TECHNICAL REFERENCE MANUAL

State of Pennsylvania

Act 129 Energy Efficiency and Conservation Program

&

Act 213 Alternative Energy Portfolio Standards

June 2015

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1 INTRODUCTION

The Technical Reference Manual (TRM) was developed to measure the resource savings from standard energy efficiency measures. The savings' algorithms use measured and customer data as input values in industry-accepted algorithms. The data and input values for the algorithms come from Alternative Energy Portfolio Standards (AEPS) application forms[1], EDC program application forms, industry accepted standard values (e.g. ENERGY STAR standards), or data gathered by Electric Distribution Companies (EDCs). The standard input values are based on the best available measured or industry data.

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

1.1 PURPOSE

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

Resource savings to be measured include electric energy (kWh) and electric capacity (kW) savings. The algorithms in this document focus on the determination of the per unit 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.

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

1.2.1 Measure Categories

The TRM categorizes all 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 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: 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

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 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

[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.

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

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 organizes all measures[8] into various end-use categories[9] (e.g. lighting, HVAC, motors & VFDs). kWh savings thresholds are established at the end-use category level and should be used to determine whether customer-specific information is 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 threshold.[11] Table 1-1 lists all the end-use categories and the sections for measures within a particular end-use category.

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

End-Use Categories	List of Measures (Sections)
Residential Market Sector	
Lighting - 2.1	2.1.1 – 2.1.5
HVAC - 2.2	2.2.1 – 2.2.9
Domestic Hot Water - 2.3	2.3.1 – 2.3.11
Appliances – 2.4	2.4.1 – 2.4.10
Consumer Electronics – 2.5	2.5.1 – 2.5.3
Building Shell – 2.6	2.6.1 – 2.6.6
Miscellaneous – 2.7	2.7.1 – 2.7.2
Commercial & Industrial Market Sector	
Lighting – 3.1	3.1.1 – 3.1.7
HVAC – 3.2	3.2.1 – 3.2.9

[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 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 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.

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

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

End-Use Categories	List of Measures (Sections)
Motors & VFDs – 3.3	3.3.1 – 3.3.4
Domestic Hot Water – 3.4	3.4.1 – 3.4.7
Refrigeration – 3.5	3.5.1 – 3.5.14
Appliances – 3.6	3.6.1
Food Service Equipment – 3.7	3.7.1 – 3.7.5
Building Shell – 3.8	3.8.1
Consumer Electronics – 3.9	3.9.1 – 3.9.3
Compressed Air – 3.10	3.10.1 – 3.10.3
Miscellaneous – 3.11	3.11.1
Agricultural Sector	
Agricultural Equipment	4.1 – 4.8

Table 1-2 shows the kWh thresholds[13] 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[14] are acceptable substitutes. The EDCs are encouraged to meter projects with savings below the thresholds that have high uncertainty but are not required 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.[15] 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: kWh Savings Thresholds

End-Use Category	Expected kWh/yr Savings Threshold[16]
C&I Lighting	>= 500,000
C&I HVAC	>= 250,000
C&I Motors & VFDs	>= 250,000
C&I Building Shell	>= 250,000
Agricultural Equipment	>= 250,000

[13] 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 thresholds 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.

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

[15] 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.

[16] 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.

1.2.4 Applicability of the TRM for Estimating *Ex Ante* (Claimed) Savings

For replacements, retrofits, and new construction appliances,[17] 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.
- **Coincidence Factor (CF)** – The ratio of the (1) sum of every unit's average kW load during the PJM peak load period (June through August, non-holiday weekdays, 2 pm to 6 pm) to the (2) sum of the non-coincident maximum kW connected load for every unit. This value is expressed in decimal format throughout the TRM unless designated otherwise.
- **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.

[17] Appliances include: dishwashers, clothes washers, dryers, ovens/ranges, refrigerators, and freezers.
[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.

- **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 method or Site Specific M&V Protocols (SSMVP). The savings calculations/estimates follow algorithms prescribed by the TRM or Site Specific M&V Protocols (SSMVP) and are based non-verified, estimated, stipulated, EDC gathered or measured values of key variables.
- **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 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 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 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, an addition to an existing facility, 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.
- **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 method or Site Specific M&V Protocols (SSMVP). The savings calculations/estimates follow algorithms prescribed by the TRM or 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:

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

1.5 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.

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

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

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

Where:

ΔkW = *Demand Savings*

ΔkW_{peak} = *Coincident Peak Demand Savings*

$\Delta kWh/yr$ = *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 Factors represent the fraction of connected load expected to be coincident with the PJM peak demand period as defined in Section 1.10.

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 (replace on burnout) or new installations (new construction)
- One for discretionary installations – often called early replacement

For all new construction (NC) and 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.

All baselines are designed to reflect current market practices that are updated periodically to reflect upgrades in code or information from evaluation results. Specifically for commercial and industrial measures, 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 Standard 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.

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. In general, this TRM addresses the ever-changing regulatory codes and recognized program standards of the energy efficiency market with the following guidance for applicable measures:

When an existing Federal standard expires in a given **calendar year**, then that change will be reflected in the **following program year**'s TRM.[19] This applies only to measures where the Federal standard is considered the baseline as described in the TRM or otherwise required by law. In the case of a January 1st effective date for a new Federal standard, the previous standard will be said to have expired on December 31 of the previous calendar year, and thus the change will be reflected in the TRM to take effect in June of that year. Likewise, it is proposed that when an existing ENERGY STAR Product Specification Version expires in a given **calendar year**, then

[19] For new Federal standards that become effective on January 1st, the previous standards are considered to expire on December 31 of the prior calendar year.

that change will be reflected in the **following program year**'s TRM.[20] This applies only to measures where the ENERGY STAR criterion is considered the eligibility requirement.

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: 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., 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

[20] For new ENERGY STAR product specifications that become effective on January 1st, the previous specifications are considered to expire on December 31 of the prior calendar year.

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[21] (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.[22]

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:

[21] This is same as the Daylight Savings Time (DST)
[22] PJM Manual 18B for Energy Efficiency Measurement & Verification

> "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 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

Throughout the TRM, the interactive effect of thermostatically sensitive building components is accounted for in specific measure protocols as appropriate. In instances where there is a measurable amount of interaction between two energy consuming sources, the energy or peak demand savings are accounted for in either the algorithms or in the modeling software used to determine energy savings.

For example, in a residential protocol where the lighting load has a direct effect on the energy used to condition the space, the TRM provides an interactive effect value to be used in the savings algorithm for certain measures. Other measures rely on the characteristics of the modeling software that account for the effect within a building, such as a new construction protocol software that will apply the effects for a measureable difference in the baseline and efficient buildings.

Likewise in Commercial and Industrial applications, the TRM accounts for the internal gains affected by implementing certain measures, also by using deemed values within the measure algorithms or by site-specific analysis where warranted, such as in the case of custom C&I measures. For example, the use of electronically commutated motors and the reduced heat output that affects the space cooling energy shall be specified by the measure protocol and where no interaction is present then the energy savings is zero.

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[23] 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 Commission 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 at the beginning of each measure protocol, as well as in Appendix A: Measure Lives, 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.

[23] 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.

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 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, however, the Commission recommends that site-specific custom measure protocols be established in general conformity to the International Performance Measurement and Verification Protocol (IPMVP)[24] or Federal Energy Management Program[25] 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[26]. 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.

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[27]. 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. 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 3.5.11) and Refrigeration – Suction Pipes Insulation (Section 3.5.14). While there are sixteen California climate zones and seven Pennsylvania cities, all protocols relying on California work paper data will use a single climate zone. Very low risk is associated with this

[24] http://www.evo-world.org/index.php?option=com_content&task=view&id=272&Itemid=279
[25] www1.eere.energy.gov/femp/pdfs/mv_guidelines.pdf
[26] 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.
[27] http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/ASHP_Sav_Calc.xls

assumption due to the small contribution of savings from these measures to the overall portfolios (<0.1%) and the inherent differences in climate when comparing California weather to Pennsylvania weather. Based on comparable average dry bulb, wet bulb, and relative humidity as well as comparable cooling degree hours, the TRM uses California climate zone 4 to best estimate the savings of refrigeration measures.

Furthermore, all the Pennsylvania zip codes are mapped to a reference city as shown in 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 or Agriculture sectors 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 or agricultural environment but is metered under a residential meter, the commercial or agricultural sector protocol is used. This is particularly relevant for residential appliances that frequently appear in small commercial spaces (commercial protocol) and residential appliances that are used in residential settings but are under commercial meters (multi-family residences). 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 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. Depending on the scale, an agricultural facility could be metered under a range of meters, but the agricultural measure protocol will supersede the meter type in the same fashion as listed for the other sectors.

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 residential, 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 LIGHTING

2.1.1 ENERGY STAR LIGHTING

Measure Name	ENERGY STAR Lighting
Target Sector	Residential Establishments
Measure Unit	Light Bulb or Fixture
Unit Energy Savings	Varies
Unit Peak Demand Reduction	Varies
Measure Life	CFL: 5.2 years[28,29] LED: 15 years[30]
Vintage	Replace on Burnout

Savings for residential energy efficient lighting products are based on a straightforward algorithm that calculates the difference between 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 3.1 Lighting for non-residential bulb savings estimates.

ELIGIBILITY

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

[28] 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.

[29] EISA 2007 legislation mandates that general service bulbs must meet a minimum of efficacy standard of 45 lumens per watt starting in 2020 (approximately equivalent to a CFL). At this point, the baseline is expected to shift to a CFL bulb and no additional savings should be claimed. Due to expected delay in clearing stock from retail outlets, this shift is assumed not to occur until 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.

[30] 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. The average measure life may be higher than this minimum, so the lifetime was rounded to 15 years.

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

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

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

For upstream buy-down, retail (time of sale), or efficiency kit programs, baseline wattages can be determined using the tables included in this protocol below. For direct install programs where wattage of the existing bulb is known, and the existing bulb was in working condition, wattage of the existing lamp removed by the program may be used in lieu of the tables below.

ALGORITHMS

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

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

ENERGY STAR CFL Bulbs (screw-in):

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

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

ENERGY STAR LED Bulbs (screw-in):

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

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

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

ENERGY STAR Torchieres:

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

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

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

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

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

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

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

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

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

$$\Delta kWh/yr = \frac{Watts_{base} - Watts_{OF}}{1000\ \frac{W}{kW}} \times HOU_{OF} \times 365\frac{days}{yr} \times ISR_{OF}$$

$$\Delta kW_{peak} = \frac{Watts_{base} - Watts_{OF}}{1000\ \frac{W}{kW}} \times CF \times ISR_{OF}$$

Ceiling Fan with ENERGY STAR Light Fixture:

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

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

DEFINITION OF TERMS

Table 2-1: ENERGY STAR Lighting - References

Component	Unit	Value	Sources
$Watts_{base}$, Wattage of baseline case lamp/fixture	*Watts*	EDC Data Gathering[32] or Table 2-2, Table 2-3 & Table 2-4	7
$Watts_{CFL}$, Wattage of CFL	*Watts*	EDC Data Gathering	Data Gathering
$HOU_{effbulb}$, Average hours of use per day per CFL	$\frac{hours}{day}$	2.8	5
IE_{kWh} , HVAC Interactive Effect for CFL or LED energy	*None*	EDC Data Gathering Default=Table 2-5	6
IE_{kW} , HVAC Interactive Effect for CFL or LED demand	*None*	EDC Data Gathering Default= Table 2-5	6
$ISR_{effbulbB}$, In-service rate per CFL or LED	*%*	97%[33]	2
$Watts_{LED}$, Wattage of LED	*Watts*	EDC Data Gathering	Data Gathering
$Watts_{Torch}$, Wattage of ENERGY STAR torchiere	*Watts*	EDC Data Gathering	Data Gathering
HOU_{Torch} , Average hours of use per day per torchiere	$\frac{hours}{day}$	3.0	1
ISR_{Torch} , In-service rate per Torchiere	*%*	83%	2
$Watts_{IF}$, Wattage of ENERGY STAR Indoor Fixture	*Watts*	EDC Data Gathering	Data Gathering
HOU_{IF} , Average hours of use per day per Indoor Fixture	*None*	2.6	1
ISR_{IF} , In-service rate per Indoor Fixture	*%*	95%	2
$Watts_{OF}$, Wattage of ENERGY STAR Outdoor Fixture	*Watts*	EDC Data Gathering	Data Gathering
HOU_{OF} , Average hours of use per day per Outdoor Fixture	$\frac{hours}{day}$	4.5	1
ISR_{OF} , In-service rate per Outdoor Fixture	*%*	87%	2
CF , Demand Coincidence Factor	*Decimal*	0.091	3
$Watts_{fan}$, Wattage of ENERGY STAR Ceiling Fan light fixture	*Watts*	EDC Data Gathering	Data Gathering
HOU_{fan} , Average hours of use per day per Ceiling Fan light fixture	$\frac{hours}{day}$	3.5	4

[32] EDCs may use the wattage of the replaced bulb for directly installed program bulbs

[33] For direct install, giveaway, and energy kit program bulbs, EDCs have the option to use an evaluated ISR when verified through PA program primary research.

Component	Unit	Value	Sources
ISR_{fan} , In-service rate per Ceiling Fan fixture	%	95%	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. See EISA legislation for the full list of exemptions.

For direct installation programs where the removed bulb is known, and the bulb is in working condition, EDCs may use the wattage of the replaced bulb in lieu of the tables below.[34] For bulbs with lumens outside of the lumen bins provided, EDCs should use the manufacturer rated comparable wattage as the $Watts_{Base}$. For EISA exempt bulbs, EDCs also have the option of using manufacturer rated comparable wattage as the $Watts_{Base}$, rather than the tables below.

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

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

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

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

[34] Bulbs that are not installed during the home visit do not qualify for this exemption. This includes bulbs that are left for homeowners to install. In these instances, baseline wattages should be estimated using Table 2-2,
Table 2-3, & Table 2-4.

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

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

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

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

Minimum Lumens (a)	Maximum Lumens (b)	Incandescent Equivalent $Watts_{Base}$ (Exempt Bulbs) (c)	$Watts_{Base}$ (Post-EISA 2007) (d)	$Watts_{base}$ post 2020[38] (e)
450	799	40	29	9
310	449	25	25	25

Baseline values in Table 2-2 column (e), $Watts_{base}$ 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, $Watts_{base}$ 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.

For bulbs that do not fall within EISA regulations, such as exempt bulbs and bulbs with lumens greater than 2,600, the manufacturer rated equivalent wattage should be used as the baseline. The manufacturer rated wattage can vary by bulb type, but is usually clearly labeled on the bulb package. Note 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 Energy Independence and Securities Act.

Baseline Wattage Values – Specialty Bulbs

ENERGY STAR provides separate equivalent incandescent wattages for specialty and decorative bulb shapes. These shapes include candle, globe, bullet, and shapes other than A-lamp bulbs.[39] For these bulbs, use the $Watts_{Base}$ from Table 2-3.

For EISA exempt specialty bulbs, use the $Watts_{base}$ value in column (c) in

Table 2-3. 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.

To determine the $Watts_{Base}$ for specialty/decorative lamps , follow these steps:

1. Identify the rated lumen output of the energy efficient lighting product

Identify if the bulb is EISA exempt

Table 2-3, find the lamp shape of the bulb (see columns (a) or (b)).

2. Table 2-3, find the lumen range into which the lamp falls (see columns (a) or (b)).
5. Find the baseline wattage ($Watts_{Base}$) in column (c) or column (d). If the bulb is exempt from EISA legislation, use column (c), else, use column (d).

39 ANSI Shapes for decorative bulbs: B, BA, C, CA, DC, and F. Globe shapes are labeled as ANSI shape G.

Table 2-3: Baseline Wattage by Lumen Output for Specialty Lamps[40]

Lumen Bins (decorative) (a)	Lumen Bins (globe) (b)	Incandescent Equivalent WattsBase (Exempt Bulbs) (c)	WattsBase (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 2-4 below.

Table 2-4. Default Baseline Wattage for Reflector Bulbs[41]

Bulb Type (a)	Incandescent Equivalent (Pre-EISA) (b)	WattsBase (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

[40] 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.

[41] 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.

Bulb Type (a)	Incandescent Equivalent (Pre-EISA) (b)	$Watts_{Base}$ (Post-EISA) (c)
R40	75	65
PAR38	90	70
PAR38	120	70
R20	≤ 45	EXEMPT
BR30	≤ 50	EXEMPT
BR40	≤ 50	EXEMPT
ER30	≤ 50	EXEMPT
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. These IE values should be used for both CFL and LED technologies.[42]

Table 2-5: CFL and LED Energy and Demand HVAC Interactive Effects by EDC[43]

EDC	IE_{kWh}	IE_{kW}
Duquesne	8%	13%
FE (Met-Ed)	-8%	13%
FE (Penelec)	1%	10%
FE (Penn Power)	0%	20%
FE (WPP)	-2%	30%
PPL	-6%	12%
PECO	1%	23%

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with

[42] Any differences in IE caused by technological differences are likely minimal and within the error bounds of CFL estimates. Difference caused by the reduced LED wattage are already accounted for in the delta watts input and multiplied by this IE value.

[43] 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. PECO values are based on an analysis of PY4 as performed by Navigant.

verification of open variables. The Pennsylvania Phase II Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

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[44]. 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%. Discount rate used was a weighted average nominal discount rate for all EDCs, 7.5%. The TRM algorithm does not adjust for lighting products sold to to customers outside the service territory (“leakage”), instead assuming that most leakage in Pennsylvania would occur back and forth between EDC service territories, and that leakage in and leakage out are offsetting.[45]
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”:

   a. Nexus Market Research, “Impact Evaluation of the Massachusetts, Rhode Island and Vermont 2003 Residential Lighting Programs”, Final Report, October 1, 2004. Table 9-7.
   b. CFL Metering Study, Final Report. Prepared for PG&E, SDG&E, and SCE by KEMA, Inc. February 25, 2005. Table 4-1.
   c. Nexus Market Research, ""Process and Impact Evaluation of the Efficiency Maine Lighting Program"", April 2007. Table 1-7."
   d. Nexus Market Research, "Residential Lighting Markdown Impact Evaluation", Final Report, January 20, 2009. Table 6-1.

[44] Evaluation Research Report: PECO Smart Lighting Discounts Program, Navigant Consulting, September 20, 2012

[45] Consistent with the Evaluation Framework for Pennsylvania At 129 Phase II Energy Efficiency and Conservation Programs, June 1, 2014, pp. C-6.

e. KEMA, Inc., "Final Evaluation Report: Upstream Lighting Program." Prepared from the California Public Utilities Commission, Febuary 8, 2010. Table 18.

f. 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.

g. TecMarket Works, "Duke Energy Residential Smart Saver CFL Program in North Carolina and South Carolina", February 2011. Table 29.

h. Glacier Consulting Group, LLC. "Adjustments to CFL Operating Hours-Residential." Memo to Oscar Bloch, Wisconsin DOA. June 27, 2005.

i. New Jersey's Clean Energy Program Residential CFL Impact Evaluation and Protocol Review. KEMA, Inc. September 28, 2008. pg. 21.

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.

2.1.2 Residential Occupancy Sensors

Measure Name	ENERGY STAR Occupancy Sensors
Target Sector	Residential Establishments
Measure Unit	Occupancy Sensor
Unit Energy Savings	Varies
Unit Peak Demand Reduction	Varies
Measure Life	10 years[46]
Vintage	Retrofit

Eligibility

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

Algorithms

$$\Delta kWh/yr = \frac{Watts_{controlled}}{1000\frac{W}{kW}} \times (RH_{old} - RH_{new}) \times 365\frac{days}{yr}$$

$$\Delta kW_{peak} = 0$$

Definition of Terms

Table 2-6: Residential Occupancy Sensors Calculations Assumptions

Component	Unit	Value	Source
$Watts_{controlled}$, Wattage of the fixture being controlled by the occupancy sensor	*kW*	EDC's Data Gathering	AEPS Application; EDC's Data Gathering
RH_{old} , Daily run[47] hours before installation	*Hours*	2.8	1
RH_{new} , Daily run hours after installation	*Hours*	2.0 (70% of RHold)	2

Evaluation Protocols

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

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

SOURCES

1. Nexus Market Research, "Residential Lighting Markdown Impact Evaluation", Final Report, January 20, 2009. Table 6-1. Reference Table 2-1: 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

2.1.3 Electroluminescent Nightlight

Measure Name	Electroluminescent Nightlight
Target Sector	Residential Establishments
Measure Unit	Nightlight
Unit Energy Savings	29.49 kWh
Unit Peak Demand Reduction	0 kW
Measure Life	8 years[48]
Vintage	Replace on Burnout

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.

Eligibility

This measure documents the energy savings resulting from the installation of an electroluminescent night light instead of a standard night light. The target sector is primarily residential.

Algorithms

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

$$\Delta\, kWh/yr = \frac{((W_{base} \times HOU_{base}) - (W_{ee} \times HOU_{ee})) \times 365\frac{days}{yr} \times ISR_{NL}}{1000\frac{W}{kW}}$$

ΔkW_{peak} = *0 (assumed)*

Definition of Terms

Table 2-7: Electroluminescent Nightlight - References

Component	Unit	Value	Sources
W_{ee} , Watts per electroluminescent nightlight	*Watts*	EDC Data Gathering Default = 0.03	1
W_{base} , Watts per baseline nightlight	*Watts*	EDC Data Gathering Default = 7	2
HOU_{ee}, Hours-of-Use per day of electroluminescent nightlight	$\frac{hours}{day}$	24	3
HOU_{base}, Hours per baseline nightlight	$\frac{hours}{day}$	12	2
ISR_{NL}, In-Service Rate per electroluminescent nightlight	*None*	EDC Data Gathering Default = 0.97	PA CFL ISR value

[48] Southern California Edison Company, "LED, Electroluminescent & Fluorescent Night Lights", Work Paper WPSCRELG0029 Rev. 1, February 2009, p. 2 & p. 3.

Deemed Energy Savings

$\Delta kWh/yr$ $= \left((7 \times 12) - (.03 \times 24)\right) \times \frac{365\frac{days}{yr}}{1000\frac{W}{kW}} \times 0.97 = 29.49\ kWh$

Evaluation Protocols

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

Sources

1. 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.

2.1.4 LED Nightlight

Measure Name	**LED Nightlight**
Target Sector	Residential Establishments
Measure Unit	LED Nightlight
Unit Energy Savings	25.49 kWh
Unit Peak Demand Reduction	0 kW
Measure Life	8 years[49]
Vintage	Replace on Burnout

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.

Eligibility

This measure documents the energy savings resulting from the installation of an LED night light instead of a standard night light. The target sector is primarily residential.

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:

$$\Delta kWh/yr = ((W_{base} - W_{NL}) \times \left(\frac{HOU \times 365 \frac{days}{yr}}{1000 \frac{W}{kW}}\right)) \times ISR$$

ΔkW_{peak} = 0 (assumed)

Definition of Terms

Table 2-8: LED Nightlight - References

Component	Unit	Value	Sources
W_{base} , *Watts per baseline*	*Watts*	EDC Data Gathering *Default = 7*	*EDC Data Gathering*
W_{NL} ,*Watts per LED Nightlight*	*Watts*	EDC Data Gathering *Default = 1*	*EDC Data Gathering*
HOU , *Hours-of-Use*	$\frac{hours}{day}$	*12*	*1*
ISR_{NL} , *In-Service Rate per LED nightlight*	%	EDC Data Gathering *Default = 97%*	*PA CFL ISR value*

[49] Southern California Edison Company, "LED, Electroluminescent & Fluorescent Night Lights", Work Paper WPSCRELG0029 Rev. 1, February 2009, p. 2. and p.3.

Deemed Savings

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

$$\Delta kWh = \left((6) \times \left(\frac{12 \times 365 \frac{days}{yr}}{1000 \frac{W}{kW}} \right) \right) \times .97 = 25.49\ kWh$$

Evaluation Protocols

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

Sources

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

2.1.5 Holiday Lights

Measure Name	Holiday Lights
Target Sector	Residential Applications
Measure Unit	One 25-bulb Strand of Holiday lights
Unit Energy Savings	10.6 kWh per strand
Unit Peak Demand Reduction	0 kW
Measure Life	10 years[50,51]
Vintage	Replace on Burnout

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

Eligibility

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

Algorithms

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

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

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

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

Key assumptions

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

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

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

51 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"

Definition of Terms

Table 2-9: Holiday Lights Assumptions

Parameter	Unit	Value	Source
LED_{mini} , Wattage of LED mini bulbs	*Watts/Bulb*	0.08	1
INC_{mini} , Wattage of incandescent mini bulbs	*Watts/Bulb*	0.48	1
LED_{C7} , Wattage of LED C7 bulbs	*Watts/Bulb*	0.48	1
INC_{C7} , Wattage of incandescent C7bulbs	*Watts/Bulb*	6.0	1
LED_{C9} , Wattage of LED C9 bulbs	*Watts/Bulb*	2.0	1
INC_{C9} , Wattage of incandescent C9 bulbs	*Watts/Bulb*	7.0	1
$\%_{Mini}$, Percentage of holiday lights that are “mini”	*%*	50%	1
$\%_{C7}$, Percentage of holiday lights that are “C7”	*%*	25%	1
$\%_{C9}$, Percentage of holiday lights that are “C9”	*%*	25%	1
$\#_{Bulbs}$, Number of bulbs per strand	*Bulbs/strand*	EDC Data Gathering Default: 50 per strand	3
$\#_{Strands}$, Number of strands of lights per package	*strands/package*	EDC Data Gathering Default: 1 strand	3
Hr , Annual hours of operation	*Hours/yr*	150	1

Deemed Savings

The deemed savings for installation of LED C9, C7, and mini lights is 37.5 kWh, 41.4 kWh, and 3 kWh, respectively. The weighted average savings are 21.2 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.

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.

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
3. Typical values of lights per strand and strands per package at home depot and other stores.

2.2 HVAC

2.2.1 Electric HVAC

Measure Name	Electric HVAC
Target Sector	Residential Establishments
Measure Unit	AC Unit, ASHP Unit, or GSHP Unit
Unit Energy Savings	Varies
Unit Peak Demand Reduction	Varies
Measure Life	Varies (See Appendix A)
Vintage	Replace on Burnout, Retrofit (Maintenance and Proper Sizing), Early Replacement

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 3.2.

Eligibility

This measure requires the purchase of an ENERGY STAR Air Conditioner, Air Source Heat Pump, 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 existing furnace. The baseline condition is an existing standard efficiency electric heating system, a gas or electric 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.

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.

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

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

$$\Delta kWh_{heat}(\text{ASHP Only}) = \frac{CAPY_{heat}}{1000\,\frac{W}{kW}} \times \left(\frac{1}{HSPF_b} - \frac{1}{HSPF_e}\right) \times EFLH_{heat}$$

$$\Delta kWh_{peak} = \frac{CAPY_{cool}}{1000\,\frac{W}{kW}} \times \left(\frac{1}{EER_b} - \frac{1}{EER_e}\right) \times CF$$

Central A/C (Proper Sizing)[52]

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

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

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

Central A/C and ASHP (Maintenance)

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

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

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

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

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

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

Ground Source Heat Pumps (GSHP)

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

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

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

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

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

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

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

GSHP Desuperheater

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

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

$$= 567\ kWh$$

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

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

Furnace High Efficiency Fan

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

ΔkWh_{heat} = *HFS*

ΔkWh_{cool} = *CFS*

ΔkW_{peak} = *PDFS*

DEFINITION OF TERMS

Table 2-10: Residential Electric HVAC - References

Component	Unit	Value	Sources
$CAPY_{cool}$, The cooling capacity of the central air conditioner or heat pump being installed[53]	*Btu/hr*	EDC Data Gathering	AEPS Application; EDC Data Gathering
$CAPY_{heat}$, The heating capacity of the central air conditioner or heat pump being installed[54]	*Btu/hr*	EDC Data Gathering	AEPS Application; EDC Data Gathering
$SEER_b$, Seasonal Energy Efficiency Ratio of the Baseline Unit (split or package units)	$\frac{Btu}{W \cdot h}$	Replace on Burnout: 13 SEER (Central A/C) or 14 SEER (ASHP)	1
	$\frac{Btu}{W \cdot h}$	Early Retirement EDC Data Gathering Default = 11 (Central A/C) or 12 (ASHP)	13; EDC Data Gathering
$SEER_e$, Seasonal Energy Efficiency Ratio of the qualifying unit being installed[55]	$\frac{Btu}{W \cdot h}$	EDC Data Gathering	AEPS Application; EDC Data Gathering
$SEER_m$, Seasonal Energy Efficiency Ratio of the Unit receiving maintenance	$\frac{Btu}{W \cdot h}$	EDC Data Gathering Default= 11 (Central A/C) or 12 (ASHP)	13; EDC Data Gathering
EER_b , Energy Efficiency Ratio of the Baseline Unit	$\frac{Btu}{W \cdot h}$	Replace on Burnout: 11.3 or 12 (ASHP)	2
	$\frac{Btu}{W \cdot h}$	EDC Data Gathering Default= 8.69	14; EDC Data Gathering
EER_e , Energy Efficiency Ratio of the unit being installed[56]	$\frac{Btu}{W \cdot h}$	$\frac{11.3}{13} \times SEER$ Or for ASHP: $\frac{12}{14} \times SEER$	2

[53] This data is obtained from the AEPS Application Form or EDC's data gathering based on the model number.
[54] Ibid.
[55] Ibid.
[56] Ibid.

Component	Unit	Value	Sources
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	$\frac{Btu}{W \cdot h}$	EDC Data Gathering	AEPS Application; EDC's Data Gathering
EER_{sys} , Ground Source Heat Pump effective system EER	$\frac{Btu}{W \cdot h}$	Calculated	Calculated
EER_m , Energy Efficiency Ratio of the Unit receiving maintenance	$\frac{Btu}{W \cdot h}$	EDC Data Gathering Default= 8.69	14; EDC Data Gathering
GSER , Factor used to determine the SEER of a GSHP based on its EERg	$\frac{Btu}{W \cdot h}$	1.02	3
$EFLH_{cool}$, Equivalent Full Load Hours of operation during the cooling season for the average unit	$\frac{hours}{yr}$	Allentown Cooling = 487 Hours Erie Cooling = 389 Hours Harrisburg Cooling = 551 Hours Philadelphia Cooling = 591 Hours Pittsburgh Cooling = 432 Hours Scranton Cooling = 417 Hours Williamsport Cooling = 422 Hours	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 Table 2-11); EDC Data Gathering
$EFLH_{heat}$, Equivalent Full Load Hours of operation during the heating season for the average unit	$\frac{hours}{yr}$	Allentown Heating = 1,193 Hours Erie Heating = 1,349 Hours Harrisburg Heating = 1,103 Hours Philadelphia Heating = 1,060 Hours Pittsburgh Heating = 1,209 Hours Scranton Heating = 1,296 Hours Williamsport Heating = 1,251 Hours	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 Table 2-12); EDC Data Gathering

Component	Unit	Value	Sources
PSF , Proper Sizing Factor or the assumed savings due to proper sizing and proper installation	*None*	0.05	5
MF_{cool} , Maintenance Factor or assumed savings due to completing recommended maintenance on installed cooling equipment	*None*	0.05	15
MF_{heat} , Maintenance Factor or assumed savings due to completing recommended maintenance on installed heating equipment	*None*	0.05	15
CF , Demand Coincidence Factor (See Section 1.5)	*Decimal*	0.647	6
$HSPF_b$, Heating Seasonal Performance Factor of the Baseline Unit	$\frac{Btu}{W \cdot h}$	Replace on Burnout: 8.2	7
	$\frac{Btu}{W \cdot h}$	Early Replacement: EDC Data Gathering Default = 6.9	20
$HSPF_e$, Heating Seasonal Performance Factor of the unit being installed[57]	$\frac{Btu}{W \cdot h}$	EDC Data Gathering	AEPS Application; EDC's Data Gathering
$HSPF_m$, Heating Seasonal Performance Factor of the unit receiving maintenance	$\frac{Btu}{W \cdot h}$	6.9	20
COP_g , Coefficient of Performance. This is a measure of the efficiency of a heat pump	*None*	EDC Data Gathering	AEPS Application; EDC's Data Gathering
GSHPDF , Ground Source Heat Pump De-rate Factor	*None*	0.885	19 (Engineering Estimate - See System Performance of Ground Source Heat Pumps)
COP_{sys} , Ground Source Heat Pump effective system COP	Variable	Calculated	Calculated
GSOP , Factor to determine the HSPF of a GSHP based on its COPg	*None*	3.413	8
GSPK , Factor to convert EERg to the equivalent EER of an air conditioner to enable comparisons to the baseline unit	*None*	0.8416	9
EFDSH , Energy Factor per desuperheater	*None*	0.17	10, 11

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

Component	Unit	Value	Sources
EDSH[58] , Fixed savings per desuperheater	*kWh/yr*	567	Calculated
EF_{base} , Energy Factor of Electric Water Heater	None	0.904	Table 2-41
HW , Daily Hot Water Use	Gallons/day	50	Table 2-41
T_h , Hot Water Temperature	°F	119	Table 2-41
T_c , Cold Water Temperature	°F	55	Table 2-41
ETDF , Fixed "Energy to Demand Factor per desuperheater	None	0.00008294	Table 2-41
PDSH , Assumed peak-demand savings per desuperheater	kW	0.05	Calculated
HFS , Assumed heating season savings per furnace high efficiency fan	kWh	311	16
CFS , Assumed cooling season savings per furnace high efficiency fan	kWh	135	17
PDFS , Assumed peak-demand savings per furnace high efficiency fan	kW	0.105	18

Alternate Equivalent Full Load Hour (EFLH) Tables

Table 2-11 and Table 2-12 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. For more information on the following two tables, see Source 4.

Table 2-11: Alternate Cooling EFLH

	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

[58] 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.

Table 2-12: Alternate Heating EFLH

	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

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 (Ref. #19), 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.

Evaluation Protocols

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

Sources

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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.
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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. Straub, Mary and Switzer, Sheldon."Using Available Information for Efficient Evaluation of Demand Side Management Programs". Study by BG&E. The Electricity Journal. Aug/Sept. 2011. Found at http://www.sciencedirect.com/science/article/pii/S1040619011001941

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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. 2014 Pennsylvania Residential Baseline Study. The Act 129 2014 Residential Baseline Study may be found at http://www.puc.pa.gov/Electric/pdf/Act129/SWE-2014_PA_Statewide_Act129_Residential_Baseline_Study.pdf
14. The same EER to SEER ratio used for SEER 13 units applied to SEER 10 units. EERm = (11.3/13) * 10.
15. 2013 Illinois Statewide TRM (Central Air Conditioning in Wisconsin, Energy Center of Wisconsin, May 2008)
16. Scott Pigg (Energy Center of Wisconsin), "Electricity Use by New Furnaces: A Wisconsin Field Study", Technical Report 230-1, October 2003, page 20. The average heating-mode savings of 400 kWh multiplied by the ratio of average heating degree days in PA compared to Madison, WI (5568/7172).
17. Ibid, page 34. The average cooling-mode savings of 88 kWh multiplied by the ratio of average EFLH in PA compared to Madison, WI (749/487).
18. Ibid, page 34. The average kW savings of 0.1625 multiplied by the coincidence factor from Table 2-10.
19. McQuay Application Guide 31-008, Geothermal Heat Pump Design Manual, 2002.
20. Based on building energy model simulations and residential baseline characteristics determined from the 2014 Residential End-use Study and applied to an HSPF listing for 12 SEER Air Source Heat Pumps at https://www.ahridirectory.org on July 28th, 2014.

2.2.2 Fuel Switching: Electric Heat to Gas/Propane/Oil Heat

Measure Name	Fuel Switching: Electric Heat to Gas/Propane/Oil Heat
Target Sector	Residential Establishments
Measure Unit	Gas, Propane, or Oil Heater
Unit Energy Savings	Variable based on system and location
Unit Peak Demand Reduction	Variable based on system and location
Measure Life	20 years[61]
Vintage	Replace on Burnout

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 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.

Eligibility

The target sector primarily consists of single-family residences.

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).

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[62]
Gas Furnace	• AFUE rating of 95% or greater • Less than or equal to 2.0% furnace fan efficiency • Less than or equal to 2.0% air leakage

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

[62] 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

Equipment	Energy Star Requirements[62]
Oil Furnace	• AFUE rating of 85% or greater • Less than or equal to 2.0% furnace fan efficiency • Less than or equal to 2.0% air leakage
Boiler	• AFUE rating of 85% or greater

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 furnace (assumes 100% efficiency):
Energy Impact:

$$\Delta kWh/yr_{elec\ furnace} = \frac{CAPY_{elec\ heat} \times EFLH_{elec\ furnace}}{3412\frac{Btu}{kWh}}$$

Heating savings with electric baseboards (assumes 100% efficiency):
Energy Impact:

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

Heating savings with electric air source heat pump:
Energy Impact:

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

For boilers, the annual pump energy consumption is negligible (<50 kWh per year) and not included in this calculation.[63]

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 fossil fuel furnace:

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

DEFINITION OF TERMS

The default values for each term are shown in Table 2-13.

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

Table 2-13: Default values for algorithm terms, Fuel Switching, Electric Heat to Gas Heat

Term	Units	Value	Source
$CAPY_{elec\ heat}$, Total heating capacity of existing electric baseboards or electric furnace	$\frac{Btu}{hr}$	Nameplate	EDC Data Gathering
$CAPY_{ASHP\ heat}$, Total heating capacity of existing electric ASHP	$\frac{Btu}{hr}$	Nameplate	EDC Data Gathering
$CAPY_{fuel\ heat}$, Total heating capacity of new natural gas furnace	$\frac{Btu}{hr}$	Nameplate	EDC Data Gathering
$EFLH_{ASHP}$, Equivalent Full Load Heating hours for Air Source Heat Pumps	$\frac{hours}{yr}$	Allentown = 1,193 Erie = 1,349 Harrisburg = 1,103 Philadelphia = 1,060 Pittsburgh = 1,209 Scranton = 1,296 Williamsport = 1,251	2014 PA TRM Table 2-10, 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 Table 2-14) or EDC Data Gathering
$EFLH_{elec\ furnace}$, Equivalent Full Load Heating hours for Electric Forced Air Furnaces	$\frac{hours}{yr}$	Allentown = 1,000 Erie = 1,075 Harrisburg = 947 Philadelphia = 934 Pittsburgh = 964 Scranton = 1,034 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 Table 2-15) or EDC Data Gathering
$EFLH_{elec\ bb}$, Equivalent Full Load Heating hours for Electric Baseboard systems	$\frac{hours}{yr}$	Allentown = 1,321 Erie = 1,396 Harrisburg = 1,265 Philadelphia = 1,236 Pittsburgh = 1,273 Scranton = 1,357 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 Table 2-16) or EDC Data Gathering
$EFLH_{fuel\ furnace}$, Equivalent Full Load Heating hours for Fossil Fuel Furnace systems	$\frac{hours}{yr}$	Allentown = 1,022 Erie = 1,098 Harrisburg = 969 Philadelphia = 955 Pittsburgh = 985 Scranton = 1,056 Williamsport = 1,033	1
	Optional	An EDC can either use the Alternate EFLH Table or	Alternate EFLH Table

Term	Units	Value	Source
		estimate it's own EFLH based on customer billing data analysis.	(See Table 2-17) or EDC Data Gathering
$EFLH_{fuel\ boiler}$, Equivalent Full Load Heating hours for Fuel Boilers	$\frac{hours}{yr}$	Allentown = 1,334 Erie = 1,411 Harrisburg = 1,279 Philadelphia = 1,249 Pittsburgh = 1,283 Scranton = 1,371 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 Table 2-18) or EDC Data Gathering
$HSPF_{ASHP}$, Heating Seasonal Performance Factor for existing heat pump	$\frac{Btu}{W \cdot hr}$	EDC Data Gathering Default = 7.7	2010 PA TRM Table 2-10
		Nameplate	EDC Data Gathering
$AFUE_{fuel\ heat}$, Annual Fuel Utilization Efficiency for the new gas furnace	%	EDC Data Gathering Default = 95% (natural gas/propane furnace) 95% (natural gas/propane steam boiler) 95% (natural gas/propane hot water boiler) 85% (oil furnace) 85% (oil steam boiler) 85% (oil hot water boiler)	ENERGY STAR requirement
		Nameplate	EDC Data Gathering
HP_{motor} , Gas furnace blower motor horsepower	hp	EDC Data Gathering Default = ½	Average blower motor capacity for gas furnace (typical range = ¼ hp to ¾ hp)
		Nameplate	EDC Data Gathering
η_{motor} , Efficiency of furnace blower motor	%	EDC Data Gathering Default = 50%	Typical efficiency of ½ hp blower motor

Alternate Equivalent Full Load Hour (EFLH) Tables

Table 2-14 through Table 2-18 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 2-14: 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 2-15: 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 2-16: 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 2-17: 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 2-18: 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

Evaluation Protocols

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

Sources

1. Based on 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.

2.2.3 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[64]
Vintage	Replace on Burnout

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

Eligibility

This protocol documents the energy savings attributed to ductless mini-split heat pumps with energy efficiency performance of 14.5/12 SEER/EER and 8.2 HSPF or greater with inverter technology.[65] The baseline heating system could be an existing electric resistance heating, a lower-efficiency ductless heat pump system, a ducted heat pump, electric furnace, or a non-electric fuel-based system. The baseline cooling system can be a standard efficiency heat pump system, central air conditioning system, or room air conditioner. In addition, this could be installed in new construction or an addition. For new construction or addition applications, the baseline assumption is a standard-efficiency ductless unit. The DHP systems could be installed as the primary heating or cooling system for the house or as a secondary heating or cooling system for a single room.

Algorithms

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

Single Zone

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

$$\Delta kWh/yr_{heat} = \frac{CAPY_{heat}}{1000\frac{W}{kW}} \times \left(\frac{OF \times DLF}{HSPF_{base}} - \frac{1}{HSPF_{ee}}\right) \times EFLH_{heat}$$

$$\Delta kWh/yr_{cool} = \frac{CAPY_{cool}}{1000\frac{W}{kW}} \times \left(\frac{OF \times DLF}{SEER_{base}} - \frac{1}{SEER_{ee}}\right) \times EFLH_{cool}$$

[64] DEER Effective Useful Life values, updated October 10, 2008. Various sources range from 12 to 20 years, DEER represented a reasonable mid-range.

[65] 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.

$$\Delta kW_{peak} = \frac{CAPY_{cool}}{1000\frac{W}{kW}} \times \left(\frac{OF \times DLF}{EER_{base}} - \frac{1}{EER_{ee}}\right) \times CF$$

MULTI-ZONE

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

$$\Delta\, kWh/yr_{heat}$$

$$= \left[\frac{CAPY_{heat}}{1000\frac{W}{kW}} \times \left(\frac{OF \times DLF}{HSPF_{base\ 1}} - \frac{1}{HSPF_{ee}}\right) \times EFLH_{heat}\right]_{zone\ 1} + \left[\frac{CAPY_{heat}}{1000\frac{W}{kW}} \times \left(\frac{OF \times DLF}{HSPF_{base\ 2}} - \frac{1}{HSPF_{ee}}\right) \times EFLH_{heat}\right]_{zone\ 2} + \cdots + \left[\frac{CAPY_{heat}}{1000\frac{W}{kW}} \times \left(\frac{OF \times DLF}{HSPF_{base\ n}} - \frac{1}{HSPF_{ee}}\right) \times EFLH_{heat}\right]_{zone\ n}$$

$$\Delta\, kWh/yr_{cool}$$

$$= \left[\frac{CAPY_{cool}}{1000\frac{W}{kW}} \times \left(\frac{OF \times DLF}{SEER_{base\ 1}} - \frac{1}{SEER_{ee}}\right) \times EFLH_{cool}\right]_{zone\ 1} + \left[\frac{CAPY_{cool}}{1000\frac{W}{kW}} \times \left(\frac{OF \times DLF}{SEER_{base\ 2}} - \frac{1}{SEER_{ee}}\right) \times EFLH_{cool}\right]_{zone\ 2} + \cdots + \left[\frac{CAPY_{cool}}{1000\frac{W}{kW}} \times \left(\frac{OF \times DLF}{SEER_{base\ n}} - \frac{1}{SEER_{ee}}\right) \times EFLH_{cool}\right]_{zone\ n}$$

$$\Delta kW_{peak}$$

$$= \left[\frac{CAPY_{cool}}{1000\frac{W}{kW}} \times \left(\frac{OF \times DLF}{EER_{base\ 1}} - \frac{1}{EER_{ee}}\right) \times CF\right]_{zone\ 1} + \left[\frac{CAPY_{cool}}{1000\frac{W}{kW}} \times \left(\frac{OF \times DLF}{EER_{base\ 2}} - \frac{1}{EER_{ee}}\right) \times CF\right]_{zone\ 2} + \cdots + \left[\frac{CAPY_{cool}}{1000\frac{W}{kW}} \times \left(\frac{OF \times DLF}{EER_{base\ n}} - \frac{1}{EER_{ee}}\right) \times CF\right]_{zone\ n}$$

Definition of Terms

Table 2-19: DHP – Values and References

Term	Unit	Values	Sources
$CAPY_{cool}$, The cooling (at 47° F) capacity of the Ductless Heat Pump unit	$\frac{Btu}{hour}$	EDC Data Gathering	AEPS Application; EDC Data Gathering
$CAPY_{heat}$, The heating (at 47° F) capacity of the Ductless Heat Pump unit	$\frac{Btu}{hour}$	EDC Data Gathering	AEPS Application; EDC Data Gathering
EFLH primary , Equivalent Full Load Hours of the primary system – If the unit is installed as the primary heating or cooling system, as defined in Table 2-20	$\frac{hours}{year}$	Allentown Cooling = 487 Hours Allentown Heating = 1,193 Hours Erie Cooling = 389 Hours Erie Heating = 1,349 Hours Harrisburg Cooling = 551 Hours Harrisburg Heating = 1,103 Hours Philadelphia Cooling = 591 Hours Philadelphia Heating = 1,060 Hours Pittsburgh Cooling = 432 Hours Pittsburgh Heating = 1,209 Hours Scranton Cooling = 417 Hours Scranton Heating = 1,296 Hours Williamsport Cooling = 422 Hours Williamsport Heating = 1,251 Hours	1
	$\frac{hours}{year}$	An EDC can either use the Alternate EFLH Table 2-12 or estimate its own EFLH based on customer billing data analysis	EDC Data Gathering
EFLH secondary , Equivalent Full Load Hours of the secondary system – If the unit is installed as the secondary heating or cooling system, as defined in Table 2-20	$\frac{hours}{year}$	Allentown Cooling = 243 Hours Allentown Heating = 800 Hours Erie Cooling = 149 Hours Erie Heating = 994 Hours Harrisburg Cooling = 288 Hours Harrisburg Heating = 782 Hours Philadelphia Cooling = 320 Hours Philadelphia Heating = 712 Hours Pittsburgh Cooling = 228 Hours Pittsburgh Heating = 848 Hours Scranton Cooling = 193 Hours Scranton Heating = 925 Hours Williamsport Cooling = 204 Hours Williamsport Heating = 875 hours	2, 3

Term	Unit	Values	Sources
$HSPF_{base}$, "Heating Seasonal Performance Factor"- heating efficiency of baseline unit	$\frac{Btu}{W \cdot h}$	Standard DHP: 8.2 Electric resistance: 3.412 ASHP: 8.2 Electric furnace: 3.242 No existing or non-electric heating: use standard DHP: 8.2	4, 6
$SEER_{base}$, "Seasonal Energy Efficiency Ratio" - Cooling efficiency of baseline unit	$\frac{Btu}{W \cdot h}$	DHP or ASHP: 14 Central AC: 13 Room AC: 11.3 No existing cooling for primary space: use Central AC: 13 No existing cooling for secondary space: use Room AC: 11.3	5, 6, 7
$HSPF_{ee}$, "Heating Seasonal Performance Factor"- heating efficiency of installed DHP	$\frac{Btu}{W \cdot h}$	Based on nameplate information. Should be at least ENERGY STAR.	AEPS Application; EDC Data Gathering
$SEER_{ee}$, "Seasonal Energy Efficiency Ratio" - Cooling efficiency of installed DHP	$\frac{Btu}{W \cdot h}$	Based on nameplate information. Should be at least ENERGY STAR.	AEPS Application; EDC Data Gathering
OF , "Oversize factor" factor to account for the fact that the baseline unit is typically 40%-50% oversized	None	Depends on baseline condition: Central AC=1.5 Central ASHP=1.4 Electric Furnace=1.4 Electric Baseboard=1.4 Room AC: 1.0 Ductless Heat Pump: 1.0	1
DLF , "Duct Leakage Factor" accounts for the fact that a % of the energy is lost to duct leakage and conduction for ducted systems, but not ductless ones	None	Depends on baseline condition: Central AC=1.15 Central ASHP=1.15 Electric Furnace=1.15 Electric Baseboard=1.00 Room AC: 1.00 Ductless Heat Pump: 1.0	10
CF , Coincidence Factor	*Decimal*	0.647	8
EER_{base} , The Energy Efficiency Ratio of the baseline unit	$\frac{Btu}{W \cdot h}$	= (11.3/13) X $SEER_b$ for DHP or central AC = 9.8 room AC	5,9
EER_{ee} , The Energy Efficiency Ratio of the installed DHP	$\frac{Btu}{W \cdot h}$	= (11.3/13) X $SEER_e$ Based on nameplate information. Should be at least ENERGY STAR.	AEPS Application; EDC Data Gathering

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 2-20.

Table 2-20: DHP – Heating Zones

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

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.

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[66] and 40% oversizing of heat pumps.[67]
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 2.2.5 Room AC Retirement measure.
3. Secondary heating hours based on a ratio of HDD base 68 and base 60 deg F. The ratio is used to reflect the heating requirement for secondary spaces is less than primary space as the thermostat set point in these spaces is generally lowered during unoccupied time periods.
4. Using the relation HSPF=COP*3.412, HSPF = 3.412 for electric resistance heating. Electric furnace efficiency typically varies from 0.95 to 1.00, so similarly a COP of 0.95 equates to an HSPF of 3.241.
5. U.S. Federal Standards for Residential Air Conditioners and Heat Pumps. Effective 1/1/2015. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/75

[66] 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

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

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. Straub, Mary and Switzer, Sheldon. "Using Available Information for Efficient Evaluation of Demand Side Management Programs". Study by BG&E. The Electricity Journal. Aug/Sept. 2011. Found at http://www.sciencedirect.com/science/article/pii/S1040619011001941

9. Average EER for SEER 13 unit. From Pennsylvania's Technical Reference Manual.

10. Assumption used in Illinois 2014 TRM, Ductless Heat Pumps Measure, pg. 531, footnote 877. Reasonable assumption when compared to http://www.energystar.gov/index.cfm?c=home_improvement.hm_improvement_ducts and Residential HVAC and Distribution Research Implementation,. Berkeley Labs. May, 2002, pg 6. http://epb.lbl.gov/publications/pdf/lbnl-47214.pdf

2.2.4 ENERGY STAR Room Air Conditioners

Measure Name	**Room Air Conditioners**
Target Sector	Residential Establishments
Measure Unit	Room Air Conditioner
Unit Energy Savings	Varies
Unit Peak Demand Reduction	Varies
Measure Life	9 years[68]
Vintage	Replace on Burnout

Eligibility

This measure relates to the purchase and installation of a room air conditioner meeting ENERGY STAR criteria.

Algorithms

The general form of the equation for the ENERGY STAR Room Air Conditioners (RAC) measure savings algorithm is:

Total Savings $= Number\ of\ Room\ Air\ Conditioners \times\ Savings\ per\ Room\ Air\ Conditioner$

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.

As of June 1, 2014 RAC units will have a “CEER” rating as well as an “EER”. CEER is the “Combined Energy Efficiency Ratio”, which incorporates standby power into the calculation. This will be the value used in the $\Delta\, kWh/yr$ calculation.

$$\Delta\, kWh/yr = \frac{CAPY}{1000\frac{W}{kW}} \times \left(\frac{1}{CEER_{base}} - \frac{1}{CEER_{ee}}\right) \times EFLH_{RAC}$$

$$\Delta kW_{peak} = \frac{CAPY}{1000\frac{W}{kW}} \times \left(\frac{1}{CEER_{base}} - \frac{1}{CEER_{ee}}\right) \times CF$$

68 Appliance Magazine, 2008.

DEFINITION OF TERMS

Table 2-21: ENERGY STAR Room AC - References

Component	Unit	Value	Sources
CAPY , The cooling capacity of the room air conditioner (RAC) being installed	$\frac{Btu}{hr}$	EDC Data Gathering	
$CEER_{base}$, Combined Energy Efficiency ratio of the baseline unit	$\frac{Btu}{W \cdot h}$	Federal Standard Values in: Table 2-22 Table 2-23 Table 2-24	1
$CEER_{ee}$, Combined Energy efficiency ratio of the RAC being installed	$\frac{Btu}{W \cdot h}$	EDC Data Gathering Default = ENERGY STAR values in: Table 2-22 Table 2-23 Table 2-24	2
$EFLH_{RAC}$, Equivalent full load hours of the RAC being installed	$\frac{hours}{year}$	Table 2-25 or alternate $EFLH_{cool}$ values × an Adjustment Factor in Section 2.2.5	3
CF , *Demand coincidence factor*	*Fraction*	Default: 0.30 Or EDC data gathering	4

Table 2-22 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.[69]

[69] Federal standards: U.S. Department of Energy. *Federal Register*. 164th ed. Vol. 76, August 24, 2011.

Table 2-22: RAC (without reverse cycle) Federal Minimum Efficiency and ENERGY STAR Version 3.1 Standards [70]

<table>
<tr><th>Capacity (Btu/h)</th><th>Federal Standard CEER, with louvered sides</th><th>ENERGY STAR CEER, with louvered sides</th><th>Federal Standard CEER, without louvered sides</th><th>ENERGY STAR CEER, without louvered sides</th></tr>
<tr><td>< 6,000</td><td rowspan="2">≥11.0</td><td rowspan="2">11.0</td><td rowspan="2">10.0</td><td rowspan="2">10.2</td></tr>
<tr><td>6,000 to 7,999</td></tr>
<tr><td>8,000 to 10,999</td><td rowspan="2">≥10.9</td><td rowspan="2">11.2</td><td>9.6</td><td>9.7</td></tr>
<tr><td>11,000 to 13,999</td><td>9.5</td><td rowspan="3">9.7</td></tr>
<tr><td>14,000 to 19,999</td><td>≥10.7</td><td>11.1</td><td>9.3</td></tr>
<tr><td>20,000 to 24,999</td><td>≥9.4</td><td rowspan="2">9.8</td><td rowspan="2">9.4</td></tr>
<tr><td>≥25,000</td><td>≥9.0</td><td>9.8</td></tr>
</table>

Table 2-23 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 2-23: Casement-Only and Casement-Slider RAC Federal Minimum Efficiency and ENERGY STAR Version 3.1 Standards

Casement	Federal Standard CEER	ENERGY STAR CEER
Casement-only	≥ 9.5	9.9
Casement-slider	≥ 10.4	10.8

Table 2-24 lists the minimum federal efficiency standards and minimum ENERGY STAR efficiency standards for reverse-cycle RAC units.

Table 2-24: Reverse-Cycle RAC Federal Minimum Efficiency Standards and ENERGY STAR Version 3.1 Standards

<table>
<tr><th>Capacity (Btu/h)</th><th>Federal Standard CEER, with louvered sides</th><th>ENERGY STAR CEER, with louvered sides</th><th>Federal Standard CEER, without louvered sides</th><th>ENERGY STAR CEER, without louvered sides</th></tr>
<tr><td>< 14,000</td><td rowspan="2">n/a</td><td rowspan="2">n/a</td><td>≥ 9.3</td><td>9.7</td></tr>
<tr><td>≥ 14,000</td><td>≥ 8.7</td><td>9.1</td></tr>
<tr><td>< 20,000</td><td>≥ 9.8</td><td>10.3</td><td rowspan="2">n/a</td><td rowspan="2">n/a</td></tr>
<tr><td>≥ 20,000</td><td>≥ 9.3</td><td>9.8</td></tr>
</table>

Table 2-25 provides deemed EFLH by city and default energy savings values (assuming CAPY=8,000 Btu/hr[71], louvered sides, no reverse cycle) if efficiency and capacity information is

[70] Federal standards: 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 3.1*. October 1, 2013.
http://www.energystar.gov/ia/partners/product_specs/program_reqs/Room_Air_Conditioner_Program_Requirements_Version_3.pdf
[71] Pennsylvania Residential Baseline Study, April 2014.

unknown. Alternate $EFLH_{cool}$ values from Table 2-11 in Section 2.2.1 may be used in conjunction with the Adjustment Factor (AF) in Section 2.2.5 to find $EFLH_{RAC}$ if desired.

Table 2-25: Deemed EFLH and Default Energy Savings

City	$EFLH_{RAC}$	ΔkWh/yr	ΔkW_{peak}
Allentown	151	3.0	.0059
Erie	121	2.4	.0059
Harrisburg	171	3.4	.0059
Philadelphia	183	3.6	.0059
Pittsburgh	134	2.6	.0059
Scranton	129	2.5	.0059
Williamsport	131	2.6	.0059

Evaluation Protocols

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

Sources

1. Federal standards: U.S. Department of Energy. Code of Federal Regulations. 10 CFR, part 430.32(b). Effective June 1, 2014. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/41
2. ENERGY STAR Program Requirements Product Specification for Room Air Conditioners, Eligibility Criteria Version 3.10. October 1, 2013. http://www.energystar.gov/products/specs/system/files/ENERGY%20STAR%20Version%203.1%20Room%20Air%20Conditioner%20Program%20Requirements.pdf
3. Based on REM/Rate modeling using models from the PA 2012 Potential Study. EFLH calculated from kWh consumption for cooling and heating. Models assume 50% over-sizing of air conditioners and 40% oversizing of heat pumps. [72]
4. Consistent with CFs found in RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008.[73]

[72] ACCA, "Verifying ACCA Manual S Procedures," http://www.acca.org/wp-content/uploads/2014/01/Manual-S-Brochure-Final.pdf.
[73] In the absence of better, Pennsylvania-specific data, this is the same source and value as the Mid-Atlantic and Illinois TRMs.

2.2.5 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 years[74]
Vintage	Early Retirement, Early Replacement

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.

Eligibility

The savings are *not* attributable to the customer that owned the RAC, but instead are attributed to a *hypothetical user of the equipment had it not been recycled*. Energy and demand savings is the estimated energy consumption of the retired unit over its remaining useful life (RUL).

Algorithms

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

Retirement-Only

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

$$\Delta\, kWh/yr = \left(\frac{CAPY}{1000\frac{W}{kW} \times EER_{RetRAC}}\right) \times EFLH_{RAC}$$

$$\Delta kW_{peak} = \left(\frac{CAPY}{1000\frac{W}{kW} \times EER_{Ret\ RAC}}\right) \times CF_{RAC}$$

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

[74] See Measure Life section of this measure.

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.

$$\Delta\, kWh/yr = \frac{CAPY}{1000\frac{W}{kW}} \times \left(\frac{1}{EER_{RetRAC}} - \frac{1}{EER_{ee}}\right) \times EFLH_{RAC}$$

$$\Delta kW_{peak} = \frac{CAPY}{1000\frac{W}{kW}} \times \left(\frac{1}{EER_{RetRAC}} - \frac{1}{EER_{ee}}\right) \times CF_{RAC}$$

After the RUL for (EUL-RUL) years: The baseline EER would revert to the minimum Federal appliance standard CEER. As of June 1, 2014 RAC units will have a "CEER" rating in addition to an "EER". CEER is the "Combined Energy Efficiency Ratio", which incorporates standby power into the calculation. This will be the value used in the $\Delta\, kWh/yr$ calculation. (CEER was not used in the previous equations however since older units were not qualified with this metric).

$$\Delta\, kWh/yr = \frac{CAPY}{1000\frac{W}{kW}} \times \left(\frac{1}{CEER_{base}} - \frac{1}{CEER_{ee}}\right) \times EFLH_{RAC}$$

$$\Delta kW_{peak} = \frac{CAPY}{1000\frac{W}{kW}} \times \left(\frac{1}{CEER_{base}} - \frac{1}{CEER_{ee}}\right) \times CF_{RAC}$$

Definition of Terms

Correction of ES RAC EFLH Values:
An additional step is required to determine $EFLH_{RAC}$ values. Normally, the EFLH values from the ENERGY STAR Room AC Calculator would be used directly,however, the current (July 2010) ES Room AC calculator EFLHs appear unreasonably high and are in the range of those typically used for the Central AC calculator. In reality, RAC full load hours should be much lower than for a CAC system and, as such, the $EFLH_{RAC}$ values were calculated from CAC EFLH values as follows:

$$EFLH_{RAC} = EFLH_{cool} \times AF$$

Where:
Note that when the ENERGY STAR RAC calculator values are eventually corrected in the ES calculator, the corrected $EFLH_{ES\text{-}RAC}$ values can be used directly and this adjustment step can be ignored and/or deleted.

Table 2-26: Room AC Retirement Calculation Assumptions

Component	Unit	Value	Sources
$EFLH_{RAC}$, 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.).	$\frac{hours}{yr}$	Table 2-27	1
$EFLH_{cool}$, Full load hours from REM/Rate modeling	$\frac{hours}{yr}$	Table 2-27	1
	$\frac{hours}{yr}$	The Alternate $EFLH_{COOL}$ values in Table 2-11 may be used	
AF , Adjustment factor for correcting current ES Room AC calculator EFLHs.	*None*	0.31	2
CAPY , Rated cooling capacity (size) of the RAC unit.	$\frac{Btu}{hr}$	EDC Data Gathering Default : 7,870	3
EER_{RetRAC} , The Energy Efficiency Ratio of the unit being retired-recycled.	$\frac{Btu}{W \cdot h}$	Default: 9.07; or EDC Data Gathering	4
EER_{ee} , The Energy Efficiency Ratio for an ENERGY STAR RAC	$\frac{Btu}{W \cdot h}$	11.3	5
$CEER_{base}$, (for a 8,000 Btu/h unit), The Combined Energy Efficiency Ratio of a RAC that just meets the minimum federal appliance standard efficiency.	$\frac{Btu}{W \cdot h}$	10.9	5
CEERee , (for a 8,000 Btu/h unit), The Combined Energy Efficiency Ratio for an ENERGY STAR RAC.	$\frac{Btu}{W \cdot h}$	EDC Data Gathering Default=11.2	5
CF_{rac} , Demand Coincidence Factor	*Fraction*	EDC Data Gathering Default= 0.30	7
RAC Time Period Allocation Factors	*%*	65.1%, 34.9%, 0.0%, 0.0%	6

Table 2-27: RAC Retirement-Only EFLH and Energy Savings by City[75]

City	Original Hours (EFLH cool)	Corrected Hours (EFLHRAC)	Energy Impact (kWh)	Demand Impact (kW)
Allentown	487	151	131	0.2603
Erie	389	121	105	
Harrisburg	551	171	148	
Philadelphia	591	183	159	
Pittsburgh	432	134	116	
Scranton	417	129	112	
Williamsport	422	131	114	

Measure Life

Room Air Conditioner Retirement = 4 years

From the PA TRM, the EUL for an ENERGY STAR Room Air Conditioner is 10 years, but the TRM does not provide an RUL for RACs. However, as shown in Table 2-28, the results from a recent evaluation of ComEd's appliance recycling program[76] 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.

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Table 2-27 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.

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

Table 2-28: Preliminary Results from ComEd RAC Recycling Evaluation[77]

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%	—

Evaluation Protocols

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

Sources

1. Based on 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[78] and 40% oversizing of heat pumps.[79]
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 Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008[80] 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. Statewide average capacity of RAC units, 2014 Pennsylvania Residential Baseline Study.
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

[77] Navigant Consulting evaluation of ComEd appliance recycling program.
[78] 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.
[79] ACCA, "Verifying ACCA Manual S Procedures," http://www.acca.org/Files/?id=67.
[80] Accesed:<http://www.puc.nh.gov/Electric/Monitoring%20and%20Evaluation%20Reports/National%20Grid/117_RLW_CF%20Res%20RAC.pdf>

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 Version 3.1 and Federal Appliance Standard minimum CEER and EER for a 6000-7999 Btu/hr unit with louvered sides. http://www.energystar.gov/products/specs/system/files/ENERGY%20STAR%20Version%203.1%20Room%20Air%20Conditioner%20Program%20Requirements.pdf
6. PA TRM June 2010, coincident demand factor and Time Period Allocation Factors for ENERGY STAR Room AC.
7. Consistent with CFs found in RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008.[81]

[81] In the absence of better, Pennsylvania-specific data, this is the same source and value as the Mid-Atlantic and Illinois TRMs.

2.2.6 Duct Sealing

Measure Name	Duct Sealing
Target Sector	Residential Establishments
Measure Unit	Office Equipment Device
Unit Energy Savings	Varies
Unit Peak Demand Reduction	Varies
Measure Life	(15max, 20 actual for TRC) years[82]
Vintage	Retrofit

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.

Three methodologies for estimating the savings associated with sealing ducts are provided. The first two require the use of a blower door and the third requires careful inspection of the duct work.

1. ***Modified Blower Door Subtraction*** – this method involves performing a whole house depressurization test, an envelope depressurization test that excludes duct leakage, and finally a duct leakage pressurization test under envelope depressurization. The subtraction of the envelope leakage in the second test from the whole house leakage in the first test, multiplied by a correction factor determined by the third test will provide an accurate measurement of the duct leakage to the outside. This technique is described in detail on p.44 of the Energy Conservatory Blower Door Manual; 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. ***RESNET Test 803.***7 – this method involves the pressurization of the house to 25 Pascals with reference to outside and a simultaneous pressurization of the duct system to reach equilibrium with the envelope or inside pressure of zero Pascals. A blower door is used to pressurize the building to 25 Pascals with reference to outside, when that is achieved the duct blaster is used to equalize the pressure difference between the duct system and the house. The amount of air required to bring the duct system to zero Pascals with reference to the building is the amount of air leaking through the ductwork to the outside. This technique is described in detail in section 803.7 of the RESNET Standards: http://www.resnet.us/professional/standards
3. ***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

[82] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007. http://library.cee1.org/sites/default/files/library/8842/CEE_Eval_MeasureLifeStudyLights%26HVACGDS_1Jun2007.pdf

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.

ALGORITHMS

Methodology 1: Modified Blower Door Subtraction

a) Determine Duct Leakage rate before and after performing duct sealing

$$CFM50_{DL} = (CFM50_{whole\ house} - CFM50_{envelope\ only}) \times SCF$$

b) Calculate duct leakage reduction, convert to CFM25DL and factor in Supply and Return Loss Factors

$$\Delta CFM25_{DL} = (CFM50_{DL\ (pre)} - CFM50_{DL\ (post)}) \times CONV \times (SLF + RLF)$$

c) Calculate Energy Savings

$$\Delta\, kWh/yr_{cooling} = \frac{\left(\frac{\Delta CFM25_{DL}}{\left(\frac{Cap_{cool}}{12{,}000\frac{Btuh}{ton}}\right) \times TCFM} \times EFLH_{\ cool} \times Cap_{cool}\right)}{\left(SEER \times 1000\frac{W}{kW}\right)}$$

$$\Delta\, kWh/yr_{heating} = \frac{\left(\frac{\Delta CFM25_{DL}}{\left(\frac{Cap_{heat}}{12{,}000\frac{Btuh}{ton}}\right) \times TCFM} \times EFLH_{\ heat} \times Cap_{heat}\right)}{\left(COP \times 3412\frac{Btu}{kWh}\right)}$$

Methodology 2: RESNET Test 803.7

a) Determine Duct Leakage rate before and after performing duct sealing

$$\Delta CFM_{25DB} = CFM_{25BASE} - CFM_{25EE}$$

b) Calculate Energy Savings

$$\Delta\, kWh/yr_{cooling} = \frac{\left(\frac{\Delta CFM_{25DB}}{\left(\frac{Cap_{cool}}{12{,}000\frac{Btuh}{ton}}\right) \times TCFM} \times EFLH_{\ cool} \times Cap_{cool}\right)}{\left(SEER \times 1000\frac{W}{kW}\right)}$$

$$\Delta kWh/yr_{heating} = \frac{\left(\frac{\Delta CFM_{25DB}}{\left(\frac{Cap_{heat}}{12{,}000\frac{Btuh}{ton}}\right) \times TCFM} \times EFLH_{\ heat} \times Cap_{heat}\right)}{\left(COP \times 3412\frac{Btu}{kWh}\right)}$$

Methodology 3: 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"

$$\Delta kWh/yr_{\ cooling} = \left\{\frac{\left(\frac{(DE_{after} - DE_{before})}{DE_{after}}\right) \times EFLH_{\ cool} \times Cap_{cool}}{SEER \times 1000\frac{W}{kW}}\right\}$$

$$\Delta kWh/yr_{\ heating} = \left\{\frac{\left(\frac{(DE_{after} - DE_{before})}{DE_{after}}\right) \times EFLH_{\ heat} \times Cap_{heat}}{COP \times 3412\frac{Btu}{kWh}}\right\}$$

Summer Coincident Peak Demand Savings

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

DEFINITION OF TERMS

Table 2-29: Duct Sealing – Values and References

Term	Unit	Value	Source
CF , Demand Coincidence Factor (See Section 1.5) for central AC systems	*Decimal*	Default = 0.647	11
$CFM50_{whole\ house}$, Duct leakage at 50 Pascal pressure differential	$\frac{ft^3}{min}$	EDC Data Gathering	EDC Data Gathering
CFM_{25DB} , Cubic feet per minute of air leaving the duct system at 25 Pascals	$\frac{ft^3}{min}$	EDC Data Gathering	12
CFM_{25BASE} , Standard Duct Leakage test result at 25 Pascal pressure differential of the duct system prior to sealing, calculated from the duct blaster fan flow chart	$\frac{ft^3}{min}$	EDC Data Gathering	12
CFM_{25EE} , Standard Duct Leakage test result at 25 Pascal pressure differential of the duct system after sealing, calculated from the duct blaster fan flow chart	$\frac{ft^3}{min}$	EDC Data Gathering	12
$CFM50_{envelope\ only}$, Standard Blower Door test result finding Cubic Feet per Minute at 50 Pascal pressure differential	$\frac{ft^3}{min}$	EDC Data Gathering	EDC Data Gathering
SCF , Subtraction Correction Factor to account for underestimation of duct	*None*	Table 4, on pg 45 of Minneapolis Blower	7, 10

Term	Unit	Value	Source
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		Door™ Operation Manual for Model 3 and Model 4 Systems (Source 10)	
Conv , Conversion factor from CFM50 to CFM25	*None*	0.64	2
SLF , Supply Loss Factor (% leaks sealed located in Supply ducts x 1)	*None*	EDC Data Gathering Default =0.5	4, EDC Data Gathering
RLF , Return Loss Factor (Portion of % leaks sealed located in Return ducts x 0.5)	*None*	EDC Data Gathering Default = 0.25	6, EDC Data Gathering
Cap_{cool} , Capacity of Air Cooling System	*Btu/hr*	EDC Data Gathering	EDC Data Gathering
Cap_{heat} , Capacity of Air Heating System	*Btu/hr*	EDC Data Gathering	EDC Data Gathering
TCFM , Conversion from tons of cooling to CFM	$\frac{CFM}{ton}$	400	7
SEER , Efficiency of cooling equipment	$\frac{Btu}{W \cdot h}$	EDC Data Gathering Default = 10	8, EDC Data Gathering
COP , Efficiency of Heating Equipment	*None*	EDC Data Gathering Default = 2.0	8, EDC Data Gathering
$EFLH_{cool}$, Cooling equivalent full load hours	$\frac{hours}{year}$	Allentown Cooling = 487 Hours Erie Cooling = 389 Hours Harrisburg Cooling = 551 Hours Philadelphia Cooling = 591 Hours Pittsburgh Cooling = 432 Hours Scranton Cooling = 417 Hours Williamsport Cooling = 422 Hours	Table 2-10Table 2-10
	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 2.2.1); EDC Data Gathering
$EFLH_{heat}$, Heating equivalent full load hours	$\frac{hours}{year}$	Allentown Heating = 1,193 Hours Erie Heating = 1,349 Hours Harrisburg Heating = 1,103 Hours Philadelphia Heating = 1,060 Hours	Table 2-10Table 2-10

Term	Unit	Value	Source
		Pittsburgh Heating = 1,209 Hours Scranton Heating = 1,296 Hours Williamsport Heating = 1,251 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 2.2.1); EDC Data Gathering
DE_{after} , Distribution efficiency after duct sealing	*None*	Variable	7, 9
DE_{before} , Distribution efficiency before duct sealing	*None*	Variable	7, 9

Evaluation Protocols

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

Sources

1. Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007. http://library.cee1.org/sites/default/files/library/8842/CEE_Eval_MeasureLifeStudyLights%26HVACGDS_1Jun2007.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
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/sites/default/files/documents/duct_blaster_manual_series_b_-_dg700.pdf

6. Assumes 50% of leaks are in return ducts (Illinois Statewide TRM 2013).
7. Illinois Statewide TRM, 2013, Section 5.3.4.
8. Minimum Federal Standards for new Central Air Conditioners and Air Source Heat Pumps between 1990 and 2006 based on VEIC estimates.
9. Building Performance Institute, Distribution Efficiency Table, http://www.bpi.org/files/pdf/DistributionEfficiencyTable-BlueSheet.pdf
10. Minneapolis Blower Door™ Operation Manual for Model 3 and Model 4 Systems. http://www.energyconservatory.com/sites/default/files/documents/mod_3-4_dg700_-_new_flow_rings_-_cr_-_tpt_-_no_fr_switch_manual_ce_0.pdf
11. Straub, Mary and Switzer, Sheldon."Using Available Information for Efficient Evaluation of Demand Side Management Programs". Study by BG&E. The Electricity Journal. Aug/Sept. 2011. http://www.sciencedirect.com/science/article/pii/S1040619011001941
12. Resnet Energy Services Network, Standards for Performance Testing. http://www.resnet.us/standards/DRAFT_Chapter_8_July_22.pdf

2.2.7 Furnace Whistle

Measure Name	Furnace Whistle
Target Sector	Residential Establishments
Measure Unit	Furnace whistle (to promote regular filter change-out)
Unit Energy Savings	Varies
Unit Peak Demand Reduction	Varies
Measure Life	14 years[83]
Vintage	Retrofit

Eligibility

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 (33 through 39) presents the annual kWh savings for each major urban center in Pennsylvania based on their respective estimated full load hours (EFLH). Where homes do not have A/C or heat pump systems for cooling, only the annual heating savings will apply.

Algorithms

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

$$\Delta kWh/yr_{heat} = kW_{motor} \times EFLH_{heat} \times EI \times ISR$$

$$\Delta kWh/yr_{cool} = kW_{motor} \times EFLH_{cool} \times EI \times ISR$$

$$\Delta kW_{peak} = \frac{\Delta kWh/yr_{cool}}{EFLH_{cool}} \times CF$$

[83] See Appendix A, assumed to be the life of the HVAC unit.

Definition of Terms

Table 2-30: Furnace Whistle - References

Component	Unit	Value	Sources
kW_{motor} , Average motor full load electric demand (kW)	kW	0.5	1, 2
$EFLH_{Heat}$, Estimated Full Load Hours (Heating) for the EDC region	$\frac{hours}{yr}$	Variable. See Table 2-31	Table 2-10
$EFLH_{Cool}$, Estimated Full Load Hours (Cooling) for the EDC region.	$\frac{hours}{yr}$	Variable. See Table 2-31	TRM Table 2-10
EI , Efficiency Improvement	%	15%	3, 6
ISR , In-service Rate	%	EDC Data Gathering Default= 47.4%	4
CF , Coincidence Factor	*Fraction*	0.647	5

Table 2-31: 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

Default Savings

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

Table 2-32: 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

ΔkW_{peak} = 0.0229 kW (Pittsburgh)

Table 2-33: 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

ΔkW_{peak} = 0.0231 (Philadelphia)

Table 2-34: 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

ΔkW_{peak} = 0.0231 kW (Harrisburg)

Table 2-35: 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

ΔkW_{peak} = 0.0231 kW (Erie)

Table 2-36: 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

ΔkW_{peak} = 0.0231 kW (Allentown)

Table 2-37: 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

ΔkW_{peak} = 0.0230 kW (Scranton)

Table 2-38: 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

ΔkW_{peak} = 0.0228 kW (Williamsport)

Evaluation Protocols

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

Sources

1. 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%.
5. Straub, Mary and Switzer, Sheldon."Using Available Information for Efficient Evaluation of Demand Side Management Programs". Study by BG&E. The Electricity Journal. Aug/Sept. 2011. http://www.sciencedirect.com/science/article/pii/S1040619011001941
6. Energy.gov. “Maintaining Your Air Conditioner”. Accessed 7/16/2014. Says that replacing a dirty air filter with a clean one can lower total air conditioner energy consumption by 5-15%. Since the algorithms in this measure only take into account the blower fan energy use, a 15% savings seems reasonable.

2.2.8 Programmable Thermostat

Measure Name	Programmable Thermostat
Target Sector	Residential Establishments
Measure Unit	Programmable Thermostat
Unit Energy Savings	*Varies*
Unit Peak Demand Reduction	*Varies*
Measure Life	11years[84]
Vintage	Retrofit

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.

Eligibility

This measure documents the energy savings resulting from the installation of a programmable thermostat instead to replace an existing standard thermostat. The target sector is primarily residential.

