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Connecticut Program Savings Document

12th Edition for 2017 Program Year

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INTRODUCTION

1.1 PURPOSE

Purpose

This Program Savings Documentation (PSD) manual provides detailed, comprehensive documentation of resource and non-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 Connecticut 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 Eversource Energy ("Eversource") of Connecticut, The United Illuminating Company ("UI"), Connecticut Natural Gas Corporation ("CNG") and The Southern Connecticut Gas Company ("SCG"), 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 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 funded measures that qualify for Class III credits. As a result, C&LM and non-C&LM funded 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 established 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. ("ISO-NE"), 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"), Eversuorce and UI submitted new demand side resource projects, including energy efficiency, that will decrease electric demand. 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 PSD provides 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:

- Section 1: Introduction
- Section 2: Commercial & Industrial Lost Opportunity
- Section 3: Commercial & Industrial Retrofit
- Section 4: Residential including Limited Income
- Appendices

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

- **Description of Measure** – describes the scope and basics of the measure
- **Savings Methodology** – lists the methods, reasoning, and tools used to perform calculations
- **Inputs** – captures required project or measure data that is used in calculations
- **Nomenclature** – captures variables, constants, and other terminology used in the measure
- **Retrofit Gross Energy Savings – Electric** – describes the calculations used to determine electric gross Energy savings
- **Retrofit Gross Energy Savings – Fossil Fuel** – describes the calculations used to determine fossil fuel gross energy savings
- **Retrofit Gross Seasonal Peak Demand Savings – Electric (Winter and Summer)** – describes the calculations used to determine gross peak electric demand savings
- **Retrofit Gross Peak Day Savings – Natural Gas** – describes the calculations used to determine gross peak gas demand savings
- **Lost Opportunity Gross Energy Savings – Electric** – describes the calculations used to determine gross lost opportunity electric savings
- **Lost Opportunity Gross Energy Savings – Fossil Fuel** – describes the calculations used to determine gross lost opportunity fossil fuel savings
- **Lost Opportunity Gross Seasonal Peak Demand Savings – Electric (Winter and Summer)** – describes the calculations used to determine gross lost opportunity seasonal peak electric demand savings
- **Lost Opportunity Gross Peak Day Savings – Natural Gas** – describes the calculations used to determine gross peak gas lost opportunity savings
- **Non Energy Benefits** – describes any benefits not directly associated with energy savings
- **Changes from Last Version** – if there are any changes from the previous version, they are described in this section
- **References** – sources used to construct the measure are listed here
- **Notes** – relevant comments and information is presented in this section

Subsections that do not apply to a particular measure are not included.

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 the CompaniesThese 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 to 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.energizect.com
Eversource Energy	www.Eversource.com
The United Illuminating Company:	www.uinet.com
Connecticut Natural Gas Corporation:	www.cngcorp.com
Southern Connecticut Gas Company:	www.soconngas.com
The Energy Efficiency Board:	http://www.ctsavesenergy.org/ecmb/

1.4 SAVINGS CALCULATIONS

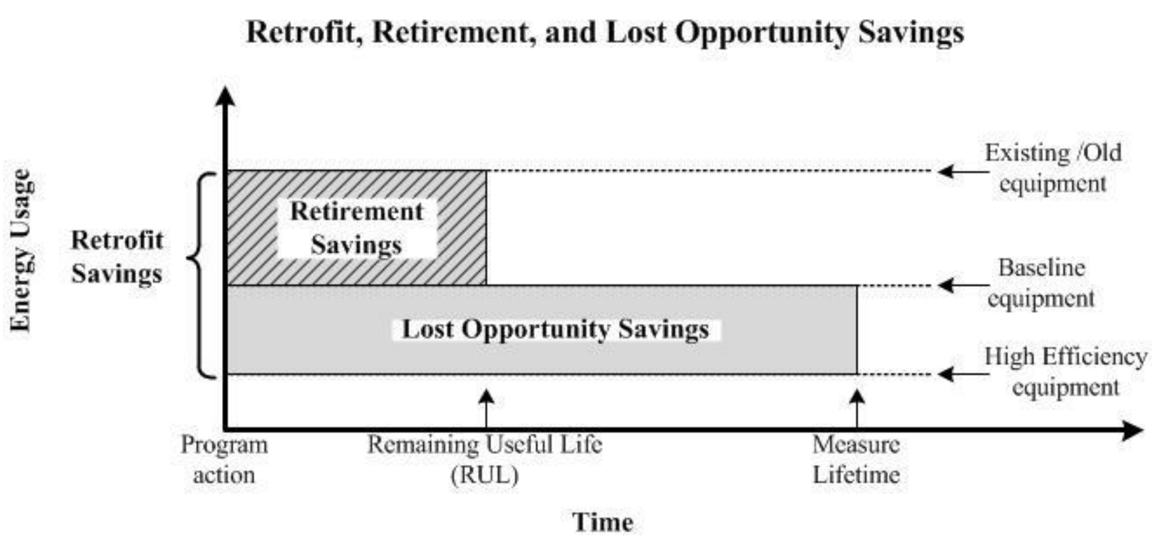
Consistent with Public Act 13-298, Public Act 11-80 S 33, and Connecticut General Statutes section 16-245m(d)(4),the Energy Efficiency Board Evaluation Road Map Process provides a mechanism to conduct independent third party evaluation studies to assess program savings. Through this process, impact evaluations are conducted to evaluate savings for programs or measures that are delivered through C&LM programs. The results of these evaluations are incorporated into the PSD. The results of evaluations may result in changes to savings algorithms in the PSD and/or may results in realization rates which are used to adjust savings.

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 assign the proper value of energy savings resulting from the implementation of C&LM measures to the corresponding time of day when those savings are realized.

Types of Savings

Energy efficiency measures are generally limited to two types:

- Replacement or "Retirement" of less efficient measures with a baseline or standard measures
- "Lost Opportunity", where measures are installed that are more efficient than a baseline or standard
  Many energy efficiency measures consist of both a retirement component and a lost opportunity component. This is illustrated by the chart below:



Some measures may utilize a two-part lifetime savings calculation. 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. For example, a working heating system may be retired prior the end of its useful life as a result of program intervention.

Lost opportunity lifetimes apply to the portion of savings resulting from choosing a high efficiency product to replace the retired product over a standard efficiency product available on the market. If the retired heating system in the above example were replaced with a high efficiency model (versus a standard baseline model) generating additional savings, it would result in lost opportunity savings.

If the retirement life is much greater than zero, the retirement and lost opportunity savings are combined to generate total Retrofit savings. When the retirement life is approximately zero, savings are reduced to lost opportunity savings only. Retirement savings are acknowledged to exist but are ignored because they are assumed to be short lived.

Peak Savings

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.)

Non-Electric Benefits

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.

Savings Adjustment Factors

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:

$$Net\ Savings = Gross\ Savings \times (1 + spillover - free\ ridership) \times Installation\ Rate$$

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. Appendix 3 contains a list of program specific realization rates. These rates have been updated from 2014 based on recent completed studies.

