** | **Livestock Waterer** |
|---|---|
| **Target Sector** | Agriculture (includes Small Commercial, Residential) |
| **Measure Unit** | Per project |
| **Unit Energy Savings** | Varies |
| **Unit Peak Demand Reduction** | 0 kW |
| **Measure Life** | 10 years |

The following protocol for the calculation of energy and demand savings applies to the installation of energy-efficient livestock waterers. In freezing climates no or low energy livestock waterers are used to prevent livestock water from freezing. These waterers are closed insulated watering containers which typically use super insulation, the relatively warmer ground water temperature, and the livestock's use of the waterer to keep water from freezing and thereby capable of watering the livestock.

### 4.6.1 Eligibility

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This measure requires the installation of an energy efficient livestock waterer that is thermostatically controlled and has a minimum of two inches of factory-installed insulation.

### 4.6.2 Algorithms

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The annual energy savings are obtained through the following formula:

$$\Delta kWh/yr = QTY \times OPRHS \times ESW \times HRT$$

No demand savings are expected for this measure, as the energy savings occur during the winter months.

### 4.6.3 Definition of Terms

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*QTY* = *Number of livestock waterers installed*

*OPRHS* = *Annual operating hours*

*ESW* = *Energy Demand Savings per waterer (deemed).*

*HRT* = *% heater run time*

### 4.6.4 Description of Calculation Method

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**Table 4-11~~4-11~~: Variables for Livestock Waterers**

| Component | Type | Value | Source |
|---|---|---|---|
| QTY | Variable | Based on customer application | EDC Data Gathering |
| OPRHS | Fixed | Allentown = 1,489<br>Erie = 1,768<br>Harrisburg = 1,302<br>Philadelphia = 1,090<br>Pittsburgh = 1,360<br>Scranton = 1,718<br>Williamsport = 1,574 | 1 |
| ESW | Fixed | 0.50 kW per livestock waterer | 2, 3, 4 |
| HRT | Fixed | 80% | 5 |

***Sources:***

1. Based on TMY3 data for various climate zones in Pennsylvania. The annual operating hours represent the annual hours when the outdoor air dry-bulb temperature is less than 32 deg F, and it is assumed that the livestock waterer electric resistance heaters are required below this temperature to prevent water freezing.
2. Field Study of Electrically Heated and Energy Free Automated Livestock Water Fountains - Prairie Agricultural Machinery Institute, Alberta and Manitoba, 1994.
3. Facts Automatic Livestock Waterers Fact Sheet, December 2008. http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex5421/$file/716c52.pdf
4. Connecticut Farm Energy Program: Energy Best Management Practices Guide, 2010. http://www.ctfarmenergy.org/Pdfs/CT_Energy_BMPGuide.pdf
5. The Regional Technical Forum (RTF) analyzed metered data from three baseline livestock waterers and found the average run time of electric resistance heaters in the waterers to be approximately 80% for average monthly temperatures similar to Pennsylvania climate zones. This run time factor accounts for warmer make-up water being introduced to the tank as livestock drinking occurs.

   Downloaded on May 30th, 2013: http://rtf.nwcouncil.org/measures/measure.asp?id=87

### 4.6.5 Measure Life

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The measure life for a livestock waterer is 10 years.[489]

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[489] California Public Utility Commission. Database for Energy Efficiency Resources 2005.

## 4.7 Variable Speed Drive (VSD) Controller on Dairy Vacuum Pumps

| **Measure Name** | **VSD Controller on Dairy Pumps Vacuum Pumps** |
|---|---|
| **Target Sector** | Agriculture (includes Small Commercial, Residential) |
| **Measure Unit** | Per dairy vacuum pump VSD |
| **Unit Energy Savings** | Varies |
| **Unit Peak Demand Reduction** | Varies |
| **Measure Life** | 15 |

The following protocol for the calculation of energy and demand savings applies to the installation of a variable speed drive (VSD) and controls on a dairy vacuum pump. The vacuum pump operates during the milk harvest and equipment washing ~~and can consume 20 percent to 25 percent of all electrical energy use~~ on a dairy farm. The vacuum pump creates negative air pressure that draws milk from the cow and assists in the milk flow from the milk receiver to either the bulk tank or the receiver bowl.

Dairy vacuum pumps are more efficient with VSDs since it enables the motor to speed up or slow down depending on the pressure demand. The energy savings for this measure is based on pump capacity and hours of use of the pump.