Algorithms

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

$$\Delta kWh_{cool} = \frac{CAPY_{cool}}{1000\frac{W}{kW}} \times \frac{1}{SEER \times Eff_{duct}} \times EFLH_{cool} \times ESF_{cool}$$

$$\Delta kWh_{heat} = \frac{CAPY_{heat}}{1000\frac{W}{kW}} \times \frac{1}{HSPF \times Eff_{duct}} \times EFLH_{heat} \times ESF_{heat}$$

$$\Delta kW_{peak} = 0$$

Definition of Terms

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

Table 2-39: Residential Electric HVAC Calculation Assumptions

Component	Unit	Value	Sources
$CAPY_{COOL}$, Capacity of air conditioning unit	$\frac{Btu}{hr}$	EDC Data Gathering of Nameplate data	EDC Data Gathering
		Default= 32,000	1
$CAPY_{HEAT}$, Normal heat capacity of Electric Furnace	$\frac{Btu}{hr}$	EDC Data Gathering of Nameplate Data	EDC Data Gathering
		Default= 32,000	1
SEER , Seasonal Energy Efficiency Ratio	$\frac{Btu}{W \cdot h}$	EDC Data Gathering of Nameplate data	EDC Data Gathering
		Default= 11.9	1
HSPF , Heating Seasonal Performance Factor of heat pump	$\frac{Btu}{W \cdot h}$	EDC Data Gathering of Nameplate data	EDC Data Gathering
		Default= 3.413 (equivalent to electric furnace COP of 1)	2
Eff_{duct} , Duct System Efficiency	*None*	0.8	3
ESF_{COOL} , Energy Saving Factor for Cooling	*None*	0.02	4
ESF_{HEAT} , Energy Saving Factor for Heating	*None*	0.036	5
$EFLH_{COOL}$, Equivalent Full Load hour for Cooling	$\frac{hours}{day}$	Allentown Cooling = 487 Hours Erie Cooling = 389 Hours Harrisburg Cooling = 551 Hours Philadelphia Cooling = 591 Hours Pittsburgh Cooling = 432 Hours Scranton Cooling = 417 Hours Williamsport Cooling = 422 Hours	6
	Optional	Can use the more EDC-specific values in Table 2-11	Alternate EFLH Table 2-11
	Optional	An EDC can estimate it's own EFLH based on customer billing data analysis.	EDC Data Gathering
$EFLH_{HEAT}$, Full Load Hours for Heating	$\frac{hours}{day}$	Allentown Heating = 1,193 Hours Erie Heating = 1,349 Hours Harrisburg Heating = 1,103 Hours Philadelphia Heating = 1,060 Hours Pittsburgh Heating = 1,209 Hours Scranton Heating = 1,296 Hours Williamsport Heating = 1,251 Hours	6
	Optional	An EDC can use the Alternate EFLH values in Table 2-12	Alternate EFLH Table 2-12
	Optional	An EDC can estimate it's own EFLH based on customer billing data analysis.	EDC Data Gathering

Evaluation Protocols

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

Sources

1. Data set from the 2012 Pennsylvania Residential End-Use and Saturation Study submitted to Pennsylvania PUC by GDS Associates, Nexant, 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[85] and 40% oversizing of heat pumps.[86]

[85] 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, http://ecw.org/sites/default/files/241-1_0.pdf

[86] ACCA, "Verifying ACCA Manual S Procedures,"http://www.acca.org/wp-content/uploads/2014/01/Manual_S_verification.pdf.

2.2.9 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[87]
Vintage	Retrofit

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.

Eligibility

This protocol documents the energy savings for the installation of a whole house fan to be used as a compliement to an existing central HVAC system. The target sector is primarily residential.

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.[88] Energy savings for this measure are based on whole house fan energy savings values reported by the energy modeling software, REM/Rate.[89]

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.[90]

[87] *DEER EUL Summary*, Database for Energy Efficient Resources, accessed October 2010, http://www.deeresources.com.
[88] *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
[89] Architectural Energy Corporation, REM/Rate v12.85.
[90] 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 2-40: 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).

Evaluation Protocols

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

2.3 DOMESTIC HOT WATER

2.3.1 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[91]
Vintage	Replace on Burnout

Efficient electric water heaters utilize superior insulation to achieve energy factors of 0.93 or above. Standard electric water heaters have energy factors of 0.904.

ELIGIBILITY

This protocol documents the energy savings attributed to electric water heaters with Energy Factor of 0.93 or greater (0.94 or greater for a 30 gallon unit). The target sector primarily consists of single-family residences.

ALGORITHMS

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

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

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 demand between 2 PM and 6 PM on summer weekdays to the total annual energy usage.

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

The Energy to Demand Factor is defined below:

$$ETDF = \frac{AverageDemand_{Summer\ WD\ 2\text{-}6\ PM}}{AnnualEnergyUsage}$$

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

The ratio of the average demand between 2 PM and 6 PM on summer weekdays to the total annual energy usage is taken from an electric water heater metering study performed by BG&E (pg 95 of Source 5).

Definition of Terms

The parameters in the above equation are listed in Table 2-41 below.

Table 2-41: Efficient Electric Water Heater Calculation Assumptions

Component	Unit	Values	Source
EF_{base} , Energy Factor of baseline water heater	*None*	See Table 2-42	1
EF_{ee} , Energy Factor of proposed efficient water heater	*None*	EDC Data Gathering Default = 0.93 (0.94 for 30 gallon)	Program Design; EDC Data Gathering
HW , Hot water used per day in gallons	$\frac{gallon}{day}$	50	2
T_{hot} , Temperature of hot water	°F	119	3
T_{cold} , Temperature of cold water supply	°F	55	4
$ETDF$, Energy to Demand Factor (defined above)	$\frac{kW}{kWh/yr}$	0.00008047	5

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 2-42: Minimum Baseline Energy Factors based on Tank Size

Tank Size (gallons)	Energy Factor
30	0.9304
40	0.9172
50	0.9040
65	0.8842
80	0.8644
120	0.8116

Note: The new Federal standards that go into effect 4/16/2015 will be incorporated into this measure in the 2016 TRM. These can be viewed at:

http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/27. Do to the increase in baseline efficiency, this measure may no longer provide savings and will be considered for removal during the 2016 TRM development cycle.

DEFAULT SAVINGS

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

$$\Delta kWh/yr = \left(\frac{1}{EF_{Base}} - \frac{1}{EF_{ee}}\right) \times (2841.27\ kWh/yr)$$

$$\Delta kW_{peak} = \left(\frac{1}{EF_{base}} - \frac{1}{EF_{ee}}\right) \times (0.22864\ kW)$$

EVALUATION PROTOCOLS

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

SOURCES

1. Federal Standards are 0.97 -0.00132 x Rated Storage in Gallons. For a 50-gallon tank this is 0.904. “Energy Conservation Program: Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters” US Dept of Energy Docket Number: EE–2006–BT-STD–0129, p. 30
2. Residential Energy Consumption Survey, EIA, 2009.
3. Pennsylvania Statewide Residential End-Use and Saturation Study, 2014.
4. Mid-Atlantic TRM Version 3.0, March 2013, footnote #314
5. Straub, Mary and Switzer, Sheldon. "Using Available Information for Efficient Evaluation of Demand Side Management Programs". Study by BG&E. The Electricity Journal, Aug/Sept. 2011. http://www.sciencedirect.com/science/article/pii/S1040619011001941

2.3.2 Heat Pump Water Heaters

Measure Name	Heat Pump Water Heaters
Target Sector	Residential Establishments
Measure Unit	Water Heater
Unit Energy Savings	Variable based on energy factors
Unit Peak Demand Reduction	Variable based on energy factors
Measure Life	14 years[92]
Vintage	Replace on Burnout

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

Eligibility

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

Algorithms

The energy savings calculation utilizes average performance data for available residential heat pump and standard electric resistance water heaters and typical water usage for residential homes. The algorithms take into account interactive effects between the water heater and HVAC system when installed inside conditioned space. The energy savings are obtained through the following formula:

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

Include below interactive effects calculations only when water heater is installed inside conditioned space with electric heating and cooling.

- If either electric heating or electric cooling is absent, then the respective interactive effect will equal zero.
- When installed outside of conditioned space, both interactive effects will equal zero, and the appropriate F_{derate} in Table 2-47 will account for reduced performance due to cooler annual temperatures.
- If installation location is unknown, use the 'Default' value for F_{derate} in Table 2-47 and both interactive effects will equal zero.

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

$$\Delta kWh/yr_{ie,cool} = \frac{HW \times 8.3\frac{lbs}{gal} \times 1\frac{Btu}{lbs\cdot°F} \times (T_{hot} - T_{cold}) \times EFLH_{cool}}{24\frac{hrs}{day} \times SEER \times 1000\frac{W}{kW}}$$

$$\Delta kWh/yr_{ie,heat} = -\left[\frac{HW \times 8.3\frac{lbs}{gal} \times 1\frac{Btu}{lbs\cdot°F} \times (T_{hot} - T_{cold}) \times EFLH_{heat}}{24\frac{hrs}{day} \times HSPF \times 1000\frac{W}{kW}}\right]$$

For heat pump water heaters, demand savings result primarily from a reduced connected load. However, since the interactive effects during the heating season have no effect on the peak demand, the heating season interactive effects are subtracted from the total kWh savings before the ETDF is applied. The demand reduction is taken as the annual energy savings multiplied by the ratio of the average demand between 2 PM and 6 PM on summer weekdays to the total annual energy usage.

$$\Delta kW_{peak} = ETDF \times \left(\Delta kWh/yr - \Delta kWh/yr_{ie,heat}\right)$$

ETDF (Energy to Demand Factor) is defined below:

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

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

Definition of Terms

The parameters in the above equation are listed in Table 2-43.

Table 2-43: Heat Pump Water Heater Calculation Assumptions

Component	Unit	Values	Source
EF_{base}, Energy Factor of baseline water heater	*None*	See Table 2-46 Default= 0.904 (EF for 50 gallon)	1, 7
EF_{ee}, Energy Factor of proposed efficient water heater	*gallons*	EDC Data Gathering Default : 2.0	Program Design; EDC Data Gathering
HW , Hot water used per day in gallons	$\frac{gallons}{day}$	50	2
T_{hot}, Temperature of hot water	*°F*	119	3
T_{cold}, Temperature of cold water supply	*°F*	55	4
F_{derate}, COP De-rating factor	*Fraction*	Table 2-47	5, and discussion below
$EFLH_{cool}$, Equivalent Full Load Hours for cooling	$\frac{hours}{yr}$	Table 2-44	6
$EFLH_{heat}$, Equivalent Full Load Hours for heating	$\frac{hours}{yr}$	Table 2-45	6
HSPF , Heating Seasonal Performance Factor	$\frac{Btu}{W \cdot h}$	EDC Data Gathering Default= 7.4	7
SEER , Seasonal Energy Efficiency Ratio	$\frac{Btu}{W \cdot h}$	EDC Data Gathering Default= 12	7
ETDF , Energy to Demand Factor (defined above)	$\frac{kW}{kWh/yr}$	0.00008047	8

Table 2-44: Equivalent Full Load Hours for Cooling Season

City	$EFLH_{cool}$
Allentown	487
Erie	389
Harrisburg	551
Philadelphia	591
Pittsburgh	432
Scranton	417
Williamsport	422

Table 2-45: Equivalent Full Load Hours for Heating Season

City	$EFLH_{heat}$
Allentown	1,193
Erie	1,349
Harrisburg	1,103
Philadelphia	1,060
Pittsburgh	1,209
Scranton	1,296
Williamsport	1,251

Energy Factors Based on Tank Size

Federal Standards for electric water heater 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 2-46: Minimum Baseline Energy Factors Based on Tank Size

Tank Size (gallons)	Minimum Energy Factor (EF_{Base})
40	0.9172
50	0.9040
65	0.8842
80	0.8644
120	0.8116

Note: The new Federal standards that go into effect 4/16/2015 will be incorporated into this measure in the 2016 TRM. These can be viewed at:

http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/27

Heat Pump Water Heater Energy Factor

The Energy Factors are determined from a DOE testing procedure that is carried out at 67.5˚F dry bulb and 56 °F wet bulb temperatures. However, the average dry and wet bulb temperatures in PA are in the range of 50-56˚F DB and 45-50 °F WB[93]. The heat pump performance is temperature and humidity dependent, therefor the location and type of installation is significant. To account for this, an EF de-rating factor (F_{derate}) has been adapted from a 2013 NEEA HPWH field study (Source 5). The results used are for "Heating Zone 1", which is comprised of Olympia, WA and Portland, OR and have average dry and wet bulb temperatures (51˚F DB, 47˚F WB and 55˚F DB, 49˚F WB, respectively) [94]comparable to Pennsylvania.

Table 2-47: EF De-rating Factor for Various Installation Locations

Installation Location	F_{derate}[95]
Inside Conditioned Space	0.98
Unconditioned Garage	0.85
Unconditioned Basement	0.72
Default[96]	0.87

Default Savings

Default savings for the installation of heat pump water heaters not located inside conditioned space are calculated using the formulas below.

$$\Delta kWh/yr = \left(\frac{1}{EF_{base}} - \frac{1}{(EF_{ee} \times F_{derate})}\right) \times (2841.27\ kWh/yr)$$

$$\Delta kW_{peak} = \left(\frac{1}{EF_{base}} - \frac{1}{(EF_{ee} \times F_{derate})}\right) \times (0.22864\ kW)$$

Evaluation Protocols

The most appropriate evaluation protocol for this measure is verification of installation coupled with calculation of energy and demand savings using above algorithms.

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

[93] Based on average weather data from weatherbase.com for the 7 Pennsylvania cities referenced elsewhere in this TRM (Allentown, Erie, Harrisburg, Philadelphia, Pittsburgh, Scranton, Williamsport).
[94] Ibid
[95] Calculated by dividing the COP in each location from Figure 15 by the rated Energy Factor (2.35) of the unit tested in the study (AirGenerate ATI66).
[96] Weighted average of values in Table 107 for water heater locations for all space heating fuel types. Northwest Energy Efficiency Alliance 2011 Residential Building Stock Assessment: Single-Family Characteristics and Energy Use. Published September 18, 2012. Online at http://neea.org/docs/reports/residential-building-stock-assessment-single-family-characteristics-and-energy-use.pdf?sfvrsn=8

2. Residential Energy Consumption Survey, EIA, 2009.
3. Pennsylvania Statewide Residential End-Use and Saturation Study, 2014.
4. Mid-Atlantic TRM Version 3.0, March 2013, footnote #314
5. NEEA Heat Pump Water Heater Field Study Report. Prepared by Fluid Market Strategies, 2013. http://neea.org/docs/default-source/reports/heat-pump-water-heater-field-study-report.pdf?sfvrsn=5 (Note: when this source discusses “ducted” vs “non-ducted” systems it refers to the water heater’s heat pump exhaust, not to the HVAC ducts.)
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 conditioners97 and 40% oversizing of heat pumps.[98]
7. 2014 Pennsylvania Residential Baseline Study. Presented to the PUC by GDS Associates.
8. Straub, Mary and Switzer, Sheldon. "Using Available Information for Efficient Evaluation of Demand Side Management Programs". Study by BG&E. The Electricity Journal, Aug/Sept. 2011. http://www.sciencedirect.com/science/article/pii/S1040619011001941

[97] 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

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

2.3.3 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	0.277 kW
Measure Life	15 years[99]
Vintage	Retrofit

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

Eligibility

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

Algorithms

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

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

The energy factor used in the above equation represents an average energy factor of market available solar water heaters[100].

The demand reduction is taken as the annual energy usage of the *baseline* water heater multiplied by the ratio of the average demand between 2PM and 6PM on summer weekdays to the total annual energy usage. Note that this is a different formulation than the demand savings calculations for other water heaters. This modification of the formula reflects the fact that a solar water heater’s capacity is subject to seasonal variation, and that during the peak summer season, the water heater is expected to fully supply all domestic hot water needs.

[99] ENERGY STAR Solar Water Heater Benefits and Savings. Accessed 8/8/2014. http://www.energystar.gov/index.cfm?c=solar_wheat.pr_savings_benefits

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

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

$$Where: \quad kWh/yr_{base} = \frac{\left(\frac{1}{EF_{base}}\right) \times HW \times 365\frac{days}{yr} \times 8.3\frac{lbs}{gal} \times 1\frac{Btu}{lbs \cdot {}^{\circ}F} \times (T_{hot} - T_{cold})}{3413\frac{Btu}{kWh}}$$

ETDF (Energy to Demand Factor) is defined below:

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

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

Definition of Terms

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

Table 2-48: Solar Water Heater Calculation Assumptions

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

Energy Factors Based on Tank Size

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

Table 2-49: Minimum Baseline Energy Factors Based on Tank Size

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

Note: The new Federal standards that go into effect 4/16/2015 will be incorporated into this measure in the 2016 TRM. These can be viewed at:

http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/27

Default Savings

The partially-deemed algorithm for savings attributable to the installation of a solar water heater is given below.

$$\Delta kWh/yr = \left(\frac{1}{EF_{base}} - \frac{1}{EF_{ee}}\right) \times \left(2841.27\,\frac{kWh}{yr}\right)$$

$$\Delta kW_{peak} = \left(\frac{1}{EF_{base}}\right) \times (0.22864\ kW)$$

Evaluation Protocols

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

Sources

1. The average energy factor for all solar water heaters with collector areas of 50 ft^2 or smaller is from https://secure.solar-rating.org/Certification/Ratings/RatingsSummaryPage.aspx. As a cross check, we have calculated that the total available solar energy in PA for the same set of solar collectors is about twice as much as the savings claimed herein – that is, there is sufficient solar capacity to actualize an average energy factor of 1.84.
2. Straub, Mary and Switzer, Sheldon. "Using Available Information for Efficient Evaluation of Demand Side Management Programs". Study by BG&E. The Electricity Journal, Aug/Sept. 2011. http://www.sciencedirect.com/science/article/pii/S1040619011001941
3. Federal Standards are 0.97 -0.00132 x Rated Storage in Gallons. For a 50 gallon tank, this is 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
4. Residential Energy Consumption Survey, EIA, 2009.
5. Pennsylvania Statewide Residential End-Use and Saturation Study, 2014.
6. Mid-Atlantic TRM Version 3.0, March 2013, footnote #314

2.3.4 Fuel Switching: Electric Resistance to Fossil Fuel Water Heater

Measure Name	Fuel Switching: Electric Resistance to Fossile Fuel Water Heater
Target Sector	Residential
Measure Unit	Water Heater
Unit Energy Savings	3,338 kWh/yr
Unit Peak Demand Reduction	0.2687 kW
Gas, Fossil Fuel Consumption Increase	Gas: 15.38 MMBtu Propane: 15.38 MMBtu Oil: 20.04 MMBtu
Measure Life	Gas:13 years[101] Propane: 13 years[102] Oil: 8 years[103]
Vintage	Replace on Burnout

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

Eligibility

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

Algorithms

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

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

[101] 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/).
[102] DEER Effective Useful Life values, updated October 10, 2008.
[103] ibid.

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:

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

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 between2 PM and 6 PM on summer weekdays to the total annual energy usage.

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

ETDF (Energy to Demand Factor) is defined below:

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

The ratio of the average energy usage between 2 PM and 6 PM on summer weekdays to the total annual energy usage is taken from an electric water heater metering study performed by BG&E (pg 95 of Source 7).

Definition of Terms

The parameters in the above equation are listed in Table 2-50 below.

Table 2-50: Calculation Assumptions for Fuel Switching Electric Resistance to Fossil Fuel Water Heater

Component	Unit	Values	Source
$EF_{elec,bl}$, Energy Factor of baseline water heater	*Fraction*	EDC Data Gathering Default: Table 2-51	1
$EF_{NG,inst}$, Energy Factor of installed natural gas water heater	*Fraction*	EDC Data Gathering Default: ≥0.67	2
$EF_{Propane,inst}$, Energy Factor of installed propane water heater	*Fraction*	EDC Data Gathering Default: ≥0.67	2
$EF_{Tankless\ Water\ Heater}$, Energy Factor of installed tankless water heater	*Fraction*	EDC Data Gathering Default: ≥0.82	2
$EF_{Oil,inst}$, Energy Factor of installed oil water heater*	*Fraction*	EDC Data Gathering Default: ≥0.514	3
HW , Hot water used per day in gallons	$\frac{gallons}{day}$	50	4
T_{hot} , Temperature of hot water	°F	119	5
T_{cold} , Temperature of cold water supply	°F	55	6
$ETDF$, Energy to Demand Factor (defined above)		0.00008047	7

Component	Unit	Values	Source
	$\frac{kW}{kWh/yr}$		

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 2-51: Minimum Baseline Energy Factors based on Tank Size

Tank Size (gallons)	Minimum Energy Factors ($EF_{elec,bl}$)
40	0.9172
50	0.9040
65	0.8842
80	0.8644
120	0.8116

Default Savings

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

$$\Delta kWh/yr = \left(\frac{1}{EF_{elec,bl}}\right) \times \left(2841.27\,\frac{kWh}{yr}\right)$$

$$\Delta kW_{peak} = \left(\frac{1}{EF_{elec,bl}}\right) \times (0.22864\ kW)$$

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 2-52 below.

Table 2-52: Energy Savings and Demand Reductions for Fuel Switching, Domestic Hot Water Electric to Fossil Fuel

Electric unit Energy Factor	Energy Savings (kWh/yr)	Demand Reduction (kW)
0.904	3143	0.2529

The 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 2-53 below.

Table 2-53: 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: 1 MMBtu of propane is equivalent to 10.87 gals of propane, and 1 MMBtu of oil is equivalent to 7.19 gals of oil[104].

Evaluation Protocols

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

Sources

1. Federal Standards are 0.97 -0.00132 x Rated Storage in Gallons. For a 50-gallon tank this is 0.904. "Energy Conservation Program: Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters" US Dept of Energy Docket Number: EE–2006–BT-STD–0129, p. 30
2. Commission Order[105] requires fuel switching to ENERGY STAR measures, not standard efficiency measures. The Energy Factor has therefore been updated to reflect the EnergyStar standard for Gas Storage Water Heaters beginning September 1, 2010. From Residential Water Heaters Key Product Criteria. http://www.energystar.gov/index.cfm?c=water_heat.pr_crit_water_heaters Accessed June 2013
3. Federal Standards are 0.67 -0.0019 x Rated Storage in Gallons for oil-fired storage water heater. For a 40-gallon tank this 0.514. "Energy Conservation Program: Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters" US Dept of Energy Docket Number: EE–2006–BT-STD–0129, p. 307. "Energy Conservation Program for Consumer Products: Test Procedure for Water Heaters", Federal Register / Vol. 63, No. 90, p. 26005-26006.
4. "Energy Conservation Program for Consumer Products: Test Procedure for Water Heaters", Federal Register / Vol. 63, No. 90, p. 26005-26006.
5. Pennsylvania Statewide Residential End-Use and Saturation Study, 2014.
6. Mid-Atlantic TRM Version 3.0, March 2013, footnote #314
7. Straub, Mary and Switzer, Sheldon. "Using Available Information for Efficient Evaluation of Demand Side Management Programs". Study by BG&E. The Electricity Journal. Aug/Sept, 2011. http://www.sciencedirect.com/science/article/pii/S1040619011001941

[104] http://www.energystar.gov/ia/business/industry/industry_challenge/QuickConverter.xls
[105] See page 42 of the 2013 TRC Test Final Order

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

Measure Name	Fuel Switching: Heat Pump Water Heater to Fossil Fuel Heater
Target Sector	Residential
Measure Unit	Water Heater
Unit Energy Savings	1,734.5 kWh (for EF = 2.0)
Unit Peak Demand Reduction	0.140kW
Gas, Fossil Fuel Consumption Increase	Gas: 15.38 MMBtu Propane: 15.38 MMBtu Oil: 20.04 MMBtu
Measure Life	Gas:13 years[106] Propane: 13 years[107] Oil: 8 years[108]
Vintage	Replace on Burnout

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

Eligibility

This protocol documents the energy savings attributed to converting from a standard heat pump water heater with Energy Factor of 2.0 or greater to an ENERGY STAR natural gas or propane water heater with Energy Factor of 0.67 or greater and 0.514 for an oil water heater. If a customer submits a rebate for a product that has applied for ENERGY STAR Certification but has not yet been certified, the savings will be counted for that product contingent upon its eventual certification as an ENERGY STAR measure. If at any point the product is rejected by ENERGY STAR, the product is then ineligible for the program and savings will not be counted.
The target sector primarily consists of single-family residences.

Algorithms

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

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

106 DEER Effective Useful Life values, updated October 10, 2008.
107 ibid.
108 ibid.

Include below interactive effects calculations only when water heater is installed inside conditioned space with electric heating and cooling.

- If either electric heating or cooling is absent, then the respective interactive effect will equal zero.
- When installed outside of conditioned space, both interactive effects will equal zero and the appropriate F_{derate}in Table 2-57 will account for reduced performance due to cooler annual temperatures.
- If installation location is unknown, use the 'Default' value for F_{derate} in Table 2-57 and both interactive effects will equal zero.

$$\Delta kWh/yr_{ie,cool} = \frac{HW \times 8.3\frac{lbs}{gal} \times 1\frac{Btu}{lbs \cdot {}^{\circ}F} \times (T_{hot} - T_{cold}) \times EFLH_{cool}}{24\frac{hrs}{day} \times SEER \times 1000\frac{W}{kW}}$$

$$\Delta kWh/yr_{ie,heat} = -\left[\frac{HW \times 8.3\frac{lbs}{gal} \times 1\frac{Btu}{lbs \cdot {}^{\circ}F} \times (T_{hot} - T_{cold}) \times EFLH_{heat}}{24\frac{hrs}{day} \times HSPF \times 1000\frac{W}{kW}}\right]$$

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:

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

Demand savings result from the removal of the connected load of the heat pump water heater. However, since the interactive effects during the heating season have no effect on the peak demand, the heating season interactive effects are subtracted from the total kWh savings before the ETDF is applied. The demand reduction is taken as the annual energy savings multiplied by the ratio of the average demand between 2 PM and 6 PM on summer weekdays to the total annual energy usage.

$$\Delta kW_{peak} = ETDF \times \left(\Delta kWh/yr - \Delta kWh/yr_{ie,heat}\right)$$

ETDF (Energy to Demand Factor) is defined below:

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

The ratio of the average energy usage between 2 PM and 6 PM on summer weekdays to the total annual energy usage is taken from an electric water heater metering study performed by BG&E (pg 95 of Source 8).

Definition of Terms

The parameters in the above equation are listed in Table 2-54.

Table 2-54: Calculation Assumptions for Heat Pump Water Heater to Fossil Fuel Water Heaters

Component	Unit	Values	Source
$EF_{HP,bl}$, Energy Factor of baseline heat pump water heater	*Fraction*	Default ≥ 2.0 or EDC Data Gathering	1
$EF_{NG,inst}$. Energy Factor of installed natural gas water heater	*Fraction*	≥ 0.67 or EDC Data Gathering	2
$EF_{Propane,inst}$, Energy Factor of installed propane water heater	*Fraction*	>=0.67 or EDC Data Gathering	2
$EF_{Tankless\ Water\ Heater}$, Energy Factor of installed tankless water heater	*Fraction*	>=0.82	2
$EF_{Oil,inst}$, Energy Factor of installed oil water heater	*Fraction*	>=0.514 or EDC Data Gathering	3
HW , Hot water used per day in gallons	$\frac{gallons}{day}$	50	4
T_{hot} , Temperature of hot water	°F	119	5
T_{cold} , Temperature of cold water supply	°F	55	6
F_{Derate} , COP De-rating factor	*Fraction*	Table 2-57	7, and discussion below
$EFLH_{cool}$, Equivalent Full Load Hours for cooling	$\frac{hours}{yr}$	Table 2-55	8
$EFLH_{heat}$, Equivalent Full Load Hours for heating	$\frac{hours}{yr}$	Table 2-56	8
HSPF , Heating Seasonal Performance Factor	$\frac{Btu}{W \cdot h}$	EDC Data Gathering Default= 7.4	9
SEER , Seasonal Energy Efficiency Ratio	$\frac{Btu}{W \cdot h}$	EDC Data Gathering Default= 12	9
ETDF, Average Usage per Average Energy Usage	$\frac{kW}{kWh/yr}$	0.00008047	10

Table 2-55: Equivalent Full Load Hours for Cooling Season

City	$EFLH_{cool}$
Allentown	487
Erie	389
Harrisburg	551
Philadelphia	591
Pittsburgh	432
Scranton	417
Williamsport	422

Table 2-56: Equivalent Full Load Hours for Heating Season

City	$EFLH_{heat}$
Allentown	1,193
Erie	1,349
Harrisburg	1,103
Philadelphia	1,060
Pittsburgh	1,209
Scranton	1,296
Williamsport	1,251

Heat Pump Water Heater Energy Factor

The Energy Factors are determined from a DOE testing procedure that is carried out at 67.5˚F dry bulb and 56 °F wet bulb temperatures. However, the average dry and wet bulb temperatures in PA are in the range of 50-56˚F DB and 45-50 °F WB[109]. The heat pump performance is temperature and humidity dependent, therefore the location and type of installation is significant. To account for this, an EF de-rating factor (F_{derate}) has been adapted from a 2013 NEEA HPWH field study (Source 7). The results used are for "Heating Zone 1", which is comprised of Olympia, WA and Portland, OR and have average dry and wet bulb temperatures (51˚F DB, 47˚F WB and 55˚F DB, 49˚F WB, respectively) [110] which is comparable to Pennsylvania.

[109] Based on average weather data from weatherbase.com for the 7 Pennsylvania cities referenced elsewhere in this TRM (Allentown, Erie, Harrisburg, Philadelphia, Pittsburgh, Scranton, Williamsport).
[110] Ibid

Table 2-57: EF De-rating Factor for Various Installation Locations

Installation Location	F_{derate}[111]
Inside Conditioned Space	0.98
Unconditioned Garage	0.85
Unconditioned Basement	0.72
Default[112]	0.87

DEFAULT SAVINGS

The savings for the installation of a fossil fuel water heater in place of a heat pump water heater not located inside conditioned space should be calculated using the partially deemed algorithm below.

$$\Delta kWh/yr = \left(\frac{1}{EF_{HP,bl} \times F_{Derate}}\right) \times \left(2841.27 \frac{kWh}{yr}\right)$$

$$\Delta kW_{peak} = \left(\frac{1}{EF_{HP,bl} \times F_{Derate}}\right) \times (0.22864\ kW)$$

The fossil fuel consumption should be calculated using the partially deemed algorithm below.

Fossil Fuel Consumption (MMBtu/yr) = $\left(\frac{1}{EF_{NG,inst}}\right) \times \left(10.3 \frac{MMBtu}{yr}\right)$

The default savings for the installation of a fossil fuel-fired water heater in place of a standard heat pump water heater in an unknown, default location are listed in Table 2-58 below.

Table 2-58: Energy Savings and Demand Reductions for Heat Pump Water Heater to Fossil Fuel Water Heater in Unknown Installation Location

Heat Pump unit Energy Factor	Energy Savings (kWh)	Demand Reduction (kW)
2.0	1632.9	0.1314

The default gas consumption for the installation of an ENERGY STAR natural gas, propane or oil water heater in place of a standard heat pump water heater is listed in
Table 2-59 below.

111 Calculated by dividing the COP in each location from Figure 15 by the rated Energy Factor (2.35) of the unit tested in the study (AirGenerate ATI66).

112 Weighted average of values in Table 107 for water heater locations for all space heating fuel types. Northwest Energy Efficiency Alliance 2011 Residential Building Stock Assessment: Single-Family Characteristics and Energy Use. Published September 18, 2012. Online at http://neea.org/docs/reports/residential-building-stock-assessment-single-family-characteristics-and-energy-use.pdf?sfvrsn=8

Table 2-59: Gas, Oil, Propane Consumption for Heat Pump Water Heater to Fossil Fuel Water Heater

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

Evaluation Protocols

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

Sources

1. Heat pump water heater efficiencies have not been set in a Federal Standard. However, the Federal Standard for water heaters does refer to a baseline efficiency for heat pump water heaters as EF = 2.0 "Energy Conservation Program: Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters" US Dept of Energy Docket Number: EE–2006–BT-STD–0129.
2. Commission Order[113] requires fuel switching to ENERGY STAR measures, not standard efficiency measures. The Energy Factor has therefore been updated to reflect the EnergyStar standard for Gas Storage Water Heaters beginning September 1, 2010. From Residential Water Heaters Key Product Criteria. http://www.energystar.gov/index.cfm?c=water_heat.pr_crit_water_heaters Accessed June 2013 Federal Standards are 0.67 -0.0019 x Rated Storage in Gallons. Federal Standards are 0.67 -0.0019 x Rated Storage in Gallons. For a 40-gallon tank this is 0.594. "Energy Conservation Program: Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters" US Dept of Energy Docket Number: EE–2006–BT-STD–0129**,** p. 30
3. Federal Standards are 0.67 -0.0019 x Rated Storage in Gallons for oil-fired storage water heater. For a 40-gallon tank this 0.514. "Energy Conservation Program: Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters" US Dept of Energy Docket Number: EE–2006–BT-STD–0129, p. 307. "Energy Conservation Program for Consumer Products: Test Procedure for Water Heaters", Federal Register / Vol. 63, No. 90, p. 26005-26006.
4. "Energy Conservation Program for Consumer Products: Test Procedure for Water Heaters", Federal Register / Vol. 63, No. 90, p. 26005-26006.
5. Pennsylvania Statewide Residential End-Use and Saturation Study, 2014.
6. Mid-Atlantic TRM Version 3.0, March 2013, footnote #314
7. NEEA Heat Pump Water Heater Field Study Report. Prepared by Fluid Market Strategies, 2013. http://neea.org/docs/default-source/reports/heat-pump-water-heater-field-study-report.pdf?sfvrsn=5 (Note: when this source discusses "ducted" vs "non-ducted" systems it refers to the water heater's heat pump exhaust, not to the HVAC ducts.)

8. 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 conditioners114 and 40% oversizing of heat pumps.[115]
9. 2014 Pennsylvania Residential Baseline Study. Presented to the PUC by GDS Associates.
10. Straub, Mary and Switzer, Sheldon. "Using Available Information for Efficient Evaluation of Demand Side Management Programs". Study by BG&E. The Electricity Journal, Aug/Sept. 2011. http://www.sciencedirect.com/science/article/pii/S1040619011001941

[114] 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

[115] ACCA, "Verifying ACCA Manual S Procedures," http://www.acca.org/wp-content/uploads/2014/01/Manual-S-Brochure-Final.pdf

2.3.6 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[116]
Vintage	Retrofit

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.

Eligibility

This measure documents the energy savings attributed to installing an insulating tank wrap on an existing electric resistance water heater. The target sector is residential.

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.

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

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

Definition of Terms

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.[117] The default inputs for the savings algorithms are given in Table 2-60. 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 2-60: Water Heater Tank Wrap – Default Values

Component	Unit	Value	Source
R_{base}, R-value is a measure of resistance to heat flow and is equal to $1/U_{base}$	$\frac{Hr\cdot F\cdot ft^2}{Btu}$	Default: 8.3 or EDC Data Gathering	1

[116] DEER Version 2008.2.05, December 16, 2008.
[117] "Energy Savers", U.S. Department of Energy, accessed November, 2010 http://www.energysavers.gov/your_home/water_heating/index.cfm/mytopic=13070

Component	Unit	Value	Source
R_{insul} , R-value is a measure of resistance to heat flow and is equal to $1/U_{insul}$	$\frac{Hr \cdot °F \cdot ft^2}{Btu}$	Default: 20 or EDC Data Gathering	2
U_{base} , Overall heat transfer coefficient of water heater prior to adding tank wrap	$\frac{Btu}{Hr \cdot °F \cdot ft^2}$	$=1/R_{base}$	
U_{insul} , Overall heat transfer coefficient of water heater after addition of tank wrap	$\frac{Btu}{Hr \cdot °F \cdot ft^2}$	$=1/R_{insul}$	
A_{base} , Surface area of storage tank prior to adding tank wrap	ft^2	See Table 2-61	
A_{insul} , Surface area of storage tank after addition of tank wrap	ft^2	See Table 2-61	
η_{Elec} , Thermal efficiency of electric heater element	*None*	0.98	3
$T_{setpoint}$, Temperature of hot water in tank	˚F	119	5
$T_{ambient}$, Temperature of ambient air	˚F	70	5
HOU , Annual hours of use for water heater tank	*Hours*	8760	4
CF , Demand Coincidence Factor	*Decimal*	1.0	4

Table 2-61: Deemed savings by water heater capacity

Capacity (gal)	R_{base}	R_{insul}	A_{base} (ft^2)[118]	A_{insul} (ft^2)[119]	ΔkWh	ΔkW
30	8	16	19.16	20.94	139.4	0.0159
30	10	18	19.16	20.94	96.6	0.0110
30	12	20	19.16	20.94	70.6	0.0081
30	8	18	19.16	20.94	158.1	0.0180
30	10	20	19.16	20.94	111.6	0.0127
30	12	22	19.16	20.94	82.8	0.0094
40	8	16	23.18	25.31	168.9	0.0193
40	10	18	23.18	25.31	117.1	0.0134
40	12	20	23.18	25.31	85.5	0.0098
40	8	18	23.18	25.31	191.5	0.0219
40	10	20	23.18	25.31	135.1	0.0154
40	12	22	23.18	25.31	100.3	0.0114
50	8	16	24.99	27.06	183.9	0.0210
50	10	18	24.99	27.06	127.8	0.0146
50	12	20	24.99	27.06	93.6	0.0107
50	8	18	24.99	27.06	208.0	0.0237

[118] 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.
[119] A_{insul} was calculated by assuming that the water heater wrap is a 2" thick fiberglass material.

Capacity (gal)	R_{base}	R_{insul}	A_{base} (ft^2)[118]	A_{insul} (ft^2)[119]	ΔkWh	ΔkW
50	10	20	24.99	27.06	147.1	0.0168
50	12	22	24.99	27.06	109.4	0.0125
80	8	16	31.84	34.14	237.0	0.0271
80	10	18	31.84	34.14	165.3	0.0189
80	12	20	31.84	34.14	121.5	0.0139
80	8	18	31.84	34.14	267.4	0.0305
80	10	20	31.84	34.14	189.6	0.0216
80	12	22	31.84	34.14	141.4	0.0161

Evaluation Protocols

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

Sources

1. 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. AHRI Directory. All electric storage water heaters have a recovery efficiency of .98. https://www.ahridirectory.org/ahridirectory/pages/rwh/defaultSearch.aspx
4. It is assumed that the tank wrap will insulate the tank during all hours of the year.
5. 2014 Residential SWE Baseline Study. GDS Associates.

2.3.7 Water Heater Temperature Setback

Measure Name	Water Heater Temperature Setback
Target Sector	Residential Establishments
Measure Unit	Water Heater Temperature
Unit Energy Savings	Varies
Unit Peak Demand Reduction	Varies
Measure Life	4 years[120]
Vintage	Retrofit

In homes where the water heater setpoint temperature is set high, savings can be achieved by 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, faucet, and dishwasher use 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.

Eligibility

This protocol documents the energy savings attributed to reducing the electric or heat pump water heater temperature setpoint. The target sector primarily consists of single-family residences.

Algorithms

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:

$$\Delta kWh/yr = \frac{A_{tank} \times (T_{hot\ i} - T_{hot\ f}) \times 8760\frac{hrs}{yr}}{R_{tank} \times \eta_{elec} \times 3412\frac{Btu}{kWh}} + \frac{V_{HW} \times \left(8.3\frac{lb}{gal}\right) \times \left(365\frac{days}{yr}\right) \times \left(1\frac{Btu}{°F \cdot lb}\right) \times (T_{hot\ i} - T_{hot\ f})}{\left(3412\frac{Btu}{kWh}\right) \times EF_{WH}}$$

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 demand between2 PM and 6 PM on summer weekdays to the total annual energy usage.

[120] GDS Associates, Inc., Measure Life Report Prepared for The New England State program Working Group (SPWG), June 2007, http://library.cee1.org/sites/default/files/library/8842/CEE_Eval_MeasureLifeStudyLights%26HVACGDS_1Jun2007.pdf

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

ETDF (Energy to Demand Factor) is defined below:

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

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

Definition of Terms

The parameters in the above equation are listed in Table 2-62 below.

Table 2-62: Water Heater Temperature Setback Assumptions

Component	Unit	Values	Source
EF_{WH} , Energy Factor of water heater	*Fraction*	EDC data collection Default: Electric Storage= 0.904 HPWH= 2.0	1
R_{tank} , R value of water heater tank,	$\frac{hr \cdot °F \cdot ft^2}{Btu}$	EDC Data Gathering Default: 8.3[121]	
A_{tank} , Surface Area of water heater tank,	ft^2	EDC Data Gathering Default: 24.99	50 gal. value in Table 2-63
η_{elec} , Thermal efficiency of electric heater element (equiv. to COP for HPWH)	*Decimal*	Electric Storage: 0.98 HPWH: 2.1	2, 3
V_{HW} , Volume of hot water used per day, in gallons	*gallons/day*	7.32	4, 5, 6, 7
T_{hot_i} , Temperature setpoint of water heater initially	*°F*	EDC Data Gathering Default: 130	8
T_{hot_f} , Temperature setpoint water heater after setback	*°F*	EDC data collection Default: 119	9
ETDF , Energy To Demand Factor (defined above)	$\frac{kW}{kWh/yr}$	0.00008047	10

Note: The new Federal standards that go into effect 4/16/2015 will be incorporated into this measure in the 2016 TRM. These can be viewed at:

http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/27

[121] Results and Methodology of the Engineering Analysis for Residential Water Heater Efficiency Standards, PNNL, 1998

Deemed Savings

The energy savings and demand reductions are prescriptive according to the above formulae. However, some values for common configurations are provided in
Table 2-63 below.

Table 2-63: Energy Savings and Demand Reductions

Type	Tank Size (gallons)	R_{tank}	A_{tank}	$T_{hot\,i} - T_{hot\,f}$ (°F)	η_{elec}	EF_{WH}	Energy Savings $(\Delta\,kWh/yr)$	Demand Reduction (ΔKW_{peak})
Electric Storage	50	8.3	24.99	10	0.98	0.904	150.8	0.0121
Electric Storage	50	8.3	24.99	5	0.98	0.904	75.4	0.0061
HPWH	50	8.3	24.99	10	2.1	2.0	69.3	0.0056
HPWH	50	8.3	24.99	5	2.1	2.0	34.7	0.0028

Evaluation Protocols

The most appropriate evaluation protocol for this measure is verification of water heater temperature setpoint coupled with assignment of stipulated energy savings.

Sources

1. Federal Standards are 0.97 -0.00132 x Rated Storage in Gallons. For a 50-gallon tank this is 0.904. "Energy Conservation Program: Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters" US Dept of Energy Docket Number: EE–2006–BT-STD–0129, p. 30
2. AHRI Directory. All electric storage water heaters have a recovery efficiency of .98. https://www.ahridirectory.org/ahridirectory/pages/rwh/defaultSearch.aspx
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
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.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".
5. Average capacity of base (3.19 cu. ft.) and energy efficient (3.64 cu. ft.) clothes washers, Table 2-107, Section 2.26.
6. 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)
7. 2007-2011 U.S. Census Data for Pennsylvania (2.47 persons per household average).
8. Engineering assumption
9. Pennsylvania Statewide Residential End-Use and Saturation Study, 2014.

10. Straub, Mary and Switzer, Sheldon. "Using Available Information for Efficient Evaluation of Demand Side Management Programs". Study by BG&E. The Electricity Journal, Aug/Sept. 2011.

2.3.8 Water Heater Pipe Insulation

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

This measure relates to the installation of foam insulation on 10 feet of exposed pipe in unconditioned space, ¾” thick. The baseline for this measure is a standard efficiency electric water heater (EF=0.904) with an annual energy usage of 3.338 kWh. [123]

Eligibility

This protocol documents the energy savings for an electric water heater attributable to insulating 10 feet of exposed pipe in unconditioned space, ¾” thick. The target sector primarily consists of residential establishments.

Algorithms

The annual energy savings are assumed to be 3% of the annual energy use of an electric water heater (3,338 kWh), or 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 (Source 1). On a per foot basis, this is equivalent to 10 kWh.

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

The summer coincident peak kW savings are calculated as follows:

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

Definition of Terms

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

122 Efficiency Vermont, Technical Reference User Manual: Measure Savings Algorithms and Cost Assumptions, TRM User Manual No. 2008-53, 07/18/08, http://www.veic.org/docs/ResourceLibrary/TRM-User-Manual-Excerpts.pdf.

123 See “Efficient Electric Water Heater” sectionfor assumptions used to calculate annual energy usage.

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

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

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

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

Evaluation Protocols

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

Sources

1. American Council for an Energy-Efficient Economy, Summit Blue Consulting, Vermont Energy Investment Corporation, ICF International, and Synapse Energy Economics, Potential for Energy Efficiency, Demand Response, and Onsite Solar Energy in Pennsylvania, Report Number E093, April 2009, p. 117.
2. Straub, Mary and Switzer, Sheldon. "Using Available Information for Efficient Evaluation of Demand Side Management Programs". Study by BG&E. The Electricity Journal. Aug/Sept. 2011.

2.3.9 Low Flow Faucet Aerators

Measure Name	Low Flow Faucet Aerators
Target Sector	Residential Establishments
Measure Unit	Aerator
Unit Energy Savings	Varies by installation location
Unit Peak Demand Reduction	Varies by installation location
Measure Life	12 years[124]
Vintage	Retrofit

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.

Eligibility

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

Algorithms

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

$$\Delta\, kWh/yr$$

$$= ISR \times ELEC \times \left[\frac{(GPM_{base} - GPM_{low}) \times T_{person/day} \times N_{persons} \times 365\frac{days}{yr} \times DF \times (T_{out} - T_{in}) \times 8.3\frac{Btu}{gal\cdot°F}}{\#_{faucets} \times 3412\frac{Btu}{kWh} \times RE}\right]$$

$$\Delta kW_{peak} = \Delta\, kWh/yr \times ETDF$$

Where:

$$\mathrm{ETDF} = \frac{\mathrm{CF}}{HOU}$$

$$CF = \frac{\%_{faucet\ use,peak} \times \mathrm{T_{person/day}} \times \mathrm{N_{persons}}}{\#_{\mathrm{faucets}} \times 240\frac{minutes}{daily\ peak}}$$

[124] California's Database of Energy Efficiency Resources (DEER).

$$HOU = \frac{T_{person/day} \times N_{persons} \times 365\frac{days}{yr}}{\#_{faucets} \times 60\frac{minutes}{hour}}$$

The ratio of the average energy usage during 2 PM and 6 PM on summer weekdays to the total annual energy usage is taken from average daily load shape data collected for faucets from an Aquacraft, Inc study.[125] The average daily load shapes (percentages of daily energy usage that occur within each hour) are plotted in Figure 2-1 below (symbol FAU represents faucets).

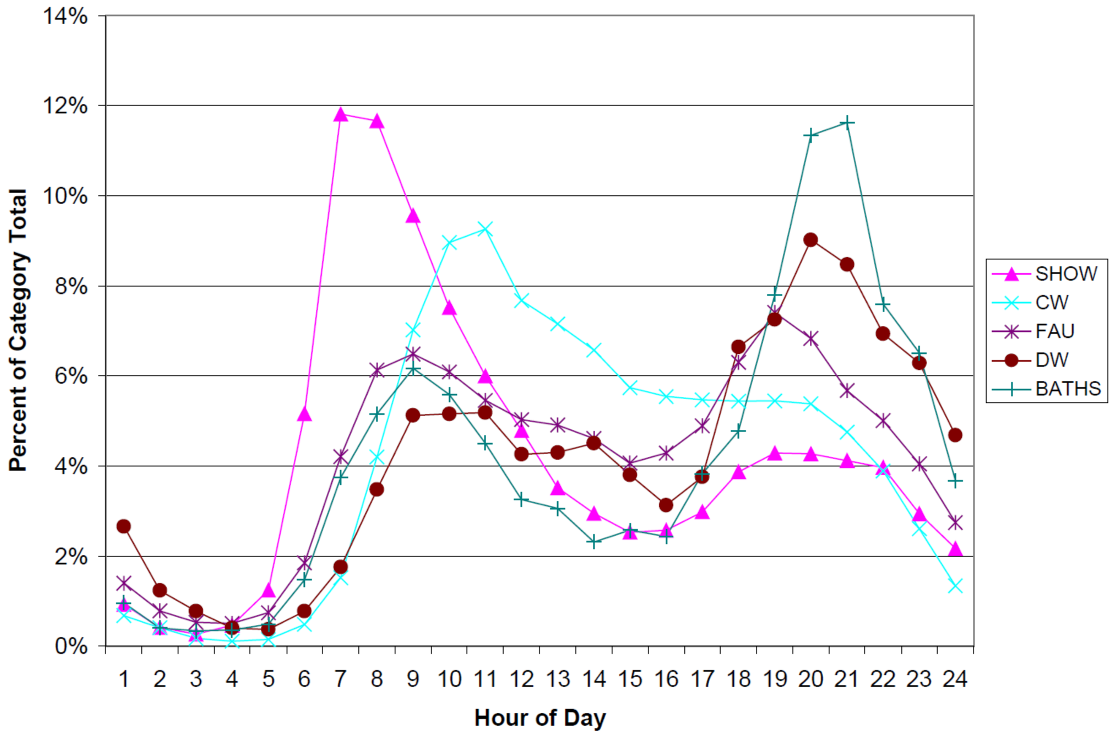

Figure 2-1: Daily Load Shapes for Hot Water Measurers

DEFINITION OF TERMS

The parameters in the above equation are defined in Table 2-64.

[125] 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.

Table 2-64: Low Flow Faucet Aerator Calculation Assumptions

Term	Unit	Value	Source
GPM_{base} , Average baseline flow rate of aerator (GPM)	$\frac{gallons}{minute}$	Default =2.2 Or EDC Data Gathering	1
GPM_{low} , Average post measure flow rate of aerator (GPM)	$\frac{gallons}{minute}$	Default = 1.5 Or EDC Data Gathering	1
$T_{Person\text{-}Day}$, Average time of hot water usage per person per day (minutes)	$\frac{minutes}{day}$	Kitchen=4.5 Bathroom=1.6 Unknown=6.1	2
$N_{Persons}$, Average number of persons per household	$\frac{persons}{house}$	Default SF=2.4 Default MF=1.9 Default Unknown=2.4 Or EDC Data Gathering	3
T_{out} , Average mixed water temperature flowing from the faucet (ºF)	˚F	Kitchen=93 Bathroom=86 Unknown= 87.8	4
T_{in} , Average temperature of water entering the house (ºF)	˚F	55	5, 6
RE , Recovery efficiency of electric water heater	*Decimal*	0.98	7
ETDF, Energy To Demand Factor	$\frac{kW}{kWh/yr}$	0.000134	8
$\#_{faucets}$, Average number of faucets in the home	$\frac{faucets}{house}$	SF: Kitchen=1.0 Bathroom=3.0 Unknown=4.0 MF: Kitchen=1.0 Bathroom=1.7 Unknown=2.7 Unknown Home Type: Kitchen=1.0 Bathroom=2.8 Unknown=3.8 Or EDC Data Gathering	9
DF , Percentage of water flowing down drain	%	Kitchen=75% Bathroom=90% Unknown=79.5%	10
ISR , In Service Rate	%	Variable	EDC Data Gathering
ELEC , Percentage of homes with electric water heat	%	Default=43% Or EDC Data Gathering	11
$\%_{faucet\ use,peak}$, percentage of daily faucet use	%	19.5%	8

Term	Unit	Value	Source
during PJM peak period			

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

$$\Delta kWh = 1.0 * 1.0 * (((2.2 - 1.5) * 4.5 * 2.4 * 365 * (93 - 55) * 8.3 * (1/3412) * 0.75 / 0.98) / 1)$$
$$= 195.2 \text{ kWh}$$

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

$$\Delta kWh = 1.0 * 1.0 * (((2.2 - 1.5) * 6.1 * 2.6 * 365 * (87.8 - 55) * 8.3 * (1/3412) * 0.795 / 0.98) / 4.0)$$
$$= 63.7 \text{ kWh per faucet}$$

Default Savings

Housing Type	Faucet Location	Unit Energy Savings (kWh)	Unit Demand Savings (kW)
Single Family	Kitchen	83.9	0.0112
	Bathroom	9.7	0.0013
	Unknown	26.0	0.0035
Multifamily	Kitchen	66.5	0.0089
	Bathroom	13.6	0.0018
	Unknown	30.5	0.0041
Statewide (Unknown Housing Type)	Kitchen	83.9	0.0112
	Bathroom	10.4	0.0014
	Unknown	27.4	0.0037

Evaluation Protocols

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

Sources

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 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 4-7, section 4.2.4. GDS Associates, Inc. Pennsylvania Statewide Residential End-Use Saturation Study, 2014. 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. 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*

7. AHRI Directory. All electric storage water heaters have a recovery efficiency of .98. https://www.ahridirectory.org/ahridirectory/pages/rwh/defaultSearch.aspx

8. 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 0.00339: [% faucet use during peak × ($T_{Person-Day}$× N_{Person}) /(F/home)] / 240 (minutes in peak period) = [19.5% × (6.1 x 2.6 / 3.8)] / 240 =0.00339. 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 be0.000134: CF / Hours = 0.00328 / 25.4 =0.000134.

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.

10. Illinois TRM Effective June 1, 2013. Faucet usages are at times dictated by volume, only “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.

11. Figure 4-17, Section 4.6.1 of the 2014 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.

2.3.10 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[126]
Vintage	Retrofit

This measure relates to the installation of a low flow (generally 1.5 GPM) showerhead in bathrooms in homes with electric water heater. The baseline is a standard showerhead using 2.5 GPM.

Eligibility

This protocol documents the energy savings attributable to replacing a standard showerhead with an energy efficient low flow showerhead for electric water heaters. The target sector primarily consists of residences establishments.

Algorithms

The annual energy savings are obtained through the following formula:

$$\Delta\, kWh/yr = ISR \times ELEC \times \left[\frac{(GPM_{base} - GPM_{low}) \times T_{person/day} \times N_{persons} \times N_{showers/day} \times 365\frac{days}{yr} \times (T_{out} - T_{in}) \times 8.3\frac{Btu}{gal{\cdot}°F}}{\#_{showers} \times 3412\frac{Btu}{kWh} \times RE}\right]$$

$$\Delta kW_{peak} = \Delta\, kWh/yr \times ETDF$$

Where:

$$\mathrm{ETDF} = \frac{\mathrm{CF}}{HOU}$$

$$CF = \frac{\%_{shower\ use,peak} \times \mathrm{T}_{\frac{\mathrm{person}}{\mathrm{day}}} \times \mathrm{N}_{\mathrm{persons}} \times N_{\frac{\mathrm{showers}}{\mathrm{day}}}}{\#_{\mathrm{showers}} \times 240\frac{minutes}{daily\ peak}}$$

$$HOU = \frac{\mathrm{T}_{\mathrm{person/day}} \times \mathrm{N}_{\mathrm{persons}} \times N_{\mathrm{showers/day}} \times 365\frac{days}{yr}}{\#_{\mathrm{showers}} \times 60\frac{minutes}{hour}}$$

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

[126] Efficiency Vermont, Technical Reference User Manual: Measure Savings Algorithms and Cost Assumptions, TRM User Manual No. 2008-53, 07/18/08, http://www.veic.org/docs/ResourceLibrary/TRM-User-Manual-Excerpts.pdf.

an Aquacraft, Inc study.[127] The average daily load shapes (percentages of daily energy usage that occur within each hour) during are plotted in Figure 2-2 below (symbol SHOW represents showerheads).

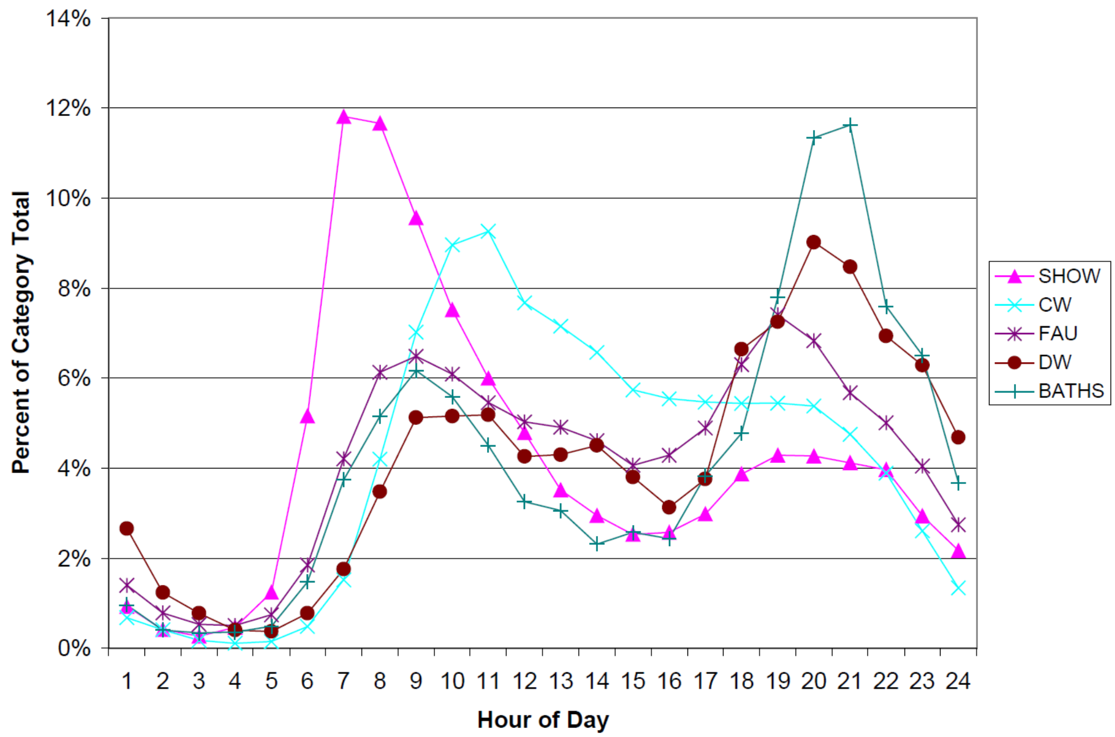

Figure 2-2: Daily Load Shapes for Hot Water Measures

Definition of Terms

Table 2-65: Low Flow Showerhead Calculation Assumptions

Term	Unit	Value	Source
GPM_{base} , Gallons per minute of baseline showerhead	$\frac{gallons}{minute}$	Default value = 2.5	1
GPM_{low} , Gallons per minute of low flow showerhead	$\frac{gallons}{minute}$	Default value = 1.5 or EDC Data Gathering	2
$T_{person/day}$, Average time of shower usage per person (minutes)	$\frac{minutes}{day}$	7.8	3
$N_{persons}$, Average number of persons per household	$\frac{persons}{house}$	Default SF=2.4 Default MF=1.9 Default unknown=2.4	4

[127] 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.

Term	Unit	Value	Source
		Or EDC Data Gathering	
$N_{\text{showers/day}}$, Average number of showers per person per day	$\frac{showers/per}{day}$	0.6	5
$\#_{showers}$, Average number of showers in the home	$\frac{showers}{house}$	Or EDC Data Gathering Default SF=1.3 Default MF=1.1 Default unknown = 1.2	6
T_{out} , Assumed temperature of water used by showerhead	° *F*	101	7
T_{in} , Assumed temperature of water entering house	° *F*	55	7,8
RE , Recovery efficiency of electric water heater	*Decimal*	0.98	9
ETDF , Energy To Demand Factor	$\frac{kW}{kWh/yr}$	0.00008013	10
ISR , In Service Rate	*%*	Variable	EDC Data Gatheri ng
ELEC , Percentage of homes with electric water heat	*%*	Default=43% Or EDC Data Gathering	11
$\%_{shower\ use,peak}$, percentage of daily shower use during PJM peak period	*%*	11.7%	10

For example, a direct-installed (*ISR=1*) 1.5 GPM low flow showerhead in a single family electric DHW home:

ΔkWh = 1.0 * 1.0 * [(2.5 – 1.5) * 7.8 * 0.6 * 2.4 * 365 * (101 - 55) * 8.3 * (1/3412) / 0.98] / 1.3
360.1 = 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 * 2.4 * 365 * (101 - 55) * 8.3 * (1/3412) / 0.98] / 1.2
390.1 = kWh

DEFAULT SAVINGS

Housing Type	Low Flow Rate (gpm)	Unit Energy Savings (kWh)	Unit Demand Savings (kW)
Single Family	2.0	77.4	0.0062
	1.75	116.1	0.0093
	1.5	154.8	0.0124
Multifamily	2.0	72.4	0.0058
	1.75	108.7	0.0087
	1.5	144.9	0.0116
Statewide (Unknown Housing Type)	2.0	83.9	0.0067
	1.75	125.8	0.0101
	1.5	167.7	0.0134

EVALUATION PROTOCOLS

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

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.
4. Table 4-7, section 4.2.4. GDS Associates, Inc. Pennsylvania Statewide Residential End-Use Saturation Study, 2014. 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.
6. Table 4-67, section 4.6.3. GDS Associates, Inc. Pennsylvania Statewide Residential End-Use Saturation Study, 2014. For The Pennsylvania Public Utility Commission.
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.

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*

9. AHRI Directory. All electric storage water heaters have a recovery efficiency of .98. https://www.ahridirectory.org/ahridirectory/pages/rwh/defaultSearch.aspx

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.

11. Figure 4-17, Section 4.6.1 of the 2014 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.

2.3.11 THERMOSTATIC SHOWER RESTRICTION VALVE

Measure Name	Thermostatic Shower Restriction Valve
Target Sector	Residential Establishments
Measure Unit	Water Heater
Unit Energy Savings	Partially Deemed
Unit Peak Demand Reduction	Partially Deemed
Measure Life	10 years[128]

This measure relates to the installation of a device that reduces hot water usage during shower warm-up by way of a thermostatic shower restriction valve, reducing hot water waste during shower warm-up.

ELIGIBILITY

This protocol documents the energy savings attributable to installing a thermostatic restriction valve, device, or equivalent product on an existing showerhead. Only homes with electric water heaters are eligible, and the savings associated with this measure may be combined with a low flow showerhead as the sum of the savings of the two measures using identical baseline GPM values. The target sector primarily consists of residences.

ALGORITHMS

The annual energy savings are obtained through the following formula:

$$\Delta kWh/yr = \frac{ISR \times ELEC \times GPM_{base}}{60\ \frac{sec}{min}} \times UH \times UE \times (T_{out} - T_{in}) \times \frac{(N_{persons} \times N_{showers-day})}{S/_{home}} \times \frac{BehavioralWasteSeconds}{RE} \times 365\frac{days}{yr}$$

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

The ratio of the average energy usage during 2 PM and 6 PM on summer weekdays to the total annual energy usage is taken from average daily load shape data collected for showerheads from an Aquacraft, Inc study.[129] The average daily load shapes (percentages of daily energy usage that occur within each hour) during are plotted in Figure 2-3 below (symbol SHOW represents showerheads).

[128] Alignment with New York and Michigan TRM.

[129] 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.

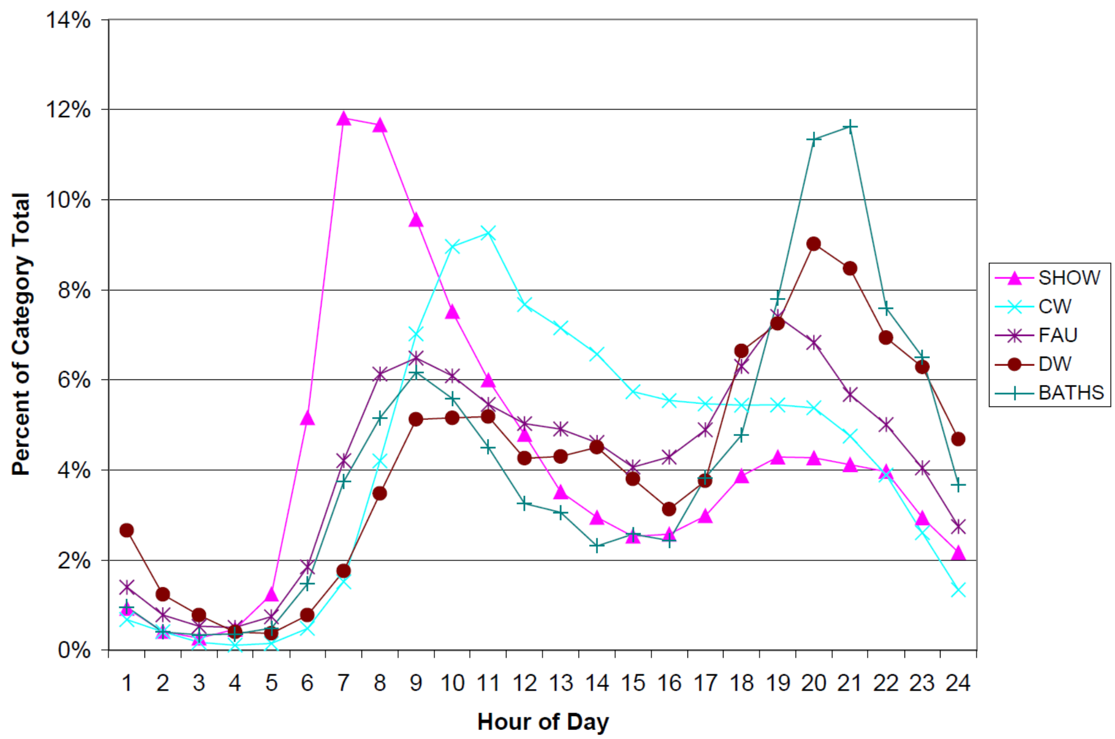

Figure 2-3: Daily Load Shapes for Hot Water Measures

Definition of Terms

Table 2-66: Assumptions for Thermostatic Shower Restriction Valve

Parameter	Unit	Value	Source
GPM_{Base}, Gallons per minute of baseline showerhead	$\frac{gallons}{min}$	Default value = 2.5 or EDC Data Gathering	1
$N_{persons}$, Average number of persons per household	$\frac{persons}{household}$	Default SF=2.4 Default MF=1.9 Default unknown=2.4 Or EDC Data Gathering	2
$N_{Showers\text{-}Day}$, Average number of showers per person per day	$\frac{showers}{day}$	0.6	3
days/year	$\frac{days}{yr}$	365	
S/home, Average number of showerhead fixtures in the home	*None*	Default SF=1.3 Default MF=1.1 Default unknown = 1.2 Or EDC Data Gathering	4
T_{out}, Assumed temperature of water used by showerhead	$^\circ F$	101 Or EDC Data Gathering	5
T_{in}, Assumed temperature of water entering house	$^\circ F$	55	6,7

Parameter	Unit	Value	Source
U_H, Unit Conversion	$\frac{Btu}{Gal \times °F}$	8.3	Convention
U_E, Unit Conversion	$\frac{kWh}{Btu}$	1/3412	Convention
RE, Recovery efficiency of electric water heater	*Decimal*	0.98	7
ETDF, Energy To Demand Factor	$\frac{kW}{kWh/yr}$	0.00008013	8
ISR, In Service Rate	*%*	Variable	EDC Data Gathering
ELEC, Percentage of homes with electric water heat	*%*	Default=43% Or EDC Data Gathering	9
BehavioralWasteSeconds, Time	*sec*	Default = 55 or EDC Data Gathering	10

Default Savings

Table 2-67: Restriction Valve Calculation Assumptions

Application	Baseline Flowrate (GPM)	Energy Savings (kWh/yr)	Peak Demand Reduction (kW)	Therm Savings
Single Family	2.5	45.5	0.0036	4.7
	2	36.4	0.0029	3.7
	1.5	27.3	0.0022	2.8
Multifamily	2.5	42.6	0.0034	4.4
	2	34.1	0.0027	3.5
	1.5	25.5	0.0020	2.6
Unknown / Default Housing Type	2.5	49.3	0.0039	5
	2	39.4	0.0032	4
	1.5	29.6	0.0024	3

Evaluation Protocols

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

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. Table 4-7, section 4.2.4. GDS Associates, Inc. Pennsylvania Statewide Residential End-Use Saturation Study, 2014. For The Pennsylvania Public Utility Commission.

3. 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. Table 4-67, section 4.6.3. GDS Associates, Inc. Pennsylvania Statewide Residential End-Use Saturation Study, 2014. For The Pennsylvania Public Utility Commission.

5. 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.

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*

7. AHRI Directory. All electric storage water heaters have a recovery efficiency of .98. https://www.ahridirectory.org/ahridirectory/pages/rwh/defaultSearch.aspx

8. 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. Figure 4-17, Section 4.6.1 of the 2014 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.

10. Estimate based on ShowerStart™ Pilot Project White Paper 2008, City of San Diego and the Pennsylvania Power and Electric Pilot Study, 2014.

2.4 Appliances

2.4.1 ENERGY STAR Refrigerators

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[130]
Vintage	Replace on Burnout

Eligibility

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.

Algorithms

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

$$Total\ Savings = Number\ of\ Refrigerators \times Savings\ per\ Refrigerator$$

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 baseline model's annual energy consumption (kWh_{base}) may be determined using Table 2-69.

The efficient model's annual energy consumption (kWh_{ee} or kWh_{me}) may be determined using manufacturers' test data for the given model. Where test data is not available the algorithms in Table 2-69 and Table 2-71 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.

ENERGY STAR Refrigerator

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

$$\Delta kW_{peak} = (kWh_{base} - kWh_{ee}) \times ETDF$$

[130] ENERGY STAR Appliances.November 2013. U.S. Environmental Protection Agency and U.S. Department of Enegy. ENERGY STAR. http://www.energystar.gov/.

ENERGY STAR Most Efficient Refrigerator

$\Delta kWh/yr \qquad = kWh_{base} - kWh_{me}$

$\Delta kW_{peak} \qquad = (kWh_{base} - kWh_{me}) \times ETDF$

DEFINITION OF TERMS

Table 2-68: Assumptions for ENERGY STAR Refrigerators

Term	Unit	Value	Source
kWh_{base} , Annual energy consumption of baseline unit	kWh/yr	Table 2-69	1
kWh_{ee} , Annual energy consumption of ENERGY STAR qualified unit	kWh/yr	EDC Data Gathering Default= Table 2-69	2
kWh_{me} , Annual energy consumption of ENERGY STAR Most Efficient qualified unit	kWh/yr	EDC Data Gathering Default = Table 2-71	3
ETDF , Energy to Demand Factor	$\frac{kW}{kWh/yr}$	0.0001119	4

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 consumption (kWh_{base}) of the federal standard model may be determined using Table 2-69. The efficient model's annual energy consumption (kWh_{ee} or kWh_{me}) may be determined using manufacturer's test data for the given model. Where test data is not available, the algorithms in Table 2-69 and Table 2-71 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" in ft^3, where AV = (Fresh Volume) + 1.63 x (Freezer Volume).

Table 2-69: Federal Standard and ENERGY STAR Refrigerators Maximum Annual Energy Consumption if Configuration and Volume Known[131]

Refrigerator Category	Federal Standard Maximum Usage in kWh/yr	ENERGY STAR Maximum Energy Usage in kWh/yr
Standard Size Models: 7.75 cubic feet or greater		
1. Refrigerator-freezers and refrigerators other than all-refrigerators with manual defrost.	7.99AV + 225.0	7.19 * AV + 202.5
1A. All-refrigerators—manual defrost.	6.79AV + 193.6	6.11 * AV + 174.2

[131] Lettering convention (1, 1A, etc) of Federal standard and ENERGY STAR specifications included for clear reference to the standards as well as for correspondence to entries in the default savings table.

Refrigerator Category	Federal Standard Maximum Usage in kWh/yr	ENERGY STAR Maximum Energy Usage in kWh/yr
2. Refrigerator-freezers—partial automatic defrost	7.99AV + 225.0	7.19 * AV + 202.5
3. Refrigerator-freezers—automatic defrost with top-mounted freezer without an automatic icemaker.	8.07AV + 233.7	7.26 * AV + 210.3
3-BI. Built-in refrigerator-freezer—automatic defrost with top-mounted freezer without an automatic icemaker.	9.15AV + 264.9	8.24 * AV + 238.4
3I. Refrigerator-freezers—automatic defrost with top-mounted freezer with an automatic icemaker without through-the-door ice service.	8.07AV + 317.7	7.26 * AV + 294.3
3I-BI. Built-in refrigerator-freezers—automatic defrost with top-mounted freezer with an automatic icemaker without through-the-door ice service.	9.15AV + 348.9	8.24 * AV + 322.4
3A. All-refrigerators—automatic defrost.	7.07AV + 201.6	6.36 * AV + 181.4
3A-BI. Built-in All-refrigerators—automatic defrost.	8.02AV + 228.5	7.22 * AV + 205.7
4. Refrigerator-freezers—automatic defrost with side-mounted freezer without an automatic icemaker.	8.51AV + 297.8	7.66 * AV + 268.0
4-BI. Built-In Refrigerator-freezers—automatic defrost with side-mounted freezer without an automatic icemaker.	10.22AV + 357.4	9.20 * AV + 321.7
4I. Refrigerator-freezers—automatic defrost with side-mounted freezer with an automatic icemaker without through-the-door ice service.	8.51AV + 381.8	7.66 * AV + 352.0
4I-BI. Built-In Refrigerator-freezers—automatic defrost with side-mounted freezer with an automatic icemaker without through-the-door ice service.	10.22AV + 441.4	9.20 * AV + 405.7
5. Refrigerator-freezers—automatic defrost with bottom-mounted freezer without an automatic icemaker.	8.85AV + 317.0	7.97 * AV + 285.3
5-BI. Built-In Refrigerator-freezers—automatic defrost with bottom-mounted freezer without an automatic icemaker.	9.40AV + 336.9	8.46 * AV + 303.2
5I. Refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker without through-the-door ice service.	8.85AV + 401.0	7.97 * AV + 369.3
5I-BI. Built-In Refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker without through-the-door ice service.	9.40AV + 420.9	8.46 * AV + 387.2
5A. Refrigerator-freezer—automatic defrost with bottom-mounted freezer with through-the-door ice service.	9.25AV + 475.4	8.33 * AV + 436.3
5A-BI. Built-in refrigerator-freezer—automatic defrost with bottom-mounted freezer with through-the-door ice service.	9.83AV + 499.9	8.85 * AV + 458.3

Refrigerator Category	Federal Standard Maximum Usage in kWh/yr	ENERGY STAR Maximum Energy Usage in kWh/yr
6. Refrigerator-freezers—automatic defrost with top-mounted freezer with through-the-door ice service.	8.40AV + 385.4	7.56 * AV + 355.3
7. Refrigerator-freezers—automatic defrost with side-mounted freezer with through-the-door ice service.	8.54AV + 432.8	7.69 * AV + 397.9
7-BI. Built-In Refrigerator-freezers—automatic defrost with side-mounted freezer with through-the-door ice service.	10.25AV + 502.6	9.23 * AV + 460.7
Compact Size Models: Less than 7.75 cubic feet and 36 inches or less in height		
11. Compact refrigerator-freezers and refrigerators other than all-refrigerators with manual defrost.	9.03AV + 252.3	8.13 * AV + 227.1
11A.Compact all-refrigerators—manual defrost.	7.84AV + 219.1	7.06 * AV + 197.2
12. Compact refrigerator-freezers—partial automatic defrost	5.91AV + 335.8	5.32 * AV + 302.2
13. Compact refrigerator-freezers—automatic defrost with top-mounted freezer.	11.80AV + 339.2	10.62 * AV + 305.3
13I. Compact refrigerator-freezers—automatic defrost with top-mounted freezer with an automatic icemaker.	11.80AV + 423.2	10.62 * AV + 389.3
13A. Compact all-refrigerators—automatic defrost.	9.17AV + 259.3	8.25 * AV + 233.4
14. Compact refrigerator-freezers—automatic defrost with side-mounted freezer.	6.82AV + 456.9	6.14 * AV + 411.2
14I. Compact refrigerator-freezers—automatic defrost with side-mounted freezer with an automatic icemaker.	6.82AV + 540.9	6.14 * AV + 495.2
15. Compact refrigerator-freezers—automatic defrost with bottom-mounted freezer.	11.80AV + 339.2	10.62 * AV + 305.3
15I. Compact refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker.	11.80AV + 423.2	10.62 * AV + 389.3

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

Table 2-70: Default Savings Values for ENERGY STAR Refrigerators[132]

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

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

Refrigerator Category	Assumed Volume of Unit (cubic feet)[133]	Conventional Unit Energy Usage in kWh/yr	ENERGY STAR Energy Usage in kWh/yr	ΔkWh/yr	ΔkW_{peak}
defrost.					
2. Refrigerator-freezers—partial automatic defrost	12.2	322	290	32	0.0036
3I. Refrigerator-freezers—automatic defrost with top-mounted freezer with an automatic icemaker without through-the-door ice service.	17.9	462	424	38	0.0042
4I. Refrigerator-freezers—automatic defrost with side-mounted freezer with an automatic icemaker without through-the-door ice service.	22.7	575	526	49	0.0055
5I. Refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker without through-the-door ice service.	20.0	578	529	49	0.0055
7. Refrigerator-freezers—automatic defrost with side-mounted freezer with through-the-door ice service.	24.6	643	587	56	0.0062
5A. Refrigerator-freezer—automatic defrost with bottom-mounted freezer with through-the-door ice service.	25.4	710	648	62	0.0070
3A. All-refrigerators—automatic defrost.	12.2	288	259	29	0.0032
Compact Size Models: Less than 7.75 cubic feet and 36 inches or less in height					
11A.Compact all-refrigerators—manual defrost.	3.3	245	220	24	0.0027
12. Compact refrigerator-freezers—partial automatic defrost	3.3	355	320	36	0.0040
13. Compact refrigerator-freezers—automatic defrost with top-mounted freezer.	4.5	392	353	39	0.0044
15. Compact refrigerator-freezers—automatic defrost with bottom-mounted freezer.	5.1	399	359	40	0.0045

ENERGY STAR Most Efficient annual energy consumption (kWh_{me}) may be determined using manufacturer's test data for the given model. Where test data is not available, the algorithms in Table 2-71 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 consumption (kWh_{base}) of the federal standard model may be determined using Table 2-69.