Common Energy Conversions

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

Energy Conversion Factors

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	MMBtu	1/0.003412
kWh Electric	Btu	1/3412
Ton (air conditioning)	Btu/h	1/12000

1.5 MAJOR CHANGES FROM 2016

See individual measure "Changes from Last Version" sections for details.

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 thermal efficiency measure of combustion equipment like furnaces and boilers. The AFUE differs from the true 'thermal efficiency' in that it is not a steady-state, peak measure of conversion efficiency, but instead attempts to represent the actual, season-long, average efficiency of that piece of equipment, including the operating transients. The method for determining the AFUE for equipment is based on ASHRAE standards.

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 Conservation: Programs that encourage customer strategies to conserve energy through changes, modifications to standard practice, or changes or modifications to customer behavior.

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 or refer to Chapter 6 of the C&LM Plan for details regarding BCR tests*.

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 hour or Tons.

CcF: 100 Cubic feet of gas; used to measure a quantity of natural gas.

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): A bulb technology that uses significantly less energy than traditional incandescent bulbs. CFLs may be classified as either General Service or Non-General Service Bulbs. *See General Service Bulb & Non-General Service Bulb*.

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 instantaneous power required by 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 measures cooling energy demand, indicates 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.

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 resulting from conservation efforts.

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

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 program costs of achieving the savings. The electric system test is a 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.

Emissions: The release or discharge of an air pollutant into the ambient air from any source. Please refer to Connecticut regulations section 22a-174-1 for further clarification. Emissions reductions for fossil fuel conservation can be estimated based on US Energy Information Administration emissions data for fossil fuels. Emissions reductions for electric conservation can be estimated using ISO New England marginal emissions factors which are published annually.

Emittance: The ratio of the radiant heat flux emitted by a specimen to that emitted by a blackbody at the same temperature and under the same conditions.

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: Energy or peak reduction resulting from changes in customer behavior(s) or program actions.

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 in the absence of a C&LM program.

General Service Bulb: General Service bulbs 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. Please note that Dimmable bulbs may be either General Service or Non-General Service bulbs. *See Non-General Service Bulb for exclusions*.

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 Btu) 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.

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, primary end-use categories include cooling, heating, lighting, refrigeration, water heating, motors, process, 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-General Service Bulb: Non-General Service CFL applications are excluded from the Energy Independence and Security Act of 2007. Listed below are all of the applications that are excluded.

- Reflector bulbs
- 3-way bulbs
- Candelabra based bulbs
- G type (globe) bulbs
- Appliance bulbs
- Black light bulbs
- Bug bulbs
- Colored bulbs
- Infrared bulbs
- Left-hand thread bulbs
- Marine bulbs
- Marine signal service bulb
- Mine service bulb
- Plant light bulb
- Rough service bulb
- Shatter-resistant/proof/protected bulb
- Sign service bulb
- Silver bowl bulb
- Showcase bulb
- Traffic signal bulb
- Vibration service bulb
- T-shape bulb
- B,BA,CA,F,G16-1/2,G-25,G30,S,M-14 bulbs

Please note that Dimmable bulbs may be either General Service or Non-General Service bulbs. *Contrast General Service Bulb*.

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.

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. 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 retrofits measure’s effective useful life (EUL). *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 Btu 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 influenced by 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

Installation of interior and/or exterior lighting which exceeds current energy code baseline

Savings Methodology

Interior lighting: The difference between installed lighting and code lighting power density (LPD, watts per square foot) for the facility is used to estimate energy and seasonal peak demand savings. In addition to the savings from reduction in power density, savings are also calculated for installation of occupancy sensors and residential fixtures as applicable (Note [1]). Reduction of lighting power reduces the cooling load and provides additional savings, which are also calculated in this measure. This measure includes baseline lighting power densities based on 2012 IECC Standard Section C405 and Additional Efficiency Section C406. If projects are initiated after the new code adoption then 2012 IECC is the default used to evaluate the energy savings. Code requires lighting controls for buildings over 5,000 square feet. Therefore, occupancy sensor savings are only calculated if buildings >5,000 square feet have occupancy sensors in addition to the code required scheduled lighting control.

Exterior lighting: The default baseline for exterior lighting is ASHRAE 90.1 – 2010 (equivalent to ASHRAE 2007). According to the ASHRAE code, the total lighting power allowance for exterior building applications is the sum of the base site allowance plus the individual allowances for areas listed in Table 3 for the applicable lighting zone. Trade-offs are allowed only among exterior lighting applications listed in the Table 3.

Inputs

Symbol	**Description**	**Units**
Allowable LPD	Allowable LPD from IECC 2012	Watts/ft^2
	Total fixture connected kW	kW
	Facility illuminated area	ft^2

Nomenclature

Item	**Description**	**Units**	**Values**	**Comments**
A	Facility illuminated area	ft^2		
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		4.5	Note [3]
$DeltaW_{hw}$	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		0.73	Note [4]
H	Facility lighting hours of use	Hours		Site Specific or Appendix 5

Item	Description	Units	Values	Comments
HVAC	Heating, Ventilation and Air Conditioning			
kW	Electric Demand	kW		
LPD	Lighting Power Density	Watts/ft^2		
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		
S_{os}	Energy savings from use of occupancy sensors, if applicable	kWh		
S_{ext}	Exterior Energy Savings	kWh		
W	Fixture input wattage	Watt		
W_n	Input watts for fixture type n			

Lost Opportunity Gross Energy Savings, Electric

Interior Lighting:

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

Calculation of savings due to lower lighting power density

$$S_{lpd} = (Allowable\ LPD - Actual\,LPD) \times H \times A$$

Allowable LPD, in W/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 IECC are provided in the table below. Refer to IECC 2012for the space-by-space method. When using the space-by-space method to calculate the LPD, an increase in the spaces' power allowances can be used, in accordance with IECC 2012 405.5.2(2)
Actual LPD, in kW/ft^2, is calculated by dividing the total Fixture Wattage by the Lighted Area, ft^2, where Fixture Wattage is the sum of the power consumed by each fixture.

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

Calculation of savings due to occupancy sensors (Note [5])

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 fraction due to the use of occupancy sensors. See Ref [1].

1000 converts watts to kW (1/1000 is the conversion)

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

Refer to PSD Section 4.1.2 “Luminaire” 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 to remove excess heat produced by the new lighting fixtures. This is due to the reduced cooling required as the result of putting the new lighting in place.

