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Connecticut Program Savings Documentation

for 2012 Program Year

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Table of Contents

INTRODUCTION

1.1 PURPOSE

This Program Savings Documentation (PSD) manual provides detailed, comprehensive documentation of all claimed resource savings corresponding to the Energy Efficiency Fund program and individual Conservation and Load Management (C&LM) program technologies. The PSD manual fulfills the former CT Department of Public Utility Control's (DPUC's) requirement to develop a Technical Reference Manual (Docket NO. 03-11-01PH02, DPUC Review of CL&P and UI Conservation and Load Management Plan for Year 2004 – Phase II, July 28, 2004). Savings calculations detailed in this document are used by The Connecticut Light and Power Company, The United Illuminating Company, Yankee Gas Services Company, Connecticut Natural Gas Corporation and The Southern Connecticut Gas Company, hereinafter referred to as the "Companies."

The Companies have worked together during the past several years to develop common engineering assumptions regarding measured savings for all types of energy-efficient measures. This manual is a compilation of those efforts. In addition, the results of program impact evaluations have been incorporated by the Program Administrators. As a result, all C&LM savings claims will be traceable through cross-references to this manual. The manual is reviewed annually and updated to reflect changes in technology, baselines, measured savings, evaluation work, and impact factors.

The C&LM savings calculations in this manual represent typical measures and the prescriptive calculations used for those measures. In some cases, projects are more comprehensive and prescriptive measure calculations are not appropriate. To accurately calculate the savings related to these types of projects, more detailed spreadsheets or computer simulation models (DOE-2, Trace, HAP) must be used. Third-party engineering consultants may be contracted to run simulations and create these spreadsheets; all simulations and spreadsheets are reviewed for reasonableness.

Legislative Imperative:

Public Act 05-01, June (2005) Special Session, "An Act Concerning Energy Independence" (the "Act") established a Class III portfolio standard requirement for electric suppliers and electric distribution companies. Following the passage of the Act, the DPUC held a proceeding to develop Class III Renewable Energy Credit standards (Docket NO. 05-07-19, DPUC Proceeding to Develop a New Distributed Resource Portfolio Standard (Class III)). Based on the DPUC Final Decision in that Docket, the Energy Efficiency Fund program and C&LM's technical reference manual must be used as the basis to calculate energy efficiency savings for both C&LM and non-C&LM measures that qualify for Class III credits. As a result, C&LM and non-C&LM measure savings will be determined using the same baseline and parameters. The exception is that non-C&LM funded projects shall not incorporate free-ridership and spillover because these factors are specific to C&LM program savings, however, other impact factors (i.e., other realization rates) that are part of the energy savings calculations and methodologies must be incorporated into non-C&LM savings calculations.

In June 2006, FERC approved a settlement that establishes a redesigned wholesale electric capacity market in New England intended to encourage the maintenance of current power plants and construction of new generation facilities. The settlement established a Forward Capacity Market ("FCM"). ISO New England, Inc., operator of the region's bulk power system and wholesale electricity markets, will project the energy needs of the region three years in advance and then hold an annual auction to purchase power resources to satisfy the region's future needs.

In response to ISO-NE solicitation for proposals for the first Forward Capacity Auction, ("FCA1"), CL&P and UI submitted new demand side resource projects, including energy efficiency, that will decrease electric demand and use. Per ISO-NE requirements, detailed Project Qualification Packages that include Measurement and Verification Plans ("M&V") were submitted. The purpose of ISO-NE's required M&V activity is to verify that energy efficiency measures promoted by the programs were actually installed, are still in place and functioning as intended, and to validate the reduction in electrical demand compared to some baseline pattern of use. The CL&P and UI PSD, this document, serves as the basis of the demand reduction value calculations that will be submitted in the FCM.

1.2 ORGANIZATION

C&LM measures in this manual are grouped by primary sector and reflect how programs and measures are organized within C&LM. Commercial and industrial measures are also categorized as either "Lost Opportunity" or "Retrofit." The main sections of the manual are as follows:

- Introduction
- Section 2: Commercial & Industrial Lost Opportunity
- Section 3: Commercial & Industrial Retrofit
- Section 4: Residential including Limited Income
- Appendices

1.3 BACKGROUND

In 1999, the State Legislature created the Energy Conservation Management Board, now called the Energy Efficiency Board ("EEB"), to guide and assist Connecticut's electric and gas distribution companies in the development and implementation of cost-effective energy conservation programs and market transformation initiatives (CGS § 16-245m). The Connecticut Energy Efficiency Fund ("CEEF") created by this legislation provides the financial support for EEB-guided programs and initiatives. The Department of Energy and Environmental Protection ("DEEP") is responsible for final approval of all Energy Efficiency Fund programs. Energy Efficiency Fund programs are administrated by the Conservation and Load Management ("C&LM") divisions of The Connecticut Light and Power Company ("CL&P") and The United Illuminating Company ("UI"). These programs are designed to realize the Energy Efficiency Fund's three primary objectives:

1. Advance the Efficient Use of Energy

Energy Efficiency Fund programs are critical in reducing overall energy consumption and reducing load during periods of high demand. They help mitigate potential electricity shortages and reduce stress on transmission and distribution lines in the State.

2. Reduce Air Pollution and Negative Environmental Impacts

Energy Efficiency Fund programs produce environmental benefits by slowing the electricity demand growth rate, thereby avoiding emissions that would otherwise be produced by increased power generation activities. The Environmental Protection Agency regulates "criteria" air pollutants under the Clean Air Act's National Ambient Air Quality Standards ("NAAQSs"). The EPA calls these pollutants "criteria" air pollutants because it regulates them by developing human health-based and/or environmentally-based criteria (science-based guidelines) for setting permissible levels. Energy Efficiency Fund programs have significantly reduced two NAAQS criteria pollutants emitted in the process of generating electricity: sulfur dioxide and nitrogen oxides. Carbon dioxide and other "greenhouse gases," such as methane, are also emitted during the process. Greenhouse gases have been linked to global warming and climate change. Energy Efficiency Fund programs have helped reduce carbon dioxide emissions by reducing electrical demand, and consequently the need for additional generation, through energy efficiency and conservation. These programs also produce environmental benefits by reducing the consumption of natural gas and fuel oil. With assistance from the EEB, the Energy Efficiency Fund programs developed by the Companies support the State's environmental initiatives to reduce these air pollutants as well as fine particulate emissions and ozone.

3. **Promote Economic Development and Energy Security**

Energy Efficiency Fund programs generate considerable benefits for Connecticut customers. These programs are tailored to meet the particular needs of all customers, thereby benefiting all State residents and businesses. Energy efficiency measures assist residential customers in reducing their energy costs. Other groups that benefit from energy efficiency programs include educational institutions, non-profit organizations, municipalities, and businesses. By reducing operating costs and enhancing productivity, Connecticut businesses remain competitive in the dynamic global economy.

Information regarding Energy Efficiency Fund programs is available at:

Connecticut's statewide energy information portal:	www.ctenergyinfo.com
The Connecticut Light and Power Company:	www.cl-p.com
The United Illuminating Company:	www.uinet.com
Connecticut Natural Gas Corporation:	www.cngcorp.com

Version Date: 9/26/2011

Southern Connecticut Gas Company:	www.soconngas.com
Yankee Gas Services Company:	www.yankeegas.com
Energy Efficiency Fund program hot line (CL&P and UI):	1-877-WISE USE
The Energy Efficiency Board:	http://www.ctsavesenergy.org/ecmb/

Organization

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- Section 4: Residential including Limited Income
- Section 5: Changes to the PSD from 2011
- Appendices

Each individual measure is divided into several or all of the following subsections:

- Description of Measure
- Savings Methodology
- Inputs
- Nomenclature
- Retrofit Gross Energy Savings – Electric
- Retrofit Gross Energy Savings – Fossil Fuel
- Retrofit Gross Seasonal Peak Demand Savings – Electric, Winter and Summer
- Retrofit Gross Peak Day Savings – Natural Gas
- Lost Opportunity Gross Energy Savings – Electric
- Lost Opportunity Gross Energy Savings – Fossil Fuel
- Lost Opportunity Gross Seasonal Peak Demand Savings – Electric, Winter and Summer
- Lost Opportunity Gross Peak Day Savings – Natural Gas
- Non-Energy Benefits
- Changes from Last Version
- References

Subsections that do not apply to a particular measure, or for which complete information is unavailable, are not included.

1.4 SAVINGS CALCULATIONS

The savings results presented in this manual (both electric and non-electric) are assumed to be the savings that would be measured at the point of use. In other words, electric savings, both energy (kWh) and demand (kW), and natural gas savings (Ccf) are savings that would occur at the customer's meter. Line losses are not included in the savings values presented here. Instead, line loss effects are captured within the screening model that the Companies use to evaluate the benefits of energy efficiency programs (Refer to Chapter 6, *Cost Benefit Analysis*, for detail on C&LM Program screening). Additionally, the annual electric savings from measures has a specified load shape (i.e., the time of day and seasonal patterns at which savings occur). See Appendix 2 for load shapes for various end-use savings. The load shapes are used to properly assign the value of energy savings resulting from the implementation of C&LM measures to the corresponding time of day when those savings are realized.

The values for electric demand savings (both winter and summer) in this manual are given based on the following definition:

- A “Seasonal Peak” reduction is based on the average peak reduction for a measure during the ISO New England definition for a Seasonal Peak Demand Resource – when the real-time system hourly load is equal to or greater than 90 percent of the most recent “50/50” system peak load forecast for the applicable summer or winter season.
- The “Summer Season” is defined as non-holiday weekdays during the months of June, July and August.
- The “Winter Season” is defined as non-holiday weekdays during December and January.

Typically, seasonal peaks are weather driven and occur in the mid-afternoon on summer weekdays, or for winter, in the early evening.

Electric peak demand savings can be calculated either on a measure-by-measure basis or on a default basis. Coincidence factors can be used to calculate demand savings based on the annual savings and load shape of the measure. Coincidence factors are multiplied by the connected load savings of the measure in order to obtain the peak demand savings. See Appendix 1 for a list of default coincidence factors that are used to calculate the peak demand savings.

For natural gas measures, the peak savings represents the estimated savings coincident with the theoretical maximum system usage in a twenty four hour period. Since the natural gas peak is driven by cold weather, the peak savings for heating related measures is estimated based on degree-day data and the estimated coldest 24 hour degree period. For measures that save natural gas continuously at an equal rate throughout the year, the peak savings is assumed to be the annual savings divided by 365. The calculations for peak natural gas savings are found in Appendix 1.

In addition to electric and natural gas benefits, some measures have other non-electric benefits. Where appropriate, these benefits (or “impacts” since they can also be negative) are defined in this manual. Non-electric, non-natural gas impacts may include quantifiable changes in other fossil fuel consumption, water use, maintenance costs, productivity improvements, replacement costs, etc. Non-electric benefits are not included in the Electric System test, as they are captured in the Total Resource Cost Test.

Energy conversions used in this document to convert energy to a specific fuel type are summarized in the following table:

To Obtain:	**Multiply :**	**By:**
BTU	MMBTU	1,000,000
Ccf* Of Gas	MMBTU	1/0.1029
Gal Of Oil (No. 2)*	MMBTU	1/0.138690
Gal Of Propane*	MMBTU	1/0.09133
kWh* Electric	BTU	1/3412
Ton (air conditioning)	BTU/h	1/12000

The savings for the measures defined in this manual are gross savings. Impact factors are applied to the gross savings to calculate the net (final) savings. Gross energy savings estimates (based on known technical parameters) represents the first step in calculating energy savings. Gross savings calculations are based on engineering algorithms or modeling that take into account technically important factors such as hours of use, differences in efficiency, differences in power consumption, etc.

When calculating the total impact of energy saving measures, there are also some other factors beyond the engineering parameters that need to be considered, such as the market effects of free-ridership, spillover or installation rate. The equation for net savings is as follows:

Net Savings = Gross Savings x (1 + spillover – free-ridership) x Installation Rate

In some cases, evaluation work may uncover differences between calculated savings and actual (metered) savings that may not be completely attributable to the impact factors above. These differences may arise when the savings calculations do not accurately capture the real savings attributable to a measure. In addition to the impact factors above, savings differences can happen for a variety of reasons such as non-standard usage patterns or operating conditions. In these cases, overall net-to-gross ratios (realization rates) may be used in addition to or instead of the aforementioned impact factors to bring the observed savings values more in line with the original savings calculations.

For instance, a billing analysis may show observed savings from a refrigerator removal program to be 60 percent of the gross (calculated) savings. In this case, the differences may be attributable to a combination of factors including refrigerators that are not being used, free-ridership, units being improperly used (e.g., the refrigerator door left open for long periods of time), and units that exhibit lower energy use because they are operating in cooler basement environments. In such a case, a 60 percent realization rate would be applied to the gross (calculated) energy savings to correct it.

Realization rates can be applied to specific measures or across programs depending on their source. Since commercial and industrial ("C&I") programs typically offer a wide range of diverse measures, defining specific impact factors for C&I programs can be difficult, and therefore program specific realization rates are usually limited to C&I programs. Table 1.3 contains a list of program specific realization rates. These rates have been updated from 2010 based on recent completed studies. Realization rates are no longer included in the description of each individual measure.

1.5 MAJOR CHANGES FROM 2011

The following changes have been made:

- Chapter 3 (C&I Retrofit) and Chapter 4 (Small Business Energy Advantage) were combined into a single Chapter 3 (C&I retrofit).
- A new formatting style was adopted which identifies the key variables that are required to calculate the savings for each measure. Specifically, each measure has:
    1. An "Inputs" section which identifies all the data that must be collected for measures. This enhancement provides a data collection check for users and improves the usability of the PSD for Program Administrators.
    2. A "Nomenclature" section to identify and define key abbreviations and variables.
    3. A brief highlight of changes from the previous version.

1.6 GLOSSARY

The glossary provides definitions of the energy conservation terms used in this PSD. Note that some of these terms may have alternative or multiple definitions some of which may be outside the context of the manual. Only definitions pertaining to this manual are included in the glossary.

Annual Fuel Utilization Factor (AFUE): The seasonal rating of a fossil fuel heating unit (furnace, boiler). The rating is calculated based on specific standard conditions based equipment type.

ASHRAE: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., an international technical society in the fields of heating, ventilation, air conditioning, and refrigeration, known for writing the industry standards for testing and practice.

Baseline Efficiency: C&LM program savings are calculated from this efficiency value. It represents the value of efficiency of the equipment that would have been installed without any influence from the program. *Contrast compliance efficiency.*

Baseline Standard: The source or document that provides the Baseline Efficiency values, or a means to calculate these values. In many cases, the baseline efficiency is the minimum efficiency required by codes and standards, such as the Connecticut Energy Code.

Behavioral Efficiency: Strategies that are incorporated to influence a customer to 1) implement more efficiency measures than what they would typically do or 2) influence them to change their business operations in order to save energy.

Benefit-cost ratio (“BCR”): The efficiency programs determine cost effectiveness using either the Utility Cost Test (Electric System, Natural Gas System) or Total Resource Test. Energy efficiency efforts are cost-effective if the benefit-cost ratio is greater than or equal to 1.0. *See Electric System Test, Natural Gas System Test, & Total Resource Test.*

BTU: British Thermal Unit. The amount of energy needed to heat one pound of water one degree Fahrenheit (from 39°F to 40°F).

Capacity: The maximum output of equipment at the standard conditions for the specific type of equipment. These are often given in units of Btu per hr or Tons.

Coefficient of Performance (COP): The efficiency rating of heating or cooling equipment. The COP is, at specific standard conditions, based on the specific type of equipment. Typically used for heat pumps in heating mode and gas driven chillers.

Compact fluorescent lamp (CFL): General service CFL's are defined as standard base bulbs that are intended for general service applications as specified in the Energy Independence and Security Act of 2007. The term ‘general service incandescent lamp’ means a standard incandescent or halogen type lamp that is intended for general service applications, has a medium screw base, has a lumen range of not less than 310 lumens and not more than 2,600 lumens, and is capable of being operated at a voltage range at least partially within 110 and 130 volts.

Non-general service CFL applications are excluded from the Energy Independence and Security Act of 2007. There are many applications that are excluded. However, the applications that apply to the bulbs in the CEEF programs are:

- Reflector bulbs
- 3-way bulbs
- Candelabra based bulbs
- Dimmable bulbs
- G type (globe) bulbs

Coincident Demand: Demand of a measure that occurs at the same time as some other peak (building peak, system peak, etc.). In the context of this document, coincident demand is a measure of demand savings that is coincident with ISO New England’s Seasonal Peak definition.

Coincidence Factor: Coincidence factors represent the fraction of connected load expected to occur at the same time as a particular system peak period on a diversified basis. Coincidence factors are normally expressed as a percent.

Compliance Efficiency: This efficiency value must be achieved in order to qualify for a C&LM program incentive. *Contrast baseline efficiency.*

Compliance Standard: The source or document that provides the Compliance Efficiency values, or a means to calculate these values. In many cases the compliance efficiency is based on standards from recognized programs such as ENERGY STAR®.

Connected Load: The maximum power required by the equipment, usually expressed as kW.

Cooling Degree Days (CDD): A measure of how hot a location is over a base temperature of 65°F over a year. *See also Degree Days*.

Degree Days - For any individual day, degree days indicate how far that day's average temperature departed from 65°F. Heating Degree Days (HDD) measure heating energy demand and indicate how far the average temperature fell below 65°F. Similarly, Cooling Degree Days (CDD), which measure cooling energy demand, indicate how far the temperature averaged above 65°F. In both cases, smaller values represent less fuel demand, but values below 0 are set equal to 0, because energy demand cannot be negative. Furthermore, since energy demand is cumulative, degree day totals for periods exceeding 1 day are simply the sum of each individual day's degree day total. For example, if a location has a mean temperature of 60°F on day 1 and 80°F on day 2, there would be 5 HDDs for day 1 (65 minus 60) and 0 for day 2 (65 minus 80, set to 0). For the day 1 + day 2 period, the HDD total would be 5 + 0 = 5. In contrast, there would be 0 CDDs for day 1 (since 60 is less than 65), 15 CDDs for day 2 (80 minus 65), resulting in a 2-day CDD total of 0 + 15 = 15.

Demand: The average electric power requirement (load) during a time period. Demand is measured in kW and the time period is usually one hour. If the time period is different than one hour, i.e., 15 minutes, the time period would be stated as "15-minute demand." Demand can refer to an individual customer's load or to the load of an entire electric system. (*See Peak Demand).*

Demand Reduction, Demand Savings: The reduction in demand due to installation of an energy efficiency measure usually expressed as kW and measured at the customer's meter. *See discussion under Peak Demand Savings.*

Demand Resources: ISO New England classifies demand reduction from energy efficiency and conservation measures into the following two categories:

- Active Resource – Demand reduction that is dispatched (i.e., demand response and emergency generation) that must respond to the electric system operator during shortage events. For example, resources entered into the ISO Demand Response Program are active resources because they are called upon for specific shortage events.
- Passive Resource – Demand reduction that is not dispatched (i.e., energy efficiency, plus a small amount of distributive generation) that reduces load during pre-defined hours and periods. Most C&LM measures are passive because they reduce load across a pre-defined operating period. For example, energy-efficient lighting will reduce load whenever lights are on throughout the year.

Diversity Factor: See Coincidence Factor.

Demand Reduction-Induced Price Effects (DRIPE): The reduction in prices in the wholesale energy and capacity markets because of the reduction in energy and demand.

Early Retirement: A measure is classified as early retirement when the participant replaces working equipment before the end of its useful life.

Electric System (benefit-cost ratio) Test: Defined as the present value of the avoided electric costs (including energy, capacity, DRIPE, transmission and distribution) divided by the costs of achieving the savings. The electric system test is the primary evaluation tool used to screen electric measures and programs in Connecticut. Energy efficiency efforts are cost-effective if the benefit-cost ratio is greater than or equal to 1.0.

End Use: Refers to a category of measures with similar load shapes. There are several different acceptable industry standards for defining end-use categories. For the purpose of this manual, end uses are cooling, heating, lighting, refrigeration, water heating, motors, process, and others.

Energy Conservation: Reducing energy usage by doing without.

Energy Efficiency: Reducing energy usage without reducing performance.

Energy Efficiency Ratio (EER): The performance rating of electrically operated cooling equipment. The rating is calculated based on specific standard conditions based equipment type.

Equivalent Full Load Hours ("EFLH"): The number of hours per year that the equipment would need to draw power at its connected (full) load rating in order to consume its estimated annual kWh. It is calculated as annual kWh/connected kW. EFLH is the same as operating hours for technologies that are either on or off, such as light bulbs; EFLH is less than operating hours for technologies that operate at part load for some of the time, such as air conditioners and motors.

Evaluation Study: Studies that evaluate program impacts, free-ridership, and spillover, as well as processes, specific measures and market assessments. Results of these studies are used by program administrators to modify the programs and savings estimates.

Free-Rider: A program participant who would have installed or implemented an energy efficiency measure even in the absence of program marketing or incentives.

Free-ridership: The fraction (usually expressed as a percent) of gross program savings that would have occurred even in the absence of a C&LM program.

Gross Savings: A savings estimate, calculated from objective technical factors. The gross savings do not include impact factors.

Heating Degree Days (HDD): A measure of how cold a location is over a base temperature of 65°F over a year. (*See also Degree Days)*.

Heating Seasonal Performance Factor (HSPF) - A measure of a heat pump's energy efficiency over one heating season. It represents the total heating output of a heat pump (including supplementary electric heat) during the normal heating season (in Btus) compared to the total electricity consumed (in watt-hours) during the same period. The higher the rating, the more efficient the heat pump.

High Efficiency: High efficiency equipment uses less energy than standard equipment.

Impact Evaluation: A study that assesses the energy, demand, and non-electric benefits associated with energy efficiency measures or programs.

Impact Factor: A number (usually expressed as a percent) used to adjust the gross savings in order to reflect the savings observed by an impact study. Examples of impact factors include free-ridership, spillover and installation rate.

Installation Rate: The fraction of the recorded products that are installed. For example, some screw-in compact fluorescent lamps are bought as spares, and will not be installed until another one burns out.

Lighting Power Density (LPD): The amount of electrical power required for the installed lighting in a building space or in an entire building, expressed as watts per square foot.

Load Factor: The average fractional load at which the equipment runs. It is calculated as average load/connected load.

Load Shape: The time-of-use pattern of a customer's energy consumption or measure. Load shape can be defined as hourly and/or seasonally (winter/summer).

Lost Opportunity: Refers to the new installation of an enduring unit of equipment (in the case of new construction) or the replacement of an enduring unit of equipment at the end of its useful life. An enduring unit of equipment is one that would normally be maintained, not replaced, until the end of its life. *Contrast "retrofit"*

Market Effect: A change in the behavior of a market because of conservation and energy efficiency efforts. "Market effect savings" are the result of changes in market behaviors.

MBTU or mmBTU: Millions of British Thermal Units.

Measure: A product (a piece of equipment) or a process that is designed to provide energy or demand savings. Measure can also refer to a service or a practice that provides savings.

Measure Cost: For new construction or measures that are installed at their natural time of replacement (replace upon burn-out), measure cost is defined as the incremental cost of upgrading to high efficiency. For retrofit measures, measure cost is defined as the full cost of the measure. Measure cost refers to the true cost of the measure regardless of whether an incentive was paid for that measure.

Measure Lifetimes: This is the average number of years (or hours) that a group of new high efficiency equipment will continue to produce energy savings or the average number of years that a service or practice will provide savings. Lifetimes are generally based on experience or studies. For retrofit or early retirement measures, the measure lifetime may include a change in baseline over time, more accurately reflecting the lifetime energy savings.

Measure Type: Refers to a category of similar measures. There are several different acceptable industry standards for defining end-use categories. For the purpose of this manual, end-use categories are Lighting, HVAC, Motors, VFD (variable frequency drives), Refrigeration, Products & Services, Envelope, Renewable, and Other.

Natural Gas System (benefit-cost ratio) Test: A ratio used to assess the effectiveness of energy efficiency efforts on the natural gas system. The natural gas system test is defined as the present value of the avoided natural gas costs divided by the program-related costs of achieving the savings. The Natural Gas System test is the primary evaluation tool used to screen natural gas measures and programs in Connecticut. Energy efficiency efforts are cost-effective if the benefit-cost ratio is greater than or equal to 1.0.

Net Savings: The final value of savings that is attributable to a program or measure. Net savings differs from "gross savings" because it includes adjustments from impact factors such as free-ridership or spillover. Net savings is sometimes referred to as "verified savings" or "final savings."

Net-to-Gross: The ratio of net savings to the gross savings (for a measure or program). Net-to-gross is usually expressed as a percent.

Non-Electric Benefits: Quantifiable benefits (beyond electric savings) that are the result of the installation of a measure. Fossil fuel, water, maintenance, and increase in productivity are examples of non-electric benefits. Non-electric benefits can be negative (i.e., increased maintenance or increased fossil fuel usage which results from a measure) and therefore are sometimes referred to as non-electric impacts. This may also include non-quantifiable benefits that are difficult or impossible to put a number on, such as increased comfort.

Non-Participant: A customer who is eligible to participate in a program, but does not. A non-participant may install a measure because they became aware of the benefits through program marketing or outreach, but the installation of the measure is not through regular program channels. As a result, their actions are normally only detected through evaluations (see spillover).

Operating Hours: The annual amount of time, in hours, that the equipment is expected to operate. *Contrast Equivalent Full Load Hours.*

Participant: A customer who installs a measure through regular program channels and receives any benefit (i.e., incentive) that is available through the program because of his participation. Free-riders are a subset of this group.

Peak Day Factor: Multipliers that are used to calculate peak day reductions based on annual gas energy savings. The unit of the peak day factor is percentage.

Peak Day, Gas: The one day (24 hours) of maximum system deliveries of gas during a year.

Peak Demand: The highest electric demand in a given period of time that is usually expressed in kW.

Peak Demand Savings: The kW demand reduction that occurs in the peak hours. The peak demand savings is usually determined by multiplying the demand reduction attributed to the measure by the appropriate seasonal or on-peak coincidence factor. There is both a summer peak and a winter peak. Coincidence factors for different measures for each peak are shown in Appendix 1. Two peak periods are used:

- **Seasonal Peak Hours** are those hours in which the actual, real-time hourly load Monday through Friday on non-holidays, during the months of June, July, August, December, and January, as determined by the ISO, is equal to or greater than 90 percent of the most recent 50/50 system peak load forecast, as determined by the ISO, for the applicable summer or winter season.
- **On-Peak Hours** are hours 1:00 - 5:00 p.m., Monday through Friday on non-holidays during the months of June, July, and August and from 5:00 - 7:00 p.m., Monday through Friday on non-holidays during the months of December and January.

The Seasonal Peak demand savings are used in the C&LM programs. *See also Coincidence Factor, Demand Savings.*

Peak Factor: Multipliers that are used to calculate peak demand reductions for measures based on the annual electric energy savings of the measure. The units of peak factors are W/kWh based on end use.

Realization of Savings: The ratio of actual measure savings to gross measure savings (sometimes referred to as the “realization rate”). This ratio takes into account impact factors that can influence the actual savings of a program such as spillover, free-ridership, etc.

Retrofit: The replacement of a piece of equipment or device before the end of its useful or planned life for the purpose of achieving energy savings. “Retrofit” measures are sometimes referred to as “early retirement” when the removal of the old equipment is aggressively pursued. *Contrast “Lost Opportunity.”*

R-Value: A measure of thermal resistance of a material or system, equal to the reciprocal of the U-Value, used to calculate heat gain or loss. The R-Value is expressed in terms of degrees Fahrenheit multiplied by hours, multiplied by square feet per Btu.

Seasonal Energy Efficiency Ratio (SEER): The total cooling output of a central air conditioning unit in Btus during its normal usage period for cooling divided by the total electrical energy input in watt-hours during the same period, as determined using specified federal test procedures.

Sector: A system for grouping customers with similar characteristics. For the purpose of this manual, the sectors are Commercial and Industrial (“C&I”), Small Business (“SMB”), Residential, Non-Limited Income (“NLI”) and Limited Income (“LI”).

Spillover: Savings attributable to a program, but additional to the gross (tracked) savings of a program. Spillover includes the effects of: (a) participants who install additional energy-efficient measures as a result of what they learned in the program; or (b) non-participants who install or influence the installation of energy efficient measures as a result of being aware of the program.

Summer Demand Savings: Refers to the demand savings that occur during the summer peak period. *See discussion under Peak Demand Savings.*

Total Resource (Benefit/Cost) Test: A test used to assess the net benefit of energy efficiency resources to society. The total resource test is different from the electric system test in that the total resource benefit consists of the avoided costs of all conserved energy (electric *and* other fuels) plus other non-energy resource impacts that may have occurred because of efficiency efforts such as reduced maintenance or higher productivity. The cost for the total resource benefit consists of all program-related costs and any costs incurred by the customer related to the installation of measures.

Winter Demand Savings: Refers to average demand savings that occurs during the winter peak period. *See discussion under Peak Demand Savings.*

C&I LOST OPPORTUNITY

2.1 LIGHTING

2.1.1 STANDARD LIGHTING

Description of Measure

Encourage and reward use of lighting power densities below the ASHRAE Standard.

Savings Methodology

Energy and seasonal peak demand savings come from reduced lighting power density, reduced cooling load, occupancy sensors and residential fixtures as applicable (see Note [1]). The baseline for lighting power density is ASHRAE Standard 90.1-2007.

Inputs

Symbol	Description	Units
	Allowable LPD from ASHRAE 90.1-2007	
	Total fixture connected kW	
	Lighted area, square feet	

Nomenclature

Item	Description	Units	Values
A	Lighted Area	Square Feet	
AKWH	Annual gross electric energy savings	kWh	
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers		
CF_L	Lighting Coincidence Factor		Appendix 1
CF_{os}	Occupancy Sensor Coincidence Factor		Appendix 1
CF_{hw}	Residential Lighting Coincidence Factor		Appendix 1
COP	Coefficient of Performance		
$DeltaW_{hw}$	Delta watts of hardwired fluorescent fixtures in residential areas as calculated per Section 4.1.2 of this document.		
F	Fraction of lighting energy that must be removed by the facilities cooling system.		
G	Estimated lighting energy heat to space based on modeling		
H	Facility lighting hours of use	Hours	Appendix 5
HVAC	Heating, Ventilation and Air Conditioning		
kW	Electric Demand	kiloWatts	
LPD	Lighting Power Density	Watts/ Sq ft	
N	Number of different fixture types with occupancy sensors		
n	Fixture number		
O_n	Quantity of fixtures of type n that have occupancy sensors		
S_c	Energy savings from reduced cooling load	kWh	
S_{hw}	Energy savings from installation of hard-wired fluorescent fixtures in residential areas	kWh	
S_{lpd}	Energy savings due to lower lighting power density	kWh	

Item	Description	Units	Values
S_{os}	Energy savings from use of occupancy sensors, if applicable	kWh	
W	Fixture input wattage	Watt	
W_n	Input watts for fixture type n		

Lost Opportunity Gross Energy Savings - Electric

$S = S_{lpd} + S_{os} + S_{hw} + S_c$

Calculation of savings due to lower lighting power density

S_{lpd} = (Allowable LPD - Actual LPD)*H*A

Allowable LPD, in kW/ft^2, is the value of Watts per ft^2 from ASHRAE for the facility type divided by 1000. The building area lighting power densities from ASHRAE are provided in Table 2 below. Refer to ASHRAE 90.1-2007 for the space by space method. (When using the space-by-space method to calculate the LPD, an increase in power allowances can be used in accordance with Section 9.6.2 of ASHRAE 90.1-2007.)

Actual LPD, in kW/ft^2, is calculated by dividing the total Fixture Wattage by the Lighted Area, ft^2

Fixture Wattage is the sum of the power consumed by each fixture's ballast, kW

A = is calculated for each project, either from architectural drawings or by physical measurement.

Calculation of savings due to occupancy sensors

If the Actual LPD is less than or equal to the Allowable LPD, then S_{OS} will be calculated as follows; otherwise, S_{OS} = 0.

$$S_{OS} = \frac{0.3H}{1000}\sum_{n=1}^{N} O_n W_n$$

Explanation of numerical constants:

0.3 is the generally accepted average energy reduction due to the use of occupancy sensors. See Ref [1].

1000 converts watts to kW

Calculation of savings from hard-wired fluorescent fixtures in residential areas

Refer to PSD Section 4.1.2 "CFL Fixtures (New Homes)" for this calculation. Normally the total number and type of fixtures in living areas is not known at the time of construction, so the LPD method cannot be used to calculate these savings. Where hard-wired fixtures are installed as part of new construction, they are usually shown on the building plans. Their savings are calculated per fixture according to the residential methodology.

Calculation of savings due to the reduced cooling required to remove excess heat produced by the lighting fixtures

S_c = Additional savings due to the reduced cooling energy required to remove the energy from lighting

$$S_C = \frac{\left(S_{lpd} + S_{os} + S_{hw}\right)\bullet F}{COP}$$

COP = 2.4

If the HVAC system includes an economizer,
Then F = 0.35
Otherwise, use Table 1 below

Table 1: Fraction of annual kWh energy savings that must be removed by the cooling system (See Ref [2])

Building Area, A, Sq ft	F
< 2,000	0.48
2,000 – 20,000	$0.48 + \frac{0.195(A - 2{,}000)}{18{,}000}$
>20,000	0.675

Table 2: Lighting Power Densities Using the Building Area Method (Ref [3])

Building Area Type (See Note [2])	Lighting Power Density (W/ft2)
Automotive Facility	0.9
Convention Center	1.2
Court House	1.2
Dining: Bar Lounge/Leisure	1.3
Dining: Cafeteria/Fast Food	1.4
Dining: Family	1.6
Dormitory	1.0
Exercise Center	1.0
Gymnasium	1.1
Healthcare-Clinic	1.0
Hospital/Healthcare	1.2
Hotel	1.0
Library	1.3
Manufacturing Facility	1.3
Motel	1.0
Motion Picture Theatre	1.2
Multi-Family	0.7
Museum	1.1
Office	1.0
Parking Garage	0.3
Penitentiary	1.0
Performing Arts Theatre	1.6
Police/Fire Station	1.0
Post Office	1.1
Religious Building	1.3
Retail	1.5
School/University	1.2
Sports Arena	1.1
Town Hall	1.1
Transportation	1.0
Warehouse	0.8
Workshop	1.4

Lost Opportunity Gross Energy Savings - Fossil Fuel

Space heating energy consumption will increase from reduced lighting load. Annual Fossil fuel Savings = -0.00079 MBTU's per annual kWh saved. See Ref [4].

Lost Opportunity Gross Seasonal Peak Demand Savings - Electric, Winter and Summer

$$KW(\text{summer}) = \left(CF_L \times (\text{Allowable LPD - Actual LPD}) \times \text{A} + CF_{os} \times \frac{\sum_{n=1}^{N} O_n W_n}{1000} + CF_{hw} \times \frac{\sum DeltaW_{hw}}{1000} \right) \times \left(1 + \frac{G}{COP} \right)$$

$$KW(\text{winter}) = \left(CF_L \times (\text{Allowable LPD - Actual LPD}) \times \text{A} + CF_{os} \times \frac{\sum_{n=1}^{N} O_n W_n}{1000} + CF_{hw} \times \frac{\sum DeltaW_{hw}}{1000} \right)$$

CF_L and CF_{os} are the lighting/occupancy sensor coincidence factor (summer/winter) taken from Appendix 1.

Allowable LPD, in kW/ft^2 = The value of Watts per ft^2 from ASHRAE for the facility type divided by 1000.

Actual LPD, in kW/ft^2 = Total Fixture Wattage (kW) divided by the Lighted Area, ft^2

A = is calculated for each project, either from architectural drawings or by physical measurement.

CF_{hw} is the residential lighting coincidence factor (summer/winter) taken from Appendix 1.

$DeltaW_{hw}$ = Delta watts of hardwired fluorescent fixtures in residential areas as calculated per Section 4.1.2 of this document.

G = 0.73

COP = 2.4

Non Energy Benefits

O&M savings are due to the reduction of lighting hours from installation of occupancy sensors. Annual O&M Savings = $0.014917 per annual kWh saved from the installation of occupancy sensors. See Ref 4.

Changes from Last Version

The baseline was changed to be consistent with new Connecticut Code.

References

[1] D. Maniccia B. Von Neida, and A. Tweed.
An analysis of the energy and cost savings potential of occupancy sensors for commercial lighting systems, Illuminating Engineering Society of North America 2000 Annual Conference: Proceedings. IESNA: New York, NY. Pp. 433-459.

[2] The source of the equation for S_c and the derivation of the values for F and COP is from “Calculating Lighting and HVAC Interactions,” ASHRAE Journal 11-93 as used by KCPL.

[3] ASHRAE 90.1-2007, TABLE 9.5.1: Lighting Power Densities Using the Building Area Method

[4] Memorandum from Optimal Energy, Inc., August 22, 2003.

Notes

[1] The heat emitted from lighting affected by this measure will decrease due to lower lighting power and use, if sensors are installed. This will result in increased space heating energy consumption.

[2] In cases where both general building area type and a specific building area type are listed, the specific building area type shall apply.

2.2 HVAC & WATER HEATING

2.2.1 CHILLERS

Description of Measure

Installation of efficient water-cooled and air-cooled water chilling packages (chillers). Chillers must use an environmentally friendly refrigerant in order to qualify for the program.

Savings Methodology

Energy savings are custom calculated for each chiller installation based on the specific equipment, operational staging, operating profile, and load profile. A temperature BIN model created by Bitterli & Associates (Ref [1]) is utilized to calculate the energy and demand savings for the chiller projects. Customer-specific information is used to estimate a load profile for the chilled water plant. Based on the loading, the chiller's actual part load performance is used to calculate chiller's demand (kW) and consumption (kWh) for each temperature BIN. The spreadsheet is also used to calculate consumption for the baseline unit. The spreadsheet can also be used to calculate the consumption of the auxiliaries (chilled water pumps, condenser water pumps and cooling tower fans). The spreadsheet can be used to estimate savings for both electric and natural gas chilled water plants for up to two chillers per plant.

Inputs

Symbol	Description	Units
	Facility occupancy hrs per week on and off-peak	h/wk
	Chiller plant availability per month	Y or N
	Peak cooling load @100°F – Occupied and Unoccupied (O&U)	Tons
	Economizer set point	°F
	Load at economizer set point – O&U	Tons
	Load at economizer @100°F – O&U	Tons
	Chiller(s) Capacity	Tons
	Condenser – Air or water cooled	
	Fuel – Electric or Gas	
	Compressor type	
	ARI part load efficiency @100% load, @75% load, @50% load, and @25% load	Ref [2]
	Primary and secondary pumping – BHP	Bhp
	Chilled water pump controls – single speed or VFD	
	Condenser water pump – BHP	Bhp
	Tower Fan – BHP	Bhp
	Tower fan control – single speed, 2 speed, VFD	
	Other (electric chiller kW not in part load performance, Gas chiller)	

Nomenclature

Symbol	Description	Units	Values	Comments
BL_{100}	Baseline efficiency@ 100% load	Note [1]		Ref [3]
BL_{75}	Baseline efficiency@ 75% load			
BL_{50}	Baseline efficiency@ 50% load			
BL_{25}	Baseline efficiency@ 25% load			

Lost Opportunity Gross Energy Savings - Electric

Equipment

Each chiller plant is characterized by:

- Number of chillers
- Sizes, in tons (the chillers may be of different sizes)
- Type, which may be:
    - Water-cooled centrifugal
    - Water-cooled screw and scroll
    - Air-cooled
- Speed, constant or variable
- Auxiliary equipment
    - Chilled water pumps
    - Cooling tower pumps
    - Cooling tower fans
    - Other

Operational Staging

If more than one chiller is used, their operational relationship can be defined. When the load is high enough to permit two chillers to operate, they can be designated to operate together at the same loading, or, alternatively, either one can be operated at full output while the other follows the cooling load profile.

Operating Profile

The customer's cooling load profile—for each of 12 months—is characterized by:

- On-peak occupied hours the chiller is operated each week
- Off-peak occupied hours the chiller is operated each week
- On-peak un-occupied hours the chiller is operated each week
- Off-peak un-occupied hours the chiller is operated each week

Load Profile

A customer's representative (typically a design engineer) provides loads at various conditions. The customer's load profile is estimated by determining the load at the peak outdoor conditions and the load at the minimum conditions. For systems with an air-side or water-side economizer, the minimum conditions are those just above the set point of the economizer. If the customer's load profile is not known, a default load profile will be developed; in this case it is also necessary to determine the value of any process loads.

Savings Calculation

With the above information (chiller load and part load efficiencies) a calculation is made for each time period of the year based on the appropriate temperature BIN data. The calculation is performed once for the chillers meeting the baseline efficiencies (Table 1) and again for the proposed chillers; the difference determines the kWh and the kW savings for each period. These are summed to yield the total savings.

Table 1: Baseline Efficiencies for Electric[1] Chillers

Equipment Type	Size Category (tons)	Units	Path A[2]		Path B[3]	
			Full load[5]	**IPLV[5]**	**Full Load[5]**	**IPLV[5]**
Air Cooled	<150	EER	≥9.562	≥12.500	NA[4]	NA[4]
	≥150	EER	≥9.562	≥12.750	NA[4]	NA[4]
Water Cooled Positive displacement	<75	kW/ton	≤0.780	≤0.630	≤0.800	≤0.600
	≥75 & <150	kW/ton	≤0.775	≤0.615	≤0.790	≤0.586
	≥150 & <300	kW/ton	≤0.680	≤0.580	≤0.718	≤0.540
	≥300	kW/ton	≤0.620	≤0.540	≤0.639	≤0.490
Water Cooled Centrifugal	<150	kW/ton	≤0.634	≤0.596	≤0.639	≤0.450
	≥150 & <300	kW/ton	≤0.634	≤0.596	≤0.639	≤0.450
	≥300 & <600	kW/ton	≤0.576	≤0.549	≤0.600	≤0.400
	≥600	kW/ton	≤0.570	≤0.539	≤0.590	≤0.400

[1] Electric baseline used for natural gas chillers. For water cooled ≤300 tons positive displacement is the baseline. For >300 tons Centrifugal is the baseline.

[2] Chillers that do not provide comfort cooling such as process chillers.

[3] Chillers that provide comfort cooling.

[4] NA means that this requirement is not applicable and cannot be used for compliance.

[5] Rated based on Ref [2]

Table 2: Baseline Part Load Efficiencies - Path A

Equipment Type	Size Category (tons)	Units	Part Load Efficiencies			
			100% Load	**75% Load**	**50% Load**	**25% Load**
Air Cooled	<150	EER	9.562	11.191	13.501	13.575
	≥150	EER	9.562	11.437	13.797	13.685
Water Cooled Positive displacement	<75	kW/ton	0.780	0.671	0.561	0.815
	≥75 & <150	kW/ton	0.775	0.655	0.547	0.799
	≥150 & <300	kW/ton	0.680	0.617	0.516	0.766
	≥300	kW/ton	0.620	0.577	0.482	0.687
Water Cooled Centrifugal	<150	kW/ton	0.634	0.612	0.565	0.667
	≥150 & <300	kW/ton	0.634	0.612	0.565	0.667
	≥300 & <600	kW/ton	0.576	0.566	0.522	0.596
	≥600	kW/ton	0.570	0.555	0.512	0.590

Table 3: Baseline Part Load Efficiencies - Path B

Equipment Type	Size Category (tons)	Units	Part Load Efficiencies			
			100% Load	**75% Load**	**50% Load**	**25% Load**
Air Cooled	<150	EER	NA	NA	NA	NA
	≥150	EER	NA	NA	NA	NA
Water Cooled Positive displacement	<75	kW/ton	0.800	0.636	0.531	0.818
	≥75 & <150	kW/ton	0.790	0.619	0.517	0.827
	≥150 & <300	kW/ton	0.718	0.573	0.479	0.721
	≥300	kW/ton	0.639	0.520	0.435	0.655
Water Cooled Centrifugal	<150	kW/ton	0.639	0.559	0.386	0.414
	≥150 & <300	kW/ton	0.639	0.559	0.386	0.414
	≥300 & <600	kW/ton	0.600	0.498	0.344	0.358
	≥600	kW/ton	0.590	0.499	0.344	0.356

Lost Opportunity Gross Energy Savings - Fossil Fuel

The additional natural gas usage, if chillers are natural gas driven, is calculated on a site specific basis using the methodology shown above. The additional usage will be negative since it is an increase in natural gas over the electric baseline option.

Non Energy Benefits

Because the baseline and high-efficiency technology are the same, the majority of the projects have no non-electric benefits. In the case of natural gas chillers, the gas chiller will have a higher maintenance cost than the baseline electric. In these cases, the non-electric benefit would be negative and calculated on a site-specific basis.

Changes from Last Version

The baseline was increased to be consistent with new Connecticut Code.

References

[1] Bitterli & Associates, 10 Station Street, Floor 2, Simsbury, CT 06070-2220

[2] ARI 550/590

[3] Developed using typical chiller part load curves and the baseline efficiencies in Table 1. Table 1 is based on ANSI/ASHRAE/IESNA Addendum to ANSI/ASHRAE/IESNA Standard 90.1-2007.

Notes

[1] Either EER for air cooled or kW/ton for water cooled, Part load performance based on Ref [2].

2.2.2 UNITARY AC & HEAT PUMPS

Description of Measure

Installation of a high-efficiency Direct-Expansion (DX) unitary or split cooling system or air source heat pump

Savings Methodology

Savings are estimated using full-load-hours analysis, comparing the difference in efficiency between a baseline (code compliant) and installed efficiency.

Inputs

Symbol	Description	Units
	Facility type served by equipment	
CAP_C	Installed Cooling Capacity	Btu/hr
EER_i	EER , $\geq$65,000 Btu/hr - Installed	Btu/watt-hr
$SEER_i$	SEER, units $<$65,000 Btu/hr - Installed	Btu/watt-hr
$HSPF_i$	HSPF, Heat pumps $<$ 65,000 Btu/hr – Installed	Btu/watt-hr
COP_i	High temperature COP, Heat pumps $\geq$65,000 Btu/hr- Installed	

Nomenclature

Symbol	Description	Units	Values	Comments
$AKWH_C$	Annual gross electric energy savings - Cooling	kWh		
$AKWH_H$	Annual gross electric energy savings - Heating	kWh		
CAP_C	Installed Cooling Capacity	Btu/hr		Input
CF_C	Seasonal summer cooling coincidence factor	%		Appendix 1
COP_b	High temperature COP, Heat pumps $\geq$65,000 Btu/h - Baseline			Note [1]
COP_i	High temperature COP, Heat pumps $\geq$65,000 Btu/h - Installed	Btu/watt-hr		Input
EER_b	EER , $\geq$65,000 Btu/h - Baseline	Btu/watt-hr		Note [1]
EER_i	EER , $\geq$65,000 Btu/h - Installed	Btu/watt-hr		Input
$EFLH_C$	Equivalent Full Load Hours - Cooling	Hrs		Appendix 5
$EFLH_H$	Equivalent Full Load Hours - Heating	Hrs		Appendix 5
$HSPF_b$	HSPF, Heat pumps $<$ 65,000 Btu/h - Baseline	Btu/watt-hr		Note [1]
$HSPF_i$	HSPF, Heat pumps $<$ 65,000 Btu/h - Installed	Btu/watt-hr		Input
Ratio	Ratio of heating capacity to cooling capacity		1.16	Note [2]
$SEER_b$	SEER, units $<$65,000 Btu/h - Baseline	Btu/watt-hr		Note [1]
$SEER_i$	SEER, units $<$65,000 Btu/h - Installed	Btu/watt-hr		Input
SKW_C	Seasonal Summer peak demand savings - Cooling	kW		
WKW_H	Seasonal Winter peak demand savings - Heating	kW	0	

Lost Opportunity Gross Energy Savings - Electric

Cooling (A/C units and Air Source Heat Pumps)

$$AKWH_C = CAP_C \times \left(\frac{1}{EER_b} - \frac{1}{EER_i} \right) \times \frac{kW}{1000W} \times EFLH_C$$

Reminder: *SEER is used in place of EER for units under 65,000 Btu/h*

Heating (Air source heat pumps only)

$$AKWH_H = CAP_C \times Ratio \times \left(\frac{1}{HSPF_b} - \frac{1}{HSPF_i} \right) \times \frac{kW}{1000W} \times EFLH_H$$

Reminder: *COP multiplied by 3.412 can be used in place of HSPF for units ≥65,000 Btu/h*

Table 1: Baseline Efficiencies		
Size (Btu/h)	**A/C only**	**Air Source Heat Pump**
<65,000	13.0 SEER	13.0 SEER, 7.7 HSPF
≥65,000 and <135,000	11.0 EER	11.0 EER , 3.3 COP
≥135,000 and <240,000	10.8 EER	10.6 EER, 3.2 COP
≥240,000 and <375,000	9.8 EER	9.5 EER, 3.2 COP
≥375,000 and <760,000	9.8 EER	9.5 EER, 3.2 COP
≥760,000	9.5 EER	9.5 EER, 3.2 COP

Example - Lost Opportunity Gross Energy Savings

A 120,000 Btu/hr rooftop A/C unit is installed on an office building. The new unit has a rated EER of 12.5. What are the annual lost opportunity savings?

Cooling (A/C units and Air Source Heat Pumps)

$$AKWH_C = CAP_C \times \left(\frac{1}{EER_b} - \frac{1}{EER_i} \right) \times \frac{kW}{1000W} \times EFLH_C$$

From Appendix 5, the cooling equivalent full load hours for an office are 797 hours.
EER_b from Table 1 = 11 EER

$$AKWH_C = 120{,}000 \times \left(\frac{1}{11} - \frac{1}{12.5} \right) \times \frac{kW}{1000W} \times 797 = 1{,}043 kWh$$

Lost Opportunity Gross Seasonal Peak Demand Savings - Electric, Winter and Summer

$$SKW_C = CAP_C \times \left(\frac{1}{EER_b} - \frac{1}{EER_i} \right) \times \frac{kW}{1000W} \times CF_C$$

$WKW_H = 0$
Reminder: *Cooling only units have no winter demand savings since they do not operate during the winter. Air source heat pumps have no winter demand savings because they use resistance back up at low outside air temperatures.*

Example - Lost Opportunity Gross Peak Demand Savings

A 120,000 Btu/h rooftop A/C unit is installed on an office building. The unit new unit has a rated EER of 12.5. What are the seasonal peak savings?

$$SKW_C = CAP_C \times \left(\frac{1}{EER_b} - \frac{1}{EER_i} \right) \times \frac{kW}{1000W} \times CF_C$$

From Appendix 1 the seasonal coincidence factor for cooling = 0.82.
EER_b from table 1 = 11 EER

$$SKW_C = 120{,}000 \times \left(\frac{1}{11} - \frac{1}{12.5} \right) \times \frac{kW}{1000W} \times 0.82 = 1.07kW$$

$WKW_H = 0$;
Reminder: *Cooling only units have no winter demand savings since they do not operate during the winter.*

Notes

[1] Table 1 above is based on 2009 International Energy Conservation Code (CT Code)

[2] Ratio of heating capacity divided by cooling capacity 13,900/12,000 = 1.16

2.2.3 WATER AND GROUND SOURCE HP

Description of Measure

High Efficiency water-source, ground water source, and ground-coupled heat pump units

Savings Methodology

Savings are estimated using a full load hour analysis, comparing the difference in efficiency between a baseline (code compliant) and installed efficiency.

Inputs

Symbol	Description	Units
	Facility type served by equipment and system type (water source, Ground water, ground loop)	
CAP_C	Installed Cooling Capacity	Btu/h
EER_i	EER - installed	Btu/watt-hr
COP_i	COP-Installed	

Nomenclature

Symbol	Description	Units	Values	Comments
$AKWH_C$	Annual electric energy savings - cooling	kWh		
$AKWH_H$	Annual electric energy savings - Heating	kWh		
CAP_C	Installed Cooling Capacity	Btu/hr		Input
CF_C	Seasonal summer cooling coincidence factor	%		Appendix 1
CF_H	Seasonal summer Heating coincidence factor	%		Appendix 1
COP_b	High temperature COP, Heat pumps $\geq$65,000 Btu/h- Baseline			Note [1]
COP_i	COP- installed			Input
EER_b	EER - Baseline	Btu/watt-hr		Note [1]
EER_i	EER- installed	Btu/watt-hr		Input
$EFLH_C$	Equivalent Full Load Hours - Cooling	Hrs		Appendix 5
$EFLH_H$	Equivalent Full Load Hours - Heating	Hrs		Appendix 5
SKW_C	Seasonal summer peak savings - cooling	kW		
WKW_H	Seasonal Winter peak savings - Heating	kW		

Lost Opportunity Gross Energy Savings - Electric

Cooling

$$AKWH_C = CAP_C \times \left(\frac{1}{EER_b} - \frac{1}{EER_i} \right) \times \frac{kW}{1000W} \times EFLH_C$$

Heating

$$AKWH_H = CAP_C \times \frac{COP_i}{EER_i} \times \left(\frac{1}{COP_b} - \frac{1}{COP_i} \right) \times \frac{kW}{1000W} \times EFLH_H$$

Table 1: Baseline Efficiencies (Ref [1])

Water Source Heat Pump		
(Closed loop within a building, served by boiler and cooling tower)		
Cooling Capacity Btu/hr	**EER_b**	**COP_b**
< 17,000	11.2	4.2
≥ 17,000 <135,000	12.0	4.2
Ground Water Heat Pump		
(The water used by the heat pump is in contact with the ground)		
Cooling Capacity Btu/hr	**EER_b**	**COP_b**
<135,000	16.2	3.6
Ground Loop Heat Pump		
(The water used by the heat pump is isolated from contact with the ground)		
Cooling Capacity Btu/hr	**EER_b**	**COP_b**
<135,000	13.4	3.1
[1] AHRI/ASHRAE 13256-1		

Example - Lost Opportunity Gross Energy Savings

A 120,000 Btu/h water to air heat pump is installed in an office building. The heat pump is operated as a ground loop. The ground loop ratings for the unit are 18 EER and 4 COP. What are the annual lost opportunity savings?

Cooling

$$AKWH_C = CAP_C \times \left(\frac{1}{EER_b} - \frac{1}{EER_i} \right) \times \frac{kW}{1000W} \times EFLH_C$$

From Appendix 5, the cooling equivalent full load hours for an office are 797 hours.
EER_b from Table 1 = 13.4

$$AKWH_C = 120{,}000 \times \left(\frac{1}{13.4} - \frac{1}{18} \right) \times \frac{kW}{1000W} \times 797 = 1{,}824 kWh$$

Heating

$$AKWH_H = CAP_C \times \frac{COP_i}{EER_i} \times \left(\frac{1}{COP_b} - \frac{1}{COP_i} \right) \times \frac{kW}{1000W} \times EFLH_H$$

From Appendix 5, the heating equivalent full load hours for an office are 1,248 hours.
COP_b from table 1 = 3.1

$$AKWH_H = 120{,}000 \times \frac{4}{18} \times \left(\frac{1}{3.1} - \frac{1}{4} \right) \times \frac{kW}{1000W} \times 1{,}248 = 2{,}415 kWh$$

Lost Opportunity Gross Seasonal Peak Demand Savings - Electric, Winter and Summer

Cooling

$$SKW_C = CF_C \times CAP_C \times \left(\frac{1}{EER_b} - \frac{1}{EER_i}\right) \times \frac{1}{1000\,{}^{W}\!/\!_{kW}}$$

Heating

$$WKW_H = CF_H \times CAP_C \times \frac{COP_i}{EER_i} \times \left(\frac{1}{COP_b} - \frac{1}{COP_i}\right) \times \frac{kW}{1000W}$$

Example - Lost Opportunity Gross Peak Demand Savings

A 120,000 Btu/h water to air heat pump is installed in an office building. The heat pump is operated as a ground loop. The ground loop ratings for the unit are 18 EER and 4 COP. What are the seasonal demand savings?