Table 2-71: ENERGY STAR Most Efficient Annual Energy Usage if Configuration and Volume Known

Refrigerator Category	ENERGY STAR Most Efficient Maximum Annual Energy Usage in kWh/yr
1. Refrigerator-freezers and refrigerators other than all-refrigerators with manual defrost.	AV ≤ 65.6, Eann ≤ 6.79*AV + 191.3 AV > 65.6, Eann ≤ 637
2. Refrigerator-freezers—partial automatic defrost	AV ≤ 65.6, Eann ≤ 6.79*AV + 191.3 AV > 65.6, Eann ≤ 637
3. Refrigerator-freezers—automatic defrost with top-mounted freezer without an automatic icemaker.	AV ≤ 63.9, Eann ≤ 6.86*AV + 198.6 AV > 63.9, Eann ≤ 637
3-BI. Built-in refrigerator-freezer—automatic defrost with top-mounted freezer without an automatic icemaker.	AV ≤ 63.9, Eann ≤ 6.86*AV + 198.6 AV > 63.9, Eann ≤ 637
3I. Refrigerator-freezers—automatic defrost with top-mounted freezer with an automatic icemaker without through-the-door ice service.	AV ≤ 51.6, Eann ≤ 6.86*AV + 282.6 AV > 51.6, Eann ≤ 637
3I-BI. Built-in refrigerator-freezers—automatic defrost with top-mounted freezer with an automatic icemaker without through-the-door ice service.	AV ≤ 51.6, Eann ≤ 6.86*AV + 282.6 AV > 51.6, Eann ≤ 637
4. Refrigerator-freezers—automatic defrost with side-mounted freezer without an automatic icemaker.	AV ≤ 53.0, Eann ≤ 7.23*AV + 253.1 AV > 53.0, Eann ≤ 637
4-BI. Built-In Refrigerator-freezers—automatic defrost with side-mounted freezer without an automatic icemaker.	AV ≤ 53.0, Eann ≤ 7.23*AV + 253.1 AV > 53.0, Eann ≤ 637
4I. Refrigerator-freezers—automatic defrost with side-mounted freezer with an automatic icemaker without through-the-door ice service.	AV ≤ 41.4, Eann ≤ 7.23*AV + 337.1 AV > 41.4, Eann ≤ 637
4I-BI. Built-In Refrigerator-freezers—automatic defrost with side-mounted freezer with an automatic icemaker without through-the-door ice service.	AV ≤ 41.4, Eann ≤ 7.23*AV + 337.1 AV > 41.4, Eann ≤ 637
5. Refrigerator-freezers—automatic defrost with bottom-mounted freezer without an automatic icemaker.	AV ≤ 48.8, Eann ≤ 7.52*AV + 269.5 AV > 48.8, Eann ≤ 637
5-BI. Built-In Refrigerator-freezers—automatic defrost with bottom-mounted freezer without an automatic icemaker.	AV ≤ 48.8, Eann ≤ 7.52*AV + 269.5 AV > 48.8, Eann ≤ 637
5I. Refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker without through-the-door ice service.	AV ≤ 37.7, Eann ≤ 7.52*AV + 353.5 AV > 37.7, Eann ≤ 637
5I-BI. Built-In Refrigerator-freezers—automatic defrost with bottom-mounted	AV ≤ 37.7, Eann ≤ 7.52*AV + 353.5

Refrigerator Category	ENERGY STAR Most Efficient Maximum Annual Energy Usage in kWh/yr
freezer with an automatic icemaker without through-the-door ice service.	AV > 37.7, Eann ≤ 637
5A. Refrigerator-freezer—automatic defrost with bottom-mounted freezer with through-the-door ice service.	AV ≤ 28.0, Eann ≤ 7.86*AV + 416.7 AV > 28.0, Eann ≤ 637
5A-BI. Built-in refrigerator-freezer—automatic defrost with bottom-mounted freezer with through-the-door ice service.	AV ≤ 28.0, Eann ≤ 7.86*AV + 416.7 AV > 28.0, Eann ≤ 637
6. Refrigerator-freezers—automatic defrost with top-mounted freezer with through-the-door ice service.	AV < 41.5, Eann ≤ 7.14*AV + 340.2 AV > 41.5, Eann ≤ 637
7. Refrigerator-freezers—automatic defrost with side-mounted freezer with through-the-door ice service.	AV ≤ 35.3, Eann ≤ 7.26*AV + 380.5 AV > 35.3, Eann ≤ 637
7-BI. Built-In Refrigerator-freezers—automatic defrost with side-mounted freezer with through-the-door ice service.	AV ≤ 35.3, Eann ≤ 7.26*AV + 380.5 AV > 35.3, Eann ≤ 637

Default Savings

The default values for each ENERGY STAR Most Efficient configuration are given in Table 2-72.

Table 2-72: Default Savings Values for ENERGY STAR Most Efficient Refrigerators[134]

Refrigerator Category	Assumed Volume of Unit (cubic feet)[135]	Conventional Unit Energy Usage in kWh/yr[136]	ENERGY STAR Most Efficient Consumption in kWh/yr[137]	ΔkWh/yr	ΔkW_{peak}
5I. Refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker without through-the-door ice service.	24.6	619	486	133	0.01494
5A. Refrigerator-freezer—automatic defrost with bottom-mounted freezer with through-the-door ice service.	32.1	772	631	141	0.0158

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with

[134] Configurations of qualified models as of July 5, 2013.
[135] Average Adjusted Volume of qualified models within the category.
[136] ENERGY STAR Residential Refrigerators Qualified Products List. August 5, 2014. Average federal standard consumption of all qualifying models by configuration.
[137] Average consumption of all qualified units as of August 5, 2014. Qualified units list from https://data.energystar.gov/Active-Specifications/ENERGY-STAR-Certified-Residential-Refrigerators/dgpf-upjt?

verification of open variables. The Pennsylvania Phase II Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1. Federal Standards for Residential Refrigerators and Freezers, Effective 9/14/2014. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/43
2. ENERGY STAR Program Requirements Product Specifications for Residential Refrigerators and Freezers Version 5.0. Effective 9/15/2014. http://www.energystar.gov/products/specs/system/files/ENERGY%20STAR%20Final%20Version%205.0%20Residential%20Refrigerators%20and%20Freezers%20Program%20Requirements.pdf
3. ENERGY STAR Recognition Criteria for Most Efficient Refrigerator-Freezers. Table 2. http://www.energystar.gov/ia/partners/downloads/most_efficient/final_criteria/Refrigerator-Freezers.pdf?6a37-2bde
4. Assessment of Energy and Capacity Savings Potential In Iowa. Quantec in collaboration with Summit Blue Consulting, Nexant, Inc., A-TEC Energy Corporation, and Britt/Makela Group, prepared for the Iowa utility Association, February 2008. http://plainsjustice.org/files/EEP-08-1/Quantec/QuantecReportVol1.pdf

2.4.2 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[138]
Vintage	Replace on Burnout

Eligibility

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.

Algorithms

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

Total Savings $= Number\ of\ Freezers \times Savings\ per\ Freezer$

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 baseline model's annual energy consumption (kWh_{base}) may be are determined using

Table **2-73**. The efficient model's annual energy consumption (kWh_{ee}) may be determined using manufacturer's test data for the given model. Where test data is not available the algorithms in Table 2-74 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

ΔkWh/yr $= kWh_{\ base} - \ kWh_{ee}$

ΔkW_{peak} $= (kWh_{\ base} - \ kWh_{ee}) \times ETDF$

Definition of Terms

Term	Unit	Value	Source
kWh_{base} , Annual energy consumption of baseline unit	*kWh/yr*	Table 2-73	1

[138] ENERGY STAR Appliances Savings Calculator. Accessed July 10, 2013.

Term	Unit	Value	Source
kWh_{ee} , Annual energy consumption of ENERGY STAR qualified unit	kWh/yr	EDC Data Gathering Default= Table 2-73	2
ETDF , Energy to Demand Factor	$\frac{kW}{kWh/yr}$	0.0001119	3

Freezer energy use is characterized by configuration (upright, chest or compact), volume and whether defrost is manual or automatic. If this information is known, annual energy consumption of the federal minimum efficiency standard model may be determined using Table **2-73**. The efficient model's annual energy consumption (kWh_{ee}) may be determined using manufacturers' test data for the given model. Where test data is not available, the algorithms in Table 2-74 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.

Table 2-73: Federal Standard and ENERGY STAR Freezers Maximum Annual Energy Consumption if Configuration and Volume Known[139]

Freezer Category	Federal Standard Maximum Usage in kWh/year	ENERGY STAR Maximum Energy Usage in kWh/year
8. Upright freezers with manual defrost.	5.57AV + 193.7	5.01 * AV + 174.3
9. Upright freezers with automatic defrost without an automatic icemaker.	8.62AV + 228.3	7.76 * AV + 205.5
9I. Upright freezers with automatic defrost with an automatic icemaker.	8.62AV + 312.3	7.76 * AV + 289.5
9-BI. Built-In Upright freezers with automatic defrost without an automatic icemaker.	9.86AV + 260.9	8.87 * AV + 234.8
9I-BI. Built-in upright freezers with automatic defrost with an automatic icemaker.	9.86AV + 344.9	8.87 * AV + 318.8
10. Chest freezers and all other freezers except compact freezers.	7.29AV + 107.8	6.56 * AV + 97.0
10A. Chest freezers with automatic defrost.	10.24AV + 148.1	9.22 * AV + 133.3
16. Compact upright freezers with manual defrost.	8.65AV + 225.7	7.79 * AV + 203.1
17. Compact upright freezers with automatic defrost.	10.17AV + 351.9	9.15 * AV + 316.7
18. Compact chest freezers.	9.25AV + 136.8	8.33 * AV + 123.1

The default values for each configuration are given in Table 2-74. 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.

139 Lettering convention (8, 9, 9I, etc) of Federal standard and ENERGY STAR specifications included for clear reference to the standards as well as for correspondence to entries in the default savings table.

Default Savings

Table 2-74: Default Savings Values for ENERGY STAR Freezers

Freezer Category	Average Adjusted Volume of Qualified Units in ft3	Conventional Unit Energy Usage in kWh/yr[140]	ENERGY STAR Energy Usage in kWh/yr[141]	ΔkWh/yr	ΔkW_{peak}
8. Upright freezers with manual defrost.	Currently no qualified units				
9. Upright freezers with automatic defrost without an automatic icemaker.	24.7	441	419	22	0.0025
10. Chest freezers and all other freezers except compact freezers.	18.5	243	215	28	0.0031
16. Compact upright freezers with manual defrost.	3.7	258	232	26	0.0029
17. Compact upright freezers with automatic defrost.	7.7	430	367	63	0.0071
18. Compact chest freezers.	8.9	219	177	42	0.0047

Evaluation Protocols

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

Sources

1. Federal Standards for Residential Refrigerators and Freezers, Effective 9/14/2014. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/43
2. ENERGY STAR Program Requirements Product Specifications for Residential Refrigerators and Freezers Version 5.0. Effective 9/15/2014. http://www.energystar.gov/products/specs/system/files/ENERGY%20STAR%20Final%20Version%205.0%20Residential%20Refrigerators%20and%20Freezers%20Program%20Requirements.pdf
3. Assessment of Energy and Capacity Savings Potential In Iowa. Quantec in collaboration with Summit Blue Consulting, Nexant, Inc., A-TEC Energy Corporation, and Britt/Makela

[140] ENERGY STAR Residential Freezers Qualified Products List. August 5, 2015. Average federal standard consumption of all qualifying models by configuration, https://data.energystar.gov/Active-Specifications/ENERGY-STAR-Certified-Residential-Freezers/2wah-sjxr?

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

Group, prepared for the Iowa utility Association, February 2008. http://plainsjustice.org/files/EEP-08-1/Quantec/QuantecReportVol1.pdf

2.4.3 Refrigerator / Freezer Recycling with and without Replacement

Measure Name	Refrigerator/Freezer Recycling and Replacement
Target Sector	Residential Establishments
Measure Unit	Refrigerator or Freezer
Default Unit Annual Energy Savings- Refrigerators	Varies by EDC
Default Unit Peak Demand Reduction- Refrigerators	Varies by EDC
Default Unit Annual Energy Savings- Freezers	Varies by EDC
Default Unit Peak Demand Reduction- Freezers	Varies by EDC
Measure Life (no replacement)	8 years[142]
Measure Life (with replacement)	7 years (see measure life discussion below)
Vintage	Early Retirement, Early Replacement

Eligibility

Refrigerator recycling programs are designed to save energy through the removal of old-but operable refrigerators from service. By offering free pickup, providing incentives, and disseminating information about the operating cost of old refrigerators, these programs are designed to encourage consumers to:

- Discontinue the use of secondary refrigerators
- Relinquish refrigerators previously used as primary units when they are replaced (rather than keeping the old refrigerator as a secondary unit)
- Prevent the continued use of old refrigerators in another household through a direct transfer (giving it away or selling it) or indirect transfer (resale on the used appliance market).

Commonly implemented by third-party contractors (who collect and decommission participating appliances), these programs generate energy savings through the retirement of inefficient appliances. The decommissioning process captures environmentally harmful refrigerants and foam and enables the recycling of the plastic, metal, and wiring components.

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[143]. The savings algorithms are based on regression analysis of metered data on kWh consumption from other States. The savings 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 values listed for each EDC in Table 2-76 and Table 2-77 or an EDC can calculate program savings using the savings algorithms, the Existing UEC regression equation coefficients, and actual program year recycled refrigerator/freezer data. An EDC's use of

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

143 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.

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.

Algorithms

The total energy savings (kWh/yr) achieved from recycling old-but-operable refrigerators is calculated using the following general algorithm:

Equation 1:

$$\Delta kWh/yr_{Gross} = N * EXISTING\_UEC * PART\_USE$$

When calculating net savings (kWh/yr) EDCs should use the following general algorithm:

Equation 2:

$$\Delta kWh/yr_{Net} = N * (NET\_FR\_SMI\_kWh - INDUCED\_kWh)$$

Note: To evaluate *NET_FR_SMI_kWh and INDUCED_kWh* refer to discussion below. If further elaboration and guidance is necessary, consult US DOE Uniform Method Project, Savings Protocol for Refrigerator Retirement, April 2013.

Peak Demand Savings

Use the below algorithm to calculate the peak demand savings. Multiply the annual kWh savings by an Energy to Demand Factor (ETDF), which is supplied in Table 2-75 below.

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

Definition of Terms

Table 2-75: Calculation Assumptions and Definitions for Refrigerator and Freezer Recycling

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

UEC Equations and Default Values

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

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

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

Refrigerator UEC (Unit Energy Consumption) Equation

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 (cubic feet)	0.067
Dummy: Single-Door Configuration	-1.977
Dummy: Side-bu-Side Configuration	1.071
Dummy: Percent of Primary Usage (in absence of program)	0.6054
Interaction: Located in Unconditioned space x CDDs	0.02
Interaction: Located in Unconditioned space x HDDs	-0.045

$$\begin{aligned} Existing\ UEC_{Freezer} &= 365.25\ days \\ &* (-0.955 + 0.0454 * [average\ age\ of\ appliance\ ] + 0.543 \\ &* [\%\ of\ appliances\ manufactured\ pre - 1990] + 0.120 \\ &* [average\ number\ of\ \ cubic\ feet] + 0.298 \\ &* [\%\ of\ appliances\ that\ are\ chest\ freezers] - 0.031 * [HDDs] + 0.082 * [CDDs]) \\ &= kWh \end{aligned}$$

Source for freezer UEC equation: Rocky Mountain Power Utah See ya later, refrigerator®: Program Evaluation Report 2011-2012. The Cadmus Group. 2013. (Used on recommendation of Doug Bruchs, author of UMP Refrigerator Recycling Protocol).

Freezer UEC (Unit Energy Consumption) Equation	
Equation Intercept and Independent Variables	**Estimate Coefficient (Daily kWh)**
Intercept	-0.955
Appliance Age (years)	0.0454
Dummy: Manufactured Pre-1990	0.543
Appliance Size (cubic feet)	0.120
% of appliances that are chest freezers	0.298
Interaction: Located in Unconditioned space x HDDs	-0.031
Interaction: Located in Unconditioned space x CDDs	0.082

The Commission has computed the EDC-specific values that are needed for input to the regression equations for determining the Unit Energy Consumption based on Act 129 PY5 data provided by each EDC for refrigerators and freezers removed in PY5. 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.

Table 2-76 and Table 2-77 below provide the equation inputs needed to calculate the UEC for removed refrigerators and freezers, respectively, as well as the calculation of the default Unit Energy Consumption value for refrigerators or freezers for each EDC.

Table 2-76: Default values for Residential Refrigerator Recycling UEC

Variable Name	Duquesne	PECO	PPL	Met Ed	Penelec	Penn Power	West Penn Power
Appliance Age (years)	16.987	20.674	29.414	23.383	26.603	26.988	23.966
Manufactured Pre-1990	0.445	0.312	0.441	0.402	0.425	0.375	0.455
Appliance Size (cubic feet)	17.580	19.018	18.340	18.725	17.901	18.512	18.096
Single-Door Configuration	0.051	0.046	0.052	0.038	0.049	0.044	0.050
Side-by-Side Configuration	0.151	0.245	0.192	0.226	0.172	0.227	0.197
Percent of Primary Usage	0.449	0.202	0.652	0.195	0.574	0.496	0.489
Unconditioned space x CDDs	0.641	1.945	0.356	1.750	0.553	0.806	0.801
Unconditioned space x HDDs	5.069	8.150	2.078	9.723	5.957	6.376	6.340
Existing Refrigerator UEC (kWh/yr)	**1024.17**	**990.17**	**1271.38**	**1013.79**	**1141.35**	**1144.13**	**1117.73**

Table 2-77: Default values for Residential Freezer Recycling UEC

Variable Name	Duquesne	PECO	PPL	Met Ed	Penelec	Penn Power	West Penn Power
Appliance Age (years)	31.973	27.586	37.487	28.964	31.062	30.991	31.316
Dummy: Manufactured Pre-1990	0.720	0.624	0.716	0.668	0.694	0.679	0.685
Appliance Size (cubic feet)	15.525	15.157	15.742	15.471	15.841	15.953	15.892
% of appliances that are chest freezers	0.251	0.198	0.279	0.359	0.292	0.327	0.276
Interaction: Located in Unconditioned space x HDDs	10.148	9.241	4.927	10.950	11.402	10.495	10.800
Interaction: Located in Unconditioned space x CDDs	1.283	2.205	0.843	1.971	1.058	1.327	1.365
Existing Freezer UEC (kWh/yr)	**955.54**	**879.61**	**1104.71**	**916.12**	**932.60**	**955.50**	**951.46**

Part_Use Factor

When calculating 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 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 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 methodology described in section 4.3 of the DOE, Uniform Methods Project protocol "Refrigerator Recycling Evaluation Protocol", April 2013.

Freeridership and Secondary Market Impacts (Evaluating "NET_FR_SMI_kWh")

To estimate freeridership and secondary market impacts, this protocol recommends that evaluators use a combination of the responses of surveyed participants, surveyed nonparticipants, and (if possible) secondary market research. These data are used together to populate a decision tree of all possible savings scenarios. A weighted average of these scenarios is then taken to calculate the savings that can be credited to the program after accounting for either freeridership or the program's interaction with the secondary market. This decision tree is populated based on what the participating household would have done outside the program and if the unit would have been transferred to another household, whether the would-be acquirer of that refrigerator finds an alternate unit instead.

In general, independent of program intervention, participating refrigerators would have been subject to one of the following scenarios:

1. The refrigerator would have been kept by the household.
2. The refrigerator would have been discarded by a method that transfers it to another customer for continued use.
3. The refrigerator would have been discarded by a method leading to its removal from service.

These scenarios encompass what has often been referred to as "freeridership" (the proportion of units would have been taken off the grid absent the program). The quantification of freeridership is detailed below, under Freeridership.

In the event that the unit would have been transferred to another household, the question then becomes what purchasing decisions are made by the would-be acquirers of participating units now that these units are unavailable. These would-be acquirers could:

1. Not purchase/acquire another unit
2. Purchase/acquire another used unit.

Adjustments to savings based on these factors are referred to as the program's secondary market impacts. The quantification of this impact is detailed below under Secondary Market Impacts.

Freeridership

The first step is to estimate the distribution of participating units likely to have been kept or discarded absent the program. Further, there are two possible scenarios for discarded units so, in total, there are three possible scenarios independent of program intervention:

1. Unit is discarded and transferred to another household
2. Unit is discarded and destroyed
3. Unit is kept in the home.

As participants often do not have full knowledge of the available options for and potential barriers to disposing refrigerators (Scenarios 1 and 2), this document recommends using nonparticipant survey data to mitigate potential self-reporting errors. The proportion of units that would have been kept in the home (Scenario 3) can be estimated exclusively through the participant survey, as participants can reliably provide this information.

Nonparticipant surveys provide information from other utility customers regarding how they actually discarded their refrigerator independent of the program. Evaluators can also use this information to estimate the proportion of discarded units that are transferred (Scenario 1) versus destroyed (Scenario 2).

Specifically, evaluators should calculate the distribution of the ratio of likely discard scenarios as a weighted average from both participants and nonparticipants (when nonparticipant surveys are possible). The averaging of participant and nonparticipant values mitigates potential biases in the responses of each group. As the true population of nonparticipants is unknown, the distribution should be weighted using the inverse of the variance of participant and nonparticipant freeridership ratios. This method of weighting gives greater weight to values that are more precise or less variable. As demonstrated in Figure 2-4, this approach results in the evaluation's estimation of the proportion of participating appliances that would have been permanently destroyed (Scenario 1), transferred to another user (Scenario 2), or kept (Scenario 3).

Discard/ Keep	Proportion of Participant Sample	Sample	Discard Scenario	N	SE	Weight	Proportion of Discards	Overall Proportion
Discard	70%	Participant	Transfer	70	0.05	0.60	80%	
			Destroy				20%	
		Nonparticipant	Transfer	70	0.06	0.40	60%	
			Destroy				40%	
		Weighted Average	Transfer				72%	50%
			Destroy				28%	20%
Kept	30%							30%

Figure 2-4: Determination of Discard and Keep Distribution

Participant Self-Reported Actions

To determine the percentage of participants in each of the three scenarios, evaluators should begin by asking surveyed participants about the likely fate of their recycled appliance had it not been decommissioned through the utility program. Responses provided by participants can be categorized as follows:

- Kept the refrigerator
- Sold the refrigerator to a private party (either an acquaintance or through a posted advertisement)
- Sold or gave the refrigerator to a used-appliance dealer
- Gave the refrigerator to a private party, such as a friend or neighbor
- Gave the refrigerator to a charity organization, such as Goodwill Industries or a church

- Had the refrigerator removed by the dealer from whom the new or replacement refrigerator was obtained
- Hauled the refrigerator to a landfill or recycling center
- Hired someone else to haul the refrigerator away for junking, dumping, or recycling.

To ensure the most reliable responses possible and to mitigate socially desirable response bias, evaluators should ask some respondents additional questions. For example, participants may say they would have sold their unit to a used appliance dealer. However, if the evaluation's market research revealed used appliance dealers were unlikely to purchase it (due to its age or condition), then participants should be asked what they would have likely done had they been unable to sell the unit to a dealer. Evaluators should then use the response to this question in assessing freeridership.

If market research determines local waste transfer stations charge a fee for dropping off refrigerators, inform participants about the fee if they initially specify this as their option and then ask them to confirm what they would have done in the absence of the program. Again, evaluators should use this response to assess freeridership.

Use this iterative approach with great care. It is critical that evaluators find the appropriate balance between increasing the plausibility of participants' stated action (by offering context that might have impacted their decision) while not upsetting participants by appearing to invalidate their initial response.

Next evaluators should assess whether each participant's final response indicates freeridership.

- Some final responses clearly indicate freeridership, such as: "I would have taken it to the landfill or recycling center myself."
- Other responses clearly indicate no freeridership, as when the refrigerator would have remained active within the participating home ("I would have kept it and continued to use it") or used elsewhere within the utility's service territory ("I would have given it to a family member, neighbor, or friend to use").

Secondary Market Impacts

If it is determined that the participant would have directly or indirectly (through a market actor) transferred the unit to another customer on the grid, the next question addresses what that potential acquirer did because that unit was unavailable. There are three possibilities:

A. None of the would-be acquirers would find another unit. That is, program participation would result in a one-for-one reduction in the total number of refrigerators operating on the grid. In this case, the total energy consumption of avoided transfers (participating appliances that otherwise would have been used by another customer) should be credited as savings to the program. This position is consistent with the theory that participating appliances are essentially convenience goods for would-be acquirers. (That is, the potential acquirer would have accepted the refrigerator had it been readily available, but because the refrigerator was not a necessity, and the potential acquirer would not seek out an alternate unit.)

B. All of the would-be acquirers would find another unit. Thus, program participation has no effect on the total number of refrigerators operating on the grid. This position is consistent with the notion that participating appliances are necessities and that customers will always seek alternative units when participating appliances are unavailable.

C. Some of would-be acquirers would find another unit, while others would not. This possibility reflects the awareness that some acquirers were in the market for a refrigerator and would acquire another unit, while others were not (and would only have taken the unit opportunistically).

It is difficult to answer this question with certainty, absent utility-specific information regarding the change in the total number of refrigerators (overall and used appliances specifically) that were active before and after program implementation. In some cases, evaluators have conducted in-depth market research to estimate both the program's impact on the secondary market and the appropriate attribution of savings for this scenario. Although these studies are imperfect, they can provide utility-specific information related to the program's net energy impact. Where feasible, evaluators and utilities should design and implement such an approach. Unfortunately, this type of research tends to be cost-prohibitive, or the necessary data may simply be unavailable.

Because the data to inform such a top-down market-based approach may be unavailable, evaluators have employed a bottom-up approach that centers on identifying and surveying recent acquirers of non-program used appliances and asking these acquirers what they would have done had the specific used appliance they acquired not been available. While this approach results in quantitative data to support evaluation efforts, it is uncertain if:

- The used appliances these customers acquired are in fact comparable in age and condition to those recycled through the program
- These customers can reliably respond to the hypothetical question.

Further, any sample composed entirely of customers who recently acquired a used appliance seems inherently likely to produce a result that aligns with Possibility B, presented above.

As a result of these difficulties and budget limitations, this protocol recommends Possibility C when primary research cannot be undertaken. Specifically, evaluators should assume that half (0.5, the midpoint of possibilities A and B) of the would-be acquirers of avoided transfers found an alternate unit.

Once the proportion of would-be acquirers who are assumed to find alternate unit is determined, the next question is whether the alternate unit was likely to be another used appliance (similar to those recycled through the program) or, with fewer used appliances presumably available in the market due to program activity, would the customer acquire a new standard-efficiency unit instead. For the reasons previously discussed, it is difficult to estimate this distribution definitively. Thus, this protocol recommends a midpoint approach when primary research is unavailable: evaluators should assume half (0.5) of the would-be acquirers of program units would find a similar, used appliance and half (0.5) would acquire a new, standard-efficiency unit.

Figure 2-5 details the methodology for assessing the program's impact on the secondary market and the application of the recommended midpoint assumptions when primary data are unavailable. As evident in the figure, accounting for market effects results in three savings scenarios: full savings (i.e., per-unit gross savings), no savings, and partial savings (i.e., the difference between the energy consumption of the program unit and the new, standard-efficiency appliance acquired instead).

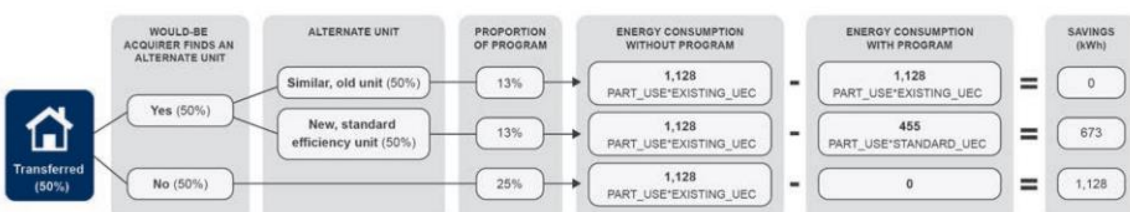

Figure 2-5: Secondary Market Impacts

Integration of Freeridership and Secondary Market Impacts

Once the parameters of the freeridership and secondary market impacts are estimated, a decision tree can be used to calculate the average per-unit program savings net of their combined effect. Figure 2-6 shows how these values are integrated into a combined estimate (NET_FR_SMI_kWh, here shown on a per-unit basis).

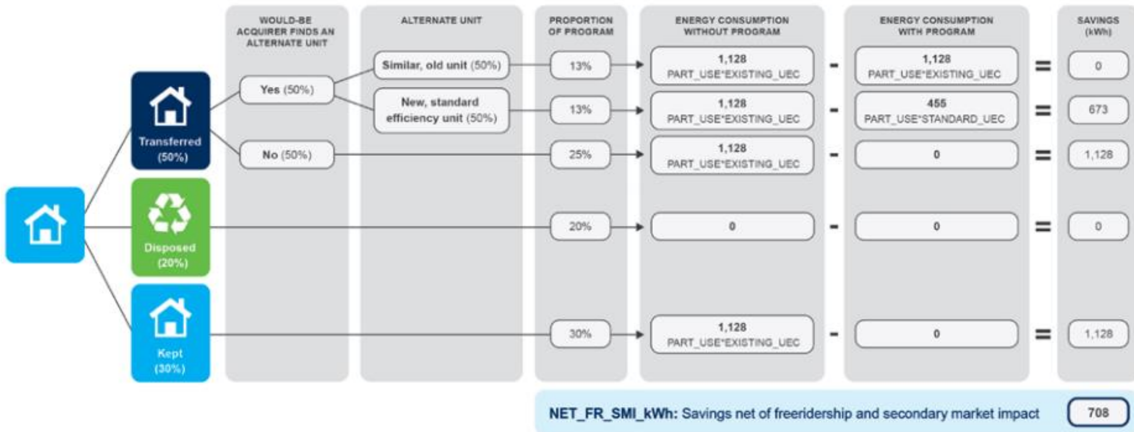

Figure 2-6: Savings Net of Freeridership and Secondary Market Impacts

As shown above, evaluators should estimate per-unit NET_FR_SMI_kWh by calculating the proportion of the total participating units associated with each possible combination of freeridership and secondary market scenarios and its associated energy savings.

Induced Replacement (Evaluating "INDUCED_kWh")

Evaluators must account for replacement units only when a recycling program induces replacement (that is, when the participant would not have purchased the replacement refrigerator in the absence of the recycling program). As previously noted, the purchase of a refrigerator in conjunction with program participation does not necessarily indicate induced replacement. (The refrigerator market is continuously replacing older refrigerators with new units, independent of any programmatic effects.) However, if a customer would have not purchased the replacement unit (put another appliance on the grid) in absence of the program, the net program savings should reflect this fact. This is, in effect, akin to negative spillover and should be used to adjust net program savings downward.

Estimating the proportion of households induced to replace their appliance can be done through participant surveys. As an example, participants could be asked, "Would you have purchased your replacement refrigerator if the recycling program had not been offered?"

Because an incentive ranging from $35 to $50 is unlikely to be sufficient motivation for purchasing an otherwise-unplanned replacement unit (which can cost $500 to $2,000), it is critical that evaluators include a follow-up question. That question should confirm the participants' assertions that the program alone caused them to replace their refrigerator.

For example, participants could be asked, "Let me be sure I understand correctly. Are you saying that you chose to purchase a new appliance because of the appliance recycling program, or are you saying that you would have purchased the new refrigerator regardless of the program?"

When assessing participant survey responses to calculate induced replacement, evaluators should consider the appliance recycled through the program, as well as the participant's stated intentions in the absence of the program. For example, when customers indicated they would have discarded their primary refrigerator independent of the program, it is not possible that the replacement was induced (because it is extremely unlikely the participant would live without a primary refrigerator). Induced replacement is a viable response for all other usage types and stated intention combinations.

As one might expect, previous evaluations have shown the number of induced replacements to be considerably smaller than the number of naturally occurring replacements unrelated to the program. Once the number of induced replacements is determined, this information is combined with the energy consumption replacement appliance, as shown in Figure 3, to determine the total energy consumption induced by the program (on a per-unit basis). As shown in the example below, this analysis results in an increase of 17 kWh per unit associated with induced replacement.

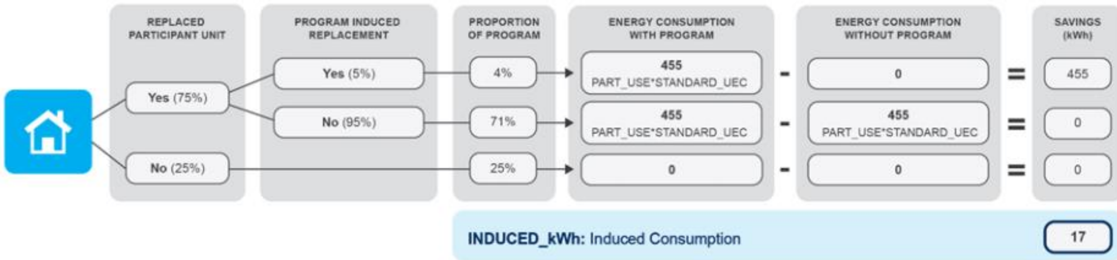

Figure 2-7: Induced Replacement

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)[144] found that among the program's target population, refrigerators are likely to be replaced less frequently than among average customers. Southern California Edison uses an EUL of 18 years for its Low-Income Refrigerator Replacement measure which reflects the less frequent replacement cycle among low-income households. The PA TRM limits measure savings to a maximum of 15 yrs.

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

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

Example Measure savings over lifetime

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

[144] 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

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*

Evaluation Protocols

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

Sources

1. U.S. Department of Energy, Uniform Methods Project protocol titled “Refrigerator Recycling Evaluation Protocol”, prepared by Doug Bruchs and Josh Keeling of the Cadmus Group, April 2013.
2. Rocky Mountain Power Utah See ya later, refrigerator®: Program Evaluation Report 2011-2012. The Cadmus Group. 2013.
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.
7. Based on program year 3 data for all EDCs.
8. Assessment of Energy and Capacity Savings Potential In Iowa. Quantec in collaboration with Summit Blue Consulting, Nexant, Inc., A-TEC Energy Corporation, and Britt/Makela Group, prepared for the Iowa utility Association, February 2008. http://plainsjustice.org/files/EEP-08-1/Quantec/QuantecReportVol1.pdf

2.4.4 ENERGY STAR Clothes Washers

Measure Name	Clothes Washers
Target Sector	Residential Establishments
Measure Unit	Clothes Washer
Unit Energy Savings	Varies by Fuel Mix
Unit Peak Demand Reduction	Varies by Fuel Mix
Measure Life	11 years[145]
Vintage	Replace on Burnout

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.

Eligibility

This protocol documents the energy savings attributed to purchasing an ENERGY STAR clothes washer instead of a standard one. 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 is residential.

Algorithms

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

Total Savings $= Number\ of\ Clothes\ Washers \times Savings\ per\ Clothes\ Washer$

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:

$$\Delta kWh/yr = Cycles \times \left(\left[\frac{CAPY_{base}}{MEF_{base}} \times \left(CW_{base} + (DHW_{base} \times \%_{ElectricDWH}) + \left(Dryer_{base} \times \%_{ElectricDryer} \times \%_{\text{dry/wash}}\right)\right)\right] - \left[\frac{CAPY_{ee}}{MEF_{ee}} \times \left(CW_{ee} + (DHW_{ee} \times \%_{ElectricDWH}) + \left(Dryer_{ee} \times \%_{ElectricDryer} \times \%_{\text{dry/wash}}\right)\right)\right]\right)$$

$$\Delta kW_{peak} = \frac{\Delta kWh/yr}{Cycles \times time_{cycle}} \times CF$$

Where MEF is the Modified Energy Factor, which is the energy performance metric for clothes washers. MEF is defined as:

145 ENERGY STAR Calculator. Accessed July 10, 2013.

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.[146]

$$MEF = \frac{C}{(M + E + D)}$$

Note: As of March 7, 2015, new Federal Standards and ENERGY STAR specifications will become effective that use "IMEF" which incorporates energy used during low power modes. These new standards and specifications will be incorporated into the 2016 TRM. In the current (2015) TRM, clothes washers carrying an IMEF rating can be substituted in the above algorithms in place of MEF when using the EDC data gathering option for $\mathrm{MEF_{ee}}$.

Definition of Terms

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 clothes washer, expressed in gallons per cubic feet. WF is the quotient of the total weighted per-cycle water consumption divided by the capacity of the clothes washer.[147]

The federal standard for a clothes washer must have a MEF ≥ 1.26 and WF ≤ 9.5.[148]

The default values for the terms in the algorithms are listed in Table 2-78. If unit information is known (such as capacity, MEF, fuel mix) then actual values should be used.

Table 2-78: ENERGY STAR Clothes Washers - References

Term	Unit	Value	Source
$CAPY_{base}$, Capacity of baseline clothes washer	ft^3	3.10	1
$CAPY_{EE}$, Capacity of ENERGY STAR clothes washer	ft^3	EDC Data Gathering	EDC Data Gathering
		Default: 3.10	2
MEF_{base} , Modified Energy Factor of baseline clothes washer	$\frac{ft^3}{(kWh/cycle)}$	1.26	1
MEF_{EE} , Modified Energy Factor of ENERGY STAR clothes washer (can also use IMEF, which has same units)	$\frac{ft^3}{(kWh/cycle)}$	EDC Data Gathering	EDC Data Gathering
		Default: 2.00	2

[146] Definition provided on ENERGY STAR Clothes Washers Key Product Criteria website: http://www.energystar.gov/index.cfm?c=clotheswash.pr_crit_clothes_washers.

[147] Based on ENERGY STAR Version 6.1 requirements, *ENERGY STAR Program Requirements Product Specification for Clothes Washers*, *Eligibility Criteria Version 6.1.* 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

[148] 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

Term	Unit	Value	Source
Cycles , Number of clothes washer cycles per year	$\frac{cycles}{yr}$	250	3
CW_{base} , % of total energy consumption for baseline clothes washer mechanical operation	%	9%	4
CW_{EE} , % of total energy consumption for ENERGY STAR clothes washer mechanical operation	%	9%	4
DHW_{base} , % of total energy consumption attributed to baseline clothes washer water heating	%	37%	4
DHW_{EE} , % of total energy consumption attributed to ENERGY STAR clothes washer water heating	%	22%	4
$\%_{ElectricDWH}$, % of total energy consumption attributed to ENERGY STAR clothes washer water heating	%	EDC Data Gathering	Appliance Saturation Studies
		Default: 43%	3
$Dryer_{base}$, % of total energy consumption for baseline clothes washer dryer operation	%	54%	4
$Dryer_{EE}$, % of total energy consumption for ENERGY STAR clothes washer dryer operation	%	69%	4
$\%_{ElectricDryer}$, Percentage of dryers that are electric	%	EDC Data Gathering	Appliance Saturation Studies
		Default: 76%	3
$\%_{\mathrm{dry/wash}}$, Percentage of homes with a dryer that use the dryer every time clothes are washed	%	Default= 95% Or EDC data gathering	5
$time_{cycle}$, average duration of a clothes washer cycle	*hours*	1	6
CF , Demand Coincidence Factor. The coincidence of average clothes washer demand to summer system peak	*Fraction*	0.029	7

Default Savings

The default values for various fuel mixes are given in Table 2-79

Table 2-79: Default Clothes Washer Savings

Fuel Mix	$\Delta kWh/yr$	ΔkW_{peak}
Electric DHW/Electric Dryer	237.8	0.02602
Electric DHW/Gas Dryer	172.6	0.01889
Gas DHW/Electric Dryer	86.9	0.00951
Gas DHW/Gas Dryer	21.7	0.00238
Default (43% Electric DHW 76% Electric Dryer)	136.2	0.01490

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 in which these standards become the baseline are detailed in Table 2-80

Note that the current standards are based on the MEF and WF, but beginning 3/7/2015 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. [149]

The corresponding ENERGY STAR updates do not include Compact washers, so these will not be included in the measure.

Table 2-80: Future Federal Standards for Clothes Washers[150]

	2016 TRM		2018 TRM	
	Minimum IMEF	Maximum IWF	Minimum IMEF	Maximum IWF
Top-loading, Standard	1.29	8.4	1.57	6.5
Front-loading, Standard	1.84	4.7	N/A	

[149] Ibid.

[150] U.S. Department of Energy. 10 CFR Parts 429 and 430. *Energy Conservation Program: Energy Conservation Standards for Residential Clothes Washers*. Direct Final Rule.

Evaluation Protocols

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

Sources

1. Energy Star Calculator, EPA research on available models. Accessed June 2013
2. Energy Star Calculator, Average MEF and capacity of all ENERGY STAR qualified clothes washers. Accessed June 2013
3. Statewide average for all housing types from Pennsylvania Statewide Residential Baseline Study, 2014.
4. The percentage of total consumption that is used for the machine, water heating and dryer varies with efficiency. Percentages 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
5. 2011-04 Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment. Residential Clothes Dryers and Room Air Conditioners, Chapter 7. Clothes Dryer Frequency from Table 7.3.3 for Electric Standard. http://www.regulations.gov/contentStreamer?objectId=0900006480c8ee11&disposition=attachment&contentType=pdf
6. Engineering assumption. Same assumption as used in 2014 Illinois TRM and 2014 Mid Atlantic TRM.
7. Value from Clothes Washer Measure, Mid Atlantic TRM 2014. Metered data from Navigant Consulting "EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (June 1, 2012 – May 31, 2013) Appliance Rebate Program." March 21, 2014, page 36.

2.4.5 ENERGY STAR DRYERS

Measure Name	ENERGY STAR Clothes Dryers
Target Sector	Residential
Measure Unit	Clothes Dryer
Unit Energy Savings	Varies by Dryer type
Unit Peak Demand Reduction	Varies by Dryer type
Measure Life	13 years[151]

ENERGY STAR Clothes Dryers are more efficient than standard ones, and thus save energy. They have a higher CEF (Combined Energy Factor) and may incorporate a moisture sensor to reduce excessive drying of clothes and prolonged drying cycles.

ELIGIBILITY

This protocol documents the energy savings attributed to purchasing a vented ENERGY STAR Dryer that meets or exceeds the CEF_{ee} requirement in Table 2-81 instead of a standard dryer. 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.[152] The target sector is residential.

ALGORITHMS

The energy savings are obtained through the following formulas:

$$\Delta kWh/yr = Cycles_{wash} \times \%_{dry/wash} \times Load_{avg} \times \left(\frac{1}{CEF_{base}} - \frac{1}{CEF_{ee}}\right)$$

$$\Delta kW_{peak} = \frac{\left(\frac{1}{CEF_{base}} - \frac{1}{CEF_{ee}}\right) \times Load_{avg}}{time_{cycle}} \times CF$$

DEFINITION OF TERMS

The parameters in the above equation are listed in Table 2-81.

[151] From National Association of Home Builders Study Table 1, 2007. http://www.nahb.org/fileUpload_details.aspx?contentID=99359
[152] The Pennsylvania SWE and PUC TUS staff added this condition relating to certification that has been applied for but not yet received at the request of several of the Pennsylvania EDCs. EDCs will be responsible for tracking whether certification is granted.

Table 2-81: Calculation Assumptions for ENERGY STAR Clothes Dryers

Component	Unit	Values	Source
$Cycles_{wash}$, Number of washing machine cycles per year	*cycles/yr*	250 cycles/year[153]	1
$Load_{avg}$, Weight of average dryer load, in pounds per load	*lbs/load*	Standard Dryer: 8.45 lbs/load[154] Compact Dryer: 3.0 lbs/load[155]	2, 3
$\%_{dry/wash}$, Percentage of homes with a dryer that use the dryer every time clothes are washed	*%*	95% Or EDC data gathering	3
CEF_{base} , Combined Energy Factor of baseline dryer, in lbs/kWh	*lbs/kWh*	Table 2-82	4
CEF_{ee} , Combined Energy Factor of ENERGY STAR dryer, in lbs/kWh	*lbs/kWh*	Table 2-82 or EDC Data Gathering	5
$time_{cycle}$, Duration of average drying cycle in hours	*hours*	Default: 1 hour[156] or EDC Data Gathering	Assumption
CF , Coincidence Factor	*Fraction*	0.042	6

Table 2-82: Combined Energy Factor for baseline and ENERGY STAR units

Product Type	CEF_{base} (lbs/kWh)	CEF_{ee} (lbs/kWh)
Vented Electric, Standard (4.4 ft³ or greater capacity)	3.73	3.93
Vented Electric, Compact (120V) (less than 4.4 ft³ capacity)	3.61	3.80
Vented Electric, Compact (240V) (less than 4.4 ft³ capacity)	3.27	3.45

DEFAULT SAVINGS

Table 2-83: Energy Savings and Demand Reductions for ENERGY STAR Clothes Dryers

Product Type	Energy Savings (kWh/yr)	Demand Reduction (kW)
Vented Electric, Standard (4.4 ft³ or greater capacity)	25.05	0.0048
Vented Electric, Compact (120V) (less than 4.4 ft³ capacity)	9.03	0.0017
Vented Electric, Compact (240V) (less than 4.4 ft³ capacity)	10.4	0.0020

153 Note: this matches the number of cycles for ENERGY STAR clothes washers
154 This figure is from the updated DOE Appendix D2 test procedure and is used in absence of a source of real world behavioral data.
155 Ibid
156 This figure is used in absence of real world behavioral data.

Evaluation Protocols

The most appropriate evaluation protocol for this measure is verification of installation coupled with calculation of energy and demand savings using above algorithms.

Sources

1. Statewide average for all housing types from Pennsylvania Statewide Residential Baseline, 2014.
2. Test Loads for Compact and Standard Dryer in Appendix D2 to Subpart B of Part 430—Uniform Test Method for Measuring the Energy Consumption of Clothes Dryers. http://www.ecfr.gov/cgi-bin/text-idx?SID=9d051184ada3b0d0b5b553f624e0ab05&node=10:3.0.1.4.18.2.9.6.14&rgn=div9
3. 2011-04 Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment. Residential Clothes Dryers and Room Air Conditioners, Chapter 7. Clothes Dryer Frequency from Table 7.3.3 for Electric Standard. http://www.regulations.gov/contentStreamer?objectId=0900006480c8ee11&disposition=attachment&contentType=pdf
4. Federal Standard for Clothes Dryers, Effective January 1, 2015. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/36
5. ENERGY STAR Specification for Clothes Dryers Version 1.0, Effective January 1, 2015. http://www.energystar.gov/products/specs/sites/products/files/ENERGY%20STAR%20Final%20Draft%20Version%201.0%20Clothes%20Dryers%20Specification_0.pdf
6. Central Maine Power Company. "Residential End-Use Metering Project". 1988. Using 8760 data for electric clothes dryers, calculating the CF according to the PJM peak definition.

2.4.6 Fuel Switching: Electric Clothes Dryer to Gas Clothes Dryer

Measure Name	Fuel Switch: Electric Clothes Dryer to Gas Clothes Dryer
Target Sector	Residential Establishments
Measure Unit	Fuel Switch: Electric Clothes Dryer to Gas Clothes Dryer
Unit Energy Savings	875 kWh -2.99 MMBtu (increase in gas consumption)
Unit Peak Demand Reduction	0.149 kW
Measure Life	14 years[157]

This protocol outlines the savings associated to purchasing a gas clothes dryers to replace an electric dryer. The measure characterization and savings estimates are based on average usage per person and average number of people per household. Therefore, this is a deemed measure with identical savings applied to all installation instances, applicable across all housing types.

Eligibility

This measure is targeted to residential customers that purchase a gas clothes dryer rather than an electric dryer.

Algorithms

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

$$\Delta MMBtu = -\Delta kWh \times 0.003413 = -2.99$$

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

Definition of Terms

Table 2-84 Electric Clothes Dryer to Gas Clothes Dryer – Values and Resources

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

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

Term	Unit	Values	Source
$\Delta MMBtu$, Weighted average gas fuel increase	MMBtu	EDC Data Gathering Default = -2.99	Calculated, 3
0.003413, Conversion factor	$\frac{MMBtu}{kWh}$	EDC Data Gathering Default = 0.003413	None
$Cycles_{wash}$, Number of washing machine cycles per year	cycles/yr	260	4
$\%_{dry/wash}$, Percentage of homes with a dryer that use the dryer every time clothes are washed	%	95%	5
$time_{cycle}$, Duration of average drying cycle in hours	hours	EDC Data Gathering Default= 1	Assumption
CF, Coincidence Factor	*Fraction*	EDC Data Gathering Default = 0.042	6

Default Savings

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

Evaluation Protocols

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

Sources

1. Average annual dryer kWh without moisture sensor per 2014 PA TRM protocol 2.2 *Electric Clothes Dryer with Moisture Sensor*.
2. 2011-04 Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment. Residential Clothes Dryers and Room Air Conditioners, Chapter 7. Median annual electricity consumption of gas dryers from Table 7.3.4: Electric Standard and Gas Clothes Dryer: Average Annual Energy Consumption Levels by Efficiency http://www.regulations.gov/#!documentDetail;D=EERE-2007-BT-STD-0010-0053
3. Negative gas fuel savings indicate increase in fuel consumption. It is assumed that gas and electric dryers have similar efficiencies. All heated air passes through the clothes and contributes to drying.
4. Statewide average for all housing types from Pennsylvania Statewide Residential End-Use and Saturation Study, 2014.
5. 2011-04 Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment. Residential Clothes Dryers and Room Air Conditioners, Chapter 7. Clothes Dryer Frequency from Table 7.3.3 for Electric Standard. http://www.regulations.gov/contentStreamer?objectId=0900006480c8ee11&disposition=attachment&contentType=pdf

6. Central Maine Power Company. “Residential End-Use Metering Project”. 1988. Using 8760 data for electric clothes dryers, calculating the CF according to the PJM peak definition.

2.4.7 ENERGY STAR Dishwashers

Measure Name	Dishwashers
Target Sector	Residential Establishments
Measure Unit	Dishwasher
Unit Energy Savings	Varies by Water Heating Fuel Mix
Unit Peak Demand Reduction	Varies by Water Heating Fuel Mix
Measure Life	10 years[158]
Vintage	Replace on Burnout

Eligibility

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.

Algorithms

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

$$\textit{Total Savings} = Number\ of\ Dishwashers \times Savings\ per\ Dishwasher$$

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:

$$\Delta\, kWh/yr = (kWh_{base} - kWh_{ee}) \times [\%kWh_{OP} + (\%kWh_{heat} \times \%Electric_{DHW})]$$

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

Definition of Terms

Table 2-85: ENERGY STAR Dishwashers - References

Component	Unit	Value	Source
kWh_{base}, Annual energy consumption of baseline dishwasher	*kWh/yr*	355	1
kWh_{ee}, Annual energy consumption of ENERGY STAR qualified unit	*kWh/yr*	295	1
$\%kWh_{op}$, Percentage of unit dishwasher energy consumption used for operation	%	44%	1

158 EnergyStar Calculator. Accessed July 2013.

Component	Unit	Value	Source
$\%kWh_{heat}$, Percentage of dishwasher unit energy consumption used for water heating	%	56%	1
$\%Electric_{DW}$, Percentage of dishwashers assumed to utilize electrically heated hot water	%	EDC Data Gathering Default = 43%	2
HOU , Hours of use per year	*hours/yr*	234	3[159]
CF, Demand Coincidence Factor. The coincidence of average dishwasher demand to summer system peak	*Fraction*	0.026	4

ENERGY STAR qualified dishwashers must use less than or equal to the water and energy consumption values given in Table 2-86. 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.[160]

Table 2-86: Federal Standard and ENERGY STAR v 5.0 Residential Dishwasher Standard

Product Type	Federal Standard[161]		ENERGY STAR v 5.0[162]	
	Water (gallons per cycle)	Energy (kWh per year)	Water (gallons per cycle)	Energy (kWh per year)
Standard	≤ 6.50	≤ 355	≤ 4.25	≤ 295

The default values for electric and non-electric water heating and the default fuel mix from Table 2-85 are given in Table 2-87.

Table 2-87: Default Dishwasher Energy Savings

Water Heating	$\Delta kWh/yr$	ΔkW_{peak}
Electric ($\%Electric_{DHW}$ = 100%)	60.0	0.00667
Non-Electric ($\%Electric_{DHW}$ = 0%)	26.4	0.00293
Default Fuel Mix ($\%Electric_{DHW}$ = 43%)	40.8	0.00453

159 HOU=(3 loads/week)*(52 weeks/yr)*(1.5 hours/load). 3 load/week comes from 2014 Baseline study. 1.5 hours/load is assumption used by Efficiency Vermont and Illinois Statewide TRMs
160 Dishwashers Key Product Criteria. http://www.energystar.gov/index.cfm?c=dishwash.pr_crit_dishwashers
161 Ibid.
162 *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

Evaluation Protocols

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

Sources

1. ENERGY STAR Appliances Calculator. Accessed July 2013.
2. Statewide average for all housing types from Pennsylvania Statewide Residential Baseline Study, 2014.
3. 2014 Pennsylvania Residential Baseline Study. Submitted by GDS Associates, April 2014.
4. Calculated from Itron eShapes, 8760 hourly data by end use for Missouri, as provided by Ameren. This is the CF value for ENERGY STAR Dishwashers from Illinois Statewide TRM Version 3.0, June 2014.

2.4.8 ENERGY STAR DEHUMIDIFIERS

Measure Name	Dehumidifiers
Target Sector	Residential Establishments
Measure Unit	Dehumidifier
Unit Energy Savings	Varies based on capacity
Unit Peak Demand Reduction	0.0098 kW
Measure Life	12 years[163]
Vintage	Replace on Burnout

ENERGY STAR qualified dehumidifiers are 15 percent more efficient than non-qualified models due to more efficient refrigeration coils, compressors and fans.

ELIGIBILITY

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

ALGORITHMS

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

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

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

Per unit energy and demand savings algorithms:

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

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

163 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/.

Definition of Terms

Table 2-88: ENERGY STAR Dehumidifier Calculation Assumptions

Component	Unit	Value	Sources
CAPY , *Average capacity of the unit*	$\frac{pints}{day}$	EDC Data Gathering	
HOU , *Annual hours of operation*	$\frac{hours}{yr}$	1632	1
L/kWh_{base} , *Baseline unit liters of water per kWh consumed*	$\frac{liters}{kWh}$	Table 2-89, Federal Standard Column	2
L/kWh_{ee} , *ENERGY STAR qualified unit liters of water per kWh consumed*	$\frac{liters}{kWh}$	EDC Data Gathering Default : Table 2-89, ENERGY STAR Column	3
CF , *Demand Coincidence Factor*	*Fraction*	0.405	4

Table 2-89 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 2-89 only presents standards for the range of dehumidifier capacities that savings can be claimed.

Table 2-89: Dehumidifier Minimum Federal Efficiency and ENERGY STAR Standards

Capacity (pints/day)	Federal Standard (L/kWh_{base})	ENERGY STAR (L/kWh_{ee})
≤ 35	1.35	≥ 1.85
> 35 ≤ 45	1.50	
>45 ≤ 54	1.60	
>54 < 75	1.70	
75 ≤ 185	2.5	≥ 2.80

Default Savings

The annual energy usage and savings of an ENERGY STAR unit over the federal minimum standard are presented in Table 2-90 for each capacity range.

Table 2-90: Dehumidifier Default Energy Savings[164]

Capacity Range (pints/day)	Default Capacity (pints/day)	Federal Standard (kWh/yr)	ENERGY STAR (kWh/yr)	ΔkWh/yr	ΔkW_{peak}
≤ 35	35	834	609	225	0.05584
> 35 ≤ 45	45	965	782	183	0.04541
>45 ≤ 54	54	1086	939	147	0.03648

[164] Derived from equations in section 2.4.8, matching values generated by Energy Star Appliance Savings Calculator: http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/appliance_calculator.xlsx

Capacity Range (pints/day)	Default Capacity (pints/day)	Federal Standard (kWh/yr)	ENERGY STAR (kWh/yr)	ΔkWh/yr	ΔkW_{peak}
>54 < 75	74	1,400	1,287	113	0.02804
75 ≤ 185	130	1,673	1,493	180	0.04467

Evaluation Protocols

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

Sources

1. ENERGY STAR Appliance Savings Calculator. Updated August, 2013.
2. US Department of ENERGY Website. Appliance and Equipment Standards. Accessed June 2014. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/55
3. 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
4. Dehumidifier Metering in PA and Ohio by ADM from 7/17/2013 to 9/22/2013. 31 Units metered. Assumes all non-coincident peaks occur within window and that the average load during this window is representative of the June PJM days as well.

2.4.9 ENERGY STAR WATER COOLERS

Measure Name	ENERGY STAR Water Coolers
Target Sector	Residential Establishments
Measure Unit	Water Cooler
Unit Energy Savings	Cold Water Only: 47 kWh Hot/Cold Water: 361 kWh
Unit Peak Demand Reduction	0.0232 kW
Measure Life	10 years[165]
Vintage	Replace on Burnout

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

ELIGIBILITY

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

ALGORITHMS

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

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

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

Per unit energy and demand savings algorithms:

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

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

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

Definition of Terms

Table 2-91: ENERGY STAR Water Coolers – References

Component	Unit	Value	Sources
kWh_{base} , Energy use of baseline water cooler	kWh/day	Cold Only: 0.29 Hot & Cold: 2.19	1
kWh_{ee} , Energy use of ENERGY STAR water cooler	kWh/day	Cold Only: 0.16 Hot & Cold Storage: 0.87 Hot & Cold On-Demand: 0.18 or EDC Data Gathering	2
HOU , Annual hours of use	Hours/year	8760	3
ETDF , Energy to Demand Factor	$\frac{kW}{kWh/yr}$	0.0001119	3

Default Savings

Table 2-92: Default Savings for ENERGY STAR Water Coolers

Cooler Type	ΔkWh	ΔkW_{peak}
Cold Only	47.5 kWh	0.00532 kW
Hot & Cold Storage	481.8 kWh	0.0539 kW
Hot & Cold On-Demand	733.65 kWh	0.0821 kW

Sources

1. ENERGY STAR Water Coolers Savings Calculator (Calculator updated: May 2013). Default values were used.
2. ENERGY STAR Product Specifications for Water Coolers Version 2.0. http://www.energystar.gov/products/specs/system/files/WC%20V2%200%20Final%20Program%20Requirements.pdf
3. Assumed to have similar behavior as a refrigerator, and thus uses same ETDF as used in refrigerator measures: Assessment of Energy and Capacity Savings Potential In Iowa. Quantec in collaboration with Summit Blue Consulting, Nexant, Inc., A-TEC Energy Corporation, and Britt/Makela Group, prepared for the Iowa utility Association, February 2008. http://plainsjustice.org/files/EEP-08-1/Quantec/QuantecReportVol1.pdf

2.4.10 ENERGY STAR Ceiling Fans

Measure Name	ENERGY STAR Ceiling Fans
Target Sector	Residential
Measure Unit	Ceiling Fan Unit
Unit Energy Savings	Varies by Ceiling Fan Type
Unit Peak Demand Reduction	Varies by Ceiling Fan Type
Measure Life	20 years for fan[166], See Section 2.1.1 for lighting

ENERGY STAR ceiling fans require a more efficient CFM/Watt rating at the low, medium, and high settings than standard ceiling fans as well ENERGY STAR qualified lighting for those with light kits included. Both of these features save energy compared to standard ceiling fans.

Eligibility

This protocol documents the energy savings attributed to installing an ENERGY STAR Version 3.0 ceiling fan (with or without a lighting kit) in lieu of a standard efficiency ceiling fan. 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.[167] The target sector primarily consists of single-family residences.

Algorithms

The total energy savings is equal to the savings contribution of the fan plus the savings contribution of the lighting, if applicable. If the ENERGY STAR fan does not include a lighting kit, then $\Delta kWh_{\text{lighting}} = 0$. These algorithms do not seek to estimate the behavioral change attributable to the use of a ceiling fan vs. a lower AC setting.

The energy savings are obtained through the following formula:

$$\Delta kWh/yr_{total} = \Delta kWh_{fan} + \Delta kWh_{lighting}$$

$$\Delta kWh_{fan} = \left[\left(\%_{low} \times (Low_{base} - Low_{ee})\right) + \left(\%_{med} \times (Med_{base} - Med_{ee})\right) + \left(\%_{high} \times (High_{base} - High_{ee})\right)\right] \times \frac{1\ kW}{1000\ W} \times HOU_{fan} \times 365\frac{days}{yr}$$

$\Delta kWh_{lighting}$ = ΔkWh from Section 2.1: Ceiling Fan with ENERGY STAR Light Fixture

Demand savings result from the lower connected load of the ENERGY STAR fan and ENERGY STAR lighting. Peak demand savings are estimated using a Coincidence Factor (CF).

166 Residential and C&I Lighting and HVAC Report Prepared for SPWG, 2007. Pg C-2.

167 The Pennsylvania SWE and PUC TUS staff added this condition relating to certification that has been applied for but not yet received at the request of several of the Pennsylvania EDCs. EDCs will be responsible for tracking whether certification is granted.

$$\Delta kW_{peak,total} = \Delta kW_{peak,fan} + \Delta kW_{peak,lighting}$$

$$\Delta kW_{peak,fan} = \left[\left(\%_{low} \times (Low_{base} - Low_{ee})\right) + \left(\%_{med} \times (Med_{base} - Med_{ee})\right) + \left(\%_{high} \times (High_{base} - High_{ee})\right)\right] \times \frac{1\ kW}{1000\ W} \times CF_{fan}$$

$\Delta kW_{peak,lighting}$ $= \Delta kW_{peak}$ from Section 2.1: Ceiling Fan with ENERGY STAR Light Fixture

Definition of Terms

The parameters in the above equations are listed in Table 2-93.

Table 2-93: Calculation Assumptions for ENERGY STAR Ceiling Fans

Component	Unit	Values	Source
$\%_{low}$, percentage of low setting use	%	40%	1
$\%_{med}$, percentage of medium setting use	%	40%	1
$\%_{high}$, percentage of high setting use	%	20%	1
Low_{base} , Wattage of low setting, baseline	Watts	15 Watts	1
Med_{base} , Wattage of medium setting, baseline	Watts	34 Watts	1
$High_{base}$, Wattage of high setting, baseline	Watts	67 Watts	1
Low_{ee} , Wattage of low setting, ENERGY STAR	Watts	EDC Data Gathering Default: 4.8 Watts[168]	2, 3
Med_{ee} , Wattage of medium setting, ENERGY STAR	Watts	EDC Data Gathering Default: 18.2 Watts[169]	2, 3
$High_{ee}$, Wattage of high setting, ENERGY STAR	Watts	EDC Data Gathering Default: 45.9 Watts[170]	2, 3
HOU_{fan} , fan daily hours of use	$\frac{hours}{day}$	EDC Data Gathering Default: 3.0 hours/day[171]	1
CF_{fan} , Demand Coincidence Factor	Fraction	EDC Data Gathering Default: 0.091[172]	4
$CF_{lighting}$, Demand Coincidence Factor	Fraction	See Section 2.1	4

[168] Equals the minimum 'Low' CFM required by ENERGY STAR divided by the average CFM/Watt on 'Low' for all fans on ES qualified products list

[169] Equals the minimum 'Medium' CFM required by ENERGY STAR divided by the average CFM/Watt on 'Medium' for all fans on ES qualified products list

[170] Equals the minimum 'High' CFM required by ENERGY STAR divided by the average CFM/Watt on 'High' for all fans on ES qualified products list

[171] The 3 hour/day for a ceiling fan is assumed here to be the same hours of use as a typical residential lightbulb, in absence of better data.. EDCs are allowed to do research on hours of use for ceiling fans in lieu of using the 3 hours/day figure. It is likely that the hours of use for ceiling fans is different than that of residential lighting.

[172] Assumed same usage characteristics as lighting, same assumption as Minnesota TRM. EDCs are allowed to do research on Coincidence Factor for ceiling fans in lieu of using the 3 hours/day figure. It is likely that the hours of use for ceiling fans is different than that of residential lighting.

Default Savings

Table 2-94: Energy Savings and Demand Reductions for ENERGY STAR Ceiling Fans

Product Type	Energy Savings (kWh)	Demand Reduction (kW)
Fan Only	16.0	0.00132

Evaluation Protocols

The most appropriate evaluation protocol for this measure is verification of installation coupled with calculation of energy and demand savings using above algorithms.

Sources

1. ENERGY STAR Lighting Fixture and Ceiling Fan Calculator. Updated September, 2013.
2. ENERGY STAR Ceiling Requirements Version 3.0
3. ENERGY STAR Certified Ceiling Fan List, Accessed April 3, 2014.
4. EmPOWER Maryland 2012 Final Evaluation Report: Residential Lighting Program, Prepared by Navigant Consulting and the Cadmus Group, Inc., March 2013, Table 50.

2.5 Consumer Electronics

2.5.1 ENERGY STAR Televisions

Measure Name	ENERGY STAR Televisions
Target Sector	Residential Establishments
Measure Unit	Television Unit
Unit Energy Savings	Varies
Unit Peak Demand Reduction	Varies
Measure Life	6 years[173]
Vintage	Replace on Burnout

ENERGY STAR certified televisions are on average over 25 percent more energy efficient than conventional models, saving energy in all usage modes: sleep, idle, and on.

Eligibility

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 requirements.

Algorithms

Energy Savings (per TV):

$$\Delta kWh/yr = \frac{(W_{base,\ active} - W_{ee,\ active})}{1000\frac{W}{kW}} \times HOU_{active} \times 365\frac{days}{yr}$$

Coincident Demand Savings (per TV):

$$\Delta kW_{peak} = \frac{(W_{base,active} - W_{ee,\ active})}{1000\frac{W}{kW}} \times CF$$

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.

[173] ENERGY STAR Program Requirements for Televisions, Partner Commitments Versions 6.0, accessed June 2013, http://www.energystar.gov/products/specs/system/files/Final%20Version%206%200%20TV%20Program%20Requirements.pdf.

Definition of Terms

Table 2-95: ENERGY STAR TVs - References

Component	Unit	Value	Source
$HOURS_{active}$, number of hours per day that a typical TV is on (active mode turned on and in use	$\frac{hours}{day}$	5	1
$W_{base,active}$, power use (in Watts) of baseline TV while in on mode (i.e. active mode turned on and operating).	*Watts*	See Table 2-96	2
$W_{ee,\ active,}$, Power use of ENERGY STAR Version 6.0 or ENERGY STAR Most Efficient TV while in on mode (i.e. active mode turned on and operating)	*Watts*	See Table 2-96	3
CF, Demand Coincidence Factor	*Fraction*	0.17	4

On Mode Power Consumption Requirements

$$P_{on\_max} = 100\ \times \{TANH[0.00085(A - 140) +\ 0.052\ ]\} +\ 14.1$$

Where:

- P_{on_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).[174]
- 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 requirements of ENERGY STAR Version 6.0 as well as the following additional requirement:[175]

$$P_{ON\ MAX} = 82\ \times TANH[0.00084(A - 150) +\ 0.05] +\ 12.75$$

Where TANH is the hyperbolic tangent function.

[174] *ENERGY STAR Program Requirements for Televisions, Partner Commitments Versions 6.0*, accessed June 2013, http://www.energystar.gov/products/specs/system/files/Final%20Version%206%200%20TV%20Program%20Requirements.pdf.

[175] *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 2-96: TV power consumption

Diagonal Screen Size (inches)[176]	Baseline Active Power Consumption [$W_{base,active}$][177]	ENERGY STAR V. 6.0 Active Power Consumption [$W_{ES,active}$][178]	ENERGY STAR Most Efficient Power Consumption [$W_{ES,active}$]
< 20	17	16	13
20 < 30	40	30	20
30 < 40	62	50	31
40 < 50	91	72	43
50 < 60	108*	92	54
≥ 60	108*	99	58

DEEMED SAVINGS

Deemed annual energy savings for ENERGY STAR 6.0 and ENERGY STAR Most Efficient TVs are given in Table 2-97.

Table 2-97: Deemed energy savings for ENERGY STAR Version 6.0and ENERGY STAR Most Efficient TVs.

Diagonal Screen Size (inches)[179]	Energy Savings ENERGY STAR V. 6.0 TVs (kWh/year)	Energy Savings ENERGY STAR Most Efficient TVs (kWh/yr)
< 20	2	7
20 < 30	18	37
30 < 40	22	57
40 < 50	35	88
50 < 60	29	99
≥ 60	16	91

Coincident demand savings are given in Table 2-98.

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[176] 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".

[177] Based on ENERGY STAR Version 5.3 requirements, from *ENERGY STAR Program Requirements for Televisions, Partner Commitments*, accessed November 2013, http://www.energystar.gov/ia/partners/prod_development/revisions/downloads/television/V5.3_Program_Requirements.pdf?db43-0cc6

[178] 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

[179] 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"

Table 2-98: Deemed coincident demand savings for ENERGY STAR Version 6.0 and ENERGY STAR Most Efficient TVs

Diagonal Screen Size (inches)[180]	Coincident Demand Savings ENERGY STAR V. 6.0 (kW)	Coincident Demand Savings ENERGY STAR Most Efficient (kW)
< 20	0.00017	0.00068
20 < 30	0.0017	0.00340
30 < 40	0.00204	0.00527
40 < 50	0.00323	0.00816
50 < 60	0.00272	0.00918
≥ 60	0.00153	0.00850

Evaluation Protocols

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

Sources

1. 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. Based on ENERGY STAR Version 5.3 requirements, from ENERGY STAR Program Requirements for Televisions, Partner Commitments, accessed November 2013, http://www.energystar.gov/ia/partners/prod_development/revisions/downloads/television/V5.3_Program_Requirements.pdf?db43-0cc6
3. 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
4. CF Value for Efficient Televisions in Efficiency Vermont TRM, 2013. The Efficiency Vermont Peak definition is June-August, 1-5PM non-holiday weekdays, close to the PJM peak definition.

[180] 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"

2.5.2 ENERGY STAR Office Equipment

Measure Name	ENERGY STAR Office Equipment
Target Sector	Residential Establishments
Measure Unit	Office Equipment Device
Unit Energy Savings	Table 2-100
Unit Peak Demand Reduction	Table 2-100
Measure Life	Computer: 4 years Monitor: 4 years Fax: 4 years Printer: 5 years Copier: 6 years Multifunction Device: 6 years
Vintage	Replace on Burnout

Eligibility

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. The target sector is primarily residential.

Algorithms

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

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

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 ENERGY STAR calculator for office equipment.

ENERGY STAR Computer

$\Delta kWh/yr = ESav_{COM}$

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

ENERGY STAR Fax Machine

$\Delta kWh/yr = ESav_{FAX}$

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

ENERGY STAR Copier

$\Delta kWh/yr = ESav_{COP}$

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

ENERGY STAR Printer

$\Delta kWh/yr = ESav_{PRI}$

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

ENERGY STAR Multifunction

$\Delta kWh/yr = ESav_{MUL}$

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

ENERGY STAR Monitor

$\Delta kWh/yr = ESav_{MON}$

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

Definition of Terms

Table 2-99: ENERGY STAR Office Equipment - References

Component	Unit	Value	Sources
$ESav_{COM}$, Electricity savings per purchased ENERGY STAR computer. $ESav_{FAX}$, Electricity savings per purchased ENERGY STAR Fax Machine $ESav_{COP}$, Electricity savings per purchased ENERGY STAR Copier $ESav_{PRI}$, Electricity savings per purchased ENERGY STAR Printer $ESav_{MUL}$, Electricity savings per purchased ENERGY STAR Multifunction Machine $ESav_{MON}$, Electricity savings per purchased ENERGY STAR Monitor	*kWh/yr*	See Table 2-100	1
$DSav_{COM}$, Summer demand savings per purchased ENERGY STAR computer. $DSav_{FAX}$, Summer demand savings per purchased ENERGY STAR Fax Machine $DSav_{COP}$, Summer demand savings per purchased ENERGY STAR Copier $DSav_{PRI}$, Summer demand savings per purchased ENERGY STAR Printer $DSav_{MUL}$, Summer demand savings per purchased ENERGY STAR Multifunction Machine $DSav_{MON}$, Monitor	*kW/yr*	See Table 2-100	2

DEFAULT SAVINGS

Table 2-100: ENERGY STAR Office Equipment Energy and Demand Savings Values

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

EVALUATION PROTOCOLS

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

SOURCES

1. ENERGY STAR Office Equipment Calculator (Referenced latest version released in May 2013). Default values were used. Using a commercial office equipment load shape, the percentage of total savings that occur during the PJM peak demand period was calculated and multiplied by the energy savings.

2.5.3 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) 58.7 kWh (7-plug, unspecified use or multiple purchased) 62.1 kWh (5-plug, Entertainment Center) 74.5 kWh (7-plug, Entertainment Center)
Unit Peak Demand Reduction	0.0056 kW (5-plug, unspecified use or multiple purchased) 0.0067 kW (7-plug, unspecified use or multiple purchased) 0.0077 kW (5-plug, Entertainment Center) 0.0092 kW (7-plug, Entertainment Center)
Measure Life	10 years[181]
Vintage	Retrofit

Smart Strips are power strips that contain a number of controlled sockets with at least one uncontrolled socket. When the appliance that is plugged into the uncontrolled socket is turned off, the power strips then shuts off the items plugged into the controlled sockets.

Eligibility

This protocol documents the energy savings attributed to the installation of smart strip plugs. The most likely area of application is within residential spaces, i.e. single family and multifamily homes. The two areas of usage considered are home 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.

Algorithms

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:

$$\Delta kWh/yr_{\text{unspecified use}} = \frac{(kW_{comp} \times HOU_{comp}) + (kW_{TV} \times HOU_{TV})}{2} \times 365\frac{days}{yr} \times ISR$$

= 48.9 kWh (5-plug); 58.7 kWh (7-plug)

$$\Delta kWh/yr_{\text{entertainment center}} = kW_{TV} \times HOU_{TV} \times 365\frac{days}{yr} \times ISR$$

= 62.1 kWh (5-plug); 74.5 kWh (7-plug)

[181] Product Lifetime of TrickleStar products, a leading manufacturer of smart strip plugs. http://www.tricklestar.com/us/index.php/knowledgebase/article/warranty.html

ΔkW_{peak} *unspecified use* $= \frac{CF \times (kW_{comp} + kW_{TV})}{2} \times ISR$ =0.0056 kW (5-plug); 0.0067 kW (7-plug)

ΔkW_{peak} *entertainment center* $= CF \times kW_{TV} \times ISR$ =0.0077 kW (5-plug); 0.0092 kW (7-plug)

Definition of Terms

The parameters in the above equation are listed in Table 2-101.

Table 2-101: Smart Strip Plug Outlet Calculation Assumptions

Parameter	Unit	Value	Source
kW_{comp} , Idle kW of computer system	*kW*	0.0049 (5-plug) 0.00588 (7-plug)	1,2,4
HOU_{comp} , Daily hours of Computer idle time	$\frac{hours}{day}$	20	1
kW_{TV} , Idle kW of TV system	*kW*	0.0085 (5-plug) 0.0102 (7-plug)	1,4
HOU_{TV} , Daily hours of TV idle time	$\frac{hours}{day}$	20	1
ISR , In-Service Rate	*Fraction*	EDC Data Gathering Default = 1.0	
CF , Coincidence Factor	*Fraction*	Entertainment Center: 0.90 Unspecified Use[182]: 0.832	3

Deemed Savings

ΔkWh = *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)

ΔkW_{peak} = *0.0056 kW (5-plug power strip, unspecified use or multiple purchase)*

0.0067 kW (7-plug power strip, unspecified use, or multiple purchased)

0.0077 kW (5-plug power strip, entertainment center)

0.0092 kW (7 plug power strip, entertainment center)

[182] CF for “unspecified use” is the average of the standby losses CF for Entertainment Center (90.0%) and Home Office (76.3%) from pg 16 Efficiency Vermont TRM, 2013. Developed through negotiations between Efficiency Vermont and the Vermont Department of Public Service.

Evaluation Protocols

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

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. CF Values of Standby Losses for Entertainment Center and Home Office in Efficiency Vermont TRM, 2013, pg 16. Developed through negotiations between Efficiency Vermont and the Vermont Department of Public Service.
4. "Advanced Power Strip Research Report", NYSERDA, August 2011.

2.6 Building Shell

2.6.1 Ceiling / Attic and Wall Insulation

Measure Name	Ceiling/Attic and Wall Insulation
Target Sector	Residential Establishments
Measure Unit	Insulation Addition
Unit Energy Savings	Varies
Unit Peak Demand Reduction	Varies
Measure Life	15 years[183]
Vintage	Retrofit

Eligibility

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.

Algorithms

The savings values are based on the following algorithms.

Cooling savings with central A/C:

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

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

Cooling savings with room A/C:

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

[183] *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 measure life is defined as 25 years; however, PA Act 129 savings can be claimed for no more than 15 years.

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

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

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

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

Cooling savings with electric ground source heat pump:

$$\Delta kWh/yr_{GSHP\ cool} = \frac{CDD \times 24\frac{hr}{day} \times DUA}{EER_{GSHP} \times GSHPDF \times GSER \times 1000\frac{W}{kW}} \times \left[AHF \times A_{roof}\left(\frac{1}{R_{roof,bl}} - \frac{1}{R_{roof,ee}}\right) + A_{wall}\left(\frac{1}{R_{wall,bl}} - \frac{1}{R_{wall,ee}}\right)\right]$$

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

Heating savings with electric ground source heat pump:

$$\Delta kWh/yr_{GSHP\ heat} = \frac{HDD \times 24\frac{hr}{day}}{COP_{GSHP} \times GSHPDF \times GSOP \times 1000\frac{W}{kW}} \times \left[A_{roof}\left(\frac{1}{R_{roof,bl}} - \frac{1}{R_{roof,ee}}\right) + A_{wall}\left(\frac{1}{R_{wall,bl}} - \frac{1}{R_{wall,ee}}\right)\right]$$

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

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

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

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

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

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

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

Definition of Terms

The default values for each term are shown in Table 2-102. The default values for heating and cooling days and hours are given in Table 2-102.