S_C = savings resulting from reduced cooling

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

F = Fraction of annual kWh energy savings that must be removed by the cooling system. If the HVAC system includes an economizer, then F = 0.35. Otherwise, use Table 1 below:

COP = 4.5 (Note: [3])

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

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

Table 2: Lighting Power Densities Using the Building Area Method – IECC 2012 Standard Section C405.5.2(1) (Ref [3])

Building Area Type (see note [2])	Lighting Power Density (W/ft^2)
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
Fire Station	0.8
Gymnasium	1.1
Health care Clinic	1.0
Hospital	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	0.9
Parking Garage	0.3
Penitentiary	1.0
Performing Arts Theatre	1.6
Police station	1.0
Post Office	1.1
Religious Building	1.3
Retail	1.4
School/University	1.2
Sports Arena	1.1
Town Hall	1.1
Transportation	1.0
Warehouse	0.6
Workshop	1.4

Table 2A: Lighting Power Densities Using the Building Area Method – IECC 2012 Section C406.3 Additional Efficiency Options (Ref [6])

Building Area Type[a] (see note [2])	Lighting Power Density (W/ft^2)
Automotive Facility	0.82
Convention Center	1.08
Court House	1.05
Dining: Bar Lounge/Leisure	0.99
Dining: Cafeteria/Fast Food	0.90
Dining: Family	0.89
Dormitory	0.61
Exercise Center	0.88
Fire Station	0.71
Gymnasium	1.00
Healthcare-Clinic	0.87
Hospital	1.10
Library	1.18
Manufacturing Facility	1.11
Hotel/Motel	0.88
Motion Picture Theatre	0.83
Multi-Family	0.60
Museum	1.06
Office	0.90/0.85[b]
Parking Garage	-
Penitentiary	-
Performing Arts Theatre	1.39
Police/Fire Station	0.96
Post Office	0.87
Religious Building	1.05
Retail	1.40/1.30[b]
School/University	0.99
Sports Arena	0.78
Town Hall	0.92
Transportation	0.77
Warehouse[c]	0.6
Workshop	1.20

a. In cases where both a general building area type and a more specific building area type are listed, the more specific building area type shall apply.
b. First LPD value applies if no less than 30 percent of conditioned floor area is in daylight zones. Automatic daylighting controls shall be installed in daylight zones and shall meet the requirements of Section C405.2.2.3. In all other cases, second LPD value applies.
c. No less than 70 percent of the floor area shall be in the daylight zone. Automatic daylighting controls shall be installed in daylight zones and shall meet the requirements of Section C405.2.2.3.

Exterior Lighting:

Calculation of savings due to lower lighting power

$$S_{ext} = (W_{ALLOWANCE} - W_{ACTUAL}) / 1000 \times H$$

Watts allowance is determined from table 3.

H = Hours of Use.

Table 3 – Exterior Lighting Power Allowances (Ref [5])

				Power Allowance			
	Category	**Space**	**Units**	**Zone 1**	**Zone 2**	**Zone 3**	**Zone 4**
Base Site Allowance			W	500	600	750	1300
Tradable Surfaces	Uncovered Parking Areas	Parking areas and drives	W/ft^2	0.04	0.06	0.10	0.13
	Building Grounds	Walkways less than 10 feet wide	W/Linear foot	0.70	0.70	0.80	1.00
	Building Grounds	Walkways 10 feet wide or greater	W/ft^2	0.14	0.14	0.16	0.20
	Building Grounds	Plaza areas	W/ft^2	0.14	0.14	0.16	0.20
	Building Grounds	Special feature areas	W/ft^2	0.14	0.14	0.16	0.20
	Building Grounds	Stairways	W/ft^2	0.75	1.00	1.00	1.00
	Building Grounds	Pedestrian tunnels	W/ft^2	0.15	0.15	0.20	0.30
	Building Grounds	Landscaping	W/ft^2	0.04	0.05	0.05	0.05
	Building Entrances and Exits	Main entries	W/Linear foot (door width)	20.00	20.00	30.00	30.00
	Building Entrances and Exits	Other doors	W/Linear foot (door width)	20.00	20.00	20.00	20.00
	Building Entrances and Exits	Entry canopies	W/ft^2	0.25	0.25	0.40	0.40
	Sales Canopies	Canopies (free standing and attached)	W/ft^2	0.60	0.60	0.80	1.00
	Outdoor Sales	Open areas (including vehicle sales lots)	W/ft^2	0.25	0.25	0.50	0.70
	Outdoor Sales	Street frontage for vehicle sales lots in addition to "open area" allowance	W/Linear foot	-	10.00	10.00	30.00

Table 3 – Exterior Lighting Power Allowances (Continued) (Ref [5])

	Category	Space	Units	Power Allowance Zone 1	Zone 2	Zone 3	Zone 4
Non-Tradable Surfaces	Building facades-ft^2 allowance		W/ft^2	-	0.10	0.15	0.20
	Building facades-Linear foot allowance		W/Linear foot for each illuminated wall or surface length	-	2.50	3.75	5.00
	Automated teller machines and night depositories		W per location	270 plus 90 W per add ATM	270 plus 90 W per add ATM	270 plus 90 W per add ATM	270 plus 90 W per add ATM
	Entrances and gatehouse inspection stations at guarded facilities		W/ft^2 of covered and uncovered area	0.75	0.75	0.75	0.75
	Loading areas for law enforcement, fire, ambulance and other emergency vehicles		W/ft^2 of covered and uncovered area	0.50	0.50	0.50	0.50
	Drive-up windows/doors		W/drive-through	400	400	400	400
	Parking near 24 hour retail entrances		W/main entry	800	800	800	800

Lost Opportunity Gross Energy Savings, Fossil Fuel

Space heating energy consumption will increase due to reduced lighting load (cooler lighting fixtures).

Annual Oil Savings = -0.0007129 MMBtu per annual kWh saved and
Annual gas savings = -0.0003649 MMBtu per kWh. See Ref [4].

Note: No heating penalties are claimed in exterior lighting installation.

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

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

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

CF_L and **CF_{os}** are the lighting (CF_L) and occupancy sensor (CF_{OS}) coincidence factors (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.

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

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

G = 0.73

COP = 4.5 Note [3]

Exterior Lighting Demand Savings:

$$SKW = (W_{ALLOWANCE} - W_{ACTUAL})/1000 \times CFs$$

$$WKW = (W_{ALLOWANCE} - W_{ACTUAL})/1000 \times CFw$$

Changes from Last Version

Added text in measure description to take into account any anticipated energy code changes in Connecticut. Additionally, inserted Table 2A, lighting power density (LPD) using building are method based on IECC 2012.

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 Sc and the derivation of the values for F is from "Calculating Lighting and HVAC Interactions," ASHRAE Journal 11-93 as used by KCPL.

[3] 2012 International Energy Conservation Code (IECC), Table C405.5.2(1) Interior Lighting Power Allowances: Building Area Method.

[4] Massachusetts Technical Reference Manual, 2012 Program Year, page 163.

[5] ASHRAE 90.1-2007 and ASHRAE 90.1 2010, Table 9.4.6: Individual Lighting Power Allowances for Building Exteriors.

[6] International Energy Conservation Code (IECC), Table C406.3 Reduced Interior Lighting Power.

Notes

[1] If sensors are installed, the heat emitted from lighting affected by this measure will decrease due to lower lighting power and use. 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.

[3] Estimated based on Connecticut Code 2009. Not updated for 2012, negligible difference between 2009 Code and 2012.

[4] An analysis was conducted by Wood, Byk, and Associates, 829 Meadowview Road, Kennett Square, PA 19348, an engineering firm which was utilized to provide technical support for C&LM programs. The analysis was based on a DOE-2 default analysis and information was provided to Eversource engineering staff on August 17, 2007.

[5] IECC-2012 requires certain space types to have occupancy sensors. Savings for these occupancy sensors required by code therefore cannot be claimed. Refer to IECC C405.2.2.2 for details.