Cooling

$$SKW_C = CF_C \times CAP_C \times \left(\frac{1}{EER_b} - \frac{1}{EER_i}\right) \times \frac{1}{1000\,{}^{W}\!/\!_{kW}}$$

From Appendix 1, the seasonal coincidence factor for cooling = 0.82.
EER_b from Table 1 = 13.4

$$SKW_C = 0.82 \times 120{,}000 \times \left(\frac{1}{13.4} - \frac{1}{18}\right) \times \frac{1}{1000\,{}^{W}\!/\!_{kW}} = 1.88\ kW$$

Heating

$$WKW_H = CF_H \times CAP_C \times \frac{COP_i}{EER_i} \times \left(\frac{1}{COP_b} - \frac{1}{COP_i}\right) \times \frac{kW}{1000W}$$

From Appendix 1, the seasonal coincidence factor for unitary = 0.82.
COP_b from table 1 = 3.1

$$WKW_H = 0.82 \times 120{,}000 \times \frac{4}{18} \times \left(\frac{1}{3.1} - \frac{1}{4}\right) \times \frac{kW}{1000W} = 0.01kW$$

References

[1] 2009 International Energy Conservation Code (CT Code).

2.2.4 DUAL ENTHALPY CONTROLS

Description of Measure

Upgrade to a dual enthalpy economizer instead of outside-air dry-bulb economizer. The system will continuously monitor the enthalpy of both the outside air and return air while controlling system dampers to adjust the outside quantity based on the two readings.

Savings Methodology

Wood, Byk and Associates (Note [1]) modeled the savings achieved by upgrading from single dry-bulb to dual enthalpy economizer control for a variety of typical commercial and industrial facility types and sizes using the hourly building simulation tool DOE-2. Simulation results were reviewed and annual electrical savings per ton calculated. The simulation revealed that peak demand savings were zero because the economizers do not operate during the seasonal peaks.

Inputs

Symbol	Description	Units
CAP_i	Installed Cooling capacity controlled by economizers	Tons

Nomenclature

Symbol	Description	Units	Values	Comments
ADET	Annual differential electrical energy savings per ton	kWh/Ton	276	Note [2]
$AKWH_C$	Annual Electric Energy Savings, Cooling	kWh		
CAP_i	Installed Cooling capacity controlled by economizers	Tons		Input
SKW	Summer Demand savings	kW	0	Note [2]
WKW	Winter Demand Savings	kW	0	Note [2]

Lost Opportunity Gross Energy Savings - Electric

$$AKWH_C = ADET \times CAP_i$$

$$AKWH_C = 276 \times CAP_i$$

Lost Opportunity Gross Seasonal Peak Demand Savings - Electric, Winter and Summer

SKW = 0 (See Note [3])

WKW = 0 (See Note [4])

Notes

[1] Wood, Byk, & Associates, Consulting Engineers, 829 Meadowview Road, Kennett Square, PA 19348

[2] Results from the modeling done by Wood, Byk, and Associates.

[3] Since economizers save when outdoor air temperature is relatively low outdoor temperature (<70 °F) and the seasonal peak is expected to occur at high outside air temperature the seasonal peak savings are assumed to be 0.

[4] Since economizers save on cooling load and typically there is little to no cooling load in the winter time the winter peak is assumed to be 0.

2.2.5 VENTILATION CO_2 CONTROLS

Description of Measure

Upgrade to CO_2 control for outside air to an air handling system. The proposed systems monitor the CO_2 in the spaces or return air and reduce the outside air when possible to save energy while meeting indoor air quality standards.

Savings Methodology

The energy savings are custom-calculated for all projects. Savings are based on hours of operation, return air dry bulb temperature, return air enthalpy, system total air flow, percent outside air, estimated average outside air reduction, and cooling efficiency. Savings are estimated based on a temperature BIN spreadsheet that calculates the difference in outside air enthalpy and return air enthalpy from the reduction in outside air.

Summer seasonal peak demand savings are calculated based on the top temperature BINs used in the spreadsheet. The baseline for this measure is a system with no ventilation control.

2.2.6 GAS FIRED BOILER AND FURNACES

Description of Measure

Installation of high-efficiency, gas-fired, hot water boilers and furnaces.

Savings Methodology

Energy savings are calculated using the efficiency of the proposed boiler or furnace versus the baseline efficiency. Baseline minimum efficiencies for boilers and furnaces are specified in ASHRAE 90.1-2007, Tables 6.8.1F and 6.8.1E, respectively.

Demand savings calculation methodology is based on the results from a sampling of projects in which local bin weather data was used to calculate savings of both high-efficiency conventional boilers and condensing boilers. The project data was used to compute savings for the coldest 24-hour period of the year. This was taken as the peak demand savings (See Note [1]). Ratios of demand savings to annual energy savings were then developed for both conventional boilers (0.0152) and condensing boilers (0.0133), as shown in the table below. Although the magnitude of the demand savings for the condensing boilers was greater than that of the conventional boilers, the condensing boiler demand-to-energy-savings ratio was smaller. This is true because the annual energy savings for condensing boilers is much greater than that of conventional boilers. In addition, the efficiency superiority of the condensing boilers over the conventional is lowest during the coldest periods.

While outdoor temperature variations have little effect on the performance of either natural gas furnaces or conventional, non-condensing boilers, the efficiencies of condensing boilers vary as the water temperature in the boiler is reduced in response to outdoor temperatures. Therefore, the peak day demand savings for natural gas furnaces is calculated by multiplying the annual savings by the factor of 0.0152, the same used for conventional boilers.

Table 1: Annual and Peak (Demand) Savings Summary

Building Number	**Annual Savings (Ccf)**	**Peak Savings (Ccf)**	**Annual Savings (Ccf)**	**Peak Savings (Ccf)**
	Condensing Boilers		**Conventional Boilers**	
1	1,919	27	966	15
2	2,399	33	1,208	18
3	4,216	59	2,122	32
4	2,384	33	1,200	18
5	1,410	18	711	11
6	3,730	49	1,881	29
7	687	9	346	5
8	471	6	238	4
9	566	7	286	4
10	1,963	26	990	15
11	2,061	27	1,039	16
12	1,973	26	995	15
13	1,639	21	826	13
14	1,968	26	992	15
15	1,968	26	992	15
16	2,640	34	1,331	20
17	2,562	33	1,292	20
Total	**34,556**	**460**	**17,416**	**265**
	Condensing Boiler Peak-to-Annual Savings Ratio = 460/34,556 = 0.0133		**Conventional Boiler Peak-to-Annual Savings Ratio = 265/17,416 = 0.0152**	

Inputs

Symbol	Description
ηp	Proposed case efficiency
Load	Peak heating load on the boiler or furnace in Btu/hr

Nomenclature

Symbol	Description	Units	Values	Comments
ACCF	Gross Annual Gas Energy Savings	Ccf		
EFLH	Equivalent hours that the boiler or furnace would need to operate at its peak capacity in order to meet its estimated energy consumption (Annual Btu's/ Full Load Btuh). The magnitude of the EFLH's in each occupancy category considers both hours occupied and internal heat release equipment.	hours	Table 2	See Appendix 5 for occupancy categories not listed below
Load	Peak heating load on the boiler or furnace in Btu/hr. This is assumed to be equal to boiler or furnace output capacity divided by an oversize factor. The oversize factor is assumed to be 1.15 for single boiler/furnace installations and 1.3 for multiple boiler/furnace installations.	Btu/ hr		
PD	Gross Peak Day Natural Gas Savings			
ηb	base case efficiency			
ηp	proposed case efficiency			

Lost Opportunity Gross Energy Savings - Fossil Fuel

Heating Savings

$$ACCF = Load \times \left(\frac{EFLH}{102900\, {}^{Btu}\!/\!{}_{Ccf}} \right) \times \left(\frac{1}{\eta b} - \frac{1}{\eta p} \right)$$

Table 2: Equivalent Full Load Heating Hour Range

Occupancy Category	Equivalent Full-Load Heating Hours
Residential, Hospitals, Police & Fire Stations	1,519
Manufacturing	1,140
Retail Sales/Restaurants	1,170
Offices	1,306
Schools	1,176

Lost Opportunity Gross Peak Day Savings - Natural Gas

Conventional (non-condensing) boiler peak day gas savings (Ccf)

$$PD = 0.0152 \times ACCF$$

Condensing boiler peak day gas savings (Ccf)

$$PD = 0.0133 \times ACCF$$

Furnace peak day gas savings (Ccf)

$$PD = 0.0152 \times ACCF$$

Changes from Last Version

Added furnaces and oversize factor for single boiler/furnace installations. Also added reference to Appendix 5 for EFLH occupancy categories not listed in the table above.

Notes

[1] Natural gas utilities measure demand as the consumption (Ccf) for the coldest day in the billing period.

2.2.7 GAS RADIANT HEATER

Description of Measure

Installation of gas-fired, low-intensity, vented, radiant heaters.

Savings Methodology

Energy savings is estimated to be 25% of the consumption of a conventional gas fired unit heater with the same heating load (based on Ref [1]).

Demand savings calculation methodology is based on the results of sample savings numbers for various building types. The sample calculations were used to compute savings for the coldest 24-hour period of the year. This was taken as the peak demand savings (See Note [1]). From this, ratios of the demand savings (Ccf) to annual energy savings (Ccf) were developed, resulting in the average demand savings fraction of annual savings of 0.00544.

Inputs

Symbol	Description
Load	Peak heating load on the heater in Btu/hr

Nomenclature

Symbol	Description	Units	Values	Comments
ACCF	Gross Annual Gas Energy Savings	Ccf/yr		
EFLH	The equivalent hours that the heater would need to operate at its peak capacity in order to consume its estimated consumption (Annual Btu's/ Full Load Btuh)	hours	Table 1, Appendix 5	Note [3]
Load	Peak heating load on the heater in Btu/hr			Note [2]
Savings Fraction	Fraction of base-case (conventional gas-fired unit heater) consumption saved with low-intensity radiant heaters. This is based on assuming a modest level of savings over conventional unit heaters due to both thermostat setpoint reduction and air temperature stratification reduction. Consumption and savings calculations were performed for various levels of reductions for a number of different building types. The total savings fraction of 25.0% of base case consumption was selected based on Ref [1].		25%	Ref [1]
PD	Gross Peak Day Natural Gas Savings			
ηb	base case or baseline efficiency		80%	Ref [2]

Lost Opportunity Gross Energy Savings - Fossil Fuel

Heating Savings

$$ACCF = \frac{Load \times EFLH \times Savings\ Fraction}{102900\ {}^{Btu}\!/_{Ccf} \times \eta b}$$

Table 1: Equivalent Full-Load Heating Hour Range (See Note [3])

Occupancy Category	Equivalent Full-Load Heating Hours
Warehouse, Storage, Fire Stations	1,519
Manufacturing	1,140
Retail Sales/Other	1,170

Lost Opportunity Gross Peak Day Savings - Natural Gas

$$PD = 0.00544 \times ACCF$$

Changes from Last Version

Refer to Appendix 5 for EFLH occupancy categories not listed in the table above.

References

[1] ASHRAE Technical Paper #4643, "Evaluation of an Infrared Two-Stage Heating System in a Commercial Application", 2003

[2] ASHRAE Standard 90.1-2007, Table 6.8.1E, for warm air unit heaters.

Notes

[1] Natural gas utilities measure demand as the consumption (Ccf) for the coldest day in the billing period.

[2] In the case of a single-heater installation, this is assumed to be equal to heater output capacity. In the case of a multiple-heater installation, the load is assumed to be the total heater output capacity divided by an oversize factor of 1.1.

[3] The equivalent full-load heating hour (EFLH) range is shown in Table 1. The magnitude of the EFLH's in each occupancy category considers both hours occupied and internal heat release equipment. Refer to Appendix 5 for occupancy categories not listed in Table 1.

2.2.8 GAS FIRED DHWH

Description of Measure

Installation of high-efficiency, gas-fired, storage-type, domestic hot water heaters.

Savings Methodology

Energy savings are calculated using proposed water heater thermal efficiency and standby losses versus baseline efficiency and standby losses. The baseline is assumed to be a gas storage water heater, >75,000 Input Btu/hr as specified in ASHRAE 90.1-2007, Table 7.8.

The demand savings is calculated using a demand savings factor, which is essentially the peak day consumption percent of the annual consumption. Multiplying annual savings by the demand savings factor determines the peak day savings.

Assumptions:

1. Base case heater is code-compliant storage gas heater
2. Proposed case heater is high-efficiency heater
3. Base case and proposed case heaters have the same output capacity and address the same DHW load.
4. If multiple heaters are used, they are treated as a single unit, with system input capacity and standby loss rate equal to the sum of all units.

Demand Assumptions:

1. Lowest cold water temperature is 44°F
2. Annual average cold water temperature is 54°F.
3. Hot water set point is 130°F.

Inputs

Symbol	Description	Units
$CAP_{H,i}$	Input capacity of proposed (installed) water heater	MBH
$CAP_{W,i}$	Water Storage capacity of proposed (installed) water heater	Gallons
ηb	Thermal efficiency of base case water heater	%
ηp	Thermal efficiency of proposed (installed) water heater	%
SLR_b	Standby loss rate of base case water heater	Btu/hr
SLR_i	Standby loss rate of proposed (installed) water heater	Btu/hr
A	Building floor area, square feet	Ft^2
	Building Occupancy Type	

Nomenclature

Symbol	Description	Units	Values	Comments
A	Building floor area in square feet	ft^2	input	
ACCF	Annual Natural Gas Energy Savings	Ccf/yr	Calculated	
$CAP_{H,b}$	Heat Input capacity of base case water heater	MBH	Calculated	
$CAP_{H,i}$	Heat Input capacity of proposed (installed) water heater	MBH	Input	
$CAP_{W,b}$	Water Storage capacity of base case water heater	Gallons		
$CAP_{W,i}$	Water Storage capacity of proposed (installed) water heater	Gallons	Input	
$CCF_{W,b}$	Annual base case DHW Gas usage	Ccf/yr		
E_b	Annual base case gas energy usage rate (per sq ft^2)	$Ccf/ft^2/yr$	Table 1	Ref [1], Note [1]

Symbol	Description	Units	Values	Comments
E_i	Annual proposed (installed) gas energy usage rate (per ft^2)	$Ccf/ft^2/yr$		
GPY_W	Annual Building Hot Water Usage	Gal/yr	Calculated	
H	Number of annual standby hours	Hrs/yr	Calculated	
PD	Peak Day Natural Gas Savings	Ccf		
SF	Peak Day Gas Demand Savings factor			
SLR_b	Base case water heater standby loss rate	Btu/hr	input	
SLR_i	Proposed (installed) water heater standby loss rate	Btu/hr	input	
ΔT	Differential Temperature rise	°F	75°F	
ηb	Base case water heater thermal efficiency	%	80%	
ηp	Thermal efficiency of proposed water heater	%		

Lost Opportunity Gross Energy Savings - Fossil Fuel

Natural Gas Energy Savings

Calculate annual base case DHW gas usage:

$$CCF_{W,b} = A \times E_b$$

Table 1: Annual Base Case Gas Usage Rate by Occupancy Type (Ref [1], Note [1]))

Building Occupancy Category	Building Occupancy Code Number	Annual Base Case Gas Usage Rate, E_b (Ccf/ft^2)
Education	1	0.048
Grocery/Convenience Store	2	0.029
Restaurant/Cafeteria	3	0.363
Inpatient Health Care	4	0.357
Outpatient Health Care	5	0.032
Lodging	6	0.265
Retail (other than in mall)	7	0.009
Retail (in mall)	8	0.028
Office	9	0.015
Police/Fire Station/Jail	10	0.137
Other	11	0.009

Calculate base case heater input capacity in BTU/hr:

$$CAP_{H,b} = CAP_{H,i} \times \frac{\eta p}{\eta b}$$

Calculate number of standby hours/year:

$$H = \frac{\left(8760\ {}^{hr}\!/\!_{yr} \times CAP_{H,b}\right) - \left(CCF_{W,b} \times 102900\ {}^{Btu}\!/\!_{Ccf}\right)}{CAP_{H,b} - \dfrac{SLR_b}{\eta b}}$$

Calculate annual building hot water usage (Gal hot water consumed/yr):

$$GPY_W = \frac{\left(CCF_{W,b} \times 102900\ {}^{Btu}\!/\!_{Ccf} \times \eta b\right) - \left(SLR_b \times H\right)}{\Delta T \times 8.33\ {}^{Btu}\!/\!_{Gal \cdot {}^\circ F}}$$

Calculate annual gas savings using the following equation:

$$ACCF_W = CCF_{W,b} - \frac{(GPY_W \times \Delta T \times 8.33\ {}^{Btu}\!/\!_{Gal \cdot {}^\circ F} + SLR_i \times H)}{102900\ {}^{Btu}\!/\!_{Ccf} \times \eta p}$$

Lost Opportunity Gross Peak Day Savings - Natural Gas

$$SF = \frac{1\,day \times (130°F - 44°F)}{365\,days \times (130°F - 54°F)} = 0.0031$$

$$PD = ACCF_W \times SF = ACCF_W \times 0.0031$$

References

[1] U.S. Energy Information Administration Table E8A.Natural Gas Consumption and Energy Intensities by End Use for All Buildings, 2003

Notes

[1] The published Ccf/ft^2 data in Ref [1] reflects existing DHW heating equipment performance. The published data was adjusted downward by a factor of 0.935 to reflect the better performance of new, standard-efficiency (code-compliant) equipment. The adjusted data is shown Table 1.

2.3 MOTORS

2.3.1 MOTORS

Description of Measure

Installation of a high-efficiency motor

Savings Methodology

Energy savings are calculated based on the difference between installed efficiency and baseline efficiency. The load factor and hours are based on actuals, if available, or defaults listed in Appendices 1 and 5, respectively.

Inputs

Symbol	Description	Units
	Application of motor (HVAC Fan, ChWP, etc.)	
HP_{HVAC}	Rated Horsepower of HVAC motor	Hp
EFF_i	Rated efficiency of installed motor	%
h	Annual hours of operation	hrs
BHP_N	Brake Horsepower for different periods non-HVAC applications	HP
$Hours_N$	Annual hours for each loading period non-HVAC applications	hrs

Nomenclature

Symbol	Description	Units	Values	Comments
CF	Coincidence factor for HVAC application	%		Appendix 1
EFF_i	Rated efficiency of installed motor	%		Input
EFF_b	Baseline efficiency	%		Tables 1 and Table 2
h	Annual hours of operation	hrs		Input or Appendix 5
$Hours_N$	Annual hours for each loading period non-HVAC applications	hrs		Input
HP_{HVAC}	Rated Horsepower of HVAC motor	Hp		Input
SKW	Summer seasonal peak savings	kW		
WKW	Winter Seasonal Peak Savings	kW		

Lost Opportunity Gross Energy Savings - Electric

For HVAC applications:

$$AKWH = HP_{HVAC} \times 0.746 \times CF \times \left[\frac{1}{EFF_b} - \frac{1}{EFF_i} \right] \times h$$

For non-HVAC applications,

$$AKWH = \sum_{1}^{N} BHP_N (0.746) \left(\frac{1}{EFF_b} - \frac{1}{EFF_i} \right) (Hours_N)$$

Reminder:

N = The total number of defined combinations of load and Hours. (e.g., 1=10% of the hours at 100% load; 2=20% of the hours at 83% load, etc.)
BHP_N = the HP required by the load at combination N
$hours_N$ = the time, in hours, that is spent at combination N

The Energy Independence and Security Act of 2007 (Ref [1]) restates the definition of General Purpose Electric Motors and classifies them as Subtype I or Subtype II.

The term ‘General Purpose electric motor (Subtype I)’ means any motor that meets the definition of ‘General Purpose’ as established in the final rule issued by the Department of Energy titled “Energy Efficiency Program for Certain Commercial and Industrial Equipment: Test Procedures, Labeling, and Certification Requirements for Electric Motors” (10 CFR 431), as in effect on the date of enactment of the Energy Independence and Security Act of 2007.

The term ‘General Purpose electric motor (Subtype II)’ means motors incorporating the design elements of a general purpose electric motor (Subtype I) that are configured as one of the following:

(i) A U-Frame Motor.
(ii) A Design C Motor.
(iii) A close-coupled pump motor.
(iv) A Footless motor.
(v) A vertical solid shaft normal thrust motor (as tested in a horizontal configuration)
(vi) An 8-pole motor (900 rpm).
(vii) A poly-phase motor with voltage of not more than 600 volts (other than 230 or 460 volts).

Table 1: General Purpose Electric Motors (Subtype I): Baseline Motor Efficiencies

	Open Drip Proof			**Totally Enclosed Fan Cooled**		
HP	**1200 rpm**	**1800 rpm**	**3600 rpm**	**1200 rpm**	**1800 rpm**	**3600 rpm**
1	82.5	85.5	77.0	82.5	85.5	77.0
1.5	86.5	86.5	84.0	87.5	86.5	84.0
2	87.5	86.5	85.5	88.5	86.5	85.5
3	88.5	89.5	85.5	89.5	89.5	86.5
5	89.5	89.5	86.5	89.5	89.5	88.5
7.5	90.2	91.0	88.5	91.0	91.7	89.5
10	91.7	91.7	89.5	91.0	91.7	90.2
15	91.7	93.0	90.2	91.7	92.4	91.0
20	92.4	93.0	91.0	91.7	93.0	91.0
25	93.0	93.6	91.7	93.0	93.6	91.7
30	93.6	94.1	91.7	93.0	93.6	91.7
40	94.1	94.1	92.4	94.1	94.1	92.4
50	94.1	94.5	93.0	94.1	94.5	93.0
60	94.5	95.0	93.6	94.5	95.0	93.6
75	94.5	95.0	93.6	94.5	95.4	93.6
100	95.0	95.4	93.6	95.0	95.4	94.1
125	95.0	95.4	94.1	95.0	95.4	95.0
150	95.4	95.8	94.1	95.8	95.8	95.0
200	95.4	95.8	95.0	95.8	96.2	95.4
250	95.4	95.8	95.0	95.8	96.2	95.8
300	95.4	95.8	95.4	95.8	96.2	95.8
350	95.4	95.8	95.4	95.8	96.2	95.8
400	95.8	95.8	95.8	95.8	96.2	95.8
450	96.2	96.2	95.8	95.8	96.2	95.8
500	96.2	96.2	95.8	95.8	96.2	95.8

Table 2: General Purpose Electric Motors (Subtype II and Design B): Baseline Motor Efficiencies

	Open Drip Proof			Totally Enclosed Fan Cooled		
HP	**1200 rpm**	**1800 rpm**	**3600 rpm**	**1200 rpm**	**1800 rpm**	**3600 rpm**
1	80.0	82.5	N/A	80.0	82.5	75.5
1.5	84.0	84.0	82.5	85.5	84.0	82.5
2	85.5	84.0	84.0	86.5	84.0	84.0
3	86.5	86.5	84.0	87.5	87.5	85.5
5	87.5	87.5	85.5	87.5	87.5	87.5
7.5	88.5	88.5	87.5	89.5	89.5	88.5
10	90.2	89.5	88.5	89.5	89.5	89.5
15	90.2	91.0	89.5	90.2	91.0	90.2
20	91.0	91.0	90.2	90.2	91.0	90.2
25	91.7	91.7	91.0	91.7	92.4	91.0
30	92.4	92.4	91.0	91.7	92.4	91.0
40	93.0	93.0	91.7	93.0	93.0	91.7
50	93.0	93.0	92.4	93.0	93.0	92.4
60	93.6	93.6	93.0	93.6	93.6	93.0
75	93.6	94.1	93.0	93.6	94.1	93.0
100	94.1	94.1	93.0	94.1	94.5	93.6
125	94.1	94.5	93.6	94.1	94.5	94.5
150	94.5	95.0	93.6	95.0	95.0	94.5
200	94.5	95.0	94.5	95.0	95.0	95.0
250	94.5	95.4	94.5	95.0	95.0	95.4
300	94.5	95.4	95.0	95.0	95.4	95.4
350	94.5	95.4	95.0	95.0	95.4	95.4
400	N/A	95.4	95.4	N/A	95.4	95.4
450	N/A	95.8	95.8	N/A	95.4	95.4
500	N/A	95.8	95.8	N/A	95.8	95.4

Lost Opportunity Gross Seasonal Peak Demand Savings - Electric, Winter and Summer

For HVAC applications:

$$SKW = HP_{HVAC} \times 0.746 \frac{kW}{HP} \times CF_S \times \left[\frac{1}{EFF_b} - \frac{1}{EFF_i} \right]$$

$$WKW = HP_{HVAC} \times 0.746 \frac{kW}{HP} \times CF_W \times \left[\frac{1}{EFF_b} - \frac{1}{EFF_i} \right]$$

Reminder: *The peak factor is based on the motor being used in an HVAC application. The peak factor includes the effect of motor over sizing, which is unavoidable in most applications because motors come only in discrete sizes. Therefore, it is usually necessary to install a motor larger than what is needed to meet minimum requirements.*

For non-HVAC applications:
The seasonal demands are determined by a custom analysis based on the application and peak definition.

References

[1] US Congress, Energy Independence and Security Act of 2007 (EISA), January 4, 2007.

2.4 VARIABLE FREQUENCY DRIVES

2.4.1 HVAC VFD

Description of Measure

Addition of variable frequency (VFD) control to a fan or pump system in a HVAC application. The fan (pump) speed will be controlled to maintain the desired system pressure. The application must have a load that varies and proper controls (i.e. two-way valves, VAV boxes) must be installed.

Savings Methodology

The baseline is a constant speed fan (AF, BI, FC) with or without inlet guide vanes or a constant speed pump. ASHRAE default performance curves (Ref [1]) are utilized to calculate the power for both the baseline equipment (constant speed) and the proposed equipment (variable speed) over the annual load profile. The difference between the base and proposed equipment determines the energy savings. Demand savings is the power (kW) savings at the highest load temperature bins.

Inputs

Symbol	Description	Comments
BHP	System brake horsepower	
EFFi	Installed motor efficiency	
H	Annual hours of operation	Default Facility Hours are taken from Appendix 5.

Nomenclature

Symbol	Description	Units	Values	Comments
AF	Air foil			Fan Type
AKWH	Gross Annual Electric Energy Savings	kWh		
BHP	System brake horsepower	HP		
BI	Backward incline			Fan Type
CHWP	Chilled water Pump			
EFF_i	Installed motor efficiency	%		
FC	Forward Curved			Fan Type
H	Annual hours of operation		Appendix 5	
HWP	Hot water pump			
IGV	Inlet guide vanes			Flow Control Device
SF_{kWh}	Annual kilowatt hour savings factor based on typical load profile for application			
$SF_{kW,S}$	Summer kW savings factor based on typical peak load of application		Table 1	
$SF_{kW,W}$	Winter kW savings factor based on typical peak load of application		Table 1	
SKW	Seasonal Summer Peak Summer Demand Savings	kW		
WKW	Seasonal Winter Peak Summer Demand Savings	kW		

Lost Opportunity Gross Energy Savings - Electric

$$AKWH = \frac{BHP}{EFF_i} \times H \times SF_{kWh}$$

Refer to Table 1 below for the appropriate SF_{kWh}.

Table 1: VFD Savings Factors (See Note [1])

HVAC Fan VFD Savings Factors			
Baseline	SF_{kWh}	$SF_{kW,S}$	$SF_{kW,W}$
AF/BI	0.35407485	0.26035565	0.40781240
AF/BI IGV	0.22666226	0.12954823	0.29144821
FC	0.17889831	0.13552275	0.18745625
FC IGV	0.09210027	0.02938371	0.13692166
HVAC Pump VFD Savings Factors			
System	SF_{kWh}	$SF_{kW,S}$	$SF_{kW,W}$
CHWP	0.41113751	0.299056883	0.0
HWP	0.42380136	0.0	0.207967853

Lost Opportunity Gross Seasonal Peak Demand Savings - Electric, Winter and Summer

$$SKW = \frac{BHP}{EFF_i} \times SF_{kW,S}$$

$$WKW = \frac{BHP}{EFF_i} \times SF_{kW,W}$$

Changes From Last Version

Revised the SF_{kWh} for pumps and removed constant volume savings factors.

References

[1] ASHRAE 90.1-1989 User's Manual

Notes

[1] The constants in Table 1 were derived using a temperature BIN spreadsheet and typical heating, cooling and fan load profiles.

2.5 REFRIGERATION

2.5.1 ICE-CUBE MAKERS

Description of Measure

Installation of efficient commercial ice-cube machines, based on the Consortium for Energy Efficiency's (CEE) commercial kitchens initiative.

Savings Methodology

Energy savings are determined based on the ice harvest rate and the difference between the baseline and actual energy consumption. Demand savings is the average hourly demand savings and is the same for both winter and summer.

The baseline energy use rate is based on the Federal Standard (Ref [1]) and listed in the tables below.

Table 1: Baseline Energy Use Rate for Air Cooled Machines (Federal Standard)

Equipment Type	**Ice Harvest Rate (HR) lb/day**	**E_b=**
Cube type only: Ice making head	<450	10.26 – 0.0086HR
	≥450	6.89 – 0.0011HR
Cube type only: Remote condensing without remote compressor	<1000	8.85 – 0.0038HR
	≥1000	5.1
Cube type only: Remote condensing with remote compressor	<934	8.85 – 0.0038HR
	≥934	5.3
Cube type only: Self contained	<175	18.0 – 0.0469HR
	≥175	9.8

Table 2: Baseline Energy Use Rate for Water Cooled Machines (Federal Standard)

Equipment Type	**Ice Harvest Rate (HR) lb/day**	**E_b=**
Cube type only: Ice making head	<500	7.80 – 0.0055HR
	≥500 and <1436	5.58 – 0.0011HR
	≥1436	4.0
Cube type only: Self contained	<200	11.40 – 0.019HR
	≥200	7.6

Table 3: Maximum Energy Rate for CEE Tier 1 Air Cooled Machines

Equipment Type	**Ice Harvest Rate (HR) lbs/day**	**kWh/100lbs**
Cube type only: Ice making head	<450	9.23 – 0.0077HR
	≥450	6.20 – 0.0010HR
Cube type only: Remote condensing without remote compressor	<1000	8.05 – 0.0035HR
	≥1000	4.64
Cube type only: Remote condensing with remote compressor	<934	8.05 – 0.0035HR
	≥934	4.82
Cube type only: Self contained	<175	16.7 – 0.0436HR
	≥175	9.11

Table 4: Maximum Energy Rate for CEE Tier 1 Water Cooled Machines

Equipment Type	Ice Harvest Rate (HR) lb/day	E_b=
Cube type only: Ice making head	<500	7.02 – 0.0049HR
	≥500 and <1436	5.13 – 0.0010HR
	≥1436	3.68
Cube type only: Self contained	<200	10.6 – 0.0177HR
	≥200	7.07

Inputs

Symbol	Description
E_A	Actual Energy Use Rate for each machine
HR	Ice Harvest Rate for each machine
	Equipment type of each machine

Nomenclature

Symbol	Description	Units	Values	Comments
AKWH	Annual Gross Electric Energy savings	kiloWatt-hours, kWh		
kW	Electric Demand	kiloWatts		
E_b	Baseline Energy Use Rate	kWh per 100lbs of ice produced		
E_A	Actual Energy Use Rate	kWh per 100lbs of ice produced		Can be found on CEE's qualified products list
HR	Ice Harvest Rate	lbs per day		
lbs	Pounds			
100	Conversion from per 100 lb to per pound		100	

Lost Opportunity Gross Energy Savings - Electric

$$AKWH = \frac{E_b - E_A}{100} \times HR \times 365 \, {}^{days}\!/_{yr}$$

Lost Opportunity Gross Seasonal Peak Demand Savings - Electric, Winter and Summer

The average hourly demand savings for both winter and summer are:

$$kW = \frac{E_b - E_A}{100} \times \frac{HR}{24 \, {}^{hr}\!/_{day}}$$

Changes from Last Version

Changed the baseline energy use rate to be consistent with Federal Standard effective 1/01/2010.

References

[1] Federal Standard: Title 10 Part 431 - Energy Efficiency Program for Certain Commercial and Industrial Equipment; Section 431.136

2.5.2 REFRIGERATORS AND FREEZERS

Description of Measure

Installation of energy-efficient commercial refrigerators and freezers, based on the Consortium for Energy Efficiency's (CEE) commercial kitchens initiative.

Savings Methodology

Energy savings are determined based on the difference between the baseline (Federal Standard, Table 1) and actual energy consumption. Demand savings is the average hourly demand savings and is the same for both winter and summer.

Table 1: Baseline Energy Use for Refrigerators and Freezers (Federal Standard, Ref [1]))

Category	**kWh/Day**
Refrigerators With Solid Doors	0.10V + 2.04
Refrigerators With Transparent Doors	0.12V + 3.34
Freezers With Solid Doors	0.40V + 1.38
Freezers With Transparent Doors	0.75V + 4.10

Table 2: CEE Qualified Refrigerators and Freezers Maximum Consumption

Product Volume (V) (Note [1])	**Refrigerators**	**Freezers**
Vertical Configuration	**kWh/Day**	**kWh/Day**
Solid Door Cabinets		
0< V >15	≤ 0.089V + 1.411	≤ 0.250 + 1.250
15≤ V >30	≤ 0.037V + 2.200	≤ 0.400V -1.000
30≤ V >50	≤ 0.056V + 1.635	≤ 0.163V + 6.125
50≤ V	≤ 0.060V + 1.416	≤ 0.158V + 6.333
Glass Door Cabinets		
0< V >15	≤ .118V +1.382	≤ 0.607V + 0.893
15≤ V >30	≤ 0.140V + 1.050	≤ 0.733V – 1.000
30≤ V >50	≤ 0.088V + 2.625	≤ 0.250V + 13.500
50≤ V	≤ 0.11V + 1.500	≤ 0.450 + 3.500
Chest Configuration		
All	≤ 0.125V + 0.475	≤ 0.270V + 0.130

Inputs

Symbol	**Description**	**Units**
E_A	Actual Energy Use Rate for each machine	kWh/ day
V	AHAM Volume for each machine (Note [1])	Ft^3
	Type of each machine	

Nomenclature

Symbol	Description	Units	Values	Comments
AHAM	Association of Home Appliance Manufacturers			
AKWH	Annual Gross Electric Energy savings	kWh		
E_b	Baseline Energy Use Rate	kWh/ day		
E_A	Actual Energy Use Rate	kWh/ day		Found on CEE's qualified products list
kW	Electric Demand Savings	kiloWatts		
AKW	Average Hourly Summer Demand Savings	kW		
V	AHAM Volume	Cubic Feet		Note [1]

Lost Opportunity Gross Energy Savings - Electric

$$AKWH = \left(E_b - E_A\right) \times 365 \, {}^{days}\!/_{yr}$$

Lost Opportunity Gross Seasonal Peak Demand Savings - Electric, Winter and Summer

The average hourly demand savings for both winter and summer are:

$$AKW = \frac{AKWH}{8760 \, {}^{hrs}\!/_{yr}}$$

Changes from Last Version

Combined solid and glass doors units into one measure. Updated the baseline and CEE compliance energy usage.

References

[1] Federal Standard: Title 10 Part 431 - Energy Efficiency Program for Certain Commercial and Industrial Equipment; Section 431.66

Notes

[1] The AHAM volume is the interior volume of a refrigerator as calculated by AHAM Standard Household Refrigerators/Household Freezers (ANSI/AHAM HRF-1-2004).

2.5.3 VENDING MACHINE OCCUPANCY CONTROLS

Description of Measure

Installation of vending machine occupancy sensors to limit energy consumption when not in use.

Savings Methodology

Energy savings are based on a study performed by Nicholas Group, P.C. in 2001 (Ref [1]). No demand savings are claimed.

Inputs

Symbol	Description
	Number of vending machines

Nomenclature

Symbol	Description	Units	Values	Comments
AKWH	Annual Gross Electric Energy savings per vending machine	kWh/yr	1600 kWh per vending machine	Prescriptive

Lost Opportunity Gross Energy Savings - Electric

$$AKWH = 1{,}600\ kWh$$

(per vending machine)

References

[1] Nicholas Group, P.C., 2001 study.

2.6 OTHER

2.6.1 LEAN MANUFACTURING

Description of Measure

Incorporating Process Re-engineering for Increased Manufacturing Efficiency (PRIME), also known as "lean manufacturing," into the manufacture process.

Savings Methodology

Incorporating PRIME in the manufacturing process allows a company to eliminate waste (i.e. of energy, materials, labor) and optimize flow in order to improve the efficiency of the manufacturing process. The savings calculations are based on Ref [1]. Savings are estimated based on facility's existing actual annual electrical usage. The savings are based on estimating the production increase with and without PRIME.

Savings are based on two concepts:

1. Producing more products in the same time period saves on the non- manufacturing consumption (mostly lighting).
2. Producing more products over the same time period reduces losses in the manufacturing equipment consumption (such as less idle time and increase in motor efficiency).

Inputs

Symbol	Description	Units
KWH_h	Facility's annual electric usage based on billing history	kWh
PAA	Percent of facilities consumption effected by PRIME	%
Na	Production after PRIME	# per hour
Ne	Existing Production	# per hour

Nomenclature

Symbol	Description	Units	Values	Comments
$AKWH_O$	Annual Electric Energy Savings -other	kWh		
$EKWH_{wop}$	Estimated annual electric usage with increase in production without PRIME	kWh		
$EKWH_{wp}$	Estimated annual electric usage with increase in production without PRIME	kWh		
IND_{wop}	Annual electric energy usage independent of production-without PRIME	kWh		
IND_{wp}	Annual electric energy usage independent of production-with PRIME	kWh		
HR_{wop}	Annual electric energy usage dependent on hours of production-without PRIME	kWh		
HR_{wp}	Annual electric energy usage dependent on hours of production-with PRIME	kWh		
KWH_h	Facility's annual electric usage based on billing history	kWh		Input
N_a	Production rate after PRIME	# per hour		Input
N_e	Existing Production rate	# per hour		Input
PAA	Percent of facilities' energy usage effected by PRIME	%		Input
PD_{wop}	Annual electric energy usage dependent on production quantity-without PRIME	kWh		
PD_{wp}	Annual electric energy usage dependent on production quantity-with PRIME	kWh		
SF	Savings factor	%		Ref [1]

<u>Lost Opportunity Gross Energy Savings - Electric</u>

$$AKWH_O = EKWH_{wop} - EKWH_{wp}$$

Estimated annual consumption with increase in productivity without PRIME:

$$EKWH_{wop} = IND_{wop} + HR_{wop} + PD_{wop}$$

$$IND_{wop} = 0.65 \times PPA \times KWH_h$$

$$HR_{wop} = 0.20 \times PPA \times KWH_h \times \frac{N_a}{N_e}$$

$$PD_{wop} = 0.15 \times PPA \times KWH_h \times \frac{N_a}{N_e}$$

Estimated annual consumption with increase in productivity with PRIME:

$$EKWH_{wp} = IND_{wp} + HR_{wp} + PD_{wp}$$

$$IND_{wp} = 0.65 \times PPA \times KWH_h$$

$$HR_{wp} = 0.20 \times PPA \times KWH_h$$

$$PD_{wp} = 0.15 \times PPA \times KWH_h \times \frac{N_a}{N_e} \times (1 - SF)$$

$$SF = 0.1168 \times \left[\frac{N_a - N_e}{N_e}\right]^3 - 0.3402 \times \left[\frac{N_a - N_e}{N_e}\right]^2 + 0.4732 \times \left[\frac{N_a - N_e}{N_e}\right] + 0.0011$$

Savings algorithms come directly from Ref [1].

<u>Example - Lost Opportunity Gross Energy Savings</u>

A manufacturing plant that has an annual electricity consumption of 1,000,000 kWh (KWH_h), It goes though the PRIME process on production lines that represent 25% or 0.25 (PPA) of their production. Production of those lines increase from 300 to 330 products per hour.

$$AKWH_O = EKWH_{wop} - EKWH_{wp}$$

Estimated annual consumption with increase in productivity without PRIME:

$$EKWH_{wop} = IND_{wop} + HR_{wop} + PD_{wop}$$

$$IND_{wop} = 0.65 \times 0.25 \times 1{,}000{,}000 = 162{,}500 kWh$$

$$HR_{wop} = 0.20 \times 0.25 \times 1{,}000{,}000 \times \frac{330}{300} = 55{,}000 kWh$$

$$PD_{wop} = 0.15 \times 0.25 \times 1{,}000{,}000 \times \frac{330}{300} = 41{,}250 kWh$$

$$EKWH_{wop} = 162{,}500 + 55{,}000 + 41{,}250 = 258{,}750 kWh$$

Estimated annual consumption with increase in productivity with PRIME:

$$EKWH_{wp} = IND_{wp} + HR_{wp} + PD_{wp}$$

$$IND_{wp} = 0.65 \times 0.25 \times 1{,}000{,}000 = 162{,}500 kWh$$

$$HR_{wp} = 0.20 \times 0.25 \times 1{,}000{,}000 = 50{,}000 kWh$$

$$SF = 0.1168 \times \left[\frac{330-300}{300}\right]^3 - 0.3402 \times \left[\frac{330-300}{300}\right]^2 + 0.4732 \times \left[\frac{330-300}{300}\right] + 0.0011 = .045$$

$$PD_{wp} = 0.15 \times 0.25 \times 1{,}000{,}000 \times \frac{330}{300} \times (1-0.045) = 39{,}394 kWh$$

$$EKWH_{wp} = 162{,}500 + 50{,}000 + 39{,}394 = 251{,}894 kWh$$

$$AKWH_O = 258{,}750 - 251{,}894 = 6{,}856 kWh$$

Lost Opportunity Gross Seasonal Peak Demand Savings - Electric, Winter and Summer

SKW = 0

WKW = 0

Non Energy Benefits

The customer's cost savings from the increase in productivity and reduction in scrap varies considerably from project to project. Therefore, it may be calculated on a case-by-case basis.

References

[1] Energy & Resource Solutions, Process Reengineering for Increased Manufacturing Efficiency (PRIME) Program Evaluation, March 26, 2007, Section 4.

2.6.2 KITCHEN EQUIPMENT

Description of Measure

Installation of a high efficiency natural gas fryer, steamer or convection oven for use in a commercial kitchen

Savings Methodology

Savings for this measure are calculated using the appropriate natural gas (fryer, steamer, or convection oven) calculator found on the food service technology center website (Ref [1]). By inputting the customer's operating hours and pounds of food cooked per day as well as the efficiency of the installed unit, the difference in savings between the installed unit and a typical unit can be determined. Peak day savings are calculated as the daily average.

Inputs

Symbol	Description	Units
	Required for all equipment	
	Type of equipment (fryer, steamer, or convection oven)	
	Product Manufacturer	
	Model no.	
H	Operating hours per day	Hrs/day
Days	Annual days of use	Days/yr
LBS	Pounds of food cooked per day	Lbs/day
	For steamer only	
N	Number of pans	
P	Potato Production Capacity	Lbs/h

Nomenclature

Symbol	Description	Units	Values	Comments
$ACCF_O$	Annual Natural gas savings	Ccf		
Days	Annual days of use	Days/yr		Input
$FHLE_b$	Fryer heavy load efficiency - baseline	%	35	Note [1]
$FHLE_i$	Fryer heavy load efficiency - installed	%		Note [2]
FIR_b	Fryer Idle Energy Rate - baseline	Btu/h	14,000	Note [1]
FIR_i	Fryer Idle Energy Rate - installed	Btu/h		Note [2]
FPC_b	Fryer Production Capacity - baseline	Lbs/h	60	Note [1]
FPC_i	Fryer Production Capacity - installed	Lbs/h		Note [2]
FPE_b	Fryer Preheat Energy - baseline	Btu	16,000	Note [1]
FPE_i	Fryer Preheat Energy - installed	Btu		Note [2]
Hrs	Operating hours per day	Hrs/day		Input
LBS	Pounds of food cooked per day	Lbs/day		Input
N	Number of pans			Input
$OHLE_b$	Oven heavy load efficiency - baseline	%	30%	Note [1]
$OHLE_i$	Oven heavy load efficiency - installed	%		Note [2]
OIR_b	Oven Idle Energy Rate - baseline	Btu/h	12,000 half-size 18,000 Full-size	Note [1]
OIR_i	Oven Idle Energy Rate - installed	Btu/h		Note [2]
OPC_b	Oven Production Capacity - baseline	Lbs/h	45 half-size 70 Full-size	Note [1]

Symbol	Description	Units	Values	Comments
OPC_i	Oven Production Capacity - installed	Lbs/h		Note [2]
OPE_b	Oven Preheat Energy - baseline	Btu	13,000 half-size 19,000 full-size	Note [1]
OPE_i	Oven Preheat Energy - installed	Btu		Note [2]
P	Potato Production Capacity	Lbs/h		Input
PD_O	Peak Day Natural Gas Savings	Ccf		
$SAWC_b$	Steamer Average water consumption rate-baseline	Gal/h	40	Note [1]
$SAWC_i$	Steamer Average water consumption rate-installed	Gal/h	40	Note [2]
$SHLE_b$	Steamer heavy load efficiency - baseline	%	15	Note [1]
$SHLE_i$	Steamer heavy load efficiency - installed	%		Note [2]
SIR_b	Steamer Idle Energy Rate - baseline	Btu/h	11,000	Note [1]
SIR_i	Steamer Idle Energy Rate - installed	Btu/h		Note [2]
SPC_b	Steamer Production Capacity - baseline	Lbs/h	65	Note [1]
SPC_i	Steamer Production Capacity - installed	Lbs/h		Note [2]
$SPCS_b$	Steamer Percent of time in constant steam mode-baseline	%	90	Note [1]
$SPCS_b$	Steamer Percent of time in constant steam mode-installed	%	90	Note [2]
SPE_b	Steamer Preheat Energy - baseline	Btu	18,000	Note [1]
SPE_i	Steamer Preheat Energy - installed	Btu		Note [2]

Lost Opportunity Gross Energy Savings - Fossil Fuel

$ACCF_O$ is calculated using the savings tool that is located on the website identified in Ref [1], using annual usage based customer usage and installed equipment efficiency. Input variables are listed above. The installed equipment variables are based on the actual model number found on the ENERGY STAR website listed in Ref [2]. Default values from the tool are used for baselines and other variables.

Lost Opportunity Gross Peak Day Savings - Natural Gas

$$PD_O = \frac{ACCF_O}{365 days / yr}$$

Changes from Previous Version

New measure

References

[1] Food Service Technology Center, Fisher-Nickel Inc., Life Cycle and Energy Cost Calculators, website, http://www.fishnick.com/saveenergy/tools/calculators/ last accessed September 22, 2011.

[2] ENERGY STAR, "Find Energy Star Products," website, http://www.energystar.gov/index.cfm?c=products.pr_find_es_products last accessed September 22, 2011.

Notes

[1] Baseline values used in energy savings calculation tool on website identified in Ref [1]

[2] Installed values from website identified in Ref [2] based on installed model

2.6.3 CUSTOM MEASURE

Description of Measure

This measure is used for C&I Lost Opportunity installations not covered by a prescriptive measure.

Savings Methodology

Energy savings are calculated on a custom basis for each customer’s specific situation. Savings are calculated as the difference in energy usage between the baseline energy use and energy use after implementation of the custom measure.

Measures may be lumped into two significantly different categories:

1. Temperature-dependent (i.e. HVAC measures that vary with ambient temperature)
2. Non-temperature-dependent (i.e. process, lighting, time control)

Temperature-dependent methodologies:

The methodology used to determine the demand savings for temperature-dependent measures will depend on the type of analysis used to estimate the savings. Savings from temperature-dependent measures are typically determined by either full load hour analysis, bin temperature analysis, or a detailed computer simulation:

1. When annual savings are calculated using a full load hour analysis, an appropriately derived coincidence factor (based on the measure end use and peak time period [Seasonal]) will be used for a measure that has a connected load that can be determined from rated or nameplate data. Demand savings will be determined by multiplying the connected load kW savings by the appropriate coincidence factor.

2. When using a temperature bin analysis to calculate the energy savings, the demand (kW) savings are averaged over the appropriate temperature bins (Seasonal).

3. When a computer simulation is used to calculate savings, the demand savings will be averaged over the appropriated peak time period (Seasonal).

Methodology for non-temperature-dependent measures:

1. Demand savings for measures that are not temperature-dependent will be determined by either the coincidence factors from Appendix 1 or the average estimated savings over the appropriate peak time periods (Seasonal). For example, for a process VFD measure, the savings will depend on cycling of the load. This cycling may occur many times during an hour.

2. If the process is operating throughout the Seasonal summer period, the average demand savings will be:

$$Average\ Demand\ Savings = \frac{Annual\ kWh\ savings}{Annual\ Equivalent\ Full\ Load\ Hours\ of\ Operation}$$

   Or, $AKW = \dfrac{AKWH}{EFLH}$

3. If the process is operated only a portion of that time period the demand savings will be pro-rated based on that portion.

Baseline efficiencies are based on code or common practice, whichever is more efficient.

2.7 ENVELOPE

2.7.1 COOL ROOF

Description of Measure

Upgrade a roof's reflectance at the time of replacement or new construction.

Savings Methodology

Wood, Byk and Associates (Note [1]) developed a number of typical HVAC system scenarios using the hourly building simulation tool DOE-2. Savings were calculated using a baseline reflectance of 0.3 (Note [2]), a high efficiency roof reflectance of 0.70, and a high efficiency roof emittance of 0.75, as certified and labeled by the Cool Roof Rating Council (CRRC). Simulation results were separated into two categories based on the location of the cooling equipment's condenser. Based on the study results, savings ratios were developed per square foot of "cool" roof over electrically air conditioned space, which can be applied to estimate energy savings. The reflectance and emittance requirements in ASHRAE 90.1-2007 are the same as 90.1-2001. Therefore, this analysis is still valid.

Inputs

Symbol	**Description**	**Units**
	Location of air conditioning systems (Rooftop vs. other).	
	Heating Fuel	
A_{ac}	Area of upgraded roof that is over electrically air conditioned spaces	ft^2

Nomenclature

Symbol	Description	Units	Values	Comments
A_{ac}	Area of upgraded roof that is over electrically air conditioned spaces	ft^2		Input
$ABTU_H$	Annual Btu savings – Heating	Btu		
$ACCF_H$	Annual natural gas savings –Heating	Ccf	102,900 Btu	
$AKWH_C$	Annual Electric Energy Savings –Cooling	kWh		
AOG_H	Annual oil savings – Heating	Gal	138,690 Btu	
APG_H	Annual propane savings – Heating	Gal	91,330 Btu	
F_C	Cooling Factor	kWh/ft^2	0.29872 or 0.08145	Note [3]
F_H	Heating Factor	BTU/ft^2	-0.0017	Note [3]
SKF	Summer Factor	kW/ft^2	0.00045 or 0.00019	Note [3]
SKW	Seasonal Summer Peak Demand Savings	kW		
WKW	Seasonal Winter Peak Demand Savings	kW		

Lost Opportunity Gross Energy Savings - Electric

When air conditioning equipment is located on the roof (rooftop units, split systems, air cooled chillers), the savings are calculated as follows:

$$F_C = 0.29872$$
$$AKWH_C = F_C \times A_{ac}$$
$$AKWH_C = 0.29872 \times A_{ac}$$

Reminder*: This does not include cooling towers that serve water cooled chillers. Water cooled chillers are grouped with cooling equipment that is not located on the roof.*

When air conditioning equipment is not located on the roof (split systems, air cooled chillers, water cooled chillers), the savings are calculated as follows:

$$F_C = 0.08145$$
$$AKWH_C = F_C \times A_{ac}$$
$$AKWH_C = 0.08145 \times A_{ac}$$

Lost Opportunity Gross Seasonal Peak Demand Savings - Electric, Winter and Summer

When air conditioning equipment is located on the roof (rooftop units, split systems, air cooled chillers), the demand savings are as follows:

$$SKF_C = 0.00045$$
$$SKW_C = SKF_C \times A_{ac}$$
$$SKW_C = 0.00045 \times A_{ac}$$

$$WKW_C = 0$$

Reminder: *This does not include cooling towers that serve water cooled chillers. Water cooled chillers are grouped with cooling equipment that is not located on the roof.*

When air conditioning equipment is not located on the roof (split systems, air cooled chillers, water cooled chillers), the savings are as follows:

$$SKF_C = 0.00019$$
$$SKW_C = SKF_C \times A_{ac}$$
$$SKW_C = 0.00019 \times A_{ac}$$

$$WKW_C = 0$$

Notes

[1] Wood, Byk, & Associates, Consulting Engineers, 829 Meadowview Road, Kennett Square, PA 19348

[2] ASHRAE 90.1-2001, Energy Cost Budget Method.

[3] Results from the modeling done by Wood, Byk, and Associates.

C&I RETROFIT

3.1 LIGHTING

3.1.1 STANDARD LIGHTING

Description of Measure

Replacement of inefficient lighting with efficient lighting.

Savings Methodology

The energy and seasonal peak demand savings come from reduced fixture wattage, reduced cooling load, and use of occupancy sensors. The baseline is the wattage and operating hours of the fixtures being replaced.

The heat emitted by lighting will be reduced by the installation of more efficient lighting and, if sensors are installed, lower hours of use. This will result in increased space heating energy use and decreased cooling energy use.

Inputs

Symbol	Description	Units
	Existing fixture connected kW	
	Replacement fixture connected kW	

Nomenclature

Item	Description	Units	Values	Comments
AKWH	Annual Gross Electric Energy savings	kWh		
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers			
CF_L	Lighting Coincidence Factor		Appendix 1	
CF_{os}	Occupancy Sensor Coincidence Factor		Appendix 1	
COP	Coefficient of Performance		2.4	
F	Fraction of lighting energy that must be removed by the facilities cooling system.			
G	Estimated lighting energy heat to space based on modeling		0.73	
H	Annual Facility lighting hours of use	Hours	Appendix 5	
HVAC	Heating, Ventilation and Air Conditioning			
kW	Fixture input kiloWatts	kW		
kW	Electric Demand	kW		
N	Number of different fixture types with occupancy sensors			
n	Fixture number			
O_n	Quantity of fixtures of type n that have occupancy sensors			
S_r	Energy savings due to lighting retrofit	kWh/yr		
S_{os}	Energy savings from use of occupancy sensors, if applicable	kWh/yr		
S_c	Additional savings due to the reduced cooling energy required to remove the energy from lighting	kWh/yr		

Item	Description	Units	Values	Comments
SKW	Seasonal Summer Peak Summer Demand Savings	kW		
W_n	Input watts for fixture type n	Watts		
WKW	Seasonal Winter Peak Demand Savings	kW		

Retrofit Gross Energy Savings - Electric

AKWh = $S_r + S_{os} + S_c$

Calculation of savings due to fixture retrofit

$S_r = (kW_B - kW_A)\, H$

kW_B = The total power usage of the lighting fixtures that are being replaced, kW.
kW_A = The total power usage of the new lighting fixtures that are being installed, kW.

Calculation of savings due to occupancy sensors

$$S_{os} = \frac{0.3H}{1000\,{}^{W}\!/\!_{kW}} \sum_{n=1}^{N} O_n W_n$$

Where, 0.3 is the generally accepted average energy reduction due to the use of occupancy sensors (See Ref [1]).

Calculation of savings due to the reduced cooling required to remove excess heat produced by the lighting fixtures

$$S_C = \frac{(S_r + S_{OS}) \times F}{COP}$$

COP = 2.4

If the HVAC system includes an economizer,
Then F = 0.35
Otherwise, use Table 1 below

Table 1: Fraction of lighting energy that must be removed by the facilities' cooling system (See Ref [2])

Building Area, A, Sq ft	F
< 2,000	0.48
2,000 – 20,000	$0.48 + \frac{0.195(A - 2{,}000)}{18{,}000}$
>20,000	0.675

Retrofit Gross Energy Savings - Fossil Fuel

Space heating energy consumption will increase from reduced lighting load. Annual Fossil fuel Savings = -0.00079 MBTU's per annual kWh saved. See Ref [3].