### 4.7.1 Eligibility

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This measure requires the installation of a VSD and controls on dairy vacuum pumps, or the purchase of dairy vacuum pumps with variable speed capability. Pre-existing pumps with VSD's are not eligible for this measure.

### 4.7.2 Algorithms

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The annual energy savings are obtained through the following formula:

$$\Delta kWh/yr = HP \times LF/\eta_{MOTOR} \times ESF \times DHRS \times ADAYS$$

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

**Coincidence Factor**

An average of pre and post kW vacuum pump power meter data from five dairy farms in the Pacific Northwest [490] are used to create the vacuum pump demand load profile in Figure 16~~Figure 2616~~. Because dairy vacuum pump operation does not vary based on geographical location, the average peak demand reduction obtained from these five sites can be applied to Pennsylvania. There are no seasonal variations in cow milking times, as dairy farms milk cows year round, so the load profile

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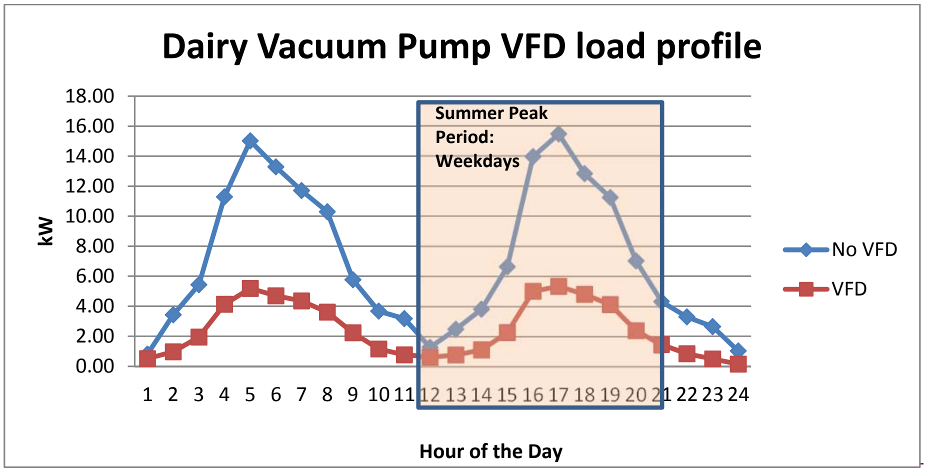
[490] Regional Technical Forum (RTF) as part of the Northwest Power & Conservation Council, Deemed Measures List. Agricultural: Variable Frequency Drives-Dairy, FY2012, V1.2. Accessed from RTF website http://rtf.nwcouncil.org/measures/Default.asp on February 27, 2013. Pre and post power meter data for five sites were used to establish RTF energy savings for this measure, and raw data used to generate the load profile referenced in this protocol can be found in the zip file on the "BPA Case Studies" tab.

below applies to 365 days of operation.  The average percent demand reduction for these five sites during the coincident peak demand period of June through September between noon and 8 pm is 46%, which is consistent with the energy savings factors and demand savings estimated for the sources cited in this protocol.

Based on this data, the demand coincidence factor is estimated by dividing the average peak coincident demand kW reduction by ∆kWh savings for a 1 horsepower motor.  The result is a coincidence factor equal to 0.00014.



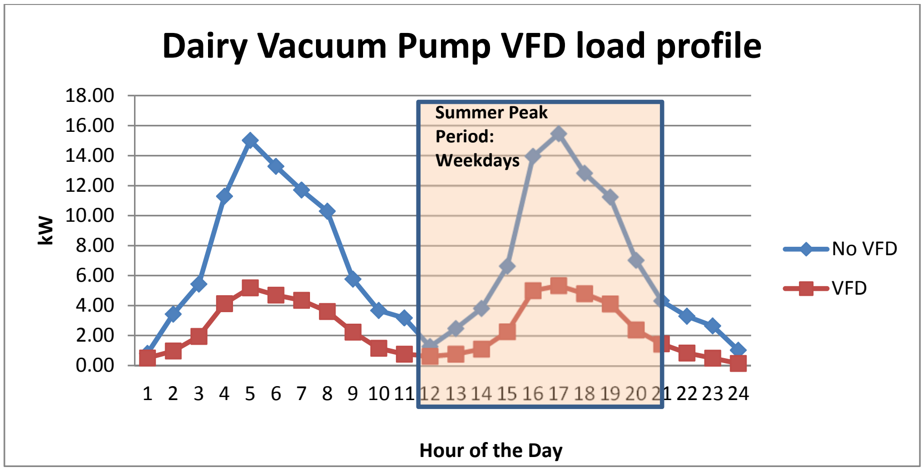


Figure 16~~26~~16: Typical Dairy Vacuum Pump Coincident Peak Demand Reduction

### 4.7.3 Definition of Terms

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*HP* = *Rated horsepower of the motor*