Table 2-102: Default values for algorithm terms, Ceiling/Attic and Wall Insulation

Term	Unit	Value	Source
A_{roof} , Area of the ceiling/attic with upgraded insulation	ft^2	Varies	EDC Data Gathering
A_{wall} , Area of the wall with upgraded insulation	ft^2	Varies	EDC Data Gathering
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.	*None*	0.75	1
AHF , Attic Heating Factor increases cooling load to home due to attic temperatures being warmer than ambient outdoor air temperature on sunny days.	*None*	1.056	2, 3
$R_{roof,bl}$[184] , Assembly R-value of ceiling/attic before retrofit	$\frac{°F \cdot ft^2 \cdot hr}{Btu}$	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
$R_{roof,ee}$[185] , Assembly R-value of ceiling/attic after retrofit	$\frac{°F \cdot ft^2 \cdot hr}{Btu}$	38	Retrofit to R-38 total attic insulation
		49	Retrofit to R-49 total attic insulation
		Retrofit Assembly R-value	EDC Data Gathering
$R_{wall,bl}$[186] , Assembly R-value of wall before retrofit	$\frac{°F \cdot ft^2 \cdot hr}{Btu}$	Default = 5.0	15 Assumes existing, un-insulated wall with 2x4 studs @ 16” o.c., w/ wood/vinyl siding

[184] 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.
[185] 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.
[186] Used eQuest 6.64 to derive wall assembly R-values.

Term	Unit	Value	Source
		Existing Assembly R-value	EDC Data Gathering
$R_{wall,ee}$[187] , Assembly R-value of wall after retrofit	$\frac{°F \cdot ft^2 \cdot hr}{Btu}$	Default = 11.0	Assumes adding R-6 per DOE recommendations[188]
		Retrofit Assembly R-value	EDC Data Gathering
$SEER_{CAC}$, Seasonal Energy Efficiency Ratio of existing home central air conditioner	$\frac{Btu}{W \cdot hr}$	Default for equipment installed before 1/23/2006 = 10 Default for equipment installed after 1/23/2006 = 13	4
		Nameplate	EDC Data Gathering
$\overline{EER}_{RAC}$, Average Energy Efficiency Ratio of existing room air conditioner	$\frac{Btu}{W \cdot hr}$	Default = 9.8	DOE Federal Test Procedure 10 CFR 430, Appendix F (Used in ES Calculator for baseline)
		Nameplate	EDC Data Gathering
$SEER_{ASHP}$, Seasonal Energy Efficiency Ratio of existing home air source heat pump	$\frac{Btu}{W \cdot hr}$	Default for equipment installed before 1/23/2006 = 10 Default for equipment installed after 1/23/2006 = 13 Default for equipment installed after 6/1/2015 = 14	4
		Nameplate	EDC Data Gathering
$HSPF_{ASHP}$, Heating Seasonal Performance Factor for existing home heat pump	$\frac{Btu}{W \cdot hr}$	Default for equipment installed before 1/23/2006 = 6.8 Default for equipment installed after 1/23/2006 = 7.7 Default for equipment installed after 6/1/2015 = 8.2	44
		Nameplate	EDC Data Gathering
EER_{GSHP} , Energy Efficiency Ratio of existing home ground source heat pump	$\frac{Btu}{W \cdot hr}$	Default for Ground Source Heat Pump = 13.4	5

187 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.
188 DOE recommendation on ENERGY STAR website for adding wall insulation to existing homes in Zones 5-8. Insulation may be loose fill in stud cavities or board insulation beneath siding.
http://www.energystar.gov/index.cfm?c=home_sealing.hm_improvement_insulation_table

Term	Unit	Value	Source
		Default for Groundwater Source Heat Pump = 16.2	
		Nameplate	EDC Gathering
GSER , Factor to determine the SEER of a GSHP based on its EER	*None*	1.02	6
COP_{GSHP} , Coefficient of Performance for existing home ground source heat pump	*None*	Default for Ground Source Heat Pump = 3.1 Default for Groundwater Source Heat Pump = 3.6	5
		Nameplate	EDC Gathering
GSOP , Factor to determine the HSPF of a GSHP based on its COP	$\frac{Btu}{W \cdot hr}$	3.413	7
GSHPDF , Ground Source Heat Pump De-rate Factor	*None*	0.885	(Engineering Estimate - See 2.2.1)
CF_{CAC} , Demand Coincidence Factor for central AC systems	*Fraction*	0.647	8
CF_{RAC} , Demand Coincidence Factor for Room AC systems	*Fraction*	0.647	9
CF_{ASHP} , Demand Coincidence Factor for ASHP systems	*Fraction*	0.647	8
CF_{GSHP} , Demand Coincidence Factor for GSHP systems	*Fraction*	0.647	8
$F_{Room,AC}$, Adjustment factor to relate insulated area to area served by Room AC units	*None*	0.38	Calculated[189]
CDD , Cooling Degree Days	$°F \cdot Days$	Table 2-103	10
HDD , Heating Degree Days	$°F \cdot Days$	Table 2-103	10
$EFLH_{cool}$, Equivalent Full Load Cooling hours for Room AC	$\frac{hours}{year}$	Table 2-103	11
$EFLH_{cool\ RAC}$, Equivalent Full Load Cooling hours for Central AC and ASHP	$\frac{hours}{year}$	Table 2-103	12

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

Table 2-103: EFLH, CDD and HDD by City

City	$EFLH_{cool}$ (Hours)	$EFLH_{cool\ RAC}$ (Hours)	CDD (Base 65)	HDD (Base 65)
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 2-11 and Table 2-12 in Section 2.1 may also be used for central air 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.

Attic Heating Effect on Cooling Loads

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%).

Evaluation Protocols

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

Sources

1. "State of Ohio Energy Efficiency Technical Reference Manual," prepared for the Public Utilities Commission of Ohio by Vermont Energy Investment Corporation. August 6, 2010.
2. "Improving Attic Thermal Performance", Home Energy, November 2004.

3. NOAA Climatic Data for Pennsylvania cities- Cloudiness (mean number of days Sunny, Partly Cloudy, and Cloudy), http://ols.nndc.noaa.gov/plolstore/plsql/olstore.prodspecific?prodnum=C00095-PUB-A0001.
4. US DOE Federal Standards for Central Air Conditioners and Heat Pumps. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/75
5. Minimum efficiency standards for Ground and Groundwater Source Heat Pumps. IECC 2009.
6. VEIC estimate. Extrapolation of manufacturer data.
7. Engineering calculation, HSPF/COP=3.413
8. Straub, Mary and Switzer, Sheldon. "Using Available Information for Efficient Evaluation of Demand Side Management Programs". Study by BG&E. The Electricity Journal. Aug/Sept. 2011. http://www.sciencedirect.com/science/article/pii/S1040619011001941
9. Consistent with CFs found in RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008.[190]
10. Climatography of the United States No. 81. Monthly Station Normals of Temperature, Precipitation, and Heating and Cooling Degree Days 1971-2000, 36 Pennsylvania. NOAA. http://cdo.ncdc.noaa.gov/climatenormals/clim81/PAnorm.pdf
11. Based on REM/Rate modeling using models from the PA 2012 Potential Study. EFLH calculated from kWh consumption for cooling and heating. Models assume 50% over-sizing of air conditioners and 40% oversizing of heat pumps.[191]
12. 2014 PA TRM Section 2.2.4 Room AC Retirement.

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

2.6.2 ENERGY STAR Windows

Measure Name	ENERGY STAR Windows
Target Sector	Residential Establishments
Measure Unit	Window Area
Unit Energy Savings	Varies
Unit Peak Demand Reduction	Varies
Measure Life	(15 max, but 20 for TRC) years[192]
Vintage	Replace on Burnout

Eligibility

This protocol documents the energy savings for replacing existing windows in a residence with ENERGY STAR certified windows. The target sector is primarily residential.

Algorithms

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

$$Total\ Savings = Area\ of\ Window\ ft^2 \times \frac{Savings}{ft^2}$$

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.[193] 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:

$$\Delta kWh/yr = ESav_{HP}$$

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

Electric Heat/Central Air Conditioning:

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

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

[192] Capped based on the requirements of the Pennsylvania Technical Reference Manual (June 2010)

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

Electric Heat/No Central Air Conditioning:

ΔkWh/yr $= ESav_{ResNoCAC}$

ΔkW_{peak} $= DSav_{NOCAC} \times CF$

Definition of Terms

Table 2-104: ENERGY STAR Windows - References

Component	Unit	Value	Sources
$ESav_{HP}$, Electricity savings (heating and cooling) with heat pump installed	$\frac{kWh}{ft^2}$	2.2395	1
HP Time Period Allocation Factors	*None*	Summer/On-Peak 10% Summer/Off-Peak 7% Winter/On-Peak 40% Winter/Off-Peak 44%	2
$ESav_{RES/CAC}$, Electricity savings with electric resistance heating and central AC installed.	$\frac{kWh}{ft^2}$	4.0	1
Res/CAC Time Period Allocation Factors	*None*	Summer/On-Peak 10% Summer/Off-Peak 7% Winter/On-Peak 40% Winter/Off-Peak 44%	2
$ESav_{RES/NOCAC}$, Electricity savings with electric resistance heating and no central AC installed	$\frac{kWh}{ft^2}$	3.97	1
Res/No CAC Time Period Allocation Factors	*None*	Summer/On-Peak 3% Summer/Off-Peak 3% Winter/On-Peak 45% Winter/Off-Peak 49%	2
$DSav_{HP}$, Summer demand savings with heat pump installed.	$\frac{kW}{ft^2}$	0.000602	1
$DSav_{CAC}$, Summer demand savings with central AC installed.	$\frac{kW}{ft^2}$	0.000602	1
$DSav_{NOCAC}$, Summer demand savings with no central AC installed.	$\frac{kW}{ft^2}$	0.00	1
CF , Demand Coincidence Factor	*Decimal*	0.647	3

Evaluation Protocols

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

Sources

1. 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. Straub, Mary and Switzer, Sheldon."Using Available Information for Efficient Evaluation of Demand Side Management Programs". Study by BG&E. The Electricity Journal. Aug/Sept. 2011. http://www.sciencedirect.com/science/article/pii/S1040619011001941
4. Prorated based on 12% of the annual degree days falling in the summer period and 88% of the annual degree days falling in the winter period.

2.6.3 Residential New Construction

Measure Name	Residential New Construction
Target Sector	Residential Establishments
Measure Unit	Multiple
Unit Energy Savings	Varies
Unit Peak Demand Reduction	Varies
Measure Life	Varies
Vintage	New Construction

Eligibility

This protocol documents the energy savings attributed to improvements to the construction of residential homes above the baseline home as calculated by the appropriate energy modeling software or as determined by deemed savings values.

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 mentioned 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[194] 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)

$$= (Heating\ kWh_{\ base} - \ Heating\ kWh_{q}) + (Cooling\ kWh_{\ base} - \ Cooling\ kWh_{q})$$

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

$$= \frac{PL_{base}}{EER_{base}}$$

Peak demand of the qualifying home

$$= \frac{PL_{q}}{EER_{q}}$$

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

Coincident system peak electric demand savings

$$= (Peak\ demand\ of\ the\ baseline\ home - Peak\ demand\ of\ the\ qualifying\ home) \times CF$$

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 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.[195]

DEFINITION OF TERMS

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

[195] 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.

Table 2-105: Residential New Construction – References

Component	Unit	Value	Sources
Heating kWh_{base}, Annual heating energy consumption of the baseline home, from software.	*kWh*	Software Calculated	1
Heating kWh_q, Annual heating energy consumption of the qualifying home, from software.	*kWh*	Software Calculated	2
Cooling kWh_{base}, Annual cooling energy consumption of the baseline home, from software.	*kWh*	Software Calculated	1
Cooling kWh_q, Annual cooling energy consumption of the qualifying home, from software.	*kWh*	Software Calculated	2
PL_{base}, Estimated peak cooling load of the baseline home, from software.	*kBtu/hr*	Software Calculated	3
EER_{base}. Energy Efficiency Ratio of the baseline unit.	$\frac{Btu}{W \cdot h}$	EDC Data Gathering or $SEER_b$ * BLEER	4
EER_q, Energy Efficiency Ratio of the qualifying unit.	$\frac{Btu}{W \cdot h}$	EDC Data Gathering or $SEER_q$ * BLEER	4
$SEER_{base}$, Seasonal Energy Efficiency Ratio of the baseline unit.	$\frac{Btu}{W \cdot h}$	13 14 (ASHP)	5
BLEER, Factor to convert baseline $SEER_b$ to EER_b.	$\frac{Btu}{W \cdot h}$	0.87	6
PL_q, Estimated peak cooling load for the qualifying home constructed, from software.	*kBtu/hr*	Software Calculated	7
$SEER_q$, SEER associated with the HVAC system in the qualifying home.	$\frac{Btu}{W \cdot h}$	EDC Data Gathering	8
CF , Demand Coincidence Factor (See Section 1.5)	*Decimal*	0.647	9

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 2-106: 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

Table 2-107: Energy Star Homes - User Defined Reference Home

Data Point	Value[196]	Source

196 Single and multiple family as noted.

Data Point	Value[196]	Source
Air Infiltration Rate	0.30 ACH for windows, skylights, sliding glass doors 0.50 ACH for swinging doors	13
Duct Leakage	12 cfm25 (12 cubic feet per minute per 100 square feet of conditioned space when tested at 25 pascals)	13
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.	10
Duct Location	50% in conditioned space, 50% unconditioned space	Program Design
Mechanical Ventilation	None	10
Lighting Systems	Minimum 50% of permanent installed fixtures to be high-efficacy lamps	10
Appliances	Use Default	
Setback Thermostat	Maintain zone temperature down to 55 ºF (13 ºC) or up to 85 ºF (29 ºC)	10
Temperature Set Points	Heating: 70°F Cooling: 78°F	10
Heating Efficiency		
Furnace	80% AFUE	11
Boiler	80% AFUE	11
Combo Water Heater	76% AFUE (recovery efficiency)	11
Air Source Heat Pump	8.2 HSPF	10
Geothermal Heat Pump	7.7 HSPF	10
PTAC / PTHP	Not differentiated from air source HP	10
Cooling Efficiency		
Central Air Conditioning	13.0 SEER	10
Air Source Heat Pump	14.0 SEER	10
Geothermal Heat Pump	13 SEER (11.2 EER)	10
PTAC / PTHP	Not differentiated from central AC	10
Window Air Conditioners	Not differentiated from central AC	10
Domestic WH Efficiency		
Electric	EF = 0.97 - (0.00132 * gallons)	12
Natural Gas	EF = 0.67 - (0.0019 * gallons)	12
Additional Water Heater Tank Insulation	None	

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with

verification of open variables. The Pennsylvania Phase II Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

SOURCES

1. 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. Straub, Mary and Switzer, Sheldon. "Using Available Information for Efficient Evaluation of Demand Side Management Programs". Study by BG&E. The Electricity Journal. Aug/Sept. 2011. Found at http://www.sciencedirect.com/science/article/pii/S1040619011001941 .
10. 2009 International Residential Code (IRC 2009, Sections N1102 – N1104)
11. 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.”
12. 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.”
13. 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.

2.6.4 Home Performance with ENERGY STAR

Measure Name	Home Performance with ENERGY STAR
Target Sector	Residential Establishments
Measure Unit	Multiple
Unit Energy Savings	Varies
Unit Peak Demand Reduction	Varies
Measure Life	Years
Vintage	Retrofit

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. These standards, along with operational guidelines on how to navigate through the HPwES program can be found on the ENERGY STAR website. Minimum requirements, Sponsor requirements, reporting requirements, and descriptions of the performance and prescriptive based options can be found in the v. 1.5 Reference Manual.[197] 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.[198]
- Software approved by the US Department of Energy's Weatherization Assistance Program.[199]
- RESNET approved rating software.[200]

There are numerous software packages that comply with these standards. Some examples of the software packages are REM/Rate, EnergyGauge, TREAT, and HomeCheck. These examples are not meant to be an exhaustive list of software approved by the bodies mentioned above.

Eligibility

The efficient condition is the performance of the residential home as modeled in the approved software after home performance improvements have been made. The baseline condition is the same home modeled prior to any energy efficiency improvements.

197 The HPwES Reference Manual may be found at https://www.energystar.gov/ia/home_improvement/downloads/HPwES_Sponsor_Guide_v1-5.pdf?07e7-3320

198 A new standard for BESTEST-EX for existing homes is currently being developed - 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.

199 A listing of the approved software available at http://www.waptac.org .

200 A listing of the approved software available at http://resnet.us .

Algorithms

There are no algorithms associated with this measure as the energy savings are shown through modeling software. For modeling software that provides 8760 energy consumption data, the following algorithm may be used as guidance to determine demand savings:

$$\Delta \boldsymbol{kW_{peak}} = \left(Average\ kW_{PJM\ PEAK}\right)_{base} - \left(Average\ kW_{PJM\ PEAK}\right)_{ee}$$

Definition of Terms

Table 2-108: Home Performance with ENERGY STAR - References

Component	Unit	Values	Source
$Average\ kW_{PJM\ PEAK}$, Average demand during the PJM Peak Period	kW	EDC Data Gathering	1

Evaluation Protocols

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

Sources

1. The coincident summer peak period is defined as the period between the hour ending 15:00 Eastern Prevailing Time[201] (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[202].

[201] This is same as the Daylight Savings Time (DST)
[202] PJM Manual 18B for Energy Efficiency Measurement & Verification

2.6.5 ENERGY STAR Manufactured Homes

Measure Name	ENERGY STAR® Manufactured Homes
Target Sector	Residential Establishments
Measure Unit	Variable
Unit Energy Savings	Variable
Unit Peak Demand Reduction	Variable
Measure Life	15 Years[203]
Vintage	New Construction

Eligibility

This measure applies to ENERGY STAR Manufactured Homes.

Algorithms

Insulation Upgrades, 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 ENERGY STAR Manufactured Homes 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[204] 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 ENERGY STAR Manufactured Homes, the baseline building thermal envelope and/or system characteristics shall be based on the current Manufactured Homes Construction and Safety Standards (HUD Code). For this measure a manufactured home "means a structure, transportable in one or more sections, which in the traveling mode, is eight body feet or more in width or forty body feet or more in length, or, when erected on site, is three hundred twenty or more square feet, and which is built on a permanent chassis and designed to be used as a dwelling with or without a permanent foundation when connected to the required utilities, and includes the plumbing, heating, air conditioning, and electrical systems contained therein."[205]

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/yr)

$$\Delta kWh = (\text{Heating kWh}_{base} - \text{Heating kWh}_{ee}) + (\text{Cooling kWh}_{base} - \text{Cooling kWh}_{ee})$$

[203] NREL, Northwest Energy Efficient Manufactured Housing Program Specification Development, T.Huges, B. Peeks February 2013 (http://www.nrel.gov/docs/fy13osti/56761.pdf)

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

[205] 24 CFR Part 3280-MANUFACTURED HOMES CONSTRUCTION AND SAFETY STANDARD(http://www.gpo.gov/fdsys/pkg/CFR-2013-title24-vol5/pdf/CFR-2013-title24-vol5-part3280.pdf)

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 Manufactured Home' program standard:

Peak demand of the baseline home

$$= \frac{PL_b}{EER_b}$$

Peak demand of the qualifying home

$$= \frac{PL_q}{EER_q}$$

Coincident system peak electric demand savings (kW)

$$\Delta kW_{peak} = (Peak\ demand\ of\ the\ baseline\ home - Peak\ demand\ of\ the\ qualifying\ home) \times CF$$

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 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.

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.[206] It was verified in the RESNET® Standard that lighting and appliances are account for as internal gains and will represnet an interaction with the HVAC systems.[207]

DEFINITION OF TERMS

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

[206] 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.

[207] http://www.resnet.us/standards/PropStdsRevision-01-11_Revised_FINAL.pdf

Table 2-109: ENERGY STAR Manufactured Homes– References

Component	Unit	Value	Sources
Heating kWh_{base}, Annual heating energy consumption of the baseline home	*kWh*	Software Calculated	1
Heating kWh_{ee}, Annual heating energy consumption of the qualifying home	*kWh*	Software Calculated	1
Cooling kWh_{base}, Annual cooling energy consumption of the baseline home	*kWh*	Software Calculated	1
Cooling kWh_{ee}, Annual cooling energy consumption of the qualifying home	*kWh*	Software Calculated	1
PL_b, Estimated peak cooling load of the baseline home	*kBtu/h*	Software Calculated	1
EER_b, Energy Efficiency Ratio of the baseline unit.	$\frac{Btu}{W \cdot h}$	EDC Data Gathering or $SEER_b$ * BLEER	2
EER_q, Energy Efficiency Ratio of the qualifying unit.	$\frac{Btu}{W \cdot h}$	EDC Data Gathering or $SEER_q$ * BLEER	2
$SEER_b$, Seasonal Energy Efficiency Ratio of the baseline unit.	$\frac{Btu}{W \cdot h}$	13 14 (ASHP)	4
BLEER, Factor to convert baseline SEERb to EERb.	$\frac{Btu}{W \cdot h}$	EDC Data Gathering Default = $\frac{11.3}{13}$ ASHP Default = $\frac{12}{14}$	3
PL_q, Estimated peak cooling load for the qualifying home constructed, in kBtu/hr, from software.	*kBtu/h*	Software Calculated	1
$SEER_q$, SEER associated with the HVAC system in the qualifying home.	$\frac{Btu}{W \cdot h}$	EDC Data Gathering	5
CF, Demand Coincidence Factor (See Section 1.5)	*Decimal*	EDC Data Gathering Default = 0.647	6

The HUD Code defines required insulation levels as an average envelope Uo value per zone. In Pennsylvania zone 3 requirements apply with a required Uo value of 0.079. This value cannot be directly used to define a baseline envelope R-values because the Uo value is dependent on both the size of the manufactured homes and insulating levels together. However because manufactured homes are typically built to standard dimensions baseline U-values can be estimated with reasonable accuracy.

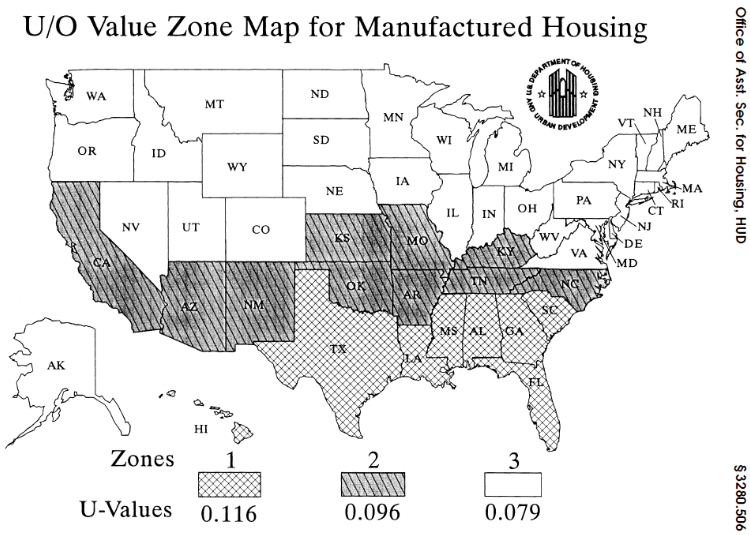

Figure 2-8: Uo Baseline Requirements[208]

The HUD Code required insulation levels can be expressed as a set of estimated envelope parameters to be used in REM/Rate's user defined reference home function. Using typical manufactured home sizes these values are expressed below along with federal standard baseline parameters below in Table 2-110.

Table 2-110: ENERGY STAR Manufactured Homes - User Defined Reference Home

Data Point	Value[209]	Source
Walls	U-value 0.090	7, 8
Ceilings	U-value 0.045	7, 8
Floor	U-value 0.045	7, 8
Windows	U-value 0.59	7, 8
Doors	U-Value 0.33	7, 8
Air Infiltration Rate	10 ACH50	7
Duct Leakage	RESNET/HERS default	7
Duct Insulation	RESNET/HERS default	7
Duct Location	Supply 100% manufactured home belly, Return 100% conditioned space	9
Mechanical Ventilation	0.035 CFM/sqft Exhaust	8
Lighting Systems	0% CFL 10% pin based (Default assumption)	10
Appliances	Use Default	7

208 24 CFR Part 3280-MANUFACTURED HOMES CONSTRUCTION AND SAFETY STANDARD(http://www.gpo.gov/fdsys/pkg/CFR-2013-title24-vol5/pdf/CFR-2013-title24-vol5-part3280.pdf)
209 Single and multiple family as noted.

Data Point	Value[209]	Source
Setback Thermostat	Non-Programmable thermostat	7
Temperature Set Points	Heating: 70°F Cooling: 78°F	11
Heating Efficiency		
Furnace	80% AFUE	12
Boiler	80% AFUE	12
Combo Water Heater	76% AFUE (recovery efficiency)	12
Air Source Heat Pump	7.7 HSPF	4
Geothermal Heat Pump	7.7 HSPF	4
PTAC / PTHP	Not differentiated from air source HP	4
Cooling Efficiency		
Central Air Conditioning	13.0 SEER	4
Air Source Heat Pump	13.0 SEER	4
Geothermal Heat Pump	13.0 SEER (11.2 EER)	4
PTAC / PTHP	Not differentiated from central AC	4
Window Air Conditioners	Not differentiated from central AC	4
Domestic WH Efficiency		
Electric	EF = 0.97 - (0.00132 * gallons) default = 0.917	13
Natural Gas	EF = 0.67 - (0.0019 * gallons) default = 0.594	14
Additional Water Heater Tank Insulation	None	15

Evaluation Protocols

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

Sources

1. Calculation of annual energy and peak load consumption of a baseline home from the home energy rating tool based on the reference home energy characteristics.
2. If the EER of the unit is known, use the EER. If only the SEER is known, then use SEER * BLEER to estimate the EER.
3. Ratio to calculate EER from SEER based average EER for SEER 13 units.
4. Federal Register / October 31, 2011 / Rules and Regulations , 10 CFR Part 430, "2011-10-31 Energy Conservation Program: Energy Conservation Standards for Residential Furnaces and Residential Central Air Conditioners and Heat Pumps; Notice of effective date and compliance dates for direct final rule." http://www.regulations.gov/#!documentDetail;D=EERE-2011-BT-STD-0011-0058
5. SEER of HVAC unit in energy efficient qualifying home.

6. Straub, Mary and Switzer, Sheldon."Using Available Information for Efficient Evaluation of Demand Side Management Programs". Study by BG&E. The Electricity Journal. Aug/Sept. 2011.
7. ENERGY STAR QUALIFIED MANUFACTURED HOMES-Guide for Retailers with instructions for installers and HVAC contractors / June 2007 / (http://www.research-alliance.org/pages/es_retail.htm)
8. 24 CFR Part 3280-MANUFACTURED HOMES CONSTRUCTION AND SAFETY STANDARD(http://www.gpo.gov/fdsys/pkg/CFR-2013-title24-vol5/pdf/CFR-2013-title24-vol5-part3280.pdf)
9. Standard manufactured home construction
10. Not a requirement of the HUD Code.
11. 2009 International Residential Code (IRC2009, Sections N1102-N1104)
12. 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.”
13. Federal Standards are 0.97 -0.00132 x Rated Storage in Gallons. For a 40-gallon tank this is 0.9172. “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
14. Federal Standards are 0.67 -0.0019 x Rated Storage in Gallons. For a 40-gallon tank this is 0.9172. “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
15. No requirement in code or federal regulation.

2.7 Miscellaneous

2.7.1 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[210]
Vintage	Retrofit

Residential pool pumps can be scheduled to avoid the 2 PM to 6 PM peak period.

Eligibility

This protocol documents the energy savings attributed to schedule residential single speed pool pumps to avoid run during the peak hours from 2 PM to 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.

Algorithms

The residential pool pump reschedule measure is intended to produce demand savings, but if the final daily hours of operation are different than the initial daily hours of operation, an energy savings (or increase) may result. The demand savings result from not running pool pumps during the peak hours of 2 PM to 6 PM.

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

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

The peak coincident factor, CF, is defined as the average coincident factor during 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 2 PM and 6 PM, divided by 4.

[210] 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.

Definition of Terms

Table 2-111: Pool Pump Load Shifting Assumptions

Component	Unit	Value	Source
Δhours/day , The change in daily operating hours.	$\frac{hours}{day}$	0	2
kW_{pump} , Electric demand of single speed pump at a given flow rate. This quantity should be measured or taken from Table 2-111	*kW*	1.364 kW or See Table 2-112	Table 2-112
CF_{pre} , Peak coincident factor of single speed pump from 2 PM to 6 PM in summer weekday prior to pump rescheduling. This quantity should be inferred from the timer settings	*Decimal*	0.306	3
CF_{post} , Peak coincident factor of single speed pump from 2 PM to 6 PM in summer weekday after pump rescheduling. This quantity should be inferred from the new timer settings.	*Decimal*	0.0	2
$Days_{operating}$, Days per year pump is in operation. This quantity should be recorded by applicant.	$\frac{days}{yr}$	100	1

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 2-112 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[211]. 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 2-112: Single Speed Pool Pump Specification[212]

Pump Horse Power (HP)	Average Pump Service Factor	Average Pump Motor Efficiency	Average Pump Power (kW)
0.50	1.62	0.66	0.946
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

211 "CEC Appliances Database – Pool Pumps." *California Energy Commission.* Updated Feb 2008. Accessed March 2008.

212 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.

Evaluation Protocol

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.

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. Calculated using the average of the 3 regions. The pool pump operating schedule is not weather dependant, but operator dependant. This is noted on page 22, paragraph 2 of the source. http://www.etcc-ca.com/sites/default/files/OLD/images/stories/pdf/ETCC_Report_473.pdf

2.7.2 Variable Speed Pool Pumps (with Load Shifting Option)

Measure Name	Residential VSD Pool Pumps
Target Sector	Residential Establishments
Measure Unit	VFD Pool Pumps
Unit Energy Savings	Variable
Unit Peak Demand Reduction	Variable
Measure Life	10 years[213]
Vintage	Replace on Burnout

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 2 PM to 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.

Eligibility

To qualify for the load shifting rebate, the pumps are required to be off during the hours of 2 PM to 6 PM weekdays. This practice results in additional demand reductions.

Algorithms

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

$$\Delta kWh/yr = kWh/yr_{base} - kWh/yr_{VFD}$$

$$kWh/yr_{base} = HOU_{ss} \times kW_{ss} \times Days$$

$$kWh/yr_{VFD} = \left[\left(HOU_{VFD,clean} \times kW_{VFD,clean}\right) + \left(HOU_{VFD,filter} \times kW_{VFD,filter}\right)\right] \times Days$$

The demand reductions are obtained through the following formula:

$$\Delta kW_{peak} = kW_{basepeak} - kW_{VFDpeak}$$

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

$$kW_{VFDpeak} = \frac{\left[\left(HOU_{peak,clean} \times kW_{VFD,clean}\right) + \left(HOU_{peak,filter} \times kW_{VFD,filter}\right)\right]}{4\ hours} \times CF_{VFD}$$

The peak coincidence factor, CF, is defined as the average coincidence factor during 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

213 DEER Effective Useful Life values, updated October 10, 2008.

number of hours that the pump was set to run between 2 PM to 6 PM, divided by 4. If this information is not available, the recommended daily hours of operation to use are 5.18 and the demand coincidence factor is 30.6%. These operation parameters are derived from the 2011 Mid Atlantic TRM.

Definition of Terms

The parameters in the above equation are listed below.

Note: The default values for $HOU_{VFD,clean}$ and $HOU_{peak,clean}$ are set to zero so that in the absence of multiple VFD mode data the algorithms reduce to those found in the 2014 Pennsylvania TRM (which only have one variable for HOU_{VFD} and kW_{VFD}).

Table 2-113: Residential VFD Pool Pumps Calculations Assumptions

Component	Unit	Values	Source
HOU_{SS} , Hours of operation per day for Single Speed Pump. This quantity should be recorded by the applicant.	$\frac{hours}{day}$	EDC Data Gathering Default= 5.18	2
$HOU_{VFD,filter}$, Hours of operation per day for Variable Frequency Drive Pump on filtration mode. This quantity should be recorded by the applicant.	$\frac{hours}{day}$	EDC Data Gathering Default = 13.00	2
$HOU_{VFD,clean}$, Hours of operation per day for Variable Frequency Drive Pump on cleaning mode. This quantity should be recorded by the applicant.	$\frac{hours}{day}$	EDC Data Gathering Default = 0	3
Days , Pool pump days of operation per year.	$\frac{days}{yr}$	100	2
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 2-114.	*Kilowatts*	EDC Data Gathering Default =1.364 kW or See Table 2-114	1 and Table 2-112 or Table 2-114
$kW_{VFD,\ filter}$, Electric demand of variable frequency drive pump during filtration mode. This quantity should be measured and recorded by the applicant.	*Kilowatts*	EDC Data Gathering	
$kW_{VFD,\ clean}$, Electric demand of variable frequency drive pump during cleaning mode. This quantity should be measured and recorded by the applicant.	*Kilowatts*	EDC Data Gathering	
$HOU_{peak,filter}$, Average daily hours of operation during peak period (between 2pm and 6pm) for Variable Frequency Drive Pump on filtration mode. This quantity should be recorded by the applicant.	$\frac{hours}{day}$	EDC Data Gathering Default = 4	4
$HOU_{peak,clean}$, Average daily hours of operation during peak period (between 2pm and 6pm) for Variable Frequency Drive Pump on cleaning mode. This quantity should be recorded by the	$\frac{hours}{day}$	EDC Data Gathering Default = 0	4

Component	Unit	Values	Source
applicant.			
CF_{SS} , Peak coincident factor of single speed pump from 2 PM to 6 PM in summer weekday. This quantity can be deduced from the pool pump timer settings for the old pump.	*Fraction*	EDC Data Gathering Default= 0.306	5
CF_{VFD} , Peak coincident factor of VFD pump from 2 PM to 6 PM in summer weekday. This quantity should be inferred from the new timer settings.	*Fraction*	EDC Data Gathering	

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 2-114 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[214]. 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 2-114: Single Speed Pool Pump Specification[215]

Pump Horse Power (HP)	Average Pump Service Factor	Average Pump Motor Efficiency	Average Pump Power (kW)
0.50	1.62	0.66	0.946
0.75	1.29	0.65	1.081
1.00	1.28	0.70	1.306
1.50	1.19	0.75	1.512
2.00	1.20	0.78	2.040
2.50	1.11	0.77	2.182
3.00	1.21	0.79	2.666

Electric Demand and Pump Flow Rate

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

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

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

214 "CEC Appliances Database – Pool Pumps." *California Energy Commission.* Updated Feb 2008. Accessed March 2008. <>

215 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.

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.

Default Savings

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

Evaluation Protocol

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.

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. The default value for $HOU_{VFD,clean}$ is set to zero so that in the absence of multiple VFD mode data the algorithms reduce to those found in the 2014 Pennsylvania TRM (which only have one variable for HOU_{VFD} and kW_{VFD}).
4. The Default values for $HOU_{peak,filter}$ *and* $HOU_{peak,clean}$ are given as 4 and 0, respectively, to collapse the formula to [$kW_{VFDpeak} = kW_{VFDfilter} \times CF_{VFD}$] in the absence of the additional necessary data.
5. Derived from Pool Pump and Demand Response Potential, DR 07.01 Report, SCE Design and Engineering, Table 16. Calculated using the average of the 3 regions. The pool pump operating schedule is not weather dependent, but operator dependent. This is noted on page 22, paragraph 2 of the source. http://www.etcc-ca.com/sites/default/files/OLD/images/stories/pdf/ETCC_Report_473.pdf

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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 LIGHTING

3.1.1 LIGHTING FIXTURE IMPROVEMENTS

Measure Name	Lighting Fixture Improvements
Target Sector	Commercial and Industrial Establishments
Measure Unit	Lighting Equipment
Unit Energy Savings	Variable
Unit Peak Demand Reduction	Variable
Measure Life	13 years[216]
Measure Vintage	Early Replacement

ELIGIBILITY

Lighting Fixture 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 II217. 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 Year 7 (June 1, 2015 – May 31, 2016) (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

[216] Measure Life Study, prepared for the Massachusetts Joint Utilities by ERS. October, 10, 2005. http://rtf.nwcouncil.org/subcommittees/nonreslighting/Measure%20Life%20Study_MA%20Joint%20Utilities_2005_ERS-1.pdf

[217] 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.

installed in PY7 will claim full savings until June 1, 2016. Savings adjustment factors[218] 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[219] (EUL) to adjust lifetime savings. Savings adjustment factors and reduced EULs for standard T-8, HPT8 and T5 measures are in Table 3-2, Table 3-3, and Table 3-4 below.

Algorithms

For all lighting fixture improvements (without control improvements), the following algorithms apply:

$$\Delta kWh = (kW_{base} - kW_{ee}) \times \left[HOU \times (1 - SVG_{base}) \times \left(1 + IF_{energy}\right)\right]$$

$$\Delta kW_{peak} = (kW_{base} - kW_{ee}) \times [CF \times (1 - SVG_{base}) \times (1 + IF_{demand})]$$

Definition of Terms

Table 3-1: Variables for Retrofit Lighting

Term	Unit	Values	Source
kW_{base} ,Connected load of the baseline lighting as defined by project classification	*kW*	See Standard Wattage Table in Appendix C: Lighting Audit and Design Tool	Appendix C: Lighting Audit and Design Tool
kW_{ee}, Connected load of the post-retrofit or energy–efficient lgithing system	*kW*	See Standard Wattage Table in Appendix C: Lighting Audit and Design Tool	Appendix C: Lighting Audit and Design Tool
SVG_{base}, Savings factor for existing lighting control (percent of time the lights are off)	*None*	EDC Data Gathering	EDC Data Gathering
		Default: See Table 3-5	See Table 3-5
CF, Demand Coincidence Factor	*Decimal*	EDC Data Gathering	EDC Data Gathering
		Default: See Table 3-6	See Table 3-6
HOU, Hours of Use – the average annual operating hours of the baseline lighting equipment, which if applied to full connected load will yield annual energy use.	$\frac{Hours}{Year}$	EDC Data Gathering	EDC Data Gathering
		Default: See Table 3-6	See Table 3-6
IF_{energy}, Interactive Energy Factor – applies to C&I interior lighting in space that has air conditioning or refrigeration only. This represents the secondary	*None*	Default: See Table 3-7	See Table 3-7

[218] 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.

[219] 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.

Term	Unit	Values	Source
energy savings in cooling required which results from decreased indoor lighting wattage.			
IF_{demand}, Interactive 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.	*None*	Default: See Table 3-7	See Table 3-7

Table 3-2: 2016 Savings Adjustment Factors and Adjusted EULs for Standard T-8 Measures[220]

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	0%	0%	0%	1	1	1
2-Lamp Relamp/Reballast	0%	0%	0%	1	1	1
3-Lamp Relamp/Reballast	0%	0%	0%	1	1	1
4-Lamp Relamp/Reballast	0%	0%	0%	1	1	1

Table 3-3: 2016 Savings Adjustment Factors and Adjusted EULs for HPT8 Measures[221]

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	47%	30%	20%	6.6	4.6	3.4
2-Lamp Relamp/Reballast	53%	30%	22%	7.4	4.6	3.6
3-Lamp Relamp/Reballast	42%	38%	21%	6.0	5.6	3.5
4-Lamp Relamp/Reballast	44%	29%	23%	6.3	4.5	3.8

[220] Since standard T8s will become the baseline in 2016, savings will be claimed the first year only.
[221] The savings adjustment is equal to the ratio between wattage reduction from T8 baseline to HPT8 or T5 lighting and wattage reduction from T12 fixture. These factors are taken from the 2013 IL TRM.

Table 3-4: 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	42%	29%	24%	6.0	4.5	3.9
2-Lamp T5 Industrial/Strip	61%	40%	34%	8.3	5.8	5.1
3-Lamp T5 Industrial/Strip	51%	40%	31%	7.1	5.8	4.7
4-Lamp T5 Industrial/Strip	60%	41%	51%	8.2	5.9	7.1

For example, a 1-lamp T12 EEmag ballast fixture with a 34 watt lamp is upgraded to a T5 fixture on June 1, 2015. This upgrade saves 8 watts during the first year of installation (full savings, first year) and has an EUL of 13 years. After the first year (June 1, 2016), the annual savings decreases due the code change mentioned above. When calculating lifetime savings, we have two options to account for this savings decrease: 1) apply a savings adjustment factor, or 2) apply an adjusted EUL.

To use a savings adjustment factor, the EDC would apply the associated savings adjustment factor (in this case, 42%) to the annual savings (8 watts) for the measure life remaining after June 1, 2016 (in our example, 12 years). The first year the measure is installed (2015) the measure receives full savings (100%); the next 12 years (or the remaining measure life) the measure receives savings adjusted by the associated adjustment factor.

Stated numerically:

$$Lifetime\ savings = (annual\ savings\ \times years\ at\ full\ savings \times 100\%) + (annual\ savings * years\ at\ reduced\ savings \times savings\ adjustment\ factor)$$

$$= \left(8\ \frac{W}{yr} \times 1\ yr \times 100\%\right) + \left(8\ \frac{W}{yr} \times 12\ yr \times 42\%\right) = 48\ W$$

The second option to calculate lifetime savings is to use the adjusted EUL option. To do this, the EDC would multiply the adjusted EUL, rather than the full 13 year EUL, by the first year savings estimate (in this case, 8 watts). In our example above, the adjusted EUL is 6.0 years.

Stated numerically:

$$Lifetime\ savings = annual\ savings\ \times adjusted\ EUL$$

$$= 8\frac{W}{yr} \times 6.0\ yr = 48\ W$$

Both options, savings adjustment factor and adjusted EUL, will result in the same lifetime savings estimate. It is up to the EDC to determine which methodology is easier in their systems.

Other factors required to calculate savings are shown in Table 3-5, 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. In addition, the site-specific CF must also be used to calculate savings if actual hours are used. 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 3-5: Savings Control Factors Assumptions[222]

Strategy	Definition	Technology	Savings %	Sources
Switch	Manual On/Off Switch	Light Switch	0%	1,2,3
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%	

Table 3-6: Lighting HOU and CF by Building Type or Function

Building Type	HOU	CF[223]	Source
Auto Related	4,056	0.62*	10
Daycare	2,590	0.62*	11
Dusk-to-Dawn / Exterior Lighting	3,833	0.00	5

[222] Subject to verification by EDC Evaluation or SWE

[223] 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.

Building Type	HOU	CF[223]	Source
Education – School	1,632	0.31	4
Education – College/University	2,348	0.76	4
Grocery	4,660	0.87	4
Health/Medical – Clinic	3,213	0.73	4
Hospitals	5,182	0.80	4
Industrial Manufacturing – 1 Shift	2,857	0.57	9
Industrial Manufacturing – 2 Shift	4,730	0.57	9
Industrial Manufacturing – 3 Shift	6,631	0.57	9
Libraries	2,566	0.62*	12
Lodging – Guest Rooms	914	0.09	4
Lodging – Common Spaces	7,884	0.90	4
Multi-Family (Common Areas) - High-rise & Low-rise	5,950	0.62*	6
Nursing Home	4,160	0.62*	7
Office	2,567	0.61	4
Parking Garages	6,552	0.62*	13
Public Order and Safety	5,366	0.62*	14
Public Assembly (one shift)	2,610	0.62*	7
Public Services (nonfood)	3,425	0.62*	8
Restaurant	3,613	0.65	4
Retail	2,829	0.73	4
Religious Worship/Church	1,810	0.62*	15
Storage Conditioned/Unconditioned	3,420	0.62*	7
Warehouse	2,316	0.54	4
24/7 Facilities or Spaces	8,760	1.00	N/A
Other224	Varies	Varies	4

* 0.62 represents the simple average of all coincidence factors listed in the 2011 Mid-Atlantic TRM

Table 3-7: Interactive Factors and Other Lighting Variables

Term	Unit	Values	Source
IF_{demand}	*None*	Cooled space (60 °F – 79 °F) = 0.34 Freezer spaces (-35 °F – 20 °F) = 0.50 Medium-temperature refrigerated spaces (20 °F – 40 °F) = 0.29 High-temperature refrigerated spaces (40 °F – 60 °F)	3

[224] 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.

Term	Unit	Values	Source
		= 0.18	
		Un-cooled space = 0	
IF_{energy}	*None*	Cooled space (60 °F – 79 °F) = 0.12 Freezer spaces (-35 °F – 20 °F) = 0.50 Medium-temperature refrigerated spaces (20 °F – 40 °F) = 0.29 High-temperature refrigerated spaces (40 °F – 60 °F) = 0.18	3
		Un-cooled space = 0	
kW_{base}	*kW*	See Standard Wattage Table in Appendix C: Lighting Audit and Design Tool	Appendix C: Lighting Audit and Design Tool
kW_{inst}	*kW*	See Standard Wattage Table in Appendix C: Lighting Audit and Design Tool	Appendix C: Lighting Audit and Design Tool

Default Savings

There are no default savings associated with this measure.

Evaluation Protocols

Methods for Determining Baseline Conditions

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

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

Detailed Inventory Form

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

Projects with connected load savings less than 20 kW

For projects having less than 20 kW in connected load savings, a detailed inventory is not required but information sufficient to validate savings according to the algorithm in 3.1.1 must be included in the documentation. This includes identification of baseline equipment utilized for quantifying kW_{base}. Appendix C: Lighting Audit and Design Tool contains a prescriptive lighting table, which can estimate savings for small, simple projects under 20 kW 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 this measure, ΔkW values will be multiplied by the number of fixtures installed. The total ΔkW savings is derived by summing the total ΔkW for each installed measure.

Within a single project, to the extent there are different control strategies (SVG), hours of use (HOU), coincidence factors (CF) or interactive factors (IF), the ΔkW will be broken out to account for these different factors. This will be accomplished using Appendix C: Lighting Audit and Design Tool, 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: Lighting Audit and Design Tool 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[225]. 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: Lighting Audit and Design Tool is more than 10%[226] 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: Lighting Audit and Design Tool. 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: Lighting Audit and Design Tool must still be used. However, if a third-party

[225] 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.

[226] 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.

lighting inventory form is provided, entries to Appendix C: Lighting Audit and Design Tool may be condensed into groups sharing common baseline fixtures, retrofit fixtures, space type, building type, and controls. Whereas Appendix C: Lighting Audit and Design Tool separates fixtures by location to facilitate evaluation and audit activities, third-party forms can serve that specific function if provided.

Appendix C: Lighting Audit and Design Tool 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: Lighting Audit and Design Tool.

- **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 deviate by more than 10% from Table 3-6 hours for the appropriate building type, the EDCs’ implementation and evaluation contractors can 1): use the HOU values from the “other” category as the building type or 2): use the facility’s actual lighting hours as collected through posted hours, interviews, or logging. Selecting the option on a project-by-project basis is unacceptable. An EDC should select one method and apply it consistently to all projects throughout a program year where actual facility lighting hours deviate by more than 10% from default hours.

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.

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**[227]

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.

[227] The exact variables that should be determined using metering are shown in Table 3-15 of the 2015 TRM.

Projects with savings of 500,000 kWh or higher

For projects with expected savings of 500,000 kWh or higher, metering is required[228] 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 or 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.

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. http://eetd.lbl.gov/sites/all/files/a_meta-analysis_of_energy_savings_from_lighting_controls_in_commercial_buildings_lbnl-5095e.pdf
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. https://focusonenergy.com/sites/default/files/bpincrementalcoststudyfinal_evaluationreport.pdf
3. 2011 Efficiency Vermont TRM
4. 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

[228] 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.

5. 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.

6. 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.

7. California Public Utility Commission. Database for Energy Efficiency Resources, 2011. www.deeresources.com

8. State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0", KEMA, March, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

9. UI and CL&P Program Savings Documentation for 2012 Program Year, United Illuminating Company, September 2011. http://www.energizect.com/sites/default/files/2012%20CT%20Program%20Savings%20Documentation%20FINAL.pdf

10. California Public Utility Commission. Database for Energy Efficiency Resources, 2011; available at www.deeresources.com

11. 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.

12. 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.

13. 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).

14. 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. http://www.eia.gov/consumption/commercial/data/2003/pdf/b1rse-b46rse.pdf

15. 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. http://www.eia.gov/consumption/commercial/data/2003/pdf/b1rse-b46rse.pdf

3.1.2 New Construction Lighting

Measure Name	New Construction Lighting
Target Sector	Commercial and Industrial Establishments
Measure Unit	Lighting Equipment
Unit Energy Savings	Variable
Unit Peak Demand Reduction	Variable
Measure Life	15 years[229]
Measure Vintage	New Construction

New Construction and Major Renovation incentives are intended to encourage decision-makers in new construction and major renovation projects to incorporate greater energy efficiency into their building design and construction practices that will result in a permanent reduction in electrical (kWh) usage above baseline practices,

Eligibility Requirements

New construction applies to new building projects wherein no structure or site footprint presently exists, addition or expansion of an existing building or site footprint, or major tenant improvements that change the use of the space. Eligible lighting equipment and fixture/lamp types include fluorescent fixtures (lamps and ballasts), compact fluorescent lamps, high intensity discharge (HID) lamps, interior and exterior LED lamps and fixtures, cold-cathode fluorescent lamps (CCFL), induction lamps, and lighting controls. The baseline demand (kW_{base}) for calculating savings is determined using one of the two methods detailed in ASHRAE 90.1-2007. The interior lighting baseline is calculated using the more conservative of the Building Area Method[230] as shown in Table 3-9 or the Space-by-Space Method[231] as shown in Table 3-10. For exterior lighting, the baseline is calculated using the Baseline Exterior Lighting Power Densities[232] as shown in Table 3-11. The post-installation demand is calculated based on the installed fixtures using the "06 Wattage Table" sheet in Appendix E: Lighting Audit and Design Tool for C&I New Construction Projects.

For eligibility requirements of solid state lighting products, see Appendix F: Eligibility Requirements for Solid State Lighting Products in Commercial and Industrial Applications.

Algorithms

For all new construction projects analyzed using the ASHRAE 90.1-2007 **Building Area Method**, the following algorithms apply:

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229 Measure Life Study, prepared for the Massachusetts Joint Utilities by ERS. October, 10, 2005. http://rtf.nwcouncil.org/subcommittees/nonreslighting/Measure%20Life%20Study_MA%20Joint%20Utilities_2005_ERS-1.pdf

230 ASHRAE 90.1-2007, Table 9.5.1 – Building Area Method. https://law.resource.org/pub/us/code/ibr/ashrae.90.1.2007.pdf

231 ASHRAE 90.1-2007, Table 9.6.1 – Space-by-Space Method. https://law.resource.org/pub/us/code/ibr/ashrae.90.1.2007.pdf

232 ASHRAE 90.1-2007, Table 9.4.5 – Baseline Exterior Lighting Power Densities. https://law.resource.org/pub/us/code/ibr/ashrae.90.1.2007.pdf

$$\Delta kWh = (kW_{base} - kW_{ee}) \times \left[HOU \times (1 - SVG) \times \left(1 + IF_{energy}\right)\right]$$

$$\Delta kW_{peak} = (kW_{base} - kW_{ee}) \times [CF \times (1 + IF_{demand})]$$

For all new construction projects analyzed using the AHRAE 90.1-2007 **Space-by-Space Method**, the following algorithms apply:

$$\Delta kWh = \sum_{i=1}^{n} \Delta kWh_1 + \Delta kWh_2 + \cdots \Delta kWh_n$$

$$\Delta kW_{peak} = \sum_{i=1}^{n} \Delta kW_{p1} + \Delta kWh_{p2} + \cdots \Delta kWh_{pn}$$

Where n is the number of spaces and:

$$\Delta kWh_1 = \left(kW_{base,1} - kW_{ee,1}\right) \times \left[HOU_1 \times (1 - SVG_1) \times \left(1 + IF_{energy,1}\right)\right]$$

$$\Delta kW_{p1} = \left(kW_{base,1} - kW_{ee,1}\right) \times \left[CF_1 \times \left(1 + IF_{demand,1}\right)\right]$$

Definition of Terms

Table 3-8: Variables for New Construction Lighting

Term	Unit	Values	Source
kW_{base}, The baseline space or building connected load as calculated by multiplying the space or building area by the appropriate Lighting Power Density (LPD) values specified in either Table 3-9 or Table 3-10	*kW*	Calculated based on space or building type and size.	Calculated Value
kW_{ee}, The calculated connected load of the energy efficient lighting	*kW*	Calculated based on specifications of installed equipment using Appendix E: Lighting Audit and Design Tool for C&I New Construction Projects	Calculated Value
SVG, Savings factor for the new lighting control (percent of time the lights are off)	*None*	Based on Metering	EDC Data Gathering
		Default: See Table 3-14	13,14,15
CF, Demand Coincidence Factor	*Decimal*	Based on Metering[233]	EDC Data Gathering
		Default: See Table 3-12	See Table 3-12
HOU, Hours of Use – the average annual operating hours of the	$\frac{Hours}{Year}$	Based on Metering[234]	EDC Data Gathering
		Default: See Table 3-12	See Table 3-12

[233] It is noted that if site-specific data is used to determine HOU, then the same data must be used to determine the site-specific CF. Similarly, if the default TRM HOU is used, then the default TRM CF must also be used in the savings calculations.
[234] Ibid.

Term	Unit	Values	Source
facility			
IF, Interactive Factor	*None*	Vary based on building type and space cooling details.	See * 0.62 represents the simple average of all coincidence factors listed in the 2011 Mid-Atlantic TRM Table 3-13

Table 3-9: Lighting Power Densities from ASHRAE 90.1-2007 Building Area Method[235]

Building Area Type[236]	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

[235] ASHRAE 90.1-2007, "Table 9.5.1 Lighting Power Densities Using the Building Area Method." https://law.resource.org/pub/us/code/ibr/ashrae.90.1.2007.pdf
[236] In cases where both a common space type and a building specific type are listed, the building specific space type shall apply.

Table 3-10: Lighting Power Densities from ASHRAE 90.1-2007 Space-by-Space Method[237]

Common Space Type[238]	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

[237] ASHRAE 90.1-2007, "Table 9.6.1 Lighting Power Densities Using the Space-by-Space Method." https://law.resource.org/pub/us/code/ibr/ashrae.90.1.2007.pdf

[238] In cases where both a common space type and a building specific type are listed, the building specific space type shall apply.

Common Space Type[238]	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	
		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

Common Space Type[238]	LPD (W/ft2)	Building Specific Space Types	LPD (W/ft2)
		Terminal—Ticket Counter	1.5

Table 3-11: Baseline Exterior Lighting Power Densities[239]

Building Exterior	Space Description	LPD
Uncovered Parking Area	Parking Lots and Drives	0.15 W/ft^2
Building Grounds	Walkways less than 10 ft. wide	1.0 W/linear foot
	Walkways 10 ft. wide or greater	0.2 W/ft^2
	Plaza areas	
	Special feature areas	
	Stairways	1.0 W/ft^2
Building Entrances and Exits	Main entries	30 W/linear foot of door width
	Other doors	20 W/linear foot of door width
Canopies and Overhangs	Free standing and attached and overhangs	1.25 W/ft^2
Outdoor sales	Open areas (including vehicle sales lots)	0.5 W/ft^2
	Street frontage for vehicle sales lots in addition to "open area" allowance	20 W/linear foot
Building facades		0.2 W/ft^2 for each illuminated wall or surface or 5.0 W/linear foot for each illuminated wall or surface length
Automated teller machines and night depositories		270 W per location plus 90 W per additional ATM per location
Entrances and gatehouse inspection stations at guarded facilities		1.25 W/ft^2 of uncovered area
Loading areas for law enforcement, fire, ambulance, and other emergency service vehicles		0.5 W/ft^2 of uncovered area
Drive-through windows at fast food restaurants		400 W per drive-through
Parking near 24-hour retail entrances		800 W per main entry

Table 3-12: Lighting HOU and CF by Building Type or Function for New Construction Lighting

Building Type	HOU	CF[240]	Source

[239] ASHRAE 90.1-2007 Table 9.4.5. https://law.resource.org/pub/us/code/ibr/ashrae.90.1.2007.pdf

Building Type	HOU	CF[240]	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[241]	Varies	Varies	1

[240] 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.

[241] 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.

*** 0.62 represents the simple average of all coincidence factors listed in the 2011 Mid-Atlantic TRM**

Table 3-13: Interactive Factors

Term	Unit	Values	Source
IF_{demand}	None	Cooled space (60 °F – 79 °F) = 0.34 Freezer spaces (-35 °F – 20 °F) = 0.50 Medium-temperature refrigerated spaces (20 °F – 40 °F) = 0.29 High-temperature refrigerated spaces (40 °F – 60 °F) = 0.18 Un-cooled space = 0	15
IF_{energy}	None	Cooled space (60 °F – 79 °F) = 0.12 Freezer spaces (-35 °F – 20 °F) = 0.50 Medium-temperature refrigerated spaces (20 °F – 40 °F) = 0.29 High-temperature refrigerated spaces (40 °F – 60 °F) = 0.18 Un-cooled space = 0	15

Table 3-14: Savings Control Factors

Control Strategy	Definition	Technology	SVG[242]	Sources
Switch	Manual On/Off Switch	Light Switch	0%	13,14,15
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%	

Default Savings

There are no default savings associated with this measure.

Evaluation Protocols

- **Detailed Inventory Form**

A detailed inventory of all installed fixtures contributing to general light requirements is mandatory for participation in this measure. Lighting that need not be included in the inventory is as follows:

1. Display or accent lighting in galleries, museums, and monuments

[242] According to Table G3.2 of the ASHRAE 90.1 standard, a savings factor of 10% is applied to new construction controls above code (dimmers, wireless on-off switches, bi-level switches, etc).

2. Lighting that is integral to:

    Equipment or instrumentation and installed by its manufacturer,

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

    Equipment used for food warming and food preparation,

    Medical equipment, or

    Advertising or directional signage

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

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

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

Installed fixture wattages are determined by selecting the appropriate fixture code from the “06 Wattage Table” sheet. The “08 Fixture Code Locator” sheet can be used to find the appropriate code for a particular lamp-ballast combination[243]. Actual wattages of fixtures determined by manufacturer’s equipment specification sheets or other independent sources may not be used unless (1) the manufacturer's cut sheet indicates that the difference in delta-watts of fixture wattages (i.e. difference in delta watts of baseline and “actual” installed efficient fixture wattage and delta watts of baseline and nearest matching efficient fixture in standard wattage table of Appendix E: Lighting Audit and Design Tool for C&I New Construction Projects is more than 10%[244] or (2) the corresponding fixture code is not listed in the Standard Wattage Table. In these cases, alternate wattages for lamp-ballast combinations can be inputted using the “02 Interior User Input” or the “04 Exterior User Input” sheets of Appendix E: Lighting Audit and Design Tool for C&I New Construction Projects. Documentation supporting the alternate wattages must be provided in the form of manufacturer provided specification sheets or other industry accepted sources (e.g. ENERGY STAR listing, Design Lights Consortium listing). It must cite test data performed under standard ANSI procedures. These exceptions will be used as the basis for periodically updating the Standard Wattage Table to better reflect market conditions and more accurately represent savings.

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[243] 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.

[244] 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.

Some lighting contractors may have developed in-house lighting inventory forms that are used to determine preliminary estimates of projects. In order to ensure standardization of all New Construction lighting projects, Appendix E: Lighting Audit and Design Tool for C&I New Construction Projectsmust still be used. However, if a third-party lighting inventory form is provided, entries to Appendix E: Lighting Audit and Design Tool for C&I New Construction Projectsmay be condensed into groups sharing installed fixtures, space type, building type, and controls. Whereas Appendix E: Lighting Audit and Design Tool for C&I New Construction Projects separates fixtures by location to facilitate evaluation and audit activities, third-party forms can serve that specific function if provided.

Appendix E: Lighting Audit and Design Tool for C&I New Construction Projects 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 E: Lighting Audit and Design Tool for C&I New Construction Projects.

- **Metering**

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[245] 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 or 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.

SOURCES

[245] 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.

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. www.deeresources.com
5. State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0", KEMA, March, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
6. UI and CL&P Program Savings Documentation for 2012 Program Year, United Illuminating Company, September 2011. http://www.energizect.com/sites/default/files/2012%20CT%20Program%20Savings%20Documentation%20FINAL.pdf
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. http://www.eia.gov/consumption/commercial/data/2003/pdf/b1rse-b46rse.pdf

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. http://www.eia.gov/consumption/commercial/data/2003/pdf/b1rse-b46rse.pdf

13. 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. http://eetd.lbl.gov/sites/all/files/a_meta-analysis_of_energy_savings_from_lighting_controls_in_commercial_buildings_lbnl-5095e.pdf

14. Goldberg et al, State of Wisconsin Public Service Commission of Wisconsin, Focus on Energy Evaluation, Business Programs, Incremental Cost Study, KEMA, October 28, 2009. https://focusonenergy.com/sites/default/files/bpincrementalcoststudyfinal_evaluationreport.pdf

15. 2011 Efficiency Vermont TRM

3.1.3 Lighting Controls

Measure Name	Lighting Controls
Target Sector	Commercial and Industrial Establishments
Measure Unit	Wattage Controlled
Unit Energy Savings	Variable
Unit Peak Demand Reduction	Variable
Measure Life	8 years[246]
Measure Vintage	Retrofit

Eligibility

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 (CF), hours of use (HOU)) 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 **3-15**.

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: Lighting Audit and Design Tool. In either case, the kW_{ee} for the purpose of the algorithm is set to kW_{base}.

Algorithms

$$\Delta kWh = kW_{controlled} \times HOU \times (SVG_{ee} - SVG_{base}) \times \left(1 + IF_{energy}\right)$$

$$\Delta kW_{peak} = kW_{controlled} \times (SVG_{ee} - SVG_{base}) \times (1 + IF_{demand}) \times CF$$

Definition of Terms

[246] DEER Effective Useful Life. October 10, 2008.

Table 3-15: Lighting Controls Assumptions

Term	Unit	Values	Source
$kW_{controlled}$, Total lighting load connected to the new control in kilowatts. Savings are per control. The total connected load per control should be collected from the customer or the default values shown in Table 3-15 should be used.	*kW*	Lighting Audit and Design Tool in Appendix C: Lighting Audit and Design Tool	EDC Data Gathering
SVG_{base} and SVG_{ee}, Savings factor for baseline lighting and new lighting control (percent of time the lights are off), typically manual switch.	*None*	Based on metering	EDC Data Gathering
		Default: See Table 3-5	1
CF, Demand Coincidence Factor	*Decimal*	Based on metering[247]	EDC Data Gathering
		By building type and size	See Table 3-6
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.	$\frac{Hours}{Year}$	Based on metering[248]	EDC Data Gathering
		By building type and size	See Table 3-6
IF, Interactive Factor	*None*	By building type and size	See Table 3-7

Default Savings

There are no default savings for this measure.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables.

It is noted that if site-specific data is used to determine HOU, then the same data must be used to determine the site-specific CF. Similarly, if the default TRM HOU is used, then the default TRM CF must also be used in the savings calculations. The Pennsylvania Phase II Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

[247] It is noted that if site-specific data is used to determine HOU, then the same data must be used to determine the site-specific CF. Similarly, if the default TRM HOU is used, then the default TRM CF must also be used in the savings calculations.
[248] Ibid.

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. http://eetd.lbl.gov/sites/all/files/a_meta-analysis_of_energy_savings_from_lighting_controls_in_commercial_buildings_lbnl-5095e.pdf

3.1.4 Traffic Lights

Measure Name	Traffic Lights
Target Sector	Government, Non-Profit and Institutional
Measure Unit	Traffic Light
Unit Energy Savings	Variable
Unit Peak Demand Reduction	Variable
Measure Life	10 years[249]
Measure Vintage	Early Replacement

Eligibility

This protocol applies to the early replacement of existing incandescent traffic lights and pedestrian signals with LEDs. New LED traffic signals must comply with ENERGY STAR requirements.[250]

Algorithms

$$\Delta kWh = (kW_{base} - kW_{ee}) \times HOU$$

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

Definition of Terms

Table 3-16: Assumptions for LED Traffic Signals

Term	Unit	Values	Source
kW_{base}, The connected load of the baseline lighting as defined by project classification.	*kW*	Vary based on fixture details, See Table 3-17	2, 3, 4, 5
kW_{ee}, The connected load of the post-retrofit or energy-efficient lighting system.	*kW*	Vary based on fixture details, See Table 3-17	2, 3, 4, 5
CF, Demand Coincidence Factor	*Decimal*	Default: Red Round: 0.55 Yellow Round: 0.02	1

249 The Measure Life Report for Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc., June 2007. http://library.cee1.org/sites/default/files/library/8842/CEE_Eval_MeasureLifeStudyLights%26HVACGDS_1Jun2007.pdf

250 ENERGY STAR Program Requirements for Traffic Signals. https://www.energystar.gov/ia/partners/product_specs/eligibility/traffic_elig.pdf?98bf-1786

Term	Unit	Values	Source
		Round Green: 0.43 Red Arrow: 0.86 Yellow Arrow: 0.08 Green Arrow: 0.08 Pedestrian: 1.00	
HOU, Annual hours of use	$\frac{Hours}{Year}$	Default: Round Red: 4,818 Round Yellow: 175 Round Green: 3,767 Red Arrow: 7,358 Yellow Arrow: 701 Green Arrow: 701 Pedestrian: 8,760	1

DEFAULT SAVINGS

Table 3-17: Default Values for Traffic Signal and Pedestrian Signage Upgrades

Fixture Type	% Burn	kW_{base}	kW_{ee}	ΔkW_{peak}	ΔkWh	Sources
Round Traffic Signals						
8" Red	55%	0.069	0.006	0.035	304	5, 2
8" Yellow	2%	0.069	0.007	0.001	11	
8" Green	43%	0.069	0.008	0.026	230	
12" Red	55%	0.150	0.006	0.079	694	5, 2
12" Yellow	2%	0.150	0.012	0.003	24	
12" Green	43%	0.150	0.007	0.061	539	
Turn Arrows						
8" Red	84%	0.116	0.005	0.093	817	5, 3
8" Yellow	8%	0.116	0.014	0.008	71	
8" Green	8%	0.116	0.006	0.009	77	
12" Red	84%	0.116	0.006	0.092	809	5, 2
12" Yellow	8%	0.116	0.006	0.009	77	
12" Green	8%	0.116	0.006	0.009	77	
Pedestrian Signs (All Burn 100%)						
9" Hand Only		0.116	0.008	0.108	946	5, 2
9" Pedestrian Only		0.116	0.006	0.110	964	
12" Hand Only		0.116	0.008	0.108	946	
12" Pedestrian Only		0.116	0.007	0.109	955	
12" Countdown Only		0.116	0.005	0.111	972	
12" Pedestrian and Hand Overlay		0.116	0.007	0.109	955	
16" Pedestrian and Hand Side by Side		0.116	0.008	0.108	946	
16" Pedestrian and Hand Overlay		0.116	0.007	0.109	955	
16" Hand with Countdown Side-by-side		0.116	0.010	0.106	929	
16" Pedestrian and Hand with Countdown Overlay		0.116	0.008	0.108	946	5, 4

Notes:
1) Energy Savings (kWh) are annual per lamp.
2) Demand Savings (kW_{peak}) listed are per lamp.

Evaluation Protocols

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

Sources

1. PECO Comments on the PA TRM, received March 30, 2009.
2. ITE Compliant LED Signal Modules Catalog by Dialight. http://www.dialight.com
3. RX11 LED Signal Modules Spec Sheet by GE Lighting Solutions, http://www.gelighting.com
4. LED Countdown Pedestrian Signals Spec Sheet by GE Lighting Solutions, http://www.gelighting.com
5. GE Lighting Product Catalog by GE Lighting Solutions. http://genet.gelighting.com

3.1.5 LED Exit Signs

Measure Name	LED Exit Signs
Target Sector	Commercial and Industrial Establishments
Measure Unit	LED Exit Sign
Unit Energy Savings	Variable
Unit Peak Demand Reduction	Variable
Measure Life	16 years[251]
Measure Vintage	Early Replacement

Eligibility

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 3-18, the default savings value for LED exit signs installed cooled spaces can be used without completing Appendix C: Lighting Audit and Design Tool.

Algorithms

$$\Delta kWh = (kW_{base} - kW_{ee}) \times \left[HOU \times \left(1 + IF_{energy}\right)\right]$$

$$\Delta kW_{peak} = (kW_{base} - kW_{ee}) \times [CF \times (1 + IF_{demand})]$$

[251] DEER Effective Useful Life. October 10, 2008. For the purpose of calculating the total Resource Cost Test for Act 129, measure cannot claim savings for more than 15 years.

Definition of Terms

Table 3-18: LED Exit Signs Calculation Assumptions

Term	Unit	Values	Source
kW_{base}, Connected load of baseline lighting as defined by project classification	*kW*	Actual Wattage	EDC Data Gathering
		Single-Sided Incandescent: 0.020 Dual-Sided Incandescent: 0.040 Single-Sided Fluorescent: 0.009 Dual-Sided Fluorescent: 0.020	Appendix C: Lighting Audit and Design Tool
kW_{ee}, Connected load of the post-retrofit or energy-efficient lighting	*kW*	Actual Wattage	EDC Data Gathering
		Single-Sided: 0.002 Dual-Sided: 0.004	Appendix C: Lighting Audit and Design Tool
CF, Demand Coincidence Factor	*Decimal*	1.0	1
HOU, Hours of Use – the average annual operating hours of the baseline lighting equipment.	$\frac{Hours}{Year}$	8,760	1
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.	*None*	See: Table 3-7	Table 3-7
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.	*None*	See: Table 3-7	Table 3-7

Default Savings

Single-Sided LED Exit Signs replacing Incandescent Exit Signs in Cooled Spaces

$$\Delta kWh = 176\ kWh$$

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

Dual-Sided LED Exit Signs replacing Incandescent Exit Signs in Cooled Spaces

$$\Delta kWh = 353\ kWh$$

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

Single-Sided LED Exit Signs replacing Fluorescent Exit Signs in Cooled Spaces

$$\Delta kWh = 69\ kWh$$

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

Dual-Sided LED Exit Signs replacing Fluorescent Exit Signs in Cooled Spaces

$$\Delta kWh = 157\ kWh$$

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

Evaluation Protocols

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

Sources

1. WI Focus on Energy, "*Business Programs: Deemed Savings Manual V1.0*." Update Date: March 22, 2010. LED Exit Lighting. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

3.1.6 LED Channel Signage

Measure Name	LED Channel Signage
Target Sector	Commercial and Industrial Establishments
Measure Unit	LED Channel Signage
Unit Energy Savings	Variable
Unit Peak Demand Reduction	Variable
Measure Life	15 years[252]
Measure Vintage	Early Replacement

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 is the most common color and the most cost-effective to retrofit, currently comprising approximately 80% of the market. Green, blue, yellow, and white LEDs are also available, but at a higher cost than red LEDs.

Eligibility

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. Replacement signs cannot use more than 20%[253] of the actual input power of the sign that is replaced. Measure the length of the sign as follows:

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

Algorithms

The savings are calculated using the equations below and the assumptions in Table 3-19.

[252] Southern California Edison Company, LED Channel Letter Signage (Red), Work 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.

[253] http://www.aepohio.com/global/utilities/lib/docs/save/programs/Application_Steps_Incentive_Process.pdf

Indoor applications:

$$\Delta kWh = [kW_{base} \times (1 + IF_{energy}) \times HOU \times (1 - SVG_{base})] - [kW_{ee} \times (1 + IF_{energy}) \times HOU \times (1 - SVG_{ee})]$$

$$\Delta kW_{peak} = [kW_{base} \times (1 + IF_{demand}) \times CF \times (1 - SVG_{base})] - [kW_{ee} \times (1 + IF_{demand}) \times CF \times (1 - SVG_{ee})]$$

Outdoor applications:

ΔkWh[254]

$$= [kW_{base} \times HOU \times (1 - SVG_{base})] - [kW_{ee} \times HOU \times (1 - SVG_{ee})]$$

$$\Delta kW_{peak} = [kW_{base} \times CF \times (1 - SVG_{base})] - [kW_{ee} \times CF \times (1 - SVG_{ee})]$$

Definition of Terms

Table 3-19: LED Channel Signage Calculation Assumptions

Term	Unit	Values	Source
kW_{base}, kW of baseline (pre-retrofit) lighting	*kW*	EDC Data Gathering Default: See Table 3-20[255]	EDC Data Gathering
kW_{ee}, kW of post-retrofit or energy-efficient lighting system (LED) lighting per letter	*kW*	EDC Data Gathering Default: See Table 3-20[256]	EDC Data Gathering
CF, Demand Coincidence Factor	*Decimal*	EDC Data Gathering Default for Indoor Applications: See Table 3-6 Default for Outdoor Applications: *0*[257]	EDC Data Gathering Table 3-6
HOU, Annual hours of Use	$\frac{Hours}{Year}$	EDC Data Gathering Default: See Table 3-6	EDC Data Gathering Table 3-6
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.	*None*	See Table 3-7	1
IF_{energy}, Interactive HVAC Energy	*None*	See Table 3-7	1

[254] For exterior measures, energy interactive effects are not included in the energy savings calculations.
[255] 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.
[256] ibid
[257] 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.

Term	Unit	Values	Source
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_{base}, Savings factor for existing lighting control (percent of time the lights are off), typically manual switch.	*None*	Default: See Table 3-5	Table 3-5
SVG_{ee}, Savings factor for new lighting control (percent of time the lights are off).	*None*	Default: See Table 3-5	Table 3-5

Table 3-20: 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

Default Savings

There are no default savings for this measure.

Evaluation Protocol

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with verification of open variables.

It is noted that if site-specific data is used to determine HOU, then the same data must be used to determine the site-specific CF. Similarly, if the default TRM HOU is used, then the default TRM CF must also be used in the savings calculations. The Pennsylvania Phase II Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1. Efficiency Vermont. Technical Reference User Manual: Measure Savings Algorithms and Cost Assumptions (July 2008).

3.1.7 LED Refrigeration Display Case Lighting

Measure Name	LED Refrigeration Display Case Lighting
Target Sector	Commercial and Industrial Establishments
Measure Unit	Refrigeration Display Case Lighting
Unit Energy Savings	Variable
Unit Peak Demand Reduction	Variable
Measure Life	8 years[258]
Measure Vintage	Early Replacement

This protocol applies to LED lamps with and without motion sensors installed in vertical display refrigerators, coolers, and freezers replacing T8 or T12 linear fluorescent lamps. The LED lamps produce less waste heat than the fluorescent baseline lamps, decreasing the cooling load on the refrigeration system and energy needed by the refrigerator compressor. Additional savings can be achieved from the installation of motion sensors which dim the lights when the space is unoccupied.

Eligibility

This measure is targeted to non-residential customers who install LED case lighting with or without motion sensors on refrigerators, coolers, and freezers - specifically on vertical displays. The baseline equipment is assumed to be cases with uncontrolled T8 or T12 linear fluorescent lamps.

Algorithms

Savings and assumptions are based on a per door basis.

$$\Delta kWh = \frac{(WATTS_{base} - WATTS_{ee})}{1000} \times N_{doors} \times HOURS \times (1 + IE)$$

$$\Delta kW_{peak} = \frac{(WATTS_{base} - WATTS_{ee})}{1000} \times N_{doors} \times (1 + IE) \times CF$$

[258] Theobald, M. A., Emerging Technologies Program: Application Assessment Report #0608, LED Supermarket Case Lighting Grocery Store, Northern California, Pacific Gas and Electric Company, January 2006. <http://www.etcc-ca.com/images/stories/pdf/ETCC_Report_204.pdf>. Assumes 6,205 annual operating hours and 50,000 lifetime hours. Most case lighting runs continuously (24/7) but some can be controlled. 6,205 annual hours of use can be used to represent the mix. Using grocery store hours of use (4,660 hr) is too conservative since case lighting is not tied to store lighting.

Definition of Terms

Table 3-21: LED: Refrigeration Case Lighting – Values and References

Term	Unit	Values	Source
$WATTS_{base}$, Connected wattage of baseline fixtures	*W*	EDC Data Gathering	EDC Data Gathering
$WATTS_{ee}$, Connected wattage of efficient fixtures	*W*	EDC Data Gathering	EDC Data Gathering
N_{doors}, Number of doors	*None*	EDC Data Gathering	EDC Data Gathering
$HOURS$, Annual operating hours	$\frac{Hours}{Year}$	EDC Data Gathering Default: 6,205	1
IE, Interactive Effects factor for energy to account for cooling savings from efficient lighting	*None*	Refrigerator and cooler: 0.41 Freezer: 0.52	2
CF, Coincidence factor	*Decimal*	0.92	3
1000, Conversion factor from watts to kilowatts	$\frac{W}{kW}$	1000	Conversion Factor

Default Savings

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

Evaluation Protocols

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

Sources

1. Theobald, M. A., Emerging Technologies Program: Application Assessment Report #0608, LED Supermarket Case Lighting Grocery Store, Northern California, Pacific Gas and Electric Company, January 2006. <http://www.etcc-ca.com/images/stories/pdf/ETCC_Report_204.pdf>. Assumes 6,205 annual operating hours and 50,000 lifetime hours. Most case lighting runs continuously (24/7) but some can be controlled. 6,205 annual hours of use can be used to represent the mix. Using grocery store hours of use (4,660 hr) is too conservative since case lighting is not tied to store lighting.
2. Values adopted from Hall, N. et al, New York Standard Approach for Estimating Energy Savings from Energy Efficiency Measures in Commercial and Industrial Programs, TecMarket Works, September 1, 2009.

http://www3.dps.ny.gov/W/PSCWeb.nsf/0/06f2fee55575bd8a852576e4006f9af7/$FILE/TechManualNYRevised10-15-10.pdf

3. Methodology adapted from Kuiken et al, “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Parameter Development”, KEMA, November 13, 2009, assuming summer coincident peak period is defined as June through August on weekdays between 3:00 p.m. and 6:00 p.m., unless otherwise noted. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

3.2 HVAC

3.2.1 HVAC Systems

Measure Name	HVAC Systems
Target Sector	Commercial and Industrial Establishments
Measure Unit	HVAC System
Unit Energy Savings	Variable
Unit Peak Demand Reduction	Variable
Measure Life	15 years[259]
Measure Vintage	Replace on Burnout, New Construction, or Early Replacement

Eligibility

The energy and demand savings for Commercial and Industrial HVAC systems is determined from the algorithms listed below. This protocol excludes water source, ground source, and groundwater source heat pumps measures that are covered in Section 3.2.3. All HVAC applications other than comfort cooling and heating, such as process cooling, are defined as non-standard applications and are ineligible for this measure.