Retrofit Gross Seasonal Peak Demand Savings - Electric, Winter and Summer

$$SKW = \left(CF_L \times \left(\sum KW_B - \sum KW_A \right) + CF_{OS} \times \frac{\sum_{n=1}^{N} O_n W_n}{1000} \right) \times \left(1 + \frac{G}{COP} \right)$$

$$WKW = CF_L \times \left(\sum KW_B - \sum KW_A \right) + CF_{os} \times \frac{\sum_{n=1}^{N} O_n W_n}{1000}$$

CF_L and CF_{os} are the lighting/occupancy sensor coincidence factor (summer/winter) taken from Appendix 1.

G = 0.73

COP = 2.4

Non Energy Benefits

O&M savings are due to the installation of new equipment. O&M Savings = $0.003667 per annual kWh saved. See Ref [3].

Changes from Last Version

Added cooling savings from occupancy sensors and heat load fraction when economizer installed.

References

[1] D. Maniccia B. Von Neida, and A. Tweed. An analysis of the energy and cost savings potential of occupancy sensors for commercial lighting systems Illuminating Engineering Society of North America 2000 Annual Conference: Proceedings. IESNA: New York, NY. Pp. 433-459.
Accessed online at http://www.lrc.rpi.edu/resources/pdf/dorene1.pdf

[2] The source of the equation for S_c and the derivation of the values for F and COP is from “Calculating Lighting and HVAC Interactions,” ASHRAE Journal 11-93 as used by KCPL.

[3] Memorandum from Optimal energy, Inc., August 22, 2003.

3.1.2 REFRIGERATOR LED

Description of Measure

Replacement of fluorescent lighting in commercial display refrigerators, coolers and freezers with LED lighting.

Savings Methodology

The savings are based on the wattage reduction achieved by replacing fluorescent lighting with LED lighting. Interactive refrigeration savings are also achieved due to the reduced heat loads associated with lighting power reduction.

Inputs

Symbol	Description	Units
EER	Energy Efficiency Ratio of Refrigeration Units	
h	Lighting annual run hours	hours
N	Number of lights	
L	Ballast location factor	
ΔkW	Reduction in power for each light	kW

Nomenclature

Symbol	Description	Units	Values	Comments
ACOP	Average Coefficient of Performance			
AKWH	Annual Gross Electric Energy savings	kWh		
CF	Seasonal peak demand coincident factor for refrigeration		Appendix 1	
COP	Coefficient of Performance			
EER	Energy Efficiency Ratio			
h	Lighting annual run hours			
AKW	KiloWatts, average demand savings for both summer and winter	kW		
L	Ballast location factor			
N	Number of lights			
ΔkW	Reduction in power for each light (Change in kiloWatts)	kW		

Retrofit Gross Energy Savings - Electric

$$AKWH = N \times \Delta kW \times h \times \left(1 + \frac{L}{ACOP}\right)$$

ACOP = 2.03 for freezers and 2.69 for coolers (used for interactive effects)

L= 1 if ballast is located in refrigerated area, 0 if not in refrigerated area and 0.5 if unknown.

If existing EER’s are available then ACOP = Average EER/3.413

Average EER = Full Load EER/0.85

Retrofit Gross Seasonal Peak Demand Savings - Electric - Winter and Summer

$$AKW = N \times \Delta kW \times \left(1 + \frac{CF \times L}{COP}\right)$$

COP = 1.72 for freezers and 2.29 for coolers (used to calculate interactive affects)

L= 1 if ballast is located in refrigerated area, 0 if not in refrigerated area and 0.5 if unknown.

If existing EER's are available then COP = EER/3.413

CF for refrigeration is the same for both winter and summer.

3.2 HVAC & WATER HEATING

3.2.1 SPRAY VALVE REPLACEMENT

Description of Measure

Installation of low-flow spray valves used for dish cleaning in place of standard pre-rinse spray valves. Low flow spray valves have an average flow rate of 1.6 gpm. This measure is applicable to non-grocery applications.

Savings Methodology

Deemed savings are based on the results of a spray valve replacement program in California (Ref [1]). An evaluation of phase 2 of this program determined that savings from grocery applications do not warrant spray valve replacement.

Peak savings are not defined.

Inputs

Symbol	Description	Units
	Number of Spray Vales	

Nomenclature

Symbol	Description	Units	Values	Comments
ACCF	Annual Natural Gas Energy Savings	Ccf/yr		
AKWH	Annual Gross Electric Energy savings	kWh		
gpm	Gallons per minute			

Retrofit Gross Energy Savings - Electric

If hot water is supplied via an electric water heater then energy savings are:
AKWH = 957 per spray valve

Retrofit Gross Energy Savings - Fossil Fuel

If hot water is supplied via a gas water heater then annual energy savings are:
ACCF = 42.0 per spray valve

Non Energy Benefits

Water savings are estimated to be 23.6 gallons per day.

Changes from Last Version

New Measure

References

[1] Impact and Process Evaluation Final Report for California Urban Water Conservation Council, 2004-5 Pre-Rinse Spray Valve Installation Program (Phase 2), February 21, 2007.

3.2.2 PIPE INSULATION

Description of Measure

Installation of insulation on bare hydronic heating pipes located in unconditioned spaces. Refer to the pipe insulation measure in the residential section for insulation savings on domestic hot water pipes.

Savings Methodology

The savings were determined using 3E Plus v4.0 software (Ref [1]). Ambient temperature was assumed to be 50 deg F and fluid temperature was assumed to be 180 deg F. The heat loss savings per linear foot for various pipe and insulation sizes/material are provided in Table 1 below.

Table 1: Heat loss savings per linear foot of insulation

Nominal Pipe Size (In)	Pipe Material	Insulation Material	Insulation Thickness (In)	HL Savings Btu/hr/ft
0.5	Copper	Polyolefin Tube C1427-04	0.5	40
			1.0	47
		Mineral fiber, Type I, C547-07	0.5	46
			1.0	52
0.75		Polyolefin Tube C1427-04	0.5	50
			1.0	57
		Mineral fiber, Type I, C547-07	0.5	57
			1.0	63
1.0		Polyolefin Tube C1427-04	0.5	62
			1.0	73
		Mineral fiber, Type I, C547-07	0.5	71
			1.0	79
1.25		Mineral fiber, Type I, C547-07	0.5	86
			1.0	96
1.5	Copper		0.5	97
			1.0	111
	Steel		0.5	114
			1.0	128
2.0	Copper		0.5	123
			1.0	137
	Steel		0.5	144
			1.0	158

Inputs

Symbol	Description	Units
	Nominal Pipe Size (Diameter)	Inches
	Pipe Material	
	Insulation Material	
	Insulation Thickness	Inches
	Length of Insulation	Linear ft

Nomenclature

Symbol	Description	Units	Values	Comments
ACCF	Annual Natural Gas Energy Savings	Ccf/yr		
EFLH	Equivalent heating full load hours for the facility type	hours	Appendix 5	
HL	Heat loss savings per linear foot of pipe	Btu/hr	Table 1	
L	Length of insulation	Linear ft		

Retrofit Gross Energy Savings - Fossil Fuel

$$ACCF_{ft} = \frac{HL \times EFLH}{102{,}900\ ^{Btu}\!/_{Ccf} \times 0.80}$$ (per linear foot of insulation)

Where, 0.80 is the estimated boiler efficiency

$$ACCF = ACCF_{ft} \times L$$

Changes from Last Version

New measure.

References

[1] NAIMA, 3E Plus software tool, Version 4.0, Released 2005.

3.2.3 DUCT SEALING

Description of Measure

Seal ducting located in unconditioned spaces. This measure is applicable to buildings that are similar to residential construction or buildings where performing duct blaster/blower door testing is practical.

Savings Methodology

Refer to the duct sealing measure (4.2.9) in the residential section of this document. The savings for the targeted buildings will be close to residential and in some cases greater.

Changes from Last Version

New measure.

3.2.4 DUCT INSULATION

Description of Measure

Installation of insulation on ducting located in unconditioned spaces in commercial buildings.

Savings Methodology

Savings were determined using 3E Plus software (Ref [1]). The savings are based on insulating existing bare ducting with R-6 insulation. Assumed ambient and supply/return air temperatures for the heating and cooling season are provided in Table 1, below. Heat transfer rates per square foot of insulation are provided in Table 2, below.

Table 1: Assumed Temperature Conditions

Duct Location	Season	Ambient Temp (deg F)	Supply Air Temp (deg F)	Return Air Temp (deg F)
Attic	Heating	30	130	65
	Cooling	120	50	80
Basement	Heating	50	130	65
	Cooling	70	50	80

Table 2: Heat transfer rates per square foot of insulation

	$BTUH_b$ (Bare)		$BTUH_a$ (Insulated R-6)	
Duct Location	Heating BTU/hr/ft^2	Cooling BTU/hr/ft^2	Heating BTU/hr/ft^2	Cooling BTU/hr/ft^2
Supply Basement	132.34	25.22	12.04	2.73
Return Basement	18.12	-	2.03	-
Supply Attic	167.14	112.11	14.67	10.42
Return Attic	45.86	61.93	4.63	6.18

Inputs

Symbol	Description
A	Insulation area in square feet

Nomenclature

Symbol	Description	Units	Values	Comments
AKWH	Annual Gross Electric Energy savings	kWh/yr		
$BTUH_{ca}$	Cooling heat transfer rate of insulated ducting	BTU/hr/ft^2		
$BTUH_{cb}$	Cooling heat transfer rate of uninsulated ducting	BTU/hr/ft^2		
$BTUH_{ha}$	Heating heat transfer rate of insulated ducting	BTU/hr/ft^2		
$BTUH_{hb}$	Heating heat transfer rate of uninsulated ducting	BTU/hr/ft^2		
COP	Coefficient of Performance			
EFLH	Equivalent heating or cooling full load hours for the facility type	hours	Appendix 5	
A	Insulation area in square feet			

Retrofit Gross Energy Savings - Electric

$$AKWH = \frac{(BTUH_{cb} - BTUH_{ca}) \times EFLH}{3412\ {}^{Btu}/_{kWh} \times 3} \times A$$

Where, 3 is the estimated cooling equipment efficiency, COP

Retrofit Gross Energy Savings - Fossil Fuel

$$ACCF = \frac{(BTUH_{hb} - BTUH_{ha}) \times EFLH}{102{,}900\ {}^{Btu}/_{Ccf} \times 0.80} \times A$$

Where, 0.80 is the estimated heating equipment efficiency

Retrofit Gross Seasonal Peak Demand Savings - Electric, Winter and Summer

Currently, no demand savings are claimed for this measure.

Changes from Last Version

New measure.

References

[1] NAIMA, 3E Plus software tool, Version 4.0, Released 2005.

3.2.5 SET BACK THERMOSTAT

Description of Measure

Installation of programmable thermostats in place of non-programmable thermostats with programmable thermostats in small business applications.

Savings Methodology

Savings estimates below are based on computer simulation models (Ref [1]). Three models were developed assuming different occupancy schedules. To select the appropriate model for calculating energy savings, choose the simulated schedule that most closely resembles the facility's actual occupancy schedule. A 10 degree setback for unoccupied periods is assumed for both heating and cooling modes. Savings will only be realized if the facility currently maintains a constant temperature for both occupied and unoccupied periods.

There are no demand savings since savings occur during off peak periods.

Inputs

Symbol	Description
Nr	Nameplate Rating of baseboard electric resistance heat in kW
CAP	Output capacity of gas heating equipment in MBh

Nomenclature

Symbol	Description	Units	Values	Comments
AKWH	Annual Gross Electric Energy savings	kWh/yr		
CAP	Output capacity of gas heating equipment	Mbh		
SF_{CCF}	Ccf savings factor	Ccf/MBh		
gpm	Gallons per minute			
$SF_{kWh,H}$	Electric Heating kWh Savings Factor	kWh/kW	Table 1	
$SF_{kWh,C}$	Electric Cooling kWh Savings Factor	kWh/Ton	Table 2	
MBh	Thousands of Btu's per hour			
Nr	Nameplate Rating of baseboard electric resistance heat	kW		

Retrofit Gross Energy Savings - Electric

Heating

$$AKWH_H = Nr \times SF_{kWh,H}$$

Table 1: Heating Savings Factor (If facility has electric resistance heat)

Occupancy		$SF_{kWh,H}$
Daily Hours	**Days of Week**	**kWh per installed kW**
	M-F	145
	M-Sa	117
6am to 6pm	M-Su	55

Cooling (Applicable only if the Facility has an existing cooling system)

$$AKWH_C = Nr \times SF_{kWh,C}$$

Table 2: Cooling Savings Factor (Only if the facility has cooling)

Occupancy		**$SF_{kWh,C}$**
Daily Hours	**Days of Week**	**kWh per installed cooling capacity (Tons)**
	M-F	93.9
	M-Sa	58.0
6am to 6pm	M-Su	19.3

Retrofit Gross Energy Savings - Fossil Fuel

$$ACCF = CAP \times SF_{CCF}$$

Table 3: Gas Heating Savings Factor (If facility has gas heating)

Occupancy		**SF_{CCF}**
Daily Hours	**Days of Week**	**Ccf/Mbh CAP**
	M-F	1.69
	M-Sa	1.37
6am to 6pm	M-Su	0.64

Changes from Last Version

Added gas heat savings and revised electric heat and cooling savings based on computer simulation model.

References

[1] Trane System Analyzer Version 6.1

3.3 OTHER

3.3.1 CUSTOM MEASURE

Description of Measure

This measure is used for C&I Retrofit installations not covered by another specific measure.

Savings Methodology

Energy savings are calculated on a custom basis for each customer's specific situation. Savings are calculated as the difference in energy usage between the baseline energy use and energy use after implementation of the custom measure

Measures may be lumped into two significantly different categories:
1. Temperature-dependent (HVAC measures that vary with ambient temperature)
2. Measures that are not temperature-dependent (process, lighting, time control)

Temperature-dependent methodologies:

The methodology used to determine the demand savings for temperature-dependent measures will depend on the type of analysis used to estimate the savings. Savings from temperature-dependent measures are typically determined by either full load hour analysis, bin temperature analysis, or a detailed computer simulation:

1. When annual savings are calculated using a full load hour analysis, an appropriately derived coincidence factor (based on the measure end use and peak time period [Seasonal]) will be used for a measure that has a connected load that can be determined from rated or nameplate data. Demand savings will be determined by multiplying the connected load kW savings by the appropriate coincidence factor.

2. When using a temperature bin analysis to calculate the energy savings, the demand (kW) savings are averaged over the appropriate temperature bins (Seasonal).

3. When a computer simulation is used to calculate savings, the demand savings will be averaged over the appropriated peak time period (Seasonal).

Methodology for non-temperature-dependent measures:

1. Demand savings for measures that are not temperature-dependent will be determined by either the coincidence factors from Appendix 1 or the average estimated savings over the appropriate peak time periods (Seasonal). For example, for a process VFD measure, the savings will depend on cycling of the load. This cycling may occur many times during an hour.

2. If the process is operating throughout the Seasonal summer period, the average demand savings will be:

$$Average\ Demand\ Savings = \frac{Annual\ kWh\ savings}{Annual\ Equivalent\ Full\ Load\ Hours\ of\ Operation}$$

   Or, $AKW = \dfrac{AKWH}{EFLH}$

3. If the process is operated only a portion of that time period the demand savings will be pro-rated based on that portion.

There are no set baseline and compliance efficiencies. The energy savings are calculated as the difference between what is observed before this measure is installed and what is observed after this measure is installed.

3.4 REFRIGERATION

3.4.1 COOLER NIGHT COVERS

Description of Measure

Installation of retractable covers for open-type multi-deck refrigerated display cases. The covers are deployed during unoccupied times in order to reduce the energy loss.

Savings Methodology

The savings values below are based on a test conducted by Southern California Edison (SCE) at its state-of-the-art Refrigeration Technology and Test Center (RTTC) in Irwindale, CA (Ref [1]). 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.

There are no demand savings for this measure because the covers will not be in use during the peak period.

Inputs

Symbol	Description
h	Hours per year the cover are in use
W	Width of the opening that the covers protect, ft

Nomenclature

Symbol	Description	Units	Values	Comments
AKWH	Annual Gross Electric Energy savings	kWh/yr		
h	Hours per year the cover are in use			
SF	Savings factor based on the temperature of the case	kW/ft		
W	Width of the opening that the covers protect	ft		

Retrofit Gross Energy Savings - Electric

$$AKWH = W \times h \times SF$$

Table 1: Savings Factor Based on Case Temperature

Case Temperature	SF (kW/ft)
Low (-35°F to -5°F)	0.03
Medium 0°F to 30°F)	0.02
High (35°F to 55°F)	0.01

References

[1] "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.

3.4.2 EVAPORATOR FAN CONTROLS

Description of Measure

Installation of evaporator fan controls to walk-in coolers and freezers using evaporator fans that run constantly. The evaporator fan control system shuts off the evaporator fans when the cooler's thermostat is not calling for cooling.

Savings Methodology

The savings from this measure are derived from a reduction in the number of hours of operation that the evaporator fans are running. If fan motors are also replaced with ECM motors in conjunction with this measure then savings are based on the reduced fan motor wattage. Interactive refrigeration savings are also achieved due to reduced fan run-hours. The off hours, power reduction factors and power factor are stipulated values based on vendor experience.

Inputs

Symbol	Description
A	Amperage
EER	Energy Efficiency Ratio of Refrigeration Units
N	Number of fans
V	Volts

Nomenclature

Symbol	Description	Units	Values	Comments
A	Amperage of existing fans			
ACOP	Average Coefficient of Performance			
AKWH	Annual Gross Electric Energy savings	kWh		
CF	Seasonal peak demand coincident factor for refrigeration from Appendix 1			
COP	Coefficient of Performance			
DP	Power reduction factor	%		
ECM	Electronically Commutated Motor			
EER	Energy Efficiency Ratio			
AKW	Average hourly demand savings for both summer and winter	kW		
N	Number of fans			
Pf	Power factor of existing fans		0.65	
PSC	Permanent Split Capacitor motor			
V	Volts of existing fans			
h	Fan off hours after measure installation		3,000	

Retrofit Gross Energy Savings - Electric

If the fan motors are single-phase then calculate the energy savings as follows:

$$AKWH = N \times V \times A \times Pf \times (1 - DP) \times \frac{h}{1000} \times \left(1 + \frac{1}{ACOP}\right)$$

If the fan motors are three-phase then calculate the energy savings as follows:

$$AKWH = N \times V \times A \times \sqrt{3} \times Pf \times (1 - DP) \times \frac{h}{1000 \, W/_{kW}} \times \left(1 + \frac{1}{ACOP}\right)$$

If existing fan motors are being replaced concurrently with this measure then DP = 0.40 for PSC motors and 0.65 for shaded pole motors. If fan motors are not being replaced then DP = 0.

Pf = estimated to be 0.65

h = 3,000.

ACOP = 2.03 for freezers and 2.69 for coolers (used for interactive affects)

If existing EER's are available then ACOP = Average EER/3.413

Average EER = Full Load EER/0.85

Retrofit Gross Seasonal Peak Demand Savings - Electric, Winter and Summer

If the fan motors are single-phase then calculate the demand savings as follows:

$$AKW = CF \times N \times V \times A \times Pf \times \frac{(1 - DP)}{1000 \, W/_{kW}} \times \left(1 + \frac{1}{COP}\right)$$

If the fan motors are three-phase then calculate demand savings as follows:

$$AKW = CF \times N \times V \times A \times \sqrt{3} \times Pf \times \frac{(1 - DP)}{1000 \, W/_{kW}} \times \left(1 + \frac{1}{COP}\right)$$

If existing fan motors are being replaced concurrently with this measure then DP = 0.40 for PSC motors and 0.65 for shaded pole motors. If fan motors are not being replaced then DP = 0.

Pf = estimated to be 0.65

COP = 1.72 for freezers and 2.29 for coolers (used to calculate interactive affects)

If existing EER's are available then COP = EER/3.413

CF for refrigeration is the same for both winter and summer.

Changes from Last Version

Added formulas for calculating fan power. Differentiated between PSC and shaded pole motors.

3.4.3 EVAPORATOR FANS MOTOR REPLACEMENT

Description of Measure

Installation of an electronically commutated motor in place of existing integral electric motor connected to evaporator fans in walk-in coolers, freezers and reach-in display cases.

Savings Methodology

The savings estimates are based on the wattage reduction from replacing an existing PSC or shaded pole motor with an electronically commutated motor. Interactive refrigeration savings are also achieved due to reduced heat loads resulting from fan power reduction. The run hours, power reduction factors and power factor are stipulated values based on vendor experience.

If controls are added along with this measure then savings are calculated based on the assumption that the evaporator fan motor is replaced before the controls are added.

Inputs

Symbol	Description
A	Amperage
EER	Energy Efficiency Ratio of Refrigeration Units
N	Number of fans
V	Volts

Nomenclature

Symbol	Description	Units	Values	Comments
A	Amperage of existing fans			
ACOP	Average Coefficient of Performance			
AKW	Average hourly demand savings for both summer and winter	kW		
AKWH	Annual Gross Electric Energy savings	kWh		
CF	Seasonal peak demand coincident factor for refrigeration from Appendix 1			
COP	Coefficient of Performance			
DP	Power reduction factor	%	0.65	
EER	Energy Efficiency Ratio			
h	Hours of operation			
kW	KiloWatts			
N	Number of fans			
Pf	Power factor of existing fans			
PSC	Permanent Split Capacitor motor			
V	Volts of existing fans			

Retrofit Gross Energy Savings - Electric

If the existing fan motors are single-phase then calculate the energy savings as follows:

$$AKWH = N \times V \times A \times Pf \times DP \times \frac{h}{1000} \times \left(1 + \frac{1}{ACOP}\right)$$

If the existing fan motors are three-phase then calculate the energy savings as follows:

$$AKWH = N \times V \times A \times \sqrt{3} \times Pf \times DP \times \frac{h}{1000 \, {}^{W}\!/\!_{kW}} \times \left(1 + \frac{1}{ACOP}\right)$$

DP = 0.40 for PSC motors and 0.65 for shaded pole motors.

Pf = estimated to be 0.65

h = 5,500 for fans with existing controls and 8,500 for fans that do not have controls.

ACOP = 2.03 for freezers and 2.69 for coolers (used for interactive affects)
If existing EER's are available then ACOP = Average EER/3.412

Average EER = Full Load EER/0.85

Retrofit Gross Seasonal Peak Demand Savings - Electric, Winter and Summer

If the existing fan motors are single-phase then calculate demand savings as follows:

$$AKW = N \times V \times A \times Pf \times \frac{DP}{1000 \, {}^{W}\!/\!_{kW}} \times \left(\frac{h}{8760 \, {}^{hrs}\!/\!_{yr}} + \frac{CF \times 1}{COP}\right)$$

If the existing fan motors are three-phase then calculate demand savings as follows:

$$AKW = N \times V \times A \times \sqrt{3} \times Pf \times \frac{DP}{1000 \, {}^{W}\!/\!_{kW}} \times \left(\frac{h}{8760 \, {}^{hrs}\!/\!_{yr}} + \frac{CF \times 1}{COP}\right)$$

DP = 0.40 for PSC motors and 0.65 for shaded pole motors.

Pf = estimated to be 0.65

COP = 1.72 for freezers and 2.29 for coolers (used to calculate interactive affects)

If existing EER's are available then COP = EER/3.413

CF for refrigeration is the same for both winter and summer.

Changes from Last Version

Added formulas for calculating power reduction. Differentiated between PSC and shaded pole motors.

3.4.4 DOOR HEATER CONTROLS

Description of Measure

Installation of a control system to an existing facility where door heaters operate continuously. This measure is applicable to walk-in coolers and freezers that have electric heaters on the doors whose purpose is to prevent condensation from forming. The control system shuts off the door heaters when the facility's humidity is too low to allow condensation to occur.

Savings Methodology

The savings from this measure result from a reduction in the operating hours of the door heaters. The off hours are stipulated values and are overall averages derived from vendor experience. They are applicable to all store types and sizes.

Inputs

Symbol	Description
A	Amperage of door heater
N	Number of Doors
V	Volts of door heater

Nomenclature

Symbol	Description	Units	Values	Comments
A	Amperage of door heater			
AKW	Average hourly demand savings for both summer and winter	kW		
AKWH	Annual Gross Electric Energy savings	kWh		
CF	Seasonal peak demand coincident factor for refrigeration		Appendix 1	
h	Heater off hours after measure installation		6,500 for coolers, 4,070 for freezers	
Pf	Power factor		1	
V	Volts of door heater			

Retrofit Gross Energy Savings - Electric

$$AKWH = \frac{N \times V \times A \times Pf \times h}{1000 W/_{kW}}$$ (Note [1])

Pf = 1

h = 6,500 for coolers
h = 4,070 for freezers

Retrofit Gross Seasonal Peak Demand Savings - Electric, Winter and Summer

$$AKW = \frac{CF \times N \times V \times A \times Pf}{1000\, {}^{W}\!/_{kW}}$$ (Note [1])

Pf = 1

Note: *CF for refrigeration is the same for both winter and summer.*

Changes from Last Version

Added formulas for calculating heater power.

Notes

[1] The above formulas assume single phase power

3.4.5 VENDING MACHINE CONTROLS

Description of Measure

Installation of on/off control for vending type machines that both illuminate and refrigerate the product. The controller can be part of a central system or a local programmable control of the individual appliance.

Savings Methodology

Savings from this measure are due to reduced hours of operation of the vending machine. Off hours are multiplied by 45% to account for compressor cycling. The stipulated adjustment factor and power factor values are based on vendor experience.

There are no demand savings for this measure.

Inputs

Symbol	Description
A	Amperage of power serving vending machine
h_A	Hours vending machine turned on after measure installation
h_B	Hours vending machine turned on before measure installation
N	Number of vending machines
V	Volts of power serving vending machine

Nomenclature

Symbol	Description	Units	Values	Comments
A	Amperage of power serving vending machine			
AKWH	Annual Gross Electric Energy savings	kWh		
h_A	Hours vending machine turned on after measure installation			
h_B	Hours vending machine turned on before measure installation		Usually 8,760	
kW	KiloWatts			
N	Number of vending machines			
Pf	Power factor		0.85	
V	Volts of power serving vending machine			

Retrofit Gross Energy Savings - Electric

$$AKWH = \frac{N \times V \times A \times Pf \times (h_B - h_A) \times 0.45}{1000 \, {}^{W}\!/_{kW}}$$

Pf=0.85

Note: *The above formula assumes single phase power.*

Changes from Last Version

Added formulas for calculating vending machine power.

RESIDENTIAL

4.1 LIGHTING

4.1.1 LIGHT BULB

Description of Measure

Replacement of low efficiency screw-based light bulbs with high efficiency screw-based bulbs of equivalent lumen output. Examples of efficient lighting technologies may include Solid State Lighting (SSL, LED), Induction Lamps, and Compact Fluorescent Lamps (CFL).

Savings Methodology

Measure lives vary according to the type of bulb and its rated lifetime hours.

For fixtures with screw-based bulbs, only the lighting savings defined here for the high efficiency screw based bulbs are evaluated.

Direct install bulbs, as their name implies, are different than “retail bulbs” because their installation is performed or verified by a professional home energy assessor. Actual rated bulb wattage and location should be used to calculate savings for direct install bulbs.

General Service bulbs are defined as medium base bulbs that are intended for general service applications as specified in the Energy Independence and Security Act of 2007 (EISA 2007, Ref [4]). Non-General Service bulbs include, but are not limited to, reflector bulbs, 3-way bulbs, and candelabra based bulbs. (See Glossary)

The retrofit baseline for General Service bulbs is based on high efficiency incandescent bulbs (such as halogen) having 75% of the wattage of the previous (EISA-compliant) bulb (Ref [4]). The Non-General Service bulb baseline is an incandescent bulb. This baseline change will be phased in over the 2012-2015 program years and impacts the watt ratio part of the savings calculation. See Table 2-A to illustrate this point. See Note [7].

Note: *Savings for direct install bulbs are found under Retrofit. For savings from retail bulbs, see Lost Opportunity.*

A lighting project should be custom only if it clearly exhibits outlier type behavior which would clearly make the existing savings algorithms inappropriate to use and if the existing savings assumptions would produce an error of unacceptable magnitude. In such a case, the energy and demand savings should be well documented.

Inputs

Symbol	**Description**	**Units**
$Watt_{post}$	Rated wattage of installed or purchased high efficiency bulb.	Watts
$Watt_{pre}$	Rated wattage of low efficiency bulb being replaced by direct install.	Watts
Location	Location of direct install bulb. Table 1 lists the available options for this.	
Bulb Type	Technology of new bulb. Used primarily to determine measure life.	
Rated Life	Rated lifetime of the bulb in hours. This value is not the same as the measure life, but is used to determine the measure life.	Hours
$Lumens_{post}$	Lumen output of installed or purchased light bulb	

Nomenclature

Symbol	Description	Units	Values	Comments
AKWH	Annual Electric Energy Savings	kWh		Calculated
BIY	Baseline Implementation Year – Program year new EISA-driven baseline is to be implemented.			Note [7]
CF_S	Average summer seasonal peak coincidence factor	unit-less		Appendix A, Ref [3]
CF_S	Average winter seasonal peak coincidence factor	unit-less		Appendix A, Ref [3]
h_d	Daily hours of use, by room type for direct install, “Unknown” type for retail.	Hours per day	Table 1. Retail: 2.77	Ref [2], Ref [1]
LI	Corresponding to the Low Income sector			
NLI	Corresponding to all Non Low Income sector			
RP	Corresponding to the Retail Products sector			
SKW	Summer Demand Savings	kW		Calculated
$Watt_\Delta$	Delta Watts, the difference between the wattage of the lower efficiency baseline bulb and the wattage of the new bulb.	Watts (W)		Calculated
$Watt_{post}$	Rated wattage of high efficiency bulb.	Watts (W)	Input	
$Watt_{pre}$	Rated wattage of existing low efficiency bulb.	Watts (W)	Input	Direct install only
$Watt_{ratio}$	Wattage ratio between low efficiency bulb and high efficiency bulb	unit-less	Table 2, Table 3	
WKW	Winter Demand Savings	kW		Calculated

Retrofit Gross Energy Savings - Electric

$$Watt_\Delta = (Watt_{ratio} - 1) \times Watt_{post}$$

$$AKWH = \frac{Watt_\Delta \times h_d \times 365 \, {}^{days}\!/\!_{yr}}{1000 \, {}^{W}\!/\!_{kW}}$$

Table 1: Hours of Use per Day by Location

Location	$h_{d,NLI}$	$h_{d,LI}$
Bedroom	1.08*	1.60***
Bathroom	0.65*	1.60***
Den/Office	2.97**	2.97**
Garage	1.32*	1.32*
Hallway	6.25*	1.74***
Kitchen	2.97**	3.66***
Living Room	2.97**	3.20***
Dining Room	2.97**	2.97**
Exterior	2.89*	2.89*
Basement	1.29*	1.45***
Closet	1.24*	1.24*
Other	2.05**	2.05**
Unknown+	2.77**	2.77**

*Ref [5], **Ref [2], ***Ref [1], +Note [2].

Table 2: Watt Ratios for Direct Install

Existing Bulb	Install Type	Bulb Type	Hi Efficiency Bulb type	$Watt_{ratio}$	Notes
All General and Non-General Service Bulb types except any General Service bulbs indicated in Table 2-A as having an adjusted baseline based on EISA implementation on and after indicated Baseline Implementation Year.					
Incandescent, known wattage	All Direct Install	General Service and Non-General Service	CFL	$\frac{Watt_{pre}}{Watt_{post}}$	Note [5]
Incandescent, unknown wattage	Non Low Income	General Service and Non-General Service	CFL, LED, Induction	4.0	Ref [2]
	Low Income	General Service and Non-General Service	CFL, LED, Induction	3.4	Ref [1]
Bulbs within the lumen ranges as specified in Table 2-A having an adjusted baseline based on EISA implementation					
Incandescent, known wattage	All Direct Install	General Service	All bulb types	$\frac{0.75 \times Watt_{pre}}{Watt_{post}}$	Note [3]
Incandescent, unknown wattage	Non Low Income	General Service	CFL, LED, Induction	3.0	Note [3]
	Low Income	General Service	CFL, LED, Induction	2.5	Note [3]

Table 2-A: EISA Schedule and Weighted Watt Ratio

Lumen Ranges	Approximate CFL Wattage within lumen range	Year EISA standard becomes effective	Baseline Implementation Year (BIY)	Weighted Watt ratio in each PSD Year for calculating average annual savings over lifetime			
				2012	2013	2014	2015
Existing wattage unknown, Retail Products and Non-low Income Direct Install							
1490–2600	23W to 30W	2012	2013	3.25	3	3	3
1050–1489	18W to <23W	2013	2014	3.5	3.25	3	3
310–749, 750–1049	9W to <18W	2015	2015	3.75	3.5	3.25	3
Existing wattage unknown, Low Income Direct Install							
1490–2600	23W to 30W	2012	2013	2.7625	2.55	2.55	2.55
1050–1489	18W to <23W	2013	2014	2.975	2.7625	2.55	2.55
310–749, 750–1049	9W to <18W	2015	2015	3.1875	2.975	2.7625	2.55

Example - Retrofit Gross Energy Savings

A 60 Watt General Service incandescent bulb is replaced with a 15-Watt CFL bulb in the living room of a non-low income home by direct install.

$$Watt_{\Delta} = \left(\frac{0.75 \times 60\, watts}{15\, watts} - 1 \right) \times 15\ watts = 30\, watts$$

$$AKWH = (30\, watts) \times 2.97\ {}^{h}\!/_{day} \times 365\ {}^{days}\!/_{yr} \div 1000\ {}^{Watts}\!/_{kWh} = 32.5\ {}^{kWh}\!/_{yr}$$

Example - Retrofit Gross Peak Demand Savings

For the above retrofit example, $SKW = 30 \times 0.09 \div 1000\ {}^{W}\!/_{kW} = .0027\ kW$

Lost Opportunity Gross Energy Savings - Electric

$$Watt_{\Delta} = (Watt_{ratio} - 1) \times Watt_{post}$$

$$AKWH = \frac{Watt_{\Delta} \times h_d \times 365 \, {}^{days}/_{yr}}{1000 \, {}^{W}/_{kW}}$$

Table 3: Watt Ratios for Retail Bulbs

Bulb Type	**Hi Efficiency Technology**	**Baseline Technology**	**$Watt_{ratio}$**	**Notes**
General	CFL, LED	EISA 2007 compliant Incandescent	3.0	Ref [2], Ref [4], Note [1]
Non-General	CFL, LED (Not downlight)	Incandescent	4.0	Ref [2], Note [6]
Downlight	LED	Incandescent	5.0	Note [6]

Example - Lost Opportunity Gross Energy Savings

A 13 Watt General Service program CFL is purchased through a retailer.

$$Watt_{\Delta} = (3.0 - 1) \times 13 \, watts = 26 \, watts$$

$$AKWH = (26 \, watts) \times 2.77 \, {}^{h}/_{day} \times 365 \, {}^{days}/_{yr} \div 1000 \, {}^{Watts}/_{kWh} = 26.3 \, {}^{kWh}/_{yr}$$

Example - Lost Opportunity Gross Peak Demand Savings

A 13 Watt program CFL is purchased through a retailer.

$$SKW = 26 \times 0.09 \div 1000 \, {}^{W}/_{kW} = .0023 \, kW$$

Non Energy Benefits

Table 4: One time O&M benefit per bulb (Note [4]):

General Service CFL bulb	$3.00
Non-General Service CFL bulb	$4.00
LED general service bulb	$11.50
LED downlight	$14.00

Changes from Last Version

Clarified documentation for hours of use. Incorporated upcoming EISA 2007 requirements into baseline for standard bulb watt ratios. Clarified calculations of Watt Ratio and Delta Watts. Updated lifetime in appendix due to updated baseline for general service.

References

[1] KEMA, Evaluation of the Weatherization Residential Assistance Partnership (WRAP) and Helps Programs, September 10, 2010. Table 22, page 7-2.

[2] Nexus Market Research (NMR), Residential Lighting Markdown Impact, January 20, 2009. Table 5-15, page 51.

[3] RLW Analytics, Coincidence Factor Study Residential and Commercial & Industrial Lighting Measures, March 25, 2007. Tables i-3 and i-4, page IV.

[4] US Congress, Energy Independence and Security Act of 2007 (EISA), Title III, "ENERGY SAVINGS THROUGH IMPROVED STANDARDS FOR APPLIANCE AND LIGHTING," January 4, 2007.

[5] RLW Analytics, Northeast Utilities SPECTRUM Lighting Catalog and Retail Lighting Programs Hours of Use Re-Analysis, December 20, 2001. Table 7, page 14.

Notes

[1] The watt ratio is modified to reflect the upcoming (to be implemented 2012 through 2014) 2007 EISA federal standards (Ref [4]) which will require new General Service incandescent bulbs to have about 75% lower wattage. Non-General Service bulbs continue to use the established watt ratio, while all General Service bulbs use 75% of this established watt ratio.

[2] The h_d value for "Unknown" location is the average hours per day across all locations. This may not be used for direct install after installation, since location must be verified by the installer. It is most applicable for retail bulbs since the final location is unknown.

[3] The upcoming federal standard requires incandescent bulbs to use 75% of the wattage of standard general service incandescent bulbs. 4/3 is the watt ratio reflecting this.

[4] One time O&M benefits are based on the avoided expense of replacement incandescent bulbs over the lifetime of the new bulb. For instance, using $0.50 per incandescent bulb, 10,000-hr CFLs avoid the use of 8 1000-hr incandescent bulbs: $4.00. 25,000-hr general service LEDs avoid the use of 23 1000-hr incandescent bulbs: $11.50.

[5] In the case of Non-General Service bulbs where existing wattage is known, the Delta Watts calculation simplifies to its definition of $Watt\Delta = Watt_{pre} - Watt_{post}$.

[6] LED watt ratios based on the labeled efficacy in lumens/Watt (lm/W) of typical LED bulbs compared to the lm/W of a typical incandescent bulb.

[7] Note that the baseline does not change until the second year of the standard; this is due to several factors causing a delay in the immediate effects of the standard such as the lifetime of existing incandescent bulbs being about a year, stockpiling, and other unknowns.

4.1.2 LUMINAIRE

Description of Measure

Replacement of low efficiency hardwired or portable lighting fixtures with luminaires incorporating high efficiency lights, excluding those with screw-based lampholders (which are treated as light bulbs in Measure 4.1.1 for savings calculations). An efficient luminaire is a complete lighting unit (such as the products meeting the Energy Star Specification for Luminaires) including lamp(s), ballast(s) (when applicable), and the parts designed to distribute the light, position and protect the lamps, and connect to the power supply.

Savings Methodology

The savings methodology can be applied to the following examples of fixture types: hardwired exterior, security exterior, hardwired indoor (such as recessed downlights, fan lighting kits-separate or included with fan), portable lamps (such as table lamps, desk lamps, floor lamps), torchieres. Multiple pin-based or integrated lighting technologies are covered that might include Solid State Lighting (SSL, LED), Induction Lamp, Fluorescent, and Compact Fluorescent Lamp (CFL). Fixtures with screw-based lampholders are not included here in order to ensure that only qualified high-efficiency bulbs will be used in the fixture. See Note [5] for restrictions to Torchieres.

Products meeting the Energy Star Specification for Luminaires are considered to be high-efficiency lighting.

Note that only the energy savings from the light is considered. Therefore, savings for this measure is based on the total light wattage of the assembly. Any fan motor savings are negligible, and cooling savings have not been determined.

A lighting project should be custom only if it clearly exhibits outlier type behavior which would clearly make the existing savings algorithms inappropriate to use and if the existing savings assumptions would produce an error of unacceptable magnitude. In such a case, the energy and demand savings should be well documented. Since linear fluorescent fixtures are less common in a residential setting, they shall be treated as a custom measure.

Inputs

Symbol	**Description**	**Units**
$Watt_{post}$	Rated wattage of installed or purchased high efficiency fixture. For fixtures with multiple bulbs, this is the total wattage (not the wattage of one bulb).	Watts
$Watt_{pre}$	Rated wattage of low efficiency fixture being replaced by direct install. For fixtures with multiple bulbs, this is the total wattage (not the wattage of one bulb).	Watts
Location	Location of direct install fixture. Table 1 lists the available options for this.	N/A
Bulb Type	Technology of new bulb. Used primarily to determine measure life.	

Nomenclature

Symbol	**Description**	**Units**	**Values**	**Comments**
AKWH	Annual Electric Energy Savings	kWh		Calculated
CF_S	Average summer seasonal peak coincidence factor	unit-less		Appendix A, Ref [3]
CF_S	Average winter seasonal peak coincidence factor	unit-less		Appendix A, Ref [3]
h_d	Daily hours of use, by room type for direct install, By fixture type or Unknown for RP	hours per day	RP: Table 2 Direct Install: Table 1	Ref [2]
LI	Corresponding to the Low Income sector			

Symbol	Description	Units	Values	Comments
RNC	Corresponding to Residential New Construction sector			
RP	Corresponding to the Retail Products sector			
SKW	Summer Demand Savings	kW		Calculated
$Watt_{\Delta}$	Delta Watts, the difference between the wattage of the lower efficiency baseline and the wattage of the new fixture.	Watts (W)		Calculated
$Watt_{post}$	Rated wattage of high efficiency fixture.	Watts (W)	Input	
$Watt_{pre}$	Rated wattage of existing low efficiency fixture.	Watts (W)	Input	Direct install only
$Watt_{ratio}$	Wattage ratio between low efficiency fixture and high efficiency fixture. Defined as $Watt_{ratio} = \frac{Watt_{pre}}{Watt_{post}}$.	unit-less	Retail CFL: 3.948 (Except Fluorescent Torchiere, 3.4) Direct Install: as found (all technologies), $Watt_{ratio} = \frac{Watt_{pre}}{Watt_{post}}$	Retail CFL: Ref [2], Table 5-19, p. 57 Retail Fluorescent Torchiere: Note [5]
WKW	Winter Demand Savings	kW		Calculated

Retrofit Gross Energy Savings - Electric

$$Watt_{\Delta} = (Watt_{ratio} - 1) \times Watt_{post}$$ (Note [4])

$$AKWH = \frac{Watt_{\Delta} \times h_d \times 365 \, {}^{days}\!/_{yr}}{1000 \, {}^{W}\!/_{kW}}$$

Table 1: Hours of Use per Day by Location, Direct Install

Location	$h_{d,NLI}$	$h_{d,LI}$
Bedroom	1.08*	1.60***
Bathroom	0.65*	1.60***
Den/Office	2.97**	2.97**
Garage	1.32*	1.32*
Hallway	6.25*	1.74***
Kitchen	2.97**	3.66***
Living Room	2.97**	3.20***
Dining Room	2.97**	2.97**
Exterior	2.89*	2.89*
Basement	1.29*	1.45***
Closet	1.24*	1.24*
Security++	11.4	11.4
Other	2.05**	2.05**
Unknown+	2.77**	2.77**

*Ref [4], **Ref [2], ***Ref [1], +Note [2], ++Note [1]

Example - Retrofit Gross Energy Savings

A 60 Watt ceiling fixture is replaced with a 15-Watt CFL pin based fixture in the bathroom of a home by direct install.

$$Watt_{\Delta} = \left(\frac{60\,watts}{15\,watts} - 1 \right) \times 15\,watts = 45\,watts$$

$$AKWH = (45\,watts) \times 1.60\,{}^{h}\!/\!{}_{day} \times 365\,{}^{days}\!/\!{}_{yr} \div 1000\,{}^{Watts}\!/\!{}_{kWh} = 26.3\,{}^{kWh}\!/\!{}_{yr}$$

Example - Retrofit Gross Peak Demand Savings

For the above retrofit example,

$$SKW = 45 \times 0.09 \div 1000\,{}^{W}\!/\!{}_{kW} = .0004\,kW$$

Lost Opportunity Gross Energy Savings - Electric

$Watt_{\Delta} = (Watt_{ratio} - 1) \times Watt_{post}$ (for Torchieres, Note [5], $Watt_{\Delta}$ is capped at 190 – $Watt_{post}$)

$$AKWH = \frac{Watt_{\Delta} \times h_d \times 365\,{}^{days}\!/\!{}_{yr}}{1000\,{}^{W}\!/\!{}_{kW}}$$

Table 2: Hours of Use per Day by Fixture Type, Retail (Ref [2])

Fixture Type	**h_d**
Hardwired Indoor	2.53
Portable – Table Lamp	2.38
Portable - Torchiere	2.38
Hardwired Exterior	2.53
Unknown (Ref [2], Table 5-15)	2.77
Security Exterior (Note [1])	11.4

Example - Lost Opportunity Gross Energy Savings

A 26 Watt ceiling fixture (using two 13 Watt pin-based CFLs) is purchased through a retailer.

$$Watt_{\Delta} = (3.948 - 1) \times 26\,watts = 77\,watts$$

$$AKWH = (77\,watts) \times 2.77\,{}^{h}\!/\!{}_{day} \times 365\,{}^{days}\!/\!{}_{yr} \div 1000\,{}^{Watts}\!/\!{}_{kWh} = 77\,{}^{kWh}\!/\!{}_{yr}$$

Example - Lost Opportunity Gross Peak Demand Savings

A 26 Watt CFL ceiling fixture is purchased through a retailer.

$$SKW = 77 \times 0.09 \div 1000\,{}^{W}\!/\!{}_{kW} = .0069\,kW$$

Non Energy Benefits

Table 2: One time O&M Benefit per Bulb (Note 3)

Type	Benefit
Hardwired Indoor	$14.00
Portable – Table Lamp	$6.00
Portable – Torchiere	$5.00
Hardwired Exterior	$14.00
Security Exterior	$14.00

Changes from Last Version

Combined several fixture types into one measure with common savings methods but varying inputs. Aligned hours of use by room type with Light Bulb hours of use.

References

[1] KEMA, Evaluation of the Weatherization Residential Assistance Partnership (WRAP) and Helps Programs, September 10, 2010. Table 22, page 7-2.

[2] Nexus Market Research (NMR), Residential Lighting Markdown Impact, January 20, 2009. Table 5-13, page 50, and Table 5-15, page 51.

[3] RLW Analytics, Coincidence Factor Study Residential and Commercial & Industrial Lighting Measures, March 25, 2007. Tables i-3 and i-4, page IV.

[4] RLW Analytics, Northeast Utilities SPECTRUM Lighting Catalog and Retail Lighting Programs Hours of Use Re-Analysis, December 20, 2001. Table 7, page 14.

Notes

[1] The "Security" location refers only to exterior lights that are programmed to run continuously through the night. The hours are based on UI annual hours for rate class MH for street lighting. The "Security" designation does not refer to exterior lights that operate sporadically.

[2] The "Other" location (Ref [2]) included exterior, mudroom, playroom, sunroom, studio, closet, laundry, and various workrooms.

[3] One time O&M benefits are based on the avoided expense of replacement incandescent bulbs over the lifetime of the new bulb.

[4] Note that in the case of direct install, where existing wattage is known, the Delta Watts calculation simplifies to its definition of $Watt_{\Delta} = Watt_{pre} - Watt_{post}$.

[5] Public Act 04-85, An Act Concerning Energy Efficiency Standards, July 2004, limits torchiere wattage to 190 Watts. Therefore, the baseline for torchieres is capped at 190 watts, and: $Watt_{ratio}$ is capped at 3.4, and $Watt_{pre}$ is capped at 190 Watts.

4.2 HVAC

4.2.1 ENERGY EFFICIENT CENTRAL AC

Description of Measure

Installation of an energy efficient central air conditioning (AC) system

Savings Methodology

Savings are based on the Residential Central AC Regional Evaluation (CAC) (Ref [1]). The regional study metered the usage of recently installed residential AC units in New England. Using these measurements the study provided factors and equations (see below) to calculate the savings using the installed capacity and the Energy Efficiency Ratio (EER).

To account for the estimated remaining life of an existing AC and the additional lost opportunity savings from a new installed unit, energy savings resulting from the removal of units in working condition are calculated in two parts:

1. Retrofit savings based on the early retirement of a working existing unit to the lost opportunity baseline for the Remaining Useful Life" (RUL) from Appendix 4, and

2. Lost opportunity savings for installing a new efficient unit for the Effective Useful Life (EUL) of the measure from Appendix 4.

Inputs

Symbol	Description	Units
Cap_i	Installed cooling capacity	Tons
EERi	Installed EER	Btu/Watt-hr

Nomenclature

Symbol	Description	Units	Values	Comments
$AKWH_C$	Annual electric energy savings - cooling	kWh		
ASF	Annual Savings factor	kWh/ton	357.6	Note [1]
CAP_i	Installed cooling capacity	Tons		Input
DSF	Seasonal demand savings factor	kW/ton	0.591	Note [1]
EER_b	Baseline EER	Btu/Watt-hr	11	Note [2]
EER_e	Existing EER	Btu/Watt-hr	8	Note [3]
EER_i	Installed EER	Btu/Watt-hr		Input
SKW_C	Summer Seasonal Demand savings-cooling	kW		

Retrofit Gross Energy Savings - Electric

$$\mathrm{AKWH_C} = \mathrm{ASF} \times CAP_i \times \left(1 - \frac{EER_e}{EER_b}\right)$$

$$\mathrm{AKWH_C} = 357.6 \times CAP_i \times \left(1 - \frac{8}{11}\right) = 97.53 \times CAP_i$$

Example - Retrofit Gross Energy Savings

An existing working central A/C is replaced by an energy efficient unit. The new installed unit has a 3 ton cooling capacity, 12.5 EER. What are the annual retrofit savings?

$$\mathrm{AKWH_C} = 97.53 \times CAP_i$$

$$\mathrm{AKWH_C} = 97.53 \times 3 = 293 kWh$$

Retrofit Gross Peak Demand Savings - Electric, Winter and Summer

$$\mathrm{SKW_C} = DSF \times CAP_i \times \left(1 - \frac{EER_e}{EER_b}\right)$$

$$\mathrm{SKW_C} = 0.591 \times CAP_i \times \left(1 - \frac{8}{11}\right) = 0.161 \times CAP_i$$

Example - Retrofit Gross Peak Demand Savings

Same example as above: What are the summer demand savings?

$$\mathrm{SKW_C} == 0.161 \times CAP_i$$

$$\mathrm{SKW_C} == 0.161 \times 3 = 0.483$$

Lost Opportunity Gross Energy Savings - Electric

$$\mathrm{AKWH_C} = \mathrm{ASF} \times CAP_i \times \left(\frac{EER_i}{EER_b} - 1\right)$$

$$\mathrm{AKWH_C} = 357.6 \times CAP_i \times \left(\frac{EER_i}{11} - 1\right)$$

Example - Lost Opportunity Gross Energy Savings

An existing working central AC is replaced with an energy efficient unit. The new installed unit has a 3 ton cooling capacity, 12.5 EER. What are the annual lost opportunity savings?

$$\mathrm{AKWH_C} = 357.6 \times CAP_i \times \left(\frac{EER_i}{EER_b} - 1 \right)$$

$$\mathrm{AKWH_C} = 357.6 \times 3 \times \left(\frac{12.5}{11} - 1 \right) = 146 kWh$$

Lost Opportunity Gross Seasonal Peak Demand Savings - Electric, Winter and Summer

$$\mathrm{SKW_C} = DSF \times CAP_i \times \left(\frac{EER_i}{EER_b} - 1 \right)$$

$$\mathrm{SKW_C} = 0.591 \times CAP_i \times \left(\frac{EER_i}{11} - 1 \right)$$

Example - Lost Opportunity Gross Peak Demand Savings

An existing working central AC is replaced with an energy efficient unit. The new installed unit has a 3 ton cooling capacity, 12.5 EER. What are the annual lost opportunity savings?

$$\mathrm{SKW_C} = 0.591 \times CAP_i \times \left(\frac{EER_i}{11} - 1 \right)$$

$$\mathrm{SKW_C} = 0.591 \times 3 \times \left(\frac{12.5}{11} - 1 \right) = 0.242 kW$$

References

[1] Residential Central AC Regional Evaluation, ADM Associates, Inc., November 2009, page 4-9 and page ES-4.

Notes

[1] The values were calculated based on the ADM study (Ref [1]), Table 4-7, page 4-9, and Table 6-2, 6-1

[2] Ref [1], ADM study page ES-3

[3] Estimated based on average installed efficiency for an approximately 15 year old unit. ASHRAE/IESNA Standard 90.1-1999 Table 6.2.1A has a minimum requirement of 10 SEER for 2011. ***Note:*** *Units of that vintage were only rated on SEER. EER is approximately 80% of SEER. 8 EER is used as the estimated existing efficiency.*

4.2.2 HEAT PUMP

Description of Measure

Installation of an efficient air source heat pump

Savings Methodology

The savings methodology presented here is for heating only; cooling savings from an efficient heat pump is the same as the cooling savings for an efficient central air conditioner, as presented in this manual.

To account for the estimated remaining life of the existing heat pump and the additional lost opportunity savings from new installed units, energy savings resulting from the removal of units in working condition are calculated in two parts:

1. Retrofit savings based on the early retirement of a working existing unit to the lost opportunity baseline for the Remaining Useful Life" (RUL) from Appendix 4, and

2. Lost opportunity savings for installing a new efficient unit for the Effective Useful Life (EUL) of the measure from Appendix 4.

Inputs

Symbol	**Description**	**Units**
CAP_i	Installed Cooling Capacity	Btu/hr
EER_i	Energy Efficiency Ratio, Installed	Btu/Watt-hr
$HSPF_e$	Heating Season Performance Factor of existing unit	Btu/Watt-hr
$HSPF_i$	Heating Season Performance Factor, installed unit	Btu/Watt-hr
	Existing heating system type	

Nomenclature

Symbol	**Description**	**Units**	**Values**	**Comments**
1 Ton	Capacity, Tonnage	Ton	12,000 Btu/hr	Conversion factor
AKWH	Annual Electric Energy Savings	kWh		
CAP_i	Installed Cooling Capacity	Btu/hr		Input
EER_b	Energy Efficiency Ratio, Baseline	Btu/Watt-hr	11.0	Ref [1]
EER_e	Energy Efficiency Ratio, Existing	Btu/Watt-hr	Use 8.0 – if EER_E existing is not known	Ref [1]
EER_i	Energy Efficiency Ratio, Installed	Btu/Watt-hr		Input
$EFLH_H$	Heating Equivalent Full-load Hours	hours	1307	Note [3]
$HSPF_b$	Heating Season Performance Factor, Baseline	Btu/Watt-hr	7.7	Note [1]
$HSPF_e$	Heating Season Performance Factor, Existing	Btu/Watt-hr	Use 6.8 if HSPF existing is not known; 3.41 for electric resistance heat	Note [2]; Conversion from Btu to kWh
$HSPF_i$	Heating Season Performance Factor, Installed	Btu/Watt-hr		Input
SKW	Summer Demand Savings	kW		
WKW	Winter Demand Savings	kW		

Retrofit Gross Energy Savings - Electric

Heating

$$\mathrm{AKWH_H} = \mathrm{EFLH_H} \times CAP_i \times \left(\frac{1}{HSPF_e} - \frac{1}{HSPF_b} \right) \times \frac{1}{1000}$$

Cooling

$AKWH_C$: Annual cooling savings is presented in Central AC measure (4.2.1)

Example - Retrofit Gross Energy Savings

A new air source heat pump with cooling capacity of 36,000 BTU/hr and $HSPF_I$ of 9 is installed in a home equipped with old working heat pump with cooling capacity of 36,000 BTU/hr, and $HSPF_e$ of 6. See Note [5].

Using equations below,

$$AKWH_H = 1307 \times 36{,}000 \times \left(\frac{1}{6} - \frac{1}{7.7} \right) \times \frac{1}{1000}$$

$AKWH_H$ = 1731.3 kWh

$AKWH_C$: Annual cooling savings as presented in Central AC measure (4.2.1)

Retrofit Gross Seasonal Peak Demand Savings - Electric, Winter and Summer

WKW= 0; Note [4]

SKW = Summer seasonal peak demand savings as presented in Central AC

Example - Lost Opportunity Gross Energy Savings

A new air source heat pump with an installed cooling capacity of 36,000 BTU/hr and HSPF of 9 is installed. What are the annual electric heating and cooling savings?
Using equation,

$$\mathrm{AKWH_H} = \mathrm{EFLH_H} \times CAP_i \times \left(\frac{1}{HSPF_b} - \frac{1}{HSPF_i} \right) \times \frac{1}{1000}$$

$$\mathrm{AKWH_H} = 1307 \times 36{,}000 \times \left(\frac{1}{7.7} - \frac{1}{9} \right) \times \frac{1}{1000}$$

$AKWH_{H=}$882.6 kWh

Lost Opportunity Gross Seasonal Peak Demand Savings - Electric, Winter and Summer

WKW= 0; Note [4]

SKW = Summer seasonal peak demand savings as presented in Central AC measure (4.2.1)

References

[1] Residential Central AC Regional Evaluation, ADM Associates, Inc., November 2009, page 4-1.