*LF* = *Load Factor. Ratio between the actual load and the rated load. The default value is 0.90.*

$\eta_{motor}$ = *Motor efficiency at the full-rated load. For VFD installations, this can be either an energy efficient motor or standard efficiency motor.*

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

*DHRS* = *Daily run hours of the motor*

*ADAYS* = *Annual operating days*

*CF* = *Demand Coincidence factor*

### 4.7.4 Description of Calculation Method

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**Table 4-124~~-12~~: Variables for VSD Controller on Dairy Vacuum Pump**

| Component | Type | Value | Source |
|---|---|---|---|
| Motor HP | Variable | Nameplate | EDC Data Gathering |
| LF | Variable | Based on spot metering and nameplate | EDC Data Gathering |
| | | Default 90%[491] | 1 |
| Efficiency - $\eta_{motor}$ | Variable | Nameplate | EDC Data Gathering |
| ESF | Fixed | 46% | 2, 3 |
| DHRS | Variable | Based on customer application | EDC Data Gathering |
| | | Default 8 hours/day | 2, 3 |
| ADAYS | Variable | Based on customer application | EDC Data Gathering |
| | | Default 365 days/year | 2, 3 |
| CF | Fixed | 0.00014 | 4 |

***Sources:***

1. Southern California Edison, Dairy Farm Energy Management Guide: California, p. 11, 2004.
2. California Public Utility Commission. *Database for Energy Efficiency Resources (DEER)* 2005. The DEER database assumes 20 hours of operation per day, but is based on much larger dairy farms (e.g. herd sizes > 300 cows). Therefore, the DEER default value was lowered to 8 hours per day, as the average heard size in 75 cows in Pennsylvania.

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[491] Default Value can be used by EDC but is subject to metering and adjustment by evaluators or SWE

3. Regional Technical Forum (RTF) as part of the Northwest Power & Conservation Council, Deemed Measures List. Agricultural: Variable Frequency Drives-Dairy, FY2012, V1.2. Accessed from RTF website http://rtf.nwcouncil.org/measures/Default.asp on February 27, 2013.
4. The coincident peak demand factor is calculated by dividing the average peak coincident demand kW reduction by ∆kWh savings for a 1 horsepower, 90% efficient motor. The motor efficiency was determined by averaging the efficiencies of NEMA premium efficiency motors for motor sizes between 1 and 50 horsepower.

### 4.7.5 Measure Life

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The measure life for VSD Controllers is 15 years. [492]

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[492] California Public Utility Commission. Database for Energy Efficiency Resources 2008.

## 4.8 Low Pressure Irrigation System

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| Measure Name | Low Pressure Irrigation System |
|---|---|
| **Target Sector** | Agriculture and Golf Courses(includes Small Commercial, Residential) |
| **Measure Unit** | Per project |
| **Unit Energy Savings** | Varies |
| **Unit Peak Demand Reduction** | Varies by application |
| **Measure Life** | 5 years |

The following protocol for the measurements of energy and demand savings applies to the installation of a low-pressure irrigation system, thus reducing the amount of energy required to apply the same amount of water.

The amount of energy saved per acre will depend on the actual operating pressure decrease, the pumping plant efficiency, the amount of water applied, and the number of nozzle, sprinkler or micro irrigation system conversions made to the system.

### 4.8.1 Eligibility

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This measure requires a minimum of 50% reduction in irrigation pumping pressure is achieved through the installation of a low-pressure irrigation system in agriculture or golf course applications. The pressure reduction can be achieved in several ways, such as nozzle or valve replacement, sprinkler head replacement, alterations ore retrofits to the pumping plant, or drip irrigation system installation, and is left up to the discretion of the owner. Pre and post retrofit pump pressure measurements are required.