Algorithms

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

For A/C units < 65,000 $\frac{Btu}{hr}$, use SEER to calculate ΔkWh and convert SEER to EER to calculate ΔkW_{peak} using 11.3/13 as the conversion factor. For units rated in both EER and IEER, use IEER for energy savings calculations.

$$\Delta kWh = \left(\frac{Btu_{cool}}{hr} \times \frac{1\ kW}{1000\ W}\right) \times \left(\frac{1}{EER_{base}} - \frac{1}{EER_{ee}}\right) \times EFLH_{cool}$$

$$= \left(\frac{Btu_{cool}}{hr} \times \frac{1\ kW}{1000\ W}\right) \times \left(\frac{1}{IEER_{base}} - \frac{1}{IEER_{ee}}\right) \times EFLH_{cool}$$

$$= \left(\frac{Btu_{cool}}{hr} \times \frac{1\ kW}{1000\ W}\right) \times \left(\frac{1}{SEER_{base}} - \frac{1}{SEER_{ee}}\right) \times EFLH_{cool}$$

$$\Delta kW_{peak} = \left(\frac{Btu_{cool}}{hr} \times \frac{1\ kW}{1000\ W}\right) \times \left(\frac{1}{EER_{base}} - \frac{1}{EER_{ee}}\right) \times CF$$

[259] The Measure Life Report for Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc., June 2007.
http://library.cee1.org/sites/default/files/library/8842/CEE_Eval_MeasureLifeStudyLights%26HVACGDS_1Jun2007.pdf

Air Source and Packaged Terminal Heat Pump

For ASHP units < 65,000 $\frac{Btu}{hr}$, use SEER to calculate ΔkWh_{cool} and HSPF to calculate ΔkWh_{heat}. Convert SEER to EER to calculate ΔkW_{peak} using 11.3/13 as the conversion factor. For units rated in both EER and IEER, use IEER for energy savings calculations.

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

$$\Delta kWh_{cool} = \left(\frac{Btu_{cool}}{hr} \times \frac{1\ kW}{1000\ W}\right) \times \left(\frac{1}{EER_{base}} - \frac{1}{EER_{ee}}\right) \times EFLH_{cool}$$

$$= \left(\frac{Btu_{cool}}{hr} \times \frac{1\ kW}{1000\ W}\right) \times \left(\frac{1}{IEER_{base}} - \frac{1}{IEER_{ee}}\right) \times EFLH_{cool}$$

$$= \left(\frac{Btu_{cool}}{hr} \times \frac{1\ kW}{1000\ W}\right) \times \left(\frac{1}{SEER_{base}} - \frac{1}{SEER_{ee}}\right) \times EFLH_{cool}$$

$$\Delta kWh_{heat} = \left(\frac{Btu_{heat}}{hr} \times \frac{1\ kW}{1000\ W}\right) \times \frac{1}{3.412} \times \left(\frac{1}{COP_{base}} - \frac{1}{COP_{ee}}\right) \times EFLH_{heat}$$

$$= \left(\frac{Btu_{heat}}{hr} \times \frac{1\ kW}{1000\ W}\right) \times \left(\frac{1}{HSPF_{base}} - \frac{1}{HSPF_{ee}}\right) \times EFLH_{heat}$$

$$\Delta kW_{peak} = \left(\frac{Btu_{cool}}{hr} \times \frac{1\ kW}{1000\ W}\right) \times \left(\frac{1}{EER_{base}} - \frac{1}{EER_{ee}}\right) \times CF$$

Definition of Terms

Table 3-22: Variables for HVAC Systems

Term	Unit	Values	Source
$\frac{Btu_{cool}}{hr}$, Rated cooling capacity of the energy efficient unit	$\frac{Btu}{hr}$	Nameplate data (AHRI or AHAM)	EDC Data Gathering
$\frac{Btu_{heat}}{hr}$, Rated heating capacity of the energy efficient unit	$\frac{Btu}{hr}$	Nameplate data (AHRI or AHAM)	EDC Data Gathering
$IEER_{base}$, Integrated energy efficiency ratio of the baseline unit.	$\frac{Btu/hr}{W}$	Early Replacement: Nameplate data	EDC Data Gathering
		New Construction or Replace on Burnout: Default values from Table 3-23	See Table 3-23
$IEER_{ee}$, Integrated energy efficiency ratio of the energy efficient unit.	$\frac{Btu/hr}{W}$	Nameplate data (AHRI or AHAM)	EDC Data Gathering
EER_{base}, Energy efficiency ratio of the baseline unit. For air-source AC and ASHP	$\frac{Btu/hr}{W}$	Early Replacement: Nameplate data	EDC Data Gathering

Term	Unit	Values	Source
units < 65,000 $\frac{Btu}{hr}$, SEER should be used for cooling savings		New Construction or Replace on Burnout: Default values from Table 3-23	See Table 3-23
EER_{ee}, Energy efficiency ratio of the energy efficient unit. For air-source AC and ASHP units < 65,000 $\frac{Btu}{hr}$, SEER should be used for cooling savings.	$\frac{Btu/hr}{W}$	Nameplate data (AHRI or AHAM)	EDC Data Gathering
$SEER_{base}$, Seasonal energy efficiency ratio of the baseline unit. For units > 65,000 $\frac{Btu}{hr}$, EER should be used for cooling savings.	$\frac{Btu/hr}{W}$	Early Replacement: Nameplate data	EDC Data Gathering
		New Construction or Replace on Burnout: Default values from Table 3-23	See Table 3-23
$SEER_{ee}$, Seasonal energy efficiency ratio of the energy efficient unit. For units > 65,000 $\frac{Btu}{hr}$, EER should be used for cooling savings.	$\frac{Btu/hr}{W}$	Nameplate data (AHRI or AHAM)	EDC Data Gathering
COP_{base}, Coefficient of performance of the baseline unit. For ASHP units < 65,000$\frac{Btu}{hr}$, HSPF should be used for heating savings.	None	Early Replacement: Nameplate data	EDC Data Gathering
		New Construction or Replace on Burnout: Default values from Table 3-23	See Table 3-23
COP_{ee}, Coefficient of performance of the energy efficient unit. For ASHP units < 65,000 $\frac{Btu}{hr}$ HSPF should be used for heating savings.	None	Nameplate data (AHRI or AHAM)	EDC Data Gathering
$HSPF_{base}$, Heating seasonal performance factor of the baseline unit. For units > 65,000 $\frac{Btu}{hr}$, COP should be used for heating savings.	$\frac{Btu/hr}{W}$	Early Replacement: Nameplate data	EDC Data Gathering
		New Construction or Replace on Burnout: Default values from Table 3-23	See Table 3-23
$HSPF_{ee}$, Heating seasonal performance factor of the energy efficiency unit. For units > 65,000 $\frac{Btu}{hr}$, COP should be used for heating savings.	$\frac{Btu/hr}{W}$	Nameplate data (AHRI or AHAM)	EDC Data Gathering

Term	Unit	Values	Source
CF, Demand Coincidence Factor	*Decimal*	See Table 3-25	1
$EFLH_{cool}$, Equivalent Full Load Hours for the cooling season – The kWh during the entire operating season divided by the kW at design conditions.	$\frac{Hours}{Year}$	Based on Logging, BMS data or Modeling[260]	EDC Data Gathering
		Default values from Table 3-24	1
$EFLH_{heat}$, Equivalent Full Load Hours for the heating season – The kWh during the entire operating season divided by the kW at design conditions.	$\frac{Hours}{Year}$	Based on Logging, BMS data or Modeling[261]	EDC Data Gathering
		Default values from Table 3-26	1
11.3/13, Conversion factor from SEER to EER, based on average EER of a SEER 13 unit	*None*	$\frac{11.3}{13}$	2
1000, conversion from watts to kilowatts	$\frac{W}{kW}$	1000	Conversion Factor

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.

Table 3-23: HVAC Baseline Efficiencies[262]

Equipment Type and Capacity	Cooling Baseline	Heating Baseline
Air-Source Air Conditioners		
< 65,000 $\frac{Btu}{hr}$	13.0 SEER	N/A
≥ 65,000 $\frac{Btu}{hr}$ and <135,000 $\frac{Btu}{hr}$	11.2 EER 11.4 IEER	N/A
≥ 135,000 $\frac{Btu}{hr}$ and < 240,000 $\frac{Btu}{hr}$	11.0 EER 11.2 IEER	N/A
≥ 240,000 $\frac{Btu}{hr}$ and < 760,000 $\frac{Btu}{hr}$	10.0 EER 10.1 IEER	N/A

260 Modeling is an acceptable substitute to metering and BMS data if 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).

261 Ibid

262 Baseline values from IECC 2009 (https://law.resource.org/pub/us/code/ibr/icc.iecc.2009.pdf), 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.

Equipment Type and Capacity	Cooling Baseline	Heating Baseline
≥ 760,000 $\frac{Btu}{hr}$	9.7 EER 9.8 IEER	N/A
Air-Source Heat Pumps		
< 65,000 $\frac{Btu}{hr}$	13 SEER	7.7 HSPF
≥ 65,000 $\frac{Btu}{hr}$ and <135,000 $\frac{Btu}{hr}$	11.0 EER 11.2 IEER	3.3 COP
≥ 135,000 $\frac{Btu}{hr}$ and < 240,000 $\frac{Btu}{hr}$	10.6 EER 10.7 IEER	3.2 COP
≥ 240,000 $\frac{Btu}{hr}$	9.5 EER 9.6 IEER	3.2 COP
Packaged Terminal Systems (Nonstandard Size) - Replacement [263, 264]		
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 (Standard Size) – New Construction [265, 266]		
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
Water-Cooled Air Conditioners		
< 65,000 $\frac{Btu}{hr}$	12.1 EER 12.3 IEER	N/A
> 65,000 $\frac{Btu}{hr}$ and <135,000 $\frac{Btu}{hr}$	12.1 EER 12.3 IEER	N/A
> 135,000 $\frac{Btu}{hr}$ and < 240,000 $\frac{Btu}{hr}$	12.5 EER 12.7 IEER	N/A
> 240,000 $\frac{Btu}{hr}$ and < 760,000 $\frac{Btu}{hr}$	12.4 EER 12.6 IEER	N/A
> 760,000 $\frac{Btu}{hr}$	11.0 EER 11.1 IEER	N/A

[263]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.
[264] Cap represents the rated cooling capacity of the product in Btu/hr. If the unit's capacity is less than 7,000 Btu/hr, 7,000 Btu/hr is used in the calculation. If the unit's capacity is greater than 15,000 Btu/hr, 15,000 Btu/hr is used in the calculation.
[265] This is intended for applications with standard size exterior wall openings.
[266] Cap represents the rated cooling capacity of the product in Btu/hr. If the unit's capacity is less than 7,000 Btu/hr, 7,000 Btu/hr is used in the calculation. If the unit's capacity is greater than 15,000 Btu/h, 15,000 Btu/hr is used in the calculation.

Evaporatively-Cooled Air Conditioners		
< 65,000 $\frac{Btu}{hr}$	12.1 EER 12.3 IEER	N/A
> 65,000 $\frac{Btu}{hr}$ and <135,000 $\frac{Btu}{hr}$	12.1 EER 12.3 IEER	N/A
> 135,000 $\frac{Btu}{hr}$ and < 240,000 $\frac{Btu}{hr}$	12.0 EER 12.2 IEER	N/A
> 240,000 $\frac{Btu}{hr}$ and < 760,000 $\frac{Btu}{hr}$	11.9 EER 12.1 IEER	N/A
> 760,000 $\frac{Btu}{hr}$	11.0 EER 11.1 IEER	N/A

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.

Table 3-24: Air Conditioning EFLHs for Pennsylvania Cities

Space and/or Building Type	Allentown	Erie	Harrisburg	Philadelphia	Pittsburgh	Scranton	Williamsport
Assembly	753	607	820	1,087	706	629	685
Education - Community College	603	436	620	695	557	515	594
Education - Primary School	250	154	277	302	255	204	208
Education - Relocatable Classroom	301	198	326	359	303	229	246
Education - Secondary School	249	204	327	375	262	219	264
Education - University	677	520	693	773	630	550	595
Grocery	654	636	453	536	638	434	442
Health/Medical - Hospital	1,030	1,038	892	1,059	788	1,022	1,013
Health/Medical - Nursing Home	477	481	540	684	511	467	476
Lodging - Hotel	1,386	1,392	1,523	1,732	1,478	1,348	1,384
Manufacturing - Bio/Tech	785	548	766	858	710	594	627
Manufacturing - Light Industrial	355	274	465	506	349	296	329
Office - Large	480	433	601	754	749	595	490
Office - Small	435	391	529	653	692	404	442
Restaurant - Fast-Food	545	478	574	790	602	524	569
Restaurant - Sit-Down	555	548	605	791	662	519	618
Retail - Multistory Large	763	595	803	807	673	629	694
Retail - Single-Story Large	747	574	771	988	738	640	642
Retail - Small	695	692	652	938	1,036	541	608

Storage - Conditioned	174	114	235	346	192	130	178
Warehouse - Refrigerated	3,130	3,080	3,163	3,200	3,116	3,094	3,135

Table 3-25: Air Conditioning Demand CFs for Pennsylvania Cities

Space and/or Building Type	Allentown	Erie	Harrisburg	Philadelphia	Pittsburgh	Scranton	Williamsport
Assembly	0.53	0.45	0.60	0.72	0.56	0.48	0.52
Education - Community College	0.49	0.37	0.49	0.53	0.49	0.48	0.52
Education - Primary School	0.10	0.07	0.16	0.16	0.17	0.11	0.12
Education - Relocatable Classroom	0.15	0.11	0.18	0.19	0.20	0.14	0.15
Education - Secondary School	0.11	0.10	0.20	0.21	0.18	0.13	0.17
Education - University	0.47	0.38	0.47	0.49	0.47	0.42	0.45
Grocery	0.33	0.27	0.24	0.26	0.27	0.21	0.24
Health/Medical - Hospital	0.43	0.37	0.39	0.44	0.39	0.37	0.42
Health/Medical - Nursing Home	0.26	0.27	0.30	0.34	0.32	0.28	0.29
Lodging - Hotel	0.72	0.77	0.78	0.83	0.83	0.73	0.78
Manufacturing - Bio/Tech	0.62	0.47	0.61	0.67	0.64	0.54	0.55
Manufacturing - Light Industrial	0.39	0.31	0.49	0.52	0.42	0.36	0.40
Office - Large	0.33	0.32	0.42	0.27	0.35	0.39	0.37
Office - Small	0.31	0.30	0.39	0.27	0.34	0.33	0.36
Restaurant - Fast-Food	0.36	0.33	0.39	0.47	0.44	0.38	0.42
Restaurant - Sit-Down	0.39	0.41	0.45	0.53	0.54	0.40	0.48
Retail - Multistory Large	0.52	0.42	0.56	0.53	0.51	0.48	0.51
Retail - Single-Story Large	0.50	0.40	0.53	0.63	0.55	0.47	0.47
Retail - Small	0.53	0.56	0.51	0.55	0.63	0.45	0.50
Storage - Conditioned	0.18	0.13	0.24	0.30	0.23	0.15	0.20
Warehouse - Refrigerated	0.50	0.48	0.52	0.53	0.51	0.48	0.51

Table 3-26: Heat Pump EFLHs for Pennsylvania Cities

Space and/or Building Type	Allentown	Erie	Harrisburg	Philadelphia	Pittsburgh	Scranton	Williamsport
Assembly	1,178	1,437	1,098	1,121	1,163	1,401	1,066
Education - Community College	816	966	620	521	734	977	783
Education - Primary School	795	830	651	557	819	879	543
Education - Relocatable Classroom	360	165	863	726	1,056	1,003	745
Education - Secondary School	752	1,002	710	654	776	893	677
Education - University	621	748	483	407	567	670	527
Grocery	733	534	1,269	1,217	564	1,737	1,419
Health/Medical - Hospital	147	95	361	345	418	106	154
Health/Medical - Nursing Home	944	1,304	854	805	1,023	1,193	958
Lodging - Hotel	2,371	3,077	2,159	2,017	2,411	2,591	2,403
Manufacturing - Bio/Tech	178	193	138	111	172	176	141
Manufacturing - Light Industrial	633	752	609	567	627	705	550
Office - Large	218	292	230	22	30	176	231
Office - Small	423	551	430	38	62	481	448
Restaurant - Fast-Food	1,227	1,627	1,112	1,078	1,363	1,612	1,295
Restaurant - Sit-Down	1,074	1,747	968	908	1,316	1,390	1,187
Retail - Multistory Large	687	828	582	447	620	736	587
Retail - Single-Story Large	791	979	674	735	849	929	654
Retail - Small	949	1,133	689	109	164	900	785
Storage - Conditioned	847	1,114	843	900	978	1,008	800
Warehouse - Refrigerated	363	534	307	222	409	439	328

Default Savings

There are no default savings for this measure.

Evaluation Protocols

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

SOURCES

1. EFLHs and CFs for Pennsylvania are calculated based on Nexant's eQuest modeling analysis 2014.
2. Average EER for SEER 13 units as calculated by EER = -0.02 × SEER^2 + 1.12 × SEER based on U.S. DOE Building America House Simulation Protocol, Revised 2010. http://www.nrel.gov/docs/fy11osti/49246.pdf

3.2.2 ELECTRIC CHILLERS

Measure Name	Electric Chillers
Target Sector	Commercial and Industrial Establishments
Measure Unit	Electric Chiller
Unit Energy Savings	Variable
Unit Peak Demand Reduction	Variable
Measure Life	20 years[267]
Measure Vintage	Replace on Burnout, New Construction, or Early Replacement

ELIGIBILITY

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 (EFLHs). 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 (including redundant or 'stand-by' chillers), 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. This protocol does not apply to VFD retrofits to an existing chiller. In this scenario, the IPLV of the baseline chiller (factory tested IPLV) would be known, but the IPLV for the old chiller/new VFD would be unknown. The algorithms, assumptions, and default factors in this section may be applied to new construction applications.

ALGORITHMS

Efficiency ratings in EER

$$\Delta kWh = Tons_{ee} \times 12 \times \left(\frac{1}{IPLV_{base}} - \frac{1}{IPLV_{ee}}\right) \times EFLH$$

$$\Delta kW_{peak} = Tons_{ee} \times 12 \times \left(\frac{1}{EER_{base}} - \frac{1}{EER_{ee}}\right) \times CF$$

[267] DEER Effective Useful Life. October 10, 2008. For the purpose of calculating the total Resource Cost Test for Act 129, measure cannot claim savings for more than fifteen years.

Efficiency ratings in kW/ton

$$\Delta kWh = Tons_{ee} \times (IPLV_{base} - IPLV_{ee}) \times EFLH$$

$$\Delta kW_{peak} = Tons_{ee} \times \left(\frac{kW}{ton_{base}} - \frac{kW}{ton_{ee}}\right) \times CF$$

Definition of Terms

Table 3-27: Electric Chiller Variables

Term	Unit	Values	Source
$Tons_{ee}$, The capacity of the chiller at site design conditions accepted by the program	*Tons*	Nameplate Data	EDC Data Gathering
$\frac{kW}{ton_{base}}$, Design Rated Efficiency of the baseline chiller.	$\frac{kW}{ton}$	Early Replacement: Nameplate Data	EDC Data Gathering
		New Construction or Replace on Burnout: Default value from Table 3-28	See Table 3-28
$\frac{kW}{ton_{ee}}$, Design Rated Efficiency of the energy efficient chiller from the manufacturer data and equipment ratings in accordance with ARI Standards.	$\frac{kW}{ton}$	Nameplate Data (ARI Standards 550/590). At minimum, must satisfy standard listed in Table 3-28	EDC Data Gathering
EER_{base}, Energy Efficiency Ratio of the baseline unit.	$\frac{Btu/hr}{W}$	Early Replacement: Nameplate Data	EDC Data Gathering
		New Construction or Replace on Burnout: Default value from Table 3-28	See Table 3-28
EER_{ee}, Energy Efficiency Ratio of the efficient unit from the manufacturer data and equipment ratings in accordance with ARI Standards.	$\frac{Btu/hr}{W}$	Nameplate Data (ARI Standards 550/590). At minimum, must satisfy standard listed in Table 3-28	EDC Data Gathering
$IPLV_{base}$, Integrated Part Load Value of the baseline unit.	*None* or $\frac{kW}{ton}$	New Construction or Replace on Burnout: See Table 3-28	See Table 3-28
$IPLV_{ee}$, Integrated Part Load Value of the efficient unit.	*None* or $\frac{kW}{ton}$	Nameplate Data (ARI Standards 550/590). At minimum, must satisfy standard listed in Table 3-28	EDC Data Gathering

Term	Unit	Values	Source
CF, Demand Coincidence Factor	*Decimal*	See Table 3-30	1
$EFLH$, Equivalent Full Load Hours – The kWh during the entire operating season divided by the kW at design conditions. The most appropriate EFLH shall be utilized in the calculation.	$\frac{Hours}{Year}$	Based on Logging, BMS data or Modeling[268]	EDC Data Gathering
		Default values from Table 3-29	1

Table 3-28: Electric Chiller Baseline Efficiencies (IECC 2009)[269]

Chiller Type	Size	Path A	Path B	Source
Air Cooled Chillers	< 150 tons	Full load: 9.562 EER IPLV: 12.500 EER	N/A	2
	>=150 tons	Full load: 9.562 EER IPLV: 12.750 EER	N/A	
Water Cooled Positive Displacement or Reciprocating Chiller	< 75 tons	Full load: 0.780 kW/ton IPLV: 0.630 kW/ton	Full load: 0.800 kW/ton IPLV: 0.600 kW/ton	
	>=75 tons and < 150 tons	Full load: 0.775 kW/ton IPLV: 0.615 kW/ton	Full load: 0.790 kW/ton IPLV: 0.586 kW/ton	
	>=150 tons and < 300 tons	Full load: 0.680 kW/ton IPLV: 0.580 kW/ton	Full load: 0.718 kW/ton IPLV: 0.540 kW/ton	
	>=300 tons	Full load: 0.620 kW/ton IPLV: 0.540 kW/ton	Full load: 0.639 kW/ton IPLV: 0.490 kW/ton	
Water Cooled Centrifugal	<300 tons	Full load: 0.634 kW/ton	Full load: 0.639 kW/ton	

268 Modeling is an acceptable substitute to metering and BMS data if 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).

269 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.

Chiller Type	Size	Path A	Path B	Source
Chiller		IPLV: 0.596 kW/ton	IPLV: 0.450 kW/ton	
	>=300 tons and < 600 tons	Full load: 0.576 kW/ton IPLV: 0.549 kW/ton	Full load: 0.600 kW/ton IPLV: 0.400 kW/ton	
	>=600 tons	Full load: 0.570 kW/ton IPLV: 0.539 kW/ton	Full load: 0.590 kW/ton IPLV: 0.400 kW/ton	

Table 3-29: Chiller EFLHs for Pennsylvania Cities

Space and/or Building Type	Allentown	Erie	Harrisburg	Philadelphia	Pittsburgh	Scranton	Williamsport
Education - Community College	634	453	661	734	564	502	608
Education - Secondary School	275	214	344	389	282	244	316
Education - University	695	526	730	805	635	545	629
Health/Medical - Hospital	1,240	1,100	1,362	1,556	1,185	1,134	1,208
Health/Medical - Nursing Home	459	408	520	622	472	418	462
Lodging - Hotel	1,397	1,317	1,511	1,654	1,432	1,352	1,415
Manufacturing - Bio/Tech	708	527	700	780	631	574	614
Office - Large	463	411	546	604	451	427	472
Office - Small	429	374	495	567	434	393	433
Retail - Multistory Large	749	609	836	897	699	659	742

Table 3-30: Chiller Demand CFs for Pennsylvania Cities

Space and/or Building Type	Allentown	Erie	Harrisburg	Philadelphia	Pittsburgh	Scranton	Williamsport
Education - Community College	0.43	0.31	0.44	0.47	0.42	0.36	0.43
Education - Secondary School	0.11	0.09	0.18	0.18	0.17	0.12	0.17
Education - University	0.40	0.30	0.41	0.44	0.39	0.32	0.37
Health/Medical - Hospital	0.50	0.48	0.50	0.54	0.48	0.48	0.50
Health/Medical - Nursing Home	0.24	0.22	0.28	0.30	0.28	0.23	0.26
Lodging - Hotel	0.62	0.61	0.68	0.69	0.71	0.60	0.68
Manufacturing - Bio/Tech	0.53	0.43	0.53	0.58	0.54	0.48	0.50
Office - Large	0.30	0.28	0.36	0.25	0.33	0.30	0.33
Office - Small	0.28	0.26	0.33	0.21	0.30	0.28	0.31
Retail - Multistory Large	0.46	0.38	0.54	0.55	0.48	0.43	0.48

Default Savings

There are no default savings for this measure.

Evaluation Protocols

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

Sources

1. Nexant's eQuest modeling analysis 2014.
2. IECC 2009 Table 503.2.3 (7). https://law.resource.org/pub/us/code/ibr/icc.iecc.2009.pdf

3.2.3 Water Source and Geothermal Heat Pumps

Measure Name	Water Source and Geothermal Heat Pumps
Target Sector	Commercial and Industrial Establishments
Measure Unit	Geothermal Heat Pump
Unit Energy Savings	Variable
Unit Peak Demand Reduction	Variable
Measure Life	15 years[270]
Measure Vintage	Replace on Burnout, New Construction, or Early Replacement

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.

Eligibility

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

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

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

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. All HVAC applications other than comfort cooling and heating, such as process cooling, are defined as non-standard applications and are ineligible for this measure.

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

[270] DEER values, updated October 10, 2008. Various sources range from 12 to 20 years, DEER represented a reasonable mid-range.

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 3-31: 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

ALGORITHMS

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 baseline units rated in both EER and IEER, use IEER in place of EER where listed in energy savings calculations below.

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

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

$$\Delta kWh_{cool} = \left\{\left(\frac{Btu_{cool}}{hr} \times \frac{1\ kW}{1000\ W}\right) \times \left(\frac{1}{SEER_{base}}\right) \times EFLH_{cool}\right\} - \left\{\left(\frac{Btu_{cool}}{hr} \times \frac{1\ kW}{1000\ W}\right) \times \left(\frac{1}{EER_{ee}}\right) \times EFLH_{cool}\right\}$$

$$\Delta kWh_{heat} = \left\{\left(\frac{Btu_{heat}}{hr} \times \frac{1\ kW}{1000\ W}\right) \times \left(\frac{1}{HSPF_{base}}\right) \times EFLH_{heat}\right\} - \left\{\left(\frac{Btu_{heat}}{hr} \times \frac{1\ kW}{1000\ W}\right) \times \left(\frac{1}{COP_{ee}}\right) \times \left(\frac{1}{3.412}\right) \times EFLH_{heat}\right\}$$

$$\Delta kWh_{pump} = \left\{HP_{basemotor} \times LF_{base} \times 0.746 \times \left(\frac{1}{\eta_{basemotor}}\right) \times \left(\frac{1}{\eta_{basepump}}\right) \times HOURS_{basepump}\right\} - \left\{HP_{eemotor} \times LF_{ee} \times 0.746 \times \left(\frac{1}{\eta_{eemotor}}\right) \times \left(\frac{1}{\eta_{eepump}}\right) \times HOURS_{eepump}\right\}$$

$$\Delta kW_{peak} = \Delta kW_{peak\ cool} + \Delta kW_{peak\ pump}$$

$$\Delta kW_{peak\ cool} = \left\{\left(\frac{Btu_{cool}}{hr} \times \frac{1\ kW}{1000\ W}\right) \times \left(\frac{1}{EER_{base}}\right) \times CF_{cool}\right\} - \left\{\left(\frac{Btu_{cool}}{hr} \times \frac{1\ kW}{1000\ W}\right) \times \left(\frac{1}{EER_{ee}}\right) \times CF_{cool}\right\}$$

$$\Delta kW_{peak\ pump} = \left\{HP_{basemotor} \times LF_{base} \times 0.746 \times \left(\frac{1}{\eta_{basemotor}}\right) \times \left(\frac{1}{\eta_{basepump}}\right) \times CF_{pump}\right\} - \left\{HP_{eemotor} \times LF_{ee} \times 0.746 \times \left(\frac{1}{\eta_{eemotor}}\right) \times \left(\frac{1}{\eta_{eepump}}\right) \times CF_{pump}\right\}$$

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

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

$$\Delta kWh_{cool} = \left\{\left(\frac{Btu_{cool}}{hr} \times \frac{1\ kW}{1000\ W}\right) \times \left(\frac{1}{EER_{base}}\right) \times EFLH_{cool}\right\} - \left\{\left(\frac{Btu_{cool}}{hr} \times \frac{1\ kW}{1000\ W}\right) \times \left(\frac{1}{EER_{ee}}\right) \times EFLH_{cool}\right\}$$

$$\Delta kWh_{heat} = \left\{\left(\frac{Btu_{heat}}{hr} \times \frac{1\ kW}{1000\ W}\right) \times \left(\frac{1}{COP_{base}}\right) \times \left(\frac{1}{3.412}\right) \times EFLH_{heat}\right\} - \left\{\left(\frac{Btu_{heat}}{hr} \times \frac{1\ kW}{1000\ W}\right) \times \left(\frac{1}{COP_{ee}}\right) \times \left(\frac{1}{3.412}\right) \times EFLH_{heat}\right\}$$

$$\Delta kWh_{pump} = \left\{HP_{basemotor} \times LF_{base} \times 0.746 \times \left(\frac{1}{\eta_{basemotor}}\right) \times \left(\frac{1}{\eta_{basepump}}\right) \times HOURS_{basepump}\right\} - \left\{HP_{eemotor} \times LF_{ee} \times 0.746 \times \left(\frac{1}{\eta_{eemotor}}\right) \times \left(\frac{1}{\eta_{eepump}}\right) \times HOURS_{eepump}\right\}$$

$$\Delta kW_{peak} = \Delta kW_{peak\ cool} + \Delta kW_{peak\ pump}$$

$$\Delta kW_{peak\ cool} = \left\{\left(\frac{Btu_{cool}}{hr} \times \frac{1\ kW}{1000\ W}\right) \times \left(\frac{1}{EER_{base}}\right) \times CF_{cool}\right\} - \left\{\left(\frac{Btu_{cool}}{hr} \times \frac{1\ kW}{1000\ W}\right) \times \left(\frac{1}{EER_{ee}}\right) \times CF_{cool}\right\}$$

$$\Delta kW_{peak\ pump} = \left\{HP_{basemotor} \times LF_{base} \times 0.746 \times \left(\frac{1}{\eta_{basemotor}}\right) \times \left(\frac{1}{\eta_{basepump}}\right) \times CF_{pump}\right\} - \left\{HP_{eemotor} \times LF_{ee} \times 0.746 \times \left(\frac{1}{\eta_{eemotor}}\right) \times \left(\frac{1}{\eta_{eepump}}\right) \times CF_{pump}\right\}$$

Definition of Terms[271]

Table 3-32: Geothermal Heat Pump– Values and Assumptions

Term	Unit	Value	Source
$\frac{Btu_{cool}}{hr}$, Rated cooling capacity of the energy efficient unit	$\frac{Btu_{cool}}{hr}$	Nameplate data (ARI or AHAM)	EDC Data Gathering
$\frac{Btu_{heat}}{hr}$, Rated heating capacity of the energy efficient unit	$\frac{Btu_{heat}}{hr}$	Nameplate data (ARI or AHAM) Use $\frac{Btu_{cool}}{hr}$ if the heating capacity is not known	EDC Data Gathering
$SEER_{base}$, the cooling SEER of the baseline unit	$\frac{Btu/_{hr}}{W}$	Early Replacement: Nameplate data	EDC Data Gathering
		New Construction or Replace on Burnout: Default values from Table 3-35	See Table 3-35
$IEER_{base}$, Integrated energy efficiency ratio of the baseline unit.	$\frac{Btu/_{hr}}{W}$	Early Replacement: Nameplate data	EDC Data Gathering
		Default: Table 3-23	See Table 3-23
EER_{base}, the cooling EER of the baseline unit	$\frac{Btu/_{hr}}{W}$	Early Replacement: Nameplate data = $SEER_{base}$ X (11.3/13) if EER not available[272]	EDC Data Gathering
		New Construction or Replace on Burnout: Default values from Table 3-35	See Table 3-35
$HSPF_{base}$, Heating Season Performance Factor of the baseline unit	$\frac{Btu/_{hr}}{W}$	Early Replacement: Nameplate data	EDC Data Gathering
		New Construction or Replace on Burnout: Default values from Table 3-35	See Table 3-35
COP_{base}, Coefficient of Performance of the baseline unit	*None*	Early Replacement: Nameplate data	EDC Data Gathering
		New Construction or Replace on Burnout: Default values from Table 3-35	See Table 3-35

271 The cooling efficiency ratings of the baseline and efficient units should be used not including pumps where appropriate.
272 11.3/13 = Conversion factor from SEER to EER, based on average EER of a SEER 13 unit.

Term	Unit	Value	Source
EER_{ee}, the cooling EER of the new ground source, groundwater source, or water source heat pumpground being installed	$\frac{Btu/hr}{W}$	Nameplate data (ARI or AHAM) = SEERee X (11.3/13) if EER not available[273]	EDC Data Gathering
COP_{ee}, Coefficient of Performance of the new ground source, groundwater source, or water source heat pump being installed	None	Nameplate data (ARI or AHAM)	EDC Data Gathering
$EFLH_{cool}$, Cooling annual Equivalent Full Load Hours EFLH for Commercial HVAC for different occupancies	$\frac{Hours}{Year}$	Based on Logging, BMS data or Modeling[274]	EDC Data Gathering
		Default values from Table 3-24	2
$EFLH_{heat}$, Heating annual Equivalent Full Load Hours EFLH for Commercial HVAC for different occupancies	$\frac{Hours}{Year}$	Based on Logging, BMS data or Modeling[275]	EDC Data Gathering
		Default values from Table 3-26	2
CF_{cool}, Demand Coincidence Factor for Commercial HVAC	Decimal	See Table 3-25	2
CF_{pump}, Demand Coincidence Factor for ground source loop pump	Decimal	If unit runs 24/7/365, CF=1.0; If unit runs only with heat pump unit compressor, See Table 3-25	2
$HP_{basemotor}$, Horsepower of base case ground loop pump motor	HP	Nameplate	EDC Data Gathering
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.	None	Based on spot metering and nameplate	EDC Data Gathering
		Default: 75%	1
$\eta_{basemotor}$, efficiency of base case ground loop pump motor	None	Nameplate	EDC Data Gathering
		If unknown, assume the federal minimum efficiency requirements in Table 3-33	See Table 3-33
$\eta_{basepump}$, efficiency of base case ground loop pump at design point	None	Nameplate	EDC Data Gathering
		If unknown, assume program compliance efficiency in Table 3-34	See Table 3-34

273 11.3/13 = Conversion factor from SEER to EER, based on average EER of a SEER 13 unit.
274 Modeling is an acceptable substitute to metering and BMS data if 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).
275 Ibid

Term	Unit	Value	Source
$HOURS_{basepump}$, Run hours of base case ground loop pump motor	*Hours*	Based on Logging, BMS data or Modeling[276]	EDC Data Gathering
		$EFLH_{cool} + EFLH_{heat}$ [277] Default values from Table 3-24 and Table 3-26	2
$HP_{eemotor}$, Horsepower of retrofit case ground loop pump motor	*HP*	Nameplate	EDC Data Gathering
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.	*None*	Based on spot metering and nameplate	EDC Data Gathering
		Default: 75%	1
$\eta_{eemotor}$, efficiency of retrofit case ground loop pump motor	*None*	Nameplate	EDC Data Gathering
		If unknown, assume the federal minimum efficiency requirements in Table 3-33	Table 3-33
η_{eepump}, efficiency of retrofit case ground loop pump at design point	*None*	Nameplate	EDC Data Gathering
		If unknown, assume program compliance efficiency in Table 3-34	See Table 3-34
$HOURS_{eepump}$, Run hours of retrofit case ground loop pump motor	*Hours*	Based on Logging, BMS data or Modeling[278]	EDC Data Gathering
		$EFLH_{cool} + EFLH_{heat}$[279] Default values from Table 3-24 and Table 3-26	2
3.412, conversion factor from kWh to kBtu	$\frac{kBtu}{kWh}$	3.412	Conversion Factor
0.746, conversion factor from horsepower to kW	$\frac{kW}{hp}$	0.746	Conversion Factor

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.

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[276] Ibid

[277] $EFLH_{cool} + EFLH_{heat}$ represent the addition of cooling and heating annual equivalent full load hours for commercial HVAC for different occupancies, respectively.

[278] Ibid

[279] Ibid.

Table 3-33: Federal Minimum Efficiency Requirements for Motors[280]

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 3-34: Ground/Water Loop Pump and Circulating Pump Efficiency[281]

HP	Minimum Pump Efficiency at Design Point (η_{pump})
1.5	65%
2	65%
3	67%
5	70%
7.5	73%
10	75%
15	77%
20	77%

280 The Department of Energy published a final rule on May 29, 2014 that applies to electric motors manufactured on or after June 1, 2016. Therefore, baseline efficiencies for electric motors will be updated in the 2016 TRM to comply with federal energy conservation standards. http://www.ecfr.gov/cgi-bin/text-idx?SID=ba6d4f97451f89bcaa13b3f5a91c54c1&node=10:3.0.1.4.19.2.47.11&rgn=div8

281 Based on program requirements submitted during protocol review.

Table 3-35: Default Baseline Equipment Efficiencies

Equipment Type and Capacity	Cooling Baseline	Heating Baseline
Water-Source Heat Pumps		
< 17,000 $\frac{Btu}{hr}$	11.2 EER	4.2 COP
> 17,000 $\frac{Btu}{hr}$ and < 65,000 $\frac{Btu}{hr}$	12.0 EER	4.2 COP
Ground Water Source Heat Pumps		
< 135,000 $\frac{Btu}{hr}$	16.2 EER	3.6 COP
Ground Source Heat Pumps		
< 135,000 $\frac{Btu}{hr}$	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.

Default Savings

There are no default savings for this measure.

Evaluation Protocols

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

Sources

1. California Public Utility Commission. *Database for Energy Efficiency Resources* 2005.
2. Based on Nexant's eQuest modeling analysis 2014.

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

Measure Name	Ductless Mini-Split Heat Pumps – Commercial < 5.4 Tons
Target Sector	Commercial and Industrial Establishments
Measure Unit	Ductless Heat Pump
Unit Energy Savings	Variable based on efficiency of systems
Unit Peak Demand Reduction	Variable based on efficiency of systems
Measure Life	15 years[282]
Measure Vintage	Replace on Burnout

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

Eligibility

This protocol documents the energy savings attributed to ENERGY STAR ductless mini-split heat pumps with energy-efficiency performance of 14.5/12 SEER/EER and 8.2 HSPF or greater with inverter technology.[283] 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. All HVAC applications other than comfort cooling and heating, such as process cooling, are defined as non-standard applications and are ineligible for this measure.

Algorithms

The savings depend on three main factors: baseline condition, usage, and the capacity of the indoor unit.

The algorithm is separated into two calculations: single zone and multi-zone ductless heat pumps. The savings algorithm is as follows:

For heat pump units < 65,000 $\frac{Btu}{hr}$, use SEER to calculate ΔkWh_{cool} and HSPF to calculate ΔkWh_{heat}. Convert SEER to EER to calculate ΔkW_{peak} using 11.3/13 as the conversion factor.

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[282] DEER values, updated October 10, 2008. Various sources range from 12 to 20 years, DEER represented a reasonable mid-range.

[283] ENERGY STAR *Air Source Heat Pumps and Central Air Conditioners Key Product Criteria.* http://www.energystar.gov/index.cfm?c=airsrc_heat.pr_crit_as_heat_pumps

Single Zone:

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

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

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

$$\Delta kW_{peak} = \frac{CAPY_{cool}}{1000\,\frac{W}{kW}} \times \left(\frac{1}{EER_b} - \frac{1}{EER_e}\right) \times CF$$

Multi-Zone:

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

$$\Delta kWh_{heat} = \left[\frac{CAPY_{heat}}{1000\,\frac{W}{kW}} \times \left(\frac{1}{HSPF_b} - \frac{1}{HSPF_e}\right) \times EFLH_{heat}\right]_{ZONE1} + \left[\frac{CAPY_{heat}}{1000\,\frac{W}{kW}} \times \left(\frac{1}{HSPF_b} - \frac{1}{HSPF_e}\right) \times EFLH_{heat}\right]_{ZONE2} + \left[\frac{CAPY_{heat}}{1000\,\frac{W}{kW}} \times \left(\frac{1}{HSPF_b} - \frac{1}{HSPF_e}\right) \times EFLH_{heat}\right]_{ZONEn}$$

$$\Delta kWh_{cool} = \left[\frac{CAPY_{cool}}{1000\,\frac{W}{kW}} \times \left(\frac{1}{SEER_b} - \frac{1}{SEER_e}\right) \times EFLH_{cool}\right]_{ZONE1} + \left[\frac{CAPY_{cool}}{1000\,\frac{W}{kW}} \times \left(\frac{1}{SEER_b} - \frac{1}{SEER_e}\right) \times EFLH_{cool}\right]_{ZONE2} + \left[\frac{CAPY_{cool}}{1000\,\frac{W}{kW}} \times \left(\frac{1}{SEER_b} - \frac{1}{SEER_e}\right) \times EFLH_{cool}\right]_{ZONEn}$$

$$\Delta kW_{peak} = \left[\frac{CAPY_{cool}}{1000\,\frac{W}{kW}} \times \left(\frac{1}{EER_b} - \frac{1}{EER_e}\right) \times CF\right]_{ZONE1} + \left[\frac{CAPY_{cool}}{1000\,\frac{W}{kW}} \times \left(\frac{1}{EER_b} - \frac{1}{EER_e}\right) \times CF\right]_{ZONE2} + \left[\frac{CAPY_{cool}}{1000\,\frac{W}{kW}} \times \left(\frac{1}{EER_b} - \frac{1}{EER_e}\right) \times CF\right]_{ZONEn}$$

Definition of Terms

Table 3-36: DHP – Values and References

Term	Unit	Values	Source
$CAPY_{cool}$, The cooling capacity of the indoor unit, given in $\frac{Btu}{hr}$ as appropriate for the calculation. This protocol is limited to units < 65,000 $\frac{Btu}{hr}$ (5.4 tons) $CAPY_{heat}$, The heating capacity of the indoor unit, given in $\frac{Btu}{hr}$ as appropriate for the calculation.	$\frac{Btu}{hr}$	Nameplate	EDC Data Gathering
$EFLH_{cool}$, Equivalent Full Load Hours for cooling $EFLH_{heat}$, Equivalent Full Load Hours for heating	$\frac{Hours}{Year}$	Based on Logging, BMS data or Modeling[284]	EDC Data Gathering
		Default: See Table 3-24 and Table 3-26	1
$HSPF_b$, Heating Seasonal Performance Factor, heating efficiency of the installed DHP	$\frac{Btu/hr}{W}$	Standard DHP: 7.7 Electric resistance: 3.413 ASHP: 7.7 PTHP[285] (Replacements): 2.9 - (0.026 x Cap / 1000) COP PTHP (New Construction): 3.2 - (0.026 x Cap / 1000) COP Electric furnace: 3.242 For new space, no heat in an existing space, or non-electric heating in an existing space: use standard DHP: 7.7	2, 4,7
$SEER_b$, Seasonal Energy Efficiency Ratio cooling efficiency of baseline unit	$\frac{Btu/hr}{W}$	DHP, ASHP, or central AC: 13 Room AC: 11.3 PTAC[286] (Replacements): 10.9 - (0.213 x Cap / 1000) EER PTAC (New Construction): 12.5 - (0.213 x Cap / 1000) EER PTHP (Replacements):	3,4,5,6,7

284 Ibid

285 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.

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

Term	Unit	Values	Source
		10.8 - (0.213 x Cap / 1000) EER PTHP (New Construction): 12.3 - (0.213 x Cap / 1000) EER For new space or no cooling in an existing space: use Central AC: 13	
$HSPF_e$, Heating Seasonal Performance Factor, heating efficiency of the installed DHP	$\frac{Btu/hr}{W}$	Based on nameplate information. Should be at least ENERGY STAR.	EDC Data Gathering
$SEER_e$, Seasonal Energy Efficiency Ratio cooling efficiency of the installed DHP	$\frac{Btu/hr}{W}$	Based on nameplate information. Should be at least ENERGY STAR.	EDC Data Gathering
CF, Demand Coincidence Factor	*Decimal*	See Table 3-25	1

Default Savings

There are no default savings for this measure.

Evaluation Protocols

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

Sources

1. Based on Nexant's eQuest modeling analysis 2014.
2. COP = HSPF/3.413. 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. https://www.ahridirectory.org/ahridirectory/pages/home.aspx
5. ENERGY STAR and Federal Appliance Standard minimum EERs for a 10,000 Btu/hr unit with louvered sides. http://www.energystar.gov/index.cfm?c=roomac.pr_crit_room_ac
6. Average EER for SEER 13 units as calculated by EER = -0.02 × SEER² + 1.12 × SEER based on U.S. DOE Building America House Simulation Protocol, Revised 2010. http://www.nrel.gov/docs/fy11osti/49246.pdf

7. 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 $\frac{Btu}{hr}$, use 7,000 $\frac{Btu}{hr}$ in the calculation. If the unit's capacity is greater than 15,000 $\frac{Btu}{hr}$, use 15,000 $\frac{Btu}{hr}$ in the calculation.

3.2.5 Fuel Switching: Small Commercial Electric Heat to Natural gas / Propane / Oil Heat

Measure Name	Fuel Switching: Small Commercial Electric Heat to Natural Gas / Propane / Oil Heat
Target Sector	Commercial and Industrial Establishments
Measure Unit	Gas, Propane or Oil Heater
Unit Energy Savings	Variable
Unit Peak Demand Reduction	Variable
Measure Life	20 years[287]
Measure Vintage	Replace on Burnout or Early Retirement or New Construction

Eligibility

The energy and demand savings for 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 $\frac{Btu}{hr}$.

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).

Table 3-37: Act 129 Sunset Dates for ENERGY STAR Furnaces

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."

[287] DEER Effective Useful Life. October 10, 2008. For the purpose of calculating the total Resource Cost Test for Act 129, measure cannot claim savings for more than fifteen years.

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

Table 3-38: ENERGY STAR Requirements for Furnaces and Boilers

Equipment	ENERGY STAR Requirements[288]
Gas Furnace	AFUE rating of 95% or greater Less than or equal to 2.0% furnace fan efficiency Less than or equal to 2.0% air leakage
Oil Furnace	AFUE rating of 85% or greater Less than or equal to 2.0% furnace fan efficiency Less than or equal to 2.0% air leakage
Boiler	AFUE rating of 85% or greater

ALGORITHMS[289]

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 $\frac{Btu}{hr}$, use HSPF instead of COP to calculate ΔkWh_{heat}.

$$\Delta kWh_{heat} = \left(\frac{Btu_{heat}}{hr} \times \frac{1\ kW}{1000\ W}\right) \times \frac{1}{3.412} \times \frac{1}{COP_{base}} \times EFLH_{heat}$$

$$= \left(\frac{Btu_{heat}}{hr} \times \frac{1\ kW}{1000\ W}\right) \times \frac{1}{HSPF_{base}} \times EFLH_{heat}$$

Baseboard heating, packaged terminal heat pump

$$\Delta kWh_{heat} = \frac{\frac{Btu_{heat}}{hr} \times EFLH_{heat}}{3412\ \frac{Btu}{kWh} \times COP_{base}} - \frac{HP_{motor} \times 746\frac{W}{HP} \times EFLH_{heat}}{\eta_{motor} \times 1000\frac{W}{kW}}$$

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.[290]

288 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

289 EDCs 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).

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

There are no peak demand savings as it is a heating only measure.

Although there are 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:

$$Fuel\ Consumption\ (MMBTU) = \frac{\frac{Btu_{fuel}}{hr} \times EFLH_{heat}}{AFUE_{fuel} \times 1{,}000{,}000 \frac{Btu}{MMBtu}}$$

DEFINITION OF TERMS

Table 3-39: Variables for HVAC Systems

Term	Unit	Values	Source
$\frac{Btu_{fuel}}{hr}$, Rated heating capacity of the new fossil fuel unit	$\frac{Btu}{hr}$	Nameplate data (AHRI or AHAM)	EDC Data Gathering
$\frac{Btu_{heat}}{hr}$, Rated heating capacity of the existing electric unit	$\frac{Btu}{hr}$	Nameplate data (AHRI or AHAM) Default: set equal to $\frac{Btu_{fuel}}{hr}$	EDC Data Gathering
COP_{base}, Efficiency rating of the baseline unit. For ASHP units < 65,000 Btu/hr, HSPF should be used for heating savings	*None*	Early Replacement: Nameplate data	EDC Data Gathering
		New Construction or Replace on Burnout: Default values from Table 3-40	See Table 3-40
$HSPF_{base}$, Heating seasonal performance factor of the baseline unit. For units >65,000 Btu/hr, COP should be used for heating savings	$\frac{Btu/hr}{W}$	Early Replacement: Nameplate data	EDC Data Gathering
		New Construction or Replace on Burnout: Default values from Table 3-40	See Table 3-40
$AFUE_{fuel}$, Annual Fuel Utilization Efficiency rating of the fossil fuel unit	*None*	Default = >= 95% (natural gas/propane furnace) >= 95% (natural gas/propane steam boiler) >= 95% (natural gas/propane hot water boiler) >= 85% (oil furnace) >= 85% (oil steam boiler) >= 85% (oil hot water boiler)	ENERGY STAR requirement
		Nameplate data (AHRI or AHAM)	EDC Data Gathering

Term	Unit	Values	Source
$EFLH_{heat}$, Equivalent Full Load Hours for the heating season – The kWh during the entire operating season divided by the kW at design conditions	$\frac{Hours}{Year}$	Based on Logging, EMS data or Modeling[291]	EDC Data Gathering
		Default values from Table 3-26	1
HP_{Motor}, Gas furnace blower motor horsepower	*HP*	Default: ½ HP for furnace	Average blower motor capacity for gas furnace (typical range = ¼ HP to ¾ HP)
		Nameplate	EDC Data Gathering
η_{motor} , Efficiency of furnace blower motor	*None*	From nameplate	EDC Data Gathering
		Default: 0.50 for furnace	Typical efficiency of ½ HP blower motor for gas furnace

Table 3-40: HVAC Baseline Efficiency Values[292]

Equipment Type and Capacity	Heating Baseline
Air-Source Heat Pumps	
< 65,000 $\frac{Btu}{hr}$	7.7 HSPF
> 65,000 $\frac{Btu}{hr}$ and <135,000 $\frac{Btu}{hr}$	3.3 COP
> 135,000 $\frac{Btu}{hr}$ and < 240,000 $\frac{Btu}{hr}$	3.2 COP
> 240,000 $\frac{Btu}{hr}$	3.2 COP
Electric Resistance Heat (Electric Furnace or Baseboard)	
All sizes	1.0 COP
Packaged Terminal Systems (Replacements)[293]	
PTHP	2.9 - (0.026 x Cap / 1000) COP
Packaged Terminal Systems (New Construction)	
PTHP	3.2 - (0.026 x Cap / 1000) COP

[291] Modeling is an acceptable substitute to metering and BMS data if 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).
[292] Baseline values from IECC 2009, after Jan 1, 2010 or Jan 23, 2010 as applicable.
[293] 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.

Default Savings

There are no default savings for this measure.

Evaluation Protocols

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

Sources

1. The Equivalent Full Load Hours (EFLH) for Pennsylvania are calculated based on Nexant's eQuest modeling analysis.

3.2.6 Small C/I HVAC Refrigerant Charge Correction

Measure Name	Small C/I HVAC Refrigerant Charge Correction
Target Sector	Commercial and Industrial Establishments
Measure Unit	Tons of Refrigeration Capacity
Unit Energy Savings	Variable
Unit Peak Demand Reduction	Variable
Measure Life	10 years[294]
Measure Vintage	Retrofit

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

Eligibility

This protocol is applicable for small commercial and industrial customers, and applies to documented tune-ups for package or split systems up to 20 tons. All HVAC applications other than comfort cooling and heating, such as process cooling, are defined as non-standard applications and are ineligible for this measure.

Algorithms

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

Air Conditioning

For A/C units < 65,000 $\frac{Btu}{hr}$, use SEER to calculate ΔkWh and convert SEER to EER to calculate ΔkW_{peak} using 11.3/13 as the conversion factor. For A/C units > 65,000 $\frac{Btu}{hr}$, if rated in both EER and IEER, use IEER for energy savings calculations.

[294] DEER 2008. Commercial Results Review: Non-Updated Measures.

$$\Delta kWh = \left(EFLH_c \times \frac{CAPY_c}{1000\frac{W}{kW}}\right) \times \left(\frac{1}{[EER \times RCF]} - \frac{1}{EER}\right)$$

$$\Delta kWh = \left(EFLH_c \times \frac{CAPY_c}{1000\frac{W}{kW}}\right) \times \left(\frac{1}{[SEER \times RCF]} - \frac{1}{SEER}\right)$$

$$\Delta kW_{peak} = \left(CF \times \frac{CAPY_c}{1000\frac{W}{kW}}\right) \times \left(\frac{1}{[EER \times RCF]} - \frac{1}{EER}\right)$$

Heat Pumps

For Heat Pump units < 65,000 $\frac{Btu}{hr}$, use SEER to calculate ΔkWh_{cool} and HSPF instead of COP to calculate ΔkWh_{heat}. Convert SEER to EER to calculate ΔkW_{peak} using 11.3/13 as the conversion factor. For Heat Pump units > 65,000 $\frac{Btu}{hr}$, if rated in both EER and IEER, use IEER to calculate:

ΔkWh_{cool}

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

$$\Delta kWh_{cool} = \left(EFLH_c \times \frac{CAPY_c}{1000\frac{W}{kW}}\right) \times \left(\frac{1}{[IEER \times RCF]} - \frac{1}{IEER}\right)$$

$$\Delta kWh_{cool} = \left(EFLH_c \times \frac{CAPY_c}{1000\frac{W}{kW}}\right) \times \left(\frac{1}{[SEER \times RCF]} - \frac{1}{SEER}\right)$$

$$\Delta kWh_{heat} = \left(EFLH_h \times \frac{CAPY_h}{1000\frac{W}{kW}}\right) \times \frac{1}{3.412} \times \left(\frac{1}{[COP \times RCF]} - \frac{1}{COP}\right)$$

$$\Delta kWh_{heat} = \left(EFLH_h \times \frac{CAPY_h}{1000\frac{W}{kW}}\right) \times \left(\frac{1}{[HSPF \times RCF]} - \frac{1}{HSPF}\right)$$

$$\Delta kW_{peak} = \left(\frac{Btu_{cool}}{hr} \times \frac{1}{1000\frac{W}{kW}}\right) \times \left(\frac{1}{EER_{base}} - \frac{1}{EER_{ee}}\right) \times CF$$

DEFINITION OF TERMS

Table 3-41: Refrigerant Charge Correction Calculations Assumptions

Term	Unit	Values	Source
$CAPY_c$, Unit capacity for cooling	$\frac{Btu}{hr}$	From nameplate	EDC Data Gathering
$CAPY_h$, Unit capacity for heating	$\frac{Btu}{hr}$	From nameplate	EDC Data Gathering
EER, Energy Efficiency Ratio. For A/C and heat pump units < 65,000 $\frac{Btu}{hr}$, SEER should be used for cooling savings.	$\frac{Btu/hr}{W}$	From nameplate	EDC Data Gathering
		Default: See Table 3-23	See Table 3-23
IEER, Integrated energy efficiency ratio of the baseline unit.	$\frac{Btu/hr}{W}$	From nameplate	EDC Data Gathering
		Default: See Table 3-23	See Table 3-23
SEER, Seasonal Energy Efficiency Ratio. For A/C and heat pump units > 65,000 $\frac{Btu}{hr}$, EER should be used for cooling savings.	$\frac{Btu/hr}{W}$	From nameplate	EDC Data Gathering
		Default: See Table 3-23	See Table 3-23
HSPF, Heating Seasonal Performance Factor. For heat pump units > 65,000 $\frac{Btu}{hr}$, COP should be used for heating savings.	$\frac{Btu/hr}{W}$	From nameplate	EDC Data Gathering
		Default: See Table 3-23	See Table 3-23
COP, Coefficient of Performance. For heat pump units < 65,000 $\frac{Btu}{hr}$, HSPF should be used for heating savings.	*None*	From nameplate	EDC Data Gathering
		Default: See Table 3-23	See Table 3-23
$EFLH_c$, Equivalent Full-Load Hours for mechanical cooling	$\frac{Hours}{Year}$	Default: See Table 3-24	1
		Based on Logging, BMS data or Modeling[295]	EDC Data Gathering
$EFLH_h$, Equivalent Full-Load Hours for Heating	$\frac{Hours}{Year}$	See Table 3-26	1
RCF, COP Degradation Factor for Cooling	*None*	See Table 3-42	2
CF, Demand Coincidence Factor	*Decimal*	See Table 3-25	1

[295] Modeling is an acceptable substitute to metering and BMS data if 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).

Term	Unit	Values	Source
1000, convert from watts to kilowatts	$\frac{W}{kW}$	1000	Conversion Factor
11.3/13, Conversion factor from SEER to EER, based on average EER of a SEER 13 unit	*None*	$\frac{11.3}{13}$	3

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.

Table 3-42: Refrigerant charge correction COP degradation factor (RCF) for various relative charge adjustments for both TXV metered and non-TXV units.[296]

% 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%

[296]Small HVAC Problems and Potential Savings Report, California Energy Commission, 2003. http://www.energy.ca.gov/2003publications/CEC-500-2003-082/CEC-500-2003-082-A-25.PDF

% 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)
38%	90%	67%	6%	100%	99%	(26%)	96%	87%
37%	91%	69%	5%	100%	100%	(27%)	96%	86%
36%	91%	71%	4%	100%	100%	(28%)	96%	85%
35%	92%	73%	3%	100%	100%	(29%)	95%	84%
34%	92%	74%	2%	100%	100%	(30%)	95%	83%
33%	93%	76%	1%	100%	100%	(31%)	95%	82%
32%	94%	77%	(0%)	100%	100%	(32%)	95%	81%
31%	94%	79%	(1%)	100%	100%	(33%)	95%	80%
30%	95%	80%	(2%)	100%	100%	(34%)	94%	78%
29%	95%	82%	(3%)	100%	100%	(35%)	94%	77%

Default Savings

There are no default savings for this measure.

Evaluation Protocols

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

Sources

1. Nexant's eQuest modeling analysis.
2. Small HVAC Problems and Potential Savings Report, California Energy Commission, 2003. http://www.energy.ca.gov/2003publications/CEC-500-2003-082/CEC-500-2003-082-A-25.PDF
3. Average EER for SEER 13 units as calculated by EER = -0.02 × SEER² + 1.12 × SEER based on U.S. DOE Building America House Simulation Protocol, Revised 2010. http://www.nrel.gov/docs/fy11osti/49246.pdf

3.2.7 ENERGY STAR ROOM AIR CONDITIONER

Measure Name	ENERGY STAR Room Air Conditioner
Target Sector	Commercial and Industrial Establishments
Measure Unit	Room Air Conditioner
Unit Energy Savings	Variable
Unit Peak Demand Reduction	Variable
Measure Life	12 years[297]
Measure Vintage	Replace on Burnout, Early Retirement, or New Construction

ELIGIBILITY

This protocol is for ENERGY STAR room air conditioner units installed in small commercial spaces. All HVAC applications other than comfort cooling and heating, such as process cooling, are defined as non-standard applications and are ineligible for this measure. Only ENERGY STAR units qualify for this protocol.

ALGORITHMS

If CEER is not available, use EER.

$$\Delta kWh = \left(\frac{1}{1000} \times \frac{Btu_{cool}}{hr}\right) \times \left(\frac{1}{EER_{base}} - \frac{1}{EER_{ee}}\right) \times EFLH_{cool}$$

$$= \left(\frac{1}{1000} \times \frac{Btu_{cool}}{hr}\right) \times \left(\frac{1}{CEER_{base}} - \frac{1}{CEER_{ee}}\right) \times EFLH_{cool}$$

$$\Delta kW_{peak} = \left(\frac{1}{1000} \times \frac{Btu_{cool}}{hr}\right) \times \left(\frac{1}{EER_{base}} - \frac{1}{EER_{ee}}\right) \times CF$$

[297] Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc., June 2007. http://library.cee1.org/sites/default/files/library/8842/CEE_Eval_MeasureLifeStudyLights%26HVACGDS_1Jun2007.pdf

DEFINITION OF TERMS

Table 3-43: Variables for HVAC Systems

Term	Unit	Values	Source
$\frac{Btu_{cool}}{hr}$, Rated cooling capacity of the energy efficient unit	$\frac{Btu}{hr}$	Nameplate data (AHRI or AHAM)	EDC Data Gathering
$CEER_{base}, EER_{base}$, Efficiency rating of the baseline unit	*None*	New Construction or Replace on Burnout: Default values from Table 3-44 to Table 3-46	See Table 3-44 to Table 3-46
		Early Replacement: Nameplate data	EDC Data Gathering
$CEER_{ee}, EER_{ee}$, Efficiency rating of the energy efficiency unit.	*None*	Nameplate data (AHRI or AHAM)	EDC Data Gathering
CF, Demand Coincidence Factor	*None*	See Table 3-25	1
$EFLH_{cool}$, Equivalent Full Load Hours for the cooling season – The kWh during the entire operating season divided by the kW at design conditions.	$\frac{Hours}{Year}$	Based on Logging, BMS data or Modeling[298]	EDC Data Gathering
		Default values from Table 3-24	1

Table 3-44 below 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, 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.[299]

[298] 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).
[299] Federal standards: U.S. Department of Energy. *Federal Register*. 164th ed. Vol. 76, August 24, 2011. http://www.gpo.gov/fdsys/pkg/FR-2013-07-16/pdf/FR-2013-07-16.pdf

Table 3-44: RAC Federal Minimum Efficiency and ENERGY STAR Version 3.0 Standards[300]

<table>
<tr><th>Capacity (Btu/h)</th><th>Federal Standard CEER, with louvered sides</th><th>ENERGY STAR EER, with louvered sides</th><th>Federal Standard EER, without louvered sides</th><th>ENERGY STAR CEER, without louvered sides</th></tr>
<tr><td>< 6,000</td><td rowspan="2">≥11.0</td><td rowspan="2">11.2</td><td rowspan="2">10.0</td><td rowspan="2">10.4</td></tr>
<tr><td>6,000 to 7,999</td></tr>
<tr><td>8,000 to 10,999</td><td rowspan="2">≥10.9</td><td rowspan="2">11.3</td><td>9.6</td><td rowspan="5">9.8</td></tr>
<tr><td>11,000 to 13,999</td><td>9.5</td></tr>
<tr><td>14,000 to 19,999</td><td>≥10.7</td><td>11.2</td><td>9.3</td></tr>
<tr><td>20,000 to 24,999</td><td>≥9.4</td><td rowspan="2">9.8</td><td rowspan="2">9.4</td></tr>
<tr><td>≥25,000</td><td>≥9.0</td></tr>
</table>

Table 3-45 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 and a height of ≤ 11.2 inches. 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.

Table 3-45: Casement-Only and Casement-Slider RAC Federal Minimum Efficiency and ENERGY STAR Version 3.0 Standards

Casement	Federal Standard CEER	ENERGY STAR EER
Casement-only	≥ 9.5	≥ 10.0
Casement-slider	≥ 10.4	≥ 10.9

Table 3-46 lists the minimum federal efficiency standards and minimum ENERGY STAR efficiency standards for reverse-cycle RAC units.

300 Ibid.

Table 3-46: Reverse-Cycle RAC Federal Minimum Efficiency Standards and ENERGY STAR Version 3.0 Standards[301]

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		

Default Savings

There are no default savings for this measure.

Evaluation Protocols

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

Sources

1. Based on Nexant's eQuest Modeling Analysis 2014.

[301] ENERGY STAR standards: ENERGY STAR Program Requirements Product Specification for Room Air Conditioners, Eligibility Criteria Version 3.0. June 22, 2012. http://www.energystar.gov/products/specs/system/files/Room_Air_Conditioner_Program_Requirements_Version_3.pdf

3.2.8 Controls: Guest Room Occupancy Sensor

Measure Name	Controls: Guest Room Occupancy Sensor
Target Sector	Commercial and Industrial Establishments
Measure Unit	Occupancy Sensor
Unit Energy Savings	Variable
Unit Peak Demand Reduction	Variable
Measure Life	15 years[302]

This protocol applies to the installation of a control system in hotel guest rooms to automatically adjust the temperature setback during unoccupied periods. Savings are based on the management of the guest room's set temperatures and controlling the HVAC unit for various occupancy modes. The savings are per guestroom controlled, rather than per sensor, for multi-room suites.

Eligibility

This measure is targeted to hotel customers whose guest rooms are equipped with energy management thermostats replacing manual heating/cooling temperature set-point and fan On/Off/Auto thermostat controls.

Acceptable baseline conditions are hotel guest rooms with manual heating/cooling temperature set-point and fan On/Off/Auto thermostat controls.

Efficient conditions are hotel/motel guest rooms with energy management controls of the heating/cooling temperature set-points and operation state based on occupancy modes.

Algorithms

Energy savings estimates are deemed using the tables below. Estimates were derived using an EnergyPlus model of a motel[303]. Model outputs were normalized to the installed capacity and reported here as kWh/Ton and coincident peak kW/Ton. Motels and hotels show differences in shell performance, number of external walls per room and typical heating and cooling efficiencies, thus savings values are presented for hotels and motels separately. Savings also depend on the size and type of HVAC unit, and whether housekeeping staff are directed to set-back/turn-off the thermostats when rooms are unrented.

$$\Delta kWh = CAPY * \mathrm{ESF}$$

$$\Delta kW_{peak} = CAPY * DSF$$

[302] DEER 2008 value for energy management systems.

[303] S. Keates, ADM Associates Workpaper: "Suggested Revisions to Guest Room Energy Management (PTAC & PTHP)", 11/14/2013 and spreadsheet summarizing the results: 'GREM Savings Summary_IL TRM_1_22_14.xlsx'.

Definition of Terms

Table 3-47: Guest Room Occupancy Sensor – Values and References

Term	Unit	Values	Source
CAPY, Cooling capacity of controlled unit in Tons	*tons*	EDC Data Gathering	
ESF, Energy savings factor	$\frac{kWh}{tons}$	See Table 3-48 and Table 3-49	1
DSF, Demand savings factor	$\frac{kW}{tons}$	See Table 3-50 and Table 3-51	1

Table 3-48: Energy Savings for Guest Room Occupancy Sensors – Motels

HVAC Type	Baseline	ESF; Energy Savings Factor (kWh/Ton)
PTAC with Electric Resistance Heating	Housekeeping Setback	559
	No Housekeeping Setback	1,877
PTAC with Gas Heating	Housekeeping Setback	85
	No Housekeeping Setback	287
PTHP	Housekeeping Setback	260
	No Housekeeping Setback	1,023

Table 3-49: Energy Savings for Guest Room Occupancy Sensors – Hotels

HVAC Type	Baseline	ESF; Energy Savings Factor (kWh/Ton)
PTAC with Electric Resistance Heating	Housekeeping Setback	322
	No Housekeeping Setback	1,083
PTAC with Gas Heating	Housekeeping Setback	259
	No Housekeeping Setback	876
PTHP	Housekeeping Setback	283
	No Housekeeping Setback	1,113
Central Hot Water Fan Coil with Electric Resistance Heating	Housekeeping Setback	245
	No Housekeeping Setback	822
Central Hot Water Fan Coil with Gas Heating	Housekeeping Setback	182
	No Housekeeping Setback	615

Table 3-50: Peak Demand Savings for Guest Room Occupancy Sensors – Motels

HVAC Type	Baseline	DSF; Demand Savings Factor (kW/Ton)
PTAC with Electric Resistance Heating	Housekeeping Setback	0.10
	No Housekeeping Setback	0.28
PTAC with Gas Heating	Housekeeping Setback	0.10
	No Housekeeping Setback	0.28
PTHP	Housekeeping Setback	0.10
	No Housekeeping Setback	0.28

Table 3-51: Peak Demand Savings for Guest Room Occupancy Sensors – Hotels

HVAC Type	Baseline	DSF; Demand Savings Factor (kW/Ton)
PTAC with Electric Resistance Heating	Housekeeping Setback	0.04
	No Housekeeping Setback	0.10
PTAC with Gas Heating	Housekeeping Setback	0.03
	No Housekeeping Setback	0.08
PTHP	Housekeeping Setback	0.03
	No Housekeeping Setback	0.09
Central Hot Water Fan Coil with Electric Resistance Heating	Housekeeping Setback	0.03
	No Housekeeping Setback	0.08
Central Hot Water Fan Coil with Gas Heating	Housekeeping Setback	0.02
	No Housekeeping Setback	0.06

Default Savings

There are no default savings for this measure.

Evaluation Protocols

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

SOURCES

1. S. Keates, ADM Associates Workpaper: "Suggested Revisions to Guest Room Energy Management (PTAC & PTHP)", 11/14/2013 and spreadsheet summarizing the results: 'GREM Savings Summary_IL TRM_1_22_14.xlsx.' Five cities in IL were part of this study. Values in this protocol are based on the model for the city of Belleville, IL due to the similarity in the weather heating and cooling degree days with the city of Philadelphia, PA.

3.2.9 Controls: Economizer

Measure Name	Controls: Economizer
Target Sector	Commercial and Industrial Establishments
Measure Unit	Economizer
Unit Energy Savings	Variable
Unit Peak Demand Reduction	Variable
Measure Life	10 years[304]
Measure Vintage	Retrofit

Dual enthalpy economizers regulate the amount of outside air introduced into the ventilation system based on the relative temperature and humidity of the outside and return air. If the enthalpy (latent and sensible heat) of the outside air is less than that of the return air when space cooling is required, then outside air is allowed in to reduce or eliminate the cooling requirement of the air conditioning equipment. Since the economizers will not be saving energy during peak hours, the demand savings are zero.

Eligibility

This measure is targeted to non-residential establishments whose HVAC equipment is not equipped with a functional economizer.

Baseline condition is an HVAC unit with no economizer installed or with a non-functional/disabled economizer.

Efficient condition is an HVAC unit with an economizer and dual enthalpy (differential) control.

Algorithms

$$\Delta kWh = \frac{SF \times AREA \times FCH_r \times 12 \frac{MBh}{ton}}{Eff}$$

$$\Delta kW_{peak} = 0$$

[304] Based on ERS measure life study for Massachusetts Joint Utilities which looked at economizer life on HVAC systems in large commercial and industrial applications. http://rtf.nwcouncil.org/subcommittees/nonreslighting/Measure%20Life%20Study_MA%20Joint%20Utilities_2005_ERS-1.pdf

Definition of Terms

Table 3-52: Economizer – Values and References

Term	Unit	Values	Source
SF, Savings factor; Annual cooling load savings per unit area of conditioned space in the building when compared with a baseline HVAC system with no economizer.	$\frac{tons}{ft^2}$	0.002	1
$AREA$, Area of conditioned space served by controlled unit	ft^2	EDC Data Gathering	
FCH_r, Free cooling hours with outdoor temperature between 60 F and 70 F. Typical operating hour conditions are defined below with standard climate zones for PA.	$\frac{Hours}{Year}$	See Table 3-53	2
Eff, Efficiency of existing HVAC equipment. Depending on the size and age, this will either be the SEER, IEER, or EER (use EER only if SEER or IEER are not available)	$\frac{MBh}{kW}$	EDC Data Gathering Default: See Table 3-54	3

Table 3-53: FCH_r for PA Climate Zones and Various Operating Conditions

Location	FCH_r by Operating Schedule			
Operating Schedule	**1 Shift, 5 days per week**	**2 Shift, 5 days per week**	**3 Shift, 5 days per week**	**24/7**
Allentown	419	653	1057	1688
Erie	384	606	977	1563
Harrisburg	377	605	1000	1746
Philadelphia	413	634	1050	1694
Pittsburgh	401	603	947	1622
Scranton	465	705	1117	1787
Williamsport	383	605	1004	1682

Table 3-54: Default HVAC Efficiencies for Non-Residential Buildings[305]

Equipment Type and Capacity	Cooling Efficiency	Heating Efficiency
Air-Source Air Conditioners		
< 65,000 $\frac{Btu}{hr}$	13.0 SEER	N/A
$\geq$ 65,000 $\frac{Btu}{hr}$ and <135,000 $\frac{Btu}{hr}$	11.2 EER / 11.4 IEER	N/A
$\geq$ 135,000 $\frac{Btu}{hr}$ and < 240,000 $\frac{Btu}{hr}$	11.0 EER / 11.2 IEER	N/A
$\geq$ 240,000 $\frac{Btu}{hr}$ and < 760,000 $\frac{Btu}{hr}$	10.0 EER / 10.1 IEER	N/A
$\geq$ 760,000 $\frac{Btu}{hr}$	9.7 EER / 9.8 IEER	N/A
Water-Source and Evaporatively-Cooled Air Conditioners		
< 65,000 $\frac{Btu}{hr}$	12.1 EER / 12.3 IEER	N/A
$\geq$ 65,000 $\frac{Btu}{hr}$ and <135,000 $\frac{Btu}{hr}$	11.5 EER / 11.7 IEER	N/A
$\geq$ 135,000 $\frac{Btu}{hr}$ and < 240,000 $\frac{Btu}{hr}$	11.0 EER / 11.2 IEER	N/A
$\geq$ 240,000 $\frac{Btu}{hr}$	11.0 EER / 11.1 IEER	N/A

Note: For air-source air conditioners, 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.

DEFAULT SAVINGS

Default savings may be claimed using the algorithms above and the variable defaults along with required EDC data gathering of customer data.

EVALUATION PROTOCOLS

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

[305] 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.

SOURCES

1. Bell Jr., Arthur A., 2007. *HVAC Equations, Data, and Rules of Thumb*, second edition, pages 51-52. Assuming 500 CFM/ton (total heat of 300-500 cfm/ton @20F delta) and interior supply flow of 1 CFM/Sq Ft as rule of thumb for all spaces, divide 1 by 500 to get 0.002 ton/Sq Ft savings factor used. This is the assumed cooling load per sq ft of a typical space and what the economizer will fully compensate for during free cooling temperatures.
2. Hours calculated based on local TMY weather data with outdoor temperature between 60°F and 70°F.
3. 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. https://law.resource.org/pub/us/code/ibr/icc.iecc.2009.pdf

3.3 Motors and VFDs

3.3.1 Premium Efficiency Motors

Measure Name	Premium Efficiency Motors
Target Sector	Commercial and Industrial Establishments
Measure Unit	Motor
Unit Energy Savings	Variable
Unit Peak Demand Reduction	Variable
Measure Life	15 years[306]
Measure Vintage	Replace on Burnout, New Construction, or Early Replacement

Eligibility

For constant speed and uniformly loaded motors, the prescriptive measurement and verification protocols described below apply to the 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 (CF) and Run Hours of Use (RHRS) 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.

[306] DEER Effective Useful Life. October 10, 2008.

Algorithms

From EDC data gathering calculate ΔkW where:

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

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

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

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

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

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

Definition of Terms

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

Table 3-55: Building Mechanical System Variables for Premium Efficiency Motor Calculations

Term	Unit	Value	Source
HP, Rated horsepower of the baseline and energy efficient motor	*HP*	Nameplate	EDC Data Gathering
$RHRS$[307], Annual run hours of the motor	$\frac{Hours}{Year}$	Based on logging, panel data or modeling[308]	EDC Data Gathering
		Default: Table 3-58 to Table 3-62	1
LF[309], 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.	*None*	Based on spot metering [310] and nameplate	EDC Data Gathering
		Default: 75%	2
η_{base}, Efficiency of the baseline motor	*None*	Early Replacement: Nameplate	EDC Data Gathering
		New Construction or Replace on Burnout: Default comparable standard motor. See Table 3-56 and Table 3-57	Table 3-56 and Table 3-57
η_{ee}, Efficiency of the energy-efficient motor	*None*	Nameplate	EDC Data Gathering
CF, Demand Coincidence Factor	*Decimal*	Table 3-58 to Table 3-62	1

Note: The Energy Independence and Security Act of 2007[311] 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.

[307] Default value can be used by EDC but is subject to metering and adjustment by evaluators or SWE
[308] Modeling is an acceptable substitute to metering and panel data if 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).
[309] Default value can be used by EDC but is subject to metering and adjustment by evaluators or SWE
[310] See definition in section 3.3.1 for specific algorithm to be used when performing spot metering analysis to determine alternate load factor.
[311] US Congress, Energy Independence and Security Act of 2007 (EISA), January 4, 2007. http://www.gpo.gov/fdsys/pkg/BILLS-110hr6enr/pdf/BILLS-110hr6enr.pdf

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)

Table 3-56: Baseline Motor Nominal Efficiencies for General Purpose Electric Motors (Subtype I)[312]

	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%

[312] The Department of Energy published a final rule on May 29, 2014 that applies to electric motors manufactured on or after June 1, 2016. Therefore, baseline efficiencies for electric motors will be updated in the 2016 TRM to comply with federal energy conservation standards. http://www.ecfr.gov/cgi-bin/text-idx?SID=ba6d4f97451f89bcaa13b3f5a91c54c1&node=10:3.0.1.4.19.2.47.11&rgn=div8

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
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%	95.40%	94.5%	95.00%	95.00%	95.40%
300	95.40%	95.40%	95.00%	95.00%	95.40%	95.40%
350	95.40%	95.40%	95.00%	95.00%	95.40%	95.40%
400	N/A	95.40%	95.40%	N/A	95.40%	95.40%
450	N/A	95.80%	95.80%	N/A	95.40%	95.40%
500	N/A	95.80%	95.80%	N/A	95.80%	95.40%

Table 3-57: Baseline Motor Nominal Efficiencies for General Purpose Electric Motors (Subtype II)[313]

Size HP	Open Drip Proof (ODP) # of Poles			Totally Enclosed Fan-Cooled (TEFC) # of Poles		
	8	6	8	6	8	6
	Speed (RPM)			Speed (RPM)		
	900	1200	900	1200	900	1200
1	74.0%	80.0%	82.5%	N/A	74.0%	80.0%
1.5	75.5%	84.0%	84.0%	82.5%	77.0%	85.5%
2	85.5%	85.5%	84.0%	84.0%	82.5%	86.5%

[313] Ibid.