Notes

[1] The federal minimum standard for heat pumps is HSPF 7.7, as of Jan 23, 2006

[2] In 1992, the federal government established the minimum heating efficiency standard for new heat pumps at 6.8 HSPF.

[3] $EFLH_H$ =1307 hours; Based on Heating degree day data and ASHRAE adjustment factor.

[4] WKW = 0; Demand savings are not claimed for this measure since backup resistance heat on the heat pump would most likely be used during winter seasonal peak periods

[5] Note that retrofit savings is based on the removal of the old unit; therefore the efficiency of the installed unit is not necessary to calculate retrofit savings. For working unit additional lost opportunity savings will be claimed which is based on the efficiency of the installed unit.

4.2.3 GEOTHERMAL HEAT PUMP

Description of Measure

Installation and commissioning of a high efficiency closed loop or Buried DX Geothermal Heat Pump system.

Savings Methodology

Savings are determined using the results of "HVAC Systems in an ENERGY STAR Home: Owning & Operating Costs (Update 2008)" (Ref [1]) as a basis for the calculation. The report analyzed the annual consumption of geothermal heat pumps. To calculate savings for this measure, the results from the study are adjusted based on size (in tons) and efficiency (COP and EER). Note: the savings baseline is an Energy Star Tier 1 geothermal system.

Inputs

Symbol	Description	Units
	Type of Geothermal system (closed loop/DX) Water to water or Water to air	
CAP_i	Installed Cooling Capacity	Tons
EER_i	EER - Installed	Btu/Watt-hr
COP_i	COP - Installed	

Nomenclature

Symbol	Description	Units	Values	Comments
AH_{CDH}	Annual heating energy usage per ton	kWh/ton/yr		Ref [1]
AH_b	Annual heating energy usage, Baseline	kWh/yr		
AH_i	Annual heating energy usage, Installed	kWh/yr		
AC_{CDH}	Annual cooling energy usage per ton	kWh/ton/yr		Ref [1]
AC_b	Annual cooling energy usage, Baseline	kWh/yr		
AC_i	Annual cooling energy usage, Installed	kWh/yr		
CAP_i	Installed Cooling Capacity in Tons	Tons		Input
CF_C	Coincidence Factor, residential cooling			Appendix 2
CF_H	Coincidence Factor, residential heating			Appendix 2
COP_b	COP - Baseline		Table 1	Energy Star Tier 1
COP_{CDH}	EER used to model consumption in the CDH study		3.9	Ref [1]
COP_i	COP - Installed			Input
EER_{CDH}	EER used to model consumption in the CDH study	Btu/Watt-hr	17.2	Ref [1]
EER_b	EER - Baseline	Btu/Watt-hr	Table 1	Energy Star Tier 1
EER_i	EER - Installed	Btu/Watt-hr		Input
SKW_C	Summer Seasonal Demand Savings	kW		
SKW_{CDH}	Summer kW per ton	kW/ton		Ref [1]
WKW_H	Winter Seasonal Demand Savings	kW		

Lost Opportunity Gross Energy Savings - Electric

The annual consumption per ton and efficiencies per cooling capacity (tons) are as follows (Ref [1]):
AH_{CDH} = 1,569 kWh/Ton at 3.9 COP
AC_{CDH} = 326 kWh/ton at 17.2 EER
SKW_{CDH} = 0.71 kW/ton

Table 1: Baseline Efficiencies

System Type	EER_b	COP_b
Closed Loop Water to Air	14.1	3.3
Closed Loop Water to Water	15.1	3.0
DGX	15.0	3.5

$$AKWH_C = (AC_b - AC_i)$$

$$AKWH_C = CAP_i \times AC_{CDH} \times \left(\frac{EER_{CDH}}{EER_b} - \frac{EER_{CDH}}{EER_i} \right)$$

$$AKWH_C = CAP_i \times 326 \times \left(\frac{17.2}{EER_b} - \frac{17.2}{EER_i} \right)$$

$$AKWH_H = (AH_b - AH_i)$$

$$AKWH_H = CAP_i \times AH_{CDH} \times \left(\frac{COP_{CDH}}{COP_b} - \frac{COP_{CDH}}{COP_i} \right)$$

$$AKWH_H = CAP_i \times 1{,}569 \times \left(\frac{3.9}{COP_b} - \frac{3.9}{COP_i} \right)$$

$$AKWH = AKWH_C + AKWH_H$$

<u>Example - Lost Opportunity Gross Energy Savings</u>

A 3 ton closed loop geothermal heat pump is installed and commissioned with an EER of 26 and COP of 4. What are the energy savings?

$$AKWH_C = 3 \times 326 \times \left(\frac{17.2}{14.1} - \frac{17.2}{26} \right) = 546 kWh$$

$$AKWH_H = 3 \times 1{,}569 \times \left(\frac{3.9}{3.3} - \frac{3.9}{4} \right) = 973 kWh$$

$$AKWH = 546 + 973 = 1{,}519 kWh$$

<u>Lost Opportunity Gross Seasonal Peak Demand Savings - Electric, Winter and Summer</u>

$$SKW_C = CAP_i \times SKW_{CDH} \times \left(\frac{EER_{CDH}}{EER_b} - \frac{EER_{CDH}}{EER_i} \right)$$

$$SKW_C = CAP_i \times 0.71 \times \left(\frac{17.2}{EER_b} - \frac{17.2}{EER_i} \right) \times CF_C$$

$$WKW_H = CAP_i \times \left(\frac{12{,}000 Btus}{Ton}\right) \times \left(\frac{kW}{3{,}412 Btus}\right) \times \left(\frac{1}{COP_b} - \frac{1}{COP_i}\right) \times CF_H$$

Changes from Last Version

The 10% savings from commissioning was removed. The baseline was changed from code to Energy Star Tier 1.

References

[1] HVAC Systems in an Energy Star Home: Owning & Operating Costs (Update 2008), CDH Energy Corp, 2008, Tables 3 and 4.

4.2.6 ELECTRONICALLY COMMUTATED MOTOR (ECM)

Description of Measure

Installation of an electronically commutated motor (ECM) or brushless permanent magnet motor (BPM) when installed as part of a new high efficiency HVAC system or as a new ECM replacement on an existing HVAC system.

Savings Methodology

Savings for this measure are calculated based on a typical home. The savings are based on the metering study "Electricity Use by New Furnaces – A Wisconsin Field Study, Energy Center of Wisconsin," Ref [1], which compared actual furnace fan annual consumption of units with ECMs to units with permanent split capacitor motors. The annual savings (kWh) of the Wisconsin-based study were adjusted to Connecticut by applying the appropriate cooling degree day (CDD) and heating degree day (HDD) adjustments. The study identified small amount of standby losses from the ECM controls. These losses were allocated proportionally to heating and cooling savings before the results were adjusted for Connecticut. Because reducing the fan energy increases heating and reduces cooling energy usage, the calculation also quantifies interactive effects.

Inputs

Symbol	**Description**	**Units**
	Number of systems with ECMs installed.	

Nomenclature

Symbol	**Description**	**Units**	**Values**	**Comments**
$ABTU_H$	Annual BTU Savings	Btu/yr		
ACCF	Annual natural gas savings	Ccf/yr		
AFUE	Annual Fuel Utilization Efficiency	%	90%	Note [4]
$AKWH_H$	Annual Electric Energy Savings during heating season	kWh/yr		
AKWHc	Annual Electric Energy Savings during cooling season	kWh/yr		
AOG	Annual oil savings	Gal/yr		
APG	Annual propane savings	Gal/yr		
CDD	Cooling Degree Days for CT		603	Note [2]
CF_C	Coincidence Factor cooling		0.75	
CF_H	Coincidence Factor heating		0.50	
HDD	Heating Degree Days for CT		5,885	Note [2]
PD_H	Peak Day heating savings	Ccf		
PDF_H	Peak Day factor heating		0.00977	
PkW_C	kW savings – Cooling mode	kW	0.16	Ref [1]
PkW_H	kW savings –Heating mode	kW	0.18	Ref [1]
SEER	Seasonal Energy Efficiency Ratio		15	Note [4]
SKW	Summer Demand Savings	kW		
WCS	Electric energy savings for Wisconsin during cooling season.	kWh	65	Note [1]
WHS	Electric energy savings for Wisconsin during heating season.	kWh	375	Note [1]
WICDD	Cooling Degree Days for WI		524	Note [3]
WIHDD	Heating Degree Days for WI		7,521	Note [3]
WKW	Winter Demand Savings	kW		

Lost Opportunity Gross Energy Savings - Electric

$$AKWH_H = WHS \times \left(\frac{HDD}{WIHDD}\right)$$

$$AKWH_H = 375 \times \left(\frac{5,885}{7,521}\right) = 293\,kWh$$

$$AKWH_C = WCS \times \left(\frac{CDD}{WICDD}\right) \times \left(1 + \frac{3.412}{SEER}\right)$$

$$AKWH_C = 65 \times \left(\frac{603}{524}\right) \times \left(1 + \frac{3.412}{15}\right) = 92\,kWh$$

Lost Opportunity Gross Energy Savings - Fossil Fuel

Interactive savings are from the reduction of fan energy. They are negative since they increase the heating consumption.

$$ABTU_H = -AKWH_H \times \frac{3,412\,Btu/kWh}{AFUE}$$

$$ABTU_H = -293 \times \frac{3,412\,Btu/kWh}{0.9} = -1,110,796\,Btu$$

Savings by fuel type:

$$ACCF_H = \frac{ABTU_H}{102,900\,Btu/ccf} = \frac{-1,110,796}{102,900\,Btu/ccf} = -10.8\,ccf$$

$$AOG_H = \frac{ABTU_H}{138,690\,Btu/Gal} = \frac{-1,110,796}{138,690\,Btu/Gal} = -8.0\,Gal$$

$$APG_H = \frac{ABTU_H}{91,330\,Btu/Gal} = \frac{-1,110,796}{91,330\,Btu/Gal} = -12.2\,Gal$$

Lost Opportunity Gross Seasonal Peak Demand Savings - Electric, Winter and Summer

$$WKW_H = PkW_H \times CF_H$$

$$WKW_H = 0.16 \times 0.5 = 0.08\,kW$$

$$WKW_C = PkW_C \times CF_C$$

$$WKW_C = 0.18 \times 0.59 = 0.11\,kW$$

Lost Opportunity Gross Peak Day Savings - Natural Gas

$$PD_H = ACCF \times PDF_H$$

$$PD_H = -11 \times 0.00977 = -0.11\,ccf$$

Changes from Last Version

Modified savings based on Ref [1] study. Savings in heating mode increased from 285 kWh to 293 kWh. Savings during the cooling mode were also added.

References

[1] Electricity Use by New Furnaces – A Wisconsin Field Study, Energy Center of Wisconsin, October 2003.

Notes

[1] The Wisconsin study (Ref [1]) savings while heating (400 kWh, page 9), Cooling (70 kWh, page 10) and Standby losses of (30 kWh, page 11). The standby losses were allocated to heating (25 kWh) and cooling (5 kWh) before the values were adjusted based on CT.

[2] Degree Day data from the National Climatic Data Center, Divisional Data, CT state, Jan 1979 to Dec 2008, 30 year average. http://www7.ncdc.noaa.gov/CDO/CDODivisionalSelect.jsp

[3] Degree Day data from the National Climatic Data Center, Divisional Data, WI state, Jan 1979 to Dec 2008, 30 year average. http://www7.ncdc.noaa.gov/CDO/CDODivisionalSelect.jsp

[4] The efficiencies assumed on an average qualifying unit’s efficiency.

4.2.9 DUCT SEALING

Description of Measure

Duct sealing to improve efficiency of air distribution from HVAC systems. Savings are verified by measuring outside duct leakage at 25 Pascal using standard duct blaster testing procedures and blower door.

Savings Methodology

Duct improvements (sealing) should be verified with duct blaster test at 25 Pa using an approved test method. Note that a blower door is required as part of this test to maintain 25 Pa in the house in order to isolate duct leakage to the outside. Alternative test methods (i.e. subtraction method, flow hood method, delta Q, etc) will generally yield inconsistent results and therefore are not permitted. Duct infiltration reduction was simulated using REM/Rate, a residential energy analysis and rating software (Ref [1]).

Reminder: *Heating savings may not be claimed if ducts are not used for heating distribution. For instance, a home with electric baseboard resistance heating or a fossil fuel boiler which has ducts used only for the Central Air Conditioner may only claim cooling savings.*

Inputs

Symbol	Description
CFM_{Pre}	Air flow rate before duct sealing at 25 Pa
CFM_{Post}	Air flow rate after duct sealing at 25 Pa
	Heating Fuel Type (Electric Resistive, HP, Gas, Oil, Propane, etc...)
	Heating System Distribution Type (Forced air with fan, heat pump, resistive, radiator, etc)

Nomenclature

Symbol	Description	Units	Values	Comments
ACCF	Annual Natural Gas Savings	Ccf/yr		
$AKWH_H$	Annual Electric Energy Savings, Heating	kWh/yr		
$AKWH_C$	Annual Electric Energy Savings, Cooling	kWh/yr		
AOG	Annual Oil Savings	Gal/yr		
APG	Annual Propane Savings	Gal/yr		
CFM_{Pre}	Air flow rate before duct sealing	CFM		Inputs
CFM_{Post}	Air flow rate after duct sealing	CFM		Inputs
SKW	Summer Demand Savings	kW		
WKW	Winter Demand Savings	kW		
PD_H	Natural gas peak day savings - heating	Ccf		
PDF_H	Natural gas peak day factor -heating		0.00977	Appendix 1
REM	Savings modeled using Residential Energy Modeling software			Ref [1]

Retrofit Gross Energy Savings - Electric

Table 1: Electric Duct Blaster Savings per CFM Reduction at 25 Pa

	$REM_{Heating}$			**REM_{AH}**	**$REM_{Cooling}$**
Duct Blaster Savings at 25 Pa	Heating (Electric Forced Air)	Heating (Heat Pumps)	Heating (Geothermal)	kWh Fan Heating Savings	Annual Electric Cooling Savings ($AKWH_C$)
Savings per CFM Reduction	7.693	3.847	2.564	1.100	1.059

For Electric (Forced Air), Heat Pump or Geothermal Heating Systems,

$$AKWH_H = REM_{Heating} \times (CFM_{Pre} - CFM_{Post})$$

For Fossil Fuel heating with air handler unit,

$$AKWH_H = REM_{AH} \times (CFM_{Pre} - CFM_{Post})$$

Home with Central AC,

$$AKWH_C = REM_{Cooling} \times (CFM_{Pre} - CFM_{Post})$$

Retrofit Gross Energy Savings - Fossil Fuel

Table 2: Fossil Fuel Duct Blaster Savings per CFM Reduction at 25 Pa

Duct Blaster Savings at 25 Pa	Heating (MMBtu)	Gallons Oil – Gallons **(REM_{Oil})**	Natural Gas – Ccf **(REM_{NG})**	Gallons Propane – Gallons **($REM_{Propane}$)**
Savings per CFM Reduction	0.035	0.250	0.359	0.383

Reminder: *Fossil fuel savings include estimated expected system efficiency including combustion and distribution.*

For homes with natural gas heating system,

$$ACCF_H = REM_{NG} \times (CFM_{Pre} - CFM_{Post})$$

For homes with oil heating system,

$$AOG_H = REM_{Oil} \times (CFM_{Pre} - CFM_{Post})$$

For homes with propane heating system,

$$APG_H = REM_{Propane} \times (CFM_{Pre} - CFM_{Post})$$

Example - Retrofit Gross Energy Savings

A duct blaster test was performed in a 1960’s ranch style home in Hartford. The size of the home is 2400 sq ft. The primary source of heating is natural gas furnace and has an Energy Star central AC. The duct blaster test was performed at 25 Pa and a blower door was used to maintain 25 Pa within the house during the duct test (to isolate outside duct leakage). The readings on the test equipment showed CFM_{Pre} of 850 and CFM_{Post} of 775. What are the electric and fossil fuel savings for this home?

This home has fossil fuel and air handler (fan) savings.

Using the equation for heating savings:

$$ACCF_H = REM_{NG} \times (CFM_{Pre} - CFM_{Post})$$

$$ACCF_H = 0.0359 \times (850 - 775)$$

$$ACCF_H = 26.9\,Ccf$$

Using the equation for electric heating fan savings,

$$AKW_H = REM_{AH} \times (CFM_{\Pr e} - CFM_{Post})$$
$$AKWH_H = 1.100 \times (850 - 775)$$
$$AKWH_H = 82.5\ kWh$$

Using the equation for central AC savings,

$$AKWH_C = REM_{Cooling} \times (CFM_{\Pr e} - CFM_{Post})$$
$$AKWH_C = 1.059 \times (850 - 775)$$
$$AKWH_C = 79.4\ kWh$$

Retrofit Gross Seasonal Peak Demand Savings - Electric, Winter and Summer

Estimated winter demand savings, REM_{WKW} = 0.0158 kW (Electric resistance forced air and Heat pumps)
Estimated winter demand savings, REM_{WKW} = 0.0053 kW (Geothermal)
Estimated winter demand savings, REM_{WKW} = 0 kW (everything else)

$$WKW_H = REM_{WKW} \times (CFM_{\Pr e} - CFM_{Post})$$

Estimated summer demand savings, REM_{SKW} = 0.0023 kW

$$SKW_C = REM_{SKW} \times (CFM_{\Pr e} - CFM_{Post})$$

Reminder: *Demand savings are based on design load calculation in REM software, hence there is no need to use coincidence factors.*

Retrofit Gross Peak Day Savings - Natural Gas

$$PD_H = ACCF_H \times PDF_H$$

Example - Retrofit Gross Peak Demand Savings

A duct blaster test was performed in a 1960's ranch style home in Hartford. The size of the home is 2400 sq ft. The primary source of heating is heat pump. The home is cooled by a central AC system. The duct blaster test was performed at 25 Pa. The readings on the test equipment showed CFM_{Pre} of 850 and CFM_{Post} of 775. What are the electric and natural gas peak demand savings for this home?

Using the equation for electric resistance and heat pump winter demand (REM_{WKW} = 0.0158 kW per CFM),

$$WKW_H = 0.0158 \times (850 - 775)$$
$$WKW_H = 1.19\ kW$$

And using the equation for summer demand savings (REM_{SKW} = 0.0023 kW per CFM),

$$SKW_C = 0.0023 \times (850 - 775)$$
$$SKW_C = 0.173\ kW$$

If the above home has a Natural Gas furnace instead of a heat pump, then the home would have natural gas energy savings and natural gas peak day savings.

Using the formula for Peak Day Natural Gas,

$$PD_H = ACCF_H \times PDF_H$$

$$PD_H = 26.9 \times 0.00977$$

$$PD_H = 0.263\, Ccf$$

Changes Since Last Version

Changed from savings “per 100 CFM” to “per 1 CFM”. Revised winter demand savings with new REM modeling.

References

[1] REM/Rate™ is a residential energy analysis, code compliance and rating software developed by Architectural Energy Corporation. This software calculates heating, cooling, hot water, lighting, and appliance energy loads, consumption and costs for new and existing single and multi-family homes. Duct blaster energy savings analysis using REM was performed by C&LM Planning team, Northeast Utilities, August 2008.

[2] Residential Central AC Regional Evaluation, ADM Associates, Inc., Final Report, November 2009

4.2.12 HEAT PUMP - DUCTLESS

Description of Measure

Installation of energy efficient Ductless Heat Pump or Mini-Split Heat Pump

Savings Methodology

Savings methodology is based on the impact evaluation of Ductless Heat Pump (DHP) pilot performed by KEMA (Ref [1]) Energy savings for DHP are determined using savings factors from the pilot study adjusted for installed efficiencies or by performing a custom analysis such as DOE-2 or Billing analysis [PRISM] (Note [2] & [3]) for a specific project. If a custom analysis is done, the savings will be capped at 50% of the heating portion of the billing history. Heating savings are calculated on the basis of either Hartford or Bridgeport climate data. Savings for actual projects are calculated using the closest location on heating degree-day (HDD) basis.

DHP installed in an existing home with Electric Resistive heating system is considered to have Retrofit savings. DHP installed in a home with fossil fuel heating system is considered to have Lost Opportunity savings.

Inputs

Symbol	Description
$HSPF_I$	Heating Season Performance Factor, Installed
$SEER_I$	Seasonal Energy Efficiency Ratio, Installed
CAP_C	Cooling Capacity
CAP_H	Heating capacity

Nomenclature

Symbol	Description	Units	Value	Comments
1 Ton	Capacity, Tonnage	Tons	12,000 Btu/hr	Unit conversion
AA_C	Hartford kWh cooling savings factor from pilot	kWh/1000 Btu	3.1	Ref [1]
AA_H	Hartford kWh heating savings factor from pilot	kWh/1000 Btu	130	Ref [1]
AKWH	Annual Electric Energy Savings	kWh		
BB_C	Hartford kW cooling savings factor from pilot	kW/1000 Btu	0.0017	Ref [1]
BB_H	Hartford kW heating savings factor from pilot	kW/1000 Btu	0.019	Ref [1]
CAP_C	Nominal Cooling Capacity	Btu/hr		Input
CAP_H	Nominal Heating capacity	Btu/hr		Input
CC_C	Bridgeport kWh cooling savings factor from pilot	kWh/1000 Btu	3.2	Ref [1]
CC_H	Bridgeport kWh heating savings factor from pilot	kWh/1000 Btu	140	Ref [1]
DD_C	Bridgeport kW cooling savings factor from pilot	kW/1000 Btu	0.0014	Ref [1]
DD_H	Bridgeport kW heating savings factor from pilot	kW/1000 Btu	0.032	Ref [1]
EE_C	Efficiency conversion factor, cooling		0.037	Ref [1]
EE_H	Efficiency conversion factor, heating		0.171	Ref [1]
$HSPF_B$	Heating Season Performance Factor, Baseline	Btu/Watt-hr	7.7 – Lost Opportunity	Note [1]
$HSPF_E$	Heating Season Performance Factor, Existing	Btu/Watt-hr	3.4 – Retrofit	Note [1]
$HSPF_I$	Heating Season Performance Factor, Installed	Btu/Watt-hr		Input
$SEER_B$	Seasonal Energy Efficiency Ratio, Baseline	Btu/Watt-hr	13.0 – Lost Opportunity	Note [1]
$SEER_E$	Seasonal Energy Efficiency Ratio, Existing	Btu/Watt-hr	10.1 – Retrofit	Note [1]
$SEER_I$	Seasonal Energy Efficiency Ratio, Installed	Btu/Watt-hr		Input

Symbol	Description	Units	Value	Comments
SKW	Summer Demand Savings	kW		
WKW	Winter Demand Savings	kW		

Retrofit Gross Energy Savings - Electric

Heating

For Hartford: $$AKWH_H = CAP_H \times \left(\frac{1}{HSPF_E} - \frac{1}{HSPF_I} \right) \times \frac{1}{EE_H} \times AA_H \times \frac{1}{1000}$$

For Bridgeport: $$AKWH_H = CAP_H \times \left(\frac{1}{HSPF_E} - \frac{1}{HSPF_I} \right) \times \frac{1}{EE_H} \times CC_H \times \frac{1}{1000}$$

Cooling

For Hartford: $$AKWH_C = CAP_C \times \left(\frac{1}{SEER_E} - \frac{1}{SEER_I} \right) \times \frac{1}{EE_C} \times AA_C \times \frac{1}{1000}$$

For Bridgeport: $$AKWH_C = CAP_C \times \left(\frac{1}{SEER_E} - \frac{1}{SEER_I} \right) \times \frac{1}{EE_C} \times CC_C \times \frac{1}{1000}$$

Example - Retrofit Gross Energy Savings

A high energy efficient ductless heat pump (DHP) is installed in an existing home with electric resistance heat in Hartford. The nominal heating capacity is 24,000 BTU, and the nominal cooling capacity is 28,000 BTU, installed HSPF is 11 and the installed SEER is 22. What are the annual electric heating and cooling savings?

Using the equation for annual electric heating savings,

$$AKWH_H = CAP_H \times \left(\frac{1}{HSPF_E} - \frac{1}{HSPF_I} \right) \times \frac{1}{EE_H} \times AA_H \times \frac{1}{1000}$$

$$AKWH_H = 24{,}000 \times \left(\frac{1}{3.413} - \frac{1}{11} \right) \times \frac{1}{0.171} \times 130 \times \frac{1}{1000} = 3{,}687\ kWh$$

Using the equation for annual electric cooling savings,

$$AKWH_C = CAP_C \times \left(\frac{1}{SEER_E} - \frac{1}{SEER_I} \right) \times \frac{1}{EE_C} \times AA_C \times \frac{1}{1000}$$

$$AKWH_C = 28{,}000 \times \left(\frac{1}{10.1} - \frac{1}{22} \right) \times \frac{1}{0.037} \times 3.1 \times \frac{1}{1000} = 126\ kWh$$

Retrofit Gross Seasonal Peak Demand Savings - Electric, Winter and Summer

Winter Demand Savings:

For Hartford: $$WKW = CAP_H \times \left(\frac{1}{HSPF_E} - \frac{1}{HSPF_I} \right) \times \frac{1}{EE_H} \times BB_H \times \frac{1}{1000}$$

For Bridgeport: $$WKW = CAP_H \times \left(\frac{1}{HSPF_E} - \frac{1}{HSPF_I}\right) \times \frac{1}{EE_H} \times DD_H \times \frac{1}{1000}$$

Summer Demand Savings:

For Hartford: $$SKW = CAP_C \times \left(\frac{1}{SEER_E} - \frac{1}{SEER_I}\right) \times \frac{1}{EE_C} \times BB_C \times \frac{1}{1000}$$

For Bridgeport: $$SKW = CAP_C \times \left(\frac{1}{SEER_E} - \frac{1}{SEER_I}\right) \times \frac{1}{EE_C} \times DD_C \times \frac{1}{1000}$$

Example - Retrofit Gross Peak Demand Savings

A high energy efficient ductless heat pump (DHP) is installed in an existing home with electric resistive heat in Hartford. The rated heating capacity is 24,000 BTU, rated cooling capacity is 28,000 BTU, installed HSPF is 11 and the installed SEER is 22. What are the annual summer and winter demand savings?

Using the equation for summer demand savings,

$$SKW = CAP_C \times \left(\frac{1}{SEER_E} - \frac{1}{SEER_I}\right) \times \frac{1}{EE_C} \times BB_C \times \frac{1}{1000}$$

$$SKW = 28{,}000 \times \left(\frac{1}{10.1} - \frac{1}{22}\right) \times \frac{1}{0.037} \times 0.0017 \times \frac{1}{1000} = 0.069\ kW$$

Using the equation for winter demand savings,

$$WKW = CAP_H \times \left(\frac{1}{HSPF_E} - \frac{1}{HSPF_I}\right) \times \frac{1}{EE_H} \times BB_H \times \frac{1}{1000}$$

$$WKW = 24{,}000 \times \left(\frac{1}{3.413} - \frac{1}{11}\right) \times \frac{1}{0.171} \times 0.019 \times \frac{1}{1000} = 0.539\ kW$$

Lost Opportunity Gross Energy Savings - Electric

Heating

For Hartford: $$AKWH_H = CAP_H \times \left(\frac{1}{HSPF_B} - \frac{1}{HSPF_I}\right) \times \frac{1}{EE_H} \times AA_H \times \frac{1}{1000}$$

For Bridgeport: $$AKWH_H = CAP_H \times \left(\frac{1}{HSPF_B} - \frac{1}{HSPF_I}\right) \times \frac{1}{EE_H} \times CC_H \times \frac{1}{1000}$$

Cooling

For Hartford: $$AKWH_C = CAP_C \times \left(\frac{1}{SEER_B} - \frac{1}{SEER_I}\right) \times \frac{1}{EE_C} \times AA_C \times \frac{1}{1000}$$

For Bridgeport: $$AKWH_C = CAP_C \times \left(\frac{1}{SEER_B} - \frac{1}{SEER_I} \right) \times \frac{1}{EE_C} \times CC_C \times \frac{1}{1000}$$

Lost Opportunity Gross Seasonal Peak Demand Savings - Electric, Winter and Summer

Winter Demand Savings:

For Hartford: $$WKW = CAP_H \times \left(\frac{1}{HSPF_B} - \frac{1}{HSPF_I} \right) \times \frac{1}{EE_H} \times BB_H \times \frac{1}{1000}$$

For Bridgeport: $$WKW = CAP_H \times \left(\frac{1}{HSPF_B} - \frac{1}{HSPF_I} \right) \times \frac{1}{EE_H} \times DD_H \times \frac{1}{1000}$$

Summer Demand Savings:

For Hartford: $$SKW = CAP_C \times \left(\frac{1}{SEER_B} - \frac{1}{SEER_I} \right) \times \frac{1}{EE_C} \times BB_C \times \frac{1}{1000}$$

For Bridgeport: $$SKW = CAP_C \times \left(\frac{1}{SEER_B} - \frac{1}{SEER_I} \right) \times \frac{1}{EE_C} \times DD_C \times \frac{1}{1000}$$

Non Energy Benefits

Ductless Heat Pump customers have reported high level of satisfaction (Ref [1]).

References

[1] Ductless Mini Pilot Study, Final Report, KEMA, June 2009, Pages vi, vii, 4-15 and 4-18.

Notes

[1] The minimum heating efficiency standard, set by federal government in 2006 for ductless heat pumps is 10.1 HSPF and cooling efficiency is 13.0 SEER. The minimum efficiency standard for electric resistive heating system is 3.4 HSPF.

[2] PRISM is an established statistical procedure for measuring energy conservation in residential housing. The PRISM software package was developed by the Center for Energy and Environmental Studies, Princeton University. The tool is used for estimating energy savings from billing data. <http://www.princeton.edu/~marean/>

[3] DOE-2 is a widely used and accepted building energy analysis program that can predict the energy use and cost for all types of buildings. DOE-2 uses a description of the building layout, constructions, operating schedules, conditioning systems (such as lighting & HVAC) and utility rates provided by the user, along with weather data, to perform an hourly simulation of the building and to estimate utility bills. <http://www.doe2.com/>

4.2.13 PACKAGE TERMINAL HEAT PUMP

Description of Measure

Installation of new energy-efficient package terminal heat pump

Savings Methodology

The savings methodology for a package terminal heat pump (PTHP) is calculated from baseline efficiencies in Ref [1]. For working units that have been removed, the savings consist of two parts:

1. Retrofit savings based on early retirement of existing unit
2. Lost opportunity savings for installing new efficient unit

Inputs

Symbol	Description	Units
EER_i	Energy Efficiency Ratio, Installed	Btu/Watt-hr
CAP_C	Cooling Capacity	Btu/hr
EER_E	Energy Efficiency Ratio, Existing	Btu/Watt-hr
EER_B	Energy Efficiency Ratio, Base line	Btu/Watt-hr
COP_B	Coefficient of Performance Base line	Btu/Watt-hr
COP_E	Coefficient of Performance Existing	Watt/Watt
COP_I	Coefficient of Performance Installed	Watt/Watt

Nomenclature

Symbol	Description	Units	Values	Comments
1 Ton	Capacity, Tonnage	Tons	12,000 Btu/hr	Unit conversion
AKWH	Annual Electric Energy Savings	kWh		
CAP_C	Cooling Capacity	Btu/hr		Input
COP_B	Coefficient of Performance, Base line	Watt/Watt		Ref [1]
COP_E	Coefficient of Performance, Existing	Watt/Watt		Input
EER_B	Energy Efficiency Ratio, Baseline	Btu/Watt-hr		Ref [1]
EER_E	Energy Efficiency Ratio, Existing	Btu/Watt-hr		Input
EER_I	Energy Efficiency Ratio, Installed	Btu/Watt-hr		Input
$EFLH_H$	Heating Equivalent Full-load Hours	hours	1307	Ref [3]
HR	Percent heating when Heat pump is not in electric resistance back up		60%	Note[1]
PTHP	Packaged Heat Pump Terminal			
S_{kWh}	Average Cooling kWh Savings per unit size	kWh/Ton	357.6	Ref [2]
S_{kW}	Average Peak kW Savings per unit size	kW/Ton	0.591	Ref [2]
SA	Seasonal Efficiency Adjustment for heating		80%	Note[2]
SKW	Summer Demand Savings	kW		
WKW	Winter Demand Savings	kW	0	Note[3]

Retrofit Gross Energy Savings - Electric

Heating

a) For replacement of old PTHP, use the following equations

$$\mathrm{AKWH_H} = \mathrm{HR} \times \mathrm{EFLH_H} \times CAP_C \times \left(\frac{1}{COP_E} - \frac{1}{COP_B} \right) \times \frac{1}{3412}$$

$$\text{Where, } \mathrm{COP_B} = 2.9 - \left(0.026 \times \mathrm{CAP_C} \times \frac{1}{1{,}000} \right)$$

b) For replacement of electric resistive system, use the following equation

$$\mathrm{AKWH_H} = \mathrm{HR} \times \mathrm{EFLH_H} \times CAP_C \times \left(1 - \frac{1}{SA \times COP_B} \right) \times \frac{1}{3412}$$

$$\text{Where, } \mathrm{COP_B} = 2.9 - \left(0.026 \times \mathrm{CAP_C} \times \frac{1}{1{,}000} \right)$$

Cooling

$$\mathrm{AKWH_C} = S_{kWh} \times CAP_C \times \left(\frac{EER_B}{EER_E} - 1 \right) \times \frac{1}{12{,}000}$$

$$\mathrm{AKWH_C} = 357.6 \times CAP_C \times \left(\frac{EER_B}{EER_E} - 1 \right) \times \frac{1}{12{,}000}$$

$$\text{Where, } \mathrm{EER_B} = 10.8 - \left(0.213 \times \mathrm{CAP_C} \times \frac{1}{1{,}000} \right)$$

Reminder: *For working unit, claim additional lost opportunity savings.*

Example - Retrofit Gross Energy Savings

A new Package Terminal Heat Pump with cooling capacity of 12,000Btu/hr, EER_I=12.5, and COP_I =3.6 is installed in an existing home equipped with old working PTHP with cooling capacity of 12,000 Btu/hr, EER_E=7.8, and COP_E= 2.5.

Heating

$$\mathrm{AKWH_H} = \mathrm{HR} \times \mathrm{EFLH_H} \times CAP_C \times \left(\frac{1}{COP_E} - \frac{1}{COP_B} \right) \times \frac{1}{3412}$$

$$\text{Where, } \mathrm{COP_B} = 2.9 - \left(0.026 \times 12{,}000 \times \frac{1}{1{,}000} \right) = 2.59$$

$$AKWH_H = 0.6 \times 1307 \times 12{,}000 \times \left(\frac{1}{2.5} - \frac{1}{2.59} \right) \times \frac{1}{3{,}412} = 38.32\ kWh$$

Cooling

$$\mathrm{AKWH_C} = 357.6 \times CAP_C \times \left(\frac{EER_B}{EER_E} - 1 \right) \times \frac{1}{12{,}000}$$

$$\text{Where, } \mathrm{EER_B} = 10.8 - \left(0.213 \times \mathrm{CAP_C} \times \frac{1}{1{,}000}\right)$$

$$\mathrm{EER_B} = 10.8 - \left(0.213 \times 12{,}000 \times \frac{1}{1{,}000}\right) = 8.24$$

$$\mathrm{AKWH_C} = 357.6 \times 12{,}000 \times \left(\frac{8.24}{7.8} - 1\right) \times \frac{1}{12{,}000} = 20.17kWh$$

Reminder: *For working unit, claim additional lost opportunity savings.*

<u>Retrofit Gross Seasonal Peak Demand Savings - Electric, Winter and Summer</u>

WKW = 0; Note [3]

$$SKW_C = S_{kW} \times CAP_C \times \left(\frac{EER_B}{EER_E} - 1\right) \times \frac{1}{12{,}000}$$

$$SKW_C = 0.591 \times CAP_C \times \left(\frac{EER_B}{EER_E} - 1\right) \times \frac{1}{12{,}000}$$

$$\text{Where, } \mathrm{EER_B} = 10.8 - \left(0.213 \times \mathrm{CAP_C} \times \frac{1}{1{,}000}\right)$$

<u>Example - Retrofit Gross Peak Demand Savings</u>

A new Package Terminal Heat Pump with cooling capacity of 1Ton/hr, EER_I=12.5, and COP_I =3.6 is installed in an existing home equipped with old working PTHP with cooling capacity of 1Ton/hr, EER_E=7.8, and COP_E= 2.5.

WKW= 0

$$\mathrm{SKW_C} = 0.591 \times CAP_C \times \left(\frac{EER_B}{EER_E} - 1\right) \times \frac{1}{12{,}000}$$

$$\text{Where, } \mathrm{EER_B} = 10.8 - \left(0.213 \times 12{,}000 \times \frac{1}{1{,}000}\right) = 8.24$$

$$\mathrm{SKW_C} = 0.591 \times 12{,}000 \times \left(\frac{8.24}{7.8} - 1\right) \times \frac{1}{12{,}000} = 0.033kW$$

<u>Lost Opportunity Gross Energy Savings - Electric</u>

Heating

$$\mathrm{AKWH_H} = \mathrm{H}R \times \mathrm{EFLH_H} \times CAP_C \times \left(\frac{1}{COP_B} - \frac{1}{COP_I}\right) \times \frac{1}{3412}$$

$$\text{Where, } \mathrm{COP_B} = 3.2 - \left(0.026 \times CAP_C \times \frac{1}{1{,}000}\right)$$

Cooling

$$\text{AKWH}_{\text{C}} = 357.6 \times CAP_C \times \left(\frac{EER_I}{EER_B} - 1 \right) \times \frac{1}{12{,}000}$$

$$\text{Where, EER}_{\text{B}} = 12.3 - \left(0.213 \times \text{CAP}_{\text{C}} \times \frac{1}{1{,}000} \right)$$

Example - Lost Opportunity Gross Energy Savings

A Package Terminal Heat Pump is installed in a new construction project; the cooling capacity 12,000 Btu/hr, EER_I =12.5, and COP_I =3.6.

Heating

$$\text{AKWH}_{\text{H}} = \text{HR} \times \text{EFLH}_{\text{H}} \times CAP_C \times \left(\frac{1}{COP_B} - \frac{1}{COP_I} \right) \times \frac{1}{3412}$$

$$\text{Where, COP}_{\text{B}} = 3.2 - \left(0.026 \times 12{,}000 \times \frac{1}{1{,}000} \right) = 2.88$$

$$AKWH_H = 0.6 \times 1307 \times 12{,}000 \times \left(\frac{1}{2.88} - \frac{1}{3.6} \right) \times \frac{1}{3412} = 191.5 kWh$$

Cooling

$$\text{AKWH}_{\text{C}} = 357.6 \times CAP_C \times \left(\frac{EER_I}{EER_B} - 1 \right) \times \frac{1}{12{,}000}$$

$$\text{Where, EER}_{\text{B}} = 12.3 - \left(0.213 \times 12{,}000 \times \frac{1}{1{,}000} \right) = 9.74$$

$$\text{AKWH}_{\text{C}} = 357.6 \times 12{,}000 \times \left(\frac{12.5}{9.74} - 1 \right) \times \frac{1}{12{,}000} = 101.3 kWh$$

Lost Opportunity Gross Seasonal Peak Demand Savings - Electric, Winter and Summer

WKW= 0

$$\text{SKW}_{\text{C}} = 0.591 \times CAP_C \times \left(\frac{EER_I}{EER_B} - 1 \right) \times \frac{1}{12{,}000}$$

$$\text{Where, EER}_{\text{B}} = 12.3 - \left(0.213 \times \text{CAP}_{\text{C}} \times \frac{1}{1{,}000} \right)$$

Example - Lost Opportunity Gross Peak Demand Savings

A Package Terminal Heat Pump is installed in a new construction project; the cooling capacity 12,000 Btu/hr, EER_I =12.5, and COP_I =3.6.

WKW= 0

$$\mathrm{SKW_C} = 0.591 \times CAP_C \times \left(\frac{EER_I}{EER_B} - 1 \right) \times \frac{1}{12{,}000}$$

$$\text{Where, } \mathrm{EER_B} = 12.3 - \left(0.213 \times \mathrm{CAP_C} \times \frac{1}{1{,}000} \right)$$

$$\mathrm{EER_B} = 12.3 - \left(0.213 \times 12{,}000 \times \frac{1}{1{,}000} \right) = 9.74$$

$$\mathrm{SKW_C} = 0.591 \times 12{,}000\ {}^{Btu}\!/_{hr} \times \left(\frac{12.5}{9.74} - 1 \right) \times \frac{1}{12{,}000} = 0.167\ kW$$

Changes from Last Version

$EFLH_H$ updated from 1,500 hours to 1,307 hours

References

[1] "Technical Support Document (TSD): Energy Efficiency Program for Commercial and Industrial Equipment: Efficiency Standards for Commercial Heating, Air Conditioning and Water heating Equipment," Table 1, Chapter 2, page 4.

[2] Average Cooling kWh Savings per unit size = 357.6 kWh/ton, Average peak kW Savings per unit size = 0.591 kW/ton and based on "Residential Central AC Regional Evaluation, ADM Associates Inc.," Table 4-7 and table 4-8, page 4-9

[3] $EFLH_H$ =1,307 hours; Based on Heating degree day data (HDD) and ASHRAE adjustment factor.

Notes

[1] HR = 60%, is Percent heating when the Heat pump is not in electric resistance back up, based on Hartford data bin analysis

[2] SA = 80%, is COP adjustment factor for temperatures below 47^0F, based on Hartford bin analysis

[3] Winter demand savings are not claimed for this measure since backup resistance heat on the heat pump would most likely be used during winter seasonal peak periods

4.2.14 QUALITY INSTALLATION VERIFICATION

Description of Measure

Perform quality installation and verification (QIV) of a residential central air ducted system as described by ENERGY STAR. Note: QIV does not apply to Ground Source Heat Pump (GSHP) and hydro air systems.

Savings Methodology

ENERGY STAR Quality Installation Guidelines, are based on the Air Conditioning Contractors of America's (ACCA) HVAC Quality Installation Specification (Ref [2] & [3]), and is recognized as an American National Standard. For new homes, ENERGY STAR Inspection Checklist for National Programs Requirements V3.0 would be used (Ref [4] & [5]).

These industry best practices help ensure that HVAC equipment is:

1. Correctly sized to meet customer home's needs
2. Connected to a well-sealed duct system
3. Operating with sufficient airflow in the system
4. Installed with the proper amount of refrigerant

Estimated savings potential (Table 1) with Quality Installation ranges from 18% to 36% for air conditioners and heat pumps and 11% to 18% for furnaces (Ref [6]). A new residential central air conditioner uses 357.6 kWh per ton annually (Ref [1]). The cooling and heating savings are a percentage of total cooling and heating energy consumption.

Table 1: QIV, Performed with New Residential Air Conditioning System Installation, Energy Star Savings Potential

	Cooling	**Heating**
Refrigerant Charge	2-6%	
Airflow	2-5%	
Sizing	3-7%	
Duct Sealing	11-18%	11-18%
Total	**18-36%**	**11-18%**

Due to these variations, the savings being estimated for this measure (Table 2) are based on the low-end of the range.

Table 2: Estimated QIV Savings

	Cooling	**Heating**
Refrigerant Charge	2%	
Airflow	2%	
Sizing	3%	
Duct Sealing	11%	11%
Total	**18%**	**11%**

Inputs

Symbol	**Description**
CAP_C	Nominal cooling capacity, Btu
Ton	Capacity of the equipment converted to tons

Nomenclature

Symbol	Description	Units	Values	Comments
$ACCF_H$	Annual Natural Gas Savings, Heating	Ccf		
$AKWH_C$	Annual Electric Cooling Savings	kWh		
$AKWH_H$	Annual Electric Heating Savings	kWh		
AOG_H	Annual Oil Savings, Heating	Gal		
APG_H	Annual Propane Savings, Heating	Gal		
CAP_C	Cooling capacity	Btu		Input
PDF_H	Natural gas peak day factor -heating		0.00977	Appendix 2
PD_H	Natural gas peak day savings – heating	Ccf		
SKW	Summer Demand Savings	kW		
Ton	Capacity of the equipment converted to tons	tons		Input
WKW	Winter Demand Savings	kW		

Lost Opportunity Gross Energy Savings - Electric

Cooling

The average new residential central air conditioners use 357.6 kWh per ton annually (Ref [1]).

Therefore;
Annual cooling kWh savings = Percent savings x 357.6 x Tons

Where:
Annual cooling savings (Refrigerant Charge) = 2% x 357.6 x tons = 7.15 x tons
Annual cooling savings (Airflow) = 2% x 357.6 x tons = 7.15 x tons
Annual cooling savings (Sizing) = 3% x 357.6 x tons = 10.73 x tons
Annual cooling savings (Duct Sealing) = 11% x 357.6 x tons = 39.34 x tons

$$Where, Ton = \frac{CAP_C}{12{,}000}$$

$$AKWH_C = 64.37 \times \frac{CAP_C}{12{,}000}$$

Heating

Using the results of 39.34 kWh duct sealing savings from the above equation and the relationship of savings from table in PSD Measure 4.2.9. Duct Sealing, the CFM reduction can be calculated as follows:

From Measure 4.2.9, for every CFM reduction the cooling savings is 1.059 kWh. Therefore, for 39.34 kWh savings, there is 37.15 CFM reduction.

$$CFMsavings = \frac{39.34}{1.059} = 37.15 CFM / ton$$

The heat pump and fan savings can be calculated using Duct Sealing, Measure 4.2.9

Heat Pump only:

$$AKWH_H = 142.9 \times \frac{CAP_C}{12{,}000}$$

Fan energy for fossil fuel systems only:

$$AKWH_H = 40.86 \times \frac{CAP_C}{12,000}$$

Lost Opportunity Gross Energy Savings - Fossil Fuel

$$ACCF_H = 13.3 \times \frac{CAP_C}{12,000}$$

$$AOG_H = 9.3 \times \frac{CAP_C}{12,000}$$

$$APG_H = 14.2 \times \frac{CAP_C}{12,000}$$

Example - Lost Opportunity Gross Energy Savings

A 1980's home has a combination natural gas furnace with a 36,000 Btu (3 tons) central air conditioning system. Quality installation and verification is performed on the systems. What are the energy savings?

Using the equation for cooling savings,

$$AKWH_C = 64.37 \times \frac{CAP_C}{12,000}$$

$$AKWH_C = 64.37 \times \frac{36,000}{12,000} = 193.1 kWh$$

Using the equation for heating fan energy,

$$AKWH_H = 41.25 \times \frac{CAP_C}{12,000}$$

$$AKWH_H = 41.25 \times \frac{36,000}{12,000} = 123.75 kWh$$

Using the equation for natural gas heating,

$$ACCF_H = 13.3 \times \frac{CAP_C}{12,000}$$

$$ACCF_H = 13.3 \times \frac{36,000}{12,000} = 39.9 ccf$$

Lost Opportunity Gross Seasonal Peak Demand Savings - Electric, Winter and Summer

The new residential central air conditioners use 0.591 kW per ton (Ref [1]).

Therefore, Annual summer kW savings = Percent savings x 0.591 x Tons

$$SKW = 0.106 \times \frac{CAP_C}{12,000}$$

Using the CFM savings from Section 5 and peak savings per CFM from PSD Measure 4.2.9, the winter demand savings for heat pumps only are as follows:

$$WKW = 0.587 \times \frac{CAP_C}{12{,}000}$$

Lost Opportunity Gross Peak Day Savings - Natural Gas

$$PD_H = ACCF_H \times PDF_H$$

Example - Lost Opportunity Gross Peak Demand Savings

A 1980's home has a 36,000 Btu (3 tons) heat pump system. Quality installation and verification is performed on the systems. What are the summer and winter demand savings?

For cooling savings:

$$SKW = 0.106 \times \frac{CAP_C}{12{,}000}$$

$$SKW = 0.106 \times \frac{36{,}000}{12{,}000} = 0.32kW$$

For heat pump savings:

$$WKW = 0.587 \times \frac{CAP_C}{12{,}000}$$

$$WKW = 0.587 \times \frac{36{,}000}{12{,}000} = 1.76kW$$

Changes from Last Version

Winter demand savings. Fan savings corrected.

References

[1] Residential Central AC Regional Evaluation, ADM Associates, Inc., November 2009, page 4-9 and page ES-4.

[2] ACCA. 2010. HVAC Quality Installation Specification – Standard 5. Air Conditioning Contractors of America, Arlington, VA.

[3] ACCA. 2009. HVAC Quality Installation Verification Protocols – Standard 9. Air Conditioning Contractors of America, Arlington, VA.

[4] ENERGY STAR Homes National Programs Requirement V3.0, www.energystar.gov

[5] ENERGY STAR Homes Inspection Checklist, www.energystar.gov

[6] ENERGY STAR Quality Installation, http://www.energystar.gov/index.cfm?c=hvac_install.hvac_install_index, last accessed May 23, 2011.

4.2.15 DUCT INSULATION

Description of Measure

Installation of insulation with an R-value greater than or equal to 6 on uninsulated heating or cooling ducts in unconditioned space (i.e. attic, unconditioned basement) in order to reduce heating and cooling losses.

Savings Methodology

Heating and cooling savings per square foot of insulated duct were modeled using “3E Plus Insulation” software (Ref [2]) under four different scenarios of duct location (supply basement, return basement, supply attic, return attic).

Cooling savings should be reported for homes equipped with central AC using the same duct being insulated.

Reminder: *Heating savings may not be claimed if ducts are not used for heating distribution; for instance, a home with electric baseboard resistance heating or a fossil fuel boiler which has ducts used only for the Central Air Conditioner.*

Inputs

Symbol	Description	Units
A	Surface area of duct area being insulated	ft^2
	System/Fuel type (Heat pump, Gas Furnace, Oil Furnace, Central AC, etc…)	
	Duct location: - Supply duct in unconditioned basement - Return duct in unconditioned basement - Supply duct in attic - Return duct in attic	
	Heating System Distribution Type (Forced air with fan, heat pump, resistance, radiator, etc)	

Nomenclature

Symbol	Description	Units	Values	Comments
A	Surface area of duct being insulated	ft^2		Input
ACCF	Annual Natural Gas Savings	Ccf		
AKWH	Annual Electric Energy Savings	kWh		
AOG	Annual Oil Savings	Gal		
APG	Annual Propane Savings	Gal		
DI_H	Annual Heating Savings per square foot	Table 2 & 3	Table 2 & 3	Ref [2]
DI_C	Annual Cooling Savings per square foot	Table 2 & 3	Table 2 & 3	Ref [2]
PD_H	Natural gas peak day savings - heating	Ccf		
PDF_H	Natural gas peak day factor -heating		0.00977	Appendix 2
SKW	Summer Demand Savings	kW		
SPF	Summer Peak Factor	W/kWh	0.017	Ref [1]
WKW	Winter Demand Savings	kW		
WPF	Winter Peak Factor	W/kWh	0.570	Ref [1]

Retrofit Gross Energy Savings - Electric

Table 1: Annual Savings per square foot for homes with Heat Pump or Central AC

Duct location	Heating		Cooling	
	DI_H	Unit	DI_C	Unit
Supply basement	13.2	kWh/ ft^2	1.5	kWh/ ft^2
Return basement	3.1	kWh/ ft^2	0.4	kWh/ ft^2
Supply Attic	14.7	kWh/ ft^2	2.9	kWh/ ft^2
Return Attic	4.2	kWh/ ft^2	1.5	kWh/ ft^2

Heating savings, Electric forced air:

$$AKWH_H = DI_H \times A$$

If Central A/C or Heat Pump providing cooling:

$$AKWH_C = DI_C \times A$$

Retrofit Gross Energy Savings - Fossil Fuel

Table 2: Annual Savings per square foot for homes with fossil fuel

Duct location	Heating Savings per square foot	
	DI_H	Unit
Supply basement	0.11	MMbtu/ ft^2
Return basement	0.03	MMbtu/ ft^2
Supply Attic	0.13	MMbtu/ ft^2
Return Attic	0.04	MMbtu/ ft^2

For homes with natural gas furnace,

$$ACCF_H = \frac{DI_H \times A}{0.10290}$$

For homes with oil furnace,

$$AOG_H = \frac{DI_H \times A}{0.13869}$$

For homes with propane furnace,

$$APG_H = \frac{DI_H \times A}{0.09133}$$

Reminder*: For homes equipped with central AC, claim electric cooling savings also.*

Example - Retrofit Gross Energy Savings

A Cape Cod style home has a gas furnace. It is also equipped with a central AC system for cooling. 50 ft^2 of insulation was installed on the supply duct in the unconditioned basement. What are the annual energy savings?

$$ACCF_H = \frac{DI_H \times A}{0.10290}$$

$$ACCF_H = \frac{0.11 \times 50}{0.10290} = 53.4\ Ccf$$

Since the house is equipped with central AC, there are cooling savings too:

$$AKWH_C = DI_C \times A$$

$$AKWH_C = 1.5 \times 50 = 75\ kWh$$

Retrofit Gross Seasonal Peak Demand Savings - Electric, Winter and Summer

Winter seasonal peak demand (kW) will be claimed for homes equipped with Heat pump:

$$WKW = \frac{WPF \times DI_H \times A}{1{,}000}$$

Summer seasonal peak demand (kW) will be claimed for homes equipped with Central AC:

$$SKW = \frac{SPF \times DI_C \times A}{1{,}000}$$

Retrofit Gross Peak Day Savings - Natural Gas

$$PD_H = ACCF_H \times PDF_H$$

Example - Retrofit Gross Peak Demand Savings

A Cape Cod style home has a gas furnace. It is also equipped with a central AC system for cooling. 50 ft^2 of insulation was installed on the supply duct in the unconditioned basement. What are the peak demand savings?

Using the formula for Peak Day Natural Gas:

$$PD_H = ACCF_H \times PDF_H$$

$$PD_H = 53.4 \times 0.00977 = 0.52\ ccf$$

Cooling demand savings may also be claimed:

$$SKW = \frac{SPF \times DI_C \times A}{1{,}000}$$

$$SKW = \frac{0.017 \times 0.15 \times 50}{1{,}000} = 0.0001\ kW$$

Changes from Last Version

Changed from annual savings per 100 sq ft to per square foot. Changed the SPF from 1.70Watt/kWh to 0.017 Watt/kWh and the WPF from 0.553 Watt/kWh to 0.570Watt/KWh. Updated with common conversion factors.

References

[1] Evaluation of the Weatherization Residential Assistance Partnership (WRAP) and Helps Programs, conducted by KEMA, table ES-6 page 1-8.

[2] NAIMA, 3E Plus software tool, Version 4.0, Released 2005.

4.2.16 HVAC SYSTEM CUSTOM

Description of Measure

Replacement of an inefficient HVAC system (or component) such as a fossil fuel furnace, boiler, heat pump, air conditioner, or any other project whose scope may be considered custom or comprehensive.

Savings Methodology

These custom measures can be evaluated using either the appropriate measure, if found in this document, or other acceptable modeling tools such as DOE-2, Elite, PRISM, REM/Rate, or engineering spreadsheets (Notes [1], [2] & [3]). Custom measures should use site-specific information when available (i.e. existing conditions, utility bills, etc.). The analysis of the site-specific measures will be reviewed for reasonableness by a qualified internal program administrator or independent third party engineer.

When a measure meets the requirements for early retirement (existing equipment is in good working order), use the partial savings methodology outline for that measure (or similar measure) outlined in this document. For an early retirement measure the savings may need to be calculated in two parts, as follows:

1. Retrofit savings based on the early retirement of a working existing unit, and
2. Lost Opportunity savings for installing a new efficient unit for the life of the measure

Notes

[1] REM/Rate™ is a residential energy analysis, code compliance and rating software developed by Architectural Energy Corporation. This software calculates heating, cooling, hot water, lighting, and appliance energy loads, consumption and costs for new and existing single and multi-family homes.