2.1.2 UPSTREAM LIGHTING

Description of Measure

This section describes the savings methodology for lighting technologies (linear fluorescent lamps and LEDs) incentivized through an upstream model.

Savings Methodology

The savings methodology was developed through a collaborative approach between Eversource Energy and the United Illuminating Company. The estimated savings (i.e. delta watts) was based on the Bright Opportunities Program, an upstream lighting initiative, in Massachusetts (Ref [1]). The final annual energy savings (i.e. kWh) was modified to suit Connecticut program rules. All lighting products should be either ENERGY STAR (Ref [3]), Design Lights Consortium (DLC) (Ref [4])or CEE qualified (Ref [2]).

Inputs

Symbol	Description	Units
	No. of units sold at the point of sale	
	Product type	

Nomenclature

Item	Description	Units	Values	Comments
AKWH	Annual energy savings	kWh		
B	Delta Watts	Watts	Table 1	
SKW	Summer demand savings	kW		
WKW	Winter demand savings	kW		
CF_S	Summer lighting coincidence factor			Appendix 1
CF_W	Winter lighting coincidence factor			Appendix 1

Lost Opportunity Gross Energy Savings, Electric

Table 1: Annual Savings and Usage Data for Bulbs

Product Type A	Delta Watts per Bulb (Notes [2]) B	Hours (Notes [1][3]) C	Annual Savings per Bulb (kWh) D = B x C/1000
LED A-line 40/60W	35.0	3,748.0	131.0
LED A-line 75/100W	53.4	3,748.0	200.3
LED Decorative	21.1	3,748.0	79.1
LED Downlight kit	40.7	3,748.0	152.5
LED MR16	23.4	3,748.0	87.7
LED PAR20	29.8	3,748.0	111.7
LED PAR30	40.4	3,748.0	151.4
LED PAR38	46.8	3,748.0	175.4
Stairwell LED Kit, low-output with sensor	24.0	6132.0	147.0
Stairwell LED Kit, mid-output with sensor	50.0	6,132.0	306.0
T5HO	4.0	3,748.0	15.0
T8 - 25	6.2	3,748.0	23.2
T8 - 28	3.5	3,748.0	13.1
T8 LED, 2 ft	6.7	3,748.0	25
T8 LED, 4ft	11.0	3,748.0	41
T8-25 U Bend	6.2	3,748.0	23.2
T8-28 U bend	3.5	3,748.0	13.1
LED 2X2 Troffer	34	3,748.0	127
LED 2X4 Troffer	57.8	3,748.0	217
LED BR30	55.6	3,748.0	208
LED BR40	74.3	3,748.0	279
LED Decorative	32.1	3,748.0	120
LED Downlight	56.5	3,748.0	212
LED Flood	162.2	3,748.0	608
LED Highbay	135.2	3,748.0	507
LED Spot	49.2	3,748.0	185
LED Surface/Wrap LED	27.5	3,748.0	103
LED Track Head	41	3,748.0	154
LED Wallpack	136.7	3,748.0	512

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

$$SKW = \frac{B \times CF_S}{1{,}000}$$

$$WKW = \frac{B \times CF_W}{1{,}000}$$

<u>Lost Opportunity Gross Seasonal Peak Demand Savings, Example</u>

A MR16 LED bulb is sold at retail and incentivized through the Upstream Lighting program.
For this bulb, the B (delta Watts per bulb) from Table 1 is 23.4. In the absence of specific locational data, the Office coincidence factors from Appendix 1 of 70.2% (summer) and 53.9% (winter) are assumed.

$$SKW = \frac{23.4 \times 70.2\%}{1{,}000} = 0.016\,kW$$

$$SKW = \frac{23.4 \times 53.9\%}{1{,}000} = 0.013\,kW$$

<u>Changes from Last Version</u>

Added stairwell LED kits and LED tubes as part of Table 1.

<u>References</u>

[1] Commercial and Industrial Upstream Lighting Program, Mass Save. <http://www.masssave.com/professionals/incentives/upstream-lighting> Last accessed May 19, 2015.

[2] Commercial Lighting System Initiative. Consortium for Energy Efficiency (CEE). <http://library.cee1.org/content/commercial-lighting-systems-initiative> Last accessed May 19, 2015..

[3] Energy Star Certified Light Bulbs < http://www.energystar.gov/productfinder/product/certified-light-bulbs/results> Last Accessed July 15, 2015.

[4] Design Lights Consortium product lists< https://www.designlights.org/qpl>

<u>Notes</u>

[1] Lighting hours of an office (general type) from Appendix 5 of the PSD.

[2] Delta Watts is the difference in consumption of an equivalent baseline lamp to a high efficiency replacement lamp.

[3] For stairwell lights with occupancy sensors reduce operating hours by 30% (see Measure 2.1.2 Standard Lighitng 8760x (1.00-.30) = 6132

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 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 [1]. A chiller spreadsheet is used to calculate consumption for both the baseline and proposed units. It is also used to calculate the consumption of the auxiliaries (chilled water pumps, condenser water pumps and cooling tower fans).

Inputs

Symbol	Description	Units
	Facility occupancy hours per week on and off-peak	hr/week
	Chiller plant availability per month	Y or N
	Peak cooling load @100°F (Occupied)	Tons
	Peak cooling load @100°F (Unoccupied)	Tons
	Economizer set point	°F
	Load at economizer set point + (Occupied)	Tons
	Load at economizer set point + (Unoccupied)	Tons
	Load at economizer set point - (Occupied)	Tons
	Load at economizer set point - (Unoccupied)	Tons
	Load at @ 0°F outside air temp- (Occupied)	Tons
	Load at @ 0°F outside air temp - (Unoccupied)	Tons
	Chiller(s) Capacity	Tons
	Condenser – Air or water cooled	
	Compressor type	
	ARI part load efficiency @100% load, @75% load, @50% load, and @25% load	Note [2]
	Primary and secondary pumping – Brake Horsepower (BHP)	Bhp
	Secondary chilled water pump controls – single speed or Variable Frequency Drive (VFD)	
	Condenser water pump – BHP	Bhp
	Tower Fan – BHP	Bhp
	Tower fan control – single speed, 2 speed, VFD	
	Percent load on lead chiller before lag chiller operation	%

Nomenclature

Symbol	Description	Units	Values	Comments
IPLV	Integrated Part Load Value			Note [2]
BL100	Baseline efficiency@ 100% load			Note [3]
BL75	Baseline efficiency@ 75% load			
BL50	Baseline efficiency@ 50% load			
BL25	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, or
  - 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 temperature bin, is characterized by:

- Occupied hours the chiller is operated each week,
- Un-occupied hours the chiller is operated each week,

Load Profile

A customer's representative (typically 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, and the difference determines the kWh and the kW savings for each period. These are summed to yield the total savings. Path A is intended for applications where significant operating time is expected at full-load and path B is intended for applications where significant operating time is expected at part-load.

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] For water cooled ≤ 300 tons positive displacement is the baseline. For > 300 tons Centrifugal is the baseline.

[2] Path A is intended for applications where significant operating time is expected at full load.