	Open Drip Proof (ODP) # of Poles			Totally Enclosed Fan-Cooled (TEFC) # of Poles		
	8	6	8	6	8	6
	Speed (RPM)			Speed (RPM)		
Size HP	**900**	**1200**	**900**	**1200**	**900**	**1200**
3	86.5%	86.5%	86.5%	84.0%	84.0%	87.5%
5	87.5%	87.5%	87.5%	85.5%	85.5%	87.5%
7.5	88.5%	88.5%	88.5%	87.5%	85.5%	89.5%
10	89.5%	90.2%	89.5%	88.5%	88.5%	89.5%
15	89.5%	90.2%	91.0%	89.5%	88.5%	90.2%
20	90.2%	91.0%	91.0%	90.2%	89.5%	90.2%
25	90.2%	91.7%	91.7%	91.0%	89.5%	91.7%
30	91.0%	92.4%	92.4%	91.0%	91.0%	91.7%
40	91.0%	93.0%	93.0%	91.7%	91.0%	93.0%
50	91.7%	93.0%	93.0%	92.4%	91.7%	93.0%
60	92.4%	93.6%	93.6%	93.0%	91.7%	93.6%
75	93.6%	93.6%	94.1%	93.0%	93.0%	93.6%
100	93.6%	94.1%	94.1%	93.0%	93.0%	94.1%
125	93.6%	94.1%	94.5%	93.6%	93.6%	94.1%
150	93.6%	94.5%	95.0%	93.6%	93.6%	95.0%
200	93.6%	94.5%	95.0%	94.5%	94.1%	95.0%
250	94.5%	95.4%	95.4%	94.5%	94.5%	95.0%
300	N/A	95.4%	95.4%	95.0%	N/A	95.0%
350	N/A	95.4%	95.4%	95.0%	N/A	95.0%
400	N/A	N/A	95.4%	95.4%	N/A	N/A
450	N/A	N/A	95.8%	95.8%	N/A	N/A
500	N/A	N/A	95.8%	95.8%	N/A	N/A

Table 3-58: Default RHRS and CFs for Supply Fan Motors in Commercial Buildings[314]

Facility Type	Parameter	Allentown	Erie	Harrisburg	Philadelphia	Pittsburgh	Scranton	Williamsburg
Assembly	Run Hours	5,188	5,217	5,172	5,186	5,201	5,207	5,184
	CF	0.53	0.45	0.60	0.72	0.56	0.47	0.52
Education - Community College	Run Hours	5,972	6,081	5,772	5,878	5,911	5,795	5,824
	CF	0.44	0.32	0.45	0.48	0.43	0.40	0.47
Education - Primary School	Run Hours	3,753	3,961	3,699	3,894	3,790	3,881	3,763
	CF	0.10	0.07	0.16	0.16	0.17	0.11	0.12
Education - Relocatable Classroom	Run Hours	5,467	5,649	5,375	5,321	5,556	5,607	5,439
	CF	0.15	0.11	0.18	0.19	0.20	0.14	0.15
Education - Secondary School	Run Hours	3,920	4,106	3,866	3,937	3,900	3,983	3,928
	CF	0.11	0.09	0.18	0.19	0.17	0.12	0.17
Education - University	Run Hours	6,111	6,196	5,948	6,053	6,053	5,957	5,985
	CF	0.41	0.31	0.43	0.45	0.40	0.36	0.40
Grocery	Run Hours	6,708	6,738	6,692	6,669	6,718	6,725	6,710
	CF	0.24	0.22	0.24	0.26	0.29	0.21	0.24
Health/Medical - Hospital	Run Hours	8,760	8,760	8,760	8,760	8,760	8,760	8,760
	CF	0.43	0.39	0.45	0.51	0.45	0.40	0.41
Health/Medical - Nursing Home	Run Hours	8,760	8,760	8,760	8,760	8,760	8,760	8,760
	CF	0.24	0.23	0.29	0.31	0.29	0.25	0.28
Lodging - Hotel	Run Hours	8,760	8,760	8,760	8,760	8,760	8,760	8,760
	CF	0.64	0.65	0.71	0.71	0.73	0.65	0.71
Manufacturing - Bio/Tech	Run Hours	3,570	3,616	3,539	3,565	3,571	3,552	3,573
	CF	0.56	0.44	0.57	0.61	0.57	0.50	0.52

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

Facility Type	Parameter	Allentown	Erie	Harrisburg	Philadelphia	Pittsburgh	Scranton	Williamsburg
Manufacturing - Light Industrial	Run Hours	4,092	4,338	3,998	4,111	4,167	4,251	4,084
	CF	0.39	0.31	0.49	0.52	0.42	0.36	0.40
Office - Large	Run Hours	4,400	4,696	4,298	4,342	4,503	4,441	4,353
	CF	0.30	0.29	0.39	0.39	0.34	0.34	0.35
Office - Small	Run Hours	3,990	4,185	3,876	3,784	3,976	4,014	3,924
	CF	0.29	0.27	0.35	0.38	0.35	0.30	0.33
Restaurant - Fast-Food	Run Hours	7,328	7,398	7,300	7,238	7,313	7,342	7,332
	CF	0.36	0.33	0.39	0.47	0.44	0.38	0.42
Restaurant - Sit-Down	Run Hours	5,236	5,332	5,203	5,213	5,286	5,288	5,239
	CF	0.39	0.41	0.45	0.53	0.54	0.40	0.48
Retail - Multistory Large	Run Hours	4,893	4,897	4,885	4,885	4,907	4,890	4,896
	CF	0.48	0.39	0.54	0.53	0.48	0.44	0.49
Retail - Single-Story Large	Run Hours	5,486	5,494	5,481	5,497	5,502	5,493	5,487
	CF	0.50	0.40	0.53	0.63	0.55	0.47	0.47
Retail - Small	Run Hours	5,031	5,083	4,959	4,895	5,030	5,063	5,018
	CF	0.53	0.52	0.51	0.53	0.59	0.45	0.50
Storage - Conditioned	Run Hours	5,037	5,222	4,980	5,168	5,110	5,188	5,028
	CF	0.18	0.13	0.24	0.30	0.23	0.15	0.20
Warehouse - Refrigerated	Run Hours	4,041	4,041	4,041	4,041	4,041	4,041	4,041
	CF	0.50	0.48	0.52	0.53	0.51	0.48	0.51

Table 3-59: Default RHRS and CFs for Chilled Water Pump (CHWP) Motors in Commercial Buildings[315]

Facility Type	Parameter	Allentown	Erie	Harrisburg	Philadelphia	Pittsburgh	Scranton	Williamsburg
Education - Community College	Run Hours	2,868	2,561	2,937	3,307	2,775	2,660	2,727
	CF	0.42	0.30	0.43	0.46	0.41	0.35	0.43
Education - Secondary School	Run Hours	2,721	2,175	2,730	3,505	2,676	2,310	2,573
	CF	0.10	0.09	0.18	0.18	0.17	0.12	0.16
Education - University	Run Hours	5,145	4,721	5,177	5,314	5,056	4,995	5,016
	CF	0.39	0.29	0.40	0.43	0.38	0.31	0.36
Health/Medical - Hospital	Run Hours	5,588	5,109	5,717	6,086	5,593	5,266	5,628
	CF	0.46	0.42	0.50	0.54	0.48	0.44	0.47
Health/Medical - Nursing Home	Run Hours	3,892	3,456	4,104	4,535	3,900	3,710	3,818
	CF	0.24	0.22	0.28	0.30	0.28	0.23	0.26
Lodging - Hotel	Run Hours	5,845	5,198	6,045	6,161	5,686	5,655	5,776
	CF	0.61	0.60	0.66	0.67	0.69	0.59	0.66
Manufacturing - Bio/Tech	Run Hours	1,735	1,448	1,742	1,891	1,606	1,558	1,633
	CF	0.53	0.43	0.53	0.58	0.54	0.48	0.50
Office - Large	Run Hours	1,873	1,713	1,912	2,173	1,876	1,741	1,815
	CF	0.30	0.28	0.36	0.37	0.33	0.30	0.33
Office - Small	Run Hours	1,705	1,456	1,696	1,899	1,602	1,534	1,606
	CF	0.28	0.26	0.33	0.35	0.32	0.28	0.31
Retail - Multistory Large	Run Hours	2,957	2,653	3,085	3,225	2,795	2,735	2,898
	CF	0.46	0.38	0.53	0.54	0.47	0.42	0.47

[315] Ibid.

Table 3-60: Default RHRS and CFs for Cooling Tower Fan (CTF) Motors in Commercial Buildings[316]

Facility Type	Parameter	Allentown	Erie	Harrisburg	Philadelphia	Pittsburgh	Scranton	Williamsburg
Education - Community College	Run Hours	2,868	2,560	2,937	3,306	2,774	2,660	2,727
	CF	0.42	0.30	0.43	0.46	0.41	0.35	0.42
Education - Secondary School	Run Hours	2,742	2,178	2,744	3,517	2,685	2,313	2,604
	CF	0.11	0.09	0.18	0.18	0.17	0.12	0.17
Education - University	Run Hours	5,143	4,721	5,176	5,312	5,053	4,993	5,015
	CF	0.39	0.29	0.40	0.43	0.38	0.31	0.36
Health/Medical - Hospital	Run Hours	5,587	5,107	5,714	6,084	5,591	5,263	5,626
	CF	0.45	0.41	0.49	0.54	0.47	0.44	0.46
Health/Medical - Nursing Home	Run Hours	3,894	3,457	4,106	4,537	3,902	3,711	3,819
	CF	0.24	0.22	0.28	0.30	0.28	0.23	0.26
Lodging - Hotel	Run Hours	5,844	5,197	6,043	6,159	5,683	5,652	5,773
	CF	0.61	0.61	0.67	0.68	0.70	0.59	0.66
Manufacturing - Bio/Tech	Run Hours	1,735	1,448	1,742	1,891	1,606	1,558	1,633
	CF	0.53	0.43	0.54	0.59	0.54	0.48	0.50
Office - Large	Run Hours	1,873	1,713	1,912	2,173	1,876	1,741	1,815
	CF	0.30	0.28	0.36	0.37	0.33	0.30	0.33
Office - Small	Run Hours	1,705	1,456	1,696	1,899	1,602	1,534	1,606
	CF	0.28	0.26	0.33	0.35	0.32	0.28	0.31
Retail - Multistory Large	Run Hours	2,957	2,653	3,085	3,226	2,795	2,736	2,898
	CF	0.46	0.38	0.53	0.54	0.47	0.42	0.47

[316] Ibid.

Table 3-61: Default RHRS and CFs for Heating Hot Water Pump (HHWP) Motors in Commercial Buildings[317]

Facility Type	Parameter	Allentown	Erie	Harrisburg	Philadelphia	Pittsburgh	Scranton	Williamsburg
Education - Community College	Run Hours	4,454	4,941	4,150	3,838	4,447	4,562	4,408
	CF	0.01	0.01	0.00	0.00	0.01	0.01	0.01
Education - Secondary School	Run Hours	3,651	4,080	3,492	3,341	3,705	3,830	3,658
	CF	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Education - University	Run Hours	4,642	5,131	4,350	4,190	4,697	4,714	4,566
	CF	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Health/Medical - Hospital	Run Hours	8,760	8,760	8,760	8,760	8,760	8,760	8,760
	CF	0.09	0.09	0.09	0.09	0.09	0.09	0.09
Health/Medical - Nursing Home	Run Hours	5,934	6,280	5,823	5,477	5,991	6,223	6,045
	CF	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lodging - Hotel	Run Hours	6,469	6,829	6,155	6,077	6,574	6,628	6,387
	CF	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Manufacturing - Bio/Tech	Run Hours	1,258	1,555	1,184	1,028	1,287	1,393	1,277
	CF	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Office - Large	Run Hours	3,705	4,097	3,503	3,112	3,703	3,809	3,652
	CF	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Office - Small	Run Hours	2,723	3,124	2,525	2,267	2,788	2,863	2,685
	CF	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Retail - Multistory Large	Run Hours	2,676	2,960	2,561	2,398	2,908	2,841	2,660
	CF	0.00	0.00	0.00	0.00	0.00	0.00	0.00

317 Ibid.

Table 3-62: Default RHRS and CFs for Condenser Water Pump Motors in Commercial Buildings[318]

Facility Type	Parameter	Allentown	Erie	Harrisburg	Philadelphia	Pittsburgh	Scranton	Williamsburg
Education - Community College	Run Hours	2,611	2,344	2,733	3,000	2,668	2,429	2,530
	CF	0.42	0.30	0.43	0.46	0.41	0.35	0.42
Education - Secondary School	Run Hours	2,448	2,039	2,539	3,346	2,409	2,164	2,423
	CF	0.11	0.09	0.18	0.18	0.17	0.12	0.17
Education - University	Run Hours	4,443	3,782	4,471	5,059	4,830	4,571	4,448
	CF	0.39	0.29	0.40	0.43	0.38	0.31	0.36
Health/Medical - Hospital	Run Hours	3,950	3,698	3,687	4,168	4,093	3,713	3,670
	CF	0.45	0.41	0.49	0.54	0.47	0.44	0.46
Health/Medical - Nursing Home	Run Hours	3,675	3,394	3,725	4,304	3,571	3,687	3,722
	CF	0.24	0.22	0.28	0.30	0.28	0.23	0.26
Lodging - Hotel	Run Hours	5,544	4,766	5,569	5,886	5,239	5,353	5,328
	CF	0.61	0.61	0.67	0.68	0.70	0.59	0.66
Manufacturing - Bio/Tech	Run Hours	1,735	1,445	1,737	1,889	1,602	1,558	1,632
	CF	0.53	0.43	0.54	0.59	0.54	0.48	0.50
Office - Large	Run Hours	1,857	1,685	1,891	2,156	1,862	1,728	1,798
	CF	0.30	0.28	0.36	0.37	0.33	0.30	0.33
Office - Small	Run Hours	1,705	1,453	1,693	1,898	1,597	1,533	1,606
	CF	0.28	0.26	0.33	0.35	0.32	0.28	0.31
Retail - Multistory Large	Run Hours	2,889	2,616	3,025	3,185	2,757	2,702	2,847
	CF	0.46	0.38	0.53	0.54	0.47	0.42	0.47

[318] Ibid.

Default Savings

There are no default savings for this measure.

Evaluation Protocols

Motor projects achieving expected kWh savings of 250,000 kWh or higher must[319] be metered to calculate *ex ante* and/or *ex post* savings. 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.

Sources

1. Results are based on Nexant eQuest modeling analysis 2014.
2. California Public Utility Commission. *Database for Energy Efficiency Resources* 2005.

[319] The Commission allows the EDCs to use alternative methods for obtaining customer-specific 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.

3.3.2 Variable Frequency Drive (VFD) Improvements

Measure Name	Variable Frequency Drive (VFD) Improvements
Target Sector	Commercial and Industrial Establishments
Measure Unit	Variable Frequency Drive
Unit Energy Savings	Variable
Unit Peak Demand Reduction	Variable
Measure Life	13 years[320]
Measure Vintage	Retrofit

Eligibility

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 3-64. The baseline condition is a motor without a VFD control. The efficient condition is a motor with a VFD control.

Algorithms

$$\Delta kWh = HP \times \frac{LF}{\eta_{motor}} \times RHRS_{base} \times ESF$$

$$\Delta kW_{peak} = HP \times \frac{LF}{\eta_{motor}} \times CF \times DSF$$

[320] The Measure Life Report for Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc., June 2007.
http://library.cee1.org/sites/default/files/library/8842/CEE_Eval_MeasureLifeStudyLights%26HVACGDS_1Jun2007.pdf

Definitions of Terms

Table 3-63: Variables for VFD Calculations

Term	Unit	Values	Source
$Motor\ HP$, Rated horsepower of the motor	*HP*	Nameplate	EDC Data Gathering
$RHRS_{base}$[321], Annual run hours of the baseline motor	$\frac{Hours}{Year}$	Based on logging, panel data or modeling	EDC Data Gathering
		Default: See Table 3-58 to Table 3-62	1
LF[322], 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.	*None*	Based on spot metering and nameplate	EDC Data Gathering
		Default: 75%	1
ESF, Energy Savings Factor. Percent of baseline energy consumption saved by installing VFD.	*None*	Default See Table 3-64	See Table 3-64
		Based on logging and panel data	EDC Data Gathering
DSF, Demand Savings Factor. Percent of baseline demand saved by installing VFD	*None*	Default: See Table 3-64	See Table 3-64
		Based on logging and panel data	EDC Data Gathering
η_{motor}, Motor efficiency at the full-rated load. For VFD installations, this can be either an energy efficient motor or standard efficiency motor. Motor efficiency varies with load and decreases dramatically below 50% load; this is reflected in the ESF term of the algorithm.	*None*	Nameplate	EDC Data Gathering
CF, Demand Coincidence Factor	*Decimal*	See Table 3-58 to Table 3-62	2

321 Default Value can be used by EDC but is subject to metering and adjustment by evaluators or SWE
322 Ibid.

Table 3-64: ESF and DSF for Typical Commercial VFD Installations[323]

HVAC Fan VFD Savings Factors		
Baseline	**ESF**	**DSF**
Constant Volume[324]	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
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

Default Savings

There are no default savings for this measure.

Evaluation Protocol

VFD projects achieving expected kWh savings of 250,000 kWh or higher must[325] be metered to calculate *ex ante* and/or *ex post* savings. Metering is not mandatory where hours can be easily verified through a building automation system schedule that clearly shows motor run time.

Sources

1. California Public Utility Commission. *Database for Energy Efficiency Resources* 2005.
2. Results are based on Nexant's eQuest modeling analysis 2014

323 UI and CL&P Program Savings Documentation for 2012 Program Year, United Illuminating Company, September 2011. Pages 44- 45. http://www.energizect.com/sites/default/files/2012%20CT%20Program%20Savings%20Documentation%20FINAL.pdf

324 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.

325 The Commission allows the EDCs to use alternative methods for obtaining customer-specific 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.

3.3.3 ECM Circulating Fan

Measure Name	ECM Circulating Fan
Target Sector	Commercial and Industrial Establishments
Measure Unit	ECM Circulating Fan
Unit Energy Savings	Variable
Unit Peak Demand Reduction	Variable
Measure Life	18 years[326]
Measure Vintage	Early Replacement

This protocol covers energy and demand savings associated with retrofit of existing shaded-pole (SP) or permanent-split capacitor (PSC) evaporator fan motors in an air handling unit with an electronically commutated motor (ECM).

Eligibility

This measure is targeted to non-residential customers whose air handling equipment currently uses a SP or PSC fan motor rather than an ECM. This measure applies only to circulating fan motors of 1 HP or less. Above 1 HP motors are governed by NEMA standards and would see little to no efficiency benefit by adding an ECM.

The targeted fan can supply heating or cooling only, or both heating and cooling. A default savings option is offered if motor input wattage is not known. However, these parameters should be collected by EDCs for greatest accuracy.

Acceptable baseline conditions are an existing circulating fan with a SP or PSC fan motor 1 HP or less.

Efficient conditions are a circulating fan with an ECM.

Algorithms

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

$$\Delta kW_{peak} = \Delta kW_{cool}$$

326 "Energy Savings from Efficient Furnace Fan Air Handlers in Massachusetts," ACEEE, Sachs and Smith, 2003. For the purpose of calculating the total Resource Cost Test for Act 129, measure cannot claim savings for more than fifteen years.

Heating

$$\Delta kWh_{heat} = \frac{(WATTS_{base} - WATTS_{ee})}{1000} \times LF \times EFLH_{heat} \times (1 + IF_{kWh})$$

$$\Delta kW_{heat} = 0$$

Cooling

$$\Delta kWh_{cool} = \frac{(WATTS_{base} - WATTS_{ee})}{1000} \times LF \times EFLH_{cool} \times (1 + IF_{kWh})$$

$$\Delta kW_{cool} = \frac{(WATTS_{base} - WATTS_{ee})}{1000} \times LF \times CF \times (1 + IF_{kW})$$

Definition of Terms

Table 3-65: ECM Circulating Fan – Values and References

Term	Unit	Values	Source
$WATTS_{base}$, Baseline watts	*W*	Nameplate data	EDC Data Gathering
		Default: See Table 3-66	1, 2, 3
$WATTS_{ee}$, Energy efficient watts	*W*	Nameplate data	EDC Data Gathering
		Default : See Table 3-66	1, 2, 3
LF , Load factor	*None*	EDC Data Gathering	EDC Data Gathering
		Default: 0.9	4
$EFLH_{heat}$, Equivalent Full-Load Hours for heating only	$\frac{Hours}{year}$	EDC Data Gathering	EDC Data Gathering
		Default : See Table 3-26	7
$EFLH_{cool}$, Equivalent Full-Load Hours for cooling only	$\frac{Hours}{year}$	EDC Data Gathering	EDC Data Gathering
		Default: See Table 3-24	7
CF, Coincidence Factor	*Decimal*	EDC Data Gathering	EDC Data Gathering
		Default: See Table 3-25	7
IF_{kWh}, Energy Interactive Factor	*None*	EDC Data Gathering	EDC Data Gathering
		$IF_{kW} \times \left(1 - \frac{EFLH_{heat}}{EFLH_{heat} + EFLH_{cool}}\right) \times \frac{13}{11.3}$	5
IF_{kW}, Demand Interactive Factor	*None*	EDC Data Gathering	EDC Data Gathering
		Default : 30%	6

Table 3-66: Default Motor Wattage (WATTSbase and WATTSee) for Circulating Fan

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

Default Savings

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

Evaluation Protocols

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

Sources

1. Regional Technical Forum (RTF) as part of the Northwest Power & Conservation Council, Deemed Measures List. Grocery Display Case ECM, FY2010, V2. http://rtf.nwcouncil.org/measures/measure.asp?id=107&decisionid=230
2. Regional Technical Forum (RTF) as part of the Northwest Power & Conservation Council, Deemed Measures List. Deemed MeasuresV26 _walkinevapfan.
3. AO Smith New Product Notification. I-motor 9 & 16 Watt. Stock Numbers 9207F2 and 9208F2. Web address: http://www.electricmotorwarehouse.com/PDF/Bulletin%206029B.pdf
4. PSC of Wisconsin, Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0, p. 4-103 to 4-106. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
5. Assuming that the waste heat is within the conditioned air stream, then the energy associated with removing the waste heat during peak times is approximated as the inverse of the COP, or 3.413/EER = 0.30 if one uses 11.3 as a default value for cooling system EER.
6. This is an approximation that accounts for the coincidence between cooling and fan operation and corrects with a factor of 11.3/13 to account for seasonal cooling efficiency rather than peak cooling efficiency.
7. Nexant eQuest modeling analysis 2014.

3.3.4 VSD on Kitchen Exhaust Fan

Measure Name	VSD on Kitchen Exhaust Fan
Target Sector	Commercial and Industrial Establishments
Measure Unit	VSD on Kitchen Exhaust Fan
Unit Energy Savings	Variable
Unit Peak Demand Reduction	Variable
Measure Life	15 years[327]
Measures Vintage	Retrofit

Installation of variable speed drives (VSD) on commercial kitchen exhaust fans allows the variation of ventilation based on cooking load and/or time of day.

Eligibility

This measure is targeted to non-residential customers whose kitchen exhaust fans are equipped with a VSD that varies the exhaust rate of kitchen ventilation based on the energy and effluent output from the cooking appliances (i.e., the more heat and smoke/vapors generated, the more ventilation needed). This involves installing a temperature sensor in the hood exhaust collar and/or an optic sensor on the end of the hood that sense cooking conditions which allows the system to automatically vary the rate of exhaust to what is needed by adjusting the fan speed.
The baseline equipment is kitchen ventilation that has a constant speed ventilation motor.

The energy efficient condition is a kitchen ventilation system equipped with a VSD and demand ventilation controls and sensors.

Algorithms

Annual energy and demand savings values are based on monitoring results from five different types of sites, as summarized in the PG&E work paper[328]. The sites included an institutional cafeteria, a casual dining restaurant, a hotel kitchen, a supermarket kitchen, and a university dining facility. Units are based on savings per total exhaust fan rated horsepower. Savings values are applicable to new and retrofit units.

$$\Delta kWh = HP \times 4{,}486$$

$$\Delta kW_{peak} = HP \times 0.76$$

[327] PGE Workpaper, Commercial Kitchen Demand Ventilation Controls, PGECOFST116. June 1, 2009
[328] Ibid.

Definition of Terms

Table 3-67: VSD on Kitchen Exhaust Fan – Variables and References

Term	Unit	Values	Source
$4{,}486$, Annual energy savings per total exhaust fan horsepower	$\frac{kWh}{HP}$	4,486	1, 2
0.76, Coincident peak demand savings per total exhaust fan horsepower	$\frac{kW}{HP}$	0.76	1, 2
HP, Horsepower rating of the exhaust fan	*HP*	Nameplate data	EDC Data Gathering

Default Savings

Savings for this measure are partially deemed based on motor horsepower.

Evaluation Protocols

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

Sources

1. PGE Workpaper, Commercial Kitchen Demand Ventilation Controls, PGECOFST116. June 1, 2009
2. SDGE Workpaper, Work Paper WPSDGENRCC0019, Commercial Kitchen Demand Ventilation Controls-Electric, Revision 0. June 15, 2012. https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0CCsQFjAA&url=https%3A%2F%2Fwww.sdge.com%2Fsites%2Fdefault%2Ffiles%2Fregulatory%2FWPSDGENRCC0019%2520Rev%25200%2520Demand%2520Ventilation%2520Controls.doc&ei=RZuMU5vCNK-lsATEqoCoAg&usg=AFQjCNFltI0wjiCmylhK06gWIEYcX7b3lw&sig2=mwHSNhg_EnQF7eSVUyvgpA&bvm=bv.67720277,d.cWc&cad=rja

3.4 Domestic Hot Water

3.4.1 Electric Resistance Water Heaters

Measure Name	Electric Resistance Water Heaters
Target Sector	Commercial and Industrial Establishments
Measure Unit	Electric Resistance Water Heater
Unit Energy Savings	Variable
Unit Peak Demand Reduction	Variable
Measure Life	15 years[329]
Measure Vintage	Replace on Burnout

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

Eligibility

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

Algorithms

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

$$\Delta kWh = \frac{\left\{\left(\frac{1}{EF_{base}} - \frac{1}{EF_{proposed}}\right) \times HW \times 8.3\frac{lb}{gal} \times 1.0\frac{Btu}{lb \cdot {}^{\circ}F} \times (T_{hot} - T_{cold})\right\}}{3412\frac{Btu}{kWh}}$$

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

329 DEER Effective Useful Life. October 10, 2008

$$\Delta kW_{peak} = ETDF \times Energy\ Savings \times RDF$$

The Energy to Demand Factor is defined below:

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

Loads

The annual loads are taken from the DEER database[330]. 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 3-68 below.

$$HW\ (Gallons) = \frac{Load \times EF_{ng,base} \times 1{,}000\ \frac{\text{Btu}}{\text{kBtu}} \times Typical\ SF}{1.0\ \frac{Btu}{lb \cdot °F} \times 8.3\ \frac{\text{lb}}{\text{gal}} \times (T_{hot} - T_{cold}) \times 1{,}000\ SF}$$

Table 3-68: Typical water heating loads

Building Type	Typical Square Footage	Average Annual Load In kBTU	Average Annual Use, Gallons
Motel	30,000	2,963	99,399
Small Office	10,000	2,214	24,757
Small Retail	7,000	1,451	11,358

Energy to Demand Factor

The ratio of the average energy usage between 2 PM to 6 PM on summer weekdays to the total annual energy usage is taken from usage profile data collected for commercial water heaters in CA[331]. The usage profiles are shown in Figure 3-1. 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 3-2, 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 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[332].

330 DEER 2008. Commercial Results Review Non-Updated Measures.

331 Ibid

332 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).

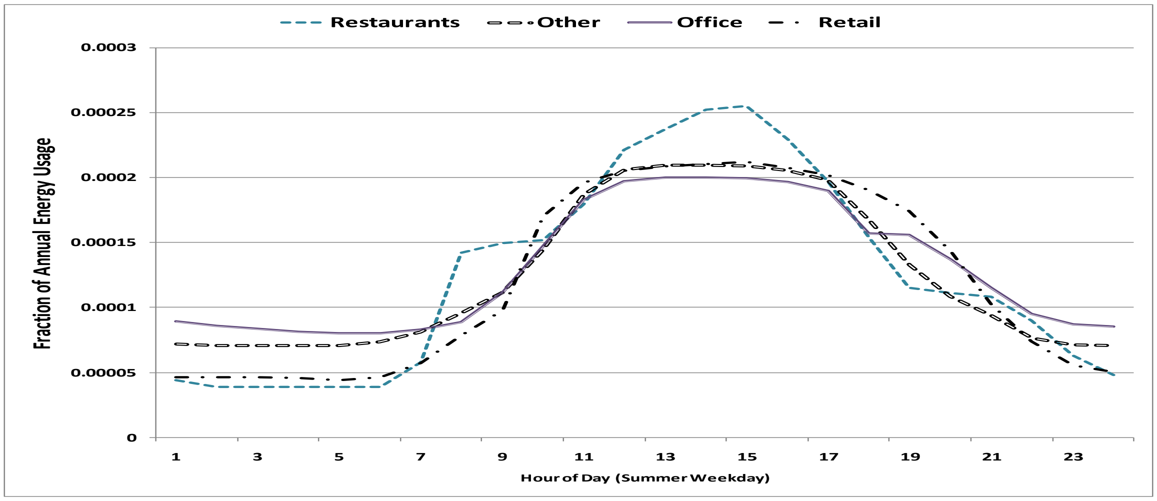


Figure 3-1: Load shapes for hot water in four commercial building types

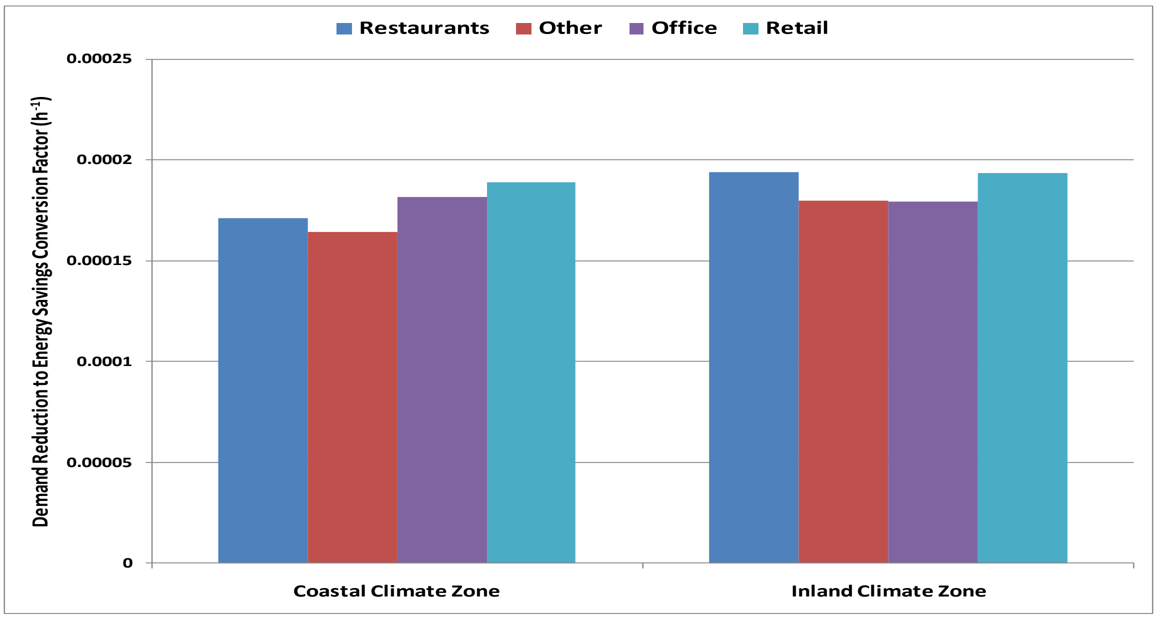


Figure 3-2: Energy to demand factors for four commercial building types

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 119 °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.

Definition of Terms

The parameters in the above equation are listed in Table 3-69.

Table 3-69: Electric Resistance Water Heater Calculation Assumptions

Term	Unit	Values	Source
EF_{base}, Energy Factor of baseline water heater	*None*	See Table 3-70	1
$EF_{proposed}$, Energy Factor of proposed efficient water heater	*None*	Default: 0.93	Program Design
		Nameplate	EDC Data Gathering
Load, Average annual Load	*kBTU*	Varies	DEER Database
T_{hot}, Temperature of hot water	*°F*	119	2
T_{cold}, Temperature of cold water supply	*°F*	55	3
ETDF, Energy To Demand Factor	*None*	0.000178	4
HW, Average annual gallons of use	*Gal*	Default: See Table 3-68	Calculation
		EDC Data Gathering	EDC Data Gathering
$EF_{ng,base}$, Energy Factor of baseline gas water heater	*None*	0.594	5
RDF, Resistive Discount Factor	*None*	1.0	6

Energy Factors based on Tank Size

Federal Standards for Energy Factors are equal to $0.97 - 0.00132 \times Rated\ Storage\ (gallons)$. The following table shows the Energy Factors for various tank sizes.

Table 3-70: 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

Default Savings

Savings for the installation of efficient electric resistance water heaters in different building types are calculated using the formulas below:

Table 3-71: Energy Savings Algorithms

Building Type	Default Algorithms
Motel	$\Delta kWh = 15{,}474.99\ (\frac{1}{EF_{base}} - \frac{1}{EF_{proposed}})$
Small Office	$\Delta kWh = 3{,}854.38\ (\frac{1}{EF_{base}} - \frac{1}{EF_{proposed}})$
Small Retail	$\Delta kWh = 1{,}768.25\ (\frac{1}{EF_{base}} - \frac{1}{EF_{proposed}})$

Evaluation Protocols

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

Sources

1. 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 http://www.gpo.gov/fdsys/pkg/FR-2010-04-16/pdf/2010-7611.pdf
2. 2014 SWE Residential Baseline Study. http://www.puc.pa.gov/Electric/pdf/Act129/SWE-2014_PA_Statewide_Act129_Residential_Baseline_Study.pdf

3. Mid-Atlantic TRM, footnote #24. http://www.neep.org/Assets/uploads/files/emv/emv-products/TRM_March2013Version.pdf
4. The ETDF 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. 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 http://www.gpo.gov/fdsys/pkg/FR-2010-04-16/pdf/2010-7611.pdf
6. Engineering Estimate. No discount factor is needed because this measure is already an electric resistance water heater system.

3.4.2 Heat Pump Water Heaters

Measure Name	Heat Pump Water Heaters
Target Sector	Commercial and Industrial Establishments
Measure Unit	Heat Pump Water Heater
Unit Energy Savings	Variable
Unit Peak Demand Reduction	Variable
Measure Life	10 years[333]
Measure Vintage	Replace on Burnout

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

Eligibility

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

Algorithms

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

$$\Delta kWh = \frac{\left\{\left(\frac{1}{EF_{base}} - \left(\frac{1}{EF_{proposed}} \times \frac{1}{F_{adjust}}\right)\right) \times HW \times 8.3\ \frac{lb}{gal} \times 1.0\ \frac{Btu}{lb \cdot {}^{\circ}F} \times (T_{hot} - T_{cold})\right\}}{3412 \frac{Btu}{kWh}}$$

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

$$\Delta kW_{peak} = ETDF \times Energy\ Savings \times RDF$$

333 DEER Effective Useful Life. October 10, 2008.

The Energy to Demand Factor is defined below:

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

Loads

The annual loads are taken from the DEER database[334]. 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 3-72 below.

$$HW\ (\text{Gallons}) = \frac{Load \times EF_{ng,base} \times 1{,}000\ \frac{Btu}{kBtu} \times Typical\ SF}{1.0\ \frac{Btu}{lb \cdot {}^{\circ}F} \times 8.3\ \frac{lb}{gal} \times (T_{hot} - T_{cold}) \times 1{,}000\ SF}$$

Table 3-72: Typical water heating loads

Building Type	Typical Square Footage	Average Annual Load In kBTU	Average Annual Use, Gallons
Motel	30,000	2,963	99,399
Small Office	10,000	2,214	24,757
Small Retail	7,000	1,451	11,358

Energy to Demand Factor

The ratio of the average energy usage between 2 PM to 6 PM on summer weekdays to the total annual energy usage is taken from usage profile data collected for commercial water heaters in CA[335]. The usage profiles are shown in Figure 3-3. 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 3-4, 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 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[336].

[334] DEER 2008 Commercial Results Review Non Updated Measures

[335] ibid

[336] One reason for the close agreement is that the factor is a ratio of the energy usage to peak demand for the same location. Even though the energy usages may vary significantly in different climate zones, the hot water usage patterns may be driven by underlying practices that carry over well from state to state (e.g. dishwashing after lunch or dinner in restaurants).

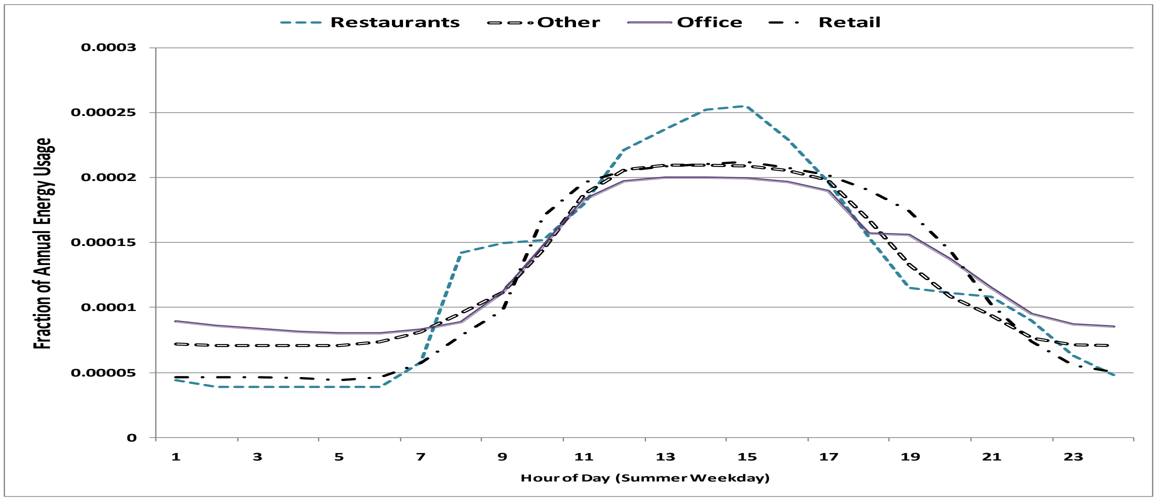


Figure 3-3: Load shapes for hot water in four commercial building types

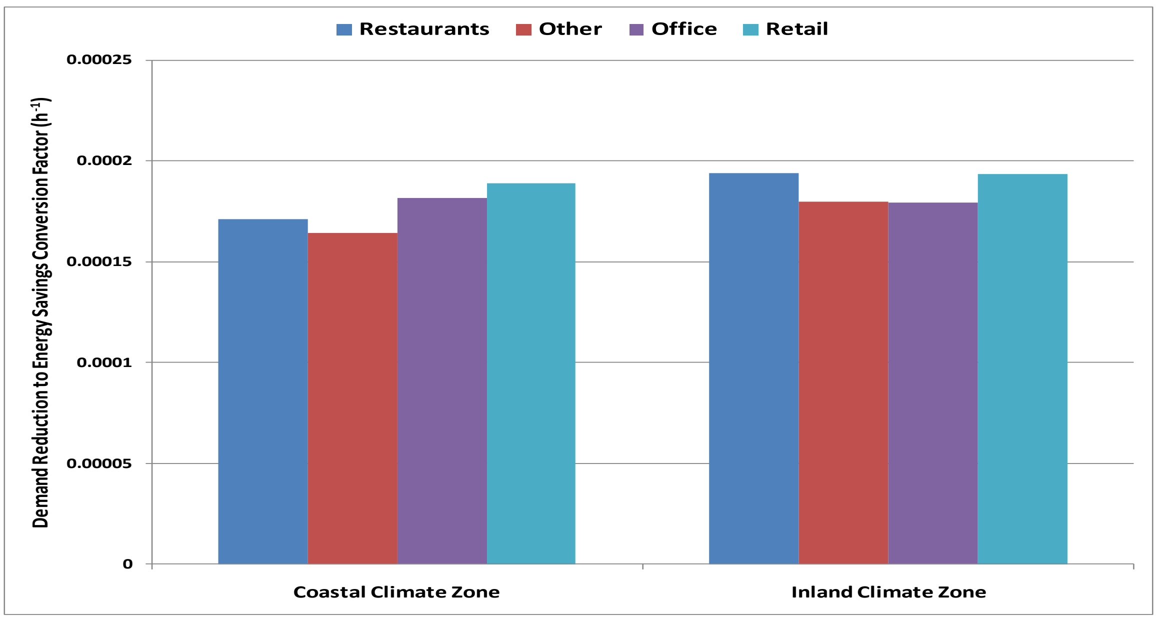


Figure 3-4: Energy to demand factors for four commercial building types

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 119 °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.

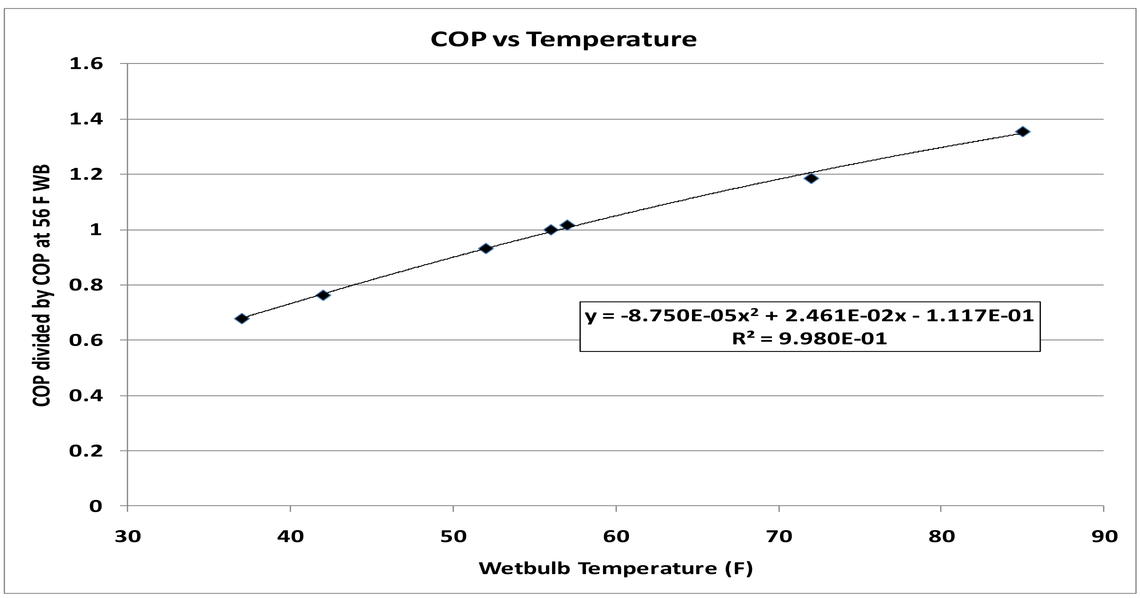
Under these operating conditions, one would expect a properly sized heat pump water heater with adequate storage capacity to require minimal reliance on resistive heating elements. A resistive heating discount factor of 0.9, corresponding to a 10% reduction in COP during peak times, is therefore taken 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[337], while the average wetbulb temperature in conditioned typically ranges from 50 °F to 80 °F. The heat pump performance is temperature dependent. Figure 3-5 below shows relative coefficient of performance (COP) compared to the COP at rated conditions[338]. According to the plotted profile, the following adjustments are recommended.

Table 3-73: 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



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337 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.

338 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 3-5: Dependence of COP on outdoor wetbulb temperature

DEFINITION OF TERMS

The parameters in the above equation are listed in Table 3-74.

Table 3-74: Heat Pump Water Heater Calculation Assumptions

Term	Unit	Values	Source
EF_{base}, Energy Factor of baseline water heater	*None*	See Table 3-75	1
$EF_{proposed}$, Energy Factor of proposed efficient water heater	*None*	Default: 2.2	Program Design
		Nameplate	EDC Data Gathering
Load, Average annual Load	*kBTU*	Varies	5
T_{hot}, Temperature of hot water	*°F*	119	2
T_{cold}, Temperature of cold water supply	*°F*	55	3
ETDF, Energy to Demand Factor	*None*	0.000178	4
F_{adjust} ,COP Adjustment factor	*None*	0.80 if outdoor 1.09 if indoor 1.30 if in kitchen	4
RDF, Resistive Discount Factor	*None*	0.90	6
HW, Average annual gallons of use	*Gallons*	Default: See Table 3-72	Calculation
		EDC Data Gathering	EDC Data Gathering
$EF_{ng,base}$, Energy Factor of baseline gas water heater	*None*	0.594	7

Energy Factors based on Tank Size

Federal Standards for Energy Factors are equal to$0.97 - 0.00132 \times Rated\ Storage\ (gallons)$. The following table shows the Energy Factors for various tank sizes.

Table 3-75: Minimum Baseline Energy Factor Based on Tank Size

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

Default Savings

As an example, the default savings for the installation of heat pump electric water heaters with an energy factor of 2.2 in various applications are calculated using the algorithms below:

Table 3-76: Energy Savings Algorithms

Building Type	Location Installed	Algorithm
Motel	Outdoor	$\Delta kWh = (\frac{15,474.99}{EF_{base}} - \frac{19,343.74}{EF_{proposed}})$
Motel	Indoor	$\Delta kWh = (\frac{15,474.99}{EF_{base}} - \frac{14,197.24}{EF_{proposed}})$
Motel	Kitchen	$\Delta kWh = (\frac{15,474.99}{EF_{base}} - \frac{11,903.84}{EF_{proposed}})$
Small Office	Outdoor	$\Delta kWh = (\frac{3,854.38}{EF_{base}} - \frac{4,817.98}{EF_{proposed}})$
Small Office	Indoor	$\Delta kWh = (\frac{3,854.38}{EF_{base}} - \frac{3,536.13}{EF_{proposed}})$
Small Office	Kitchen	$\Delta kWh = (\frac{3,854.38}{EF_{base}} - \frac{2,964.91}{EF_{proposed}})$
Small Retail	Outdoor	$\Delta kWh = (\frac{1,768.25}{EF_{base}} - \frac{2,210.31}{EF_{proposed}})$
Small Retail	Indoor	$\Delta kWh = (\frac{1,768.25}{EF_{base}} - \frac{1,622.24}{EF_{proposed}})$
Small Retail	Kitchen	$\Delta kWh = (\frac{1,768.25}{EF_{base}} - \frac{1,360.19}{EF_{proposed}})$

Evaluation Protocols

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

Sources

1. 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. 2014 SWE Residential Baseline Study. http://www.puc.pa.gov/Electric/pdf/Act129/SWE-2014_PA_Statewide_Act129_Residential_Baseline_Study.pdf
3. Mid-Atlantic TRM, footnote #24. http://www.neep.org/Assets/uploads/files/emv/emv-products/TRM_March2013Version.pdf
4. The ETDF 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 2008. Commercial Results Review Non-Updated Measures.
6. Engineering Estimate
7. Federal Standards are 0.67 -0.0019 x Rated Storage in Gallons. For a 40-gallon tank this is 0.594. “Energy Conservation Program: Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters” US Dept of Energy Docket Number: EE–2006–BT-STD–0129, p. 30 http://www.gpo.gov/fdsys/pkg/FR-2010-04-16/pdf/2010-7611.pdf

3.4.3 Low Flow Pre-Rinse Sprayers for Retrofit Programs

Measure Name	Low Flow Pre-Rinse Sprayers for Retrofit Programs
Target Sector	Commercial and Industrial Establishments
Measure Unit	Pre Rinse Sprayer
Unit Energy Savings	Groceries: 151 kWh; Food Services: 1,222 kWh
Unit Peak Demand Reduction	Groceries: 0.03kW; Food Services: 0.22 kW
Measure Life	5 years[339]
Measure Vintage	Early Replacement

Eligibility

This protocol documents the energy savings and demand reductions attributed to efficient low flow pre-rinse sprayers in grocery and 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 a 2.25 GPM[340] and 2.15 GPM[341] for food service and grocery applications respectively.

Algorithms

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

$$\Delta kWh \text{ for Food Services} = \frac{\left(\left(F_{bfs} \times U_{bfs}\right) - \left(F_{pfs} \times U_{pfs}\right)\right) \times 365\,\frac{days}{yr} \times 8.3\,\frac{lbs}{gal} \times \left(T_{hfs} - T_c\right)}{EF \times 3412\,\frac{Btu}{kWh}}$$

$$\Delta kWh \text{ for Groceries} = \frac{\left(\left(F_{bg} \times U_{bg}\right) - \left(F_{pg} \times U_{pg}\right)\right) \times 365\,\frac{days}{yr} \times 8.3\,\frac{lbs}{gal} \times \left(T_{hg} - T_c\right)}{EF \times 3412\,\frac{Btu}{kWh}}$$

The demand reduction is taken as the annual energy savings multiplied by the ratio of the average energy usage between 2 PM to 6 PM on summer weekdays to the total annual energy usage.

[339] *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
[340] ibid
[341] ibid

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

The Energy to Demand Factor is defined below:

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

The ratio of the average energy usage between 2 PM to 6 PM on summer weekdays to the total annual energy usage is taken from usage profile data collected for commercial water heaters in CA. The usage profiles are shown in Figure 3-6. 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 3-7, 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 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[342].

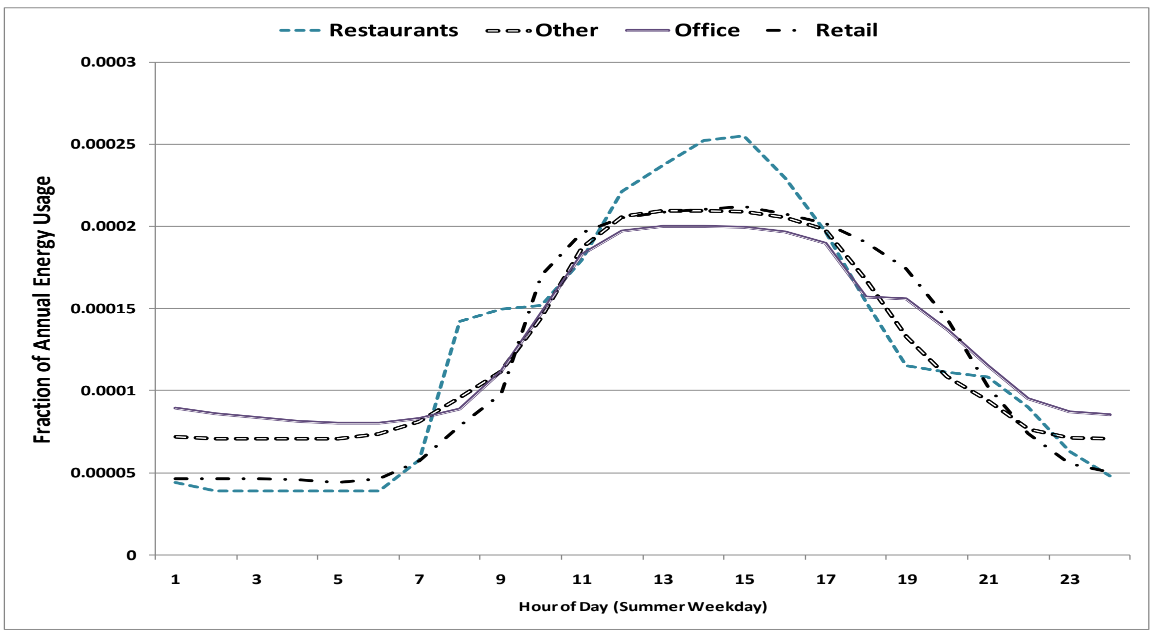

Figure 3-6: Load shapes for hot water in four commercial building types

[342] 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).

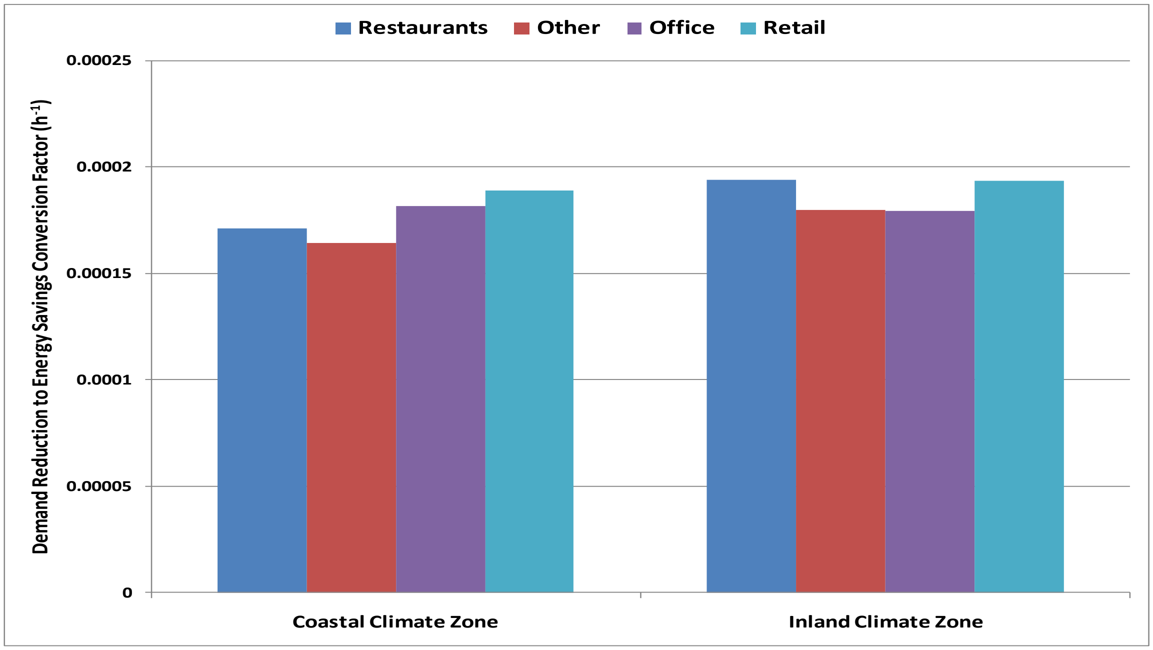

Figure 3-7: Energy to demand factors for four commercial building types.

DEFINITION OF TERMS

The parameters in the above equation are listed in Table 3-77 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.

Table 3-77: Low Flow Pre-Rinse Sprayer Calculations Assumptions

Term	Unit	Values	Source
F_{bfs} , Baseline flow rate of sprayer for food service applications	GPM	2.25	1, 7
F_{pfs}, Post measure flow rate of sprayer for food service applications	GPM	EDC Data Gathering	EDC Data Gathering
		Default: 1.12	1
U_{bfs}, Baseline water usage duration for food service applications	$\frac{min}{day}$	32.4	2
U_{pfs}, Post measure water usage duration for food service applications	$\frac{min}{day}$	43.8	2
F_{bg}, Baseline flow rate of sprayer for grocery applications	GPM	2.15	1, 7
F_{pg}, Post measure flow rate of sprayer for grocery applications	GPM	EDC Data Gathering	EDC Data Gathering
		Default: 1.12	1
U_{bg}, Baseline water usage duration for grocery applications	$\frac{min}{day}$	4.8	2
U_{pg}, Post measure water usage duration for grocery applications	$\frac{min}{day}$	6	2
T_{hfs}, Temperature of hot water coming from the spray nozzle for food service application	°F	107	3
T_c, Incoming cold water temperature for grocery and food service application	°F	55	6
T_{hg}, Temperature of hot water coming from the spray nozzle for grocery application	°F	97.6	3
$EF_{electric}$, Energy factor of existing electric water heater system	None	EDC Data Gathering	EDC Data Gathering
		0.904	4
ETDF, Energy to demand factor	None	0.000178	5
Days per year pre-rinse spray valve is used at the site	Days	365[343]	1
Specific mass in pounds of one gallon of water	$\frac{lb}{gal}$	8.3	8

[343] Days per year pre-rinse spray valve is used at the site is assumed to be 365days/yr.

3,412	$\frac{Btu}{kWh}$	3,412	Conversion Factor

Default Savings

The default savings for the installation of a low flow pre-rinse sprayer compared to a standard efficiency sprayer is 184 kWh/year for pre-rinse sprayers installed in grocery stores and 1,218 kWh/year for pre-rinse sprayers installed in food service 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 0.22 kW for pre-rinse sprayers installed in food service building types such as restaurants.

Evaluation Protocol

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

Sources

1. *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. http://www.allianceforwaterefficiency.org/WorkArea/DownloadAsset.aspx?id=976
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. http://www.allianceforwaterefficiency.org/WorkArea/DownloadAsset.aspx?id=976
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. http://www.allianceforwaterefficiency.org/WorkArea/DownloadAsset.aspx?id=976
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 http://www.gpo.gov/fdsys/pkg/FR-2010-04-16/pdf/2010-7611.pdf
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.

   http://www.neep.org/Assets/uploads/files/emv/emv-products/TRM_March2013Version.pdf
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.

8. The Engineering ToolBox. “Water-Thermal Properties.” http://www.engineeringtoolbox.com/water-thermal-properties-d_162.html

3.4.4 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 and Industrial Establishments
Measure Unit	Pre Rinse Sprayer
Unit Energy Savings	See Table 3-79
Unit Peak Demand Reduction	See Table 3-79
Measure Life	5 years[344]
Measure Vintage	Replace on Burnout

Eligibility

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 cafeterias. 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[345].

Algorithms

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

$$\Delta kWh = \frac{(F_b - F_p) \times U \times 60\frac{mins}{hour} \times 365\frac{days}{yr} \times 8.3\frac{lbs}{gal} \times 1\frac{Btu}{lb \cdot °F} \times (T_h - T_c)}{EF \times 3412\frac{Btu}{kWh}}$$

The demand reduction is taken as the annual energy savings multiplied by the ratio of the average energy usage between noon and 8PM on summer weekdays to the total annual energy usage.

344 *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

345 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.

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

The ETDF is defined below:

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

The ratio of the average energy usage between 2 PM to 6 PM on summer weekdays to the total annual energy usage is taken from usage profile data collected for commercial water heaters in CA. The usage profiles are shown in Figure 3-8. 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 Table 3-79 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 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.[346]

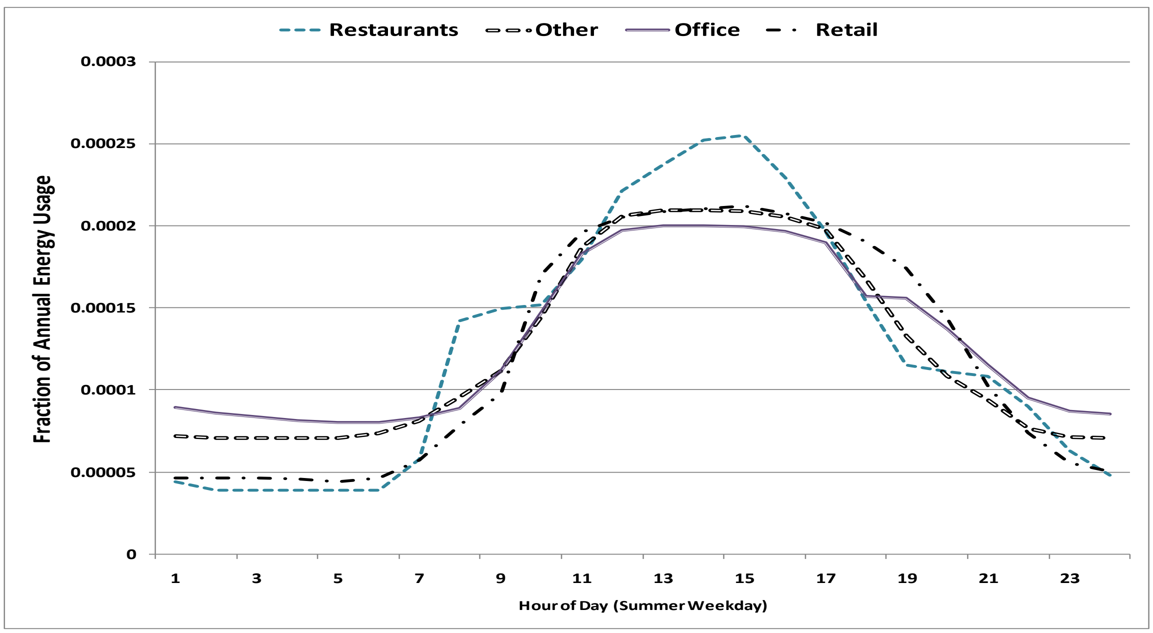

Figure 3-8: Load shapes for hot water in four commercial building types

346 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).

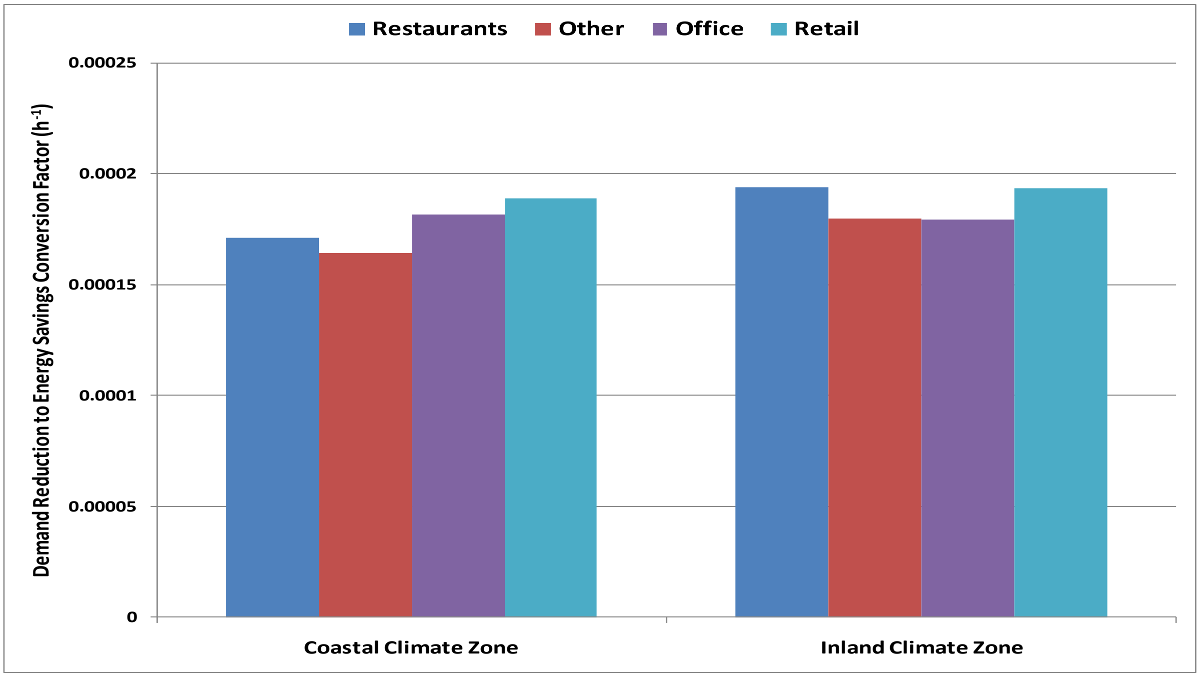

Figure 3-9: Energy to demand factors for four commercial building types.

Definition of Terms

Table 3-78: Low Flow Pre-Rinse Sprayer Calculations Assumptions

Term	Unit	Values	Source
F_b , Baseline flow rate of sprayer	*GPM*	Default: Time of Sale/Retail: 1.52 GPM	1, 2
F_p , Post measure flow rate of sprayer	*GPM*	EDC Data Gathering	EDC Data Gathering
		Default: Time of Sale/Retail: 1.06 GPM	3
U, Baseline and post measure water usage duration based on application	$\frac{Hours}{day}$	Default: Small, quick- service restaurants: 0.5 Medium-sized casual dining restaurants: 1.5 Large institutional establishments with cafeteria: 3	4
T_h, Temperature of hot water coming from the spray nozzle	*°F*	125.6	1
T_c, Incoming cold water temperature	*°F*	55	5
$EF_{electric}$, Energy factor of existing electric water heater system	*None*	EDC Data Gathering	EDC Data Gathering
		Default: 0.904	6
ETDF, EnergyToDemandFactor	*None*	0.000178	7
Specific mass in pounds of one gallon of water	$\frac{lb}{gal}$	8.3	8
Specific heat of water	$\frac{Btu}{lb \cdot °F}$	1.0	8
Days per year pre-rinse spray valve is used at the site	*Days*	365[347]	1
Minutes per hour pre-rinse spray valve	$\frac{Minutes}{Hour}$	60	Conversion Factor
3,412	$\frac{Btu}{kWh}$	3,412	Conversion Factor

DEFAULT SAVINGS

347 Days per year pre-rinse spray valve is used at the site is assumed to be 365days/yr.

The default savings for the installation of a low flow pre-rinse sprayer compared to a standard efficiency sprayer for retail programs are listed in Table 3-79 below.

Table 3-79: Low Flow Pre-Rinse Sprayer Default Savings

Application	Retail	
	kWh	kW
Small quick service restaurants	957	0.170
Medium-sized casual dining restaurants	2,871	0.511
Large institutional establishments with cafeteria	5,741	1.022

Evaluation Protocol

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

Sources

1. 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). http://www.allianceforwaterefficiency.org/WorkArea/DownloadAsset.aspx?id=976
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. http://www.fishnick.com/equipment/sprayvalves/
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. Mid-Atlantic TRM, footnote #24. http://www.neep.org/Assets/uploads/files/emv/emv-products/TRM_March2013Version.pdf
6. Federal Standards are 0.97 -0.00132 x Rated Storage in Gallons. For a 50-gallon tank this is approximately 0.90. “Energy Conservation Program: Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters” US Dept. of Energy Docket Number: EE–2006–BT-STD–0129, p. 30 http://www.gpo.gov/fdsys/pkg/FR-2010-04-16/pdf/2010-7611.pdf
7. The ETDF 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
8. The Engineering ToolBox. “Water-Thermal Properties.” http://www.engineeringtoolbox.com/water-thermal-properties-d_162.html

3.4.5 Fuel Switching: Electric Resistance Water Heaters to Gas / Oil / Propane

Measure Name	Fuel Switching: Electric Resistance Water Heaters to Gas/Oil/Propane
Target Sector	Commercial and Industrial Establishments
Measure Unit	Gas, Oil or Propane Heater
Unit Energy Savings	Variable
Unit Peak Demand Reduction	Variable
Measure Life	13 years[348] for natural gas or propane 8 years[349] for oil
Measure Description	Replace on Burnout

Eligibility

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 ENERGY STAR gas and propane-fired water heaters have energy factors of 0.67 for a 50 gal unit and 0.495 for an oil-fired 50 gal unit. This protocol does not apply for units >55 gal.

This protocol documents the energy savings attributed to converting from a standard electric water heater to an ENERGY STAR natural gas/propane-fired water heater with Energy Factor of ≥0.67 and ≥0.495 for a standard oil-fired water heater. The target sector primarily consists of motels, small offices, 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.

Algorithms

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:

[348] From ENERGY STAR: http://www.energystar.gov/index.cfm?c=gas_storage.pr_savings_benefits
[349] http://www.aceee.org/consumer/water-heating

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

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:

$$Fuel\ Consumption\ (MMBtu) = \frac{\left\{\left(\frac{1}{EF_{fuel,inst}} \times \frac{1}{DF_{fuel,adjust}}\right) \times \left(HW \times 1\frac{Btu}{lb \cdot {}^{\circ}F} \times 8.3\frac{lb}{gal} \times (T_{hot} - T_{cold})\right)\right\}}{1{,}000{,}000\ \frac{Btu}{MMBtu}}$$

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

$$\Delta kW_{peak} = ETDF \times Energy\ Savings \times RDF$$

The Energy to Demand Factor is defined below:

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

Loads

The annual loads are taken from the DEER database[350]. 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 3-80 below, assuming a 40 gal natural gas water heater with a standard efficiency of 0.594.

$$HW\ (Gallons) = \frac{Load\ \times EF_{ng,base} \times 1000\frac{Btu}{kBtu} \times Typical\ SF}{1\frac{Btu}{lb \cdot {}^{\circ}F} \times 8.3\frac{lb}{gal} \times (T_{hot} - T_{cold}) \times 1000\ SF}$$

350 DEER 2008. Commercial Results Review Non-Updated Measures.

Table 3-80: Typical Water Heating Loads

Building Type	Typical Square Footage	Average Annual Load in $\frac{kBtu}{1000ft^2}$	Average Annual Use, Gallons
Motel	30,000	2,963	99,399
Small Office	10,000	2,214	24,757
Small Retail	7,000	1,451	11,358

Energy to Demand Factor

The ratio of the average energy usage between 2 PM to 6 PM on summer weekdays to the total annual energy usage is taken from usage profile data collected for commercial water heaters in CA[351]. The usage profiles are shown in Figure 3-10. 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 3-11, 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 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[352].

Figure 3-10: Load shapes for hot water in four commercial building types

351 ibid

352 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).

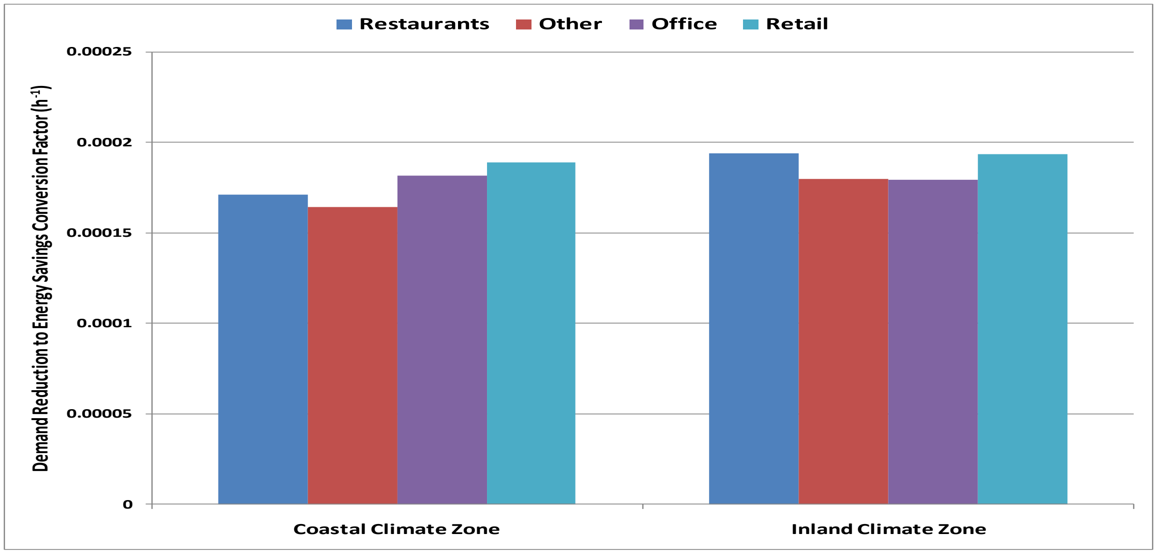

Figure 3-11: Energy to demand factors for four commercial building types

Definition of Terms

The parameters in the above equation are listed in Table 3-81.

Table 3-81: Commercial Water Heater Fuel Switch Calculation Assumptions

Term	Unit	Values	Source
EF_{base}, Energy Factor of baseline water heater	*None*	Default: 0.904	1
		Nameplate	EDC Data Gathering
EF_{fuel}[353], Energy Factor of installed fossil fuel water heater*	*None*	>=0.67 for Natural Gas and Propane >=0.495 for Oil	5, EDC Data Gathering
$EF_{tankless\ water\ heater}$, Energy Factor of installed tankless water heater	*None*	>=0.82	5
$DF_{fuel,adjust}$, Fossil fuel water heaters derating adjustment factor	*None*	Storage Water Heaters: 1.0 Tankless Water Heaters: 0.91	7
$Load$, Average annual load	*kBtu*	Varies	DEER Database
T_{hot}, Temperature of hot water	*°F*	119	2
T_{cold}, Temperature of cold water supply	*°F*	55	3
HW, Average annual gallons of use	*Gallons*	Default: See Table 3-80	Calculation
		EDC Data Gathering	EDC Data Gathering
ETDF, Energy To Demand Factor	*None*	0.000178	4
[354]$EF_{NG,base}$, Energy Factor of baseline gas water heater	*None*	0.594	5
RDF, Resistive Discount Factor	*None*	1.0	6

Energy Factors based on Tank Size

Federal Standards for Energy Factors are equal to $0.97 - 0.00132 \times Rated\ Storage\ (gallons)$. The following table shows the Energy Factors for various tank sizes.

353 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.

354 The protocol assumes a 40 gal natural gas water heater with a standard efficiency of 0.594 to calculate the loads summarized in Table 3-80Table 3-80: Typical Water Heating Loads.

Table 3-82: 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

DEFAULT SAVINGS

The default savings for the replacement of 50 gal electric water heater with a 50 gal fossil fuel units in various applications are listed below.

Table 3-83: Water Heating Fuel Switch Energy Savings Algorithms

Building Type	∆kWh	Fuel Consumption (MMBtu)
Motel	$\frac{15,474.99}{EF_{elec,bl}}$	$\frac{52.80}{EF_{fuel,inst}} \times \frac{1}{DF_{fuel,adjust}}$
Small Office	$\frac{3,854.38}{EF_{elec,bl}}$	$\frac{13.15}{EF_{fuel,inst}} \times \frac{1}{DF_{fuel,adjust}}$
Small Retail	$\frac{1,768.25}{EF_{elec,bl}}$	$\frac{6.03}{EF_{fuel,inst}} \times \frac{1}{DF_{fuel,adjust}}$

EVALUATION PROTOCOLS

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

SOURCES

1. 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. http://www.gpo.gov/fdsys/pkg/FR-2010-04-16/pdf/2010-7611.pdf
2. 2014 SWE Residential Baseline Study. http://www.puc.pa.gov/Electric/pdf/Act129/SWE-2014_PA_Statewide_Act129_Residential_Baseline_Study.pdf
3. Mid-Atlantic TRM, footnote #24. http://www.neep.org/Assets/uploads/files/emv/emv-products/TRM_March2013Version.pdf

4. The ETDF 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. Commission Order[355] requires fuel switching to ENERGY STAR measures, not standard efficiency measures. The Energy Factor has therefore been updated to reflect the Energy Star 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 0.59 – 0.0019 x Rated Storage in Gallons for oil. For a 50-gallon tank this is 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. No discount factor is needed because the baseline is already an electric resistance water heater system.
7. 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. http://eetd.lbl.gov/sites/all/files/water_heaters_and_hot_water_distribution_systems.pdf

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

3.4.6 Fuel Switching: Heat Pump Water Heaters to Gas / Oil / Propane

Measure Name	Heat Pump Water Heaters
Target Sector	Commercial and Industrial Establishments
Measure Unit	Gas, Oil, or Propane Heater
Unit Energy Savings	Variable
Unit Peak Demand Reduction	Variable
Measure Life	13 years[356] for natural gas/propane 8 years[357] for oil
Measure Vintage	Replace on Burnout

Eligibility

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 an ENERGY STAR gas and propane water heater have an energy factor of 0.67 for a 50 gal unit and 0.495 for an oil-fired 50 gal unit. This protocol does not apply for units >55 gal.

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.