[2] PRISM is an established statistical procedure for measuring energy conservation in residential housing. The PRISM software package was developed by the Center for Energy and Environmental Studies, Princeton University. The tool is used for estimating energy savings from billing data. <http://www.princeton.edu/~marean/>

[3] DOE-2 is a widely used and accepted building energy analysis program that can predict the energy use and cost for all types of buildings. DOE-2 uses a description of the building layout, constructions, operating schedules, conditioning systems (such as lighting & HVAC) and utility rates provided by the user, along with weather data, to perform an hourly simulation of the building and to estimate utility bills. <http://www.doe2.com/>

4.2.17 BOILER

Description of Measure

Installation of an Energy-efficient boiler

Savings Methodology

The fossil fuel savings for this measure are calculated using the same methodology as the Energy Star Boiler calculator, which is located on the Energy Star Website (Ref [1]). The calculator uses the home's year of construction, location, and area to determine the home's annual heating load. The age on the boiler is used to determine the efficiency. When a boiler is also used for domestic hot water, hot water savings are also estimated. Hot water savings are calculated based on the hot water load used in the water heater Measure 4.5.7.

To account for the estimated remaining life of an existing boiler and the additional lost opportunity savings from a new installed unit, energy savings resulting from the removal of units in working condition are calculated in two parts:

1. Retrofit savings based on the early retirement of a working existing unit to the lost opportunity baseline for the Remaining Useful Life (RUL) from Appendix 4, and

2. Lost opportunity savings for installing a new efficient unit for the Effective Useful Life (EUL) of the measure from Appendix 4.

Inputs

Symbol	Description	Units
	Heating Fuel (Natural gas, oil, propane)	
YR_h	Year of home construction	Year
YR_e	Year existing boiler installed	Year
SF	Heated area served by boiler	SF
$AFUE_I$	AFUE-installed	%

Nomenclature

Symbol	Description	Units	Values	Comments
A	Heated area served by boiler	ft^2		Input
$ABTU_H$	Annual Btu savings - heating	Btu/yr		
ACCF	Annual natural gas savings	Ccf/yr		
$ACCF_H$	Annual natural gas savings -heating	Ccf/yr		
$ACCF_W$	Annual natural gas savings - water heating	Ccf/yr		
ADHW	Annual domestic water heating load	Btu/yr	11,197,132	From water heater measure
$AFUE_B$	Annual Fuel Utilization Efficiency, Baseline	%	78% - Gas or Propane 80% - Oil	Note [1]
$AFUE_E$	Annual Fuel Utilization Efficiency, Existing	%		Ref [1]
$AFUE_I$	Annual Fuel Utilization Efficiency, Installed	%		Input
EUL	Effective Useful Life			Appendix 4
HF	Heating Factor based on age of home	Btu/ ft^2/ Yr		Ref [1]
PD	Natural gas peak day savings	Ccf/yr		
PD_H	Natural gas peak day savings - heating	Ccf/yr		
PD_W	Natural gas peak day savings - water heating	Ccf/yr		

Symbol	Description	Units	Values	Comments
PDF_H	Natural gas peak day factor - heating		0.00977	Appendix 1
PDF_W	Natural gas peak day factor - water heating		0.00321	Appendix 1
RUL	Remaining Useful Life			Appendix 4
YR_h	Year of home construction	Years		Input
YR_e	Year existing boiler installed	Years		Input

<u>Retrofit Gross Energy Savings - Fossil Fuel</u>

Using the tables below, select the home's estimated heating load and existing boiler efficiency based on age.

Table 1: Residential Heating Factor

Year of home Construction (YR_h)	HF (BTU/SF/year)
Before 1940	45,000
1940 to 1949	41,400
1950 to 1959	38,700
1960 to 1969	36,000
1970 to 1979	33,300
1980 to 1989	30,600
1990 to 1999	27,900
2000 to present	26,100

Table 2: Existing AFUE

Year existing Boiler installed (YR_e)	Gas AFUE	Oil AFUE
Before 1960	60%	60%
1960 to 1969	60%	65%
1970 to 1974	65%	75%
1975 to 1983	65%	75%
1984 to 1987	70%	80%
1988 to 1991	77%	80%
1992 to present (baseline)	80%	80%

$$ABTU_H = A \times HF \times \left(\frac{1}{AFUE_E} - \frac{1}{AFUE_B} \right)$$

Savings by heating fuel:

$$ACCF_H = \frac{ABTU_H}{102{,}900 \, {}^{Btu}\!/\!{}_{Ccf}}$$

$$AOG_H = \frac{ABTU_H}{138{,}690 \, {}^{Btu}\!/\!{}_{Gal}}$$

$$APG_H = \frac{ABTU_H}{91{,}330 \, {}^{Btu}\!/\!{}_{Gal}}$$

If Boiler also provides DHW:

$$ABTU_W = ADHW \times \left(\frac{1}{AFUE_e} - \frac{1}{AFUE_b} \right)$$

$$ABTU_W = 11{,}197{,}132 \times \left(\frac{1}{AFUE_e} - \frac{1}{AFUE_b} \right)$$

Water Heating Savings by water heating fuel:

$$ACCF_W = \frac{ABTU_W}{102{,}900\ ^{Btu}\!/_{Ccf}}$$

$$AOG_W = \frac{ABTU_W}{138{,}690\ ^{Btu}\!/_{Gal}}$$

$$APG_W = \frac{ABTU_W}{91{,}330\ ^{Btu}\!/_{Gal}}$$

Reminder:
Early retirement savings = Retrofit Savings (Existing Unit Retirement RUL) + Lost Opportunity savings (New unit EUL).

Example - Retrofit Gross Energy Savings

A boiler is installed in a natural gas heated home. The boiler is used to heat domestic hot water in addition to heating the home which is 2,000 square feet. The home was built in 1974 and the existing boiler was installed in 1985.

From Tables above:
HF = 33,300
$AFUE_E$= 70% or 0.70
$AFUE_B$= 80% or 0.80

Reminder: *Retrofit savings do not depend on the efficiency of the new installed unit.*

$$ABTU_H = 2{,}000 \times 33{,}300 \times \left(\frac{1}{0.70} - \frac{1}{0.80}\right) = 11{,}892{,}857\ Btu$$

$$ACCF_H = \frac{11{,}892{,}857}{102{,}900\ ^{Btu}\!/_{Ccf}} = 116\ Ccf$$

Water Heating:

$$ABTU_W = 11{,}197{,}132 \times \left(\frac{1}{0.70} - \frac{1}{0.80}\right) = 1{,}999{,}488\ Btu$$

$$ACCF_W = \frac{1{,}999{,}488\ Btu}{102{,}900\ ^{Btu}\!/_{Ccf}} = 19\ Ccf$$

Total:

$$ACCF = ACCF_H + ACCF_W = 116 + 19 = 135\ Ccf$$

Retrofit Gross Peak Day Savings - Natural Gas

$$PD_H = ACCF_H \times PDF_H$$

If Boiler also provides DHW:

$$PD_W = ACCF_W \times PDF_W$$

Example - Retrofit Gross Peak Demand Savings

For same example as above:

$$PD_H = 144 \times 0.00977 PDF_H = 1.4\, Ccf$$
$$PD_W = 19 \times 0.00321 = 0.1\, Ccf$$
$$PD = PD_H + PD_W = 1.5\, Ccf$$

Lost Opportunity Gross Energy Savings - Fossil Fuel

$$ABTU_H = SF \times HF \times \left(\frac{1}{AFUE_b} - \frac{1}{AFUE_i} \right)$$

Savings by heating fuel:

$$ACCF_H = \frac{ABTU_H}{102{,}900\, {}^{Btu}\!/_{Ccf}}$$
$$AOG_H = \frac{ABTU_H}{138{,}690\, {}^{Btu}\!/_{Gal}}$$
$$APG_H = \frac{ABTU_H}{91{,}330\, {}^{Btu}\!/_{Gal}}$$

Example - Lost Opportunity Gross Energy Savings

A boiler is installed in a natural gas heated home. The boiler is used to heat domestic hot water in addition to heating the home which is 2,000 square feet. The home was built in 1974 and the existing boiler was installed in 1985. The installed boiler has efficiency (AFUE) of 88 percent.

From the Tables above:
HF = 39,200
$AFUE_I$= 88% or 0.88
$AFUE_B$= 80% or 0.80

$$ABTU_H = 2{,}000 \times 33{,}300 \times \left(\frac{1}{0.80} - \frac{1}{0.88} \right) = 7{,}568{,}181\, Btu$$

$$ACCF_H = \frac{7{,}568{,}181 Btu}{102{,}900\, {}^{Btu}\!/_{Ccf}} = 74\, Ccf$$

Water Heating:

$$ABTU_W = 11{,}197{,}132 \times \left(\frac{1}{0.80} - \frac{1}{0.88} \right) = 1{,}272{,}401\, Btu$$
$$ACCF_W = \frac{1{,}272{,}401}{102{,}900\, {}^{Btu}\!/_{Ccf}} = 12\, Ccf$$

Total:

$$ACCF = ACCF_H + ACCF_W = 74 + 12 = 86\, Ccf$$

Lost Opportunity Gross Peak Day Savings - Natural Gas

$$PD_H = ACCF_H \times PDF_H$$

Example - Lost Opportunity Gross Peak Demand Savings

For the same example as above:

$$PD_h = 74 \times 0.00977 PDF_h = 0.72\, Ccf$$

$$PD_W = 12 \times 0.00321 = 0.04\, Ccf$$

Total:

$$PD = PD_H + PD_W = 0.76\, Ccf$$

Changes from Last Version

New Measure

References

[1] Energy Star MS Excel tool, "Life Cycle Cost Estimate for an ENERGY STAR Residential Boiler, http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_Boilers.xls, last updated July, 2009, last accessed March 23, 2011.

Notes

[2] The baseline values are taken from Ref [1] efficiency for 2011.

4.2.18 FURNACE

Description of Measure

Installation of the Energy Efficient Furnace

Savings Methodology

The fossil fuel savings for this measure are calculated using the same methodology as the in ENERGY STAR furnace calculator, located on the ENERGY STAR Website (Ref [1]) with the exception of heating factor (Note [2]). The calculator uses the home's year of construction, location, and area to determine the home's annual heating load. The age on the furnace is used to determine the efficiency. This measure can be either lost opportunity or early retirement.

To account for the estimated remaining life of an existing furnace and the additional lost opportunity savings from a new installed unit, energy savings resulting from the removal of units in working condition are calculated in two parts:

1. Retrofit savings based on the early retirement of a working existing unit to the lost opportunity baseline for the Remaining Useful Life" (RUL) from Appendix 4, and

2. Lost opportunity savings for installing a new efficient unit for the Effective Useful Life (EUL) of the measure from Appendix 4.

In addition to the fossil fuel savings, this measure can include electric savings if the furnace is installed with an energy efficient fan motor. For these savings, see Measure 4.2.6, Electrically Commutated Motor (ECM).

Inputs

Symbol	**Description**	**Units**
	Heating Fuel (Natural gas, oil, propane)	
YR_h	Year of home construction	Year
YR_e	Year existing furnace installed	Year
SF	Heated area served by furnace	ft^2
$AFUE_E$	AFUE –existing (if available)	%
$AFUE_I$	AFUE -installed	%

Nomenclature

Symbol	**Description**	**Units**	**Values**	**Comments**
A	Heated area served by furnace	ft^2		Input
$ABTU_H$	Annual Btu savings - heating	Btu		
$ACCF_H$	Annual natural gas savings -heating	Ccf	102,900 Btu	
$AFUE_E$	AFUE of existing furnace		Table 2 if unknown	
AOG_H	Annual oil savings – heating	Gallons	138,690 Btu	
APG_H	Annual propane savings –heating	Gallons	91,330 Btu	
EUL	Effective Useful Life			Appendix 4
HF	Heating Factor based on age of home	Btu/ft^2	Table 1	Note [2]
PD_H	Natural gas peak day savings - heating	Ccf		
PDF_H	Natural gas peak day factor -heating		0.00977	Appendix 2
RUL	Remaining Useful Life			Appendix 4

Symbol	Description	Units	Values	Comments
YR_h	Year of home construction	Years		Input
YR_e	Year existing furnace installed	Years		Input

Retrofit Gross Energy Savings - Fossil Fuel

Using the tables below the home's heating load and existing furnace efficiency can be estimated.

Table 1: Residential Heating Factor

Year of home Construction (YR_h)	HF (BTU/SF/year)
Before 1940	52,900
1940 to 1949	48,700
1950 to 1959	45,500
1960 to 1969	42,400
1970 to 1979	39,200
1980 to 1989	36,000
1990 to 1999	32,800
2000 to present	30,700

Table 2: Existing AFUE

Year existing furnace installed (YR_e)	Gas/Propane AFUE	Oil AFUE
Before 1960	60%	60%
1960 to 1969	60%	65%
1970 to 1974	65%	72%
1975 to 1983	68%	75%
1984 to 1987	68%	80%
1988 to 1991	76%	80%
1992 to present (baseline)	78%	80%

$$ABTU_H = A \times HF \times \left(\frac{1}{AFUE_E} - \frac{1}{AFUE_B} \right)$$

Savings by heating fuel:

$$ACCF_H = \frac{ABTU_H}{102{,}900\ {}^{Btu}\!/_{Ccf}}$$

$$AOG_H = \frac{ABTU_H}{138{,}690\ {}^{Btu}\!/_{Gal}}$$

$$APG_H = \frac{ABTU_H}{91{,}330\ {}^{Btu}\!/_{Gal}}$$

Example - Retrofit Gross Energy Savings

A 2,000 square foot home is built in 1974. The home is heated by a natural gas furnace. The existing natural gas furnace was installed in 1985. What are the annual fossil fuel savings for the replacement of this furnace?

Reminder: *Retrofit savings do not depend on the efficiency of the new installed unit.*

From Tables:
HF = 39,200
$AFUE_E$= 68% or 0.68
$AFUE_B$= 78% or 0.78

$$ABTU_H = 2{,}000 \times 39{,}200 \times \left(\frac{1}{0.68} - \frac{1}{0.78} \right) = 14{,}781{,}297\ Btu$$

$$ACCF_H = \frac{14{,}781{,}297}{102{,}900\, Btu / ccf} = 144\ Ccf$$

<u>Retrofit Gross Peak Day Savings - Natural Gas</u>

$$PD_H = ACCF_H \times PDF_H$$

<u>Example - Retrofit Gross Peak Demand Savings</u>

A 2,000 sq ft home is built in 1974. The home is heated by a natural gas Furnace. The existing natural gas furnace was installed in 1985. What are the Peak Day Natural Gas savings?

$$PD_H = 144 \times 0.00977 = 1.4\ Ccf$$

<u>Lost Opportunity Gross Energy Savings - Fossil Fuel</u>

$$ABTU_H = A \times HF \times \left(\frac{1}{AFUE_B} - \frac{1}{AFUE_I} \right)$$

Savings by heating fuel:

$$ACCF_H = \frac{ABTU_H}{102{,}900\ {}^{Btu}\!/\!_{Ccf}}$$

$$AOG_H = \frac{ABTU_H}{138{,}690\ {}^{Btu}\!/\!_{Gal}}$$

$$APG_H = \frac{ABTU_H}{91{,}330\ {}^{Btu}\!/\!_{Gal}}$$

<u>Example - Lost Opportunity Gross Energy Savings</u>

A 2,000 sq ft home is built in 1974. The home is heated by a natural gas Furnace. The existing natural gas furnace was installed in 1985. A new natural gas furnace with an AFUE of 95% is installed. What are the annual fossil fuel savings?

From Tables:
HF = 39,200
$AFUE_I$= 95% or 0.95
$AFUE_B$= 78% or 0.78

$$ABTU_H = 2{,}000 \times 39{,}200 \times \left(\frac{1}{0.78} - \frac{1}{0.95} \right) = 17{,}986{,}505\ Btu$$

$$ACCF_H = \frac{16{,}211{,}745 Btu}{102{,}900\ {}^{Btu}\!/\!_{Ccf}} = 175\ Ccf$$

Lost Opportunity Gross Peak Day Savings - Natural Gas

$$PD_H = ACCF_H \times PDF_H$$

Example - Lost Opportunity Gross Peak Demand Savings

A 2,000 sq ft home is built in 1974. The home is heated by a natural gas Furnace. The existing natural gas furnace was installed in 1985. A new natural gas furnace with an AFUE of 95% is installed. What are the Peak Day Natural Gas savings?

$$PD_H = 175 \times 0.00977 = 1.7\ Ccfs$$

Changes from Last Version

New Measure

References

[1] ENERGY STAR Microsoft Excel tool, "Life Cycle Cost Estimate for an ENERGY STAR Residential Furnace," http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_Furnaces.xls, last updated July, 2009, last accessed Mar 23, 2011.

Notes

[1] The baseline values are based on Ref [1] efficiency for 2011.

[2] The Heating Factor from Ref [1] was increased by 15% to account for Duct losses. 15% is based on the Energy Star Quality Installation and Verification Potential (QIV) Savings. These are outlined in Measure 4.2.14, QIV.

4.3 APPLIANCES

4.3.6 ROOM AIR CONDITIONER

Description of Measure

Replacement of inefficient room air conditioners which are in working condition with high efficiency models

Savings Methodology

Turn-in (Note [1]) and Replacement (Low Income, Note [2]) savings are claimed in two parts:

1. The primary part, retrofit, claims savings based on the Federal Standard verses the new unit, using the effective useful lifetime (EUL) and the new unit's size.

2. At the same time, the second part, retirement, claims additional savings based on the existing unit compared to the Federal Standard, using the remaining useful lifetime (RUL) and the existing unit's size, assuming the existing unit would have been installed until failure. ***Note:*** *The retirement portion of savings may only be claimed if the efficiency of the existing unit can be determined.*

Retail Lost Opportunity savings is the difference in consumption between the new CEE Tier unit and a unit of the same size at the Federal Standard efficiency.

Inputs

Symbol	Description
EER_{old}	Energy Efficiency Ratio of existing unit
$Size_{old}$	Rated cooling capacity of existing unit, in Btu/hr
$Size_{new}$	Rated cooling capacity of new unit, in Btu/hr

Nomenclature

Symbol	Description	Units	Values	Comments
$AKWH_{LO}$	Annual gross kWh lost opportunity savings.	kWh/yr	Calculated	
$AKWH_{retire}$	Annual gross kWh savings due to early retirement of the old unit.	kWh/yr	Calculated	
$AKWH_{retrofit}$	Annual gross kWh new unit retrofit savings.	kWh/yr	Calculated	
CAP_{new}	Rated cooling capacity of new unit, in Btu/hr	Btu/hr		
CAP_{old}	Rated cooling capacity of existing unit	Btu/hr	$Size_{new}$ if Unknown	
CF_S	Summer Seasonal Peak Coincidence Factor	unitless	Appendix 1	
$EER_{fed\ std}$	Energy Efficiency Ratio of federal standard unit of the same size	Btu/ Watt-hr	Table 1	
EER_{new}	Energy Efficiency Ratio of new unit	Btu/ Watt-hr	Table 1	
EER_{old}	Energy Efficiency Ratio of existing unit	Btu/ Watt-hr	Actual as found value	
EUL	Effective Useful Life: Measure life of the new unit.	years	Appendix 4	
FLH	Annual Full Load Hours	hr/yr	272	Ref [1]
$LKWH_{total}$	Total Gross Lifetime kWh savings for turn-in or early retirement measure.	kWh	Calculated	

Symbol	Description	Units	Values	Comments
RUL	Remaining Useful Life: remaining number of years the existing unit would have operated until failure.	years	Appendix 4	
SKW_{LO}	Annual gross Summer Seasonal Peak Demand lost opportunity savings.	kW	Calculated	
SKW_{retire}	Annual gross Summer Seasonal Peak Demand savings due to early retirement of the old unit.	kW	Calculated	
$SKW_{retrofit}$	Annual gross Summer Seasonal Peak Demand new unit retrofit savings.	kW	Calculated	
Sleeve	Unit without louvered sides			
Window	Unit with louvered sides			

Retrofit Gross Energy Savings - Electric

Table 1: EER of Federal Standard, Energy Star, and CEE Tiers (Note [3])

Product Size (Btu/hr)	Current Federal Std		Current Nov. 2005 Energy Star V2.1		Anticipated Oct. 2012 Energy Star V3.0		CEE Tier 1	CEE Tier 2
Type:	*Window*	*Sleeve*	*Window*	*Sleeve*	*Window*	*Sleeve*	*Window*	*Window*
<8,000	9.7	9.0	10.7	9.9	11.2	10.4	11.2	11.6
8,000 to 13,999	9.8	8.5	10.8	9.4	11.3	9.8	11.3	11.8
14,000 to 19,999	9.7		10.7		11.2		11.2	11.6
>20,000	8.5		9.4		9.8		9.8	10.2

$$AKWH_{retire} = FLH \times CAP_{old} \times \left(\frac{1}{EER_{old}} - \frac{1}{EER_{fed\ std}} \right) \div 1000\, {}^{W}\!/_{kW}$$

$$AKWH_{retrofit} = FLH \times CAP_{new} \times \left(\frac{1}{EER_{fed\ std}} - \frac{1}{EER_{new}} \right) \div 1000\, {}^{W}\!/_{kW}$$

$$LKWH_{total} = \left(AKWH_{retrofit} \times EUL\right) + \left(AKWH_{retire} \times RUL\right)$$

Example - Retrofit Gross Energy Savings

What are the savings from the early retirement and replacement of a 5,200 Btu/hr 8 EER window air conditioner with the same size but at the minimum CEE Tier 1 level EER (11.2) in an existing home?

$$AKWH_{retire} = 272\, hrs \times 5200\, {}^{Btu}\!/_{hr} \times \left(\frac{1}{8\, {}^{Btu}\!/_{W \bullet hr}} - \frac{1}{9.7\, {}^{Btu}\!/_{W \bullet hr}} \right) \div 1000\, {}^{W}\!/_{kW} = 31\, {}^{kWh}\!/_{yr}$$

$$AKWH_{retrofit} = 272\, hrs \times 5200\, {}^{Btu}\!/_{hr} \times \left(\frac{1}{9.7\, {}^{Btu}\!/_{W \bullet hr}} - \frac{1}{11.2\, {}^{Btu}\!/_{W \bullet hr}} \right) \div 1000\, {}^{W}\!/_{kW} = 20\, {}^{kWh}\!/_{yr}$$

$$LKWH_{total} = 31\, {}^{kWh}\!/_{yr} \times 4 + 20\, {}^{kWh}\!/_{yr} \times 9 = 304\, kWh$$

Retrofit Gross Seasonal Peak Demand Savings - Electric, Winter and Summer

$$SKW_{retire} = CF_s \times CAP_{old} \times \left(\frac{1}{EER_{old}} - \frac{1}{EER_{fed\ std}} \right) \div 1000\, {}^{W}\!/_{kW}$$

$$SKW_{retrofit} = CF_s \times CAP_{new} \times \left(\frac{1}{EER_{fed\ std}} - \frac{1}{EER_{new}} \right) \div 1000 \, {}^{W}\!/_{kW}$$

Example - Retrofit Gross Peak Demand Savings

In the above example, what are the Summer Seasonal Peak Demand Savings?

$$SKW_{retire} = 0.303 \times 5200 \, {}^{Btu}\!/_{hr} \times \left(\frac{1}{8 \, {}^{Btu}\!/_{W \bullet hr}} - \frac{1}{9.7 \, {}^{Btu}\!/_{W \bullet hr}} \right) \div 1000 \, {}^{W}\!/_{kW} = 0.035 \, kW$$

$$SKW_{retrofit} = 0.303 \times 5200 \, {}^{Btu}\!/_{hr} \times \left(\frac{1}{9.7 \, {}^{Btu}\!/_{W \bullet hr}} - \frac{1}{11.2 \, {}^{Btu}\!/_{W \bullet hr}} \right) \div 1000 \, {}^{W}\!/_{kW} = 0.022 \, kW$$

Lost Opportunity Gross Energy Savings - Electric

$$AKWH_{LO} = FLH \times CAP_{new} \times \left(\frac{1}{EER_{fed\ std}} - \frac{1}{EER_{new}} \right) \div 1000 \, {}^{W}\!/_{kW}$$

Lost Opportunity Gross Seasonal Peak Demand Savings - Electric, Winter and Summer

$$SKW_{LO} = CF_s \times CAP_{new} \times \left(\frac{1}{EER_{fed\ std}} - \frac{1}{EER_{new}} \right) \div 1000 \, {}^{W}\!/_{kW}$$

Changes from Last Version

All Room Air Conditioning measures have been combined.

References

[1] LW Coincidence Factor Study: Room Air Conditioners, Prepared for: Northeast Energy Efficiency Partnerships' New England Evaluation and State Program Working Group, June 23, 2008.

[2] Consortium for Energy Efficiency. CEE Super-Efficient Appliances Initiative: High Efficiency Specifications for Room Air Conditioners, Effective January 1, 2003. ©2003.

[3] Energy Star Program Requirements for Room Air Conditioners, Version 2.1. Effective November 16, 2005. Revised on December 17, 2010.

[4] Energy Star Program Requirements Product Specification for Room Air Conditioners, Version 3.0. Effective October 1, 2012. Draft 2: May 17, 2011.

Notes

[1] The size (Btu/Hr) and efficiency rating of the old air conditioner for the turn-in program is based on Ref [1], which studied the 2004 and 2005 RAC retirement programs. The assumptions used for determining the gross savings in Ref [1] remain valid.

[2] The size (Btu/Hr) and efficiency rating of the old ("Typical") air conditioner for the Low Income Replacement Program is based on 1999 AHAM shipment weighted averages.

[3] CEE values for Table 1 were obtained from Ref [2]. Energy Star values were obtained from the current V2.1 (Ref [3]) and the V3.0 proposed criteria that will be effective Oct 1, 2012, Ref [4]. Federal Standard values were also obtained from Energy Star. This measure does not cover Casement or Reverse Cycle units.

4.3.7 CLOTHES WASHER

Description of Measure

Replacement of a standard residential clothes washer with a high efficiency clothes washer.

Savings Methodology

Energy savings other than direct machine energy use come from two additional sources: the reduction in hot water use that occurs because of lower overall water consumption, and the shorter drying times needed because high spin speeds leave less water in the clothes. As a result, energy savings vary depending on the type of energy used for drying and water heating.

Machine energy savings is always electric energy. Water Heater savings may only be claimed for the fuel that is used in the home's water heater. Dryer savings may be only claimed for the fuel that is used in the dryer that is to be used in conjunction with the washer; if there is no dryer, no dryer savings can be claimed.

For replacement in an existing home, savings may be claimed in two parts, since additional "retirement" savings may be claimed in the case of early retirement of an old unit.

1. The primary part, "retrofit," claims savings from an Energy Star 2009 unit versus the new unit, using the effective useful lifetime (EUL) (Note [1]).

2. At the same time, the second part, "retirement," may claim additional savings based on the existing "typical" unit versus the Energy Star 2009 unit, using the remaining useful lifetime (RUL), assuming the existing unit would have been installed until failure.

In a new home, savings for the new unit may be calculated the same as the primary part, "retrofit," savings in an existing home.

Note: *If the existing unit is a front-loading/horizontal axis orientation, only the "retrofit" portion of the savings may be claimed; the "retirement" portion may not be claimed (Note [2]).*

For new "retail" units, average savings are claimed for a mix of fuels since the hot water/dryer fuel type combinations are not known. Prescriptive savings can be found in Table 2 corresponding to the various Tiers of efficiency.

No demand savings have been identified for this measure.

Inputs

Symbol	**Description**
WH Fuel	Water heating fuel
Dryer Type	Type of dryer to be used with the new unit: Electric, Gas, or None
MEF_{new}	Modified Energy Factor of new unit
WF_{new}	Water Factor of new unit
Axis Orientation	Existing unit's configuration: Horizontal Axis (Front Loading) or Vertical Axis (Top Loading).
$size_{old}$	Compartment Capacity of old unit in Cu ft.
$size_{new}$	Compartment Capacity of new unit in Cu ft.

Nomenclature

Symbol	Description	Units	Values	Comments
AOG	Annual Oil Savings	Gal/yr	Calculated	
APG	Annual Propane Savings	Gal/yr	Calculated	
BER	Total annual clothes washer Btu Equivalent energy Reduction; the sum of Machine, Water Heating, and Drying energy savings.	Btu/yr	Calculated	Definition of MEF
Cycles per year	Average number of loads per year	Cycles/ yr	Residential: 392	Ref [5]
DP	Drying energy proportion; average percentage of SEA going to drying energy	unitless	Retirement: 76.8%, New: 82.2%	Note [3]
EUL	Effective Useful Life: Measure life of the new unit.	years	Appendix 4	
$LKWH_{total}$	Total Gross Lifetime kWh savings for early retirement measure.	kWh	Calculated	
MEF_{new}	Modified Energy Factor: the energy efficiency metric for clothes washers; new refers to the new unit	ft^3/kWh/ cycle	New unit: as found Others: Table 1	Ref [1]
MP	Machine energy proportion; average percentage of SEA going to machine energy	unitless	Retirement:5.6% New: 5.3%	Note [3]
RUL	Remaining Useful Life: remaining number of years the existing unit would have operated until failure.	years	Appendix 4	
$S_{D,E}$	Annual energy savings for Electric Dryer (post-washer moisture removal)	kWh/yr		
$S_{D,G}$	Annual energy savings for Gas Dryer (post-washer moisture removal)	Ccf/yr		
$S_{M,E}$	Electric Machine Energy savings per year	kWh/yr		
$S_{W,E}$	Annual energy savings for electric water heater	kWh/yr		
$S_{W,G}$	Annual energy savings for natural gas water heater	Ccf/yr		
$S_{W,O}$	Annual energy savings for oil water heater	Gal of Oil/yr		
$S_{W,P}$	Annual energy savings for propane water heater	Gal of Propane/yr		
$size_{old}$	Compartment capacity of old clothes washer unit	cubic feet, ft^3	As found; use $size_{new}$ if unknown	
$size_{new}$	Compartment capacity of new clothes washer unit	cubic feet, ft^3	As found	
WF	Water Factor: the number of gallons needed for each cubic foot of laundry	gal/ft^3	New unit: as found. Others: Table 1	
WH EF	Water Heating Efficiency for fossil fuel water heaters	unitless	0.62	Ref [7]
WP	Water Heating energy proportion; average percentage of SEA going to water heating energy	unitless	Retirement:17.6%, New: 12.5%	Note [3]
$\ldots_{ES\ 09}$	July 1, 2009 Energy Star, baseline for new unit		Table 1	Ref [1]
$\ldots_{fed\ std}$	Federal Standard, baseline for retirement of vertical axis unit		Table 1	Ref [6]

Retrofit Gross Energy Savings - Electric

Table 1: MEF and WF Ratings for Specifications (Ref [6])

Level	MEF	WF
Federal Standard	1.26	9.5
2009 Energy Star	1.8	7.5
CEE Tier 1, 2011 Energy Star	2.0	6.0
CEE Tier 2	2.2	4.5
CEE Tier 3	2.4	4.0

Retrofit New Unit portion of savings:

$$BER_{new} = size_{new} \times 3412\ {}^{Btu}\!/_{kWh} \times 392\ {}^{cycles}\!/_{yr} \times \left(\frac{1}{MEF_{ES\ 09}} - \frac{1}{MEF_{new}} \right)$$

$$S_{M,E,retrofit} = \frac{MP_{new} \times BER_{new}}{3412\ {}^{Btu}\!/_{kWh}}$$

$$S_{W,E,retrofit} = \frac{WP_{new} \times BER_{new}}{3412\ {}^{Btu}\!/_{kWh}}$$ (Applicable only to electric water heater)

$$S_{D,E,retrofit} = \frac{DP_{new} \times BER_{new}}{3412\ {}^{Btu}\!/_{kWh}}$$ (Applicable only to electric clothes dryer)

$$AKWH_{retrofit} = S_{M,E,retrofit} + S_{W,E,retrofit} + S_{D,E,retrofit}$$

Retirement portion of savings:

$$BER_{retire} = size_{old} \times 3412\ {}^{Btu}\!/_{kWh} \times 392\ {}^{cycles}\!/_{yr} \times \left(\frac{1}{MEF_{fed\ std}} - \frac{1}{MEF_{ES\ 09}} \right)$$

$$BER_{retire} = size_{old} \times 3412\ {}^{Btu}\!/_{kWh} \times 392\ {}^{cycles}\!/_{yr} \times \left(\frac{1}{1.26} - \frac{1}{1.8} \right) = size_{old} \times 318453\ {}^{Btu}\!/_{ft^3}$$

$$S_{M,E,retire} = \frac{MP_{retire} \times BER_{retire}}{3412\ {}^{Btu}\!/_{kWh}}$$

$$S_{W,E,retire} = \frac{WP_{retire} \times BER_{retire}}{3412\ {}^{Btu}\!/_{kWh}}$$ (Applicable only to electric water heater)

$$S_{D,E,retire} = \frac{DP_{retire} \times BER_{retire}}{3412\ {}^{Btu}\!/_{kWh}}$$ (Applicable only to electric clothes dryer)

$$AKWH_{retire} = S_{M,E,retire} + S_{W,E,retire} + S_{D,E,retire}$$

Lifetime savings in existing home:

$$LKWH_{total} = \left(AKWH_{retrofit} \times EUL \right) + \left(AKWH_{retire} \times RUL \right)$$

Retrofit Gross Energy Savings - Fossil Fuel

Retrofit New Unit portion of savings:

$$S_{W,G,retrofit} = \frac{WP_{new} \times BER_{new}}{102900\ {}^{Btu}\!/_{Ccf} \times 0.62}$$ (Applicable only to gas water heater)

$$S_{D,G,retrofit} = \frac{DP_{new} \times BER_{new}}{102900\ {}^{Btu}\!/_{Ccf} \times 0.62}$$ (Applicable only to gas clothes dryer)

$$Annual\ Gas\ Ccf = S_{W,G} + S_{D,G}$$

$$AOG_{retrofit} = S_{W,O,retrofit} = \frac{DP_{new} \times BER_{new}}{138690\,{}^{Btu}/_{Gal} \times 0.62}$$ (Applicable only to oil water heater)

$$APG_{retrofit} = S_{W,P,retrofit} = \frac{DP_{new} \times BER_{new}}{91330\,{}^{Btu}/_{Gal} \times 0.62}$$ (Applicable only to propane water heater)

Retirement portion of savings:

$$S_{W,G,retire} = \frac{WP_{retire} \times BER_{retire}}{102900\,{}^{Btu}/_{Ccf} \times 0.62}$$ (Applicable only to gas water heater)

$$S_{D,G,retire} = \frac{DP_{retire} \times BER_{retire}}{102900\,{}^{Btu}/_{Ccf} \times 0.62}$$ (Applicable only to gas clothes dryer)

$$Annual\ Gas\ Ccf = S_{W,G} + S_{D,G}$$

$$AOG_{retire} = S_{W,O,retire} = \frac{DP_{retire} \times BER_{retire}}{138690\,{}^{Btu}/_{Gal} \times 0.62}$$ (Applicable only to oil water heater)

$$APG_{retire} = S_{W,P,retire} = \frac{DP_{retire} \times BER_{retire}}{91330\,{}^{Btu}/_{Gal} \times 0.62}$$ (Applicable only to propane water heater)

Lifetime savings in existing home:

$$Lifetime\ Ccf_{total} = \left(Annual\ Ccf_{retrofit} \times EUL\right) + \left(Annual\ Ccf_{retire} \times RUL\right)$$
$$Lifetime\ Gal\ oil_{total} = \left(AOG_{retrofit} \times EUL\right) + \left(AOG_{retire} \times RUL\right)$$
$$Lifetime\ Gal\ propane_{total} = \left(APG_{retrofit} \times EUL\right) + \left(APG_{retire} \times RUL\right)$$

<u>Example - Retrofit Gross Energy Savings</u>

In an existing home, a 2.96 ft^3 capacity unit with an MEF at the CEE Tier 2 level (MEF=2.2, WF=4.5). The home uses an electric dryer and a gas water heater. The existing unit is the same size as the new unit and is top-loading. What are the total savings?

Annual Gross Retrofit savings are:

$$BER_{retrofit} = 2.96\,ft^3 \times 3412\,{}^{Btu}/_{kWh} \times 392\,{}^{cycles}/_{yr} \times \left(\frac{1}{1.8} - \frac{1}{2.2}\right) = 399{,}900\ Btu$$

$$S_{M,E} = \frac{5.3\% \times 399{,}900\ Btu}{3412\,{}^{Btu}/_{kWh}} = 6.2\ kWh$$

$$S_{D,E} = \frac{82.2\% \times 399{,}900\ Btu}{3412\,{}^{Btu}/_{kWh}} = 96.3\ kWh$$

There are no electric water heating savings ($S_{W,E}$) in this example.

$$AKWH_{retrofit} = 6.2 + 96.3 = 103\,{}^{kWh}/_{yr}$$ $$Annual\ gas\ Ccf_{retrofit} = S_{W,G} = \frac{12.5\% \times 399{,}900\ Btu}{102{,}900\,{}^{Btu}/_{kWh} \times 0.62} = 0.78\,{}^{Ccf}/_{yr}$$

$$Annual\ Water\ Savings_{retrofit} = 2.96\,ft^3 \times 392\,{}^{cycles}/_{yr} \times (7.5 - 4.5) = 3{,}481\,{}^{gal}/_{yr}$$

Annual Gross Retirement Savings are:

$$BER_{retire} = 2.96\,ft^3 \times 318453\,{}^{Btu}\!/_{ft^3} = 942{,}622\ Btu$$

$$S_{M,E} = \frac{5.6\% \times 942{,}622\ Btu}{3412\,{}^{Btu}\!/_{kWh}} = 15.5\,kWh$$

$$S_{D,E} = \frac{76.8\% \times 942{,}622\ Btu}{3412\,{}^{Btu}\!/_{kWh}} = 212.2\ kWh$$

$$AKWH_{retire} = 15.5 + 212.2 = 228\ {}^{kWh}\!/_{yr}$$

$$Annual\ gas\ Ccf_{retire} = S_{W,G} = \frac{17.6\% \times 942{,}622\ Btu}{102{,}900\,{}^{Btu}\!/_{kWh} \times 0.62} = 2.60\ {}^{Ccf}\!/_{yr}$$

$$Annual\ Water\ Savings_{retire} = 2.96\,ft^3 \times 392\,{}^{cycles}\!/_{yr} \times (9.5 - 7.5) = 2{,}321\,{}^{gal}\!/_{yr}$$

Lifetime Savings are:

$$\left(103\,{}^{kWh}\!/_{yr} + 0.78\,{}^{Ccf\ gas}\!/_{yr} + 3{,}481\,{}^{gal\ water}\!/_{yr}\right) \times 11\ yrs + \left(228\,{}^{kWh}\!/_{yr} + 2.60\,{}^{Ccf\ gas}\!/_{yr} + 2{,}321\,{}^{gal\ water}\!/_{yr}\right) \times 4\ yrs$$

for a total savings of 3,641 kWh, 19 Ccf of Gas, and 47,575 Gallons of water.

Lost Opportunity Gross Energy Savings - Electric

Table 2: Prescriptive Annual Gross Energy Savings for Retail Units (Estimated Fuel Mix), New Unit vs. Energy Star 2009

Level	Electric Energy (kWh)	Fossil Fuel Mix (WH)			Fossil Fuel Mix (Dryer)	Water (Gal)
		Gas – 30% (Ccf)	Oil – 60% (Gal)	Propane – 10% (Gal)	Gas - 100% (Ccf)	
CEE Tier 2	77	0.3	0.37	0.09	0.93	3481
CEE Tier 3	106	0.3	0.51	0.13	1.27	4061

Lost Opportunity Gross Energy Savings - Fossil Fuel

See Table 2.

Example - Lost Opportunity Gross Energy Savings

A program CEE Tier 3 Unit was purchased through at a retail store.
The savings include 106 kWh/yr electricity, 0.3+1.3=1.6 Ccf/yr Gas, 0.51 Gal Oil, 0.13 Gal Propane, and 4061 Gal/yr water.

Non Energy Benefits

Water Savings:

$$Annual\ Water\ Savings_{retrofit} = size_{new} \times 392\,{}^{cycles}\!/_{yr} \times \left(WF_{ES\ 09} - WF_{new}\right)$$

$$Annual\ Water\ Savings_{retire} = size_{old} \times 392\,{}^{cycles}\!/_{yr} \times \left(WF_{fed\ std} - WF_{ES\ 09}\right)$$

$$Lifetime\ Water\ Savings_{total} = \left(Annual\ Water\ Savings_{retrofit} \times EUL\right) + \left(Annual\ Water\ Savings_{retire} \times RUL\right)$$

$$Annual\ Water\ Savings_{retail} = size_{new} \times 392\ {}^{cycles}\!/_{yr} \times \left(WF_{ES\ 09} - WF_{new}\right)$$

Other Benefits:
New units may have new useful features, do a better job cleaning, and leave less water weight remaining in the clean items.

Changes from Last Version

Updated to reflect latest Energy Star and CEE criteria, used common conversion factors, changed from table to equations.

References

[1] Energy Star Program Requirements Product Specification for Clothes Washers: Eligibility Criteria, Version 5.1. Effective January 1, 2011.

[2] U.S. D.O.E. Clothes Washer Technical Support Document, Chapter 4, Engineering Analysis. December 2000 Document was retrieved on June 13, 2011, from the web page. Website content last updated August 15, 2008.

[3] U.S. D.O.E. Energy Conservation Standards Rulemaking Framework Document for Residential Clothes Washers, August 21, 2009.

[4] Energy Star Consumer Clothes Washer Calculator, Excel Spreadsheet Tool, updated October 2009 by Cadmus Group, Available Online at http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/CalculatorConsumerClothesWasher.xls , last accessed June 13, 2011.

[5] DOE Federal Test Procedure 10 CFR 430, Appendix J1, as of June 14, 2011.

[6] Consortium for Energy Efficiency (CEE) Super Efficient Home Appliances Initiative (SEHA): High efficiency specification for residential clothes washers. January 1, 2011.

[7] Federal Register Part III, DOE Energy Conservation Program: Energy Conservation standards for Residential Water Heaters, Direct Heating Equipment, Pool Heater; (Final Rule, Table I.2). April 16, 2010.

Notes

[1] Energy Star Tier 1 and Tier 2 requirements are based on Ref [1]. Tier 1 was effective July 1, 2009, and Tier 2 is effective January 1, 2011. Savings assume that apart from the program, a unit meeting Energy Star Tier 1 would have been purchased.

[2] According to the Engineering Analysis section of Ref [3], “a survey of frontloading clothes washers in the CEC *[California Energy Commission]* appliance database shows that there are no frontloading washers with efficiencies at the existing Federal standards level, or, for that matter, any below the *[January 2007]* ENERGY STAR level (1.72 MEF/8.00 WF).” (Italicized text within brackets was added for clarification and is not part of the original document.).

[3] The Energy Star Calculator tool (Ref [4]) gives average energy consumption based on all qualified models and the same average for all non-qualified models. While manufacturers are permitted to achieve the MEF by varying any blend of the three energy areas, the energy proportion values are derived from those average consumptions and reflect the average weight each component contributes to total energy use.

4.3.8 DISHWASHER

Description of Measure

Replacement of a standard size residential dishwasher with a new unit that meets the 2012 Consortium for Energy Efficiency (CEE) Tier 2 efficiency standard or better.

Savings Methodology

Beginning January 20, 2012, the requirements for Energy Star (Ref [4]) labeling of dishwashers essentially bring the efficiency level up to meet the CEE Tier 2 efficiency level (Ref [2]), which requires an Efficiency Factor (EF) of 0.75 (Note [3]), maximum annual kWh of 295, and maximum hot water demand of 4.25 gallons per cycle.

For replacement in an existing home, savings may be claimed in two parts, since additional "retirement" savings may be claimed in the case of early retirement of the old unit:

1. The primary part, "retrofit," claims savings from an Energy Star 2009 unit versus the new (CEE Tier 2) unit, using the effective useful lifetime (EUL) (Note [1]).

2. At the same time, the second part, "retirement," may claim additional savings based on the existing "typical" unit versus the Energy Star 2009 unit, using the remaining useful lifetime (RUL), assuming the existing unit would have been installed until failure.

When water heater (WH) fuel type is unknown, such as "retail" units, savings are claimed for a mix of fuels, between the CEE Tier 2 unit and the Energy Star 2009 unit (See Note [1]).

When the water heater fuel is known, WH energy savings may only be claimed for that fuel type. If the water heating fuel type for a retail unit could be obtained, the new unit savings would be the same as the new unit "retrofit" part of savings for units in an existing home.

Each savings component is a prescriptive value (See Note [2]) which is listed in the Nomenclature table. No electric or gas demand savings have been determined for this measure.

Inputs

Symbol	**Description**
WH Fuel	Water Heater fuel type
EF	Rated Energy Factor of new unit (Not required for savings)
kWh/yr rating	Rated kWh/yr of new unit (Not required for savings)
Water Gal/ Cycle	Rated gallons of water per cycle of new unit (Not required for savings)

Nomenclature

Symbol	**Description**	**Units**	**Values**	**Comments**
AKWH	Annual gross electric savings	kWh/yr		
EF	Energy Factor	unitless	as found	

Symbol	Description	Units	Values	Comments
AOG	Annual savings from oil water heating if there is an oil water heater.	Gal Oil per yr	Retro: 2.22 Retire: 1.72 Retail: 1.07	Notes [1],[2]
APG	Annual savings from propane water heating if there is a propane water heater.	Gal Propane per yr	Retro: 3.38	Notes [1],[2]
$S_{M,E}$	Machine electric Savings, including motor, heater, and dryer energy.	kWh/yr	Retro: 0 Retire: 10.2 Retail: 0	Notes [1],[2]
$S_{W,E}$	Annual Savings from electric water heating only if there is electric water heater (WH).	kWh/yr	Retro: 37 Retire: 10.2 Retail: 0	Notes [1],[2]
$S_{W,G}$	Annual savings from gas water heating if there is a gas water heater.	Ccf/yr	Retro: 3.00 Retire: 2.3 Retail: 0.72 Retire: 2.61 Retail: 0.27	Notes [1],[2]
$\ldots_{retire}$	Subscript indicating retirement portion.			
$\ldots_{retro}$	Subscript indicating retrofit (new unit) portion.			

Retrofit Gross Energy Savings - Electric

$AKWH_{retrofit} = S_{M,E,retro} + S_{W,E,retro}$ (if applicable)
$AKWH_{retire} = S_{M,E,retire} + S_{W,E,retire}$ (if applicable)

Retrofit Gross Energy Savings - Fossil Fuel

Fossil Fuel savings are prescriptive values found in the Nomenclature table.

Example - Retrofit Gross Energy Savings

In a home with a gas hot water heater, a dishwasher is replaced with a new CEE Tier 2 unit. What are the annual retirement and retrofit savings?

See the Nomenclature table. Retrofit annual savings include 0 kWh/yr and 3.0 Ccf/yr of gas. Retirement savings include 10.2 kWh/yr and 2.3 Ccf/yr of gas.

Lost Opportunity Gross Energy Savings - Fossil Fuel

Retail Gross Annual Fossil Fuel Savings = $S_{W,G,retail} + AOG_{retail} + APG_{retail}$

Example - Lost Opportunity Gross Energy Savings

A CEE Tier 2 unit is purchased. What average savings may be claimed?

There are no Electric savings. Fossil Fuel savings are 0.72 Ccf Gas/yr + 1.07 Gal Oil/yr + 0.27 Gal Propane per year.

Changes from Last Version

Updated to most recent expected Energy Star and CEE specifications. Made water heater efficiency and energy conversions consistent with other PSD measures.

References

[1] DOE Federal Test Procedure 10 CFR 430, Appendix C, as of June 20, 2011.

[2] Consortium for Energy Efficiency (CEE) Super Efficient Home Appliances Initiative (SEHA): Dish Washer Specification August 11, 2009.

[3] Energy Star Program Requirements Product Specification for Dish Washers: Eligibility Criteria, Version 4.1. Effective August 11, 2009.

[4] Energy Star Program Requirements Product Specification for Dish Washers: Eligibility Criteria, Version 5.0. Effective January 20, 2012.

[5] Federal Register Part III, DOE Energy Conservation Program: Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, Pool Heater; Final Rule,Table I.2. April 16, 2010.

Notes

[1] Due in part to the fact that the primary component of the CEE specification savings comes from water heating, combined with the weighting process (20% Electric WH and 80% Fossil fuel-further broken 30% gas, 60% oil, and 10% propane), the weighted savings average for new units has no electric savings and very low fossil fuel savings.

[2] Energy usage comparison was based on: the CEE Tier 2 Specifications for a new unit (Ref [2]), the 2009 Energy Star Specifications (Ref [3]) for the new unit baseline. “Typical” unit specifications included: kWh/cycle based on 1994 NAECA (a federal standard), hot water usage based on AHAM shipment weighted average for 1999. Number of cycles per year (215), hot water temperature rise (70 °F), and specific heat of water (8.2 Btu per Gal per °F) are taken from Ref [1]. 62% fossil fuel water heater efficiency was taken from Ref [5].

[3] The Energy Factor (0.75) is listed in the CEE criteria, but is not explicitly required by 2012 Energy Star Criteria. The kWh/year and Water/cycle requirements are otherwise identical.

4.3.9 REFRIGERATOR

Description of Measure

Replacement of a standard size refrigerator with a new unit that meets or exceeds current ENERGY STAR efficiency criteria.

Savings Methodology

For replacement in an existing home, savings may be claimed in two parts, since additional “retirement” savings may be claimed in the case of early retirement of the old unit:

1. The primary part, new unit “retrofit,” claims savings from an ENERGY STAR 2004 unit (Ref [3]) versus the new unit, using the new unit’s Adjusted Volume (AV) and the effective useful lifetime (EUL) (Note [1]).

2. At the same time, the second part, “retirement,” may claim additional savings based on the existing unit (See Note [1]) versus the Energy Star 2004 unit, using the existing unit’s AV and the remaining useful lifetime (RUL), assuming the existing unit would have been installed until failure.

Exceptions to standard calculations for replacement of existing units may occur in the following special situations:

1. If the annual kWh usage of the existing unit is already less than or equal to Energy Star 2004 level ($E_{retire} \leq E_{ES04}$), no retirement savings may be claimed.

2. If the annual kWh usage of existing unit is less than Energy Star 2004 but greater than the annual kWh usage of the new unit ($E_{new} < E_{retire} < E_{ES04}$), the new unit retrofit savings may still be claimed, but the existing Annual kWh usage must be used for the baseline rather than Energy Star 2004.

3. If new unit Annual kWh is greater than or equal to the existing unit kWh ($E_{retire} \leq E_{new}$), regardless of size, no savings may be claimed.

The AV of an existing unit may be determined by measuring the interior fresh and freezer volumes and calculating as shown. Energy usage is primarily based on size and type. The type of refrigerators and freezers is categorized by:

1. Configuration (side-by-side, top freezer, bottom freezer, single door refrigerator and freezer, single door refrigerator only, chest freezer, and upright freezer)

2. Automatic or manual defrost

3. Whether or not they have through-the-door ice service

To calculate energy usage of any efficiency level, first the Adjusted Volume must be calculated, from which the Federal Standard level energy usage is calculated for that size and type using formulas in Table 1. Units that meet 2004 Energy Star specifications use 15% less energy than Federal Standard, Energy Star 2008 units use 20% less (Ref [3]), the Consortium for Energy Efficiency (CEE) Tier 2 units use 25% less, and CEE Tier 3 units use 30% less (Ref [4]). Consumption for new units including Energy Star 2004 and higher are modified to include a “Site/Lab Factor” (Ref [1], pages 7-2 and 7-3).

Retail unit savings is a lost opportunity measure; it may be calculated the same way as the new unit “retrofit” savings portion.

Inputs

Symbol	Description
AV_{new}	Adjusted Volume of new unit
AV_{retire}	Adjusted Volume of existing unit
$V_{fresh,new}$	Fresh Volume of new unit (only if AV is not given)
$V_{fresh,retire}$	Fresh Volume of existing unit
$V_{frz,new}$	Freezer Volume of new unit (only if AV is not given)
$V_{frz,retire}$	Freezer Volume of existing unit
E_{new}	Actual rated kWh energy usage for the new unit
E_{retire}	Actual rated kWh energy usage for the existing unit
Type	Type of refrigerator (See Table 1 for options)

Nomenclature

Symbol	Description	Units	Values	Comments
$AKWH_{retire}$	Gross annual retirement savings	kWh/yr	Calculated	
$AKWH_{new}$	Gross annual new unit retrofit or retail savings	kWh/yr	Calculated	
AV	Adjusted Volume, calculated from the measured fresh and freezer volumes.	ft^3	actual; can be calculated	
E_{ES04}	Electric energy usage of Energy Star 2004 level unit	kWh/yr		Ref [3]
$E_{fed\ std}$	Electric energy usage of Federal Standard unit, varies according to size and type	kWh/yr	calculated for 'retire' and 'new'	
E_{new}	Electric energy usage of new unit	kWh/yr	calculated	
PF_S	Summer Peak Factor	W/ kWh	0.1834	Ref [1]
PF_W	Winter Peak Factor	W/ kWh	0.1031	Ref [1]
SKW	Summer electric demand savings	kW		
SLF_{new}	Site/Lab Factor, an adjustment for DOE test lab performance of new refrigerators to in situ performance		0.881	Ref [1], Ref [2]
V_{fresh}	Fresh volume, the total volume of the main refrigerator compartment	ft^3	actual	
V_{frz}	Freezer volume, the total volume of the freezer compartment	ft^3	actual	
WKW	Winter electric demand savings	kW		

Retrofit Gross Energy Savings - Electric

$$AV = V_{fresh} + 1.63 \times V_{frz}$$

Table 1: Federal Standard Energy Use (Based on Size), in kWh/yr

Type	$kWh_{fed\ std}$
Manual Defrost Refrigerators	8.82*AV+248.4
Partial Automatic Defrost Refrigerators	8.82*AV+248.4
Top Mount Freezer without through-the-door ice	9.8*AV+276
Side Mount Freezer without through-the-door ice	4.91*AV+507.5
Bottom Mount Freezer without through-the-door ice	4.6*AV+459
Top Mount Freezer with through-the-door ice	10.2*AV+356
Side Mount Freezer with through-the-door ice	10.1*AV+406

$$E_{ES04,new} = 0.85 \times E_{fed\ std,new}$$ (based on new unit's AV)

$$AKWH_{new} = \left(SLF_{new} \times E_{ES04,new}\right) - \left(SLF_{new} \times E_{new}\right)$$

$$AKWH_{new} = (0.881 \times 0.85 \times E_{fed\ std,new}) - (0.881 \times E_{new})$$
$$AKWH_{new} = (0.75 \times E_{fed\ std,new}) - (0.881 \times E_{new})$$

$$E_{ES04,retire} = 0.85 \times E_{fed\ std,retire}$$ (based on existing unit's AV)

When energy usage of the existing unit is known:

$$AKWH_{retire} = E_{retire} - (SLF_{new} \times E_{ES04,retire})$$
$$AKWH_{retire} = E_{retire} - (0.881 \times E_{ES04,retire})$$

When energy usage of the existing unit is unknown (See Note [1]):

$$AKWH_{retire} = E_{fed\ std,retire} - (SLF_{new} \times E_{ES04,retire})$$
$$AKWH_{retire} = [1 - (0.881 \times 0.85)] \times E_{fed\ std,retire}$$
$$AKWH_{retire} = 0.25 \times E_{fed\ std,retire}$$

Example - Retrofit Gross Energy Savings

A 15 year old refrigerator in an existing home, unknown energy usage, with a top-mount freezer without through-the-door ice, is being replaced by a new high efficiency unit. The old unit's freezer volume is 2.80 ft^3, and its fresh volume is 10.50 ft^3. The new unit is nominally 17 ft^3, its Adjusted Volume is 18.86 ft^3, and its energy use is equal to the CEE Tier 3 efficiency level. What are the energy savings?