[3] Path B is intended for applications where significant operating time is expected at part load.

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

[5] Rated based on Note [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

None

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

The peak demand savings from the spreadsheet are assumed to be 100% coincident to the ISO-NE Summer seasonal peak demand. There are no winter peak demand savings.

Non Energy Benefits

Because the baseline and high-efficiency technology are the same for electric chillers, the majority of the projects have no non-electric benefits.

Changes from Last Version

Modified Note[3] to include ASHRAE 90.1 - 2010

Notes

[1] The temperature bin model was originally created by Bitterli & Associates, 10 Station Street, Simsbury, CT and has subsequently been modified by the engineering group at CL&P.

[2] Either EER for air cooled or kW/ton for water cooled, Part load performance based on 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 Standard 90.1-2007 with Addenda 2008 Supplement, and on ASHRAE 90.1 - 2010 Table 6.8.1C

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. This measure includes baseline Efficiency Values based on 2009 International Energy Conservation Code as well as 2012 International Energy Conservation Code. If projects are initiated after the new code adoption then 2012 International Energy Conservation Code must be used to evaluate the energy savings

Inputs

Symbol	Description	Units
	Facility type served by equipment	
CAP_C	Installed Cooling Capacity	Btu/hr
CAP_H	Installed Heating Capacity	Btu/hr
EER_i	EER , ≥ 65,000 Btu/hr – Installed (ARI 340/360)	Btu/watt-hr
$SEER_i$	SEER, units < 65,000 Btu/hr – Installed (ARI 210/240)	Btu/watt-hr
$HSPF_i$	HSPF, Heat pumps < 65,000 Btu/hr – Installed (ARI 210/240)	Btu/watt-hr
COP_i	High temperature COP, Heat pumps ≥ 65,000 Btu/hr- Installed (ARI 340/360)	

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
CAP_H	Installed Heating Capacity	Btu/hr		Input
CF_C	Seasonal summer cooling coincidence factor	%		Appendix 1
COP_b	High temperature COP, Heat pumps ≥ 65,000 Btu/h - Baseline			Note [1]
COP_i	High temperature COP, Heat pumps ≥ 65,000 Btu/h - Installed	Btu/watt-hr		Input
EER_b	EER , ≥ 65,000 Btu/h - Baseline	Btu/watt-hr		Note [1]
EER_i	EER , ≥ 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
$SEER_b$	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 used in place of EER for units under 65,000 Btu/h

Heating (Air source heat pumps only)

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

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

Table 1: Baseline Efficiencies –Unitary and Split System AC – IECC 2009/2012 (Note [1])

Size (Btu/h)	Units With Electric Resistance or No Heating Section	Units With Heating Section Other Than Electric Resistance
< 65,000	13.0 SEER	13.0 SEER
≥ 65,000 and < 135,000	11.2 EER	11.0 EER
≥ 135,000 and < 240,000	11.0 EER	10.8 EER
≥ 240,000 and < 375,000	10.0 EER	9.8 EER
≥ 375,000 and < 760,000	10.0 EER	9.8 EER
≥ 760,000	9.7 EER	9.5 EER

Table 2: Baseline Efficiencies – Unitary and Split System Heat Pumps– IECC 2009/2012 (Note [2])

	Cooling Mode		Heating Mode @ 47°F db/43°F wb
Size (Btu/h)	Units With Electric Resistance or No Heating Section	Units With Heating Section Other Than Electric Resistance	
< 65,000	13.0 SEER	13.0 SEER	7.7 HSPF
≥ 65,000 and < 135,000	11.0 EER	10.8 EER	3.3 COP
≥ 135,000 and < 240,000	10.6 EER	10.4 EER	3.2 COP
≥ 240,000 and < 375,000	9.5 EER	9.3 EER	3.2 COP
≥ 375,000 and < 760,000	9.5 EER	9.3 EER	3.2 COP
≥ 760,000	9.5 EER	9.3 EER	3.2 COP

Table 1A: Baseline Efficiencies –Unitary and Split System AC– IECC 2012 (Note [3])

Size (Btu/h)	Units With Electric Resistance or No Heating Section	Units With Heating Section Other Than Electric Resistance
< 65,000 (split)	15.0 SEER	14.8 SEER
≥ 65,000 and < 240,000	12.0 EER	11.8 EER
≥ 240,000 and < 760,000	10.8 EER	10.6 EER
≥ 760,000	10.2 EER	10 EER

Table 2A: Baseline Efficiencies – Unitary and Split System Heat Pumps– IECC 2012 (Note [4])

	Cooling Mode		Heating Mode @ 47°F db/43°F wb
Size (Btu/h)	Units With Electric Resistance or No Heating Section	Units With Heating Section Other Than Electric Resistance	
< 65,000 (split)	15.0 SEER	14.8 SEER	8.5 HSPF
≥ 65,000 and < 135,000	12.4 EER	12.2 EER	3.4 COP
≥ 135,000 and < 240,000	12.4 EER	12.2 EER	3.2 COP
≥ 240,000 and < 375,000	12.4 EER	12.2 EER	3.2 COP
≥ 375,000 and < 760,000	12.4 EER	12.2 EER	3.2 COP
≥ 760,000	12.4 EER	12.2 EER	3.2 COP

Lost Opportunity Gross Energy Savings, Example

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.

Lost Opportunity Gross Peak Demand Savings, Example

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

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

$WKW_H = 0$

Cooling only units have no winter demand savings since they do not operate during the winter.

Changes from Last Version

Updated table 1 and 2 for IECC 2012 code
Added table 1A and 2A for new IECC 2012 code

Notes

[1] Table 1 above is based on 2009 International Energy Conservation Code (CT Code) table C503.2.3(1) and 2012 International Energy Conservation Code (CT Code) table C403.2.3(1).
[2] Table 2 above is based on 2009 International Energy Conservation Code (CT Code) table C503.2.3(2) and 2012 International Energy Conservation Code (CT Code) Table C403.2.3(2).
[3] Table 1A above is based on 2012 International Energy Conservation Code (CT Code) table C406.2(1)
[4] Table 2A above is based on 2012 International Energy Conservation Code (CT Code) table C406.2(2)

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
CAP_H	Installed Heating Capacity	Btu/h
EER_i	EER – installed (ISO 13256-1)	Btu/watt-hr
COP_i	COP-Installed (ISO 13256-1)	

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
CAP_H	Installed Heating 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 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

$$AKWH_H = CAP_H \times \left(\frac{1}{COP_b} - \frac{1}{COP_i} \right) \times \frac{1}{3.412} \times \frac{kW}{1000W} \times EFLH_H$$

Table 1: Baseline Efficiencies (Note [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

Lost Opportunity Gross Energy Savings, Example

A ground loop water to air heat pump is installed in an office building. The heating capacity is 99,000 Btu/hr with a COP of 3.5. The cooling capacity is 125,000 Btu/h with an EER of 15. What are the annual lost opportunity energy 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

$$AKWH_C = 125{,}000 \times \left(\frac{1}{13.4} - \frac{1}{15} \right) \times \frac{kW}{1000W} \times 797 = 793\,kWh$$

Heating

$$AKWH_H = CAP_H \times \left(\frac{1}{COP_b} - \frac{1}{COP_i} \right) \times \frac{1}{3.412} \times \frac{kW}{1000W} \times EFLH_H$$

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

$$AKWH_H = 99{,}000 \times \left(\frac{1}{3.1} - \frac{1}{3.5} \right) \times \frac{1}{3.412} \times \frac{kW}{1000W} \times 1{,}248 = 1{,}335$$

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

Cooling

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

Heating

$$WKW_H = CF_H \times CAP_H \times \left(\frac{1}{COP_b} - \frac{1}{COP_i} \right) \times \frac{1}{3.412} \times \frac{kW}{1000W}$$

Lost Opportunity Gross Peak Demand Savings, Example

A ground loop water to air heat pump is installed in an office building. The heating capacity is 99,000 Btu/hr with a COP of 3.5. The cooling capacity is 125,000 Btu/h with an EER of 15. What are the lost opportunity seasonal demand savings?