Algorithms

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:

$$\Delta kWh = \frac{\left\{\left(\left(\frac{1}{EF_{base}} \times \frac{1}{F_{adjust}}\right)\right) \times HW \times 8.3\,\frac{lb}{gal} \times 1.0\,\frac{Btu}{lb \cdot °F} \times (T_{hot} - T_{cold})\right\}}{3412\,\frac{Btu}{kWh}}$$

356 From ENERGY STAR: http://www.energystar.gov/index.cfm?c=gas_storage.pr_savings_benefits

357 http://www.aceee.org/consumer/water-heating

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:

$$\text{Fuel Consumption (MMBtu)} = \frac{\left\{\left(\frac{1}{EF_{fuel,inst}} \times \frac{1}{DF_{fuel,adjust}}\right) \times \left(HW \times 1.0\,\frac{Btu}{lb \cdot {}^{\circ}F} \times 8.3\,\frac{lb}{gal} \times (T_{hot} - T_{cold})\right)\right\}}{1{,}000{,}000\,\frac{Btu}{MMBtu}}$$

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

$$\Delta kW_{peak} = ETDF \times Energy\ Savings \times RDF$$

The ETDF is defined below:

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

Loads

The annual loads are taken from the DEER database[358]. 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 3-84, assuming a 40 gal natural gas water heater with a standard efficiency of 0.594.

$$\text{HW (Gallons)} = \frac{Load \times EF_{ng,base} \times 1{,}000\,\frac{Btu}{kBtu} \times Typical\ SF}{1\,\frac{Btu}{lb \cdot {}^{\circ}F} \times 8.3\,\frac{lb}{gal} \times (T_{hot} - T_{cold}) \times 1{,}000\ SF}$$

Table 3-84: Typical Water Heating Loads

Building Type	Typical Square Footage	Average Annual Load In $\frac{kBTU}{1000\ ft^2}$	Average Annual Use, Gallons
Motel	30,000	2,963	99,399
Small Office	10,000	2,214	24,757
Small Retail	7,000	1,451	11,358

358 DEER 2008. Commercial Building Results Review of Non-Updated Measures.

Energy to Demand Factor (ETDF)

The ratio of the average energy usage between 2 PM to 6 PM on summer weekdays to the total annual energy usage is taken from usage profile data collected for commercial water heaters in CA[359]. The usage profiles are shown in Figure 3-12. 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 3-13, 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 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.[360]

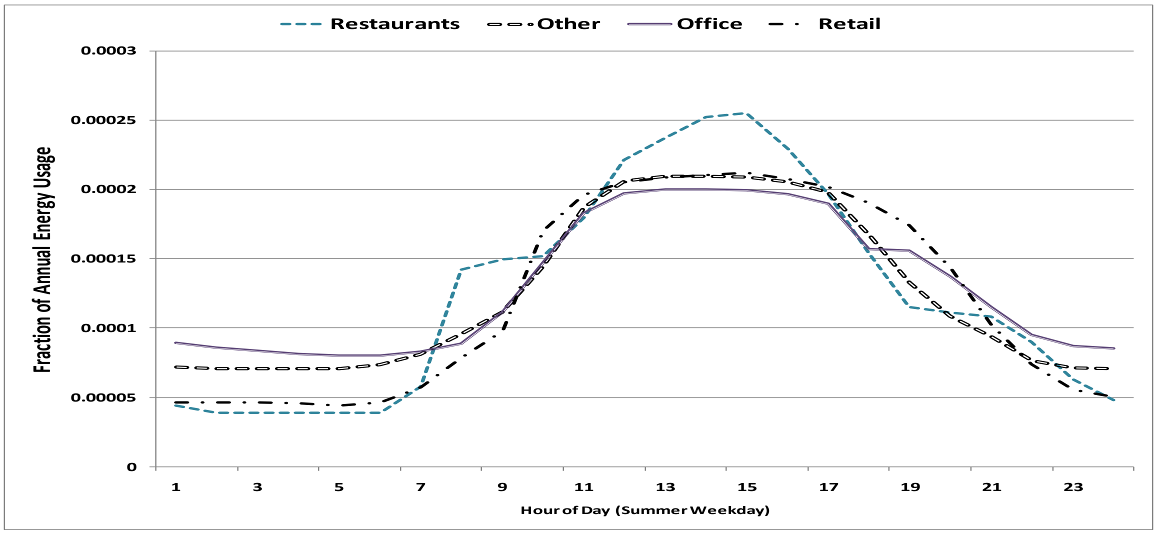

Figure 3-12: Load shapes for hot water in four commercial building types

[359] Ibid

[360] 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).

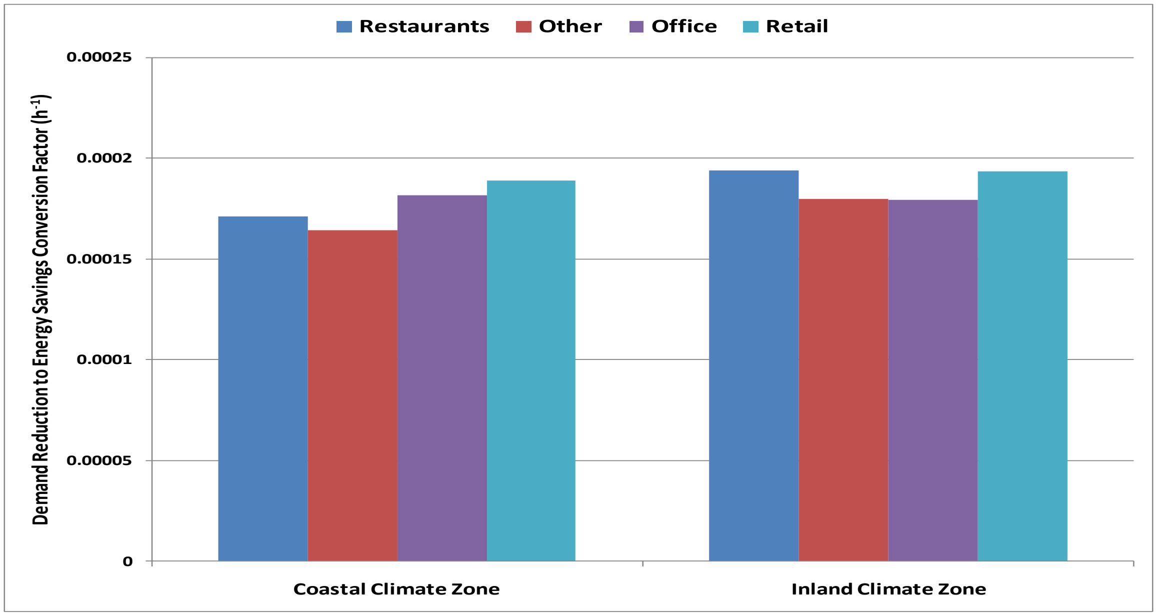

Figure 3-13: Energy to demand factors for four commercial building types

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 119 °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[361], while the average wetbulb temperature in conditioned typically ranges from 50 °F to 80 °F. The heat pump performance is temperature dependent. Figure 3-14 below shows relative coefficient of

[361] 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[362]. According to the plotted profile, the following adjustments are recommended.

Table 3-85: 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

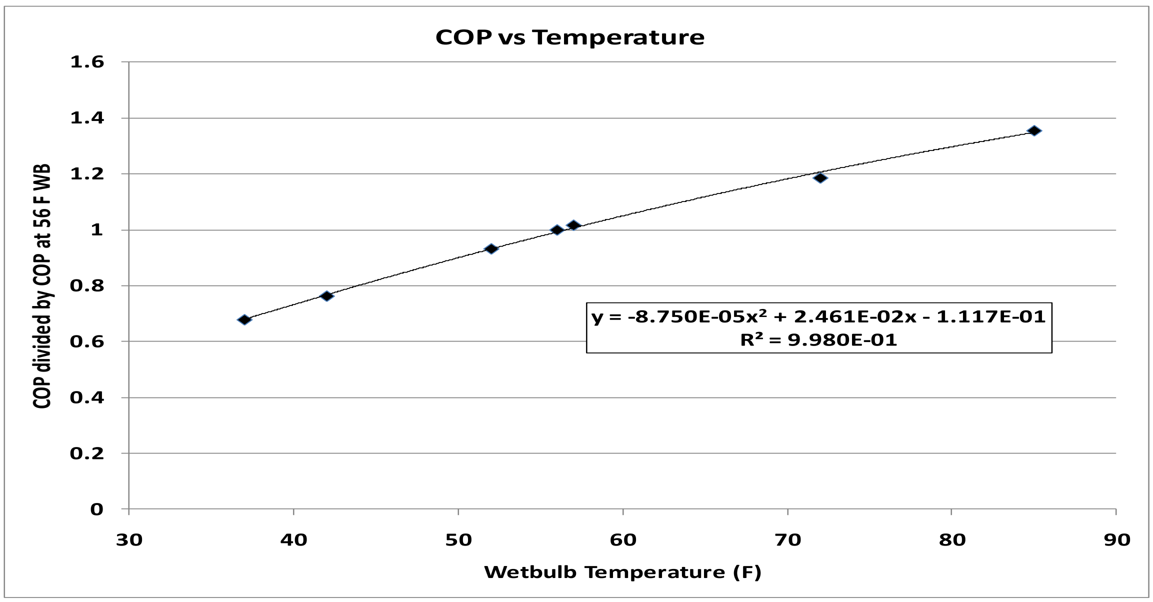

Figure 3-14: Dependence of COP on outdoor wetbulb temperature.

Definition of Terms

The parameters in the above equation are listed in Table 3-86.

[362] 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 3-86: Heat Pump Water Heater Fuel Switch Calculation Assumptions

Term	Unit	Values	Source
EF_{base}, Energy Factor of baseline water heater	*None*	Default: >= 2	1
		Nameplate	EDC Data Gathering
EF_{fuel}[363], Energy Factor of installed fossil fuel water heater*	*None*	>=0.67 for Natural Gas and Propane >=0.495 for Oil	7, EDC Data Gathering
$EF_{tankless\ water\ heater}$, Energy Factor of installed tankless water heater	*None*	>=0.82	7
$DF_{fuel,adjust}$, Fossil Fuel Water Heaters Derating Adjustment factor	*None*	Storage Water Heaters: 1.0 Tankless Water Heaters: 0.91	8
Load, Average annual load	*kBtu*	Varies	5
T_{hot}, Temperature of hot water	*°F*	119	2
T_{cold}, Temperature of cold water supply	*°F*	55	3
ETDF, Energy To Demand Factor	*None*	0.000178	4
F_{adjust},COP Adjustment factor	*None*	0.80 if outdoor 1.09 if indoor 1.30 if in kitchen	4
HW, Average annual gallons of use	*Gallons*	Default: See Table 3-84	Calculation
		EDC Data Gathering	EDC Data Gathering
RDF, Resistive Discount Factor	*None*	0.90	6
[364]$EF_{NG,base}$, Energy Factor of baseline gas water heater, see 3.4.2	*None*	0.594	7

Energy Factors based on Tank Size

Federal Standards for Energy Factors are equal to $0.97 - 0.00132 \times Rated\ Storage\ (gallons)$. The following table shows the Energy Factors for various tank sizes.

[363] 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.

[364] The protocol assumes a 40 gal natural gas water heater with a standard efficiency of 0.594 to calculate the loads summarized in Table 3-72: Typical water heating loads.

Table 3-87: Minimum Baseline Energy Factors based on Tank Size

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

Default Savings

The default savings for the replacement of heat pump electric water heaters with fossil fuel units in various applications are listed below.

Table 3-88: Energy Savings Algorithms

Building Type	Location Installed	ΔkWh	Fuel Consumption (MMBtu)
Motel	Outdoor	$\frac{19{,}343.74}{EF_{base}}$	$\frac{56.10}{EF_{fuel,inst}} \times \frac{1}{DF_{fuel,adjust}}$
Motel	Indoor	$\frac{14{,}197.24}{EF_{base}}$	
Motel	Kitchen	$\frac{11{,}903.84}{EF_{base}}$	
Small Office	Outdoor	$\frac{4{,}817.98}{EF_{base}}$	$\frac{13.97}{EF_{fuel,inst}} \times \frac{1}{DF_{fuel,adjust}}$
Small Office	Indoor	$\frac{3{,}536.13}{EF_{base}}$	
Small Office	Kitchen	$\frac{2{,}964.91}{EF_{base}}$	
Small Retail	Outdoor	$\frac{2{,}210.31}{EF_{base}}$	$\frac{6.41}{EF_{fuel,inst}} \times \frac{1}{DF_{fuel,adjust}}$
Small Retail	Indoor	$\frac{1{,}622.24}{EF_{base}}$	
Small Retail	Kitchen	$\frac{1{,}360.19}{EF_{base}}$	

Evaluation Protocols

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

Sources

1. 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, p. 34. http://www.gpo.gov/fdsys/pkg/FR-2010-04-16/pdf/2010-7611.pdf
2. 2014 SWE Residential Baseline Study http://www.puc.pa.gov/Electric/pdf/Act129/SWE-2014_PA_Statewide_Act129_Residential_Baseline_Study.pdf
3. Mid-Atlantic TRM Version 3.0, March 2013, footnote #314. http://www.neep.org/Assets/uploads/files/emv/emv-products/TRM_March2013Version.pdf
4. The ETDF 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 2008. Commercial Results Review Non-Updated Measures.
6. Engineering Estimate.
7. Commission Order[365] requires fuel switching to ENERGY STAR measures, not standard efficiency measures. The Energy Factor has therefore been updated to reflect the ENERGY STAR 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 0.59 – 0.0019 x Rated Storage in Gallons for oil. For a 50-gallon tank this is 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. 33.
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. http://eetd.lbl.gov/sites/all/files/water_heaters_and_hot_water_distribution_systems.pdf

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

3.5 REFRIGERATION

3.5.1 HIGH-EFFICIENCY REFRIGERATION/FREEZER CASES

Measure Name	High-Efficiency Refrigeration/Freezer Cases
Target Sector	Commercial and Industrial Establishments
Measure Unit	Refrigeration/Freezer Case
Unit Energy Savings	Variable
Unit Peak Demand Reduction	Variable
Measure Life	12 years[366]
Measure Vintage	Replace on Burnout

ELIGIBILITY

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

ALGORITHMS

Products that can be ENERGY STAR 2.0 Qualified
Examples of product types that may be eligible for qualification include: reach-in, roll-in, or pass-through units; merchandisers; under counter units; milk coolers; back bar coolers; bottle coolers; glass frosters; deep well units; beer-dispensing or direct draw units; and bunker freezers.

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

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

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.

366 DEER Effective Useful Life. October 10, 2008.

Definition of Terms

Table 3-89: Refrigeration Cases - References

Term	Unit	Values	Source
kWh_{base}, The unit energy consumption of a standard unit	$\frac{kWh}{day}$	See Table 3-90 and Table 3-91	1
kWh_{ee}, The unit energy consumption of the ENERGY STAR-qualified unit	$\frac{kWh}{day}$	See Table 3-90 and Table 3-91	2
V, Internal Volume	ft^3	EDC data gathering	EDC data gathering
$\frac{days}{year}$, days per year	$\frac{days}{year}$	365	Conversion Factor
CF, Demand Coincidence Factor	Decimal	0.772	3

Table 3-90: Refrigeration Case Efficiencies

Volume (ft^3)	Glass Door		Solid Door	
	$\frac{kWh_{ee}}{day}$	$\frac{kWh_{base}}{day}$	$\frac{kWh_{ee}}{day}$	$\frac{kWh_{base}}{day}$
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 3-91: Freezer Case Efficiencies

Volume (ft^3)	Glass Door		Solid Door	
	$\frac{kWh_{ee}}{day}$	$\frac{kWh_{base}}{day}$	$\frac{kWh_{ee}}{day}$	$\frac{kWh_{base}}{day}$
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	

Default Savings

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

Table 3-92: 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	0.0636	0.0236
15 ≤ V < 30	683	424	0.0602	0.0374
30 ≤ V < 50	763	838	0.0672	0.0739
50 ≤ V	927	1,205	0.0817	0.1062

Table 3-93: Freezer Case Savings

Volume (ft3)	Annual Energy Savings (kWh)		Demand Impacts (kW)	
	Glass Door	Solid Door	Glass Door	Solid Door
V < 15	1,901	814	0.1675	0.0717
15 ≤ V < 30	1,992	869	0.1756	0.0766
30 ≤ V < 50	4,417	1,988	0.3893	0.1752
50 ≤ V	6,680	3,405	0.5887	0.3001

Evaluation Protocols

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

Sources

1. Energy Conservation Program: Energy Conservation Standards for Commercial Refrigerators, Freezers, and Refrigerator-Freezers. Pg. 538 http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec431-66.pdf
2. ENERGY STAR Program Requirements for Commercial Refrigerators and Freezers. Version 2.1 http://www.energystar.gov/sites/default/files/specs//private/Commercial_Refrigerator_and_Freezer_Program_Requirements%20v2_1.pdf
3. 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 Update New

York.
http://issuu.com/neepenergy/docs/trm_march2013version/286?e=12509042/8424791

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

Measure Name	High-Efficiency Evaporator Fan Motors for Reach-In Refrigerated Cases
Target Sector	Commercial and Industrial Establishments
Measure Unit	Evaporator Fan Motor
Unit Energy Savings	Variable
Unit Peak Demand Reduction	Variable
Measure Life	15 years[367]
Measure Vintage	Early Replacement

Eligibility

This protocol covers energy and demand savings associated with the replacement of existing shaded-pole evaporator fan motors or Permanent Split Capacitor (PSC) motors in reach-in refrigerated display cases with an Electronically Commutated (ECM). This measure is not applicable for new construction or replace on burnout projects. 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:

1. The direct savings associated with replacement of an inefficient motor with a more efficient one;
2. The indirect savings of a reduced cooling load on the refrigeration unit due to less heat gain from the more efficient evaporator fan motor in the air-stream.

Algorithms

Cooler

$$\Delta kW_{peak\ per\ unit} = \frac{W_{base} - W_{ee}}{1{,}000} \times LF \times DC_{evapcool} \times \left(1 + \frac{1}{DG \times COP_{cooler}}\right)$$

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

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

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

[367] DEER Effective Useful Life. October 10, 2008.

Freezer

$$\Delta kW_{peak\ per\ unit} = \frac{W_{base} - W_{ee}}{1{,}000} \times LF \times DC_{evapfreeze} \times \left(1 + \frac{1}{DG \times COP_{freezer}}\right)$$

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

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

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

Default (case service temperature not known)

$$\Delta kW_{peak\ per\ unit} = \frac{(1 - PctCooler) \times kW_{freezer}}{motor} + \frac{PctCooler \times kW_{cooler}}{motor}$$

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

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

$$\Delta kWh = \frac{N \times kWh_{default}}{motor}$$

Definition of Terms

Table 3-94: Variables for High-Efficiency Evaporator Fan Motor[368]

Term	Unit	Values	Source
N, Number of motors replaced	*None*	EDC Data Gathering	EDC Data Gathering
W_{base}, Input wattage of existing/baseline evaporator fan motor	*W*	Nameplate Input Wattage	EDC Data Gathering
		Default values from Table 3-95	Table 3-95
W_{ee}, Input wattage of new energy efficient evaporator fan motor	*W*	Nameplate Input Wattage	EDC Data Gathering
		Default values from Table 3-95	Table 3-95
LF, Load factor of evaporator fan motor	*None*	0.9	1
$DC_{evapcool}$, Duty cycle of evaporator fan motor for cooler	*None*	100%	2
$DC_{evapfreeze}$, Duty cycle of evaporator fan motor for freezer	*None*	94.4%	2
DG, Degradation factor of compressor COP	*None*	0.98	3
COP_{cooler}, Coefficient of performance of compressor in the cooler	*None*	2.5	1
$COP_{freezer}$, Coefficient of performance of compressor in the freezer	*None*	1.3	1
$PctCooler$, Percentage of coolers in stores vs. total of freezers and coolers	*None*	68%	3
$8{,}760$, Hours per year	$\frac{Hours}{Year}$	8,760	Conversion Factor

[368] PSC of Wisconsin, Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0, p. 4-103 to 4-106. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

Table 3-95: Variables for HE Evaporator Fan Motor

Motor Category	Weighting Percentage (population)	Motor Output Watts	SP Efficiency	SP Input Watts	PSC Efficiency	PSC Input Watts	ECM Efficiency	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

Default Savings

Table 3-96: 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 3-97: Shaded Pole to ECM Deemed Savings

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

Table 3-98: 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	0.0129	113	0.0154	135	0.0137	120
Shaded Pole to ECM	0.0509	446	0.0609	534	0.0541	474

Evaluation Protocols

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

Sources

1. "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.

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

Measure Name	High-Efficiency Evaporator Fan Motors for Walk-in Refrigerated Cases
Target Sector	Commercial and Industrial Establishments
Measure Unit	Fan Motor
Unit Energy Savings	Variable
Unit Peak Demand Reduction	Variable
Measure Life	15 years[369]
Measure Vintage	Early Replacement

Eligibility

This protocol covers energy and demand savings associated with the replacement 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:

1. The direct savings associated with replacement of an inefficient motor with a more efficient one;
2. The indirect savings of a reduced cooling load on the refrigeration unit due to less heat gain from the more efficient evaporator fan motor in the air-stream.

Algorithms

Cooler

$$\Delta kW_{peak\ per\ unit} = \frac{(W_{base} - W_{ee})}{1{,}000} \times LF \times DC_{evapcool} \times \left[1 + \left(\frac{1}{DG \times COP_{cooler}}\right)\right]$$

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

$$\Delta kWh_{peak} = N \times \Delta kW_{peak\ per\ unit}$$

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

[369] Appliance Magazine. "*Evaporator Fan Motor Energy Monitoring.*" http://www.appliancemagazine.com/editorial.php?article=1570

Freezer

$$\Delta kW_{peak\ per\ unit} = \frac{(W_{base} - W_{ee})}{1{,}000} \times LF \times DC_{evapfreeze} \times \left[1 + \left(\frac{1}{DG \times COP_{freezer}}\right)\right]$$

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

$$\Delta kWh_{peak} = N \times \Delta kW_{peak\ per\ unit}$$

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

Default (case service temperature not known)

$$\Delta kW_{peak\ per\ unit} = \frac{(1 - PctCooler) \times kW_{freezer}}{motor} + \frac{PctCooler \times kW_{cooler}}{motor}$$

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

$$\Delta kWh_{peak} = N \times \Delta kW_{peak\ per\ unit}$$

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

Definition of Terms

Table 3-99: Variables for High-Efficiency Evaporator Fan Motor

Term	Unit	Values	Source
N, Number of motors replaced	*None*	EDC Data Gathering	EDC Data Gathering
W_{base}, Input wattage of existing/baseline evaporator fan motor	*W*	Nameplate Input Wattage	EDC Data Gathering
		Default Table 3-100	Table 3-100
W_{ee}, Input wattage of new energy efficient evaporator fan motor	*W*	Nameplate Input Wattage	EDC Data Gathering
		Default Table 3-100	Table 3-100
LF, Load factor of evaporator fan motor	*None*	0.9	1
$DC_{evapcool}$, Duty cycle of evaporator fan motor for cooler	*None*	100%	2
$DC_{evapfreeze}$, Duty cycle of evaporator fan motor for freezer	*None*	94.4%	2
DG, Degradation factor of compressor COP	*None*	0.98	3
COP_{cooler}, Coefficient of performance of compressor in the cooler	*None*	2.5	1
$COP_{freezer}$, Coefficient of performance of compressor in the freezer	*None*	1.3	1
PctCooler, Percentage of walk-in coolers in stores vs. total of freezers and coolers	*None*	69%	3
Hr, Operating hours per year	$\frac{Hours}{Year}$	8,273	2

Table 3-100: Variables for HE Evaporator Fan Motor

Motor Category	Weighting Number (population)	Motor Output Watts	SP Efficiency[370,371]	SP Input Watts	PSC Efficiency[372]	PSC Input Watts	ECM Efficiency	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

Default Savings

Table 3-101: 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

[370] 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://rtf.nwcouncil.org//measures/measure.asp?id=162 on July 30, 2010

[371] 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://rtf.nwcouncil.org//measures/measure.asp?id=162

[372] AO Smith New Product Notification. I-motor 9 & 16 Watt. Stock Numbers 9207F2 and 9208F2.

Table 3-102: Shaded Pole to ECM Deemed Savings

Measure	W_{base} (Shaded Pole)	W_{ee} (ECM)	LF	DC_{Evap}	DG	COP per case Temp	Demand Impact (kW)	Energy Impact (kWh)
Cooler: Shaded Pole to ECM: 1/40 HP (16-23 Watt)	93	30	0.9	100%	0.98	2.5	0.0798	661
Cooler: Shaded Pole to ECM: 1/20 HP (37 Watt)	142	56	0.9	100%	0.98	2.5	0.1090	902
Cooler: Shaded Pole to ECM: 1/15 HP (49 Watt)	191	75	0.9	100%	0.98	2.5	0.1470	1,216
Freezer: Shaded Pole to ECM: 1/40 HP (16-23 Watt)	93	30	0.9	94.4%	0.98	1.3	0.0955	790
Freezer: Shaded Pole to ECM: 1/20 HP (37 Watt)	142	56	0.9	94.4%	0.98	1.3	0.1304	1,079
Freezer: Shaded Pole to ECM: 1/15 HP (49 Watt)	191	75	0.9	94.4%	0.98	1.3	0.1759	1,455

Table 3-103: 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

Evaluation Protocols

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

Sources

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

https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

2. Efficiency Vermont, Technical Reference Manual 2009-54, 12/08. Hours of operation accounts for defrosting periods where motor is not operating. http://www.greenmountainpower.com/upload/photos/371TRM_User_Manual_No_2013-82-5-protected.pdf

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://rtf.nwcouncil.org/meetings/2009/03/ on September 7, 2010.

3.5.4 Controls: Evaporator Fan Controllers

Measure Name	Controls: Evaporator Fan Controllers
Target Sector	Commercial and Industrial Establishments
Measure Unit	Evaporator Fan Controller
Unit Energy Savings	Variable
Unit Peak Demand Reduction	Variable
Measure Life	10 years[373]
Measure Vintage	Retrofit

This measure is for the installation of evaporator fan controls[374] in medium-temperature walk-in coolers with no pre-existing controls. Evaporator fans run constantly to provide cooling when the compressor is running, and to provide air circulation when the compressor is not running. The equations specified in the Algorithms section are for fans that are turned off and/or cycled. A fan controller saves energy by reducing fan usage, by reducing the refrigeration load resulting from the heat given off by the fan and by reducing compressor energy resulting from the electronic temperature control. This protocol documents the energy savings attributed to evaporator fan controls.

Eligibility

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

Algorithms[375]

$$\Delta kWh = \Delta kWh_{fan} + \Delta kWh_{heat} + \Delta kWh_{control}$$

$$\Delta kWh_{fan} = kW_{fan} \times 8{,}760 \times \%Off$$

$$\Delta kWh_{heat} = \Delta kWh_{fan} \times 0.28 \times Eff_{rs}$$

$$\Delta kW_{control} = \left[kW_{cp} \times Hours_{cp} + kW_{fan} \times 8{,}760 \times (1 - \%Off)\right] \times 5\%$$

$$\Delta kW = \frac{\Delta kWh}{8{,}760}$$

Determine kW_{fan} and kW_{cp} variables using any of the following methods:

1. Calculate using the nameplate horsepower and load factor.

373 Energy & Resource Solutions (2005). Measure Life Study. Prepared for the Massachusetts Joint Utilities; Table 1-1.

374 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).

375 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, 2012.

$$\Delta kW_{fan}\ or\ kW_{cp} = \frac{HP \times LF \times 0.746}{\eta_{motor}}$$

2. Calculate using the nameplate amperage and voltage and a power factor.

$$\Delta kW_{fan}\ or\ kW_{cp} = V \times A \times PF_{motor} \times LF$$

3. Measure the input kW fan using a power meter reading true RMS power.

Definition of Terms

Table 3-104: Evaporator Fan Controller Calculations Assumptions

Term	Unit	Values	Source
ΔkWh_{fan}, Energy savings due to evaporator being shut off	*kWh*	Calculated	Calculated
ΔkWh_{heat}, Heat energy savings due to reduced heat from evaporator fans	*kWh*	Calculated	Calculated
$\Delta kWh_{control}$, Control energy savings due to electronic controls on compressor and evaporator	*kWh*	Calculated	Calculated
kW_{fan}, Power demand of evaporator fan calculated from any of the methods described above	*kW*	Calculated	Calculated
kW_{cp}, Power demand of compressor motor and condenser fan calculated from any of the methods described above	*kW*	Calculated	Calculated
0.28, Conversion from kW to tons	$\frac{kW}{tons}$	0.28	Conversion Factor
5%, Reduced run-time of compressor and evaporator due to electronic controls	*None*	5%	7
0.746, Conversion factor from kW to horsepower	$\frac{kW}{hp}$	0.746	Conversion Factor
PF, Power Factor of the motor	*None*	Fan motor: 0.75 Compressor motor: 0.9	1, 5, 6
%Off, Percent of annual hours that the evaporator is turned off	*None*	46%	2
Eff_{rs}, Efficiency of typical refrigeration system	$\frac{kW}{ton}$	1.6	3
$Hours_{cp}$, Equivalent annual full load hours of	$\frac{Hours}{Year}$	EDC Data Gathering	EDC Data Gathering

compressor operation		4,072	1, 4
HP, Rated horsepower of the motor	*HP*	EDC Data Gathering	EDC Data Gathering
η_{motor}, Efficiency of the motor	*None*	EDC Data Gathering	EDC Data Gathering
LF, Load factor of motor	*None*	0.9	Section 3.5.2
Voltage, Voltage of the motor	*Volts*	EDC Data Gathering	EDC Data Gathering
Amperage, Rated amperage of the motor	*Amperes*	EDC Data Gathering	EDC Data Gathering

Default Savings

There are no default savings for this measure.

Evaluation Protocols

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

Sources

1. 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 for Estimating Savings from Energy Efficiency Measures. October 2012. Pg. 191
4. 2012 Program Year Rhode Island Technical Reference Manual for Estimating Savings from Energy Efficiency Measures
5. ESource Customer Direct to Touchstone Energy for Evaporator Fan Controllers, 2005
6. LBNL 57651 Energy Savings in Refrigerated Walk-in Boxes, 1998 http://gaia.lbl.gov/btech/papers/57651.pdf
7. 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.

3.5.5 Controls: Floating Head Pressure Controls

Measure Name	Controls: Floating Head Pressure Control
Target Sector	Commercial and Industrial Establishments
Measure Unit	Floating Head Pressure Control
Unit Energy Savings	Deemed by location, kWh
Unit Peak Demand Reduction	0 kW
Measure Life	15 years[376]
Measure Vintage	Retrofit

Installers conventionally design a refrigeration system to condense at a set pressure-temperature point, typically 90 ºF. By installing a floating head pressure control[377] (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 70 ºF or less. Either a balanced-port or electronic expansion valve that is sized to meet the load requirement at a 70 ºF 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.

Eligibility

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 ≤ 70 ºF. The use of FHPC would require balanced-port expansion valves, allowing satisfactory refrigerant flow over a range of head pressures. The compressor must be 1 HP or larger.

Algorithms

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:

$$\Delta kWh = HP_{compressor} \times \frac{kWh}{HP}$$

If the refrigeration system is rated in tonnage:

[376] Grocery Floating Head Pressure Controls for Single Compressor Systems, FY2010, V1.3. Accessed from RTF website http://rtf.nwcouncil.org/measures/measure.asp?id=108&decisionid=444 on September 06, 2011.

[377] Also called as flood back control

$$\Delta kWh = \frac{4.715}{COP} \times Tons \times \frac{kWh}{HP}$$

$$\Delta kW_{peak} = 0$$

Definition of Terms

Table 3-105: Floating Head Pressure Controls – Values and References

Term	Unit	Values	Source
$HP_{compressor}$, Rated horsepower (HP) per compressor	*HP*	EDC Data Gathering	EDC Data Gathering
$\frac{kWh}{HP}$, Annual savings per HP	$\frac{kWh}{HP}$	See Table 3-106	1
COP, Coefficient of Performance	*None*	Based on design conditions	EDC Data Gathering
		Default: Condensing Unit; Refrigerator (Medium Temp: 28 °F – 40 °F): 2.55 COP Freezer (Low Temp: -20 °F – 0 °F): 1.32 COP Remote Condenser; Refrigerator (Medium Temp: 28 °F – 40 °F): 2.49 COP Freezer (Low Temp: -20 °F – 0 °F): 1.45 COP	2
$Tons$, Refrigeration tonnage of the system	*Tons*	EDC Data Gathering	EDC Data Gathering
4.715, Conversion factor to convert from tons to HP	*None*	Engineering Estimate	3

Table 3-106: Annual Savings kWh/HP by Location

Climate Zone	Condensing Unit (kWh/HP)			Remote Condenser (kWh/HP)		
	Refrigerator (Medium Temp)	Freezer (Low Temp)	Default[378] (Temp Unknown)	Refrigerator (Medium Temp)	Freezer (Low Temp)	Default[379] (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 3-107: Default Condenser Type Annual Savings kWh/HP by Location

Climate Zone	Unknown Condenser Type Default380 (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

Default Savings

There are no default savings for this measure.

[378] 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."
[379] Ibid.
[380] 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.

Evaluation Protocols

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

Sources

1. 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

3.5.6 Controls: Anti-Sweat Heater Controls

Measure Name	Anti-Sweat Heater Controls
Target Sector	Commercial and Industrial Establishments
Measure Unit	Case door
Unit Energy Savings	Variable
Unit Peak Demand Reduction	Variable
Measure Life	12 years[381]
Measure Vintage	Retrofit

Eligibility

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

Algorithms

Refrigerator/Cooler

$$\Delta kWh_{per\ unit} = \frac{kW_{coolerbase}}{DoorFt} \times (8{,}760 \times CHA_{off}) \times \left(1 + \frac{R_h}{COP_{cool}}\right)$$

$$\Delta kW_{peak\ per\ unit} = \frac{kW_{coolerbase}}{DoorFt} \times CHP_{off} \times \left(1 + \frac{R_h}{COP_{cool}}\right) \times DF$$

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

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

[381] DEER Effective Useful Life. October 10, 2008.

Freezer

$$\Delta kWh_{per\ unit} = \frac{kW_{freezerbase}}{DoorFt} \times (8{,}760 \times FHA_{off}) \times \left(1 + \frac{R_h}{COP_{freeze}}\right)$$

$$\Delta kW_{peak\ per\ unit} = \frac{kW_{freezerbase}}{DoorFt} \times FHP_{off} \times \left(\frac{1 + R_h}{COP_{freeze}}\right) \times DF$$

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

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

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.

$$\Delta kWh_{per\ unit} = (1 - PctCooler) \times \frac{kWh_{freezer}}{DoorFt} + \frac{PctCooler \times kWh_{cooler}}{DoorFt}$$

$$\Delta kW_{peak\ per\ unit} = (1 - PctCooler) \times \frac{kW_{freezer}}{DoorFt} + \frac{PctCooler \times kW_{cooler}}{DoorFt}$$

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

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

DEFINITION OF TERMS

Table 3-108 Anti-Sweat Heater Controls – Values and References

Term	Unit	Values	Source
N, Number of doors or case length in linear feet having ASH controls installed	*None*	# of doors or case length in linear feet	EDC Data Gathering
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	*None*	0.65	1
$Unit$, Refrigeration unit	*Door or ft*	Door = 1 Linear Feet = 2.5	2
8,760, Hours in a year	$\frac{Hours}{year}$	8,760	Conversion Factor
Refrigerator/Cooler			
$kW_{cooler\ base}$, Per door power consumption of cooler case ASHs without controls	*kW*	0.109	1
CHP_{off}, Percent of time cooler case ASH with controls will be off during the peak period	*None*	20%	1
CHA_{off}, Percent of time cooler case ASH with controls will be off annually	*None*	85%	1
DF_{cool}, Demand diversity factor of cooler, accounting for	*None*	1	3

Term	Unit	Values	Source
the fact that not all anti-sweat heaters in all buildings in the population are operating at the same time.			
COP_{cool}, Coefficient of performance of cooler	*None*	2.5	1
Freezer			
$kW_{freezerbase}$, Per door power consumption of freezer case ASHs without controls	*kW*	0.191	1
FHP_{off}, Percent of time freezer case ASH with controls will be off during the peak period	*None*	10%	1
FHA_{off}, Percent of time freezer case ASH with controls will be off annually	*None*	75%	1
DF_{freeze}, Demand diversity factor of freezer, accounting for the fact that not all anti-sweat heaters in all buildings in the population are operating at the same time.	*None*	1	3
COP_{freeze}, Coefficient of performance of freezer	*None*	1.3	1
$PctCooler$, Typical percent of cases that are medium-temperature refrigerator/cooler cases	*None*	68%	4

Default Savings

Table 3-109: 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.

Evaluation Protocols

For most projects, the appropriate evaluation protocol is to verify installation and proper selection of default values. For projects using customer specific data for open variables, the appropriate evaluation protocol is to verify installation and proper application of TRM protocol along with

verification of open variables. The Pennsylvania Phase II Evaluation Framework provides specific guidelines and requirements for evaluation procedures.

Sources

1. State of Wisconsin, Public Service Commission of Wisconsin, Focus on Energy Evaluation, Business Programs Deemed Savings Manual, March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
    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. http://www3.dps.ny.gov/W/PSCWeb.nsf/0/06f2fee55575bd8a852576e4006f9af7/$FILE/TechManualNYRevised10-15-10.pdf
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."

3.5.7 Controls: Evaporator Coil Defrost Control

Measure Name	Controls: Evaporator Coil Defrost Control
Target Sector	Commercial and Industrial Establishments
Measure Unit	Evaporator Coil Defrost Control
Unit Energy Savings	Variable
Unit Peak Demand Reduction	Variable
Measure Life	10 years[382]
Measure Vintage	Retrofit

This protocol applies to electric defrost control on small commercial walk-in cooler and freezer systems. A freezer refrigeration system with electric defrost is set to run the defrost cycle periodically throughout the day. A defrost control uses temperature and pressure sensors to monitor system processes and statistical modeling to learn the operation and requirements of the system. When the system calls for a defrost cycle, the controller determines if it is necessary and skips the cycle if it is not.

Eligibility

This measure is targeted to non-residential customers whose equipment uses electric defrost controls on small commercial walk-in freezer systems.

Acceptable baseline conditions are existing small commercial walk-in coolers or freezers without defrost controls.

Efficient conditions are small commercial walk-in coolers or freezers with defrost controls installed.

Algorithms

$$\Delta kW_{peak} = FANS \times kW_{DE} \times SVG \times BF$$

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

[382] Estimate from Heatcraft based on expected component expected life. The only moving part is a relay which has a cycle life that is well over 15 years based on the frequency of the relay operation.

Definition of Terms

Table 3-110: Evaporator Coil Defrost Control – Values and References

Term	Unit	Values	Source
$FANS$, Number of evaporator fans	*Fan*	EDC Data Gathering	EDC Data Gathering
kW_{DE} , kW of defrost element	*kW*	EDC Data Gathering Default: 0.9	EDC Data Gathering 1
SVG, Savings percentage for reduced defrost cycles	*None*	30%	2
BF , Savings factor for reduced cooling load from eliminating heat generated by the defrost element	*None*	See Table 3-111	3
$HOURS$, Average annual full load defrost hours	$\frac{Hours}{year}$	EDC Data Gathering Default: 487	EDC Data Gathering 4

Table 3-111: Savings Factor for Reduced Cooling Load

Equipment Type	Savings Factor for Reduced Cooling Load (BF)
Cooler	1.3
Freezer	1.67

Default Savings

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

Evaluation Protocols

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

Sources

1. Efficiency Vermont Technical Reference Manual, 2013. The total Defrost Element kW is proportional to the number of evaporator fans blowing over the coil. The typical wattage of the defrost element is 900W per fan. See Bohn <Bohn Evap 306-0D.pdf> and Larkin <LC-03A.pdf>specifications.
2. Smart defrost kits claim 30-40% savings (with 43.6% savings by third party testing by Intertek Testing Service). MasterBilt Demand defrost claims 21% savings for northeast.

Smart Defrost Kits are more common so the assumption of 30% is a conservative estimate.

3. ASHRAE Handbook 2006 Refrigeration, Section 46.15 Figure 24.
4. Efficiency Vermont Technical Reference Manual, 2013. The refrigeration system is assumed to be in operation every day of the year, while savings from the evaporator coil defrost control will only occur during set defrost cycles. This is assumed to be (4) 20-minute cycles per day, for a total of 487 hours.

3.5.8 Variable Speed Refrigeration Compressor

Measure Name	VSD Refrigeration Compressor
Target Sector	Commercial and Industrial Establishments
Measure Unit	VSD Refrigeration Compressor
Unit Energy Savings	Variable
Unit Peak Demand Reduction	Variable
Measure Life	15 years[383]
Measure Vintage	Retrofit

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.

Eligibility

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.

Algorithms

The savings algorithms are 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:

$$\Delta kWh = 0.445 \times HP_{compressor} \times ES_{value}$$

$$\Delta kW_{peak} = 0.445 \times HP_{compressor} \times DS_{value}$$

383 DEER Effective Useful Life. October 10, 2008.

Definition of Terms

Table 3-112: VSD Compressor – Values and References

Term	Unit	Values	Sources
$Tons$, Refrigeration tonnage of the system	*Tons*	EDC Data Gathering	EDC Data Gathering
$HP_{compressor}$, Rated horsepower per compressor	*HP*	EDC Data Gathering	EDC Data Gathering
ES_{value}, Energy savings value in kWh per compressor HP	$\frac{kWh}{ton}$	1,696	1
DS_{value}, Demand savings value in kW per compressor HP	$\frac{kW}{ton}$	0.22	1
0.445, Conversion factor to convert from tons to HP	*None*	0.445	2,3

Default Savings

There are no default savings for this measure.

Evaluation Protocols

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

Sources

1. 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[384] and all vintages (excluding new construction). http://www.deeresources.com/index.php/deer2005
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

[384] The deemed savings was averaged across all climate zones since the variance between all cases was less than 5%.

3.5.9 Strip Curtains for Walk-In Freezers and Coolers

Measure Name	Strip Curtains for Walk-In Coolers and Freezers
Target Sector	Commercial and Industrial Establishments
Measure Unit	Walk-in unit door
Unit Energy Savings	Fixed
Unit Peak Demand Reduction	Fixed
Measure Life	4 years[385]
Measure Vintage	Retrofit

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,[386] 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.[387]

Eligibility

This protocol documents the energy savings attributed to strip curtains applied on walk-in cooler and freezer doors in commercial applications. The most likely areas of application are large and small grocery stores, supermarkets, restaurants, and refrigerated warehouses. 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 temperature strip curtains must be used on low temperature applications.[388]

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385 DEER Effective Useful Life. October 10, 2008.

386 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.

387 See source 1 for Table 3-55

388 http://energysmartonline.org/documents/EnergySmart_BPA_T&Cs.pdf

ALGORITHMS

$$\Delta kWh = \frac{\Delta kWh}{sqft} \times A$$

$$\Delta kW_{peak} = \frac{\Delta kW}{sqft} \times A$$

The annual energy savings due to infiltration barriers is quantified by multiplying savings per square foot by area using assumptions for independent variables described in the protocol introduction. The source algorithm from which the savings per square foot values are determined is based on Tamm's equation[389] (an application of Bernoulli's equation) and the ASHRAE handbook.[390] 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.

$$\frac{\Delta kWh}{sqft} = \frac{365 \times t_{open} \times (\eta_{new} - \eta_{old}) \times 20 \times CD \times A \times \left\{\left[\frac{(T_i - T_r)}{T_i}\right] \times g \times H\right\}^{0.5} \times [\rho_i \times h_i - \rho_r \times h_r]}{3{,}412 \frac{Btu}{kWh} \times COP_{adj} \times A}$$

The peak demand reduction is quantified by multiplying savings per square foot by area. The source algorithm is the annual energy savings divided by 8,760. 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.

$$\frac{\Delta kW_{peak}}{sqft} = \frac{\Delta kWh}{8{,}760}$$

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[391] in the study of strip curtains in supermarkets, convenience stores, and restaurants.

389 *Kalterveluste durch kuhlraumoffnungen*. Tamm W,.Kaltetechnik-Klimatisierung 1966;18;142-144

390 American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE). 2010. *ASHRAE Handbook,* Refrigeration: 13.4, 13.6

391 http://www.calmac.org/publications/ComFac_Evaluation_V1_Final_Report_02-18-2010.pdf

Definition of Terms

Table 3-113: Strip Curtain Calculation Assumptions

Term	Unit	Values	Source
$\frac{\Delta kWh}{ft^2}$, Average annual kWh savings per square foot of infiltration barrier	$\frac{\Delta kWh}{ft^2}$	Calculated	Calculated
$\frac{\Delta kW}{ft^2}$, Average kW savings per square foot of infiltration barrier	$\frac{\Delta kW}{ft^2}$	Calculated	Calculated
20, Product of 60 seconds per minute and an integration factor of 1/3	$\frac{sec}{min}$	20	4
g, Gravitational constant	$\frac{ft}{s^2}$	32.174	Constant
3,412, Conversion factor: number of Btus in one kWh	$\frac{Btu}{kWh}$	3,412	Conversion factor

Default Savings

The default savings values are listed in Table 3-114. Default parameters used in the source equations are listed in Table 3-115, Table 3-116, Table 3-117, and Table 3-118. 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.[392] The original work included 8,760-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.

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.

[392] 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.

Table 3-114: Default Energy Savings and Demand Reductions for Strip Curtains

Type	Pre-existing Curtains	Energy Savings $\frac{\Delta kWh}{ft^2}$	Demand Savings $\frac{\Delta kWh}{ft^2}$
Supermarket - Cooler	Yes	37	0.0042
Supermarket - Cooler	No	108	0.0123
Supermarket - Cooler	Unknown	108	0.0123
Supermarket - Freezer	Yes	119	0.0136
Supermarket - Freezer	No	349	0.0398
Supermarket - Freezer	Unknown	349	0.0398
Convenience Store - Cooler	Yes	5	0.0006
Convenience Store - Cooler	No	20	0.0023
Convenience Store - Cooler	Unknown	11	0.0013
Convenience Store - Freezer	Yes	8	0.0009
Convenience Store - Freezer	No	27	0.0031
Convenience Store - Freezer	Unknown	17	0.0020
Restaurant - Cooler	Yes	8	0.0009
Restaurant - Cooler	No	30	0.0034
Restaurant - Cooler	Unknown	18	0.0020
Restaurant - Freezer	Yes	34	0.0039
Restaurant - Freezer	No	119	0.0136
Restaurant - Freezer	Unknown	81	0.0092
Refrigerated Warehouse	Yes	254	0.0290
Refrigerated Warehouse	No	729	0.0832
Refrigerated Warehouse	Unknown	287	0.0327

Table 3-115: Strip Curtain Calculation Assumptions for Supermarkets

Term	Unit	Values		Source
		Cooler	Freezer	
η_{new} , Efficacy of the new strip curtain – an efficacy of 1 corresponds to the strip curtain thwarting all infiltration, while an efficacy of zero corresponds to the absence of strip curtains.	*None*	0.88	0.88	1
η_{old} , Efficacy of the old strip curtain with Pre-existing curtain with no Pre-existing curtain unknown	*None*	0.58 0.00 0.00	0.58 0.00 0.00	1
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	*None*	0.366	0.415	1
t_{open} , Minutes walk-in door is open per day	$\frac{minutes}{day}$	132	102	1
A , Doorway area	ft^2	35	35	1
H, Doorway height	ft	7	7	1
T_i, Dry-bulb temperature of infiltrating air, Rankine = Fahrenheit + 459.67	$°F$	71	67	1 and 2
T_r, Dry-bulb temperature of refrigerated air, Rankine = Fahrenheit + 459.67	$°F$	37	5	1
ρ_i , Density of the infiltration air, based on 55% RH	$\frac{lb}{ft^3}$	0.074	0.074	3
h_i, Enthalpy of the infiltrating air, based on 55% RH.	$\frac{Btu}{lb}$	26.935	24.678	3
ρ_r, Density of the refrigerated air, based on 80% RH.	$\frac{lb}{ft^3}$	0.079	0.085	3
h_r , Enthalpy of the refrigerated air, based on 80% RH.	$\frac{Btu}{lb}$	12.933	2.081	3
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.	*None*	3.07	1.95	1 and 2

Table 3-116: Strip Curtain Calculation Assumptions for Convenience Stores

Term	Unit	Values		Source
		Cooler	Freezer	
η_{new} , Efficacy of the new strip curtain – an efficacy of 1 corresponds to the strip curtain thwarting all infiltration, while an efficacy of zero corresponds to the absence of strip curtains.	*None*	0.79	0.83	1
η_{old} , Efficacy of the old strip curtain with Pre-existing curtain with no Pre-existing curtain unknown	*None*	0.58 0.00 0.34	0.58 0.00 0.30	1
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	*None*	0.348	0.421	1
t_{open} , Minutes walk-in door is open per day	$\frac{minutes}{day}$	38	9	1
A , Doorway area	ft^2	21	21	1
H, Doorway height	ft	7	7	1
T_i, Dry-bulb temperature of infiltrating air, Rankine = Fahrenheit + 459.67	$°F$	68	64	1 and 2
T_r, Dry-bulb temperature of refrigerated air, Rankine = Fahrenheit + 459.67	$°F$	39	5	1
ρ_i , Density of the infiltration air, based on 55% RH	$\frac{lb}{ft^3}$	0.074	0.075	3
h_i, Enthalpy of the infiltrating air, based on 55% RH.	$\frac{Btu}{lb}$	25.227	23.087	3
ρ_r, Density of the refrigerated air, based on 80% RH.	$\frac{lb}{ft^3}$	0.079	0.085	3
h_r , Enthalpy of the refrigerated air, based on 80% RH.	$\frac{Btu}{lb}$	13.750	2.081	3
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.	*None*	3.07	1.95	1 and 2

Table 3-117: Strip Curtain Calculation Assumptions for Restaurants

Term	Unit	Values		Source
		Cooler	Freezer	
η_{new} , Efficacy of the new strip curtain – an efficacy of 1 corresponds to the strip curtain thwarting all infiltration, while an efficacy of zero corresponds to the absence of strip curtains.	*None*	0.80	0.81	1
η_{old} , Efficacy of the old strip curtain with Pre-existing curtain with no Pre-existing curtain unknown	*None*	0.58 0.00 0.33	0.58 0.00 0.26	1
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	*None*	0.383	0.442	1
t_{open} , Minutes walk-in door is open per day	$\frac{minutes}{day}$	45	38	1
A , Doorway area	ft^2	21	21	1
H, Doorway height	ft	7	7	1
T_i, Dry-bulb temperature of infiltrating air, Rankine = Fahrenheit + 459.67	$°F$	70	67	1 and 2
T_r, Dry-bulb temperature of refrigerated air, Rankine = Fahrenheit + 459.67	$°F$	39	8	1
ρ_i , Density of the infiltration air, based on 55% RH	$\frac{lb}{ft^3}$	0.074	0.074	3
h_i, Enthalpy of the infiltrating air, based on 55% RH.	$\frac{Btu}{lb}$	26.356	24.678	3
ρ_r, Density of the refrigerated air, based on 80% RH.	$\frac{lb}{ft^3}$	0.079	0.085	3
h_r , Enthalpy of the refrigerated air, based on 80% RH.	$\frac{Btu}{lb}$	13.750	2.948	3
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.	*None*	3.07	1.95	1 and 2

Table 3-118: Strip Curtain Calculation Assumptions for Refrigerated Warehouses

Term	Unit	Values	Source
η_{new} , Efficacy of the new strip curtain – an efficacy of 1 corresponds to the strip curtain thwarting all infiltration, while an efficacy of zero corresponds to the absence of strip curtains.	*None*	0.89	1
η_{old} , Efficacy of the old strip curtain with Pre-existing curtain with no Pre-existing curtain unknown	*None*	0.58 0.00 0.54	1
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	*None*	0.425	1
t_{open} , Minutes walk-in door is open per day	$\frac{minutes}{day}$	494	1
A , Doorway area	ft^2	80	1
H, Doorway height	ft	10	1
T_i, Dry-bulb temperature of infiltrating air, Rankine = Fahrenheit + 459.67	$°F$	59	1 and 2
T_r, Dry-bulb temperature of refrigerated air, Rankine = Fahrenheit + 459.67	$°F$	28	1
ρ_i , Density of the infiltration air, based on 55% RH	$\frac{lb}{ft^3}$	0.076	3
h_i, Enthalpy of the infiltrating air, based on 55% RH.	$\frac{Btu}{lb}$	20.609	3
ρ_r, Density of the refrigerated air, based on 80% RH.	$\frac{lb}{ft^3}$	0.081	3
h_r , Enthalpy of the refrigerated air, based on 80% RH.	$\frac{Btu}{lb}$	9.462	3
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.	*None*	1.91	1 and 2

Evaluation Protocols

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

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

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

Sources

1. 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. http://www.calmac.org/publications/ComFac_Evaluation_V1_Final_Report_02-18-2010.pdf.
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.
4. In the original equation (Tamm's equation) the height is taken to be the difference between the midpoint of the opening and the 'neutral pressure level' of the cold space. In the case that there is just one dominant doorway through which infiltration occurs, the neutral pressure level is half the height of the doorway to the walk-in refrigeration unit. The refrigerated air leaks out through the lower half of the door, and the warm, infiltrating air enters through the top half of the door. We deconstruct the lower half of the door into infinitesimal horizontal strips of width W and height dh. Each strip is treated as a separate window, and the air flow through each infinitesimal strip is given by 60 x CD x A x {[(Ti – Tr) / Ti] x g x ΔHNPL }^0.5 where ΔHNPL represents the distance to the vertical midpoint of the door. In effect, this replaces the implicit wh1.5 (one power from the area, and the other from ΔHNPL) with the integral from 0 to h/2 of wh'0.5 dh' which results in wh1.5/(3×20.5¬). For more information see: Are They Cool(ing)?:Quantifying the Energy Savings from Installing / Repairing Strip Curtains, Alereza, Baroiant, Dohrmann, Mort, Proceedings of the 2008 IEPEC Conference.

3.5.10 NIGHT COVERS FOR DISPLAY CASES

Measure Name	Night Covers for Display Cases
Target Sector	Commercial and Industrial Establishments
Measure Unit	Display Case
Unit Energy Savings	Variable
Unit Peak Demand Reduction	Variable
Measure Life	5 years[393,394]
Measure Vintage	Retrofit

ELIGIBILITY

This measure documents the energy savings associated with the installation of night covers on existing open-type refrigerated display cases, where covers are deployed during the facility's 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 is below 0 °F for low-temperature display cases, between 0 °F to 30 °F for medium-temperature display cases, and between 35 °F to 55 °F for high-temperature display cases[395]. The main benefit of using night covers on open display cases is a reduction of infiltration and radiation cooling loads. It is recommended that these covers have small, perforated holes to decrease moisture buildup.

ALGORITHMS

The energy savings and demand reduction are obtained through the following calculation.[396]

$$\Delta kWh = W \times SF \times HOU$$

There are no demand savings for this measure because the covers will not be in use during the peak period[397].

393 DEER Effective Useful Life. October 10, 2008.
394 The Measure Life Report for Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc., June 2007. http://library.cee1.org/sites/default/files/library/8842/CEE_Eval_MeasureLifeStudyLights%26HVACGDS_1Jun2007.pdf
395 Massachusetts 2012 Technical Reference Manual, pg. 229
396 "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.
397 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.

Definition of Terms

Table 3-119: Night Covers Calculations Assumptions

Term	Unit	Values	Source
W, Width of the opening that the night covers protect	*ft*	EDC Data Gathering	EDC Data Gathering
SF, Savings factor based on the temperature of the case	$\frac{kW}{ft}$	Default values in Table 3-120	1
HOU, Annual hours that the night covers are in use	$\frac{Hours}{Year}$	EDC Data Gathering Default: 2,190[398]	EDCs Data Gathering

Table 3-120: 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.

Default Savings

There are no default savings for this measure.

Evaluation Protocols

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

[398] Hours should be determined on a case-by-case basis. Default value of 2,190 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

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*. http://www.energizect.com/sites/default/files/2012%20CT%20Program%20Savings%20Documentation%20FINAL.pdf

3.5.11 AUTO CLOSERS

Measure Name	Auto Closers
Target Sector	Commercial and Industrial Establishments
Measure Unit	Walk-in Cooler and Freezer Door
Unit Energy Savings	Fixed
Unit Peak Demand Reduction	Fixed
Measure Life	8 years[399]
Measure Vintage	Retrofit

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

ELIGIBILITY[400]

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

ALGORITHMS

Auto-closers are treated in the Database for Energy Efficient Resources (DEER) as weather-sensitive; therefore the recommended deemed savings values indicated below are derived from the DEER runs. Climate zone 4 has been chosen as the most similar zone to the climate zones of the main seven Pennsylvania cities. This association is based on cooling degree hours (CDHs) and wet bulb temperatures. Savings estimates for each measure are averaged across six building vintages for climate-zone 4 and building type 9, Grocery Stores. The peak demand savings provided by DEER was calculated using the following peak definition:

> *"The demand savings due to an energy efficiency measure is calculated as the average reduction in energy use over a defined nine-hour demand period."*[401]

The nine hours correspond to 2 PM through 5 PM during 3-day heat waves.[402]

399 http://energysmartonline.org/documents/EnergySmart_BPA_T&Cs.pdf
400 Ibid
401 http://www.deeresources.com/files/DEER2011/download/2011_DEER_Documentation_Appendices.pdf
402 Zarnikau, J. and Zhu, S.S. (2014) The Identification of Peak Period Impacts When a TMY Weather File Is Used in Building Energy Use Simulation. *Open Journal of Energy Efficiency*, **3**, 25-33. http://dx.doi.org/10.4236/ojee.2014.31003

Main Cooler Doors

$$\Delta kWh = \Delta kWh_{cooler}$$

$$\Delta kW_{peak} = \Delta kW_{cooler}$$

Main Freezer Doors

$$\Delta kWh = \Delta kWh_{freezer}$$

$$\Delta kW_{peak} = \Delta kW_{freezer}$$

DEFINITION OF TERMS

Table 3-121: Auto Closers Calculation Assumptions

Term	Unit	Values	Source
ΔkWh_{cooler}, Annual kWh savings for main cooler doors	kWh	Table 3-122	1
ΔkW_{cooler}, Summer peak kW savings for main cooler doors	kW	Table 3-122	1
$\Delta kWh_{freezer}$, Annual kWh savings for main freezer doors	kWh	Table 3-122	1
$\Delta kW_{freezer}$, Summer peak kW savings for main freezer doors	kW	Table 3-122	1

DEEMED SAVINGS

Table 3-122: Refrigeration Auto Closers Deemed Savings

Reference City	Associated California Climate Zone	Value			
		Cooler		Freezer	
		kWh_{cooler}	kW_{cooler}	$kWh_{freezer}$	$kW_{freezer}$
All PA cities	4	961	0.135	2319	0.327

EVALUATION PROTOCOLS

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

Sources

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

3.5.12 Door Gaskets for Walk-in and Reach-in Coolers and Freezers

Measure Name	Door Gaskets for Walk-in and Reach-in Coolers and Freezers
Target Sector	Commercial and Industrial Establishments
Measure Unit	Walk-in Coolers and Freezers
Unit Energy Savings	Fixed
Unit Peak Demand Reduction	Fixed
Measure Life	4 years[403]
Measure Vintage	Replace on Burnout

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.

Eligibility

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

Algorithms

The demand and energy savings assumptions are based on analysis performed by Southern California Edison.

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

$$\Delta kWh = \frac{\Delta kWh}{ft} \times L$$

$$\Delta kW_{peak} = \frac{\Delta kW}{ft} \times L$$

403 Commercial Facilities Contract Group 2006-2008 Direct Impact Evaluation, California Public Utility Commission, February 2010.

Definition of Terms

Table 3-123: Door Gasket Assumptions

Term	Unit	Values	Source
$\frac{\Delta kWh}{ft}$, Annual energy savings per linear foot of gasket	$\frac{\Delta kWh}{ft}$	Table 3-124	1
$\frac{\Delta kW}{ft}$, Demand savings per linear foot of gasket	$\frac{\Delta kW}{ft}$	Table 3-124	1
L, Total gasket length	*ft*	As Measured	EDC Data Gathering

Default Savings

The default savings values below are weather sensitive, therefore the values reference CA climate zone 4, which is the zone chosen as the most similar to the seven major Pennsylvania cities. The demand and energy savings assumptions are based on DEER 2005 and analysis performed by Southern California Edison (SCE)[404].

Table 3-124: Door Gasket Savings Per Linear Foot for Walk-in and Reach-in Coolers and Freezers

Building Type	Coolers		Freezers	
	$\frac{\Delta kW}{ft}$	$\frac{\Delta kWh}{ft}$	$\frac{\Delta kW}{ft}$	$\frac{\Delta kWh}{ft}$
Restaurant	0.000886	18	0.001871	63
Small Grocery Store/ Convenience Store	0.000658	15	0.00162	64
Medium/Large Grocery Store/ Supermarkets	0.0006425	15	0.001593	91

Evaluation Protocols

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

Sources

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

[404] Work papers developed by SCE filed with the CA PUC in support of its 2006 – 2008 energy efficiency program plans

3.5.13 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 Temperature Cases
Target Sector	Commercial and Industrial Establishments
Measure Unit	Display Cases
Unit Energy Savings	Variable
Unit Peak Demand Reduction	Variable
Measure Life	15 years[405]
Measure Vintage	Retrofit

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

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

Eligibility

For this measure, a no-heat/low-heat clear glass door must be installed on an upright display case. It is limited to door heights of 57 inches or more. Doors must have either heat reflective treated glass, be gas filled, or both. This measure applies to low temperature cases only—those with a case temperature below 0°F. Doors must have 3 or more panes. Total door rail, glass, and frame heater amperage (@ 120 volt) cannot exceed 0.39[406] amps per door for low temperature display cases. Rebate is based on the door width (not including case frame).

Algorithms

The energy savings and demand reduction are obtained through the following calculations adopted from San Diego Gas & Electric Statewide Express Efficiency Program [407].

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

405 http://energysmartonline.org/documents/EnergySmart_BPA_T&Cs.pdf
406 Pacific Gas & Electric Company. Refrigeration Rebate Catalog. Pg. 5. http://www.fishnick.com/saveenergy/rebates/2014_PG&E_refrigeration_catalog_final.pdf
407 San Diego Gas & Electric Statewide Express Efficiency Program https://www.sdge.com/sites/default/files/regulatory/Express%20and%20SBS%20Workpapers.pdf

Compressor Savings (excluding condenser):

$$\Delta kW_{compressor} = \frac{1}{1000} \times \frac{Q_{cooling\_svg}}{EER}$$

$$\Delta kWh_{compressor} = \Delta kW \times EFLH$$

$$Q_{cooling\_svg} = Q_{cooling} \times K_{ASH}$$

Anti-Sweat Heater Savings:

$$\Delta kW_{ASH} = \frac{\Delta\ ASH}{1000}$$

$$\Delta kWh_{ASH} = \Delta kW_{ASH} \times t$$

Definition of Terms

Table 3-125: Special Doors with Low or No Anti-Sweat Heat for Low Temp Case Calculations Assumptions

Term	Unit	Values	Source
$Q_{cooling}$, Case rating by manufacturer	$\frac{Btu}{hr} \times \frac{1}{door}$	From nameplate	EDC Data Gathering
$Q_{cooling\_svg}$, Cooling savings	$\frac{Btu}{hr} \times \frac{1}{door}$	Calculated Value	Calculated Value
$\Delta kW_{compressor}$, Compressor power savings	$\frac{kW}{door}$	Calculated Value	Calculated Value
ΔkW_{ASH}, Reduction due to ASH	$\frac{kW}{door}$	Calculated Value	Calculated Value
K_{ASH}, % of cooling load reduction due to low anti-sweat heater	None	1.5%	1
$\Delta\ ASH$, Reduction in ASH power per door	$\frac{W}{door}$	83[408]	1
$\Delta kWh_{compressor}$, Annual compressor energy savings (excluding condenser energy)	$\frac{kWh}{door}$	Calculated Value	Calculated Value
ΔkWh_{ASH}, Annual reduction in energy	$\frac{kWh}{door}$	Calculated Value	Calculated Value
EER, Compressor rating from manufacturer	*None*	Nameplate	EDC Data Gathering
EFLH, Equivalent full load annual operating	$\frac{Hours}{Year}$	Based on Logging, BMS data or Modeling	EDC Data Gathering

[408] From Actual Test: 0.250 kW per 3 doors

Term	Unit	Values	Source
hours		Default: 5,700[409]	1
t, Annual operating hours of Anti-sweat heater	$\frac{Hours}{Year}$	8,760	1

Default Savings

There are no default savings for this measure.

Evaluation Protocols

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

Sources

1. San Diego Gas & Electric Statewide Express Efficiency Program https://www.sdge.com/sites/default/files/regulatory/Express%20and%20SBS%20Workpapers.pdf

[409] 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.

3.5.14 Suction Pipe Insulation for Walk-In Coolers and Freezers

Measure Name	Suction Pipe Insulation for Walk-In Coolers and Freezers
Target Sector	Commercial and Industrial Establishments
Measure Unit	Walk-In Coolers and Freezers
Unit Energy Savings	Fixed
Unit Peak Demand Reduction	Fixed
Measure Life	11 years[410,411]
Measure Vintage	Retrofit

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.

Eligibility

This protocol documents the energy savings attributed to insulation of bare refrigeration suction pipes. The following are the eligibility requirements[412]:

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

Algorithms

The demand and energy savings assumptions are based on DEER 2005 and analysis performed by Southern California Edison (SCE)[413]. Measure savings per linear foot of insulation installed on bare suction lines in Restaurants and Grocery Stores is provided in Table 3-126 and Table 3-127 below lists the “default” savings for the associated with California Climate Zone 4 which has been chosen as the representative zone for all seven major Pennsylvania cities.

[410] Southern California Edison Company, “Insulation of Bare Refrigeration Suction Lines”, Work Paper WPSCNRRN0003.
[411] DEER database, EUL/RUL for insulation bare suction pipes.
[412] Commonwealth Edison Refrigeration Incentives Worksheet 2014. https://www.comed.com/documents/business-savings/sifyb_py6_refrigeration.pdf
[413] Work papers developed by SCE filed with the CA PUC in support of its 2006 – 2008 energy efficiency program plans

$$\Delta kWh = \frac{\Delta kWh}{ft} \times L$$

$$\Delta kW_{peak} = \frac{\Delta kW}{ft} \times L$$

Definition of Terms

Table 3-126: Insulate Bare Refrigeration Suction Pipes Calculations Assumptions

Term	Unit	Values	Source
$\frac{\Delta kWh}{ft}$, Annual energy savings per linear foot of insulation	$\frac{\Delta kWh}{ft}$	Table 3-127	1
$\frac{\Delta kW}{ft}$, Demand savings per linear foot of insulation	$\frac{\Delta kW}{ft}$	Table 3-127	1
L, Total insulation length	*ft.*	As Measured	EDC Data Gathering

Default Savings

Table 3-127: Insulate Bare Refrigeration Suction Pipes Savings per Linear Foot for Walk-in Coolers and Freezers of Restaurants and Grocery Stores[414]

City	Associated California Climate Zone[415]	Medium-Temperature Walk-in Coolers		Low-Temperature Walk-in Freezers	
		ΔkW/ft.	ΔkWh/ft.	ΔkW/ft.	ΔkWh/ft.
All PA cities	4	0.00219	11.3	0.002726	14.8

Evaluation Protocols

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

Sources

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

[414] A zip code mapping table is located in Appendix F: Eligibility Requirements for Solid State Lighting Products in Commercial and Industrial Applications. This table should be used to identify the reference Pennsylvania city for all zip codes in Pennsylvania

[415] The default 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.

3.6 APPLIANCES

3.6.1 ENERGY STAR CLOTHES WASHER

Measure Name	ENERGY STAR Clothes Washer
Target Sector	Commercial and Industrial Establishments
Measure Unit	Clothes Washer
Unit Energy Savings	See Table 3-129 to Table 3-132
Unit Peak Demand Reduction	See Table 3-129 to Table 3-132
Measure Life	11.3 years for Multifamily and 7.1 years for Laundromats[416]
Measure Vintage	Replace on Burnout

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 $\geq 2.2 \frac{(ft^3 \times cycle)}{kWh}$. The Federal efficiency standard is $\geq 1.60 \frac{(ft^3 \times cycle)}{kWh}$ for Top Loading washers and $\geq 2.0 \frac{(ft^3 \times cycle)}{kWh}$ for Front Loading washers[417].

ELIGIBILITY

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.

ALGORITHMS

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

$$Total\ Savings = Number\ of\ Clothes\ Washers \times Savings\ per\ Clothes\ Washer$$

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:

[416] "Energy Conservation Program: Energy Conservation Standards for Certain Consumer Products (Dishwashers, Dehumidifiers, Microwave Ovens, and Electric and Gas Kitchen Ranges and Ovens) and for Certain Commercial and Industrial Equipment (Commercial Clothes Washers); Final Rule," 75 *Federal Register* 5 (January 8, 2010), pp.1140.
[417] ibid.

$$\Delta kWh = [(HE_{t,base} + ME_{t,base} + D_{e,base}) - (HE_{t,new} + ME_{t,new} + D_{e,new})] \times N$$

Where:

D_e $= LAF \times WGHT_{max} \times DEF \times DUF \times (RMC^3 - 4\%)$

RMC $= (-0.156 \times MEF) + 0.734$

HE_t $= \left(\frac{Cap}{MEF}\right) - ME_t - D_e$

ΔkW_{peak} $= \Delta kWh \times UF$

The algorithms used to calculate energy savings are taken from the U.S. Department of Energy's Supplemental Notice of Proposed Rulemaking (SNOPR).[418] 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.*[419]
>
> $MEF = \frac{C}{M+E+D}$

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 0.133 $\frac{kWh}{cycle}$ for MEFs up to 1.40 and 0.114 $\frac{kWh}{cycle}$ 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

418 Commercial Clothes Washer Supplemental Notice of Proposed Rulemaking, Chapter 6. http://www1.eere.energy.gov/buildings/appliance_standards/commercial/pdfs/ccw_snopr_chap6.pdf

419 Definition provided on ENERGY STAR Clothes Washers Key Product Criteria website: http://www.energystar.gov/index.cfm?c=clotheswash.pr_crit_clothes_washers

container volume divided by the MEF) and then subtracting from it the per-cycle clothes-drying and machine energy.

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 3-15 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 approaches 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.

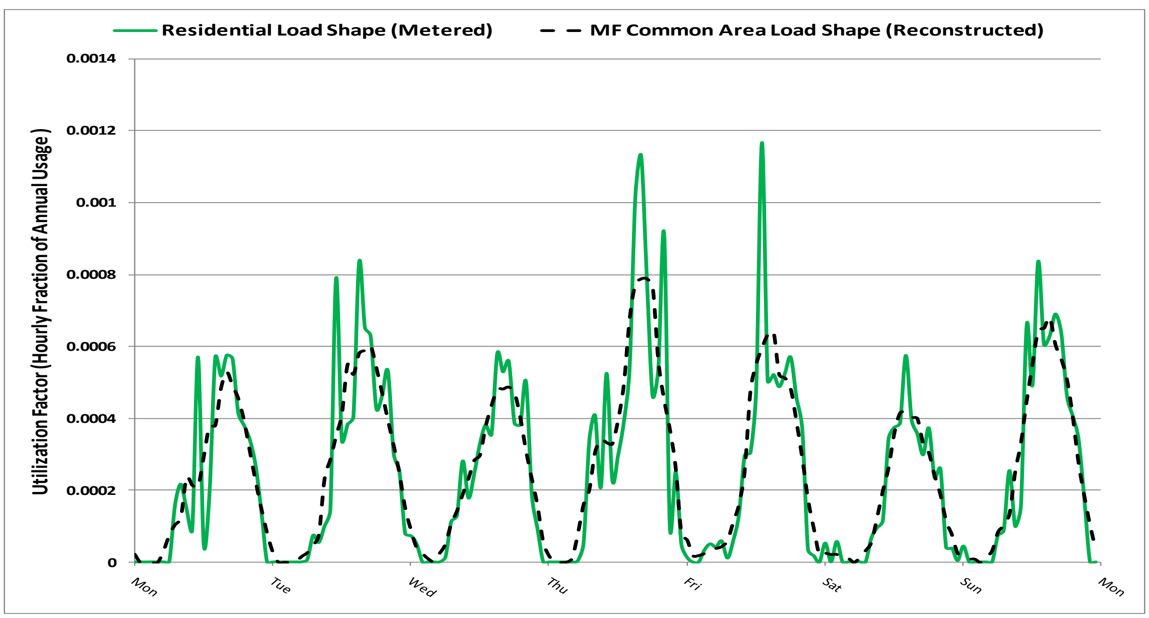

Figure 3-15: Utilization factor for a sample week in July[420]

[420] 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.

Definition of Terms

The parameters in the above equation are listed in Table 3-128 below.

Table 3-128: Commercial Clothes Washer Calculation Assumptions

Term	Unit	Values	Source
MEF_b , Base Federal Standard Modified Energy Factor	*None*	Top loading: 1.6 Front loading: 2.0	3
MEF_p , Modified Energy Factor of ENERGY STAR Qualified Washing Machine	*None*	Nameplate	EDC Data Gathering
	None	Default: 2.2	3
HE_t , Per-cycle water heating consumption	$\frac{kWh}{cycle}$	Calculation	Calculation
D_e , Per-cycle energy consumption for removal of moisture i.e. dryer energy consumption	$\frac{kWh}{cycle}$	Calculation	Calculation
ME_t , Per-cycle machine electrical energy consumption	$\frac{kWh}{cycle}$	0.114[421]	1
Cap_{base}, Capacity of baseline clothes washer	ft^3	Nameplate	EDC Data Gathering
		Default: Front Loading: 2.84 Top Loading: 2.95	5
Cap_{ee} , Capacity of efficient clothes washer	ft^3	Nameplate	EDC Data Gathering
		Front Loading: 2.84 Top Loading: 2.84	5
LAF, Load adjustment factor	*None*	0.52	1
DEF, Nominal energy required for clothes dryer to remove moisture from clothes	$\frac{kWh}{lb}$	0.5	1
DUF, Dryer usage factor, percentage of washer loads dried in a clothes dryer	*None*	0.84	1
$WGHT_{max}$, Maximum test-load weight	$\frac{lbs}{cycle}$	11.7	1
RMC, Remaining moisture content	lbs	Calculation[422]	Calculation
N, Number of cycles per year	*Cycle*	Multifamily: 1,241 Laundromats: 2,190	1
UF, Utilization Factor	*None*	0.0002382	2

[421] Based on residential clothes washer data from DOE 2000 Technical Support Document (TSD)
[422] Based on the relationship: RMC = -0.156* MEF + 0.734

DEFAULT SAVINGS

The default savings for the installation of a washing machine with a MEF of 2.2 or higher, is dependent on the energy source for washer. Table 3-129 thru Table 3-132 show savings for ENERGY STAR washing machines with different combinations of water heater and dryer types in multifamily buildings and landromats. The values are based on the difference between the baseline clothes washer with MEF Federal efficiency standard of $\geq$ 1.60 $\frac{(ft^3 \times cycle)}{kWh}$ for top loading washers and $\geq$ 2.0 $\frac{(ft^3 \times cycle)}{kWh}$ for front loading washers and minimum ENERGY STAR qualified front loading[423] clothes washer of $\geq$ 2.2 $\frac{(ft^3 \times cycle)}{kWh}$.

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 Table 3-129 through Table 3-132 below.

$$ESav_{cw} = kWh_{gwh-gd} \times \%GWH - GD_{cw} + kWh_{gwh-ed} \times \%GWH - ED_{cw} + kWh_{ewh-gd} \times \%EWH - GD_{cw} + kWh_{ewh-ed} \times \%EWH - ED_{cw}$$

Where:

kWh_{gwh-gd} = Energy savings for clothes washers with gas water heater and non-electric dryer fuel from tables below

kWh_{gwh-ed} = Energy savings for clothes washers with gas water heater and electric dryer fuel from tables below

kWh_{ewh-gd} = Energy savings for clothes washers with electric water heater and non-electric dryer fuel from tables below

kWh_{ewh-ed} = Energy savings for clothes washers with electric water heater and electric dryer fuel from tables below

$\%GWH - GD_{cw}$ = Percent of clothes washers with gas water heater and non-electric dryer fuel

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

$\%EWH - GD_{cw}$ = Percent of clothes washers with electric water heater and non-electric dryer fuel

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

423 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

Table 3-129: Default Savings for Top Loading ENERGY STAR Clothes Washer for Laundry in Multifamily Buildings[424]

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)[425]	1,241	206	0.049

Table 3-130: Default Savings for Front Loading ENERGY STAR Clothes Washer for Laundry in Multifamily Buildings [426]

Fuel Source	$\frac{Cycles}{Year}$	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)[427]	1,241	52	0.012

[424]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.
[425] Commercial Clothes Washer SNOPR Life Cycle Calculator Excel Spread Sheet
[426]ibid
[427] ibid

Table 3-131: Default Savings for Top Loading ENERGY STAR Clothes Washer for Laundromats[428]

Fuel Source	$\frac{Cycles}{Year}$	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)[429]	2,190	0	0

Table 3-132: Default Savings Front Loading ENERGY STAR Clothes Washer for Laundromats[430]

Fuel Source	$\frac{Cycles}{Year}$	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)[431]	2,190	0	0

Evaluation Protocols

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

Sources

2. U.S. Department of Energy. Commercial Clothes Washer Supplemental Notice of Proposed Rulemaking, Chapter 6. http://www1.eere.energy.gov/buildings/appliance_standards/commercial/pdfs/ccw_snopr_chap6.pdf
3. Annual hourly load shapes taken from Energy Environment and Economics (E3), Reviewer2: 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

[428] ibid
[429] ibid
[430] Ibid
[431] ibid

4. "Energy Conservation Program: Energy Conservation Standards for Certain Consumer Products (Dishwashers, Dehumidifiers, Microwave Ovens, and Electric and Gas Kitchen Ranges and Ovens) and for Certain Commercial and Industrial Equipment (Commercial Clothes Washers); Final Rule," 75 Federal Register 5 (8 January 2010), pp. 1123

5. ENERGY STAR. U.S. Environmental Protection Agency and U.S. Department of Energy. "ENERGY STAR Program Requirements Product Specification for Clothes Washers." *ENERGY STAR Version 6.1 Clothes Washers Specification* (Jan. 2013): 5. http://www.energystar.gov/products/specs/system/files/Clothes_Washers_Program_Requirements_Version_6_1.pdf
http://www1.eere.energy.gov/buildings/appliance_standards/commercial/clothes_washers.html

6. California Energy Commission ("CEC") Appliance Efficiency database, http://www.appliances.energy.ca.gov/QuickSearch.aspx

3.7 Food Service Equipment

3.7.1 High-Efficiency Ice Machines

Measure Name	High-Efficiency Ice Machines
Target Sector	Commercial and Industrial Establishments
Measure Unit	Ice Machine
Unit Energy Savings	Variable
Unit Peak Demand Reduction	Variable
Measure Life	10 Years[432]
Measure Vintage	Replace on Burnout

Eligibility

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 batch-type ice makers to qualify, which can include self-contained, ice-making heads, or remote-condensing units. The baseline equipment is a commercial ice machine that meets federal equipment standards. The efficient machine must conform to the minimum ENERGY STAR efficiency requirements and meet the ENERGY STAR requirements for water usage given under the same criteria.

Algorithms

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

$$\Delta kWh = \frac{(kWh_{base} - kWh_{he})}{100} \times H \times 365 \times D$$

$$\Delta kW_{peak} = \frac{\Delta kWh}{8760 \times D} \times CF$$

Definition of Terms

The reference values for each component of the energy impact algorithm are shown in Table 3-133. 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.

[432] DEER Effective Useful Life. October 10, 2008.