First, calculate the Federal Standard usage for the new and existing units, and rated usage for the new unit:

$$E_{fed\ std,new} = 9.8 \times 18.86 + 276 = 460.8\ {}^{kWh}\!/_{yr}$$
$$E_{new} = 0.70 \times E_{fed\ std,new} = 322.6\ {}^{kWh}\!/_{yr}$$
$$AV_{retire} = 10.50 + 1.63 \times 2.80 = 15.06\ ft^3$$
$$E_{fed\ std,retire} = 9.8 \times 15.06 + 276 = 423.6\ {}^{kWh}\!/_{yr}$$

Then, calculate savings using the formulas:

$$AKWH_{new} = (0.75 \times 460.8\ kWh) - (0.881 \times 322.6) = 61.4\ {}^{kWh}\!/_{yr}$$
$$AKWH_{retire} = 0.25 \times E_{fed\ std,retire} = 0.25 \times 423.6 = 105.9\ {}^{kWh}\!/_{yr}$$

Retrofit Gross Seasonal Peak Demand Savings - Electric, Winter and Summer

$$WKW = AKWH \times PF_W / 1000\ {}^{W}\!/_{kW}$$
$$SKW = AKWH \times PF_S / 1000\ {}^{W}\!/_{kW}$$

Example - Retrofit Gross Peak Demand Savings

In the above example, what are the demand savings?

$$WKW_{new} = 61.4\ {}^{kWh}\!/_{yr} \times 0.1031 / 1000\ {}^{W}\!/_{kW} = 0.0063\ kW$$
$$SKW_{new} = 61.4 \times 0.1834 / 1000\ {}^{W}\!/_{kW} = 0.0113\ kW$$

$$WKW_{retire} = 105.9 \, {}^{kWh}\!/_{yr} \times 0.1031/1000 \, {}^{W}\!/_{kW} = 0.0109 \, kW$$
$$SKW_{retire} = 105.9 \times 0.1834/1000 \, {}^{W}\!/_{kW} = 0.0194 kW$$

Example - Lost Opportunity Gross Energy Savings

A new retail unit is nominally 17 ft^3, its Adjusted Volume is 18.86 ft^3, and its energy use is equal to the CEE Tier 3 efficiency level. What are the energy savings?

$$E_{fed\ std,new} = 9.8 \times 18.86 + 276 = 460.8 \, {}^{kWh}\!/_{yr}$$
$$E_{new} = 0.70 \times E_{fed\ std,new} = 322.6 \, {}^{kWh}\!/_{yr}$$
$$AKWH_{new} = (0.75 \times 460.8 \, kWh) - (0.881 \times 322.6) = 61.4 \, {}^{kWh}\!/_{yr}$$

Example - Lost Opportunity Gross Peak Demand Savings

In the above retail example, what are the demand savings?

$$WKW_{new} = 61.4 \, {}^{kWh}\!/_{yr} \times 0.1031/1000 \, {}^{W}\!/_{kW} = 0.0063 \, kW$$
$$SKW_{new} = 61.4 \times 0.1834/1000 \, {}^{W}\!/_{kW} = 0.0113 \, kW$$

Changes from Last Version

Baseline for retirement when existing unit usage is unknown was "typical" but is now a unit at the Federal Standard. Combined both Refrigerator measures.

References

[1] KEMA, Evaluation of the Weatherization Residential Assistance Partnership and Helps Programs (WRAP/Helps), September 10, 2010

[2] Blasnik, Michael, Proctor Engineering Group Limited, Michael Blasnik & Associates, and Conservation Services Group. Measurement and Verification of Residential Refrigerator Energy Use: Final Report, 2003-2004 Metering Study. July 29, 2004.

[3] Energy Star Program Requirements Product Specification for Residential Refrigerators and Freezers: Eligibility Criteria, Version 4.1. Effective April 28, 2008.

[4] Consortium for Energy Efficiency (CEE) Super-Efficient Home Appliances Initiative (SEHA) High-efficiency Specifications for Refrigerators, Effective Jan 1, 2007.

Notes

[1] If existing unit kWh usage is unknown, and the unit was manufactured prior to the effective date of the federal standard (2001), $E_{fed\ std}$ as calculated based on the AV of the existing unit may be used for the existing kWh usage.

4.3.12 FREEZER

Description of Measure

Replacement of standard size freezer with new unit that meets or exceeds the Energy Star level.

Savings Methodology

For replacement in an existing home, savings may be claimed in two parts, since additional "retirement" savings may be claimed in the case of early retirement of the old unit:

1. The primary part, "retrofit," claims savings from a Federal Standard unit (Ref [2]) versus the new (Energy Star, Ref [2]) unit, using the new unit's Adjusted Volume (AV) and the effective useful lifetime (EUL) (Note [1]).

2. At the same time, the second part, "retirement," may claim additional savings based on the existing unit (below federal standard) versus the Federal Standard unit, using the existing unit's AV and the remaining useful lifetime (RUL), assuming the existing unit would have been installed until failure.

Note: *Retirement savings may not be claimed if the existing unit was manufactured in 2001 or later, since the NAECA federal standards went into effect July 1, 2001.*

The AV of an existing unit may be determined by measuring the interior freezer volume and calculating as shown. Energy usage is primarily based on size and type. The type of refrigerators and freezers is categorized by:

1. Configuration (chest freezer and upright freezer)

2. Automatic or manual defrost

To calculate energy usage of any efficiency level, first the Adjusted Volume must be calculated, from which the Federal Standard level energy usage is calculated for that size and type using formulas in Table 1. Units that meet 2008 Energy Star specifications use 10% less energy than Federal Standard (Ref [2]).

Retail unit savings is a lost opportunity measure; it may be calculated the same way as the new unit "retrofit" savings portion.

Inputs

Symbol	**Description**
AV_{new}	Adjusted Volume of new unit
AV_{retire}	Adjusted Volume of existing unit
$V_{frz,new}$	Freezer Volume of new unit (only if AV is not given)
$V_{frz,retire}$	Freezer Volume of existing unit
E_{new}	Actual rated kWh consumption for the new unit
Type	Type of freezer (See Table 1 for options)

Nomenclature

Symbol	Description	Units	Values	Comments
AV	Adjusted Volume, calculated from the measured fresh and freezer volumes.	ft^3	actual; can be calculated	
V_{frz}	Freezer volume, the total volume of the freezer compartment	ft^3	actual	
E_{retire}	Annual electric energy usage of existing freezer	kWh/yr	actual	Note [1]
$E_{fed\ std}$	Electric energy usage of Federal Standard unit, varies according to size and type	kWh/yr	calculated	
kWh_{ES08}	Electric energy usage of Energy Star 2008 level unit	kWh/yr	Calculated	Ref [2]
kWh_{new}	Electric energy usage of new unit	kWh/yr	As rated	
$AKWH_{retire}$	Gross annual retirement savings	kWh/yr	Calculated	
$AKWH_{new}$	Gross annual new unit retrofit or retail savings	kWh/yr	Calculated	
WKW	Winter electric demand savings	kW		
SKW	Summer electric demand savings	kW		
PF_S	Summer Peak Factor	W/ kWh	0.1834	Ref [1]
PF_W	Winter Peak Factor	W/ kWh	0.1031	Ref [1]

Retrofit Gross Energy Savings - Electric

$$AV = 1.73 \times V_{frz}$$

Table 1: Federal Standard Energy Use (Based on Size), in kWh/yr

Type	$E_{fed\ std}$
Upright freezers with manual defrost	7.55*AV + 258.3
Chest freezers and all other freezers except compacts	9.88*AV + 143.7
Upright freezers with auto defrost	12.43*AV + 326.1

$$AKWH_{new} = E_{fed\ std,new} - E_{new}$$ (based on new unit's AV)

$$AKWH_{retire} = E_{retire} - E_{fed\ std,retire}$$ (based on existing unit's AV)

Example - Retrofit Gross Energy Savings

A manual defrost chest freezer in an existing home is being replaced by a new high efficiency unit. The old unit's freezer volume is 12 ft^3 and it uses 395 kWh/yr. The new unit's Adjusted Volume is 21.5 ft^3, and its energy use is equal to the Energy Star efficiency level. What are the energy savings?

First, calculate the federal standard usage for the new and existing units, and rated usage for the new unit:

$$E_{fed\ std,new} = 9.88 \times 21.5 + 143.7 = 356.1\ {}^{kWh}\!/_{yr}$$

$$E_{new} = 0.90 \times kWh_{fed\ std,new} = 320.5\ {}^{kWh}\!/_{yr}$$

$$AV_{retire} = 1.73 \times 12.0 = 20.8\ ft^3$$

$$E_{fed\ std,retire} = 9.88 \times 20.8 + 143.7 = 347.5\ {}^{kWh}\!/_{yr}$$

Then, calculate savings using the formulas:

$$AKWH_{new} = 356.1\,kWh - 320.5\,kWh = 35.6\,{}^{kWh}\!/_{yr}$$

$$AKWH_{retire} = 395\,kWh - 347.5\,kWh = 47.5\,{}^{kWh}\!/_{yr}$$

Retrofit Gross Seasonal Peak Demand Savings - Electric, Winter and Summer

$$WKW = AKWH \times PF_W / 1000\,{}^{W}\!/_{kW}$$

$$SKW = AKWH \times PF_S / 1000\,{}^{W}\!/_{kW}$$

Example - Retrofit Gross Peak Demand Savings

In the above example, what are the demand savings?

$$WKW_{new} = 35.6\,{}^{kWh}\!/_{yr} \times 0.1031 / 1000\,{}^{W}\!/_{kW} = 0.0037\ kW$$

$$SKW_{new} = 35.6 \times 0.1834 / 1000\,{}^{W}\!/_{kW} = 0.0065\,kW$$

$$WKW_{retire} = 47.5\,{}^{kWh}\!/_{yr} \times 0.1031 / 1000\,{}^{W}\!/_{kW} = 0.0049\ kW$$

$$SKW_{retire} = 47.5 \times 0.1834 / 1000\,{}^{W}\!/_{kW} = 0.0087 kW$$

Changes from Last Version

Removed defaults from body of the measure to make it clearer that actuals should be used.

References

[1] KEMA, Evaluation of the Weatherization Residential Assistance Partnership and Helps Programs (WRAP/Helps), September 10, 2010

[2] Energy Star Program Requirements Product Specification for Residential Refrigerators and Freezers: Eligibility Criteria, Version 4.1. Effective April 28, 2008.

Notes

[1] If actual usage of the existing unit is not known, calculate Federal Standard based on the existing unit's size, and assume the old existing unit consumes 118% of the energy of a federal standard unit, based on the following: A 21.01 ft^3 size (based on 1999 AHAM shipment weighted average) unit's consumption = 472 kWh (based on AHAM Energy Efficiency and Consumption Trends). Weighted average consumption for a 21.56 ft^3 Adjusted Volume Federal Standard chest and upright freezers = 400 kWh. 472/400 = 118%. This gives the following equation to estimate existing usage: $kWh_{retire} = 1.18 \times kWh_{fed\ std,retire}$.

4.3.13 DEHUMIDIFIER

Description of Measure

Replacement of older dehumidifier with high efficiency dehumidifier. New unit use must be at least 10% better than the 2008 Energy Star requirements.

Savings Methodology

For replacement in an existing home, savings may be claimed in two parts, since additional "retirement" savings may be claimed in the case of early retirement of the old unit.

1. The primary part, "retrofit," claims savings from the 2008 Energy Star (Ref [2]) unit versus a unit that is 10% better than 2008 Energy Star, using the new unit's capacity and the effective useful lifetime (EUL, Appendix 4) (Note [1]).

2. At the same time, the second part, "retirement," may claim additional savings based on the existing unit versus the 2008 Energy Star unit, using the existing unit's capacity and the remaining useful lifetime (RUL, Appendix 4), assuming the existing unit would have been installed until failure.

Annual savings for retail units are calculated the same as the "retrofit" new unit portion of the savings in existing homes.

Inputs

Symbol	Description
$size_{new}$	Capacity of the new unit, in pints/day
$size_{retire}$	Capacity of the existing unit, in pints/day
EF_{new}	Energy Factor of the new unit
EF_{retire}	Energy Factor of the existing unit

Nomenclature

Symbol	Description	Units	Values	Comments
days/yr	Equivalent Annual Days per year equaling 1620 hrs/yr	days/yr	67.5	Ref [4]
$E_{ES08,new}$	Annual usage at Energy Star 2008 EF level based on new unit size	kWh/yr	calculated	
E_{new}	Annual usage of new unit based on new size and EF	kWh/yr	calculated	
E_{retire}	Annual usage of existing unit based on existing size and EF	kWh/yr	calculated	
$EF_{ES08,new}$	Energy Factor at Energy Star 2008 level based on size of new unit	L/kWh	Table 1	
$EF_{ES08,retire}$	Energy Factor at Energy Star 2008 level based on size of existing unit	L/kWh	Table 1	
EF_{new}	Energy Factor of new unit	L/kWh	actual	
EF_{retire}	Energy Factor of existing unit	L/kWh	actual	Note [2]
$kWh_{ES08,retire}$	Annual usage at Energy Star 2008 EF level based on existing unit size	kWh/yr	calculated	
$size_{new}$	Capacity of the new unit	pints/day		
$size_{retire}$	Capacity of the existing unit	pints/day		

Retrofit Gross Energy Savings - Electric

Table 1: Energy Factor for Various Specifications

Capacity (Pints/day)	**Federal Standard Effective 2007 (Ref [3])**	**Energy Star 2008 (Ref [2])**	**10% better than Energy Star 2008**
≤ 25	1.00	1.20	1.32
> 25 to ≤ 35	1.20	1.40	1.54
> 35 to ≤ 45	1.30	1.50	1.65
> 45 to ≤ 54	1.30	1.60	1.76
> 54 to < 75	1.50	1.80	1.98
≥ 75 to ≤ 185	2.25	2.50	2.75

$$AKWH_{new} = size_{new} \times 0.473\, {}^{Liters}\!/\!_{p\,int} \times 67.5\, {}^{days}\!/\!_{yr} \times \left(\frac{1}{EF_{ES08,new}} - \frac{1}{EF_{new}} \right)$$

$$AKWH_{retire} = size_{retire} \times 0.473\, {}^{Liters}\!/\!_{p\,int} \times 67.5\, {}^{days}\!/\!_{yr} \times \left(\frac{1}{EF_{retire}} - \frac{1}{EF_{ES08}} \right)$$

Example - Retrofit Gross Energy Savings

A 50 pint/day unit is replaced with the same size unit in an existing home. The existing unit had an EF of 1.20 Liters/kWh, and the new unit has an EF of 1.90 Liters/kWh. What are the energy savings?

First, determine the EF for a unit meeting Energy Star Standards. This is the midpoint. In this case, the size of both units is the same, therefore:
$EF_{ES08,retire} = EF_{ES08new}$, and $E_{ES08,retire} = E_{ES08,new}$
$EF_{ES08} = 1.60$ Liters/yr

Then calculate AKWH for both retrofit new unit and retirement of existing unit.

$$AKWH_{new} = 50\, {}^{p\,int\,s}\!/\!_{day} \times 0.473\, {}^{Liters}\!/\!_{p\,int} \times 67.5\, {}^{days}\!/\!_{yr} \times \left(\frac{1}{1.6} - \frac{1}{1.9} \right) = 157.5\, {}^{kWh}\!/\!_{yr}$$

$$AKWH_{retire} = 50\, {}^{p\,int\,s}\!/\!_{day} \times 0.473\, {}^{Liters}\!/\!_{p\,int} \times 67.5\, {}^{days}\!/\!_{yr} \times \left(\frac{1}{1.2} - \frac{1}{1.6} \right) = 332.6\, {}^{kWh}\!/\!_{yr}$$

Retrofit Gross Seasonal Peak Demand Savings - Electric, Winter and Summer

$$SKW_{new} = AKWH_{new} / 1620\, {}^{hrs}\!/\!_{yr}$$ (Note [3])

$$SKW_{retire} = AKWH_{retire} / 1620\, {}^{hrs}\!/\!_{yr}$$ (Note [3])

Example - Retrofit Gross Peak Demand Savings

Demand Savings for the above retrofit example are:

$$SKW_{new} = 157.5\, {}^{kWh}\!/\!_{yr} / 1620\, {}^{hrs}\!/\!_{yr} = 0.097\, {}^{kW}\!/\!_{yr}$$

$$SKW_{retire} = 332.6\, {}^{kWh}\!/\!_{yr} / 1620\, {}^{hrs}\!/\!_{yr} = 0.205\, {}^{kW}\!/\!_{yr}$$

Changes from Last Version

Removed defaults from body of the measure to make it clearer that actuals should be used.

References

[1] US Congress, Energy Independence and Security Act of 2007 (EISA), Title III, "ENERGY SAVINGS THROUGH IMPROVED STANDARDS FOR APPLIANCE AND LIGHTING," January 4, 2007. Section 311 (a)(1) Dehumidifiers, Effective October 1, 2012.

[2] Energy Star Program Requirements Product Specification for Dehumidifiers: Eligibility Criteria, Version 2.1. Effective June 1, 2008.

[3] US Congress, Energy Policy Act of 2005 (EPACT), Title I, “ENERGY EFFICIENCY”, Subtitle C, “Energy Efficient Products”, January 4, 2005, Section 135 (cc), “DEHUMIDIFIERS”, effective October 1, 2007.

[4] US EPA, with the Cadmus Group. Energy Star Energy Savings Calculator for Energy Star Dehumidifier. Available online through the Energy Star website: http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/CalculatorConsumerDehumidifier.xls . Last Updated April, 2009. Last Accessed June 26, 2011.

Notes

[1] Because the Federal Standard effective October 2012 in Ref [1] will bring standard efficiency levels up to the current Energy Star (Ref [2]), replacement of units in existing homes must also use 10% less energy than the current Energy Star qualifications in order to continue to exceed the standard level. Current Federal Standards (Ref [3]) applied to dehumidifiers manufactured on or after October 1, 2007.

[2] If Energy Factor of existing unit is unknown, it shall be based on the Federal Standard EF established in Ref [3] and listed in Table 1 for the existing unit’s size.

[3] Due to insufficient peak coincident data, the average kW savings, which is conservatively lower than the coincident peak, shall be claimed for the summer seasonal peak demand savings. No winter demand savings shall be claimed.

4.4 ENVELOPE

4.4.1 REM SAVINGS

Description of Measure

Residential Energy Modeling (REM) savings for ENERGY STAR certified residential new construction

Savings Methodology

An ENERGY STAR Home must be certified through Home Energy Rating System (HERS). ENERGY STAR Homes are limited to single family homes or multi-family homes that are five stories or less. Hi-rise units do not qualify for ENERGY STAR certification and the savings methodology below does not apply to those units.

The traditional method of qualifying ENERGY STAR Homes is through a HERS rating. The rating involves inputting the key energy features into a computer program (geometry, orientation, thermal performance, mechanical systems, etc.) that will generate a HERS score and other useful information regarding the energy usage of the home. REM/Rate™ (REM) is the software that is used in Connecticut (and in most jurisdictions) to generate HERS ratings (Note [1]).

A feature of REM is that it enables the user to define a base home ("user defined reference home," or UDRH) and calculate the savings of an actual home relative to the UDRH. The UDRH is the same size as the "as-built" and utilizes the same type of mechanical systems and fuels. However, the thermal and mechanical efficiencies of the UDRH are set to baseline levels. The baseline levels are prescriptive code values or those established from the most recent baseline studies available and program administrator field experience.

Inputs

Symbol	Description
REM	REM simulation file submitted by an HERS rater

Nomenclature

Symbol	Description	Units	Values	Comments
1 Ton	Capacity, Tonnage	Tons	12,000 Btu/hr	Conversion
AKWH	Annual Electric Energy Savings	kWh		
SKW	Summer Demand Savings	kW		
WKW	Winter Demand Savings	kW		

Lost Opportunity Gross Energy Savings - Electric

The UDRH report generates heating, cooling and water heating consumption for the "as-built" home and the defined "base" home (i.e. Table 1). The difference between those values is the energy savings. This savings is referred to as "REM" savings.

Table 1: Example of a Typical UDRH Report

	UDRH Consumption (MMBtu)	As-Built Consumption (MMBtu)	Energy Savings (MMBtu)
Heating	40.5	34.8	5.7
Cooling	4.5	2.3	2.2
Water Heating	20.6	17.5	3.1

The REM savings above includes the effect of installing a programmable thermostat, so additional savings should not be claimed if one (or more) is programmable thermostat is installed. Also, REM has the ability to incorporate lights and appliances into an "expanded" rating. Connecticut does NOT use the expanded rating. Therefore, the REM savings does not include savings for lights and appliances. These savings (if any) are calculated separately.

Since REM savings is based on a whole building approach (i.e. it includes the effects of upgraded insulation, tighter ducts, increased efficiencies, etc.), this savings methodology takes precedence over "code-plus" measures. Savings for homes that have a REM analysis done should be calculated using the UDRH Report; and no additional savings should be claimed based on code-plus measures.

There are two baselines from which savings are calculated. Of the following two options, the baseline that produces the least savings will be the baseline of the claimed savings, either:

1. A home based on minimum prescriptive code.

2. An "average" home built in Connecticut as determined by a baseline evaluation (and used as a baseline home UDRH). ***Note:*** *the baseline may differ from a home built to minimum prescriptive code. While many homes fail to meet some aspects of the energy code, their performance overall exceeds minimum code performance substantially and therefore, the baseline exceeds minimum code performance as well.*

Lost Opportunity Gross Energy Savings - Fossil Fuel

Described above in lost opportunity gross energy savings - electric

Lost Opportunity Gross Seasonal Peak Demand Savings - Electric, Winter and Summer

Described above in lost opportunity gross energy savings - electric

Lost Opportunity Gross Peak Day Savings - Natural Gas

Described above in lost opportunity gross energy savings - Electric

Non Energy Benefits

Improves personal comfort and health. It also increases a home's durability and value.

Notes

[1] REM/Rate™ is a residential energy analysis, code compliance and rating software developed by Architectural Energy Corporation. This software calculates heating, cooling, hot water, lighting, and appliance energy loads, consumption and costs for new and existing single and multi-family homes.

4.4.4 INFILTRATION REDUCTION TESTING (BLOWER DOOR TEST)

Description of Measure

Blower Door Test equipment is used to determine infiltration reduction. The test is conducted in accordance with ASHRAE Standard 119-1988 (R2004).

Savings Methodology

REM/Rate—a residential energy analysis, code compliance and rating software—was used to simulate infiltration reductions in homes (Ref [1]). The savings results are based on shell reductions only and should not be applied to duct sealing reductions which are addressed as a separate measure. The average energy savings in MMBtu and kWh was calculated based on the REM/Rate simulations and based on air leakage (CFM) reduction at 50 Pascals pressure differences. The energy savings was then converted to the appropriate fuels using unit conversions and assumed distribution losses. The demand savings was based on the REM simulation.

Inputs

Symbol	Description
CFM_{Pre}	Infiltration before air sealing @ 50 Pa
CFM_{Post}	Infiltration after air sealing @ 50 Pa
	Heating Fuel Type (Electric Resistive, HP, Gas, Oil, Propane, etc...)
	Heating System Distribution Type (Forced air with fan, heat pump, resistive, radiator, etc)

Nomenclature

Symbol	Description	Units	Value	Comments
$ACCF_H$	Annual Natural Gas Savings, Heating	Ccf		
$AKWH_H$	Annual Electric Energy Savings, Heating	kWh		
$AKWH_C$	Annual Electric Energy Savings, Cooling	kWh		
AOG_H	Annual Oil Savings, Heating	Gal		
APG_H	Annual Propane Savings, Heating	Gal		
CFM_{Pre}	Infiltration before air sealing measured with the house being negatively pressurized to 50 Pa relative to outdoor conditions.	CFM		Inputs
CFM_{Post}	Infiltration after air sealing measured with the house being negatively pressurized to 50 Pa relative to outdoor conditions.	CFM		Inputs
PD_H	Natural gas peak day savings, Heating	Ccf		
PDF_H	Natural gas peak day factor – Heating		0.00977	Appendix 1
SKW	Summer Demand Savings	kW		
WKW	Winter Demand Savings	kW		

Retrofit Gross Energy Savings - Electric

Table 1 - Retrofit Electric Savings per CFM Reduction (at 50 Pa)

Measure		Energy Savings	Units
Electric Resistance Heat	$REM_{Heating}$	2.638	kWh
Heat Pump Heating	$REM_{Heating}$	1.319	kWh
Geothermal Heating	$REM_{Heating}$	0.879	kWh
Air Handler (fan) Heating	REM_{AH}	0.06	kWh
Cooling (Central Air Only)	$REM_{Cooling}$	0.0593	kWh

For Electric Resistive, Heat Pump or Geothermal Heating Systems,

$$AKWH_H = REM_{Heating} \times (CFM_{Pre} - CFM_{Post})$$

For Fossil Fuel heating with air handler unit,

$$AKWH_H = REM_{AH} \times (CFM_{Pre} - CFM_{Post})$$

Home with Central AC,

$$AKWH_C = REM_{Cooling} \times (CFM_{Pre} - CFM_{Post})$$

Retrofit Gross Energy Savings - Fossil Fuel

Table 2 – Retrofit Fossil Fuel Savings

Savings per CFM (at 50 Pa) reduction			
Measure		**Energy Savings**	**Units**
Fossil Fuel Heating		0.012	MMBtu
Natural Gas	REM_{NG}	0.123	Ccf
Propane	$REM_{Propane}$	0.131	Gal
Oil	REM_{Oil}	0.086	Gal

For homes with natural gas heating system,

$$ACCF_H = REM_{NG} \times \left(CFM_{Pre} - CFM_{Post}\right)$$

For homes with oil heating system,

$$AOG_H = REM_{Oil} \times \left(CFM_{Pre} - CFM_{Post}\right)$$

For homes with propane heating system,

$$APG_H = REM_{Propane} \times \left(CFM_{Pre} - CFM_{Post}\right)$$

Example - Retrofit Gross Energy Savings

A blower door test was performed in a 1940’s Cape Cod style home in Hartford. The size of the home is 2400 sq ft. The primary source of heating is an oil boiler. Minneapolis Blower Door test equipment was used to measure the infiltration of the home at 50 Pa. The readings on the test equipment showed CFM_{Pre} of 1850 and CFM_{Post} of 1575. What are the electric and fossil fuel savings for this home?

$$AOG_H = REM_{Oil} \times (CFM_{Pre} - CFM_{Post})$$

$AOG_H = 0.086 \times (1850 - 1575)$ =23.7 gallons

Retrofit Gross Seasonal Peak Demand Savings - Electric, Winter and Summer

REM_{WKW} = 0.00117 kW (Electric Resistance and HP)
REM_{WKW} = 0.00039 kW (Geothermal - Retrofit)

$$WKW_H = REM_{WKW} \times (CFM_{Pre} - CFM_{Post})$$

REM_{SKW} = 0.00009 kW

$$SKW_C = REM_{SKW} \times (CFM_{Pre} - CFM_{Post})$$

Reminder: *Demand savings are based on design load calculation in REM software hence there is no need to use coincidence factors.*

Retrofit Gross Peak Day Savings - Natural Gas

$$PD_H = ACCF_H \times PDF_H$$

Example - Retrofit Gross Peak Demand Savings

Blower test was performed in a 1940's Cape Cod style home in Hartford. The size of the home is 2400 sq ft. The primary source of heating is an air source heat pump. In Minneapolis Blower Door test equipment was used to measure the infiltration of the home at 50 Pa. The readings on the test equipment showed CFM_{Pre} of 1850 and CFM_{Post} of 1575. What are the summer and winter demand savings for this home?

$$SKW_C = REM_{SKW} \times (CFM_{Pre} - CFM_{Post})$$
$$SKW_C = 0.00009 \times (1850 - 1575) = 0.025kW$$

$$WKW_H = REM_{WKW} \times (CFM_{Pre} - CFM_{Post})$$
$$WKW_H = 0.00117 \times (1850 - 1575) = 0.332kW$$

Changes from Last Version

Changed savings from "per 100 CFM" to "per 1 CFM".

References

[1] REM/Rate™ is a residential energy analysis, code compliance and rating software developed by Architectural Energy Corporation. This software calculates heating, cooling, hot water, lighting, and appliance energy loads, consumption and costs for new and existing single and multi-family homes. Blower Door energy savings analysis using REM was performed by C&LM Planning team, Northeast Utilities, August 2008.

4.4.8 WINDOW REPLACEMENT

Description of Measure

Installation of Energy Star window to replace existing single pane window located between the conditioned space and the outdoors.

Savings Methodology

The savings for this measure are calculated using the installed area of the replacement window and usage factors develop using RESFEN (Ref [1]) to model different window types and heating fuels. The results of this analysis are shown in tables 1 & 2. The energy savings are calculated by subtracting the heating fuel specific ENERGY Star Value single pane “tight” value and multiplying by the window area. For homes that have central cooling, the same analysis is done using the cooling energy usage.

Note: *Savings may not be claimed if the window is located in an unconditioned space such as an unheated porch, basement, or hallway.*

Inputs

Symbol	**Description**	**Units**
	Cooling system type of home	
	Heating fuel of home	
D_H	Height of the window	Inches
D_W	Width of the window	Inches
U	Rated U value of window. (Not required for savings calculation)	BTU/ft^2 x h x ^{0}F

Nomenclature

Symbol	**Description**	**Units**	**Values**	**Comments**
A	Area of the window	ft^2		
$ACCF_H$	Annual Gas Savings - heating	Ccf/yr		
AEC	Annual Electric Cooling Usage	kWh/ft^2/yr	Table 1	Note [2]
AEH	Annual Electric Heating Usage	kWh/ft^2/yr	Table 1	Note [2]
AGU	Annual Gas Usage	Ccf/ ft^2/yr	Table 2	Note [2]
$AKWH_C$	Annual Electric energy savings-Cooling	kWh/yr		
$AKWH_H$	Annual Electric energy savings-Heating	kWh/yr		
AOG_H	Annual Oil Savings - heating	gal/yr		
AOU	Annual Oil Usage	gal/ft^2/yr	Table 2	Note [2]
APG_H	Annual Propane Savings - heating	gallons/yr		
APU	Annual Propane Usage	gal/ft^2/yr	Table 2	Note [2]
CF_S	Summer Seasonal Peak Coincidence Factor		0.59	Appendix 1
D_H	Height of the window	inch		
D_W	Width of the window	inch		
PF_W	Winter Peak Factor	W/kWh	0.570	Ref [2]
WKW	Winter coincident peak demand savings	kW		
SKW	Summer coincident peak demand savings	kW		
PDF_H	Peak Day Factor - Heating		0.00977	Appendix 1
PD_H	Peak Day savings - Heating			
$\ldots_b$	Baseline			

Symbol	Description	Units	Values	Comments
…es	Energy Star			
…HP	Heat Pump Heating Only			
…R	Electric Resistance Heating Only			

Retrofit Gross Energy Savings - Electric

Window Type	AEH (kWh/ft²)	AEC (kWh/ft²)
Single pane ("leaky")	28.61	2.65
Single pane ("tight") (baseline)	22.02	2.57
Double Pane (or single with storm)	10.79	2.57
Energy Star	5.66	1.49

$$A = \frac{D_H \times D_W}{144\, {}^{in^2}\!/_{ft^2}}$$

Heating (Note [1])**:**

$$AKWH_{H,R} = (AEH_b - AEH_{es}) \times A = (22.02 - 5.66) \times A$$

$$AKWH_{H,R} = 16.36 \times A$$

$$AKWH_{H,HP} = \frac{16.36}{2} \times A = 8.18 \times A$$

Cooling:

$$AKWH_C = (AEC_b \times AEC_{es}) \times A = (2.57 - 1.49) \times A$$

$$AKWH_C = 1.08 \times A$$

Retrofit Gross Energy Savings - Fossil Fuel

Table 2: Annual Fossil Fuel Energy Usage

Window Type	AGU (Ccf/ft²)	AOU (gal/ft²)	AOU (gal/ft²)
Single pane ("leaky")	1.39	1.03	1.57
Single pane ("tight") (baseline)	1.08	0.80	1.21
Double Pane (or single with storm)	0.53	0.39	0.59
Energy Star	0.28	0.20	0.31

$$A = \frac{D_H \times D_W}{144\, {}^{in^2}\!/_{ft^2}}$$

Savings by heating fuel:

$$ACCF_H = (AGU_b - AGU_{es}) \times A = (1.08 - 0.28) \times A$$

$$ACCF_H = 0.80 \times A$$

$$AOG_H = (AOU_b - AOU_{es}) \times A = (0.80 - 0.20) \times A$$

$$AOG_H = 0.60 \times A$$

$$APG_H = (APU_b - APU_{es}) \times A = (1.21 - 0.31) \times A$$
$$APG_H = 0.90 \times A$$

Example - Retrofit Gross Energy Savings

A single pane 24" x 36" window is replaced by an Energy Star window in a home cooled by central AC and heated by electric resistance.

$$A = \frac{24\,in \times 36\,in}{144\,{}^{sq\,in}\!/_{sf}} = 6\,sq\ ft$$

$$AKWH_H = 16.36\,{}^{kWh}\!/_{sf} \times 6\,sqft = 98\,kWh$$
$$AKWH_C = 1.08\,{}^{kWh}\!/_{sf} \times 6\,sqft = 6.5\,kWh$$

Retrofit Gross Seasonal Peak Demand Savings - Electric, Winter and Summer

If home has electric heat or heat pump (Note [1]),

$$WKW = AKWH_{H,R} \times \frac{PFW}{1000\,{}^{W}\!/_{kW}} = 16.36\,{}^{kWh}\!/_{sf} \times A \times \frac{0.570\,{}^{W}\!/_{kWh}}{1000\,{}^{W}\!/_{kW}} = 0.0093\,{}^{kW}\!/_{sf} \times A$$

If home has central air conditioning:

$$SKW = (0.055\,{}^{kW}\!/_{sf} - 0.03\,{}^{kW}\!/_{sf}) \times CF_S \times A$$
$$SKW = 0.0015\,{}^{kW}\!/_{sf} \times A$$

Retrofit Gross Peak Day Savings - Natural Gas

$$PD_H = ACCF_H \times PDF_H$$

Example - Retrofit Gross Peak Demand Savings

For the above example with electric resistance heat and central air, demand savings are as follows:

$$WKW = 0.0093\,{}^{kW}\!/_{sf} \times 6\,sq\ ft = 0.056\,kW$$
$$SKW = 0.0015\,{}^{kW}\!/_{sf} \times 6\,sq\ ft = 0.009\,kW$$

Changes from Last Version

Savings changed from per window to per square foot. Added Peak Day Savings for Gas.

References

[1] Lawrence Berkeley National Laboratory, RESFEN 5.0 computer software, May 12, 2005. http://windows.lbl.gov/software

[2] KEMA, Evaluation of the Weatherization Residential Assistance Partnership and Helps Programs (WRAP/Helps), September 10, 2010.

Notes

[1] Heat pump energy savings are one half of electric resistance savings based on a 2.0 COP. Since heat pumps use backup resistance heat during winter peak, winter demand savings for heat pumps equals resistance heat demand savings.

[2] The usage values were developed for different fuel types and windows using RESFEN from Ref [1]. The values from that analysis are shown in the tables.

4.4.9 THERMAL ENCLOSURE

Description of Measure

Meet ENERGY STAR thermal enclosure requirements, such as using ceiling insulation R-value of R-40 or better and above grade wall insulation better than R-21 (may not include batt insulation).

Savings Methodology

The R values for walls and ceilings reflect the nominal R value, not the total R value of the assembly. ***Note****: Thermal mass does not equate to R-value. Solid wood walls (log cabins) are not considered high performance walls and do not qualify because they do not meet the R-value or infiltration requirements.*

Because the savings calculation includes the effects of decreased infiltration, homes that qualify for this measure do NOT qualify for any incentive for blower door reduction, nor should savings for both measures be counted; either the infiltration as determined below or the blower door test may be used, but not both. Also, if a home is HERS rated, the UDRH savings takes precedent over the savings presented here; if a home meets ENERGY STAR standards via the EPA approved Building Option Packages (BOP), then savings from this measure should not be counted.

CFM reduction and energy analysis were based on a sample of actual ENERGY STAR rated homes in the existing residential new construction program. CFM savings from code-minimum home to an ENERGY STAR rated home is 0.50 CFM per square feet of floor area. The annual energy savings are estimated based on CFM reduction. Square feet of floor area refers to above grade conditioned floor area.

Inputs

Symbol	Description	Units
A	Surface area above grade of conditioned space	sf
	System/Fuel Type (Electric Resistive, Heat Pump, air handler, Central Ac, Gas, Oil, Propane, etc...)	

Nomenclature

Symbol	Description	Units	Values	Comments
A	Surface area above grade of conditioned space	sf		Inputs
$ACCF_H$	Annual Natural Gas Savings, Heating	Ccf		
$AKWH_H$	Annual Electric Energy Savings, Heating	kWh		
$AKWH_C$	Annual Electric Energy Savings, Cooling	kWh		
AOG_H	Annual Oil Savings, Heating	Gal		
APG_H	Annual Propane Savings, Heating	Gal		
PD_H	Natural gas peak day savings – heating		0.00977	Appendix 2
REM	Savings using residential energy modeling software			Note [1]
REM_{SKW}	Modeled Summer kW per square foot	kW/ft^2	0.00009	Note [1]
REM_{WKW}	Modeled Winter kW per square foot	kW/ft^2	0.00117	Note [1]
SKW	Summer Demand Savings	kW		
WKW	Winter Demand Savings	kW		

<u>Lost Opportunity Gross Energy Savings - Electric</u>

Table 1 –Electric Savings per square foot (Note [1])

System type	Symbol	Energy Savings	Units
Electric Resistance Heat	REM_H	1.32	kWh/ ft^2
Heat Pump Heating	REM_H	0.66	kWh/ ft^2
Air Handler (fan) Heating	REM_F	0.03	kWh/ ft^2
Cooling	REM_C	0.03	kWh/ ft^2

For Electric Resistive, or Heat Pump Systems,

$$AKWH_H = REM_H \times A$$

For Fossil Fuel heating with air handling unit,

$$AKWH_H = REM_F \times A$$

Homes with Central AC,

$$AKWH_C = REM_C \times A$$

<u>Lost Opportunity Gross Energy Savings - Fossil Fuel</u>

Table 2 –Fossil Fuel Savings per square foot (Note [1])

Heating Fuel	Symbol	Energy Savings	Units
Fossil Fuel Heating		0.0045	MMBtu/ft^2
Natural Gas	REM_G	0.044	Ccf/ft^2
Propane	REM_P	0.049	Gal/ft^2
Oil	REM_O	0.032	Gal/ ft^2

For homes with natural gas heating system,

$$ACCF_H = REM_G \times A$$

For homes with oil heating system,

$$AOG_H = REM_O \times A$$

For homes with propane heating system,

$$APG_H = REM_P \times A$$

<u>Example - Lost Opportunity Gross Energy Savings</u>

Insulation was installed in a new home and the insulation meets the ENERGY STAR thermal bypass requirements. The home is equipped with a natural gas furnace and a central AC. The total floor area of conditioned space is 1,100 sf. What are the annual energy savings?

$$ACCF_H = REM_G \times A = 0.044 \times 1{,}100 = 54\ Ccf$$

Additional electric savings claimed for air handling system,

$$AKWH_H = REM_F \times A = 0.03 \times 1{,}100 = 33\ kWh$$

Lost Opportunity Gross Seasonal Peak Demand Savings - Electric, Winter and Summer

$WKW_H = REM_{WKW} \times A$ (Electric Resistance and Heat Pump)

$SKW_C = REM_{SKW} \times A$ (Central Air Conditioner or Heat Pump providing cooling)

Lost Opportunity Gross Peak Day Savings - Natural Gas

$$PD_H = ACCF_H \times PDF_H$$

Example - Lost Opportunity Gross Peak Demand Savings

Insulation was installed in a new home. The insulation meets the ENERGY STAR thermal bypass requirements. The home is equipped with a natural gas furnace and a central AC. The total floor area of conditioned space is 1,100 sf. What are the peak demand savings (electric and natural gas)?

Summer demand savings,

$$SKW_C = REM_{SKW} \times A = 0.00009 \times 1{,}100 = 0.099\ kW$$

Natural gas peak day savings,

$$PD_H = ACCF_H \times PDF_H = 54 \times 0.00977 = 0.53\ Ccf$$

Non Energy Benefits

Increased personal comfort

Changes from Last Version

Updated Gas savings value from 0.045 Ccf/sf in Table 1, based on revised gas Btu content of 9.72 Ccf/MMBtu.

Notes

[1] REM/Rate™ is a residential energy analysis, code compliance and rating software developed by Architectural Energy Corporation. This software calculates heating, cooling, hot water, lighting, and appliance energy loads, consumption and costs for new and existing single and multi-family homes.

4.4.10 INSTALL STORM WINDOW

Description of Measure

Installation of a storm window to augment an existing single pane window located between the conditioned space and the outdoors.

Savings Methodology

The savings for this measure are calculated using the installed storm window area and usage factors develop using RESFEN (Ref [1]) to model different window types and heating fuels. The results of that analysis are shown in tables 1 & 2. The energy savings are calculated by subtracting the heating fuel specific Double Pane Value from the single pane "tight" value and multiplying by the storm window area. Because the cooling usage was the same for the baseline and the Double Pane the cooling savings are 0.

Note: *Savings may not be claimed if the window is located in an unconditioned space such as an unheated porch, basement, or hallway.*

Inputs

Symbol	Description	Units
	Number storm windows installed	
D_H	Height of the window	Inches
D_W	Width of the window	Inches

Nomenclature

Symbol	Description	Units	Values	Comments
A	Area of the window	ft^2		
$ACCF_H$	Annual Gas Savings - heating	Ccf		
AEC	Annual Electric Cooling Usage	kWh/ft^2	Table 1	Note [2]
AEH	Annual Electric Heating Usage	kWh/ft^2	Table 1	Note [2]
AGU	Annual Gas Usage	Ccf/ft^2	Table 2	Note [2]
$AKWH_C$	Annual Electric energy savings-Cooling	kWh		
$AKWH_H$	Annual Electric energy savings-Heating	kWh		
AOG_H	Annual Oil Savings - heating	gallons		
AOU	Annual Oil Usage	gal/ft^2	Table 2	Note [2]
APG_H	Annual Propane Savings - heating	gallons		
APU	Annual Propane Usage	gal/ft^2	Table 2	Note [2]
D_H	Height of the window	inch		
D_W	Width of the window .	inch		
PFW	Winter Peak Factor	W per kWh	0.570	Ref [2]
SKW	Summer coincident peak demand savings	kW		
WKW	Winter coincident peak demand savings	kW		
$\ldots_b$	baseline			
$\ldots_{dp}$	double pane			
$\ldots_{HP}$	Heat Pump Heating			
$\ldots_R$	Resistance Heating			

Retrofit Gross Energy Savings - Electric

Table 1: Annual Electric Energy Usage

Window Type	AEH (kWh/ft^2)	AEC (kWh/ft^2)
Single pane ("leaky")	28.61	2.65
Single pane ("tight")	22.02	2.57
Double Pane (or single with storm)	10.79	2.57
Energy Star	5.66	1.49

$$A = \frac{D_H \times D_W}{144 \, {}^{in^2}/_{ft^2}}$$

$$AKWH_{H,R} = (AEH_b - AEH_{es}) \times A = (22.02 - 10.79) \times A$$

$$AKWH_H = 11.23 \times A$$

$$AKWH_{H,HP} = \frac{11.23}{2} \times A = 5.62 \times A$$ (Note 1)

Retrofit Gross Energy Savings - Fossil Fuel

Table 2: Annual Gas Energy Usage

Window Type	AGU (kWh/ft^2)	AOU (gal/ft^2)	AOU (gal/ft^2)
Single pane ("leaky")	1.39	1.03	1.57
Single pane ("tight")	1.08	0.80	1.21
Double Pane (or single with storm)	0.53	0.39	0.59
Energy Star	0.28	0.20	0.31

$$A = \frac{D_H \times D_W}{144 \, {}^{in^2}/_{ft^2}}$$

Savings by heating fuel:

$$ACCF_H = (AGU_b - AGU_{es}) \times A = (1.08 - 0.53) \times A$$
$$ACCF_H = 0.55 \times A$$

$$AOG_H = (AOU_b - AOU_{es}) \times A = (0.80 - 0.39) \times A$$
$$AOG_H = 0.41 \times A$$

$$APG_H = (APU_b - APU_{es}) \times A = (1.21 - 0.59) \times A$$
$$APG_H = 0.62 \times A$$

Example - Retrofit Gross Energy Savings

A new storm window is added to a single pane 24" x 36" window heated by electric resistance.

$$A = \frac{24\,in \times 36\,in}{144\,{}^{in^2}\!/\!_{ft^2}} = 6\,sq\ ft$$

$$AKWH_H = 11.25\,{}^{kWh}\!/\!_{ft^2} \times 6\ ft^2 = 68\,kWh$$

Retrofit Gross Seasonal Peak Demand Savings - Electric, Winter and Summer

If home has electric heat or heat pump (Note [1]),

$$WKW = AKWH_H \times \frac{PFW}{1000\,{}^{W}\!/\!_{kW}} = 11.25\,{}^{kWh}\!/\!_{sf} \times A \times \frac{0.570}{1000} = 0.0064\,{}^{kW}\!/\!_{sf} \times A$$

$$SKW = 0$$

Example - Retrofit Gross Peak Demand Savings

For the above example with electric resistance heat and central air, demand savings are as follows:

$$WKW = 0.0064\,{}^{kW}\!/\!_{sf} \times 6\,sq\ ft = 0.038\,kW$$

$$SKW = 0\,kW$$

Changes from Last Version

Savings changed from per window to per square foot and now require area measurements of windows.

References

[1] Lawrence Berkeley National Laboratory, RESFEN 5.0 computer software, May 12, 2005. http://windows.lbl.gov/software

[2] KEMA, Evaluation of the Weatherization Residential Assistance Partnership and Helps Programs (WRAP/Helps), September 10, 2010

Notes

[1] Heat pump savings are one half of electric resistance savings. Since heat pumps use backup resistance heat during winter peak, winter demand savings for heat pumps equals resistance heat demand savings.

[2] The usage values were developed for different fuel types and windows using RESFEN from Ref [1]. The values from that analysis are shown in the tables.

4.4.11 INSULATE ATTIC OPENINGS

Description of Measure

Insulation and weather stripping applied to an attic hatch, insulation and weather-stripping of attic stairs, or insulation of a whole house fan

Savings Methodology

The energy savings are estimated in two parts: conductive and infiltration reduction. The conductive savings are calculated using a degree day analysis. The infiltration reduction will be included in the blower door reduction (Measure 4.4.4) whenever possible or be estimated based on the KEMA Evaluation (Ref [1]) in combination with ASHRAE 1997 Fundamentals Handbook (Note [1]).

Reminder*: Only include the infiltration savings if infiltration from this measure was not included in a blower door test.*

Inputs

Symbol	Description	Units
	Type of attic penetration being insulated.	
	Was the infiltration reduction included in blower door measurements?	

Nomenclature

Symbol	Description	Units	Values	Comments
A	Total area of insulation	ft^2		
ABTU	Annual Btu savings	Btu/yr		
$ABTU_{Conductive}$	Annual Btu savings - conductive	Btu/yr	Table 1	
$ABTU_{Infiltration}$	Annual Btu savings - Infiltration	Btu/yr	Table 2	
$ACCF_H$	Annual Natural Gas Savings- Heating	Ccf/yr	Table 4	
$AKWH_H$	Annual Electric Savings - Heating	kWh/yr		
$AKWH_{Conductive}$	Annual Electric Savings - Conductive	kWh/yr	Table 3	
$AKWH_{Infiltration}$	Annual Electric Savings - Infiltration	kWh/yr	Table 3	
AOG_H	Annual Oil Savings - Heating	Gal/yr	Table 4	
APG_H	Annual Propane savings - Heating	Gal/yr	Table 4	
EF	Heating System Efficiency	%	75	Estimated
F_{adj}	ASHRAE adjustment factor		0.64	Ref [3]
HDD	Heating Degree Days-CT average	^{0}F-day	5,885	Ref [2]
PD_H	Peak Day savings - Heating	Ccf	Table 6	
PDF_H	Peak Day Factor - Gas Heating		0.00977	Appendix 1
PF_W	Peak Factor - winter	Watts/kWh	0.57	Ref [1]
R_e	Effective R-value - existing	ft^2hr^oF/Btu		
R_i	Effective R-value - installed	ft^2hr^oF/Btu		
WKW_H	Winter Seasonal Demand Savings - Heating	kW	Table 5	

Retrofit Gross Energy Savings - Electric

$ABTU = ABTU_{Conductive} + ABTU_{Inflitration}$

Conductive Savings:

$$ABTU_{Conductive} = A \times \left(\frac{1}{R_e} - \frac{1}{R_i} \right) \times HDD \times 24 \frac{hrs}{day} \times F_{adj}$$

Table 1: Annual Btu Savings - Conductive

Insulation Measure	R_e	R_i	A	$ABTU_{Conductive}$
Attic Hatch	1.69	21.7	5.60	276,065
Attic pull down Stairs	1.69	11.7	11.25	514,816
Whole House Fan	1.32	11.3	4.00	241,922

Table 2: Annual Btu Savings - Infiltration

Insulation Measure	$ABTU_{Inflitration}$
Attic Hatch	154,876
Attic pull down Stairs	533,461
Whole House Fan	243,195

Reminder: *Only include infiltration savings if measure if not included in blower door.*

Annual Electric Savings:

$AKWH_H = AKWH_{Conductive} + AKWH_{Infiltration}$

$$kWh = \frac{Btu}{3{,}412\,Btu / kWh}$$

Table 3: Annual Electric Savings

Insulation Measure	$AKWH_{Conductive}$	$AKWH_{Infiltration}$
Attic Hatch	81	45
Attic pull down Stairs	151	156
Whole House Fan	71	71

Reminder: *Only include infiltration savings if measure if not included in blower door.*

Retrofit Gross Energy Savings - Fossil Fuel

Using savings from Tables 1 and 2 and an Energy Factor (EF) of 75%, the fossil fuel savings are as follows.

Savings by fuel type:

$$ACCF_H = \frac{ABTU_H}{75\% \times 102{,}900\, {}^{Btu}\!/_{Ccf}}$$

$$APG_H = \frac{ABTU_H}{75\% \times 91{,}330\, {}^{Btu}\!/_{Gal}}$$

$$AOG_H = \frac{ABTU_H}{75\% \times 138{,}690\, {}^{Btu}\!/_{Gal}}$$

Table 4: Annual Fossil Fuel Savings

Insulation Measure	$ACCF_H$		AOG_H		APG_H	
	Cond	Infil	Cond	Infil	Cond	Infil
Attic Hatch	3.6	2.0	2.7	1.5	4.0	2.3
Attic pull down Stairs	6.7	6.9	4.9	5.1	7.5	7.8
Whole House Fan	3.1	3.2	2.3	2.3	3.5	3.6

Reminder: *Only include infiltration savings if measure if not included in blower door.*

Retrofit Gross Seasonal Peak Demand Savings - Electric, Winter and Summer

$$WKW_H = AKWH_H \times PF_W / 1000 \, {}^{W}\!/\!_{kW}$$

Table 5: Winter Demand Savings

Insulation Measure	$WKW_{Conductive}$	$WKW_{Infiltration}$
Attic Hatch	0.05	0.03
Attic pull down Stairs	0.09	0.09
Whole House Fan	0.04	0.04

Retrofit Gross Peak Day Savings - Natural Gas

$$PD_H = ACCF_H \times PDF_H$$

Table 6: Peak Day Savings

Insulation Measure	$PD_{Conductive}$	$PD_{Infiltration}$
Attic Hatch	0.03	0.02
Attic pull down Stairs	0.07	0.07
Whole House Fan	0.03	0.03

Changes from Last Version

Minor revision based on energy content modification.

References

[1] Evaluation of WRAP and Helps Programs, KEMA, 2010, Table ES-8, page 1-10.

[2] Degree day data from the National Climatic Data Center, Divisional Data, CT state, Jan 1979 to Dec 2008, 30 day average. http://www7.ncdc.noaa.gov/CDO/CDODivisionalSelect.jsp

[3] ASHRAE degree-day correction.1989 ASHRAE Handbook – Fundamentals, 28.2, Fig 1.

Notes

[1] ASHRAE 1997 Handbook – Fundamentals, page 25.16, was used calculate relative infiltration of these measures to the Infiltration savings from Ref [1].

4.4.13 INFILTRATION REDUCTION (PRESCRIPTIVE)

Description of Measure

Prescriptive infiltration reduction measures not validated by Blower Door testing, including: Electric Outlet Covers, Door Sweep, Door Kit, Caulking and Sealing, Polyethylene Tape, Weatherstrip Door or Window, and Window Repair.

Savings Methodology

Savings from this measure shall only be claimed if a blower door test (5.4.4) is not feasible. Savings estimates based on actual measured infiltration reduction (through blower door testing) are more precise.

Note: *Infiltration reduction measures must be located between conditioned space and unconditioned space (outside) to be eligible for energy savings. Savings may not be claimed for both Door Sweep and Door Kit for weatherization of a single door.*

Savings are calculated by multiplying the savings per unit by the number of units and adding all the different measure types together to get total savings.

No summer demand savings may be claim since cooling energy savings are not quantified.

A weatherization project should be custom only if it clearly exhibits outlier type behavior which would clearly make the existing savings algorithms inappropriate to use and if the existing savings assumptions would produce an error of unacceptable magnitude. In such a case, the energy and demand savings should be well documented.

Inputs

Symbol	Description
n	Number of each air sealing unit installed
length	Total length installed of caulking and sealing, including polyethylene tape, in linear feet.

Nomenclature

Symbol	Description	Units	Values	Comments
$\ldots_{gasket}$	Installation of air sealing gasket on an electric outlet	per gasket	Tables 1, 2	Ref [1], p. 1-11, Table ES 9
$\ldots_{door\ kit}$	Installation of Door Sweep or Door Kit	per sweep	Tables 1, 2	Ref [1], p. 1-11, Table ES 9
$\ldots_{sealing}$	Foot of Caulking, Sealing, or Polyethylene Tape	per foot	Tables 1, 2	Ref [1], p. 1-11, Table ES 9
$\ldots_{wx}$	Window Repaired, Window Weatherstripped, or Door Weatherstripped	per linear foot	Tables 1, 2	Ref [1], p. 1-11, Table ES 9
ACCF	Annual Natural Gas Savings	Ccf/yr		
AOG	Annual Savings for Oil Heat	Gal/yr/unit		
APG	Annual Savings for Propane Heat	Gal/yr/unit		
EF	Fossil Fuel System Efficiency including distribution loss	unitless	0.75	
PF_S	Summer Peak Factor	W/kWh	0.017	Ref [1]
PF_W	Winter Peak Factor	W/kWh	0.570	Ref [1]
WKW	Winter Seasonal Peak Electric Demand Savings	kW		

Retrofit Gross Energy Savings - Electric

Table 1: Electric Savings for Infiltration Reduction Measures

Savings	**Units**	**Annual Savings for Electric Resistance Heating (kWh)**	**Annual Savings for Heat Pump (kWh)**
$AKWH_{gasket}$	kWh per gasket	9	4.5
$AKWH_{door\ kit}$	kWh per sweep	173	86.5
$AKWH_{sealing}$	kWh per linear ft	9.9	4.95
$AKWH_{wx}$	kWh per linear ft	11.5	5.75

Retrofit Gross Energy Savings - Fossil Fuel

$$Annual\ Btu\ Savings = \frac{AKWH \times 3412\ {}^{Btu}\!/_{kWh}}{75\%}$$

Table 2: Fossil Fuel Savings for Infiltration Reduction Measures

Measure	**Units**	**ACCF ($^{Ccf}/_{unit\bullet yr}$)**	**AOG ($^{Gal}/_{unit\bullet yr}$)**	**APG ($^{Gal}/_{unit\bullet yr}$)**
Gasket	fuel per gasket	0.41	0.29	0.45
Door Kit	fuel per sweep	7.87	5.62	8.59
Sealing	fuel per linear foot	0.451	0.322	0.492
WX	fuel per linear foot	0.524	0.374	0.571

Retrofit Gross Seasonal Peak Demand Savings - Electric, Winter and Summer

$$WKW = AKWH \times PF_W / 1000\ {}^{W}\!/_{kW}$$

Non Energy Benefits

Increased personal comfort and decreased draftiness.