Cooling

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

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

$$SKW_C = 0.82 \times 125{,}000 \times \left(\frac{1}{13.4} - \frac{1}{15} \right) \times \frac{kW}{1000W} = 0.82\,kW$$

Heating

$$WKW_H = CF_H \times CAP_H \times \left(\frac{1}{COP_b} - \frac{1}{COP_i} \right) \times \frac{1}{3.412} \times \frac{kW}{1000W}$$

The seasonal coincidence factor is assumed to be the same as the summer factor = 0.82.
COP_b from table 1 = 3.1

$$WKW_H = 0.82 \times 99{,}000 \times \left(\frac{1}{3.1} - \frac{1}{3.5} \right) \times \frac{1}{3.412} \times \frac{kW}{1000W} = 0.88\,kW$$

Changes from Last Version

No Changes between 2009 IECC and 2012 IECC

Notes

[1] Table 1 is based on 2009 and 2012 International Energy Conservation Code table C403.2.3 (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 summer and winter peak demand savings were zero because economizer cooling does not occur 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 [3]
WKW	Winter Demand Savings	kW	0	Note [3]

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 [3])

Changes from Last Version

No changes.

Notes

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

[2] Results are from the modeling performed by Wood, Byk, and Associates in 2001. The model provided savings for several locations throughout the Northeast. Savings for this measure is based on Hartford, CT.

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

2.2.5 VENTILATION CO2 CONTROLS

Description of Measure

Upgrade to HVAC system to control outside air flow based on CO2 levels. The proposed systems monitor the CO2 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 calculated based on site specific input 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, cooling and heating efficiencies. Savings are estimated using a temperature bin spreadsheet that uses the reduction of outside air to calculate the energy saved by not having to condition that air. The savings is calculated for each temperature bin with the exception of bins that would include economizer cooling.

Summer seasonal peak demand savings are calculated based on the top two temperature bins used in the spreadsheet. Natural gas peak day savings are calculated using the peak day factor for furnace/boiler of 0.0152 from measure 2.2.6 since the savings for this measure are consistent with the furnace/boiler savings profile.

The baseline for this measure is a system with no CO2 ventilation control.

Inputs

Symbol	Description	Units
	Operation Schedule of HVAC Unit including days and time	
	Area type Served by HVAC Unit	
EER	Cooling Efficiency	Btu/watt-hr
	Heating Efficiency	%
	Total System Air Flow	CFM
	Design Outside Air percentage	%
	Average Expected Reduction in Air Flow	%
	Return Air Temperature	^oF
	Building Balance Point	^oF

Changes from Last Version

No changes.

2.2.6 GAS FIRED BOILER AND FURNACE

Description of Measure

This measure encourages the installation of high-efficiency, gas-fired, hydronic heating 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 or ASHRAE 90.1-2010[1], Tables 6.8.1F and 6.8.1E, respectively (Note [3]). If the boiler is used for Domestic Hot Water in addition to heating the project should be handled as a custom measure (2.6.3 LOST OPPORTUNITY CUSTOM).

The Peak day factors developed for this prescriptive approach are based on the results from a sampling of existing custom projects in which local bin weather data was used to calculate savings of both high-efficiency conventional and condensing boilers. The data from the temperature bin analysis was used to compute savings for the coldest 24-hour period of the year. The peak day factors were based on the average of these projects (Note [1]). Ratios of demand savings to annual energy savings were then developed for both conventional (0.0152) and condensing boilers (0.0133). The peak factor for furnaces is estimated at 0.0152 since furnace savings follow the same load shape as the conventional boilers. 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. To meet the heating load, hot water reset increases the boiler water temperature as the outside air temperature decreases. The higher water temperature has a negative effect on the condensing boiler's efficiency at those conditions. The effect reduces the percent savings during the peak day.

Inputs

Symbol	Description	Units
	Facility type	
ηp	Proposed case efficiency	
CAP	Boiler or furnace output capacity	Btu/hr

Nomenclature

Symbol	Description	Units	Values	Comments
ACCF	Gross annual energy savings	CcF		
AF	Adjustment Factor		1.0 or 0.97	Use 1.0 for non-condensing units and 0.97 for condensing units
CAP	Installed boiler or furnace output capacity.	Btu/ hr		
EFLH	Equivalent Full Load Hours	hours	Table 1	See Appendix 5 for occupancy categories not listed below
OF	Oversize Factor			Note [2]
PD	Gross Peak Day Natural Gas Savings			
ηb	base case efficiency			ASHRAE 90.1-2007 or ASHRAE 90.1-2010
ηp	proposed case efficiency			

[1] Note, the baseline standards for furnaces and boilers have not changed in ASHRAE Standard 90.1-2010

Lost Opportunity Gross Energy Savings, Fossil Fuel

Heating Savings

$$ACCF = \left[\frac{CAP}{OF} \times \left(\frac{EFLH}{102{,}900 Btu/ccf}\right) \times \left(\frac{1}{\eta b} - \frac{1}{AF \times \eta p}\right)\right]$$

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

Occupancy Category	Equivalent Full-Load Heating Hours[2]
Residential, Hospitals, Police & Fire Stations (24/7 operation)	1,519
Manufacturing	1,140
Retail Sales/Restaurants	1,170
Offices	1,306
Schools	1,176
Average Value for Upstream Program	1,100

Lost Opportunity Gross Peak Day Savings, Natural Gas

Factors based

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

Referenced ASHRAE 90.1-2010 baseline which is equivalent to ASHRAE 90.1-2007

Notes

[1] Peak day factors and full load hours were developed by third party engineers (Fuss & O'Neill, Manchester, CT) in 2008 using a temperature bin analysis. The engineering analysis was provided to LDCs to help support natural gas conservation efforts.

[2] The oversize factor (OF) is assumed to be 1.15 for single boiler/furnace installations reflecting the industry standard of installing equipment that has an output greater than estimated peak load. The oversizing factor for multiple boiler and furnace installation is 1.3 reflecting the industry practice of oversizing multiple pieces of equipment to allow for one piece of equipment to provide a higher percentage of load in emergency situations.