### 4.8.2 Algorithms

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The annual energy savings are obtained through the following formula:

*Agriculture applications:*

$$\Delta kWh/yr = \cancel{\frac{\{ACRES \times (PSI_{base} - PSI_{eff}) \times GPM1)\}}{1{,}714 \frac{gpm\ psi}{HP} \times \eta_{MOTOR}}} \frac{\{ACRES \times (PSI_{base} - PSI_{eff}) \times GPM1)\}}{1{,}714 \frac{gpm\ psi}{HP} \times \eta_{MOTOR}} \times 0.746 \frac{kW}{HP} \times OPRHS \frac{Irrigation\ Hours}{Growing\ Season}$$

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

*Golf Course applications:*

$$\Delta kWh/yr = \cancel{\frac{\{(PSI_{base} - PSI_{eff}) \times GPM2)\}}{1{,}714 \frac{gpm\ psi}{HP} \times \eta_{MOTOR}}} \frac{\{(PSI_{base} - PSI_{eff}) \times GPM2)\}}{1{,}714 \frac{gpm\ psii}{HP} \times \eta_{MOTOR}} \times 0.746 \frac{kW}{HP}$$

$$\times DHRS \times MONTHS \times 30 \frac{Avg.\ days}{month}$$

No peak demand savings may be claimed for golf course applications as watering typically occurs during non-peak demand hours.

### 4.8.3 Definition of Terms

*ACRES* = *Number of acres irrigated*

$PSI_{base}$ = *Baseline pump pressure in pounds per square inch (psi). Baseline pump pressure must be measured and recorded prior to installing low-pressure irrigation equipment.*

$PSI_{eff}$ = *Installed pump pressure in psi. Installed pump pressure must be measured and recorded after the installation of low-pressure irrigation equipment by the installer.*

*GPM1* = *Pump flow rate in gallons per minute (gpm) per acre for agriculture applications.*

*GPM2* = *Pump flow rate in gallons per minute (gpm) for pumping system for golf courses.*

*1714* = *This is a constant used in calculating hydraulic horsepower for conversion between horsepower and pressure and flow.*

*OPHRS* = *Average irrigation hours per growing season for agriculture*

*DHRS* = *Hours of watering per day for golf courses*

*MONTHS* = *Number of months of irrigation for golf courses*

$\eta_{MOTOR}$ = *Pump motor efficiency (%)*

*CF* = *Demand coincidence factor for agriculture*

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### 4.8.4 Description of Calculation Method

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**Table 4-134~~-13~~: Variables for Low Pressure Irrigation Systems**

| Component | Type | Value | Source |
|---|---|---|---|
| ACRES | Variable | Based on customer application | EDC Data Gathering,1 |
| $PSI_{base}$ | Variable | Based on pre retrofit pressure measurements taken by the installer | EDC Data Gathering,1 |
| $PSI_{eff}$ | Variable | Based on post retrofit pressure measurements taken by the installer | EDC Data Gathering,1 |
| GPM1 | Variable | Based on pre retrofit flow measurements taken by the installer | EDC Data Gathering,1 |
| GPM2 | Variable | Based on pre retrofit flow measurements taken by the installer | EDC Data Gathering,1 |
| OPHRS | Variable | Based on customer application | EDC Data Gathering |
| DHRS | Variable | Based on customer application | EDC Data Gathering |
| MONTHS | Variable | Based on customer application | EDC Data Gathering |
| $\eta_{MOTOR}$ | Variable | Based on customer application | EDC Data Gathering |
| | Default | Look up pump motor efficiency based on the pump nameplate horsepower (hp) from customer application and nominal efficiencies defined in Table 3-14. | 2 |
| CF | Fixed | 0.0026 | 3, 4 |

***Sources:***

1. Based on Alliant Energy program evaluation assumptions for low-flow pressure irrigation systems. Evaluation of Alliant Energy Agriculture Program, Appendix F, 2008.
2. Table 3-14 contains motor efficiency values from NEMA EPACT efficiency motor standards by motor size and type. If existing motor nameplate data is not available, these tables will be used to establish motor efficiencies.
3. The coincidence factor was only estimated for agricultural applications, and was determined by using the following formula: CF = ∆kW savings per acre / ∆kWh/yr savings per acre. Pennsylvania census data was used to estimate an average ∆kW savings/acre and ∆kWh/yr savings/acre values.
4. Pennsylvania Census data: http://www.nass.usda.gov/Statistics_by_State/Pennsylvania/Publications/Annual_Statistical_Bulletin/2009_2010/fris.pdf

   http://pubs.usgs.gov/circ/2004/circ1268/htdocs/table07.html

### 4.8.5 Measure Life

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The measure life for low pressure irrigation systems is 5 years. [493]

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[493] California Public Utility Commission. Database for Energy Efficiency Resources 2008.