Changes from Last Version

Caulking and sealing converted from per 10 linear feet to per foot.

References

[1] KEMA, Evaluation of the Weatherization Residential Assistance Partnership and Helps Programs (WRAP/Helps), September 10, 2010

4.4.14 WALL INSULATION

Description of Measure

Batt or blown-in insulation installed in a wall located between conditioned area and ambient (attic or outside) space.

Savings Methodology

Energy savings are calculated using parallel flow method based on a typical 2x4 wall. Factors 7/12 and 3 are used to adjust for typical wall structure and framing. The savings are calculated using a degree day analysis and the difference in the pre and post R-values.

Note: *The savings presented here do not apply to walls between conditioned spaces and fully enclosed unconditioned spaces, such as porches or hallways.*

Inputs

Symbol	Description	Units
R_{pre}	Existing Insulation R-value	ft^2hr^oF/Btu
R_{post}	Insulation R-value after upgrade	ft^2hr^oF/Btu
A	Total area of wall insulation	ft^2

Nomenclature

Symbol	Description	Units	Values	Comments
1 kWh	Unit conversion	kWh	3,412 Btu	Unit conversion
A	Total gross area of wall insulation	ft^2		
$ACCF_H$	Annual Natural Gas Savings	Ccf/yr		
AKWH	Annual Electric Energy Savings	kWh/yr		
$AKWH_{H,HP}$	Annual Electric Savings due to Heat Pump heating	kWh/yr		
$AKWH_{H,R}$	Annual Electric Savings due to electric resistance heating	kWh/yr		
AOG_H	Annual Savings for Oil Heat	Gal/yr/unit		
APG_H	Annual Savings for Propane Heat	Gal/yr/unit		
CF	Summer Seasonal Peak Coincidence Factor		0.59	Appendix 1
EER_B	Energy Efficiency Ratio, Baseline	Btu/Watt-hr	11	
EF	Heating system efficiency	%	75	Estimated
F_{adj}	ASHRAE adjustment factor		0.64	Ref [1]
HDD	Heating Degree Days, CT state average	^0F-day	5,885	Ref [2]
PDF_H	Peak Day Factor - Heating		0.00977	Appendix 1
PD_H	Peak Day savings - Heating			
$R_{existing}$	Effective R-value before upgrade	ft^2hr^oF/Btu		
R_{new}	Effective R-value after upgrade	ft^2hr^oF/Btu		
R_{pre}	Existing Insulation R-value	ft^2hr^oF/Btu		
R_{post}	Insulation R-value after upgrade	ft^2hr^oF/Btu		
$SEER_B$	Seasonal Energy Efficiency Ratio, Baseline	Btu/Watt-hr	13	
SKW	Summer Peak Demand Savings	kW		
WKW	Winter Peak Demand Savings	kW		

Symbol	Description	Units	Values	Comments
WPF	Winter Peak Factor	W/ kWh	0.57	Ref [4]
ΔT_{Bin}	The sum of the temperature BIN hours (based on Hartford) times delta between outside air for each BIN and average indoor temperature (T_i = 76.5 ºF)		3,888	Ref [3]a
ΔT_{summer}	Temperature Difference (peak $T_{outside}$ = 97 ºF, T_{inside} = 76.5 ºF)	ºF	20.5 ºF	Ref [3] a and b

Retrofit Gross Energy Savings - Electric

Effective R-value,

$$R_{existing} = \left(\frac{7}{12} \times R_{pre} \right) + 3$$

$$R_{new} = \left(\frac{7}{12} \times R_{post} \right) + 3$$

Heating Savings,

$$ABTU_H = \left(\frac{1}{R_{existing}} - \frac{1}{R_{new}} \right) \times HDD \times 24 \times F_{Adj} \times A$$

For Electric Resistance Heating,

$$AKWH_{H,R} = \frac{ABTU_H}{3{,}412}$$

For Heat Pump,

$$AKWH_{H,HP} = \frac{AKWH_{H,R}}{2}$$

Cooling Savings,

$$AKWH_C = \left(\frac{1}{R_{existing}} - \frac{1}{R_{new}} \right) \times \Delta T_{Bin} \times A \times \frac{1}{SEER_B \times 1{,}000}$$

Reminder: *Cooling Savings will only be calculated for homes with central air conditioning.*

Retrofit Gross Energy Savings - Fossil Fuel

$$ACCF_H = \frac{ABTU_H}{75\% \times 102{,}900}$$

$$APG_H = \frac{ABTU_H}{75\% \times 91{,}330}$$

$$AOG_H = \frac{ABTU_H}{75\% \times 138{,}690}$$

Reminder: *System Efficiency is 75%*

Example - Retrofit Gross Energy Savings

Insulation in a house is upgraded from R-6 to a total of R-13. The total square feet insulation added is 100. The home is heated by electric resistance heating system and has a central AC. What are the annual electric energy savings?

$$R_{existing} = \left(\frac{7}{12} \times R_{pre}\right) + 3$$
$$R_{existing} = \left(\frac{7}{12} \times 6\right) + 3$$
$$R_{existing} = 6.5$$

$$R_{new} = \left(\frac{7}{12} \times R_{post}\right) + 3$$
$$R_{new} = \left(\frac{7}{12} \times 13\right) + 3$$
$$R_{new} = 10.6$$

Using the equation for heating savings,

$$ABTU_H = \left(\frac{1}{R_{existing}} - \frac{1}{R_{new}}\right) \times HDD \times 24 \times F_{Adj} \times A$$
$$ABTU_H = \left(\frac{1}{6.5} - \frac{1}{10.6}\right) \times 5{,}885 \times 24 \times 0.64 \times 100$$
$$ABTU_H = 537{,}901\, Btu$$

Heating savings for electric resistance system,

$$AKWH_{H,R} = \frac{ABTU_H}{3{,}412}$$
$$AKWH_{H,R} = \frac{537{,}901}{3{,}412} = 158\, kWh$$

Using the equation for cooling savings,

$$AKWH_C = \left(\frac{1}{R_{existing}} - \frac{1}{R_{new}}\right) \times \Delta THR \times A \times \frac{1}{SEER_B \times 1{,}000}$$

$$AKWH_C = \left(\frac{1}{6.5} - \frac{1}{10.6}\right) \times 3{,}888 \times 100 \times \frac{1}{13 \times 1{,}000}$$
$$AKWH_C = 1.8 kWh$$

Retrofit Gross Seasonal Peak Demand Savings - Electric, Winter and Summer

For homes with electric resistance heat,

$$WKW = \frac{AKWH_H(\text{Electric\_Resistance})}{1{,}000} \times WPF$$

$$WKW = \frac{AKWH_H(\text{Electric\_Resistance})}{1{,}000} \times 0.57$$

For homes with heat pump,

$$WKW = \frac{AKWH_H}{1,000} \times 0.57$$

$$SKW = CF \times \left(\frac{1}{R_{Existing}} - \frac{1}{R_{New}} \right) \times \Delta T_{Summer} \times A \times \frac{1}{EER_B \times 1,000}$$

<u>Retrofit Gross Peak Day Savings - Natural Gas</u>

$PDF_H = 0.00977$

$$PD_H = ACCF_H \times PDF_H$$

<u>Example - Retrofit Gross Peak Demand Savings</u>

Insulation in a house is upgraded from R-6 to a total of R-13. The total square feet insulation added is 100. The home is heated by electric resistance heating system and has a central AC. What are the demand savings?

Using the equation,

$$WKW = \frac{AKWH_H(\text{Electric\_Resistance})}{1,000} \times 0.57$$

From the previous example, $AKWH_H$ = 158 kWh, therefore,

$$WKW = \frac{158}{1,000} \times 0.57$$

$$WKW = 0.090kW$$

Using the equation,

$$SKW = CF \times \left(\frac{1}{R_{Existing}} - \frac{1}{R_{New}} \right) \times \Delta T_{Summer} \times A \times \frac{1}{EER_B \times 1,000}$$

$$SKW = 0.59 \times \left(\frac{1}{6.5} - \frac{1}{10.6} \right) \times 20.5 \times 100 \times \frac{1}{11 \times 1,000}$$

$$SKW = 0.0065$$

<u>References</u>

[1] ASHRAE degree-day correction.1989 ASHRAE Handbook – Fundamentals, 28.2, Fig 1.

[2] Degree day data from the National Climatic Data Center, Divisional Data, CT state, Jan 1979 to Dec 2008, 30 day average. http://www7.ncdc.noaa.gov/CDO/CDODivisionalSelect.jsp

[3] Residential Central AC Regional Evaluation, ADM Associates, Inc., November 2009, a) Table B-4 (Hartford) and page B-9 and b) Figures 4-1&2 (Hartford) and page 4-15.

[4] Evaluation of WRAP and Helps Programs, KEMA, 2010, Table ES-8, page 1-10.

4.4.15 CEILING INSULATION

Description of Measure

Installation of batt or loose fill insulation located between conditioned area and ambient (attic or outside) space.

Savings Methodology

Energy savings are calculated using parallel flow method and typical ceiling structure. The savings are calculated using a degree day analysis and the difference in the pre and post R-values. The conductive savings are calculated using a degree day analysis. 0.5, 3 and 2 are factors used to adjust for typical wall structure/framing.

Note: *The savings presented here do not apply to ceilings between conditioned space and fully enclosed unconditioned spaces, such as basement ceilings. It is assumed that attics are properly ventilated to the outside.*

Inputs

Symbol	Description	Units
R_{pre}	Existing Insulation R-value	ft^2hr^oF/Btu
R_{post}	Insulation R-value after upgrade	ft^2hr^oF/Btu
A	Total gross area of ceiling insulation	ft^2

Nomenclature

Symbol	Description	Units	Values	Comments
1 kWh	Unit conversion	kWh	3,412 Btu	Unit conversion
A	Total gross area of ceiling insulation	ft^2		
AKWH	Annual Electric Energy Savings	kWh		
$ACCF_H$	Annual Natural Gas Savings	Ccf/yr		
AKWH	Annual Electric Energy Savings	kWh/yr		
$AKWH_{H,HP}$	Annual Electric Savings due to Heat Pump heating	kWh/yr		
$AKWH_{H,R}$	Annual Electric Savings due to electric resistance heating	kWh/yr		
AOG_H	Annual Savings for Oil Heat	Gal/yr/unit		
APG_H	Annual Savings for Propane Heat	Gal/yr/unit		
CF	Summer Seasonal Peak Coincidence Factor		0.59	Appendix 1
EER_B	Energy Efficiency Ratio, Baseline	Btu/Watt-hr	11	
EF	Heating system efficiency	%	75	Estimated
F_{adj}	ASHRAE adjustment factor		0.64	Ref [1]
HDD	Heating Degree Days, CT state average	^0F-day	5,885	Ref [2]
PD_H	Peak Day savings - Heating			
PDF_H	Peak Day Factor - Heating		0.00977	Appendix 1
$R_{existing}$	Effective R-value before upgrade	ft^2hr^oF/Btu	Calculated	
R_{new}	Effective R-value after upgrade	ft^2hr^oF/Btu	Calculated	
R_{pre}	Existing Insulation R-value	ft^2hr^oF/Btu	Input	
R_{post}	Insulation R-value after upgrade	ft^2hr^oF/Btu	Input	
$SEER_B$	Seasonal Energy Efficiency Ratio, Baseline	Btu/Watt-hr	13	
SKW	Summer Peak Demand Savings	kW		
WKW	Winter Peak Demand Savings	kW		
WPF	Winter Peak Factor	W/ kWh	0.57	Ref [4]

Symbol	Description	Units	Values	Comments
ΔT_{Bin}	Is the sum of the temperature BIN hours (based on Hartford) times delta between outside summer air for each BIN and average indoor temperature (T_i = 76.5 ºF)		3,888	Ref [3]a
ΔT_{summer}	Temperature Difference (peak $T_{outside}$ = 97 ºF, T_{inside} = 76.5 ºF)	ºF	20.5 ºF	Ref [3] a and b
$\ldots_{H,R}$	Electric Resistance Heating			
$\ldots_{H,HP}$	Heat Pump Heating			

<u>Retrofit Gross Energy Savings - Electric</u>

Table 1: Effective R-values

If	Use
R_{pre} <10	$R_{existing} = (0.5 \times R_{pre}) + 3$
If R_{pre} >=10	$R_{existing} = R_{pre} - 2$
R_{post} <10	$R_{new} = (0.5 \times R_{post}) + 3$
R_{post} >=10	$R_{new} = R_{post} - 2$

$$ABTU_H = \left(\frac{1}{R_{existing}} - \frac{1}{R_{new}} \right) \times HDD \times 24 \times F_{Adj} \times A$$

For Electric Resistance Heating Savings,

$$AKWH_{H,R} = \frac{ABTU_H}{3{,}412 \, {}^{Btu}\!/_{kWh}}$$

For Heat Pump,

$$AKWH_{H,HP} = \frac{AKWH_{H,R}}{2}$$

Cooling Savings,

$$AKWH_C = \left(\frac{1}{R_{existing}} - \frac{1}{R_{new}} \right) \times \Delta T_{Bin} \times A \times \frac{1}{SEER_B \times 1{,}000}$$

Reminder: *Cooling Savings will only be calculated for homes with central air conditioning.*

<u>Retrofit Gross Energy Savings - Fossil Fuel</u>

$$ACCF_H = \frac{ABTU_H}{75\% \times 102{,}900 \, {}^{Btu}\!/_{Ccf}}$$

$$APG_H = \frac{ABTU_H}{75\% \times 91{,}330 \, {}^{Btu}\!/_{Gal}}$$

$$AOG_H = \frac{ABTU_H}{75\% \times 138{,}690 \, {}^{Btu}\!/_{Gal}}$$

Reminder: *EF = 75%*

Example - Retrofit Gross Energy Savings

Ceiling insulation in a house is upgraded from R-9 to a total of R-60. The total square feet insulation added is 1000. The home is heated by electric resistance heating system and has a central AC. What are the annual electric energy savings?

Since R_{pre} <10;

$$R_{existing} = (0.5 \times R_{pre}) + 3$$

$$R_{existing} = (0.5 \times 9) + 3 = 7.5$$

Since R_{post} >=10;

$$R_{new} = R_{post} - 2$$

$$R_{new} = 60 - 2 = 58$$

$$ABTU_H = \left(\frac{1}{R_{existing}} - \frac{1}{R_{new}}\right) \times HDD \times 24 \times F_{Adj} \times A$$

$$ABTU_H = \left(\frac{1}{7.5} - \frac{1}{58}\right) \times 5{,}885 \times 24 \times 0.64 \times 1000 = 10{,}493{,}969\ Btu$$

$$AKWH_{H,R} = \frac{ABTU_H}{3{,}412\ ^{Btu}\!/_{kWh}}$$

$$AKWH_{H,R} = \frac{10{,}493{,}969\ Btu}{3{,}412\ ^{Btu}\!/_{kWh}} = 3075\ kWh$$

$$AKWH_C = \left(\frac{1}{R_{existing}} - \frac{1}{R_{new}}\right) \times \Delta THR \times A \times \frac{1}{SEER_B \times 1{,}000}$$

$$AKWH_C = \left(\frac{1}{7.5} - \frac{1}{58}\right) \times 3{,}888 \times 1000 \times \frac{1}{13 \times 1{,}000} = 35\ kWh$$

Retrofit Gross Seasonal Peak Demand Savings - Electric, Winter and Summer

For homes with electric resistance heat,

$$WKW = \frac{AKWH_{H,R}}{1{,}000} \times WPF$$

$$WKW = \frac{AKWH_{H,R}}{1{,}000} \times 0.57$$

For homes with heat pump,

$$WKW = \frac{AKWH_{H,HP}}{1{,}000} \times 0.57$$

For Homes with Central Air or heat pump providing cooling,

$$SKW = CF \times \left(\frac{1}{R_{Existing}} - \frac{1}{R_{New}}\right) \times \Delta T_{Summer} \times A \times \frac{1}{EER_B \times 1{,}000}$$

$$SKW = CF \times \left(\frac{1}{R_{Existing}} - \frac{1}{R_{New}} \right) \times 20.5 \times A \times \frac{1}{11 \times 1{,}000}$$

Retrofit Gross Peak Day Savings - Natural Gas

$$PD_H = ACCF_H \times PDF_H$$

Example - Retrofit Gross Peak Demand Savings

Ceiling insulation in a house is upgraded from R-9 to a total of R-60. The total square feet insulation added is 100. The home is heated by electric resistance heating system and has a central AC. What are the demand savings?

Using the equation for winter demand savings,

$$WKW = \frac{AKWH_{H,R}}{1{,}000} \times 0.57$$

From previous example, $AKWH_H$ = 308 kWh. Therefore,

$$WKW = \frac{3075}{1{,}000} \times 0.57 = 1.75\ kW$$

Using the equation for summer demand savings,

$$SKW = CF \times \left(\frac{1}{R_{Existing}} - \frac{1}{R_{New}} \right) \times \Delta T_{Summer} \times A \times \frac{1}{EER_B \times 1{,}000}$$

$$SKW = 0.59 \times \left(\frac{1}{7.5} - \frac{1}{58} \right) \times 20.5 \times 1000 \times \frac{1}{11 \times 1{,}000}$$

$$SKW = 0.127$$

References

[1] ASHRAE degree-day correction.1989 ASHRAE Handbook – Fundamentals, 28.2, Fig 1.

[2] Degree day data from the National Climatic Data Center, Divisional Data, CT state, Jan 1979 to Dec 2008, 30 day average. http://www7.ncdc.noaa.gov/CDO/CDODivisionalSelect.jsp

[3] Residential Central AC Regional Evaluation, ADM Associates, Inc., November 2009, a) Table B-4 (Hartford) and page B-9 and b) Figures 4-1&2 (Hartford) and page 4-15.

[4] Evaluation of WRAP and Helps Programs, KEMA, 2010, Table ES-8, page 1-10.

4.5 WATER HEATING

4.5.1 WATER HEATER THERMOSTAT SETTING

Description of Measure

Lowering the temperature set point of a domestic hot water heater.

Savings Methodology

Please see the tables below. 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 an application such as a shower or faucet where the user demands a certain water temperature and will increase the hot water flow to make up for the lower temperature. Additionally, this measure may increase a dishwasher's electricity consumption due to the lower hot water supply temperature; therefore negative savings are claimed when the home also has a dishwasher.

Inputs

Symbol	**Description**
Dishwasher presence	Whether or not home has dishwasher
WH fuel	Type of fuel used in hot water heater.

Nomenclature

Symbol	**Description**	**Units**	**Values**	**Comments**
$ACCF_W$	Annual Gas Savings	Ccf/yr	Calculated	
$AKWH_D$	Annual Electric Energy Savings – Dishwasher	kWh/ yr	87 kWh	Deemed
$AKWH_W$	Annual Electric Energy Savings – Water Heating	kWh/ yr	87 kWh	Deemed
AOG_W	Annual Oil Savings	Gal/yr	Calculated	
APG_W	Annual Propane Savings	Gal/yr	Calculated	
EF_E	Energy Factor of Electric Water Heater		0.95	Ref [4]
EF_F	Energy Factor of Fossil Fuel Water Heater		0.62	Ref [4]

Retrofit Gross Energy Savings - Electric

Table 1: Hot Water Consumption of Clothes Washer

Number of cycles per year	392.0
Water use per cycle (Note [1])	26.16
Percent Hot Water (Ref [1])	29%
Annual clothes washer hot water consumption (Gal)	**2,974.2**

Table 2: Hot Water Consumption of Dishwasher

Number of cycles per year (Ref [4])	215.0
Water use per cycle (Note [1])	4.36
Percent Hot Water (Ref [1])	100%
Annual dishwasher hot water consumption (Gal)	**937.4**

Table 3: Savings from Lowering Electric Hot Water Heater Temperature from 140°F to 125 °F

Energy Savings = Delta Temp x 8.3 X water savings / 10^6	
Temp of water into house (Deg F)	55
Temp of hot water from tank (Deg F)	140
Temp of hot water from tank after Reset (Deg F)	125
Delta Temp (Deg F)	15
Pounds per gallon	8.3
Btu savings per gallon	124.5
Mbtu savings per year (clothes washer)	0.37
Mbtu savings per year (dishwasher)	-0.12
Total Mbtu saved per year	0.25
Water Heater Electricity Savings = Mbtu savings x 293 / water heater EF	
kWh/Mbtu	293
Elect saved per year from clothes washing (kWh)	108
Electric Water Heater Energy Factor (Ref [3])	0.95
Total electricity saved per year at water heater for electric heat without dishwasher, $AKWH_W$ (kWh)	**114.2**
When dishwasher is present, Electricity Increase Due to Dishwasher Preheater, $AKWH_D$ (kWh)	-34.2
Total electricity saved per year for electric DHW with dishwasher, AKWH (kWh)	**80.0**

Retrofit Gross Energy Savings - Fossil Fuel

Table 4: Savings for Homes with Gas Water Heaters

Natural gas savings = savings in BTU / EF_F/ 102,900 Btu/Ccf	
Gas saved per year at the water heater (MBTU)	0.37
Gas Water Heater Energy Factor (Ref [3])	0.62
Total gas saved per year at water heater, $ACCF_W$ (Ccf)	**5.80**
When dishwasher is present, **Electricity Savings Due to Dishwasher Preheater, $AKWH_D$ (kWh)**	**-34.2**

Table 5: Savings for Homes with Oil Hot Water Heaters

Number 2 oil saved = savings in BTU / water heater EF / 138690	
No 2 oil BTU per gallon	138,690
Oil saved at the water heater (Gal)	2.67
Oil Fired Water Heater Energy Factor (Ref [3])	0.62
Total oil saved per year at water heater, AOG_W (Gal)	**4.31**
When dishwasher is present, **Electricity Savings Due to Dishwasher Preheater, $AKWH_D$ (kWh)**	**-34.2**

Table 6: Savings for Homes with Propane Water Heaters

Number 2 propane saved = savings in BTU / water heater EF / 91330	
Propane BTU per gallon	91,330
Propane saved at the water heater (Gal)	4.05
Propane Fired Water Heater Energy Factor (Ref [3])	0.62
Total Propane saved per year at water heater, APG_W (Gal)	**6.54**
When dishwasher is present, **Electricity Savings Due to Dishwasher Preheater, $AKWH_D$ (kWh)**	**-34.2**

Changes from Last Version

Updated Energy Factors and References.

References

[1] Table 2, LBNL-35475, "The Effect of Efficiency Standards on Water Usage and Water Heating Energy Use in the U.S.: A Detailed End-use Treatment", May 1994

[2] US EPA Energy Star Energy Savings Calculator, 2008.

[3] Federal Register Part III, DOE Energy Conservation Program: Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, Pool Heater; Final Rule, Table I.2. April 16, 2010.

[4] DOE Federal Test Procedure 10 CFR 430, Appendix C, as of June 20, 2011.

Notes

[1] Weighted average of ENERGY STAR and conventional water consumption from (Ref [2]).

4.5.2 WATER HEATER WRAP

Description of Measure

Wrapping electric hot water heaters with fiberglass insulation with an insulating blanket to reduce standby heat loss through the skin. Not necessary for newer units which are already insulated with foam.

Savings Methodology

The (deemed) savings for this measure are calculated based on the water heating load calculated in measure 4.5.7 and the difference of efficiency between an existing electric resistance water heater without and with an insulating blanket. Oak Ridge National Laboratory performed a study to determine the increase in water heater energy factor (EF) due to the additional insulation (Ref [1]). In this study, the home studied in the Northeast had a gas fired water heater, and was not applicable, since only electric water heaters are wrapped in this program. The southern home in the study did have an electric water heater. The difference in the actual heating and storage of hot water may be a little different in the South versus the Northeast, but the southern home can still be used as a good approximation (Note [1]).

The Oak Ridge study (Ref [1]) predicted that wrapping a 40 gallon water heater would result in an increase in the energy factor (EF) from 0.86 to 0.88. The calculations below show how a reasonable deemed savings estimate of 87 kWh has been derived.

No demand savings are claimed for this measure since there is insufficient peak coincident data.

Inputs

Symbol	Description	Comments
	Water Heater Fuel	This should only be applied to electric water heaters
EF	Existing EF	Not required for savings calculation

Nomenclature

Symbol	Description	Units	Values	Comments
$ABTU_W$	Annual BTU savings – water heating	Btu		
ADHW	Annual domestic hot water load	Btu		
$AKWH_W$	Annual Electric Energy Savings – Water Heating	kWh/ yr	87 kWh	Deemed
EF_B	Energy Factor - Baseline		0.86	Ref [1]
EF_I	Energy factor – Insulated Unit		0.88	Ref [1]
GPY	Annual domestic hot water usage in Gallons	Gal/yr	19,839	Measure 4.5.7
T_{dhw}	Domestic hot water heater set point	ºF	125	Measure 4.5.1
T_{aiw}	Average annual incoming water temperature	ºF	57	Note [2]

Retrofit Gross Energy Savings - Electric

$$ADHW = GPY \times 8.3 \, {}^{lbs}\!/\!_{gal} \times \left(T_{dhw} - T_{aiw}\right)$$

$$ADHW = 19{,}839 \times 8.3 \, {}^{lbs}\!/\!_{gal} \times \left(125 - 57\right)$$

$$ADHW = 11{,}197{,}132 \, Btu$$

$$ABTU_W = ADHW \times \left(\frac{1}{EF_B} - \frac{1}{EF_I} \right)$$

$$ABTU_W = 11{,}197{,}132 \times \left(\frac{1}{0.86} - \frac{1}{0.88} \right) = 295{,}907\ Btu$$

$$AKWH_W = \frac{ABTU_W}{3412\ {}^{Btu}\!/\!_{kWh}} = \frac{295{,}907\ Btu}{3412\ {}^{Btu}\!/\!_{kWh}}$$

$$AKWH_W = 87\ kWh$$

Changes from Last Version

Water load updated based on calculation in Measure 4.5.7.

References

[1] Oak Ridge National Laboratory. "Meeting the Challenge: The Prospect of Achieving 30 Percent Energy Savings Through the Weatherization Assistance Program," May 2002.

[2] Tool for Generating Realistic Residential Hot Water Event Schedules, Preprint, NREL, August 2010.

Notes

[1] The temperature of the water entering the heater may be warmer in the South versus the Northeast, especially in the winter, but this would not affect standby losses which the wrapping seeks to reduce. The other difference is that the heat loss from the tank to the environment may be greater in the Northeast than the South because of the more mild Southern winters and the warmer southern summers. However, the Southern house can be used as a good conservative approximation to a house in the Northeast.

[2] These values were developed using the Tool in Ref [2] for Hartford area weather data and a three bedroom house.

4.5.3 SHOWERHEAD

Description of Measure

Installation of low flow showerheads meeting the EPA WaterSense specification (2.0 gpm) (Ref [1]) to replace Federal Standard (2.5 gpm) or higher flow showerheads.

Savings Methodology

Savings shall be claimed based on the type of fuel used for water heating. Water savings is based on the difference between the Federal Standard (2.5 gpm) versus WaterSense (2.0 gpm).

No electric demand savings are claimed for this measure because there is insufficient peak coincident data.

Inputs

Symbol	Description
WH Fuel	Water Heater Fuel Type
n_i	Number of low flow showerheads installed
$gpm_{installed}$	Flow rate of installed showerhead (not required for savings)

Nomenclature

Symbol	Description	Units	Values	Comments
AKWH	Annual Electric savings for homes with Electric HW	kWh/yr	Calculated	
ACCF	Annual Gas Savings	Ccf/yr	Calculated	
AOG	Annual Oil Savings	Gal/yr	Calculated	
APG	Annual Propane Savings	Gal/yr	Calculated	
d_e	Median duration per event	minutes	8.3	Ref [4]
d_W	Density of water	lb/ Gal	8.31	
EF_E	Energy Factor of Electric Water Heater		0.95	Ref [3]
EF_F	Energy Factor of Fossil Fuel Water Heater		0.62	Ref [3]
gpm	Gallons per minute flow rate	gal/min	Fed Std: 2.5 Water Sense: 2.0	Ref [1]
n_a	Average total number showerheads per household		2.3	Ref [4], p185-186 Table 66
n_e	Average number of shower events per day per household		1.97	Ref [4], p144 Table 41
n_i	number of low flow showerheads installed		As found	
r_g	Ratio to adjust usage for cooler climate		0.9344	Note [1], Ref [4]
S_W	Annual Water Savings per showerhead	gal/yr	Calculated	
T_{shower}	Temperature of water from shower	°F	105 °F	
T_{supply}	Temperature of water into house	°F	55 °F	
PDF_{WH}	Peak Day Factor, Water Heating		0.00321	Appendix 1
PD_{WH}	Peak Day savings, Water Heating			

Retrofit Gross Energy Savings - Electric

$$S_W = n_e \times d_e \times 365\,{}^{days}\!/_{yr} \times r_g \times \left(gpm_{federal\ std} - gpm_{WaterSense}\right)/n_a$$
$$S_W = 1.97\ events \times 8.3\,{}^{\min}\!/_{event} \times 365\,{}^{days}\!/_{yr} \times 0.9344 \times \left(2.5\ gpm - 2.0\ gpm\right)/2.3$$
$$S_W = 829.5\,{}^{Gal}\!/_{fixture \bullet yr}$$

$$MMBtu\ Savings = \sqrt{n_i} \times \left(T_{shower} - T_{Supply}\right) \times d_W \times SH_W \times S_W \,/10^6\,{}^{Btu}\!/_{MMBtu}$$ (See Note [2])
$$MMBtu\ Savings = \sqrt{n_i} \times \left(105°F - 55°F\right) \times 8.31\,{}^{lb}\!/_{Gal} \times 829.5\,{}^{Gal}\!/_{fixture \bullet yr}\,/10^6\,{}^{Btu}\!/_{MMBtu}$$
$$MMBtu\ Savings = 0.727\,{}^{MMBtu}\!/_{fixture} \times \sqrt{n_i}$$

$$AKWH = \frac{MMBtu\ Savings}{.003412\,{}^{MMBtu}\!/_{kWh} \times EF_E} = \frac{0.727 \times \sqrt{n_i}}{0.003412 \times 0.95}$$
$$AKWH = 224.4\,{}^{kWh}\!/_{faucet} \times \sqrt{n_i}$$

Retrofit Gross Energy Savings - Fossil Fuel

$$ACCF = \frac{MMBtu\ Savings}{.102900\,{}^{MMBtu}\!/_{Ccf} \times EF_F} = \frac{0.727 \times \sqrt{n_i}}{0.102900 \times 0.62}$$
$$ACCF = 11.4 \times \sqrt{n_i}$$

$$AOG = \frac{MMBtu\ Savings}{.138690\,{}^{MMBtu}\!/_{Gal\ oil} \times EF_F} = \frac{0.727 \times \sqrt{n_i}}{0.138690 \times 0.62}$$
$$AOG = 8.46 \times \sqrt{n_i}$$

$$APG = \frac{MMBtu\ Savings}{0.09133\,{}^{MMBtu}\!/_{Gal\ propane} \times EF_F} = \frac{0.727 \times \sqrt{n_i}}{0.09133 \times 0.62}$$
$$APG = 12.8 \times \sqrt{n_i}$$

Example - Retrofit Gross Energy Savings

Two showerheads are replaced in bathrooms of a home which uses electric hot water heating. What are the savings?

$$AKWH = 224.4\,{}^{kWh}\!/_{faucet} \times \sqrt{2} = 317\,{}^{kWh}\!/_{yr}$$
$$Annual\ Gal\ Water\ Savings = 829.5\,{}^{Gal}\!/_{yr} \times \sqrt{2} = 1173\,{}^{Gal}\!/_{yr}$$

Two showerheads are replaced in bathrooms of a home which uses gas hot water heating. What are the savings?

$$Annual\ Gas\ Ccf = 11.4 \times \sqrt{2} = 16\,{}^{Ccf}\!/_{yr}$$
$$Annual\ Gal\ Water\ Savings = 829.5\,{}^{Gal}\!/_{yr} \times \sqrt{2} = 1173\,{}^{Gal}\!/_{yr}$$

Retrofit Gross Peak Day Savings - Natural Gas

$$PD_{WH} = ACCF \times PDF_{WH}$$

Non Energy Benefits

$$Annual\ Gal\ Water\ Savings = S_W \times \sqrt{n} = 829.5\ {}^{Gal}\!/_{yr} \times \sqrt{n_i}$$

Changes from Last Version

Simplified so low income and non-low income use the same method. Added 2011 Aquacraft study (Ref [4]) for several water usage assumptions. Updated with common conversion factors. Included Gas Peak Day savings.

References

[1] EPA WaterSense® Specification for Showerheads, Version 1.0, effective February 9, 2010. Accessed on July 21, 2010.

[2] KEMA. Evaluation of the Weatherization Residential Assistance Partnership (WRAP) and Helps Programs, Final Report, September 10, 2010.

[3] Federal Register Part III, DOE Energy Conservation Program: Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, Pool Heater; Final Rule, Table I.2. April 16, 2010.

[4] Aquacraft Water Engineering & Management. California Single Family Water Use Efficiency Study. June 1, 2011.

Notes

[1] Ref [4] (Table 35, page 128) showed water usage for northern sites versus southern sites to have the ratio 171/183 = 0.9344.

[2] Ref [2] recommends this method of reducing savings for additional water fixtures by multiplying by the square root of the number installed.

4.5.4 FAUCET AERATOR

Description of Measure

Installation of aerators meeting the EPA WaterSense specification (Ref [1]) to replace Federal Standard (2.2 gpm) or higher flow lavatory faucet aerators.

Savings Methodology

Savings shall be claimed based on the type of fuel used for water heating. Water savings is based on the difference between the Federal Standard (2.2 gpm) versus WaterSense (1.5 gpm).

The savings presented here are not applicable for installations where the flow rate does not reduce the total hot water used (i.e. kitchen sinks, laundry rooms, or tubs).

Note: *No demand savings are claimed for this measure since there is insufficient peak coincident data.*

Inputs

Symbol	Description
WH Fuel	Water Heater Fuel Type
n_i	Number of low flow faucet aerators installed
$gpm_{installed}$	Flow rate of installed faucet, (not required for savings)

Nomenclature

Symbol	Description	Units	Values	Comments
AKWH	Annual Electric savings for homes with Electric HW	kWh/yr	Calculated	
ACCF	Annual Gas Savings	Ccf/yr	Calculated	
AOG	Annual Oil Savings	Gal/yr	Calculated	
APG	Annual Propane Savings	Gal/yr	Calculated	
d_e	Average duration per event	minutes	0.6167	Ref [4]
d_W	Density of water	lb/ Gal	8.31	
EF_E	Energy Factor of Electric Water Heater		0.95	Ref [3]
EF_F	Energy Factor of Fossil Fuel Water Heater		0.62	Ref [3]
gpm	Gallons per minute flow rate	gal/min	Fed Std: 2.2 Water Sense: 1.5	Ref [1]
n_a	Estimated average total number faucets (all types) per household		5.1	Note [3], Ref [4]
n_e	Median number of faucet events per day per household		42.9	Ref [4]
n_i	number of aerators installed		As found	
r_g	Ratio to adjust usage for cooler climate		0.9344	Note [1], Ref [4]
S_W	Annual Water Savings per faucet	gal/yr	Calculated	
T_{faucet}	Temperature of water from faucet	°F	80 °F	
T_{supply}	Temperature of water into house	°F	55 °F	
PDF_{WH}	Peak Day Factor, Water Heating		0.00321	Appendix 1
PD_{WH}	Peak Day savings, Water Heating			

Retrofit Gross Energy Savings - Electric

$$S_W = n_e \times d_e \times 365 \, {}^{days}\!/_{yr} \times r_g \times \left(gpm_{federal\ std} - gpm_{WaterSense}\right)/n_a$$
$$S_W = 42.9 \times 0.6167 \times 365 \, {}^{days}\!/_{yr} \times 0.9344 \times \left(2.2\ gpm - 1.5\ gpm\right)/5.1$$
$$S_W = 1{,}238 \, {}^{Gal}\!/_{faucet \bullet yr}$$

$$MMBtu\ Savings = \sqrt{n} \times \left(T_{Faucet} - T_{Supply}\right) \times d_W \times SH_W \times S_W / 10^6 \, {}^{Btu}\!/_{MMBtu}$$ **(See Note [2])**
$$MMBtu\ Savings = \sqrt{n} \times \left(80°F - 55°F\right) \times 8.31 \, {}^{lb}\!/_{Gal} \times 1{,}238 \, {}^{Gal}\!/_{faucet \bullet yr} / 10^6 \, {}^{Btu}\!/_{MMBtu}$$
$$MMBtu\ Savings = 0.257 \, {}^{MMBtu}\!/_{faucet} \times \sqrt{n}$$

$$AKWH = \frac{MMBtu\ Savings}{.003412 \, {}^{MMBtu}\!/_{kWh} \times EF_E} = \frac{0.257 \times \sqrt{n}}{0.003412 \times 0.95}$$
$$AKWH = 79.3 \, {}^{kWh}\!/_{faucet} \times \sqrt{n}$$

Retrofit Gross Energy Savings - Fossil Fuel

$$ACCF = \frac{MMBtu\ Savings}{.102900 \, {}^{MMBtu}\!/_{Ccf} \times EF_F} = \frac{0.257 \times \sqrt{n}}{0.102900 \times 0.62}$$
$$ACCF = 4.03 \times \sqrt{n}$$

$$AOG = \frac{MMBtu\ Savings}{.138690 \, {}^{MMBtu}\!/_{Gal\ oil} \times EF_F} = \frac{0.257 \times \sqrt{n}}{0.138690 \times 0.62}$$
$$AOG = 2.99 \times \sqrt{n}$$

$$APG = \frac{MMBtu\ Savings}{0.09133 \, {}^{MMBtu}\!/_{Gal\ propane} \times EF_F} = \frac{0.257 \times \sqrt{n}}{0.09133 \times 0.62}$$
$$APG = 4.54 \times \sqrt{n}$$

Example - Retrofit Gross Energy Savings

Two aerators are replaced in bathrooms of home which uses electric hot water heating. What are the total savings?

$$AKWH = 79.3 \, {}^{kWh}\!/_{faucet} \times \sqrt{2} = 112 \, {}^{kWh}\!/_{yr}$$
$$Annual\ Gal\ Water\ Savings = S_W \times \sqrt{n} = 1{,}238 \, {}^{Gal}\!/_{yr} \times \sqrt{2} = 1751 \, {}^{Gal}\!/_{yr}$$

Two aerators are replaced in bathrooms of a home which uses gas hot water heating. What are the savings?

$$Annual\ Gas\ Ccf = 4.03 \times \sqrt{2} = 5.7 \, {}^{Ccf}\!/_{yr}$$
$$Annual\ Gal\ Water\ Savings = S_W \times \sqrt{n} = 1{,}238 \, {}^{Gal}\!/_{yr} \times \sqrt{2} = 1751 \, {}^{Gal}\!/_{yr}$$

Retrofit Gross Peak Day Savings - Natural Gas

$$PD_{WH} = ACCF \times PDF_{WH}$$

Non Energy Benefits

$$Annual\ Gal\ Water\ Savings = S_W \times \sqrt{n} = 1{,}238\ {}^{Gal}\!/_{yr} \times \sqrt{n}$$

Changes from Last Version

Simplified so low income and non-low income use the same method. Added 2011 Aquacraft study (Ref [4]) for several water usage assumptions. Updated with common conversion factors.

References

[1] U.S. EPA WaterSense High-Efficiency Lavatory Faucet Specification, Effective October 1, 2007, Accessed July 21, 2010.

[2] KEMA. Evaluation of the Weatherization Residential Assistance Partnership (WRAP) and Helps Programs, Final Report, September 10, 2010.

[3] Federal Register Part III, DOE Energy Conservation Program: Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, Pool Heater; Final Rule, Table I.2. April 16, 2010.

[4] Aquacraft Water Engineering & Management. California Single Family Water Use Efficiency Study. June 1, 2011.

Notes

[1] Ref [4] (Table 35, page 128) showed water usage for northern sites versus southern sites to have the ratio 171/183 = 0.9344.

[2] Ref [2] recommends this method of reducing savings for additional aerators by multiplying by the square root of the number installed.

[3] Ref [4] gave the number of toilets per household, 2.4 (Table 66, pages 185-186). Assuming the number of toilets = number of primary lavatory sinks, add one primary faucet for the kitchen, add 1.3+0.4 for number of tub faucets per household, total faucets = 2.4+1+1.7=5.1. Including the tubs/HH in the calculation may understate the lavatory faucet savings since tub use is about 1/10 of the average sink faucet use per year.

4.5.7 GAS FIRED WATER HEATER

Description of Measure

Installation of a high efficiency natural gas or propane-fired tankless water heater.

Savings Methodology

Savings calculation for Tankless units are showed below. Savings for high efficiency indirect water heater and integrated water heater attached to an ENERGY STAR rated boiler are shown as lost opportunity water heating portion of the high efficiency boiler measure. Many of the inputs for this measure are based on the Tool for Generating Realistic Residential Hot Water Event Schedules (Ref [1]). The tool estimates hourly hot water consumption in gallons based on location of home and number of bedrooms. The tool used results from a number of metering studies to develop usage profiles based on location of home and number of bedrooms. These profiles along with incoming water temperature for Connecticut were used to calculate the water heating load for a typical Connecticut home. Assumed water heater efficiencies (energy factors) were used to calculate natural gas and propane savings from the gross energy savings.

Inputs

Symbol	Description	Units
	Water heating fuel.	
EF_I	Energy Factor-installed (Tankless)	**%**
	Boiler units below	
YR_h	Year of home construction	Year
$AFUE_i$	AFUE-installed	%
SF	Heated area served by Boiler	SF

Nomenclature

Symbol	Description	Units	Values	Comments
$ABTU_W$	Annual BTU savings – water heating	Btu		
$ACCF_W$	Annual Natural gas savings – water heating	Ccf		
ADHW	Annual domestic hot water load	Btu		
APG_W	Annual Propane savings – water heating	Gal		
EF_B	Energy Factor - Baseline		0.62	Note [2]
EF_I	Energy Factor - Installed			Input
GPY	Annual domestic hot water usage in Gallons	Gal	19,839	Note [1]
PD_W	Peak Day water heating savings	Ccf		
PDF_W	Peak Day factor water heating		0.00321	
T_{aiw}	Average annual incoming water temperature	ºF	57	Note [1]
T_{dhw}	Domestic hot water heater set point	ºF	125	Assumed

Lost Opportunity Gross Energy Savings - Fossil Fuel

$$ADHW = GPY \times 8.3\,{}^{lbs}\!/_{Gal} \times \left(\mathrm{T_{dhw}} - \mathrm{T_{aiw}}\right)$$

$$ADHW = 19{,}839\,{}^{Gal}\!/_{yr} \times 8.3\,{}^{lbs}\!/_{Gal} \times \left(125°F - 57°F\right)$$

$$ADHW = 11{,}197{,}132\ Btu$$

$$ABTU_W = ADHW \times \left(\frac{1}{EF_B} - \frac{1}{EF_I} \right)$$

$$ABTU_W = 11{,}197{,}132\ Btu \times \left(\frac{1}{0.62} - \frac{1}{EF_I} \right)$$

Savings by water heating fuel:

$$ACCF_W = \frac{ABTU_W}{102{,}900\ {}^{Btu}/_{Ccf}}$$

$$APG_W = \frac{ABTU_W}{91{,}330\ {}^{Btu}/_{Gal}}$$

Example - Lost Opportunity Gross Energy Savings

A natural gas water heater with an EF = 82% (0.82) is installed. What are the annual natural gas savings?

$$ABTU_W = 11{,}197{,}132\ Btu \times \left(\frac{1}{0.62} - \frac{1}{0.82} \right) = 4{,}404{,}851\ Btu$$

$$ACCF_W = \frac{4{,}404{,}851\ Btu}{102{,}900\ {}^{Btu}/_{Ccf}} = 42.8\ Ccf$$

Lost Opportunity Gros Peak Day Savings - Natural Gas

$$PD_W = ACCF_W \times PDF_W$$

$$PD_W = ACCF_W \times 0.00321$$

Changes from Last Version

The water heating load was modified. Calculations for savings based on actual installed efficiencies. Water heating done with boilers calculation moved to new boiler measure.

References

[1] Tool for Generating Realistic Residential Hot Water Event Schedules, Preprint, NREL, August 2010.

Notes

[1] These values were developed using the Tool in Ref [1] for Hartford area weather data and a three bedroom house.

[2] Federal Register Part III, April 16, 2010, DOE Energy Conservation Program: Energy Conservation standards for Residential Water Heaters, Direct Heating Equipment, Pool Heater; Final Rule

4.5.8 HEAT PUMP WATER HEATER

Description of Measure

Installation of a heat pump water heater in place of an electric resistance water heater

Savings Methodology

The (deemed) savings for this measure are calculated based on the water heating load calculated in Measure 4.5.7 and the difference of efficiency between a baseline electric resistance water heater and heat pump water heater. Because the efficiency of a heat pump water heater is affected by air temperature and the ENERGY STAR is RATED for an average air temperature higher than what is expected in Connecticut, the analysis adjusted the minimum ENERGY STAR qualifying COP based on the estimated basement temperature for a home in Connecticut (average day, summer day, and winter day). Effective efficiency is also affected by the recovery and location adjustments. That adjustment is described below as a space heating penalty and recovery adjustment. The peak demand savings are estimated based on the “Tool for Generating Realistic Residential Hot Water Event Schedules” (Ref [1]). The tool estimates hourly hot water usage in gallons based on location of home and number of bedrooms. The tool used results from a number of metering studies and developed usage profiles based on location of home and number of bedrooms. These profiles along with incoming water temperature for Connecticut were used to calculate the water heating load for a typical Connecticut home. Water heater Energy factors were used to calculate energy usage.

Nomenclature

Symbol	Description	Units	Values	Comments
ADHW	Annual domestic hot water load	Btu/ yr	11,197, 132	Measure 4.5.7
AKWH	Annual electric energy savings	kWh/yr		
COP_{55}	COP at the estimated average basement temperature of 55 ºF - winter		1.75	Note [2]
COP_{60}	COP at the estimated average basement temperature of 60 ºF – annual average		1.85	Note [2]
COP_{65}	COP at the estimated average basement temperature of 65 ºF -summer		1.95	Note [2]
EF_b	Energy Factor - baseline	%	90	Ref [3]
GPH	Average gallons per hour during peak time	gph	1.96	Note [1]
P	Heating penalty and recovery adjustment	%	90	Assumed
$PDHW_s$	Peak hour hot water load - summer	Btu		
$PDHW_w$	Peak hour hot water load - winter	Btu		
SKW	Summer electric demand savings	kW		
T_{dhw}	Domestic hot water heater set point	ºF	125	Assumed
T_{siw}	Average Summer incoming water temperature	ºF	65	Note [1]
T_{wiw}	Average Winter incoming water temperature	ºF	46	Note [1]
WKW	Winter electric demand savings	kW		

Lost Opportunity Gross Energy Savings - Electric

$$ADHW = 11{,}197{,}132\ Btu$$

$$AEDHW_b = ADHW \times \frac{1}{3{,}412\ {}^{Btu}\!/\!_{kWh}} \times \frac{1}{EF_b}$$

$$AEDHW_b = 11{,}197{,}132\ Btu \times \frac{1}{3{,}412\ {}^{Btu}\!/\!_{kWh}} \times \frac{1}{0.9} = 3{,}646\ kWh$$

$$AEDHW_i = ADHW \times \frac{1}{3{,}412\ {}^{Btu}\!/\!_{kWh}} \times \left[\frac{1}{COP_{60} \times P}\right]$$

$$AEDHW_i = 11{,}197{,}132 Btu \times \frac{1}{3{,}412\ {}^{Btu}\!/\!_{kWh}} \times \left[\frac{1}{1.85 \times 0.9}\right] = 1{,}971\ kWh$$

$$AKWH_W = AEDHW_b - AEDHW_i = 3{,}646 - 1{,}971 = 1{,}675\ kWh$$

Lost Opportunity Gross Seasonal Peak Demand Savings - Electric, Winter and Summer

$$PDHW_s = \mathrm{G}PH \times 8.3\ {}^{lbs}\!/\!_{Gal} \times \left(\mathrm{T_{dhw}} - \mathrm{T_{siw}}\right)$$

$$PDHW_s = 1.96\ {}^{Gal}\!/\!_{hr} \times 8.3\ {}^{lbs}\!/\!_{Gal} \times \left(125°F - 65°F\right) = 976\ Btu$$

$$SKW_s = PDHW_s \times \frac{1}{3{,}412\ {}^{Btu}\!/\!_{kWh}} \times \left(\frac{1}{\mathrm{EF_b}} - \frac{1}{COP_{65}}\right)$$

$$SKW_s = 976\ Btu \times \frac{1}{3{,}412\ {}^{Btu}\!/\!_{kWh}} \times \left(\frac{1}{0.9} - \frac{1}{1.95}\right) = 0.17\ kW$$

$$PDH_w = \mathrm{G}PH \times 8.3\ {}^{lbs}\!/\!_{Gal} \times \left(\mathrm{T_{dhw}} - \mathrm{T_{wiw}}\right)$$

$$PDHW_w = 1.96\ {}^{Gal}\!/\!_{hr} \times 8.3\ {}^{lbs}\!/\!_{Gal} \times \left(125°F - 46°F\right) = 1{,}285\ Btu$$

$$WKW_w = PDHW_w \times \frac{1}{3{,}412\ {}^{Btu}\!/\!_{kWh}} \times \left(\frac{1}{\mathrm{EF_b}} - \frac{1}{COP_{55}}\right)$$

$$WKW_{ws} = 1{,}285\ Btu \times \frac{1}{3{,}412\ {}^{Btu}\!/\!_{kWh}} \times \left(\frac{1}{0.9} - \frac{1}{1.75}\right) = 0.20\ kW$$

Changes from Last Version

The majority of the input values were updated based on Ref [1]. The annual savings decreased from 1,762 kWh to 1,675 kWh.

References

[1] Tool for Generating Realistic Residential Hot Water Event Schedules, Preprint, NREL, August 2010.

[2] Nyle Heat Pump Water Heater Evaluation, Final Report, AIL Research, Inc. Jan 2002.

[3] 2004 federal standard (10CFR 430) for 50 gallon tank

Notes

[1] These values were developed using the Tool in Ref [1] for Hartford area weather data and a three bedroom house.

[2] The minimum ENERGY STAR COP of 2 rated at 67.5 ºF was adjusted using Ref [2] to develop a relationship between COP and air temperature. The annual average basement air temperature was estimated at 60ºF, and 65ºF average summer and 55ºF average winter temperatures.

4.5.9 PIPE INSULATION

Description of Measure

Installation of insulation on domestic hot water (DHW) pipes in unconditioned basements to reduce heat loss.

Savings Methodology

Annual savings for DHW pipes estimated based on pipe size in table below. The savings values are per foot of hot pipe coming from the water heater in unconditioned space and are based on the outputs of Ref [1], based on the inputs listed in Note [1], also recommended in Ref [2].

Inputs

Symbol	Description
Pipe Diameter	Diameter of hot water pipe, inches (savings are shown for ½” and ¾” pipes)
Length	Length of pipe insulation, in feet.

Nomenclature

Symbol	Description	Units	Values	Comments
$ACCF_W$	Annual Gas Savings, Water Heating	Ccf/yr		
AKWH	Annual kWh Energy Savings, Water Heating	kWh/yr		
AOG_W	Annual Oil Savings, Water Heating	Gal/yr		
APG_W	Annual Propane Savings, Water Heating	Gal/yr		
PD_W	Peak Day savings, Water Heating			
PDF_W	Peak Day Factor, Water Heating		0.00321	Appendix 1
PF_S	Summer Seasonal Peak Factor	W/kWh	0.1147	Ref [3]
PF_W	Winter Seasonal Peak Factor	W/kWh	0.1747	Ref [3]
SKW	Summer Seasonal Peak Demand Savings	kW		
WKW	Winter Seasonal Peak Demand Savings	kW		

Retrofit Gross Energy Savings - Electric

Table 1: Annual Electrical Savings per Linear Foot of Pipe Insulation

Pipe Diameter (inches)	Savings (kWh)
0.50	10.4
0.75	15.9

Retrofit Gross Energy Savings - Fossil Fuel

Table 2: Annual Fossil Fuel Savings per Linear Foot of Pipe Insulation

Pipe Diameter (inches)	$ACCF_W$ (Ccf/yr)	AOG_W (Gallons)	APG_W (Gallons/yr)
0.50	0.55	0.46	0.60
0.75	0.85	0.70	0.92

Example - Retrofit Gross Energy Savings

Five feet of pipe insulation are installed on a ½" diameter hot water pipe. The home has oil hot water heating. What are the annual energy savings?

$$AOG_W = 5\ feet \times 0.46\ {}^{Gal}\!/_{yr \bullet ft} = 2.3\ {}^{Gal}\!/_{yr}$$

Retrofit Gross Seasonal Peak Demand Savings - Electric, Winter and Summer

$$SKW = \frac{(AKWH \times PF_S)}{1000\ {}^{W}\!/_{kW}}$$

$$WKW = \frac{(AKWH \times PF_W)}{1000\ {}^{W}\!/_{kW}}$$

Retrofit Gross Peak Day Savings - Natural Gas

$$PD_W = ACCF_W \times PDF_W$$

Example - Retrofit Gross Peak Demand Savings

5 feet of pipe insulation are installed on a ½" diameter hot water pipe. The home has electric hot water heating. What are the summer and winter peak demand savings?

$$AKWH = 5\ feet \times 10.4\ {}^{kWh}\!/_{ft \bullet yr} = 52\ {}^{kWh}\!/_{yr}$$

$$SKW = \frac{(52\ kWh \times 0.1147\ {}^{W}\!/_{kWh})}{1000\ {}^{W}\!/_{kW}} = 0.0060\ kW$$

$$WKW = \frac{(52\ kWh \times 0.1747\ {}^{W}\!/_{kWh})}{1000\ {}^{W}\!/_{kW}} = 0.0091\ kW$$

Changes from Last Version

Values converted from per 10 linear feet to per foot.

References

[1] NAIMA, 3E Plus software tool, Version 4.0, Released 2005.

[2] Nexant. Home Energy Solutions Evaluation: Final Report, submitted to Connecticut Energy Efficiency Board. March 2011.

[3] KEMA. Evaluation of the Weatherization Residential Assistance Partnership (WRAP) and Helps Programs, Final Report, September 10, 2010.