[3] ASHRAE- Minimum Efficiency requirements are based on input capacity

[2] The above EFLH should be used for boilers and furnaces and not Appendix 5 values. Appendix 5 heating EFLH are for heat pumps only.

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 using a temperature bin model. To calculate the peak demand factor the savings from the coldest 24-hour period of the year was divided by the total 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
CAP	Installed heating Capacity in Btu/hr
	Facility type

Nomenclature

Symbol	Description	Units	Values	Comments
ACCF	Gross annual gas energy savings	Ccf		
Ccf	100 Cubic Feet	Ccf		
EFLH	The equivalent hours that the heater would need to operate at its peak capacity in order to consume its estimated consumption (Annual Btu/ Full Load Btu/hr)	hours	Table 1, Appendix 5	Note [3]
CAP	Installed heating Capacity in Btu/hr			Note [2]
OF	Oversize Factor			Note [2]
PD	Gross peak day savings	Ccf		
SFR	Savings Fraction		25%	Ref [1]
ηb	Base case efficiency		80%	Ref [2]

Lost Opportunity Gross Energy Savings, Fossil Fuel

Heating Savings

$$\text{ACCF} = \frac{CAP}{OF} * EFLH * \frac{SFR}{(102{,}900 btu / Ccf \times \eta b)}$$

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

Occupancy Category	Equivalent Full-Load Heating Hours
Warehouse, Storage, Fire Stations (24/7 operation)	1,519
Manufacturing	1,140
Retail Sales/Other	1,170

Lost Opportunity Gross Peak Day Savings, Natural Gas

PD= 0.00544 x ACCF

Changes from Last Version

Referenced ASHRAE 90.1-2010 baseline which is equivalent to ASHRAE 90.1-2007.

References

[1] ASHRAE Technical Paper #4643, "Evaluation of an Infrared Two-Stage Heating System in a Commercial Application", 2003, Conclusions page 138.

[2] ASHRAE Standard 90.1-2007 and ASHRAE Standard 90.1-2010, Table 6.8.1E, for warm air unit heaters.

Notes

[1] Peak day factors and full load hours were developed by third party engineers (Fuss & O'Neill, Manchester, CT) in 2008 using a temperature bin analysis. The engineering analysis was provided to LDCs to help support natural gas conservation efforts.

[2] In the case of a single-heater installation, the oversize factor is 1.0. In the case of a multiple-heater installation, the total heater output capacity shall be used and the oversize factor is 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>75,000 Btu/hr.

Savings Methodology

Energy savings are calculated using proposed water heater thermal efficiency and standby losses versus baseline efficiency and standby losses. The baseline for efficiency and standby losses were based on gas storage water heater, >75,000 Input Btu/hr as specified in ASHRAE 90.1-2007 (Ref [1]).

Based on facility type and square footage, Table 1 (Note [1]) and baseline standby losses are used to estimate the annual water heating baseline usage. Using the baseline efficiency (80%) the baseline hot water load is calculated. Using the calculated load, the installed efficiency and standby high efficiency consumption and savings can be calculated.

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 a code-compliant storage gas heater.
2. Proposed case heater is a 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. (Ref [3])
2. Annual average cold water temperature is 54°F. (Ref [3])
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_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		
$CAP_{H,b}$	Heat Input capacity of base case water heater	MBH		
$CAP_{H,i}$	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 ft^2)	$Ccf/ft^2/yr$	Table 1	Ref [2], Note [1]
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		
H	Number of annual standby hours	Hrs/yr		
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		Ref [1]
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%	Ref [1]
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 [2])

Building Occupancy Category	Annual Base Case Gas Usage Rate, E_b (Ccf/ft^2)
Education	0.068
Food sales	0.043
Food service	0.382
Health care	0.232
Inpatient Health care	0.334
Outpatient Health care	0.038
Lodging	0.258
Mercantile	0.103
Retail (other than mall)	0.024
Enclosed and strip malls	0.137
Office	0.047
Public assembly	0.02
Public order and safety	0.209
Service	0.147
Warehouse and storage	0.028
Other	0.023
Vacant	0.013

Calculate base case heater input capacity in Btu/hr:

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

Calculate the baseline standby losses:

$$SLR_b = CAP_{H,i} \times \frac{1{,}000}{800} + 110 \times \sqrt{CAP}_{w,i} \text{ Ref [1]}$$

Calculate number of standby hours/year:

$$H = \frac{\left(8760\,{}^{hr}\!/_{yr} \times CAP_{H,b} \times 1{,}000\right) - \left(CCF_{W,b} \times 102{,}900\,{}^{Btu}\!/_{Ccf}\right)}{\left(CAP_{H,b} \times 1{,}000\right) - \frac{SLR_b}{\eta b}}$$

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

$$GPY_W = \frac{\left(CCF_{W,b} \times 102{,}900\,{}^{Btu}\!/_{Ccf} \times \eta b\right) - \left(SLR_b \times H\right)}{\Delta T \times 8.33\,{}^{Btu}\!/_{Gal \cdot {}^\circ F}}$$

Calculate annual gas savings using the following equation:

$$ACCF_W = CCF_{W,b} - \frac{(GPY_W \times \Delta T \times 8.33\,{}^{Btu}\!/_{Gal \cdot {}^\circ F} + SLR_i \times H)}{102{,}900\,{}^{Btu}\!/_{Ccf} \times \eta \text{p}}$$

Lost Opportunity Gross Energy Savings, Example

A 50,000 square foot inpatient health care facility installs a new energy efficient gas storage type domestic hot water heater with the following ratings:

- Capacity = 300 MBH
- Storage capacity = 100 gallons
- Thermal Efficiency = 91%
- Rated standby loss = 1,044 Btu/hr

What are the annual energy savings?

Calculate annual base case DHW gas usage:

$$CCF_{W,b} = A \times E_b = 50{,}000 \times 0.357 = 17{,}850 Ccf$$

Calculate base case heater input capacity in Btu/hr:

$$CAP_{H,b} = CAP_{H,i} \times \frac{\eta p}{\eta b} = 300 \times \frac{0.91}{0.80} = 341 \text{ MBH}$$

Calculate the baseline standby losses:

$$SLR_b = CAP_{H,i} \times \frac{1{,}000}{800} + 110 \times \sqrt{CAP}_{w,i} = 300 \times \frac{1{,}000}{800} + 110 \times \sqrt{100} = 1{,}475$$

Calculate number of standby hours/year:

$$H = \frac{\left(8760\,{}^{hr}\!/_{yr} \times CAP_{H,b} \times 1{,}000\right) - \left(CCF_{W,b} \times 102{,}900\,{}^{Btu}\!/_{Ccf}\right)}{\left(CAP_{H,b} \times 1{,}000\right) - \dfrac{SLR_b}{\eta b}}$$

$$H = \frac{\left(8760\,{}^{hr}\!/_{yr} \times 341 \times 1{,}000\right) - \left(17{,}850 \times 102{,}900\,{}^{Btu}\!/_{Ccf}\right)}{\left(341 \times 1{,}000\right) - \dfrac{1{,}475}{0.80}} = 3{,}392$$