-The measure lifeabove is based upon retrofit of existing equipment. Complete system replacement may be determined based upon the system conditions.

# 5 APPENDICES

## 5.1 Appendix A: Measure Lives

**Measure Lives Used in Cost-Effectiveness Screening**
**August 2013**

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

| Measure | Measure Life |
|---|---|
| **RESIDENTIAL SECTOR** | |
| ***Lighting End-Use*** | |
| Electroluminescent Nightlight | 8 |
| LED Nightlight | 8 |
| Compact Fluorescent Light Bulb | 6.8 |
| Recessed Can Fluorescent Fixture | 20* |
| Torchieres | 10 |
| Fixtures Other | 20* |
| ENERGY STAR LEDs | 14.7 |
| Residential Occupancy Sensors | 10 |
| Holiday Lights | 10 |
| | |
| ***HVAC End-Use*** | |
| Central Air Conditioner (CAC) | 14 |
| Air Source Heat Pump | 12 |
| Central Air Conditioner proper sizing/install | 14 |
| Central Air Conditioner Quality Installation Verification | 14 |
| Central Air Conditioner Maintenance | 7 |
| Central Air Conditioner duct sealing | 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* |
| Room Air Conditioner Retirement | 4 |
| Furnace Whistle | 15 |
| Programmable Thermostat | 11 |
| Room AC (RAC) Retirement | 4 |
| Residential Whole House Fans | 15 |
| Ductless Mini-Split Heat Pumps | 15 |
| Fuel Switching: Electric Heat to Gas Heat | 20* |
| Efficient Ventilation Fans with Timer | 10 |
| New Construction (NC): Single Family - gas heat with CAC | 20* |
| NC: Single Family - oil heat with CAC | 20* |

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

| | |
|---|---|
| ENERGY STAR Copier | 6 |
| | |
| ***Building Shell End-Use*** | |
| Ceiling / Attic and Wall Insulation | 25* |
| 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* |
| | |
| ***Agricultural End-Use*** | |
| Automatic Milker Takeoffs | 10 |
| Dairy Scroll Compressors | 15 |
| High Efficiency Ventilation Fans with or without Thermostats | 10 |
| Heat Reclaimers | 15 |
| High Volume Low Speed Fans | 15 |
| Livestock Waterer | 10 |
| Variable Speed Drive (VSD) Controller on Dairy Vacuum Pumps | 15 |
| Low Pressure Irrigation System | 5 |
| | |
| ***Miscellaneous*** | |
| Home Audit Conservation Kits | 8.1 |
| Home Performance with ENERGY STAR | 5 |
| Pool Pump Load Shifting | 1 |
| High Efficiency Two-Speed Pool Pump | 10 |
| Variable Speed Pool Pumps (with Load Shifting Option) | 10 |
| | |
| **COMMERCIAL & INDUSTRIAL SECTOR** | |
| ***Lighting End-Use*** | |
| Lighting (Non-SSL) — New/Remodel/Replacement | 15 |
| Lighting (SSL – 25,000 hours) — New/Remodel/Replacement | 6 |
| Lighting (SSL – 30,000 hours) — New/Remodel/Replacement | 7 |
| Lighting (SSL – 35,000 hours) — New/Remodel/Replacement | 8 |
| Lighting (SSL – 40,000 hours) — New/Remodel/Replacement | 10 |
| Lighting (SSL – 45,000 hours) — New/Remodel/Replacement | 11 |
| Lighting (SSL – 50,000 hours) — New/Remodel/Replacement | 12 |
| Lighting (SSL – 55,000 hours) — New/Remodel/Replacement | 13 |
| Lighting (SSL – 60,000 hours) — New/Remodel/Replacement | 14 |
| Lighting (SSL – ≥60,000 hours) — New/Remodel/Replacement | 15* |
| LED Channel Signage | 15 |
| | |
| ***Motors & VFDs End-Use*** | |