Notes

[1] 3E Plus Inputs:

1. Polyolefin (Polyethylene) Foam Tube insulation, 3/8" Thk for 1/2" pipe, 1/2" Thk for 3/4" pipe.
2. No Jacket installed, so assume emittance (emissivity) of "jacket" is 1.0 (maximum)
3. Ambient Temp range 40-70 deg F, no wind speed (used 60 typical)
4. Process Temp (water heater temp) 90 deg F to reflect average temperatures (normal range of WH setting is 120-140; 120 for energy savings, 140 carries risk of scalding)
5. Tubing is copper
6. Savings counted 8760 hours/yr since average temperature is used.
7. Heat in pipes will dissipate during the time hot water is not being used, thus reducing the average water temperature in the pipe.
8. Only 0.5 and 0.75 inch pipe necessary, since most HW supply pipes are either 1/2 or 3/4 in
9. 3E Plus software (from NAIMA) used to calculate heat loss
10. Temp difference between ambient temperatures and pipe temperatures: 30 correlates with 90 F pipe and 60 F ambient
11. Efficiency of water heaters same as that used for faucet aerators and showerheads, see 13.
12. Horizontal pipes
13. WH efficiencies: Electric 90%, Oil 49.5%, Gas and propane: 57.5%

APPENDIX 1. PEAK FACTORS

Coincidence Factors for ISO-NE Seasonal Peak Demand Reductions

Commercial and Industrial Lighting and Occupancy Sensors				
	Lighting		**Occupancy Sensors**	
Facility Type	**Summer**	**Winter**	**Summer**	**Winter**
Grocery	90%	77%		
Manufacturing	67%	43%	20%	17%
Medical (Hospital)	74%	62%	24%	22%
Office	70%	54%	27%	30%
Other	48%	43%	2%	7%
Restaurant	78%	64%		
Retail	80%	65%		
University / College	65%	53%	28%	23%
Warehouse	73%	54%	25%	18%
School	60%	38%	21%	16%

Other Commercial and Industrial Measures		
Measure	**Summer**	**Winter**
Unitary A/C	82%	0%
Efficient Motors (cooling)	73%	60%
Efficient Motors (heating)	0%	80%
Refrigeration	10%	10%
Heating	0%	See Note [1]

Residential		
Measure	**Summer**	**Winter**
Lighting	9%	26%
Central A/C	59%	0%
Window A/C	30%	0%
Heating	0%	50%
Refrigeration	30%	21%
Water Heating	10%	15%

Calculating Peak Day Savings for Gas Measures

Natural gas peak day usage is driven by the heating load; thus peak day savings is the savings associated with conservation measures that takes place during the coldest continuous 24 hour period of the year.

The methodology for peak day savings estimating for natural gas efficiency measures is summarized below:

1. **Residential space heating efficiency upgrades**: Since energy savings correlate directly to outside air temperatures, the demand savings for residential space heating measures is estimated based on as a percentage (0.977%) of annual savings The 0.977% factor is based on Bradley Airport peak degree day average (58.5) of the last thirty years divided by the average heating degree days (5,990) for the last thirty years. (note 1)

   Peak Day savings (residential heating) = 0.00977 x annual heating savings

2. **Residential gas water heating:** The peak day savings are estimated by estimating the percent of hot water consumption during the peak day. This is done by multiplying the annual savings associate with a hot water measure by 0.321%. This factor is based on water heating load and inlet temperatures from the NREL tool (Ref [1]). Hartford the coldest inlet water temperature was 45.96 degrees and average is 56.72 degrees. Assumed hot water set point is 120 degrees. Therefore,

$$Peak\ Factor = \frac{(1\,day)\times(120° - 45.96°)}{(365\,days)\times(120° - 56.72°)} = 0.00321$$

   Peak Day savings (residential water) = 0.00321 x annual water heating savings

3. **Measures with savings daily constant saving:** An example would be a process heating measure. For these measures the peak day savings will be estimated by dividing the annual savings by 365 days per year.

$$Peak\ Day\ Savings = \frac{Annual\ Ccf\ \ Savings}{365\ {}^{days}\!/_{year}}$$

4. **Custom measures:** Measures that are not weather dependent, nor have consistent savings from day to day or are analyzed with a more detailed analysis tool such as the hourly DOE-2 program will be analyzed on a case by case basis. For example a complex boiler replacement or controls measure might be modeled using DOE-2. In this case hourly building simulation can calculate the savings for the peak day based on (TMY) data used in the program. These measures are typically analyzed by a third party consultant and reviewed for reasonableness.

Changes from Last Version

The gas peak day for water was updated based on data from Ref [1]. The value increased from 0.00310 to 0.00321.

References

[1] Tool for Generating Realistic Residential Hot Water Event Schedules, Preprint, NREL, August 2010.

[2] Residential Central AC Regional Evaluation: Final Report, Prepared by ADM Associates, Inc., November 2009.

[3] 2005 Coincident Factor Study for UI & CL&P by RLW, January 2007

[4] Coincidence Factor Study Residential and Commercial Industrial Lighting Measures by RLW, Spring 2007

[5] Coincidence Factor Study, Residential Room Air Conditioners, Prepared by RLW, December 2007.

Notes

[1] Coincidence is specific to each measure.

APPENDIX 2. LOAD SHAPES

Load Shapes by End Use and Sector

End Use	Winter Peak Energy %	Winter Off-Peak Energy %	Summer Peak Energy %	Summer Off-Peak Energy %
	Residential			
Cooling	5.0%	5.0%	65.0%	25.0%
Heating	55.0%	30.0%	5.0%	10.0%
Lighting	30.0%	40.0%	10.0%	20.0%
Refrigeration	30.0%	30.0%	20.0%	20.0%
Water Heating	30.0%	30.0%	20.0%	20.0%
	Commercial & Industrial			
Cooling	3.0%	2.0%	80.0%	15.0%
Heating	60.0%	35.0%	5.0%	0.0%
Lighting	50.0%	10.0%	30.0%	10.0%
Refrigeration	30.0%	30.0%	20.0%	20.0%
Other	50.0%	10.0%	30.0%	10.0%
Motors	50.0%	10.0%	30.0%	10.0%
Process	50.0%	10.0%	30.0%	10.0%

Notes

[1] Winter is defined as October – May

[2] Summer is defined as June – September

[3] Peak is defined as 6:00 AM – 11:00 PM weekdays (no holidays)

[4] Off-peak is defined 11:00 PM to 6:00 AM, plus all weekend and holiday hours.

APPENDIX 3. REALIZATION RATES

CL&P Commercial & Industrial Realization Rates

	Gross Realization % (Note [1])				FR & SO (Note [2])		Net Realization % (Note [3], Note [5])		
Program	**End-use**	**kWh**	**Winter Seasonal Peak kW**	**Summer Seasonal Peak kW**	**Free-ridership**	**Spillover**	**kWh**	**Winter Seasonal Peak kW**	**Summer Seasonal Peak kW**
Energy Conscious Blueprint	**Cooling**	77.0%	235.0%	72.0%	16.6%	0.2%	**64.4%**	**196.5**	**60.2%**
	Heating	134.0%	169.0%	50.0%	8.3%	4.1%	**128.4%**	**161.9%**	**47.9%**
	Lighting	98.0%	87.0%	72.0%	24.3%	1.3%	**75.5%**	**67.0%**	**55.4%**
	Motors	118.0%	115.0%	89.0%	42.1%	0.7%	**69.1%**	**67.4%**	**52.2%**
	Other	118.0%	115.0%	89.0%	55.2%	7.1%	**61.2%**	**59.7%**	**46.2%**
	Process	112.0%	106.0%	199.0%	15.3%	4.4%	**99.8%**	**94.4%**	**177.3%**
	Refrigeration	118.0%	115.0%	89.0%	7.3%	54.9%	**174.2%**	**169.7%**	**131.4%**
Energy Opportunities	**Cooling**	84.3%	136.3%	80.2%	2.5%	0.3%	**82.4%**	**133.3%**	**78.4%**
	Heating	84.3%	136.3%	80.2%	8.7%	0.0%	**77.0%**	**124.3%**	**73.2%**
	Lighting	98.8%	106.7%	104.8%	6.0%	4.1%	**96.9%**	**104.7%**	**102.8%**
	Motors	84.3%	136.3%	80.2%	24.9%	0.0%	**63.3%**	**102.4%**	**60.2%**
	Other	84.3%	136.3%	80.2%	34.3%	1.0%	**56.2%**	**90.9%**	**53.5%**
	Process	84.3%	136.3%	80.2%	21.0%	5.3%	**71.1%**	**114.9%**	**67.6%**
	Refrigeration	84.3%	136.3%	80.2%	41.1%	2.4%	**51.7%**	**83.3%**	**49.2%**
	Demand R	84.3%	136.3%	80.2%	34.3%	1.0%	**56.2%**	**90.9%**	**53.5%**
Small Business Energy Advantage	**Cooling**	100.0%	100.0%	100.0%	0.8%	0.0%	**99.2%**	**99.2%**	**99.2%**
	Heating	100.0%	100.0%	100.0%	0.8%	0.0%	**99.2%**	**99.2%**	**99.2%**
	Lighting	97.8%	75.5%	81.0%	1.6%	0.1%	**96.3%**	**74.4%**	**79.8%**
	Other	100.0%	100.0%	100.0%	0.8%	0.0%	**99.2%**	**99.2%**	**99.2%**
	Comp. Air	14.9%	95.3%	95.3%	0.8%	0.0%	**14.8%**	**94.5%**	**94.5%**
	Refrigeration	106.9%	20.9%	17.2%	0.8%	0.0%	**106.0%**	**20.7%**	**17.1%**
O&M	**PRIME**	100.0%	100.0%	100.0%	0.0%	0.0%	**100.0%**	**100.0%**	**100.0%**
	Cooling	88.2%	88.2%	88.2%	12.1%	0.0%	**77.5%**	**77.5%**	**77.5%**
	Heating	100.0%	100.0%	100.0%	0.0%	0.0%	**100.0%**	**100.0%**	**100.0%**
	Other	100.0%	100.0%	100.0%	0.0%	0.0%	**100.0%**	**100.0%**	**100.0%**
	Process	81.8%	81.8%	81.8%	3.1%	0.0%	**79.3%**	**79.3%**	**79.3%**
	Retro-com	100.0%	100.0%	100.0%	0.0%	0.0%	**100.0%**	**100.0%**	**100.0%**
Load Management	**Load-Response**	100.0%	100.0%	100.0%	0.0%	0.0%	**100.0%**	**100.0%**	**100.0%**

UI Commercial & Industrial Realization Rates

	Gross Realization % (Note [1])				FR & SO (Note [2])		Net Realization % (Note [3], Note [5])		
Program	**End-use**	**kWh**	**Winter Seasonal Peak kW**	**Summer Seasonal Peak kW**	**Free-ridership**	**Spillover**	**kWh**	**Winter Seasonal Peak kW**	**Summer Seasonal Peak kW**
Energy Conscious Blueprint	**Lighting**	98.0%	87.0%	72.0%	36.8%	0.7%	**62.6%**	**55.6%**	**46.0%**
	Motors	118.0%	115.0%	89.0%	41.0%	0.0%	**69.6%**	**67.9%**	**52.5%**
	Cooling Unitary	77.0%	235.0%	72.0%	45.2%	0.0%	**42.2%**	**100.0%**	**39.5%**
	Cooling - Other	77.0%	235.0%	72.0%	46.7%	7.4%	**46.7%**	**100.0%**	**43.7%**
	Heating	134.0%	169.0%	50.0%	3.9%	34.8%	**100.0%**	**100.0%**	**65.5%**
	Custom	118.0%	115.0%	89.0%	3.9%	34.8%	**100.0%**	**100.0%**	**100.0%**
	Process	112.0%	106.0%	199.0%	3.9%	34.8%	**100.0%**	**100.0%**	**100.0%**
	Other	118.0%	115.0%	89.0%	3.9%	34.8%	**100.0%**	**100.0%**	**100.0%**
	Refrigeration	118.0%	115.0%	89.0%	3.9%	34.8%	**100.0%**	**100.0%**	**100.0%**
	VFD's	118.0%	115.0%	89.0%	24.7%	0.0%	**88.9%**	**86.6%**	**67.0%**
Energy Opportunities	**Lighting**	98.8%	106.7%	104.8%	17.5%	6.2%	**87.6%**	**94.6%**	**93.0%**
	Custom	84.3%	136.3%	80.2%	3.2%	0.5%	**82.0%**	**100.0%**	**78.0%**
	Other	84.3%	136.3%	80.2%	0.0%	0.0%	**84.3%**	**100.0%**	**80.2%**
Small Business Energy Advantage	**Lighting**	99.1%	66.9%	77.3%	6.3%	0.1%	**93.0%**	**62.8%**	**72.5%**
	Refrigeration	105.8%	9.3%	8.9%	0.0%	0.0%	**100.0%**	**9.3%**	**8.9%**
	Custom	100.0%	100.0%	100.0%	5.5%	9.4%	**100.0%**	**100.0%**	**100.0%**
O&M	**PRIME**	100.0%	100.0%	100.0%	0.0%	0.0%	**100.0%**	**100.0%**	**100.0%**
	Cooling	88.2%	88.2%	88.2%	12.1%	0.0%	**77.5%**	**77.5%**	**77.5%**
	Heating	100.0%	100.0%	100.0%	0.0%	0.0%	**100.0%**	**100.0%**	**100.0%**
	Other	100.0%	100.0%	100.0%	0.0%	0.0%	**100.0%**	**100.0%**	**100.0%**
	Process	81.8%	81.8%	81.8%	3.1%	0.0%	**79.3%**	**79.3%**	**79.3%**
	Retro-com	100.0%	100.0%	100.0%	0.0%	0.0%	**100.0%**	**100.0%**	**100.0%**

CL&P & UI Residential Realization Rates

CL&P & UI Residential Realization Rates									
Gross Realization %					**FR & SO**		**Net Realization % (Note [4], Note [5])**		
Measure	**kWh or (Ccf)**	**Winter Seasonal Peak kW or (Peak Day Ccf)**	**Summer Seasonal Peak kW**	**Installation Rate**	**Free-ridership**	**Spillover**	**kWh**	**Winter Seasonal Peak kW**	**Summer Seasonal Peak kW**
Home Energy Solutions In Home Services (Ref [6])									
Electric measures	97.6%	91.9%	83.4%	100.0%	0.0%	0.0%	**97.6%**	**91.9%**	**83.4%**
Gas Measures (Ccf)	107.5%	107.5%	N/A	100.0%	0.0%	0.0%	**107.5%**	**107.5%**	**N/A**
Home Energy Solutions-Income Eligible (Ref [7])									
Bulbs (Note 6)	100.0%	73.1%	100.0%	75.0%	0.0%	0.0%	**75.0%**	**54.8%**	**75.0%**
Portable Lamps (Note 6)	100.0%	73.1%	100.0%	75.0%	0.0%	0.0%	**75.0%**	**54.8%**	**75.0%**
Fixtures	100.0%	73.1%	100.0%	100.0%	0.0%	0.0%	**100.0%**	**73.1%**	**100.0%**
Other Electric Measures	100.0%	100.0%	100.0%	100.0%	0.0%	0.0%	**100.0%**	**100.0%**	**100.0%**
Gas Measures (Ccf)	100.0%	100.0%	N/A	100.0%	0.0%	0.0%	**100.0%**	**100.0%**	**N/A**
Retail Products (Refs [8],[9],[11], Note [6])									
CFL Bulbs	100.0%	100.0%	100.0%	87.1%	19.0%	0.0%	**70.6%**	**70.6%**	**70.6%**
LED Bulbs	100.0%	100.0%	100.0%	100.0%	0.0%	0.0%	**100.0%**	**100.0%**	**100.0%**
Portable Lamps	100.0%	100.0%	100.0%	70.0%	3.1%	6.0%	**72.0%**	**72.0%**	**72.0%**
Torchiere	100.0%	100.0%	100.0%	70.0%	3.1%	6.0%	**72.0%**	**72.0%**	**72.0%**
Hard Wired Fixtures	100.0%	100.0%	100.0%	80.0%	3.1%	6.0%	**82.3%**	**82.3%**	**82.3%**
Ceiling Fans & Lights	100.0%	100.0%	100.0%	80.0%	3.1%	6.0%	**82.3%**	**82.3%**	**82.3%**
CFL giveaway	100.0%	100.0%	100.0%	87.1%	19.0%	0.0%	**70.6%**	**70.6%**	**70.6%**
HES Rebate (Ref [10])									
Central AC/HP-CLP	100.0%	100.0%	100.0%	100.0%	42.0%	0.0%	**58.0%**	**58.0%**	**58.0%**
Central AC/HP-UI	100.0%	100.0%	100.0%	100.0%	26.0%	0.0%	**74.0%**	**74.0%**	**74.0%**
Other Electric Measures	100.0%	100.0%	100.0%	100.0%	0.0%	0.0%	**100.0%**	**100.0%**	**100.0%**
Gas Measures (Ccf)	100.0%	100.0%	100.0%	100.0%	0.0%	0.0%	**100.0%**	**100.0%**	**100.0%**

Changes from Last Version

The Energy Conscious Blueprint gross realization rates were updated based on Ref [1]. Home Energy Solutions realization rates were updated with final report values (Ref [6]). Retail Products CFL Bulbs installation rate was updated with Ref [9], and FR & SO was Updated with Ref [11].

References

[1] Global Energy Partners, Evaluation of The Energy Conscious Blueprint Program, August 4, 2011

[2] KEMA, 2008 Energy Opportunities Program Impact Evaluation, June 18, 2010

[3] The Cadmus Group, Connecticut Small Business Energy Advantage Year 2007 Impact Evaluation, Final Report, August 24, 2009

[4] PA Consulting Group, CL&P/UI 2007 C&I Program Free-ridership & Spillover, October 28, 2008

[5] RLW Analytics, Inc., 1999 O&M Services Program Impact Evaluation, Final Report, October 2001

[6] Nexant, Home Energy Solutions Evaluation, Final Report, March 2011

[7] KEMA, Evaluation of the Weatherization Residential Assistance Partnership (WRAP) and Helps Programs, September 10, 2010

[8] Point of Purchase Lighting Impact Evaluation, 2003

[9] NMR, Residential Markdown Impact Evaluation, January 20, 2009

[10] ADM Associates, Inc., Residential Central AC Regional Evaluation Free-Ridership Analysis, Oct 2009

[11] NMR, 2010 Results of the Multistate CFL Modeling Effort, February 2, 2010

Notes

[1] Realization rates based on references [1], [2], [3] & [5]. If study not available value set to 100%.

[2] Based on Ref [4]. If study not available values set to 0.

[3] Net Realization = (Gross realization %) x (100%-Freeridership %+ Spillover %)

[4] Net Realization = (Gross realization %) x (Installation rate %) x (100%-Freeridership %+ Spillover %)

[5] UI caps net realization rate at 100%.

[6] The CFL bulb installation rate is the average between the first year installation rate and lifetime installation rate given in Ref [9] since the lifetime of this measure is capped at 4 years (halfway between 1 year and the 7 year measure life in the study). The installation rate given in Ref [11] is translated here into 19% freeridership and 0% spillover, since the report gave a combined freeridership and spillover realization rate without differentiating.

APPENDIX 4. LIFETIMES

Commercial & Industrial Measure Lifetimes

Description

C&I measure Life includes equipment life and measure persistence (not savings persistence).

1. Equipment Life means the number of years that a measure is installed and will operate until failure, and
2. Measure Persistence takes into account business turnover, early retirement of installed equipment, and other reasons measures might be removed or discontinued.

For retrofit/early retirement programs, the measure life will take into account both the expected remaining life of the measure being replaced and the expected changes in baselines over time.

Description	Retrofit	Lost Opportunity	Operations	Maintenance	RCx
Lighting Systems, including					
Fixtures	13[1]	15[1]	N/A	N/A	N/A
Lamp and Ballast Conversions	13[1]	N/A	N/A	N/A	N/A
Remove Unnecessary Lighting Fixtures	5[7]	N/A	N/A	N/A	N/A
Sweep Controls / EMS Based Controls	10[1*]	15[1*]	N/A	N/A	N/A
Occupancy Sensors	9[1]	10[1]	N/A	N/A	N/A
Automatic Photocell Dimming Systems	9[1]	10[1]	N/A	N/A	N/A
Recircuiting and New Controls	10[1*]	N/A	N/A	N/A	N/A
Bi-Level Switching (Demand Reduction)	10[1*]	10[18]	N/A	N/A	N/A
Timer Switch	10[1*]	N/A	N/A	N/A	N/A
Reprogramming of EMS Controls	N/A	N/A	5[2]	N/A	8[7]
Fluorescent Lighting system power reduction controls	9[1*]	N/A	N/A	N/A	N/A
Building Envelope					
Insulation	20[3]	20[3]	N/A	N/A	N/A
New Windows	N/A	20[3]	N/A	N/A	N/A
Window Film	10[3]	10[3]	N/A	N/A	N/A
Movable Window Insulation	10[7]	10[7]	N/A	N/A	N/A
Roof Spray Cooling	15[7]	15[7]	N/A	N/A	N/A
Cool Roofs	N/A	15[3]	N/A	N/A	N/A

Description	Retrofit	Lost Opportunity	Operations	Maintenance	RCx
Domestic Hot Water					
Heat Pump Water Heater	10[3*]	10[3*]	N/A	N/A	N/A
Point-of-Use Water Heater	20[3]	20[3]	N/A	N/A	N/A
Gas Fired Water Heater	N/A	15[3]	N/A	N/A	N/A
Solar Water Heater	20[7]	20[7]	N/A	N/A	N/A
Heat Recovery	15[7]	15[7]	N/A	N/A	N/A
Energy-Efficient Motors	15[1]	20[1]	N/A	N/A	N/A
Pre-Rinse Spray Valve	5[8]	N/A	N/A	N/A	N/A
Heating, Ventilating and Air Condition (HVAC) Systems					
Energy-Efficient Motors	15[1]	20[1]	N/A	N/A	N/A
Variable Speed Drives	13[2]	15[2]	N/A	N/A	N/A
High-Efficiency Unitary Equipment (A/C and Heat Pumps)	N/A	15[1]	N/A	N/A	N/A
Energy-Efficient Packaged Terminal Units	N/A	15[1]	N/A	N/A	N/A
Dehumidifiers	13[7]	15[7]	N/A	N/A	N/A
Evaporative Cooling (unitary)	N/A	15[1*]	N/A	N/A	N/A
2-Speed Motor Control in Rooftop units	13[1*]	15[1*]	N/A	N/A	N/A
Electric Chillers	N/A	23[1]	N/A	N/A	N/A
Gas Engine Chillers	N/A	15[4]	N/A	N/A	N/A
Cool Thermal Storage	15[7]	15[7]	N/A	N/A	N/A
Cooling Tower Alternates	13[7]	15[3*]	N/A	N/A	N/A
Air Distribution System Modifications & Conversions	20[7]	20[7]	N/A	N/A	N/A
VAV System Components	13[7]	N/A	N/A	N/A	N/A
Plate/Heat Pipe Type Heat Recovery System	14[3]	14[3]	N/A	N/A	N/A
Rotary Type Heat Recovery System	14[3]	14[3]	N/A	N/A	N/A
Economizer - Air/Water	7[1]	10[1]	N/A	N/A	N/A
Low-Leakage Damper	12[7]	12[7]	N/A	5[2]	N/A
Repair Air Side Economizer	N/A	N/A	N/A	5[2]	N/A
Outdoor Air Damper Adjustment or Modification	N/A	N/A	N/A	5[2]	N/A
Make-up Air Unit for Exhaust Hood	15[7]	15[7]	N/A	N/A	N/A
Paddle Type Air Destratification Fan	15[6*]	15[6*]	N/A	N/A	N/A
Duct Type Air Destratification System	15[6*]	15[6*]	N/A	N/A	N/A
Air Curtain	15[7]	15[7]	N/A	N/A	N/A
Water/Steam Distribution System Modifications & Conversions	20[7]	20[7]	N/A	N/A	N/A
Zoned Circulator Pump System	15[7]	N/A	N/A	N/A	N/A
Electric Spot Radiant Heat	10[7]	10[7]	N/A	N/A	N/A
Additional Vessel Insulation	10[7]	10[7]	N/A	N/A	N/A

Description	Retrofit	Lost Opportunity	Operations	Maintenance	RCx
Additional Pipe Insulation	10[7]	10[7]	N/A	N/A	N/A
Repair Steam/Air Leaks	N/A	N/A	N/A	5[2]	N/A
Gas Fired Boiler (Non-Condensing)	N/A	20[3]	N/A	N/A	N/A
Gas Fired Boiler (Condensing)	N/A	15[7]	N/A	N/A	N/A
Gas Furnace	N/A	20*[3]	N/A	N/A	N/A
Gas Fired Radiant Heater	N/A	15[7]	N/A	N/A	N/A
Duct Sealing	18[3]	N/A	N/A	N/A	N/A
Duct Insulation	20*[1]	N/A	N/A	N/A	N/A
HVAC Controls					
EMS/Linked HVAC Controls	10[1]	15[1]	N/A	N/A	8[7]
New/Additional EMS Points	10[1]	15[1]	N/A	N/A	N/A
Single Zone Controls NOT Linked to other Controls	10[1]	N/A	N/A	N/A	N/A
Time Clocks	11[3]	N/A	N/A	N/A	N/A
Modify HVAC Controls	10[1]	N/A	N/A	N/A	8[7]
Repair HVAC Controls	N/A	N/A	N/A	5[2]	N/A
Adjust Scheduling	N/A	N/A	5[2]	N/A	6[7]
Reset Setpoints	N/A	N/A	5[2]	N/A	6[7]
Reprogramming of EMS Controls	N/A	N/A	5[2]	N/A	8[7]
Controls to Eliminate Simultaneous Heating and Cooling	10[1]	N/A	5[2]	N/A	8[7]
Demand Control Ventilation - Single Zone	10[1]	10[7]	N/A	N/A	8[7]
Demand Control Ventilation - Multi Zone	10[1]	10[7]	N/A	N/A	N/A
Enthalpy Control Economizer	7[1]	10[1]	N/A	N/A	N/A
Upgrade to dual/comparative Enthalpy Economizer	10[1*]	10[1*]	N/A	N/A	N/A
Programmable Tstat	8[1]	N/A	N/A	N/A	N/A
Refrigeration					
Industrial Refrigeration Systems/Components	20[1]	20[1]	3[7]	N/A	N/A
Commercial Refrigeration Systems/Components	15[3]	15[3]	3[7]	N/A	N/A
Heat Recovery from Refrigeration System	10[3]	13[7]	N/A	N/A	N/A
Refrigeration Controls	10[2]	10[2]	5[2]	N/A	10[3]
Adjust Scheduling	N/A	N/A	5[2]	N/A	8[7]
Reset Setpoints	N/A	N/A	5[2]	N/A	8[7]
Mechanical Subcooling	15[3]	15[3]	N/A	N/A	N/A
Ambient Subcooling	15[3]	15[3]	N/A	N/A	N/A
Auto Cleaning System for Condenser Tubes	10[7]	10[7]	N/A	N/A	N/A
Hot Gas Bypass for Defrost or Regeneration	10[7]	10[7]	N/A	N/A	N/A
Open or Enclosed Display Cases	12[3]	12[3]	N/A	N/A	N/A

Description	Retrofit	Lost Opportunity	Operations	Maintenance	RCx
Case Cover	5[3]	5[3]	N/A	N/A	N/A
Polyethylele Strip Curtain	4[3]	4[3]	N/A	N/A	N/A
Motorized Insulated Doors	8[3]	8[3]	N/A	N/A	N/A
Oversized Condensers	15[3]	15[3]	N/A	N/A	N/A
Low Case HVAC Returns	10[7]	10[7]	N/A	N/A	N/A
Demineralized Water for Ice	10[7]	10[7]	N/A	N/A	N/A
Electronically Commutated Motors	15[3]	15[3]	N/A	N/A	N/A
Low Emissivity Ceiling Surface	15[7]	15[7]	N/A	N/A	N/A
Additional Pipe Insulation - Refrigeration System	11[3]	11[3]	N/A	N/A	N/A
Additional Vessel Insulation - Refirgeration System	11[3]	11[3]	N/A	N/A	N/A
Process Equipment					
Air Compressor	13[1]	15[1]	N/A	N/A	N/A
Refrigerated Air Dryer	13[7]	15[1]	N/A	N/A	N/A
Variable Frequency Drives	13[1]	15[1]	N/A	N/A	N/A
Repair Steam/Compressed Air Leaks	N/A	N/A	N/A	5[2]	N/A
Add Regulator Valves in Compressed Air System	10[7]	10[7]	N/A	N/A	10[3]
Install Air Compressor No-Loss Condenser Drains	10[7]	10[7]	N/A	5[2]	10[3]
Interlock Air System Solenoid Valves with Machine Operation	10[1*]	10[1*]	N/A	N/A	10[3]
Interlock Exhaust Fans with Machine Operations	10[1*]	10[1*]	N/A	N/A	10[3]
Injection Molding Machine Jackets	5[7]	N/A	N/A	N/A	N/A
Compressed Air Distribution and Storage Systems	10[7]	N/A	N/A	N/A	N/A
Plastic Injection Molding Machine	13[7]	15[7]	N/A	N/A	N/A
Energy-Efficient Motors	15[1]	20[1]	N/A	N/A	N/A
Energy Efficient Transformers	15[1*]	20[1*]	N/A	N/A	N/A
Water treatment magnets	10[7]	N/A	N/A	N/A	N/A
PRIME	N/A	5[5]	N/A	N/A	N/A
Kitchen Equipment					
Natural Gas Fryer	N/A	12[3]	N/A	N/A	N/A
Natural Gas Streamer	N/A	12[3]	N/A	N/A	N/A
Natural Gas Convection Oven	N/A	12[3]	N/A	N/A	N/A

Changes from Last Version

Identified Source References

References

[1] GDS Associates Inc, Measure Life Report, Residential and Commercial Industrial Lighting and HVAC Measures, June 2007.

[2] Energy & Resource Solutions (ERS), Measure Life Study: prepared for The Massachusetts Joint Utilities, October 10, 2005.

[3] California Public Utilities Commission, 2008 Database for Energy-Efficient Resources, Version 2008.2.05, December 16, 2008, EUL/RUL (Effective/Remaining Useful Life) Values, MS Excel Spreadsheet.

[4] Gas chiller measure life was set by the CT DPUC in their decision, in Docket 09-02-18, in response to Public Act 05-01, "An Act Concerning Energy Independence".

[5] Energy & Resource Solutions (ERS), Reengineering for Increased Manufacturing Efficiency Program Evaluation, March 26, 2007.

[6] Efficiency Maine TRM, 3/5/07

[7] Estimated

[8] Veritec Consulting, "Region of Waterloo Pre-Rinse Spray Valve Pilot Study Final Report", January, 2005

Notes

[1] Directly from Ref [1]
[1*] Similar measure from Ref [1]

[2] Directly from Ref [2]
[2*] Similar measure from Ref [2]

[3] Directly from Ref [3]
[3*] Similar measure from Ref [3]

[4] Directly from Ref [4]
[4*] Similar measure from Ref [4]

[5] Directly from Ref [5]
[5*] Similar measure from Ref [5]

[6] Directly from Ref [6]
[6*] Similar measure from Ref [6]

Residential Measure Lifetimes

Description

Measure Life for Residential measures includes equipment life and measure persistence (not savings persistence).

Equipment Life means the number of years that a measure is installed and will operate until failure, and Measure Persistence takes into account transfer of ownership, early retirement of installed equipment, and other reasons measures might be removed or discontinued.

Gross lifetime energy savings are calculated by multiplying the gross annual energy savings by the measure life in the following table. Likewise, net lifetime savings are calculated by multiplying the net energy by the measure life in the following table.

The residential programs use a slightly different definition of "Retrofit" savings than C&I programs. Where "retrofit" measures in C&I utilize a blended "retrofit" lifetime, Residential measures utilize a two-part lifetime savings calculation. In certain situations, such as early retirement, savings may be claimed in two parts, where the retirement part is additional to the lost opportunity part until the end of the remaining useful life (RUL), after which lost opportunity savings continue until the last year of the retrofit measure's effective useful life (EUL).

For example, in an "Early Retirement" case where the existing unit (using lower efficiency, out-of date technology) would have been operating until failure and early retirement is stimulated by the program measure, savings may be claimed between the existing unit to the standard baseline unit (driven by the level of efficiency most standard units achieve), for the retirement measure life. The residential "retirement" lifetime refers to how much longer the existing unit would have operated absent the influence of the program.

Lost Opportunity lifetimes apply to the portion of savings due to choosing a high efficiency product over a standard efficiency product available on the market.
Both Retail and New Home measure applications fall under the Lost Opportunity category, while measures applied in existing homes and turn-in measures may be eligible for both Retirement and Retrofit.

Numbers in parentheses refer to lifetimes specially pertaining to a low income home.

	Existing Home, Retirement RUL	**Existing Home, New Unit Retrofit EUL**	**New Home & Retail: Lost Opportunity**	**Comments**
Light Bulbs				
CFL, General Service	N/A	4	4	Notes [1], [2]
CFL, Non-General Service, 8,000 hr	N/A	5	5	Note [1]
CFL, Non-General Service, 10,000 hr	N/A	6	6	Note [1]
CFL, Non-General Service, 12,000 hr	N/A	7	7	Note [1]
CFL, Non-General Service, 15,000 hr	N/A	8	8	Note [1]
LED, Down light	N/A	16	16	Ref [2], Note [4]
LED, General Service	N/A	10	10	Ref [2], Note [4]
Luminaires				
CFL, Hardwired Indoor Fixture	N/A	16	16	Ref [2]
CFL, Hardwired Exterior Fixture	N/A	6	6	Note [3]
CFL, Portable Table Lamp	N/A	8	8	Ref [3]
CFL, Portable Torchiere	N/A	8	8	Ref [3]
CFL, Security Exterior	N/A	15	15	Ref [2]
LED Luminaire		16	16	Ref [2], Note [4]
Heating, Ventilation, and Air-Conditioning (HVAC) systems				

	Existing Home, Retirement RUL	Existing Home, New Unit Retrofit EUL	New Home & Retail: Lost Opportunity	Comments
Central Air Conditioning System	5	18	25	Ref [3]
Air Source Heat Pump	5	18	25	Ref [3]
Geothermal Heat Pump	N/A	18	25	Ref [3]
Ductless Split Heat Pump	N/A	18	N/A	
Package Terminal Heat Pump	5	18	N/A	Ref [3]
Furnace (Gas)	5	20		
Boiler (Gas)	5	20		
QIV, Central Air Conditioning System	N/A	18	18	Ref [3]
QIV, Air Source Heat Pump	N/A	18	18	Ref [3]
QIV, Geothermal Heat Pump	N/A	18	18	Ref [3]
QIV, Boiler (Boiler Reset)	N/A	20		
Electronically Commutated Motor		18	18	Ref [3]
Duct Blaster Test (New Construction)		N/A	25	Ref [3]
Duct Sealing	N/A	20	N/A	Ref [3]
Duct Insulation	N/A	20	N/A	Ref [3]
Appliances				
Room AC Units	4	9	9	Ref [1]
Clothes Washers	4	11		Ref [1]
Dish Washers	4	10	N/A	Ref [1]
Refrigerators	5 (10)	12	N/A	Ref [1]
Freezers	4 (8)	11	N/A	Ref [1]
Dehumidifiers	4	12		Ref [3]
Envelope				
Blower Door	N/A	20	25	
Air Sealing and Weatherization (Non-Blower Door)	N/A	20	N/A	
Thermal Bypass	N/A	N/A	25	Ref [3]
Insulation		25		Ref [3]
Window Replacement		25		
Storm Window Installation		20		
Broken Window Repair		5		
Insulating Attic Openings		25		
Domestic Hot Water				
Water Heater Thermostat Setting (Existing Unit)		4		
Low Flow Shower Head		5		
Water Heater Wrap		5		
Faucet Aerator		5		
Flip Aerator		5		
Pipe Insulation		15		
Heat Pump Water Heater		12		
High Efficiency Indirect Gas Water Heater		N/A	20	
On Demand Tank less Gas Water Heater		12	12	Ref [2]
REM Savings (for Energy Star Homes)				
Heating	N/A	N/A	25	Ref [3]
Cooling	N/A	N/A	25	Ref [3]
Dom. Water Heating	N/A	N/A	25	Ref [3]
BOP (Builder Option Plan for Energy Star homes)				
Heating	N/A	N/A	25	Ref [3]
Cooling	N/A	N/A	25	Ref [3]
Dom. Water Heating	N/A	N/A	25	Ref [3]

Changes from Last Version

Included Retirement lifetimes. Added lifetimes for new measures.

References

[1] Appliance Magazine. U.S. Appliance Industry: Market Share, Life Expectancy & Replacement Market, and Saturation Levels. January 2010. Page 10.

[2] California Public Utilities Commission. 2008 Database for Energy-Efficient Resources, Version 2008.2.05, December 16, 2008, EUL/RUL (Effective/Remaining Useful Life) Values, MS Excel Spreadsheet. Indoor fixture: Row 126. Security: Row 141, Gas Water Heater. http://www.deeresources.com/deer0911planning/downloads/EUL_Summary_10-1-08.xls , last accessed May 31, 2011.

[3] GDS Associates Inc. Measure Life Report, Residential and Commercial Industrial Lighting and HVAC Measures, June 2007.

[4] Jump, Corina, James J. Hirsch, James J. Hirsch and Associates, Jane S. Peters, Research Into Action, Inc., Dulane Moran, Research Into Action, Inc. “Welcome to the Dark Side: The Effect of Switching on CFL Measure Life,” 2008 ACEEE Summer Study Proceedings Paper, Panel 2, Paper 13, August 17, 2008.

[5] Nexus Market Research, Inc. (NMR). RLW Analytics, Inc. Residential Lighting Measure Life Study, Submitted to: New England Residential Lighting Program Sponsors, June 4, 2008.

[6] US Congress. Energy Independence and Security Act of 2007 (EISA), January 4, 2007.

Notes

[1] Based on Ref [4], Ref [2], and Ref [5]. References [4] and [2] present a CFL switching degradation factor (SDF) of 0.523 to calculate Effective Useful Life (EUL): EUL = Rated lifetime hours * SDF / (annual hours). Based on 2.8 hr/day from NMR 2009.

[2] General Service CFLs have been capped at 4 years to reflect measure persistence.

[3] Exterior fixture from Ref [5], Table 1-2, Page 1.

[4] LED Bulbs are rated at 25,000 hour life, but have been capped here to the fixture lifetime.

APPENDIX 5. HOURS OF USE

C&I Hours of Use and EFLH

Facility Type	Lighting Hours	Cooling FLHrs	Heating FLHrs	Fan Motor Hours	CHWP & Cooling Towers	Heating Pumps
Auto Related	4,056	837	1,171	4,056	1,878	6,000
Bakery	2,854	681	1,471	2,854	1,445	6,000
Banks, Financial Centers	3,748	797	1,248	3,748	1,767	6,000
Church	1,955	564	1,694	1,955	1,121	6,000
College - Cafeteria	6,376	1,139	594	6,376	2,713	6,000
College - Classes/Administrative	2,586	646	1,537	2,586	1,348	6,000
College - Dormitory	3,066	709	1,418	3,066	1,521	6,000
Commercial Condos	4,055	837	1,172	4,055	1,877	6,000
Convenience Stores	6,376	1,139	594	6,376	2,713	6,000
Convention Center	1,954	564	1,695	1,954	1,121	6,000
Court House	3,748	797	1,248	3,748	1,767	6,000
Dining: Bar Lounge/Leisure	4,182	854	1,140	4,182	1,923	6,000
Dining: Cafeteria / Fast Food	6,456	1,149	574	6,456	2,742	6,000
Dining: Family	4,182	854	1,140	4,182	1,923	6,000
Entertainment	1,952	564	1,695	1,952	1,120	6,000
Exercise Center	5,836	1,069	728	5,836	2,518	6,000
Fast Food Restaurants	6,376	1,139	594	6,376	2,713	6,000
Fire Station (Unmanned)	1,953	564	1,695	1,953	1,121	6,000
Food Stores	4,055	837	1,172	4,055	1,877	6,000
Gymnasium	2,586	646	1,537	2,586	1,348	6,000
Hospitals	7,674	1,308	270	7,674	3,180	6,000
Hospitals / Health Care	7,666	1,307	272	7,666	3,177	6,000
Industrial - 1 Shift	2,857	681	1,470	2,857	1,446	6,000
Industrial - 2 Shift	4,730	925	1,003	4,730	2,120	6,000
Industrial - 3 Shift	6,631	1,172	530	6,631	2,805	6,000
Laundromats	4,056	837	1,171	4,056	1,878	6,000
Library	3,748	797	1,248	3,748	1,767	6,000
Light Manufacturers	2,857	681	1,470	2,857	1,446	6,000
Lodging (Hotels/Motels)	3,064	708	1,418	3,064	1,521	6,000
Mall Concourse	4,833	938	978	4,833	2,157	6,000
Manufacturing Facility	2,857	681	1,470	2,857	1,446	6,000
Medical Offices	3,748	797	1,248	3,748	1,767	6,000
Motion Picture Theatre	1,954	564	1,695	1,954	1,121	6,000
Multi-Family (Common Areas)	7,665	1,306	273	7,665	3,177	6,000
Museum	3,748	797	1,248	3,748	1,767	6,000
Nursing Homes	5,840	1,069	727	5,840	2,520	6,000
Office (General Office Types)	3,748	797	1,248	3,748	1,767	6,000
Office/Retail	3,748	797	1,248	3,748	1,767	6,000
Parking Garages & Lots	4,368	878	1,094	4,368	1,990	6,000
Penitentiary	5,477	1,022	817	5,477	2,389	6,000
Performing Arts Theatre	2,586	646	1,537	2,586	1,348	6,000
Police / Fire Stations (24 Hr)	7,665	1,306	273	7,665	3,177	6,000
Post Office	3,748	797	1,248	3,748	1,767	6,000
Pump Stations	1,949	563	1,696	1,949	1,119	6,000
Refrigerated Warehouse	2,602	648	1,533	2,602	1,354	6,000
Religious Building	1,955	564	1,694	1,955	1,121	6,000

Facility Type	Lighting Hours	Cooling FLHrs	Heating FLHrs	Fan Motor Hours	CHWP & Cooling Towers	Heating Pumps
Residential (Except Nursing Homes)	3,066	709	1,418	3,066	1,521	6,000
Restaurants	4,182	854	1,140	4,182	1,923	6,000
Retail	4,057	837	1,171	4,057	1,878	6,000
School / University	2,187	594	1,637	2,187	1,205	6,000
Schools (Jr./Sr. High)	2,187	594	1,637	2,187	1,205	6,000
Schools (Preschool/Elementary)	2,187	594	1,637	2,187	1,205	6,000
Schools (Technical/Vocational)	2,187	594	1,637	2,187	1,205	6,000
Small Services	3,750	798	1,247	3,750	1,768	6,000
Sports Arena	1,954	564	1,695	1,954	1,121	6,000
Town Hall	3,748	797	1,248	3,748	1,767	6,000
Transportation	6,456	1,149	574	6,456	2,742	6,000
Warehouse (Not Refrigerated)	2,602	648	1,533	2,602	1,354	6,000
Waste Water Treatment Plant	6,631	1,172	530	6,631	2,805	6,000
Workshop	3,750	798	1,247	3,750	1,768	6,000

References

[1] "CT & MA Utilities 2004-2005 Lighting Hours of Use for School Buildings Baseline Study", Final Report, September 7, 2006, by RWL Analytics.

APPENDIX 6. NOMENCLATURE

Abbreviations/Acronyms

Symbol	Description (See Note [1])	Units
A	Amperage (of fan)	Amps
A	Area	Ft^2, in^2
AA	Hartford kWh savings factor from pilot	kWh/ 1000 Btu
ABTU	Annual Btu Savings	Btu/yr
AC	Air Conditioning	
AC	Annual Cooling Energy Usage	kWh/yr
ACCF	Annual Natural Gas Energy Savings	Ccf/yr
ACOP	Average Coefficient of Performance	
ADET	Annual Differential Electrical energy savings per Ton	kWh/Ton /yr
ADHW	Annual domestic water heating load	Btu/yr
AEC	Annual Electric Cooling Usage per sq ft	kWh/ft^2/ yr
AEH	Annual Electric Heating Usage per sq ft	kWh/ft^2/ yr
AF/BI	Air foil / backward inclined fan	
AFUE	Annual Fuel Utilization Efficiency	
AGU	Annual Gas Usage per sq ft	Ccf/ ft^2/yr
AH	Annual heating energy usage	kWh/yr
AKW	Average hourly demand savings for both summer and winter	
AKWH	Annual gross electric energy savings	kWh/yr
AOG	Annual Oil Savings	Gallon/yr
AOU	Annual Oil Usage per sq ft	gal/ft^2/yr
APG	Annual Propane Savings	Gallon/yr
APU	Annual Propane Usage per sq ft	gal/ft^2/yr
ASF	Annual Savings Factor	kWh/ton
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers	
AV	Adjusted Volume	ft^3
BB	Hartford kW savings factor from pilot	kW/ 1000 Btu
BCR	Benefit Cost Ratio	
BER	Total Annual Clothes Washer Btu Equivalent energy Reduction	Btu/yr
BHP	Brake Horsepower (motor load)	
BI	Backward Incline (Fan)	
BIY	Baseline Implementation Year	
BTU	British Thermal Unit	BTU
BTUH	Heat Transfer rate of ducting	Btu/hr/ 100 ft^2
C&I	Commercial and Industrial	

Symbol	Description (See Note [1])	Units
C&LM	Conservation And Load Management	
CAC	Central Air Conditioning	
CAP	Capacity of the Equipment	BTU/h or Ton
CC	Bridgeport kWh savings factor from pilot	kWh/ 1000 Btu
Ccf, CCF	100 Cubic Feet, quantity of natural gas	100 Cubic Feet
CDD	Cooling Degree Days for CT	603
CEEF	Connecticut Energy Efficiency Fund	
CF	Seasonal Coincidence Factor	
CFL	Compact Florescent Light	
CFM	Cubic Feet per Minute, Air Flow rate	ft^3/min
CHWP	Chilled Water Pump	
CL&P	Connecticut Light and Power	
COP	Coefficient of Performance	
CWP	Condenser Water Pump	
d	Duration	minutes
D	Density	lb/Gal
D	Dimension (height or width)	inches
Days	Annual Days of use	Days/yr
DD	Bridgeport kW savings factor from pilot	kW/ 1000 Btu
DEEP	Department of Energy and Environmental Protection	
DHW	Domestic Hot Water	
DHWH	Domestic Hot Water Heater	
DI	Annual savings per sq ft of duct insulation	
DOE-2	Computer Energy Simulation Tool	
DP	Power Reduction Factor	%
DP	Drying Proportion of clothes washer energy	%
DPUC	Department of Public Utility Control	
DRIPE	Demand Reduction-Induced Price Effects	
DSF	Seasonal Demand Savings Factor	kW/ton
E	Energy use rate	
ECM	Electronically Commutated Motor	
EE	Efficiency conversion factor	
EEB	Energy Efficiency Board	
EER	Energy Efficiency Ratio	

Symbol	Description (See Note [1])	Units
EF	Energy Factor (Dehumidifier, Water Heater)	L/kWh, %
EF	Efficiency Factor	
EF	Heating System Efficiency	
EFF	Rated Motor Efficiency	
EFLH	Equivalent Full Load Hours	hours
EKWH	Estimated Annual electric usage with increase in production	
EUL	Effective Useful Life	years
F	Fraction of lighting heat affecting cooling	
F	Factor	various
FC	Forward Curved Fan	
FCM	Forward Capacity Market	
FHLE	Fryer Heavy Load Efficiency	
FIR	Fryer Idle Energy Rate	Btu/hr
FLH	Annual Full Load Hours	Hr/yr
FPC	Fryer Production Capacity	Lbs/hr
FPE	Fryer Preheat Energy	Btu
FR	Free-rider	
ACCF	Annual Gas Savings	Ccf/yr
G	Estimated lighting energy heat to space based on modeling	
GPH	Average Peak Gallons per hour	Gal/hr
gpm	Gallons Per Minute	
GPY	Gallons (of water) per year	Gal/yr
GSHP	Ground Source Heat Pump	
H, h	hours (annual or daily)	hours
HAP	Computer Energy Simulation Tool	
HDD	Heating Degree Days for CT	°F
HF	Heating Factor	Btu/ft^2/yr
HL	Heat loss savings per linear foot	Btu/hr/ft
HP	Horsepower (nameplate)	
HPWH	Heat Pump Water Heater	
HR	Ice Harvest Rate for ice-cube machines	
HR	Annual Electric Energy Usage Dependent on hours of Production	kWh/yr
HR	Percent heating not using backup electric resistance	%
Hrs	Operating hours per day	Hr/day
HSPF	Heating Seasonal Performance Factor	
HVAC	Heating, Ventilation, and Air Conditioning	
HWP	Hot Water Pump	
IGV	Inlet Guide Vane fan control	
IND	Annual Electric Energy Usage Independent of Production	kWh/yr
IPLV	Integrated Part Load Value	EER or kW/ton
ISO-NE	Independent System Operator New England	

Symbol	Description (See Note [1])	Units
kW	Electric Demand, kiloWatts	1,000 Watts
kW	Fixture Input kW, total rated power usage of lighting fixtures	kW
kWh	Kilowatt Hour	kWh
KWH	Annual Electric Energy Usage	kWh/yr
KWHSF	Annual kWh savings factor based on typical load profile for application	
lbs	Pounds (Weight)	lbs
L	Ballast Location Factor	
LBS	Pounds of food cooked per day	Lbs/day
LKWH	Lifetime kWh Savings	kWh
LI	Limited Income sector	
LN	Natural Log	
LO	Lost Opportunity	
Load	Peak Heating load on the gas boiler or furnace	Btu/hr
LPD	Lighting Power Density	Watts/ ft^2
M&V	Measurement and Verification	
MBH	Thousands of Btus per hour	1000 Btu/hr
MEF	Clothes Washer Modified Energy Factor	ft^3/kWh/ cycle
MMBTU	One Million of British Thermal Units	1,000,00 0 BTU
MP	Machine Proportion of clothes washer energy	%
MW	Megawatt a unit of electric demand equal 1000 Kilo-Watt	
N	Production Rate	
N	Number of…	
n	Fixture number	
NAAQS	National Ambient Air Quality Standards	
NLI	Non-Low Income sector	
Nr	Nameplate Rating of baseboard electric resistance heat	kW
O	Quantity of fixtures that have occupancy sensors	
OHLE	Oven Heavy Load Efficiency	%
OIR	Oven Idle Energy Rate	Btu/h
OPC	Oven Production Capacity	Lbs/h
OPE	Oven Preheat Energy	Btu
O&M	Operation and Maintenance	
P	Heating Penalty and Recovery adjustment	%
P	Potato Production Capacity	Lbs/h
PAA	Percent of facilities' energy use effected by PRIME	
PD	Peak Day savings for Gas measures	CcF
PD	Annual electric energy usage dependent on production quantity	kWh/yr
PDF	Peak Day Factor (Gas)	
PDHW	Peak hour hot water load	Btu

Symbol	Description (See Note [1])	Units
PF	Peak Factor	kW/kWh
Pf	Power factor	
PkW	kW demand savings	kW
PSC	Permanent Split Capacitor	
PSD	Program Savings Documentation	
PTAC	Package Terminal Air Conditioner	
PTHP	Package Terminal Heat Pump	
r	Climate Adjustment Ratio	
R	R value is a measure of thermal resistance	ft^2 x h x ^{0}F / BTU
Ratio	Ratio of heating capacity to cooling capacity	
REM	Residential Energy Modeling software or results	
RNC	Residential New Construction sector	
RP	Retail Products sector	
RTU	Roof Top Unit	
RUL	Remaining Useful Life	Years
S	Savings	varies
S	C&I Lighting annual kWh savings	kWh
SA	Seasonal efficiency adjustment	%
Savings Fraction	Fraction of base-case consumption saved with low-intensity radiant heaters.	
SAWC	Steamer Average Water Consumption Rate	Gal/h
SEER	Seasonal Energy Efficiency Ratio	
SF	Area	Square Feet
SF	Savings Factor	
SHLE	Steamer Heavy Load Efficiency	%
SIR	Steamer Idle Energy Rate	Btu/h
size	Capacity (Volume)	ft^3, pints/day
SKF	Summer Factor	kW/ft^2
SKW	Seasonal Summer Peak Summer Demand Savings	kW
Sleeve	Unit without louvered sides	
SLR	Standby Loss Rate	Btu/hr

Symbol	Description (See Note [1])	Units
SMB	Small Business	
SO	Spill-over	
SPC	Steamer Production Capacity	Lbs/h
SPCS	Steamer Percent of time in Constant Steam mode	%
SPE	Steamer Preheat Energy	Btu
T	Temperature	°F
TON	Capacity of the Equipment, Tons	12,000 BTU/h
TRACE	Computer Energy Simulation Tool	
UDRH	User defined reference home	
UI	United Illuminating	
V	Volts of existing fans	Volts
V	Volume	ft^3
VAV	Variable Air Volume	
VFD	Variable Frequency Drives	
W	Width	ft
Watt, W	Wattage	Watt
$Watt_{\Delta}$	Delta Watts	
WCS	Electric Cooling energy savings from Wisconsin study	kWh
WF	Water Factor	Gal/ft^3
WH	Water Heater, Water Heating	
WHS	Electric Heating energy savings from Wisconsin study	
WICDD	Cooling Degree Days for WI	
WIHDD	Heating Degree Days for WI	
Window	Unit with louvered sides	
WKW	Seasonal Winter Peak Demand Savings	kW
WP	Water Heating Proportion of clothes washer energy	%
WPF	Winter Peak Factor	W/kWh
WSHP	Water Source Heat Pump	
YR	Year	
ΔkW	Reduction in power for each light	kW
ΔT	Delta (or Differential) Temperature	°F
ηb	base case efficiency	
ηp	proposed case efficiency	

Notes

[1] Many of these terms have more complete definitions in the Glossary section.

Subscripts

Symbol	Description (See Note [1])	Units
$\ldots_{A}$	Actual/installed Unit	
$\ldots_{a}$	After PRIME	
$\ldots_{b}$	Baseline Unit	
$\ldots_{BD}$	Blower Door flow rate reading performed at 50 Pa	Cubic Feet per Minute
$\ldots_{Bin}$	Temperature BIN hours	
$\ldots_{C}$	Cooling	
$\ldots_{CDH}$	From CDH HVAC study	
$\ldots_{d}$	number of hours that piece of equipment is expected to operate per Day	h
$\ldots_{\Delta}$	Delta	
$\ldots_{dp}$	Double pane window	
$\ldots_{door\ kit}$	Door kit, Door sweep	
$\ldots_{DS}$	Duct Sealing flow rate reading performed at 25 Pa	Cubic Feet per Minute
$\ldots_{E}$	Electric energy	
$\ldots_{e}$	Existing (unit, production rate, etc)	
$\ldots_{es}$	Energy Star	
$\ldots_{ES\ 09}$	Energy Star 2009 unit	
$\ldots_{fed\ std}$	Federal Standard unit	
$\ldots_{G}$	Natural Gas	
$\ldots_{gasket}$	Air sealing gasket	
$\ldots_{h}$	Based on billing history	
$\ldots_{H}$	Heating	
$\ldots_{HP}$	Heat Pump	
$\ldots_{HVAC}$	HVAC motor	
$\ldots_{hw}$	Hard Wired light fixtures	
$\ldots_{i}$	incoming	
$\ldots_{i}$	Installed Unit	
$\ldots_{ic}$	Interactive Cooling	
$\ldots_{L}$	Lighting	
$\ldots_{LI}$	Low Income sector	

Symbol	Description (See Note [1])	Units
$\ldots_{LO}$	Lost Opportunity measure	
$\ldots_{lpd}$	Lighting Power Density	
$\ldots_{lt}$	Life Time	
$\ldots_{M}$	Motors	
$\ldots_{N}$	Non-HVAC applications	
$\ldots_{NLI}$	Non-Low Income sector	
$\ldots_{O}$	Oil	
$\ldots_{O}$	Others	
$\ldots_{os}$	Occupancy Sensors	
$\ldots_{P}$	Process	
$\ldots_{P}$	Propane	
$\ldots_{post}$	Final Reading	
$\ldots_{pre}$	Initial Reading	
$\ldots_{R}$	Electric Resistance	
$\ldots_{R}$	Refrigeration	
$\ldots_{ratio}$	Ratio between low efficiency value and high efficiency value	
$\ldots_{retire}$	Retirement portion	
$\ldots_{retro}$	Retrofit portion	
$\ldots_{retrofit}$	Retrofit portion	
$\ldots_{S}$	Summer	
$\ldots_{sealing}$	Caulking, sealing, polyethylene tape	foot
$\ldots_{total}$	Total, Sum	
$\ldots_{W}$	Water Heating	
$\ldots_{wop}$	Without PRIME	
$\ldots_{wp}$	With PRIME	
$\ldots_{wt}$	Winter	
$\ldots_{wx}$	Weatherstrip, repair	
$\ldots_{y}$	number of hours that piece of equipment is expected to operate per Year	h