Table 3-133: Ice Machine Reference Values for Algorithm Components

Term	Unit	Values	Source
kWh_{base} , Baseline ice machine energy usage per 100 lbs. of ice	$\frac{kWh}{100\ lbs}$	Table 3-134	1
kWh_{he} , High-efficiency ice machine energy usage per 100 lbs. of ice	$\frac{kWh}{100\ lbs}$	Table 3-135	2
H, Ice harvest rate per 24 hrs.	$\frac{lbs}{day}$	Manufacturer Specs	EDC Data Gathering
D, Duty cycle of ice machine expressed as a percentage of time machine produces ice	*None*	Custom	EDC Data Gathering
		Default: 0.4[433]	3
365, Days per year	$\frac{Days}{year}$	365	Conversion Factor
100, Conversion to obtain energy per pound of ice	$\frac{lbs}{100\ lbs}$	100	Conversion Factor
8760, Hours per year	$\frac{Hours}{year}$	8,760	Conversion Factor
Ice maker type	*None*	Manufacturer Specs	EDC Data Gathering
CF, Demand Coincidence Factor	*Decimal*	0.77	4

433 *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.

Table 3-134: Ice Machine Baseline Efficiencies

Ice machine type	Ice harvest rate (H) $\left(\frac{lbs}{day}\right)$	Baseline energy use per 100 lbs. of ice (kWh_{base})
Ice-Making Head	<450	10.26 – 0.0086*H
	≥450	6.89 – 0.0011*H
Remote-Condensing w/out remote compressor	<1000	8.85 – 0.0038*H
	≥1000	5.1
Remote-Condensing with remote compressor	<934	8.85 – 0.0038*H
	≥934	5.3
Self-Contained	<175	18 – 0.0469*H
	≥175	9.8

Table 3-135: Ice Machine ENERGY STAR Efficiencies

Ice machine type	Ice harvest rate (H) $\left(\frac{lbs}{day}\right)$	Energy use per 100 lbs. of ice (kWh_{ee})
Ice-Making Head	200 ≤ H ≤ 1600	$\leq 37.72*H^{-0.298}$
Remote-Condensing Unit	400 ≤ H ≤ 1600	$\leq 22.95*H^{-0.258} + 1.00$
	1600 ≤ H ≤ 4000	≤ -0.00011*H + 4.60
Self-Contained (SCU)	50 ≤ H ≤ 450	$\leq 48.66*H^{-0.326} + 0.08$

Default Savings

There are no default savings associated with this measure.

Evaluation Protocols

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

Sources

1. Federal energy conservation standard for automatic commercial ice makers. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/21

2. Commercial Ice Maker Key Product Criteria Version 2.0. https://www.energystar.gov/index.cfm?c=comm_ice_machines.pr_crit_comm_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.

3.7.2 Controls: Beverage Machine Controls

Measure Name	Controls: Beverage Machine Controls
Target Sector	Commercial and Industrial Establishments
Measure Unit	Machine Control
Unit Energy Savings	Variable
Unit Peak Demand Reduction	Variable
Measure Life	5 years[434,435]
Measure Vintage	Retrofit

Eligibility

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 for one to three hour intervals, sufficient to maintain beverage temperature, and when powered on at any time will be allowed to complete at least one cycle to prevent excessive wear and tear.

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

Algorithms

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

$$\Delta kWh = kWh_{base} \times E$$

$$\Delta kW_{peak} = 0$$

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.

[434] DEER Effective Useful Life. October 10, 2008.
[435] Deru et al. suggest that beverage machine life will be extended from this measure due to fewer lifetime compressor cycles.

Definition of Terms

Table 3-136: Beverage Machine Control Calculation Assumptions

Term	Unit	Values	Source
kWh_{base}, Baseline annual beverage machine energy consumption	$\frac{kWh}{year}$	EDC Data Gathering Default: Table 3-137	EDC Data Gathering
E, Efficiency factor due to control system, which represents percentage of energy reduction from baseline	*None*	EDC Data Gathering	EDC Data Gathering

Default Savings

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%.[436,437,438,439] It should be noted that various studies found savings values ranging between 30-65%, most likely due to differences in customer occupation.

The default baseline energy consumption and default energy savings are shown in Table 3-137. 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.

[436] 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
[437] 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
[438] *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
[439] *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

Table 3-137: Beverage Machine Controls Energy Savings

Machine Can Capacity	Default Baseline Energy Consumption (kWh_{base}) $\left(\frac{kWh}{year}\right)$	Default Energy Savings (ΔkWh); $\left(\frac{kWh}{year}\right)$	Source
< 500	3,113	1,432	1
500	3,916	1,801	1
600	3,551	1,633	1
700	4,198	1,931	1
800+	3,318	1,526	1

Evaluation Protocols

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

Sources

1. ENERGY STAR Calculator, Assumptions for Vending Machines, accessed 8/2010

3.7.3 Controls: Snack Machine Controls

Measure Name	Controls: Snack Machine Controls
Target Sector	Commercial and Industrial Establishments
Measure Unit	Machine Control
Unit Energy Savings	Variable
Unit Peak Demand Reduction	0 kW
Measure Life	5 years[440]
Measure Vintage	Retrofit

A snack machine controller is an energy control device for non-refrigerated snack vending machines. The controller turns off the machine‘s lights based on times of inactivity. This protocol is applicable for conditioned indoor installations.

Eligibility

This measure is targeted to non-residential customers who install controls to non-refrigerated snack vending machines.

Acceptable baseline conditions are non-refrigerated snack vending machines.

Efficient conditions are non-refrigerated snack vending machines with controls.

Algorithms

The energy savings for this measure result from reduced lighting operation.

$$\Delta kWh = \frac{Watts_{base}}{1000} * HOURS * ESF$$

$$\Delta kW_{peak} = 0$$

Definition of Terms

Table 3-138: Snack Machine Controls – Values and References

Term	Unit	Values	Source
$Watts_{base}$, Wattage of vending machine	W	EDC Data Gathering Default: 85	EDC Data Gathering 1
$HOURS$, Annual hours of operation	$\frac{Hours}{Year}$	EDC Data Gathering Default: 8,760	EDC Data Gathering 1

[440] Measure Life Study, prepared for the Massachusetts Joint Utilities, Energy & Resource Solutions, November 2005. http://rtf.nwcouncil.org/subcommittees/nonreslighting/Measure%20Life%20Study_MA%20Joint%20Utilities_2005_ERS-1.pdf

Term	Unit	Values	Source
ESF, Energy savings factor	*None*	46	1

Default Savings

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

Evaluation Protocols

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

Sources

1. Illinois Statewide TRM, 2014. Machine wattages assume that the peak period is coincident with periods of high traffic diminishing the demand reduction potential of occupancy based controls. Hours of operation assume operation 24 hrs/day, 365 days/yr. http://www.efi.org/specs/snackmiser.pdf.

3.7.4 ENERGY STAR ELECTRIC STEAM COOKER

Measure Name	ENERGY STAR Electric Steam Cooker
Target Sector	Commercial and Industrial Establishments
Measure Unit	Electric Steam Cooker
Unit Energy Savings	See Table 3-140
Unit Peak Demand Reduction	See Table 3-140
Measure Life	12 years[441]
Measure Vintage	Replace on Burnout

ELIGIBILITY

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

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

ALGORITHMS

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

[441] http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=COC

$$\Delta kWh = \Delta kWh_{cooking} + \Delta kWh_{idle}$$

$$\Delta kWh_{cooking} = lbsfood \times EnergytoFood \times \left(\frac{1}{Eff_b} - \frac{1}{Eff_{ee}}\right)$$

$$\Delta kWh_{idle} = \left[\left(Power_{idle-b} \times (1 - \%HOURS_{consteam}) + \%HOURS_{consteam} \times CAPY_b \times Qty_{pans} \times \left(\frac{EnergytoFood}{Eff_b}\right) \times HOURS_{op} - \left(\frac{lbsfood}{CAPY_b \times Qty_{pans}}\right) - HOURS_{pre}\right)\right] - \left[\left(Power_{idle-ee} \times (1 - \%HOURS_{consteam}) + \%HOURS_{consteam} \times CAPY_{ee} \times Qty_{pans} \times \left(\frac{EnergytoFood}{Eff_{ee}}\right) \times HOURS_{op} - \left(\frac{lbsfood}{CAPY_{ee} \times Qty_{pans}}\right) - HOURS_{pre}\right)\right]$$

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

Definition of Terms

Table 3-139: Steam Cooker - Values and References

Term	Unit	Values	Source
$lbsfood$, Pounds of food cooked per day in the steam cooker	lbs	Nameplate	EDC Data Gathering
		Default values in Table 3-140	Table 3-140
$EnergyToFood$, ASTM energy to food ratio; energy (kilowatt-hours) required per pound of food during cooking	$\frac{kWh}{pound}$	0.0308	1
Eff_{ee} , Cooking energy efficiency of the new unit	None	Nameplate	EDC Data Gathering
		Default values in Table 3-140	Table 3-140
Eff_b , Cooking energy efficiency of the baseline unit	None	See Table 3-140	Table 3-140
$Power_{idle-b}$, Idle power of the baseline unit	kW	See Table 3-140	Table 3-140
$Power_{idle-ee}$, Idle power of the new unit	kW	Nameplate	EDC Data Gathering
		Default values in Table 3-140	Table 3-140
$HOURS_{op}$, Total operating hours per day	$\frac{Hours}{Day}$	Nameplate	EDC Data Gathering
		12 hours	1
$HOURS_{pre}$, Daily hours spent preheating the steam cooker	$\frac{Hours}{Day}$	0.25	1
$\%HOURS_{consteam}$, 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.	None	40%	1
$CAPY_b$, Production capacity per pan of the baseline unit	$\frac{lb}{hr}$	See Table 3-140	Table 3-140
$CAPY_{ee}$, Production capacity per pan of the new unit	$\frac{lb}{hr}$	See Table 3-140	Table 3-140
Qty_{pans} , Quantity of pans in the unit	None	Nameplate	EDC Data Gathering
$EFLH$, Equivalent full load hours per year	$\frac{Hours}{Year}$	4,380	2
CF, Demand Coincidence Factor	Decimal	0.84	3,4
1000, Conversion from watts to kilowatts	$\frac{W}{kW}$	1000	Conversion factor

Default Savings

Table 3-140: Default Values for Electric Steam Cookers by Number of Pans[442]

# of Pans	Parameter	Baseline Model	Efficient Model	Savings
3	$Power_{idle}$ (kW)[443]	1.000	0.27	
	$CAPY\left(\frac{lb}{hr}\right)$	23.3	16.7	
	$lbsfood$	100	100	
	Eff [444]	30%	59%	
	ΔkWh			2,813
	ΔkW_{peak}			0.54
4	$Power_{idle}$ (kW)	1.325	0.30	
	$CAPY\left(\frac{lb}{hr}\right)$	21.8	16.8	
	$lbsfood$	128	128	
	Eff	30%	57%	
	ΔkWh			3,902
	ΔkW_{peak}			0.75
5	$Power_{idle}$ (kW)	1.675	0.31	
	$CAPY\left(\frac{lb}{hr}\right)$	20.6	16.6	
	$lbsfood$	160	160	
	Eff	30%	70%	
	ΔkWh			5,134
	ΔkW_{peak}			0.98
6	$Power_{idle}$ (kW)	2.000	0.31	
	$CAPY\left(\frac{lb}{hr}\right)$	20.0	16.7	
	$lbsfood$	192	192	
	Eff	30%	65%	
	ΔkWh			6,311
	ΔkW_{peak}			1.21

[442] 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.
[443] Efficient values calculated from a list of ENERGY STAR qualified products.
[444] Ibid.

Evaluation Protocols

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

Sources

1. ENERGY STAR. US Environmental Protection Agency and US Department of Energy. ENERGY STAR Commercial Kitchen Equipment Calculator.
2. Food Service Technology Center (FSTC) 2012, *Commercial Cooking Appliance Technology Assessment,* pg 8-14.
3. *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.
4. 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. http://www.puc.nh.gov/Electric/Monitoring%20and%20Evaluation%20Reports/National%20Grid/116_RLW_CF%20Res%20C&I%20ltg.pdf

3.7.5 ENERGY STAR Refrigerated Beverage Machine

Measure Name	ENERGY STAR Refrigerated Beverage Vending Machine
Target Sector	Commercial and Industrial Establishments
Measure Unit	Refrigerated Beverage Vending Machine
Unit Energy Savings	Variable
Unit Peak Demand Reduction	0 kW
Measure Life	14 years[445]
Measure Vintage	Replace on Burnout

ENERGY STAR vending machines are equipped with more efficient compressors, fan motors and lighting systems. In addition to more efficient components, ENERGY STAR qualified machines are programmed with software that reduces lighting and refrigeration loads during times of inactivity.

Eligibility

This measure is targeted to non-residential customers who purchase and install a beverage vending machine that meets ENERGY STAR specifications rather than a non-ENERGY STAR unit. The energy efficient refrigerated vending machine can be new or rebuilt.

Algorithms

Energy savings are dependent on decreased machine lighting and cooling loads during times of lower customer sales. The savings are 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. 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.

Class A Vending Machine
A Class A machine is defined as a refrigerated bottled or canned beverage vending machine that is fully cooled, and is not a combination vending machine.

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

$$\Delta kWh_{base} = (0.055V + 2.56) \times 365$$

$$\Delta kWh_{ee} = (0.0523V + 2.432) \times 365$$

$$\Delta kW_{peak} = 0$$

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445 "Energy Savings Potential and R&D Opportunities for Commercial Refrigeration," Navigant Consulting, Final Report submitted to US DOE, September 2009. http://apps1.eere.energy.gov/buildings/publications/pdfs/corporate/commercial_refrig_report_10-09.pdf

Class B Vending Machine
A Class B machine is defined as any refrigerated bottled or canned beverage vending machine not considered to be Class A, and is not a combination vending machine.

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

$$\Delta kWh_{base} = (0.073V + 3.16) \times 365$$

$$\Delta kWh_{ee} = (0.0657V + 2.844) \times 365$$

$$\Delta kW_{peak} = 0$$

Definition of Terms

Table 3-141: ENERGY STAR Refrigerated Beverage Vending Machine – Values and Resources

Term	Unit	Values	Source
kWh_{base} ,energy usage of baseline vending machine	kWh	EDC Data Gathering[446]	EDC Data Gathering
kWh_{ee}, energy usage of ENERGY STAR vending machine	kWh	EDC Data Gathering[447]	EDC Data Gathering
V, refrigerated volume of the vending machine	ft^3	EDC Data Gathering Default: 24.3	3
365, days per year	$\frac{Days}{yr}$	365	Conversion Factor

Default Savings

Table 3-142: Default Beverage Vending Machine Energy Savings

Equipment Class	Default kWh Savings
Class A	71
Class B	180

Energy savings for this measure are fully deemed and may be claimed using the algorithm above and the variable defaults.

[446] Data gathering of vending machine volume
[447] Data gathering of annual energy consumption of vending machine

Evaluation Protocols

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

Sources

1. ENERGY STAR. US Environmental Protection Agency and US Department of Energy. "Program Requirements; Product Specification for Refrigerated Beverage Vending Machines." http://www.energystar.gov/products/specs/system/files/Vending%20Machines%20Program%20Requirements%20Version%203%201.pdf
2. US Department of Energy. "Refrigerated Beverage Vending Machines." http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/24
3. ENERGY STAR. US Environmental Protection Agency and US Department of Energy. "ENERGY STAR Certified Vending Machines Spread Sheet" http://www.energystar.gov/productfinder/product/certified-vending-machines/results

3.8 BUILDING SHELL

3.8.1 WALL AND CEILING INSULATION

Measure Name	Wall and Ceiling Insulation
Target Sector	Commercial and Industrial Establishments
Measure Unit	Wall and Ceiling Insulation
Unit Energy Savings	Variable
Unit Peak Demand Reduction	Variable
Measure Life	15 years[448]
Measure Vintage	New Construction or Retrofit

Wall and ceiling insulation is one of the most important aspects of the energy system of a building. Insulation dramatically minimizes energy expenditure on heating and cooling. Increasing the R-value of wall insulation above building code requirements generally lowers heating and cooling costs. Incentives are offered with regard to increases in R-value rather than type, method, or amount of insulation.

An R-value indicates the insulation's resistance to heat flow – the higher the R-value, the greater the insulating effectiveness. The R-value depends on the type of insulation and its material, thickness, and density. When calculating the R-value of a multilayered installation, add the R-values of the individual layers.

ELIGIBILITY

This measure applies to non-residential buildings 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.

ALGORITHMS

The savings depend on four main factors: baseline condition, heating system type and size, cooling system type and size, and location. The algorithm for Central AC and Air Source Heat Pumps (ASHP) is as follows:

[448] DEER 2008 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.

Ceiling/Wall Insulation

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

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

$$\Delta kWh_{heat} = \left(\frac{HDD \times 24}{COP \times 3{,}413}\right) \times \left[A_{ceiling}\left(\frac{1}{Ceiling\ R_i} - \frac{1}{Ceiling\ R_f}\right) + A_{wall}\left(\frac{1}{WallR_i} - \frac{1}{Wall\ R_f}\right)\right]$$

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

DEFINITION OF TERMS

Table 3-143: Non-Residential Insulation – Values and References

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

Term	Unit	Values	Source
		existing buildings: See Table 3-144 and Table 3-145 for values by building type	
$Ceiling\ R_f$, Total R-value of all ceiling/attic insulation after the additional insulation is installed	$\frac{°F \cdot ft^2 \cdot hr}{Btu}$	EDC Data Gathering	EDC Data Gathering
$Wall\ R_f$, Total R-value of all wall insulation after the additional insulation is installed	$\frac{°F \cdot ft^2 \cdot hr}{Btu}$	EDC Data Gathering	EDC Data Gathering
$EFLH_{cool}$, Equivalent full load cooling hours	$\frac{Hours}{Year}$	Based on Logging, BMS data or Modeling[449]	EDC Data Gathering
		Default: See Table 3-24	5
CF, Demand Coincidence Factor	*Decimal*	See Table 3-25	5
Eff, Efficiency of existing HVAC equipment. Depending on the size and age, this will either be the SEER, IEER, or EER (use EER only if SEER or IEER are not available)[450]	$\frac{Btu/hr}{W}$	Nameplate	EDC Data Gathering
		Default: See Table 3-23	See Table 3-23
COP, Efficiency of the heating system	*None*	Nameplate	EDC Data Gathering
		Default: See Table 3-23	See Table 3-23

Table 3-144: Ceiling R-Values by Building Type

Building Type	Ceiling R_i-Value (New Construction)	Ceiling R_i-Value (Existing)
Large Office Large Retail Lodging Health Education Grocery	20	9
Small Office Warehouse	24.4	13.4
Small Retail Restaurant Convenience Store	20	9

449 Modeling is an acceptable substitute to metering and BMS data if 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).
450 Site-specific design values should be used in the calculation wherever possible, to avoid overestimating the savings using the default minimally compliant EERs.

Table 3-145: Wall R-Values by Building Type

Building Type	Wall R_i-Value (New Construction)	Wall R_i-Value (Existing)
Large Office	14	1.6
Small Office Large Retail Small Retail Convenience Store	14	3.0
Lodging Health Education Grocery	13	2.0
Restaurant	14	3.2
Warehouse	14	2.5

Default Savings

There are no default savings for this measure.

Evaluation Protocols

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

Sources

1. 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. https://law.resource.org/pub/us/code/ibr/icc.iecc.2009.pdf
3. The initial R-value for a wall assumes that there was no existing insulation, or that it has fallen down resulting in an R-value equivalent to that of the building materials. Building simulation modeling using DOE-2.2 model (eQuest) was performed for a building with no wall insulation. The R-value is dependent upon the construction materials and their thickness. Assumptions were made about the building materials used in each sector.

4. 2009 International Energy Conservation Code. Used climate zone 5 which covers the majority of Pennsylvania. The R-values required by code were used as inputs in the eQuest building simulation model to calculate the total R-value for the wall including the building materials. https://law.resource.org/pub/us/code/ibr/icc.iecc.2009.pdf
5. Based on results from Nexant's eQuest modeling analysis 2014.

3.9 Consumer Electronics

3.9.1 ENERGY STAR Office Equipment

Measure Name	ENERGY STAR Office Equipment
Target Sector	Commercial and Industrial Establishments
Measure Unit	Office Equipment
Unit Energy Savings	Fixed
Unit Peak Demand Reduction	Fixed
Measure Life	Table 3-147
Measure Vintage	Replace on Burnout

Eligibility

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

Algorithms

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

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

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 ENERGY STAR calculator for office equipment.

ENERGY STAR Computer

$$\Delta kWh = ESAV_{com}$$

$$\Delta kW_{peak} = DSAV_{com}$$

ENERGY STAR Fax Machine

$$\Delta kWh = ESav_{fax}$$

$$\Delta kW_{peak} = DSav_{fax}$$

ENERGY STAR Copier

$$\Delta kWh = ESav_{cop}$$

$$\Delta kW_{peak} = DSav_{cop}$$

ENERGY STAR Printer

$$\Delta kWh = ESav_{pri}$$

$$\Delta kW_{peak} = DSav_{pri}$$

ENERGY STAR Multifunction

$$\Delta kWh = ESav_{mul}$$

$$\Delta kW_{peak} = DSav_{mul}$$

ENERGY STAR Monitor

$$\Delta kWh = ESav_{mon}$$

$$\Delta kW_{peak} = DSav_{mon}$$

Definition of Terms

Table 3-146: ENERGY STAR Office Equipment - References

Term	Unit	Values	Source
$ESav_{com}$, Electricity savings per purchased ENERGY STAR computer $ESav_{fax}$, Electricity savings per purchased ENERGY STAR fax machine. $ESav_{cop}$, Electricity savings per purchased ENERGY STAR copier. $ESav_{pri}$, Electricity savings per purchased ENERGY STAR printer. $ESav_{mul}$, Electricity savings per purchased ENERGY STAR multifunction machine. $ESav_{mon}$, Electricity savings per purchased ENERGY STAR monitor.	kWh	See Table 3-148	1
$DSav_{com}$, Summer demand savings per purchased ENERGY STAR computer. $DSav_{fax}$, Summer demand savings per purchased ENERGY STAR fax machine. $DSav_{cop}$, Summer demand savings per purchased ENERGY STAR copier. $DSav_{pri}$, Summer demand savings per purchased ENERGY STAR printer. $DSav_{mul}$, Summer demand savings per purchased ENERGY STAR multifunction machine. $DSav_{mon}$, Summer demand savings per purchased ENERGY STAR monitor.	kW	See Table 3-148	2

ENERGY STAR office equipment have the following measure lives:

Table 3-147: ENERGY STAR Office Equipment Measure Life[451]

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

Deemed Savings

Table 3-148: ENERGY STAR Office Equipment Energy and Demand Savings Values

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

[451] ENERGY STAR Office Equipment Savings Calculator

100+ images/min	730 kWh	0.0984 kW	
Monitor	15 kWh	0.0020 kW	1

Evaluation Protocols

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

Sources

1. ENERGY STAR Office Equipment Savings Calculator (Referenced latest version released in May 2013). Default values were used. Using a commercial office equipment load shape, the percentage of total savings that occur during the PJM peak demand period was calculated and multiplied by the energy savings.

3.9.2 Office Equipment – Network Power Management Enabling

Measure Name	Network Power Management Enabling
Target Sector	Commercial and Industrial Establishments
Measure Unit	One copy of licensed software installed on a PC workstation
Unit Energy Savings	Fixed
Unit Peak Demand Reduction	Fixed
Measure Life	5 years[452]
Measure Vintage	Retrofit

Over the last few 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.

Eligibility

The deemed savings reported in Table 3-149 are applicable to any software that meets the following Pacific Northwest Regional Technical Forum's ("RTF") Networked Computer Power Management Control Software Specifications[453]:

- 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.

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[452] 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.

[453] Network PC Power Management Presentation, Regional Technical Forum, May 4, 2010.

- 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.

Algorithms

There are no algorithms for this measure.

Definition of Terms

There are no definitions of terms.

Deemed Savings

The energy savings per unit found in various studies specific to the Verdiem Surveyor software varied from 33.8 kWh/year to 330 kWh/year, with an average savings of about 200 kWh/year. This includes the power savings from the PC as well as the monitor. Deemed savings are based on 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 offices and small offices) in combination with different HVAC systems types (electric heat, gas heat, and heat pumps). The deemed savings values in Table 3-149 also take into account the HVAC interactive effects. A simple average is reported for Pennsylvania.

Table 3-149: Network Power Controls, Per Unit Summary Table

Measure Name	Unit	Gross Peak kW Reduction per Unit	Gross kWh Reduction per Unit	Effective Useful Life
Network PC Plug Load Power Management Software	One copy of licensed software installed on a PC workstation	0.00625[454]	135[455]	5

Evaluation Protocols

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

454 http://www.nwcouncil.org/energy/rtf/measures/measure.asp?id=95&decisionid=117
455 ibid

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., Steiner, J., & Vellinga, N. (2006). *San Diego Gas & Electric 2004-2005 Local Energy Savers Program Evaluation Report* (Study ID: SDG0212). Portland, OR: Quantec LLC. http://www.calmac.org/publications/SDGE_ESP_EMV_Report_073106_Final.pdf
3. Greenberg, D. (2004). *Network Power Management Software: Saving Energy by Remote Control* (E source report No. ER-04-15). Boulder, CO: Platts Research & Consulting.
4. Roth, K., Larocque, G., & Kleinman, J. (2004). *Energy Consumption by Office and Telecommunications Equipment in Commercial Buildings Volume II: Energy Savings Potential* (U.S. DOE contract No. DE-AM26-99FT40465). Cambridge, MA: TIAX LLC. http://www.eere.energy.gov/buildings/info/documents/pdfs/office_telecom-vol2_final.pdf

3.9.3 Smart Strip Plug Outlets

Measure Name	Smart Strip Plug Outlets
Target Sector	Commercial and Industrial Establishments
Measure Unit	Smart Strip Plug Outlet
Unit Energy Savings	Fixed
Unit Peak Demand Reduction	Fixed
Measure Life	5 years[456]
Measure Vintage	Retrofit

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

Eligibility

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

Algorithms

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

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

$$\text{Average daily commercial computer system idle time} = \frac{Hours\ per\ week - (workdays \times daily\ computer\ usage)}{days\ per\ week}$$

$$16.86\ hours = \frac{168\ hours - (5\ days \times 10\ hours)}{7\ days}$$

[456] DSMore Michigan Database. http://michigan.gov/mpsc/0,4639,7-159-52495_55129---,00.html

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

$$\Delta kWh = (kW_{comp} \times Hr_{comp}) \times 365 = \mathbf{123.69kWh\ (rounded\ to\ 124kWh)}$$

$$\Delta kW_{peak} = CF \times kW_{comp} = \mathbf{0.0101kW}$$

Definition of Terms

The parameters in the above equation are listed below.

Table 3-150: Smart Strip Calculation Assumptions

Term	Unit	Values	Source
kW_{comp} , Idle kW of computer system	*kW*	0.0201	1
Hr_{comp} , Daily hours of computer idle time	$\frac{Hours}{Day}$	16.86	1
CF, Coincidence Factor	*Decimal*	0.50	1

Deemed Savings

$$\Delta kWh = 124\ kWh$$

$$\Delta kW_{peak} = 0.0101\ kW$$

Evaluation Protocols

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

Sources

1. DSMore Michigan Database of Energy Efficiency Measures. http://michigan.gov/mpsc/0,4639,7-159-52495_55129---,00.html

3.10 COMPRESSED AIR

3.10.1 CYCLING REFRIGERATED THERMAL MASS DRYER

Measure Name	Cycling Refrigerated Thermal Mass Dryer
Target Sector	Commercial and Industrial Establishments
Measure Unit	Cycling Refrigerated Thermal Mass Dryer
Unit Energy Savings	Variable
Unit Peak Demand Reduction	Variable
Measure Life	10 years[457]
Measure Vintage	Early Replacement

When air is compressed, water vapor in the air condenses and collects in liquid form. Some of this condensate collects in the air distribution system and can contaminate downstream components such as air tools with rust, oil, and pipe debris. Refrigerated air dryers remove the water vapor by cooling the air to its dew point and separating the condensate. Changes in production and seasonal variations in ambient air temperature lead to partial loading conditions on the dryer. Standard air dryers use a hot gas bypass system that is inefficient at partial loads. A Cycling Thermal Mass Dryer uses a thermal storage medium to store cooling capacity when the system is operated at partial loads allowing the dryer refrigerant compressor to cycle.

ELIGIBILITY

This measure is targeted to non-residential customers whose equipment is a non-cycling refrigerated air dryer with a capacity of 600 cfm or below.

Acceptable baseline conditions are a non-cycling (e.g. continuous) air dryer with a capacity of 600 cfm or below. The replacement of desiccant, deliquescent, heat-of-compression, membrane, or other types of dryers does not qualify under this measure.

Efficient conditions are a cycling thermal mass dryer with a capacity of 600 cfm or below.

ALGORITHMS

$$\Delta kWh = ((CFM \times HP_{compressor} \times \frac{CFM_{comp.}}{kW_{dryer}} \times HOURS \times (1 - APC)) \times RTD)$$

$$\Delta kW_{peak} = \frac{\Delta kWh}{HOURS} * CF$$

457 Based on market activity as reported by several compressed air equipment vendors. See “Compiled Data Request Results.xls”, Efficiency Vermont, Technical Reference Manual 2013-82 for details. http://www.greenmountainpower.com/upload/photos/371TRM_User_Manual_No_2013-82-5-protected.pdf

Definition of Terms

Table 3-151: Cycling Refrigerated Thermal Mass Dryer – Values and References

Term	Unit	Values	Source
CFM , Compressor output per HP	$\frac{CFM}{HP}$	EDC Data Gathering Default: 4	EDC Data Gathering 1
$HP_{compressor}$, Nominal HP rating of the air compressor motor	*HP*	Nameplate data	EDC Data Gathering
CFM/kW_{dryer}, Ratio of compressor CFM to dryer kW	$\frac{CFM}{kW}$	EDC Data Gathering Default: 0.0087	EDC Data Gathering 2
RTD , Chilled coil response time derate	*Hours*	EDC Data Gathering Default: 0.925	EDC Data Gathering 2
APC , Average compressor operating capacity	*None*	EDC Data Gathering Default: 65%	EDC Data Gathering 3
HOURS , Annual hours of compressor operation	$\frac{Hours}{year}$	EDC Data Gathering Default: See Table 3-152	EDC Data Gathering 4
CF, Coincidence Factor	*Decimal*	EDC Data Gathering Default: See Table 3-153	EDC Data Gathering 5

Table 3-152: Annual Hours of Compressor Operation

Operation Facility Schedule (hours per day / days per week)	HOURS
Single Shift (8/5)	2080
2-Shift (16/5)	4160
3-Shift (24/5)	6240
4-Shift (24/7)	8320

Table 3-153: Coincidence Factors

Coincidence Factor	%
Single Shift (8/5)	66.7
2-Shift (16/5)	100
3-Shift (24/5)	100
4-Shift (24/7)	100

Default Savings

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

Evaluation Protocols

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

Sources

1. Manufacturer's data suggests that cfm output per compressor HP ranges from 4 to 5. The lower estimate of 4 will slightly underestimate savings.
2. Conversion factor based on a linear regression analysis of the relationship between air compressor full load capacity and non-cycling dryer full load kW assuming that the dryer is sized to accommodate the maximum compressor capacity. See "Compressed Air Analysis.xls" for source calculations, Efficiency Vermont, Technical Reference Manual 2013-82. http://www.greenmountainpower.com/upload/photos/371TRM_User_Manual_No_2013-82-5-protected.pdf
3. Based on an analysis of load profiles from 50 facilities using air compressors 40 HP and below. See "BHP Weighted Compressed Air Load Profiles.xls" for source calculations, Efficiency Vermont, Technical Reference Manual 2013-82. http://www.greenmountainpower.com/upload/photos/371TRM_User_Manual_No_2013-82-5-protected.pdf
4. Hours account for holidays and scheduled downtime. Efficiency Vermont, Technical Reference Manual 2013-82. http://www.greenmountainpower.com/upload/photos/371TRM_User_Manual_No_2013-82-5-protected.pdf
5. Efficiency Vermont, Technical Reference Manual 2013-82. Compressed Air Loadshape calcs (compressed_air_loadshape_calc_1-4_shifts.xls). The CF is drawn from the summer period, which is when the PA peak kW peak is calculated. http://www.greenmountainpower.com/upload/photos/371TRM_User_Manual_No_2013-82-5-protected.pdf

3.10.2 Air-Entraining Air Nozzle

Measure Name	Air-entraining Air Nozzle
Target Sector	Commercial and Industrial Establishments
Measure Unit	Air-entraining Air Nozzle
Unit Energy Savings	Variable
Unit Peak Demand Reduction	Variable
Measure Life	15 years[458]
Measure Vintage	Early Replacement

Air entraining air nozzles use compressed air to entrain and amplify atmospheric air into a stream, increasing pressure with minimal compressed air use. This decreases the compressor work necessary to provide the nozzles with compressed air. Air entraining nozzles can also reduce noise in systems with air at pressures greater than 30 psig.

Eligibility

This measure is targeted to non-residential customers whose compressed air equipment uses stationary air nozzles in a production application with an open copper tube of 1/8" or 1/4" orifice diameter.

Energy efficient conditions require replacement of an inefficient, non-air entraining air nozzle with an energy efficient air-entraining air nozzle that use less than 15 CFM at 100 psi for industrial applications.

Algorithms

$$\Delta kWh = (CFM_{base} - CFM_{ee}) \times COMP \times HOURS \times \% USE$$

$$\Delta kW_{peak} = \frac{\Delta kWh}{HOURS} * CF$$

[458] PA Consulting Group (2009). *Business Programs: Measure Life Study*. Prepared for State of Wisconsin Public Service Commission. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf

Definition of Terms

Table 3-154: Air-entraining Air Nozzle – Values and References

Term	Unit	Values	Source
CFM_{base}, Baseline nozzle air mass flow	CFM $\left(\frac{ft^3}{min}\right)$	EDC Data Gathering Default: See Table 3-155	1
CFM_{ee}, Energy efficient nozzle air mass flow	CFM $\left(\frac{ft^3}{min}\right)$	EDC Data Gathering Default: See Table 3-156	2
$COMP$, Ratio of compressor kW to CFM	$\frac{kW}{CFM}$	EDC Data Gathering Default: See Table 3-157	3
$HOURS$, Annual hours of compressor operation	$\frac{Hours}{year}$	EDC Data Gathering Default: See Table 3-158	4
$\%\ USE$, Percent of hours when nozzle is in use	None	EDC Data Gathering Default: 5%	5
CF, Coincidence Factor	Decimal	EDC Data Gathering Default: See Table 3-159	6

Table 3-155: Baseline Nozzle Mass Flow

Nozzle Diameter	Air Mass Flow (CFM)
1/8”	21
1/4"	58

Table 3-156: Air Entraining Nozzle Mass Flow

Nozzle Diameter	Air Mass Flow (CFM)
1/8”	6
1/4"	11

Table 3-157: Average Compressor kW / CFM (COMP)

Compressor Control Type	Average Compressor kW/CFM (COMP)
Modulating w/ Blowdown	0.32
Load/No Load w/ 1 gal/CFM Storage	0.32
Load/No Load w/ 3 gal/CFM Storage	0.30
Load/No Load w/ 5 gal/CFM Storage	0.28
Variable Speed w/ Unloading	0.23

Table 3-158: Annual Hours of Compressor Operation

Facility Schedule (hours per day / days per week)	HOURS
Single Shift (8/5)	2080
2-Shift (16/5)	4160
3-Shift (24/5)	6240
4-Shift (24/7)	8320

Table 3-159: Coincidence Factor

Coincidence Factor	*Decimal*
Single Shift (8/5)	0.667
2-Shift (16/5)	1.00
3-Shift (24/5)	1.00
4-Shift (24/7)	1.00

Default Savings

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

Evaluation Protocols

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

Sources

1. Machinery's Handbook 25th Edition.
2. Survey of Engineered Nozzle Suppliers.
3. Efficiency Vermont, Technical Reference Manual 2013-82. The average compressor kW/CFM values were calculated using DOE part load curves and load profile data from 50 facilities employing compressors less than or equal to 40 hp. http://www.greenmountainpower.com/upload/photos/371TRM_User_Manual_No_2013-82-5-protected.pdf
4. Efficiency Vermont, Technical Reference Manual 2013-82. Accounts for holidays and scheduled downtime. http://www.greenmountainpower.com/upload/photos/371TRM_User_Manual_No_2013-82-5-protected.pdf
5. Assumes 50% handheld air guns and 50% stationary air nozzles. Manual air guns tend to be used less than stationary air nozzles, and a conservative estimate of 1 second of blow-off per minute of compressor run time is assumed. Stationary air nozzles are commonly more wasteful as they are often mounted on machine tools and can be manually operated resulting in the possibility of a long term open blow situation. An assumption of 5 seconds of blow-off per minute of compressor run time is used.

6. Efficiency Vermont, Technical Reference Manual 2013-82. Compressed Air Loadshape calcs (compressed_air_loadshape_calc_1-4_shifts.xls). The CF is drawn from the summer period, which is when the PA peak kW peak is calculated. http://www.greenmountainpower.com/upload/photos/371TRM_User_Manual_No_2013-82-5-protected.pdf

3.10.3 No-Loss Condensate Drains

Measure Name	No-loss Condensate Drains
Target Sector	Commercial and Industrial Establishments
Measure Unit	No-loss Condensate Drains
Unit Energy Savings	Variable
Unit Peak Demand Reduction	Variable
Measure Life	5 years[459]
Measure Vintage	Early Replacement

When air is compressed, water vapor in the air condenses and collects in the system. The water must be drained to prevent corrosion to the storage tank and piping system, and to prevent interference with other components of the compressed air system such as air dryers and filters. Many drains are controlled by a timer and are opened for a fixed amount of time on regular intervals regardless of the amount of condensate. When the drains are opened compressed air is allowed to escape without doing any purposeful work. No-loss Condensate Drains are controlled by a sensor that monitors the level of condensate and only open when there is a need to drain condensate. They close before compressed air is allowed to escape.

Eligibility

This measure is targeted to non-residential customers whose equipment is a timed drain that operates on a pre-set schedule.

Acceptable baseline conditions are compressed air systems with standard condensate drains operated by a solenoid and timer.

Energy efficient conditions are systems retrofitted with new No-loss Condensate Drains properly sized for the compressed air system.

Algorithms

The following algorithms apply for No-loss Condensate Drains.

$$\Delta kWh = ALR \times COMP \times OPEN \times AF \times PNC$$

$$\Delta kW_{peak} = \frac{\Delta kWh}{HOURS} * CF$$

[459] Based on market activity as reported by several compressed air equipment vendors. See "Compiled Air Analysis.xls," Efficiency Vermont TRM 2013 for details.

Definition of Terms

Table 3-160: No-loss Condensate Drains – Values and References

Term	Unit	Values	Source
ALR, Air Loss Rate; an hourly average rate for the timed drain dependent on drain orifice diameter and system pressure.	CFM $\left(\frac{ft^3}{min}\right)$	EDC Data Gathering Default: See Table 3-161	1
$COMP$, Compressor kW / CFM; the amount of electrical demand in KW required to generate one cubic foot of air at 100 PSI.	$\frac{kW}{CFM}$	EDC Data Gathering Default See: Table 3-162	2
$OPEN$, Hours per year drain is open	$\frac{Hours}{year}$	EDC Data Gathering Default: 146	3
AF, Adjustment Factor; accounts for periods when compressor is not running and the system depressurizes due to leaks and operation of time drains.	*None*	EDC Data Gathering Default: See Table 3-163	4
PNC, Percent Not Condensate; accounts for air loss through the drain after the condensate has been cleared and the drain remains open.	*None*	EDC Data Gathering Default: 0.75	4
$HOURS$, Annual hours of compressor operation	$\frac{Hours}{year}$	EDC Data Gathering Default: See Table 3-164	5
CF, Coincidence Factor	$Decimal$	EDC Data Gathering Default: Table 3-165	6

Table 3-161: Average Air Loss Rates (ALR)

Pressure (psig)	Orifice Diameter (inches)					
	1/64	1/32	1/16	1/8	1/4	3/8
70	0.29	1.16	4.66	18.62	74.4	167.8
80	0.32	1.26	5.24	20.76	83.1	187.2
90	0.36	1.46	5.72	23.1	92	206.6
95	0.38	1.51	6.02	24.16	96.5	216.8
100	0.4	1.55	6.31	25.22	100.9	227
105	0.42	1.63	6.58	26.31	105.2	236.7
110	0.43	1.71	6.85	27.39	109.4	246.4
115	0.45	1.78	7.12	28.48	113.7	256.1
120	0.46	1.86	7.39	29.56	117.9	265.8
125	0.48	1.94	7.66	30.65	122.2	275.5
For well-rounded orifices, values should be multiplied by 0.97. For sharp orifices, values should be multiplied by 0.61. When the baseline value is unknown, use 100.9 CFM[460].						

Table 3-162: Average Compressor kW / CFM (COMP)

Compressor Control Type	Average Compressor kW/CFM (COMP)
Modulating w/ Blowdown	0.32
Load/No Load w/ 1 gal/CFM Storage	0.32
Load/No Load w/ 3 gal/CFM Storage	0.30
Load/No Load w/ 5 gal/CFM Storage	0.28
Variable Speed w/ Unloading	0.23

[460] Ibid.

Table 3-163: Adjustment Factor (AF)

Compressor Operating Hours	AF
Single Shift – 2080 Hours	0.62
2-Shift – 4160 Hours	0.74
3-Shift – 6240 Hours	0.86
4-Shift – 8320 Hours	0.97

Table 3-164: Annual Hours of Compressor Operation

Facility Schedule (hours per day / days per week)	HOURS
Single Shift (8/5)	2080
2-Shift (16/5)	4160
3-Shift (24/5)	6240
4-Shift (24/7)	8320

Table 3-165: Coincidence Factor

Coincidence Factor	*Decimal*
Single Shift (8/5)	0.667
2-Shift (16/5)	1.00
3-Shift (24/5)	1.00
4-Shift (24/7)	1.00

Default Savings

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

Evaluation Protocols

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

Sources

1. US DOE Compressed Air Tip Sheet #3, August 2004, from Fundamentals for Compressed Air Systems Training offered by the Compressed Air Challenge. http://www1.eere.energy.gov/manufacturing/tech_assistance/pdfs/compressed_air3.pdf

2. The average compressor kW/CFM values were calculated using DOE part load curves and load profile data from 50 facilities employing compressors less than or equal to 40 hp. Efficiency Vermont, Technical Reference Manual 2013-82. http://www.greenmountainpower.com/upload/photos/371TRM_User_Manual_No_2013-82-5-protected.pdf
3. Assumes 10 seconds per 10 minute interval. Efficiency Vermont, Technical Reference Manual 2013-82. http://www.greenmountainpower.com/upload/photos/371TRM_User_Manual_No_2013-82-5-protected.pdf
4. Based on observed data. Efficiency Vermont, Technical Reference Manual 2013-82. http://www.greenmountainpower.com/upload/photos/371TRM_User_Manual_No_2013-82-5-protected.pdf
5. Accounts for holidays and scheduled downtime. Efficiency Vermont, Technical Reference Manual 2013-82. http://www.greenmountainpower.com/upload/photos/371TRM_User_Manual_No_2013-82-5-protected.pdf
6. Efficiency Vermont, Technical Reference Manual 2013-82. Compressed Air Loadshape calcs (compressed_air_loadshape_calc_1-4_shifts.xls). The CF is drawn from the summer period, which is when the PA peak kW peak is calculated. http://www.greenmountainpower.com/upload/photos/371TRM_User_Manual_No_2013-82-5-protected.pdf

3.11 MISCELLANEOUS

3.11.1 ENERGY STAR SERVERS

Measure Name	ENERGY STAR Servers
Target Sector	Commercial and Industrial Establishments
Measure Unit	Variable
Unit Energy Savings	Variable
Unit Peak Demand Reduction	Variable
Measure Life	4 years[461]
Measure Vintage	Replace on Burnout

ELIGIBILITY

This measure applies to the replacement of existing servers in a data center or server closet with new ENERGY STAR servers of similar computing capacity. On average, ENERGY STAR servers are 30% more efficient than standard servers. The servers operate particularly efficiently at low loads due to processor power management requirements that reduce power consumption when servers are idle.

ALGORITHMS[462]

$$kW_{es} = \sum_{ES=1}^{n} kW_{es,idle} + \left[U_{es} \times \left(\frac{kW_{es,idle}}{b} - kW_{es,idle}\right)\right]$$

$$\frac{\Delta kWh}{yr} = \left[\frac{1}{(1-a)} - 1\right] \times kW_{es} \times 8{,}760\ \frac{hours}{year}$$

$$\Delta kW_{peak} = \left[\frac{1}{(1-a)} - 1\right] \times kW_{es}$$

[461] The three International Data Corporation (IDC) studies indicate organizations replace their servers once every three to five years(Source 8)

[462] The energy consumption and savings algorithms represented in this section were derived from the Uniform Methods Project: Methods for Determining Energy-Efficiency Savings for Specific Measures, Draft Data Center IT Measures, 2013.

DEFINITION OF TERMS

Table 3-166: ENERGY STAR Server Measure Assumptions

Term	Unit	Values	Source
$kW_{es,idle}$, Power draw of ENERGY STAR server in idle mode	*kW*	EDC Data Gathering	1
U_{es}, utilization of ENERGY STAR server	*None*	EDC Data Gathering Default: See Table 3-167	EDC Data Gathering 2,3,4
a, percentage ENERGY STAR server is more efficient than “standard” or “typical” unit	*None*	Fixed = 30% or most current ENERGY STAR specification	5
b, ratio of idle power to full load power for an ENERGY STAR server	*None*	EDC Data Gathering Default: See Table 3-168	EDC Data Gathering 6
n, number of ENERGY STAR servers	*Servers*	EDC Data Gathering	EDC Data Gathering
ΔkW_{peak}, peak demand savings	*kW*	Calculated per algorithm	7

Table 3-167: ENERGY STAR Server Utilization Default Assumptions

Server Category	Installed Processors	U_{es} (%)
A, B	1	15%
C, D	2	40%

Table 3-168: ENERGY STAR Server Ratio of Idle Power to Full Load Power Factors

Server Category	Installed Processors	Managed Server[463]	Ratio of ES Idle/ES Full Load (b)
A	1	No	52.1%
B	1	Yes	53.2%
C	2	No	61.3%
D	2	Yes	55.8%

[463] Managed Server: A computer server that is designed for a high level of availability in a highly managed environment. For purposes of this specification, a managed server must meet all of the following criteria (from ENERGY STAR server specification 2.0):

A. is designed to be configured with redundant power supplies; and
B. contains an installed dedicated management controller (e.g., service processor).

Default Savings

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

Evaluation Protocols

When possible, perform M&V to assess the energy consumption. However, where metering of IT equipment in a data center is not allowed, follow the steps outlined.

- Invoices should be checked to confirm the number and type of ENERGY STAR servers purchased.
- If using their own estimate of active power draw, $kW_{energy\ star}$, the manager should provide a week's worth of active power draw data gathered from the uninterruptible power supply, PDUs, in-rack smart power strips, or the server itself.
- Idle power draws of servers, $kW_{es,idle}$, should be confirmed in the "Idle Power Typical or Single Configuration (W)" on the ENERGY STAR qualified product list[464] .
- If not using the default values listed in Table 3-167, utilization rates should be confirmed by examining the data center's server performance software.

Sources

1. An ENERGY STAR qualified server has an "Idle Power Typical or Single Configuration (W)" listed in the qualified product list for servers. The EDC should use the server make and model number to obtain the $kW_{es,idle}$ variable used in the algorithms. The ENERGY STAR qualified server list is located at here: http://www.energystar.gov/productfinder/product/certified-enterprise-servers/results .
2. Utilization of a server can be derived from a data center's server performance software. This data should be used, instead of the default values listed in Table 3-168, when possible.
3. The estimated utilization of the ENERGY STAR server for servers with one processor was based on the average of two sources, as follows.
    a. Glanz, James. Power Pollution and The Internet, The New York Times, September 22, 2012. This article cited to sources of average utilization rates between 6 to 12%.
    b. Stakeholders interviewed during the development of the ENERGY STAR server specification reported that the average utilization rate for servers with 1 processor is approximately 20%.
4. The estimated utilization of the ENERGY STAR server for servers with two processor was based on the average of two sources, as follows.
    a. Using Virtualization to Improve Data Center Efficiency, Green Grid White Paper, Editor: Richard Talaber, VMWare, 2009. A target of 50% server utilization is recommended when setting up a virtual host.
    b. Stakeholders interviewed during the development of the ENERGY STAR server specification reported that the average utilization rate for servers with two processors is approximately 30%.

464 http://www.energystar.gov/productfinder/product/certified-enterprise-servers/results

5. The default percentage savings on the ENERGY STAR server website was reported to be 30% on May 20th, 2014.
6. In December 2013, ENERGY STAR stopped including full load power data as a field in the ENERGY STAR certified product list. In order to full load power required in the Uniform Methods Project algorithm for energy efficient servers, a ratio of idle power to full load power was estimated. The idle to full load power ratios were estimated based on the ENERGY STAR qualified product list from November 18th, 2013. The ratios listed in Table 3-168 are based on the average idle to full load ratios for all ENERGY STAR qualified servers in each server category.
7. The coincident peak demand factor was assumed to be 100% since the servers operate 24 hours per day, 365 days per year and the demand reduction associated with this measure is constant.
8. The three International Data Corporation (IDC) studies indicate organizations replace their servers once every three to five years
    a. IDC (February 2012). "The Cost of Retaining Aging IT Infrastructure." Sponsored by HP. Online. http://mjf.ie/wp-content/uploads/white-papers/IDC-White-Paper_the-cost-of-retaining-aging-IT-infrastructure.pdf
    b. IDC (2010). "Strategies for Server Refresh." Sponsored by Dell. Online. http://i.dell.com/sites/content/business/smb/sb360/en/Documents/server-refresh-strategies.pdf
    c. DC (August 2012). "Analyst Connection: Server Refresh Cycles: The Costs of Extending Life Cycles." Sponsored by HP/Intel. Online. http://resources.itworld.com/ccd/assets/31122/detaill

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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 AGRICULTURAL

4.1.1 AUTOMATIC MILKER TAKEOFFS

Measure Name	Automatic Milker Takeoffs
Target Sector	Agriculture (includes Residential and Commercial)
Measure Unit	Milker Takeoff System
Unit Energy Savings	Variable
Unit Peak Demand Reduction	Variable
Measure Life	10 years[465]
Measure Vintage	Retrofit

ELIGIBILITY

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.

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 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.

ALGORITHMS

The annual energy savings are obtained through the following formulas:

$$\Delta kWh = COWS \times \frac{MPD}{2 \times \frac{avg.milkings}{day}} \times ESC$$

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

[465] Idaho Power Demand Side Management Potential Study – Volume II Appendices, Nexant, 2009.

Definition of Terms

Table 4-1: Variables for Automatic Milker Takeoffs

Term	Unit	Values	Source
$COWS$, Number of cows milked per day	*Cows*	Based on customer application	EDC Data Gathering
MPD, Number of milkings per day per cow	*Milkings*	Based on customer application	EDC Data Gathering
		Default: 2	1
ESC, Energy Savings per cow per year	$\frac{kWh \cdot yr}{cow}$	7.5	1, 2, 3, 4, 5,6
CF, Demand Coincidence factor	*Decimal*	0.00014	6

Default Savings

There are no default savings for this protocol.

Evaluation Protocols

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

Sources

1. 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. David W. Kammel: "Dairy Modernization: Growing Pennsylvania Family Dairy Farms", Biological Systems Engineering, University of Wisconsin. http://www.padairysummit.org/_files/live/Dairy_Modernization_PA_Program_2014_Final.pdf
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 is 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 that are estimated at 50-70% pump savings. It is assumed that the pump VFD savings are 46%, therefore the average remaining savings can be attributed to automatic milker take-offs. http://www.mnproject.org/resourcecenter/Vacuum%20System%20options.pdf

6. 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.

4.1.2 Dairy Scroll Compressors

Measure Name	Dairy Scroll Compressors
Target Sector	Agriculture (includes Residential and Commercial)
Measure Unit	Compressor
Unit Energy Savings	Variable
Unit Peak Demand Reduction	Variable
Measure Life	15 years[466]
Measure Vintage	Replace on Burnout or New Construction

Eligibility

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 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.

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.

Algorithms

The energy and peak demand savings are dependent on the presence of a precooler in the system, and are obtained through the following formulas:

$$\Delta kWh = \left(\frac{CBTU}{EER_{base}} - \frac{CBTU}{EER_{ee}}\right) \times \frac{1 \cdot kW}{1000 \cdot W} \times HRS \times DAYS \times COWS$$

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

[466]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 https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf

Definition of Terms

Table 4-2: Variables for Dairy Scroll Compressors

Term	Unit	Values	Source
EER_{base}, Baseline compressor efficiency	*None*	Baseline compressor manufacturers data based upon customer application	EDC Data Gathering
		Default: 5.85	1
EER_{ee}, Installed compressor efficiency	*None*	From nameplate	EDC Data Gathering
$CBTU$, Heat load of milk per cow per day for a given refrigeration system	$\frac{Btu}{Cow \cdot day}$	System without precooler: 2,864 System with precooler: 922	2, 3
HRS, Operating hours per day	$\frac{hours}{day}$	Customer application	EDC Data Gathering
		Default: 8 hours	4
$DAYS$, Milking days per year	*Days*	Based on customer application	EDC Data Gathering
		Default: 365 days/year	3, 4
$COWS$, Average number of cows milked per day	*Cows*	Based on customer application	EDC Data Gathering
CF, Demand Coincidence factor	*Decimal*	0.00014	5

Default Savings

There are no default savings for this measure.

Evaluation Protocols

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

Sources

1. Based on 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 $\frac{Btu}{lb \cdot °F}$ 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 (temperature difference between the milk leaving the cow and the cooled milk in tank storage) 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. KEMA 2009 Evaluation of IPL Energy Efficiency Programs, Appendix F, pg.

347. http://alliantenergy.com/wcm/groups/wcm_internet/@int/documents/document/mdaw/mdey/~edisp/012895.pdf

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 herd size is 75 cows in Pennsylvania.

5. 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.

4.1.3 High Efficiency Ventilation Fans with and without Thermostats

Measure Name	High Efficiency Ventilation Fans with and without Thermostats
Target Sector	Agriculture (includes Residential and Commercial)
Measure Unit	Fan
Unit Energy Savings	Variable
Unit Peak Demand Reduction	Variable
Measure Life	10 years[467]
Measure Vintage	Replace on Burnout or New Construction

Eligibility

The following protocol for the calculation of energy and demand savings applies to the installation of high efficiency ventilation fans to replace standard efficiency ventilation fans or the installation of a high efficiency ventilation fans in a new construction application. The high efficiency fans move more cubic feet of air per watt 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.

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.

Algorithms

The annual energy savings are obtained through the following formulas:

$$\Delta kWh_{fan} = Qty_{std} \times \left(\frac{1}{Eff_{std}}\right) \times CFM \times hours \times \frac{1}{1{,}000} - Qty_{high} \times \left(\frac{1}{Eff_{high}}\right) \times CFM \times hours \times \frac{1}{1{,}000}$$

$$\Delta kWh_{tstat} = \left(\frac{1}{Eff_{installed}}\right) \times CFM \times hours_{tstat} \times \frac{1}{1{,}000}$$

$$\Delta kWh_{total} = \Delta kWh_{fan} + \Delta kWh_{tstat}$$

$$\Delta kW_{peak} = \Delta kWh_{fan} \times CF$$

[467] New York Standard Approach for Estimating Energy Savings from Energy Efficiency Measures in Commercial and Industrial Programs, September 1, 2009, based on DEER. http://www3.dps.ny.gov/W/PSCWeb.nsf/0/06f2fee55575bd8a852576e4006f9af7/$FILE/TechManualNYRevised10-15-10.pdf

DEFINITION OF TERMS

Table 4-3: Variables for Ventilation Fans

Term	Unit	Values	Source
Qty_{std}, Quantity of the standard efficiency fans	*None*	Based on customer application	EDC Data Gathering
Qty_{high}, Quantity of high efficiency fans that were installed	*None*	Based on customer application	EDC Data Gathering
Eff_{std}, Efficiency of the standard efficiency fan at a static pressure of 0.1 inches water	$\frac{cfm}{W}$	Based on customer application	EDC Data Gathering
		Default values in Table 4-4	1
Eff_{high}, Efficiency of the high efficiency fan at a static pressure of 0.1 inches water	$\frac{cfm}{W}$	Based on customer application.	EDC Data Gathering, 2, 3
		Default values in Table 4-4	1, 2, 3
$Eff_{installed}$, Efficiency at a static pressure of 0.1 inches water for the installed fans controlled by the thermostat	$\frac{cfm}{W}$	Based on customer application.	EDC Data Gathering, 2, 3
		Default values in 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
$hours$, operating hours per year of the fan without thermostat	*Hours*	Based on customer application	EDC Data Gathering
		Default use values in Table 4-5	1, 4
CFM, cubic feet per minute of air movement	$\frac{ft^3}{min}$	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
		Default values in Table 4-4	1
$hours_{tstat}$, reduction in operating hours of the fan due to the thermostat	*Hours*	Default values in Table 4-6	4
1,000, watts per kilowatt	$\frac{watts}{kilowatt}$	1,000	Conversion Factor
CF, demand coincidence factor	*Decimal*	0.000197	Engineering calculations

Table 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. 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. 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 house ventilation needs are based on humidity; therefore a thermostat will not reduce the number of hours the fans operate.

DEFAULT SAVINGS

There are no default savings for this measure.

Evaluation Protocols

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

Sources

1. KEMA. 2009 Evaluation of IPL Energy Efficiency Programs, Appendix F, 2008. See Table H-5. http://alliantenergy.com/wcm/groups/wcm_internet/@int/documents/document/mdaw/mdey/~edisp/012895.pdf
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
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 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.
4. Based on the methodology in KEMA's evaluation of the Alliant Energy Agriculture Program (Source 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.

4.1.4 Heat Reclaimers

Measure Name	Heat Reclaimers
Target Sector	Agriculture (includes Residential and Commercial)
Measure Unit	Heat Reclaimer
Unit Energy Savings	Variable
Unit Peak Demand Reduction	Variable
Measure Life	15 years[468]
Measure Vintage	Replace on Burnout or New Construction

Eligibility

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.

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, or Therma-Stor.

Algorithms

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:

$$\Delta kWh = \frac{ES}{\eta_{water\ heater}} \times DAYS \times COWS \times HEF$$

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

[468] State of Wisconsin. Focus on Energy Evaluation, Business Program: Measure Life Study Final Report: August 25, 2009. Appendix B. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf

Definition of Terms

Table 4-7: Variables for Heat Reclaimers

Term	Unit	Values	Source
ES , Energy savings for specified system	$\frac{kWh}{cow \cdot day}$	System with precooler: 0.29 System without precooler: 0.38	1,2
$DAYS$, Milking days per year	$\frac{days}{year}$	Based on customer application	EDC Data Gathering
		Default: 365	2
$COWS$, Average number of cows milked per day	*Cows*	Based on customer application	EDC Data Gathering
HEF, Heating element factor	*None*	Heat reclaimers with no back-up heat = 1.0 Heat reclaimers with back-up heating elements = 0.50	3
$\eta_{water\ heater}$, Electric water heater efficiency	*None*	Standard electric tank water heater = 0.908 High efficiency electric tank water heater = 0.93 Heat pump water heater = 2.0	4, 5
CF, Demand Coincidence factor	*Decimal*	0.00014	6

Default Savings

There are no default savings for this measure.

Evaluation Protocols

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

SOURCES

1. Based on 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 (temperature difference between the milk leaving the cow and the cooled milk in tank storage) 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 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. http://alliantenergy.com/wcm/groups/wcm_internet/@int/documents/document/mdaw/mdey/~edisp/012895.pdf
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 Conservation Code (IECC). High efficiency water heater based on water heater efficiencies defined in Table 3-85: COP Adjustment Factors of the TRM. https://law.resource.org/pub/us/code/ibr/icc.iecc.2009.pdf
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. 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.

4.1.5 HIGH VOLUME LOW SPEED FANS

Measure Name	High Volume Low Speed Fans
Target Sector	Agriculture (includes Residential and Commercial)
Measure Unit	Fan
Unit Energy Savings	Variable
Unit Peak Demand Reduction	Variable
Measure Life	15 years[469]
Measure Vintage	Replace on Burnout or New Construction

ELIGIBILITY

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.

This measure requires the installation of HVLS fans in either new construction or retrofit applications where conventional circulating fans are replaced.

ALGORITHMS

The annual energy and peak demand savings are obtained through the following formulas:

$$\Delta kW = \frac{(W_{conventional} - W_{hvls})}{1{,}000}$$

$$\Delta kWh = \Delta kW \times HOU$$

$$\Delta kW_{peak} = \Delta \mathrm{k}W \times CF$$

469 State of Wisconsin. Focus on Energy Evaluation, Business Program: Measure Life Study Final Report: August 25, 2009. Appendix B. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf

Definition of Terms

Table 4-8: Variables for HVLS Fans

Term	Unit	Values	Source
$W_{conventional}$, Wattage of the removed conventional fans	*W*	Based on customer application	EDC Data Gathering
		Default values in Table 4-9	1
W_{hvls}, Wattage of the installed HVLS fan	*W*	Based on customer application	EDC Data Gathering
		Default values in Table 4-4	1
HOU, annual hours of operation of the fans	*Hours*	Based on customer application	EDC Data Gathering
		Default values in Table 4-10	2
1000, conversion of watts to kilowatts	$\frac{watts}{kilowatts}$	1,000	Conversion Factor
CF, Demand coincidence factor	*Decimal*	1.0	2

Table 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. Default Hours by Location for Dairy/Poultry/Swine Applications

Location	$\frac{Hours}{year}$
Allentown	2,446
Erie	2,107
Harrisburg	2,717
Philadelphia	2,914
Pittsburgh	2,292
Scranton	2,145
Williamsport	2,371

Default Savings

There are no default savings for this measure.

Evaluation Protocols

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

Sources

1. KEMA. 2009 Evaluation of IPL Energy Efficiency Programs, Appendix F Group I Programs Volume 2. See Table H-17. http://alliantenergy.com/wcm/groups/wcm_internet/@int/documents/document/mdaw/mdey/~edisp/012895.pdf
2. Number of hours above 65 degrees Fahrenheit. Based on TMY3 data. The coincidence factor has been set at 1.0 as the SWE believes all hours during the peak window will be above 65 degrees Fahrenheit.

4.1.6 Livestock Waterer

Measure Name	Livestock Waterer
Target Sector	Agriculture (includes Residential and Commercial)
Measure Unit	Livestock Waterer System
Unit Energy Savings	Variable
Unit Peak Demand Reduction	0 kW
Measure Life	10 years[470]
Measure Vintage	Replace on Burnout or New Construction

Eligibility

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 watering containers that typically use super insulation, relatively warmer ground water temperatures, and the livestock's use of the waterer to keep water from freezing.

This measure requires the installation of an energy efficient livestock watering system that is thermostatically controlled and has a minimum of two inches of factory-installed insulation.

Algorithms

The annual energy savings are obtained through the following formula:

$$\Delta kWh \quad = QTY \times OPRHS \times ESW \times HRT$$

No demand savings are expected for this measure, as the energy savings occur during the winter months.

[470] State of Wisconsin. Focus on Energy Evaluation, Business Program: Measure Life Study Final Report: August 25, 2009. Appendix B. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf

Definition of Terms

Table 4-11: Variables for Livestock Waterers

Term	Unit	Values	Source
QTY, Number of livestock waterers installed	*None*	Based on customer application	EDC Data Gathering
$OPRHS$, Annual operating hours	*Hours*	Allentown = 1,489 Erie = 1,768 Harrisburg = 1,302 Philadelphia = 1,090 Pittsburgh = 1,360 Scranton = 1,718 Williamsport = 1,574	1
ESW, Change in connected load (deemed)	$\frac{Kilowatts}{waterer}$	0.50	2, 3, 4
HRT, % heater run time	*None*	80%	5

Default Savings

There are no default savings for this measure.

Evaluation Protocols

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

Sources

1. Based on 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 °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

4.1.7 Variable Speed Drive (VSD) Controller on Dairy Vacuum Pumps

Measure Name	VSD Controller on Dairy Pumps Vacuum Pumps
Target Sector	Agriculture (includes Residential and Commercial)
Measure Unit	Dairy Vacuum Pump VSD
Unit Energy Savings	Variable
Unit Peak Demand Reduction	Variable
Measure Life	15 years[471]
Measure Vintage	Retrofit or New Construction

Eligibility

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 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 they enable 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.

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.

Algorithms

The annual energy savings are obtained through the following formulae:

$$\Delta kWh = HP \times \frac{LF}{\eta_{motor}} \times ESF \times DHRS \times ADAYS$$

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

Coincidence Factor

An average of pre and post kW vacuum pump power meter data from five dairy farms in the Pacific Northwest[472] are used to create the vacuum pump demand load profile in Figure 4-1. 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.

[471] DEER Effective Useful Life. October 10, 2008.

[472] 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.

There are no seasonal variations in cow milking times, as dairy farms milk cows year round, so the load profile 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 ΔkWh savings for a 1 horsepower motor. The result is a coincidence factor equal to 0.00014.

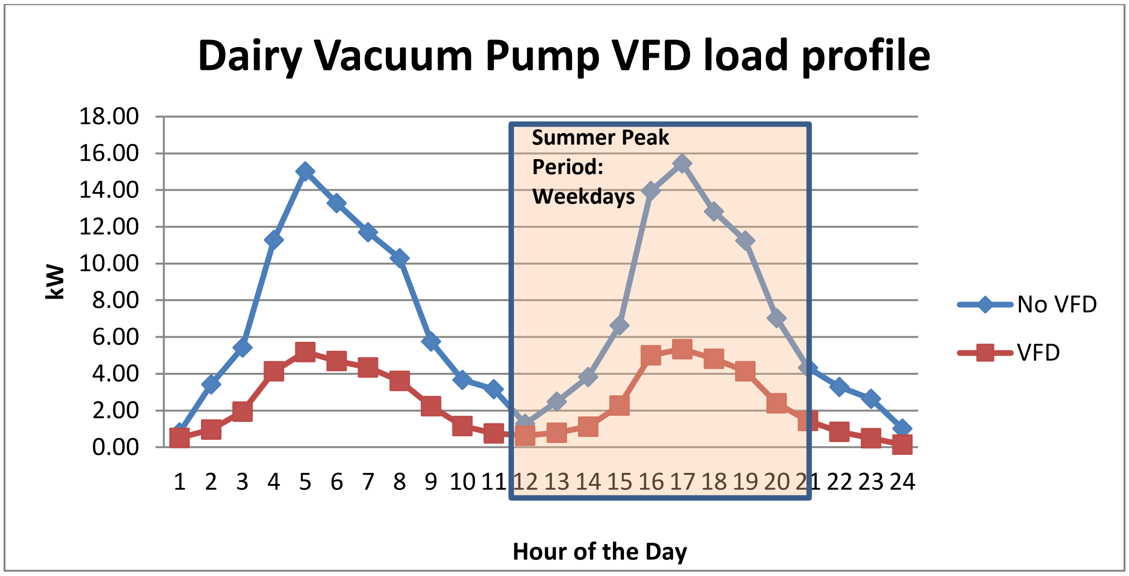

Figure 4-1: Typical Dairy Vacuum Pump Coincident Peak Demand Reduction

Definition of Terms

Table 4-12: Variables for VSD Controller on Dairy Vacuum Pump

Term	Unit	Values	Source
$Motor\ HP$, Rated horsepower of the motor	*HP*	Nameplate	EDC Data Gathering
LF, Load Factor. Ratio between the actual load and the rated load. The default value is 0.90	*None*	Based on spot metering and nameplate	EDC Data Gathering
		Default: 90%[473]	1
η_{motor}, Motor efficiency at the full-rated load. For VFD installations, this can be either an energy efficient motor or standard efficiency motor.	*None*	Nameplate	EDC Data Gathering
ESF, Energy Savings Factor. Percent of baseline energy consumption saved by installing VFD.	*None*	46%	2, 3
$DHRS$, Daily run hours of the motor	*Hours*	Based on customer application	EDC Data Gathering
		Default: 8 $\frac{hours}{day}$	2, 3
$ADAYS$, Annual operating days	*Days*	Based on customer application	EDC Data Gathering
		Default: 365 $\frac{days}{year}$	2, 3
CF, Demand Coincidence factor	*Decimal*	0.00014	3

Default Savings

There are no default savings for this measure.

Evaluation Protocols

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

473 Default Value can be used by EDC but is subject to metering and adjustment by evaluators or SWE

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. 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.

4.1.8 Low Pressure Irrigation System

Measure Name	Low Pressure Irrigation System
Target Sector	Agriculture and Golf Courses (includes Residential and Commercial)
Measure Unit	Irrigation System
Unit Energy Savings	Variable
Unit Peak Demand Reduction	Variable
Measure Life	5 years[474]
Measure Vintage	Replace on Burnout or New Construction

Eligibility

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.

This measure requires a minimum of 50% reduction in irrigation pumping pressure 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 or 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.

Algorithms

The annual energy savings are obtained through the following formulas:

Agriculture applications:

$$\Delta kWh = \frac{\{ACRES \times (PSI_{base} - PSI_{eff}) \times GPM1\}}{1{,}714\frac{gpm \cdot psi}{HP} \times \eta_{motor}} \times 0.746\frac{kW}{HP} \times OPRHS\frac{Irrigation\ Hours}{Growing\ Season}$$

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

474 DEER Effective Useful Life. October 10, 2008.

Golf Course applications:

$$\Delta kWh = \frac{\{(PSI_{base} - PSI_{eff}) \times GPM2\}}{1{,}714 \frac{gpm\ psi}{HP} \times \eta_{motor}} \times 0.746 \frac{kW}{HP} \times DHRS \times MONTHS \times 30 \frac{avg.days}{month}$$

No peak demand savings may be claimed for golf course applications as watering typically occurs during non-peak demand hours.

Definition of Terms

Table 4-13: Variables for Low Pressure Irrigation Systems

Term	Unit	Values	Source
$ACRES$, Number of acres irrigated	*Acres*	Based on customer application	EDC Data Gathering,1
PSI_{base}, Baseline pump pressure, must be measured and recorded prior to installing low-pressure irrigation equipment.	*Pounds per square inch (psi)*	Based on pre retrofit pressure measurements taken by the installer	EDC Data Gathering,1
PSI_{eff}, Installed pump pressure, must be measured and recorded after the installation of low-pressure irrigation equipment by the installer.	*Pounds per square inch (psi)*	Based on post retrofit pressure measurements taken by the installer	EDC Data Gathering,1
$GPM1$, Pump flow rate per acre for agriculture applications.	*Gallons per minute (gpm)*	Based on pre retrofit flow measurements taken by the installer	EDC Data Gathering,1
$GPM2$, Pump flow rate for pumping system for golf courses.	*Gallons per minute (gpm)*	Based on pre retrofit flow measurements taken by the installer	EDC Data Gathering,1
1714, Constant used to calculate hydraulic horsepower for conversion between horsepower and pressure and flow	*None*	$HP = \frac{PSI \times GPM}{1714}$	Conversion Factor
$OPHRS$, Average irrigation hours per growing season for agriculture	*Hours*	Based on customer application	EDC Data Gathering
$DHRS$, Hours of watering per day for golf courses	*Hours*	Based on customer application	EDC Data Gathering
$MONTHS$, Number of months of irrigation for golf courses	*Months*	Based on customer application	EDC Data Gathering
η_{motor}, Pump motor efficiency	*None*	Based on customer application	EDC Data Gathering
		Look up pump motor efficiency based on the pump nameplate horsepower (HP) from customer application and nominal efficiencies defined in Table 3-55	2

Term	Unit	Values	Source
CF, Demand coincidence factor for agriculture	*Decimal*	0.0026	3, 4

Default Savings

There are no default savings for this measure.

Evaluation Protocols

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

Sources

1. Based on Alliant Energy program evaluation assumptions for low-flow pressure irrigation systems. Evaluation of Alliant Energy Agriculture Program, Appendix F, 2008. http://alliantenergy.com/wcm/groups/wcm_internet/@int/documents/document/mdaw/mdey/~edisp/012895.pdf
2. Table 3-55 contains federal motor efficiency values by motor size and type. If existing motor nameplate data is not available, these tables will be used to establish motor efficiencies. The CF was only estimated for agricultural applications, and was determined by using the following formula $CF = \frac{\Delta kW\ savings\ per\ acre}{\frac{\Delta kWh}{yr}savings\ per\ acre}$.
3. Pennsylvania census data was used to estimate an average ΔkW savings/acre and ΔkWh/yr/savings/acre value. Pamela Kanagy. Farm and Ranch Irrigation. Pennsylvania Agricultural Statistics 2009-2010. http://www.nass.usda.gov/Statistics_by_State/Pennsylvania/Publications/Annual_Statistical_Bulletin/2009_2010/fris.pdf
4. Irrigation Water Withdrawals, 2000 by the U.S. Geological Society. http://pubs.usgs.gov/circ/2004/circ1268/htdocs/table07.html

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5 APPENDICES

5.1 APPENDIX A: MEASURE LIVES

Measure Lives Used in Cost-Effectiveness Screening
August 2014

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

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

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

ENERGY STAR Printer	5
ENERGY STAR Copier	6
Building Shell End-Use	
Ceiling / Attic and Wall Insulation	15
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*
Home Audit Conservation Kits	8.1
Home Performance with ENERGY STAR	5
Miscellaneous	
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 Fixture Improvements	13
New Construction Lighting	15
Lighting Controls	8
Traffic Lights	10
LED Exit Signs	16*
LED Channel Signage	15
LED Refrigeration Case Lighting	8
HVAC End-Use	
HVAC Systems —	15
Electric Chillers —	20*
Water Source and Geothermal Heat Pumps	15
Ductless Mini-Split Heat Pumps - Commercial < 5.4 tons	15
Commercial Chiller Optimization	18*
Fuel Switching: Small Commercial Electric Heat to Natural Gas/ Propane/ Oil Heat	20*
Small C/I HVAC Refrigerant Charge Correction	10
ENERGY STAR Room Air Conditioner	12
Controls: Guest Room Occupancy Sensor	15
Controls: Economizer	10
Motors & VFDs End-Use	
Premium Efficiency Motors —	15

Variable Frequency Drive (VFD) Improvements —	13
Variable Frequency Drive (VFD) Improvement for Industrial Air Compressors	20*
ECM Circulating Fan	18
VSD on Kitchen Exhaust Fan	15
Domestic 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: Electric Resistance Water Heaters to Gas or Propane Water Heater	13
Fuel Switching: Electric Resistance Water Heaters 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	
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
–Controls: Evaporator Fan Controllers	10
–Controls: Floating Head Pressure Controls	15
Controls: Anti-Sweat Heater Controls	12
Controls: Evaporator Coil Defrost Control	10
–Variable Speed Refrigeration Compressor	15
Strip Curtains for Walk-In Freezers and Coolers	4
Night Covers for Display Cases	5
Auto Closers	8
Door Gaskets for Walk-in and Reach-in Coolers and Freezers	4
Special Doors with Low or No Anti-Sweat Heat for Low Temp Case	15
Suction Pipes Insulation for Walk-in Coolers and Freezers	11
Appliances End-Use	
ENERGY STAR Clothes Washer Multifamily	11.3
ENERGY STAR Clothes Washer Laundromats	7.1
Food Service Equipment End-Use	
High-Efficiency Ice Machines	10
Controls: Beverage Machine Controls	5
Controls: Snack Machine Controls	5

ENERGY STAR Electric Steam Cooker	12
ENERGY STAR Refrigerated Beverage Vending Machine	14
Building Shell End-Use	
Wall and Ceiling Insulation	15
Consumer 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
Compressed Air	
Cycling Refrigerated Thermal Mass Dryer	10
Air-entraining Air Nozzle	15
No-Loss Condensate Drains	5
Miscellaneous	
Commercial Comprehensive New Construction Design	18*
O&M Savings	3
ENERGY STAR Servers	4
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

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: Website Link TBD.

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: Website Link TBD.

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: Website Link TBD.

5.6 Appendix F: Eligibility Requirements for Solid State Lighting Products in Commercial and Industrial Applications

The SSL market 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 diversity of product technologies 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.

All SSL products must be submitted for three tests before they can be distributed. The In Situ Temperature Measurement Test (ISTMT) measures the LED source case temperature within the LED system while it is operating in its designed position and environment. The LM-79 test measures the electrical and photometric details of an SSL product including the total luminous flux, luminous intensity distribution, electrical power, efficacy, and color characteristics. The LM-80 test measures the lumen maintenance of a product to determine the point at which the light emitted from an LED depreciates to a level where it is no longer considered adequate for a specific application.

ENERGY STAR (a standard developed by the Environmental Protection Agency and the Department of Energy) and the Design Lights Consortium (a project developed by the Northeast Energy Efficiency Partnership) both provide "Qualified Products Lists" for consumer use in selecting the most efficient equipment. Both standards set minimum requirements for all categories tested under ISTMT, LM-79, and LM-80 tests. Besides meeting the minimum requirements, both standards also require that the testing be done at a testing facility approved by the standard's governing agency.

For Act 129 energy efficiency measure saving qualification, products must meet the minimum requirements of either agency. Products found on the Qualified Products List[475] set by either agency can be submitted for Act 129 energy efficiency programs with no additional supporting information. Products meeting the minimum requirements but not listed 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)

[475] ENERGY STAR®'s "Qualified Products List" can be found at http://www.energystar.gov/productfinder/product/certified-light-bulbs/results. The Design Lights Consortium's "Qualified Products List" can be found at https://www.designlights.org/qpl.

- 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
15005	Pittsburgh
15006	Pittsburgh
15007	Pittsburgh
15009	Pittsburgh
15010	Pittsburgh
15012	Pittsburgh
15014	Pittsburgh
15015	Pittsburgh
15017	Pittsburgh
15018	Pittsburgh
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15042	Pittsburgh
15043	Pittsburgh
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15054	Pittsburgh

Zip	Reference City
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15062	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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