| | |
|---|---|
| Premium Efficiency Motors — New or Replacement | 20* |
| Variable Frequency Drive (VFD) Improvements — New / Retrofit | 15 |
| Variable Frequency Drive (VFD) Improvement for Industrial Air Compressors | 20* |
| | |
| ***HVAC  End-Use*** | |
| HVAC Systems — New or Replacement | 15 |
| Electric Chillers — New or Replacement | 20* |
| Water Source and Geothermal Heat Pumps | 15 |
| Ductless Mini-Split Heat Pumps - Commercial < 5.4 tons | 15 |
| Commercial Chiller Optimization | 18* |
| Fuel Switching: Electric Heat to Gas Heat | 20* |
| Small C/I HVAC Refrigerant Charge Correction | 10 |
| | |
| ***Hot Water End-Use*** | |
| Electric Resistance Water Heaters | 15 |
| Heat Pump Water Heaters | 10 |
| Low Flow Pre-Rinse Sprayers for Retrofit Programs | 5 |
| Low Flow Pre-Rinse Sprayers for Time of Sale / Retail Programs | 5 |
| Fuel Switching: Domestic Hot Water Electric to Gas or Propane Water Heater | 13 |
| Fuel Switching: Domestic Hot Water Electric to Oil Water Heater | 8 |
| Fuel Switching: Heat Pump Water Heater to Gas or Propane Water Heater | 13 |
| Fuel Switching: Heat Pump Water Heater to Oil Water Heater | 8 |
| | |
| ***Refrigeration End-Use*** | |
| Anti-Sweat Heater Controls | 12 |
| High-Efficiency Refrigeration/Freezer Cases | 12 |
| High-Efficiency Evaporator Fan Motors for Reach-In Refrigerated Cases | 15 |
| High-Efficiency Evaporator Fan Motors for Walk-In Refrigerated Cases | 15 |
| Strip Curtains for Walk-In Freezers and Coolers | 4 |
| Refrigeration - Night Covers for Display Cases | 5 |
| Refrigeration - Auto Closers | 8 |
| Refrigeration - Door Gaskets for Walk-in Coolers and Freezers | 4 |
| Refrigeration - Suction Pipes Insulation | 11 |
| Refrigeration - Evaporator Fan Controllers | 10 |
| Refrigeration - Special Doors with Low or No Anti-Sweat Heat for Low Temp Case | 15 |
| Refrigeration - Floating Head Pressure Controls | 15 |
| Refrigeration - VFD Compressor | 10 |
| | |

| | |
|---|---|
| ***Office Equipment / Electronics End-Use*** | |
| ENERGY STAR Computer | 4 |
| ENERGY STAR Monitor | 4 |
| ENERGY STAR Fax | 4 |
| ENERGY STAR Multifunction Device | 6 |
| ENERGY STAR Printer | 5 |
| ENERGY STAR Copier | 6 |
| Office Equipment - Network Power Management Enabling | 5 |
| Smart Strip Plug Outlets | 5 |
| | |
| ***Food Service Equipment End-Use*** | |
| Beverage Machine Controls | 5 |
| High-Efficiency Ice Machines | 10 |
| ENERGY STAR Electric Steam Cooker | 12 |
| | |
| ***Appliances End-Use*** | |
| ENERGY STAR Clothes Washer Multifamily | 11.3 |
| ENERGY STAR Clothes Washer Laundromats | 7.1 |
| | |
| ***Building Shell End-Use*** | |
| Wall and Ceiling Insulation | 15 |
| | |
| ***Agricultural End-Use*** | |
| Automatic Milker Takeoffs | 10 |
| Dairy Scroll Compressors | 15 |
| High Efficiency Ventilation Fans with or without Thermostats | 10 |
| Heat Reclaimers | 15 |
| High Volume Low Speed Fans | 15 |
| Livestock Waterer | 10 |
| Variable Speed Drive (VSD) Controller on Dairy Vacuum Pumps | 15 |
| Low Pressure Irrigation System | 5 |
| | |
| ***Miscellaneous*** | |
| Commercial Custom — New/Replacement | 18* |
| Commercial Comprehensive New Construction Design | 18* |
| Industrial Custom — Non-Process | 18* |
| Industrial Custom — Process | 10 |

## 5.2 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 two 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

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.

Custom measures are outside the scope of the TRM. The EDCs are not required to submit savings protocols for custom measures to the Commission or the SWE for each measure/technology type prior to implementing the custom measure. The Commission recommends that these protocols be established in general conformity to the IPMVP or Federal Energy Management Program M&V Guidelines. The SWE reserves the right to audit and review claimed and verified impacts of all custom measures as part of its role to perform EM&V services for the Commission.

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.

## 5.3 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/filing_resources/issues_laws_regulations/act_129_information/technical_reference_manual.aspx.

## 5.4 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/filing_resources/issues_laws_regulations/act_129_information/technical_reference_manual.aspx.

## 5.5 Appendix E: Lighting Audit and Design Tool for C&I New Construction Projects

The Lighting Audit and Design Tool is located on the Public Utility Commission's website at: http://www.puc.state.pa.us/filing_resources/issues_laws_regulations/act_129_information/technical_reference_manual.aspx.

## 5.6 Appendix F: 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.

### 5.6.1 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[494], the product shall meet the minimum ENERGY STAR requirements[495] [496] for the given product category. Products are not required to be on the ENERGY STAR Qualified Product List[497], 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

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

[495] "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

[496] "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

[497] 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[498], the product shall meet the minimum DLC requirements[499] for the given product category. Products are not required to be on the DLC Qualified Product List[500], 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)

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[498] 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

[499] Ibid.

[500] 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.

## 5.7 Appendix G: Zip Code Mapping

Per Section 1.17, 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 |
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| 15006 | Pittsburgh |
| 15007 | Pittsburgh |
| 15009 | 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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| 15780 | Pittsburgh |
| 15781 | Pittsburgh |
| 15783 | Pittsburgh |
| 15784 | Pittsburgh |
| 15801 | Pittsburgh |
| 15821 | Williamsport |
| 15822 | Williamsport |

| Zip | Reference City |
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| 15824 | Pittsburgh |
| 15825 | Pittsburgh |
| 15827 | Williamsport |
| 15828 | Erie |
| 15829 | Pittsburgh |
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| 15832 | Williamsport |
| 15834 | Williamsport |
| 15840 | Pittsburgh |
| 15841 | Williamsport |
| 15845 | Erie |
| 15846 | Williamsport |
| 15847 | Pittsburgh |
| 15848 | Pittsburgh |
| 15849 | Williamsport |
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| 15856 | Pittsburgh |
| 15857 | Williamsport |
| 15860 | Erie |
| 15861 | Williamsport |
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| 15865 | Pittsburgh |
| 15866 | Pittsburgh |
| 15868 | Williamsport |
| 15870 | Erie |
| 15901 | Pittsburgh |
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| 15904 | Pittsburgh |
| 15905 | Pittsburgh |
| 15906 | Pittsburgh |
| 15907 | Pittsburgh |
| 15909 | Pittsburgh |
| 15915 | Pittsburgh |
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| 15921 | Pittsburgh |
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| Zip | Reference City |
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| Zip | Reference City |
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| 18902 | Philadelphia |
| 18910 | Philadelphia |

| Zip | Reference City |
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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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| 19395 | Philadelphia |
| 19397 | Philadelphia |
| 19398 | Philadelphia |
| 19399 | Philadelphia |
| 19401 | Philadelphia |

| Zip | Reference City |
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| 19409 | Philadelphia |
| 19415 | Philadelphia |
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| 19450 | Philadelphia |
| 19451 | Philadelphia |
| 19453 | Philadelphia |
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| 19460 | Philadelphia |
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| 19480 | Philadelphia |
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| 19485 | Philadelphia |
| 19486 | Philadelphia |
| 19487 | Philadelphia |
| 19488 | Philadelphia |
| 19489 | Philadelphia |
| 19490 | Philadelphia |
| 19492 | Philadelphia |
| 19493 | Philadelphia |
| 19494 | Philadelphia |
| 19495 | Philadelphia |
| 19496 | Philadelphia |
| 19501 | Allentown |
| 19503 | Allentown |
| 19504 | Allentown |
| 19505 | Allentown |
| 19506 | Allentown |
| 19507 | Harrisburg |
| 19508 | Allentown |
| 19510 | Allentown |
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| 19512 | Allentown |
| 19516 | Allentown |
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| 19601 | Allentown |
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