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

$$GPY_W = \frac{\left(CCF_{W,b} \times 102{,}900\,{}^{Btu}\!/_{Ccf} \times \eta b\right) - \left(SLR_b \times H\right)}{\Delta T \times 8.33\,{}^{Btu}\!/_{Gal \cdot {}^\circ F}}$$

$$GPY_W = \frac{\left(17{,}850 \times 102{,}900\,{}^{Btu}\!/_{Ccf} \times 0.8\right) - \left(1{,}475 \times 3{,}392\right)}{75 \times 8.33\,{}^{Btu}\!/_{Gal \cdot {}^\circ F}} = 2{,}343{,}992$$

Calculate annual gas savings using the following equation:

$$ACCF_W = CCF_{W,b} - \frac{(GPY_W \times \Delta T \times 8.33\,{}^{Btu}\!/_{Gal \cdot {}^\circ F} + SLR_i \times H)}{102{,}900\,{}^{Btu}\!/_{Ccf} \times \eta p}$$

$$ACCF_W = 17{,}850 - \frac{(2{,}343{,}992 \times 75 \times 8.33\,{}^{Btu}\!/_{Gal \cdot {}^\circ F} + 1{,}044 \times 3{,}392)}{102{,}900\,{}^{Btu}\!/_{Ccf} \times 0.91} = 2{,}173$$

Lost Opportunity Gross Peak Day Savings, Natural Gas

$$SF = \frac{1\ day \times \left(130^\circ F - 46^\circ F\right)}{365\ days \times \left(130^\circ F - 57^\circ F\right)} = 0.0032$$

$$PD = ACCF_W \times SF = ACCF_W \times 0.0032$$

Changes from Last Version

Updated Table 1 in accordance with 2012 Commercial Buildings Energy Consumption Survey (CBECS) data provided by the U.S. Energy Information Administration

References

[1] ASHRAE 90.1-2007 and ASHRAE 90.1-2010, Table 7.8.

[2] U.S. Energy Information Administration, Table E8. Natural gas consumption and conditional energy intensities (cubic feet) by end use, 2012, Released May 2016..

[3] Tool for Generating Realistic Residential Hot Water Event Schedules, Reprint, NREL, August 2010.
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2.3 MOTORS AND TRANSFORMERS

2.3.2 LOW VOLTAGE DRY TYPE DISTRIBUTION TRANSFORMERS

Description of Measure

Measure discontinued in 2017 due to implementation on New Federal Energy Standard which makes potential savings negligible to support incentives for this program. .

Savings Methodology

Not Applicable (see above). Savings had been based on CEE Tier level efficiency requirements however CEE Initiative has been suspended.

Changes from Last Version

Measure discontinued for 2017

References

[1] Federal Standard: Title 10 Part 431 - Energy Efficiency Program for Certain Commercial and Industrial Equipment; Section 431.196.

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, Variable Air Volume boxes) must be installed.

Savings Methodology

The baseline is a constant speed fan (Air Foil (AF), Backward incline (BI), Forward Curved (FC)) with or without inlet guide vanes or a constant speed/flow centrifugal 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
BHP	Brake Horsepower
EFFi	Installed motor efficiency
H	Annual hours of operation
	Fan type

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			
CV	Constant Volume Fan			
EFF_i	Motor Efficiency - installed	%		
FC	Forward Curved			Fan Type
H	Annual Hours of operation			site specific or default 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	(kW/HP)	Table 1	
$SF_{kW,S}$	Summer seasonal demand savings based on typical load profile for application	(kW/HP)	Table 1	
$SF_{kW,W}$	Summer seasonal demand savings based on typical load profile for application	(kW/HP)	Table 1	
SKW	Seasonal Summer Peak Savings	kW		
WKW	Seasonal Winter Peak 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 riding the curve	0.35407485	0.26035565	0.40781240
AF/BI with IGV	0.22666226	0.12954823	0.29144821
FC riding the curve	0.17889831	0.13552275	0.18745625
FC with IGV	0.09210027	0.02938371	0.13692166
CV	0.53450577	0.34753664	0.65064177
HVAC Pump VFD Savings Factors			
Baseline	SF_{kWh}	$SF_{kW,S}$	$SF_{kW,W}$
CHWP (constant flow)	0.41113751	0.299056883	0.0
HWP (constant flow)	0.42380136	0.0	0.207967853

Lost Opportunity Peak Seasonal 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

No changes.

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. For each pump application and fan type savings factors were developed. These were based on the difference in power based on the estimated load at each temperature BIN using equations from Ref [1].

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 manufacturing 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).

The PRIME process also reduces waste. Since this is very site dependent it is not considered in this calculation

For projects with gas savings, the calculations will be done on a customer basis for that specific manufacturing process.

Inputs

Symbol	Description	Units
KWH_h	Facility's annual consumption based on billing history	kWh
PPA	Percent of facility's consumption effected by PRIME	%
Na	Production after PRIME	units per hour
Ne	Existing Production	units per hour

Nomenclature

Symbol	Description	Units	Values	Comments
AKWH	Annual Electric Energy Savings	kWh		
EKWH	Estimated annual electric usage with increase in production	kWh		
IND	Annual electric energy usage independent of production hours and production quantity	kWh		
HR	Annual electric energy usage dependent on hours of production	kWh		
KWH_h	Facility's annual electric usage based on billing history	kWh		Input
N_a	Production rate after PRIME	units per hour		Input
N_e	Existing Production rate	units per hour		Input
PPA	Percent of facility's energy usage effected by PRIME	%		Input
PD	Annual electric energy usage dependent on production quantity	kWh		
SF	Savings factor	%		Ref [1]
$\ldots_{wop}$	Without PRIME			
$\ldots_{wp}$	With PRIME			

Lost Opportunity Gross Energy Savings, Electric

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

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 Reference [1].

Lost Opportunity Gross Energy Savings, Example

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.

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

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

PRIME reduces waste and increases productivity. 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.

Changes from Last Version

No changes.

References

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

2.6.2 COMMERCIAL KITCHEN EQUIPMENT

Description of Measure

Installation of ENERGY STAR qualified commercial kitchen equipment.

Savings Methodology

Energy savings for this measure are calculated using the savings calculator for ENERGY STAR qualified commercial kitchen equipment located on the ENERGY STAR website (Ref [1]). Note that the input and equipment tabs within the spreadsheet have default values that can be overridden by the user when project specific details are available. The peak electric and gas demand savings are calculated as specified below. The baselines from which savings are calculated are provided in Table below.

Table 1: Savings Baseline

Equipment	Baseline
Oven	Conventional unit per Reference [1] calculator
Dishwasher	Conventional unit per Reference [1] calculator
Freezer	Reference [3]
Fryer	Conventional unit per Reference [1] calculator
Griddle	Conventional unit per Reference [1] calculator
Hot Food Holding Cabinet	Conventional unit per Reference [1] calculator
Ice Machine	Reference [2]
Refrigerator	Reference [3]
Steam Cooker	Conventional unit per Reference [1] calculator
WaterSense Pre-Rinse Spray Valve	See Water Savings Measures 3.2.1

Nomenclature

Symbol	Description	Units	Values	Comments
$ACCF_O$	Annual Natural gas savings	Ccf		
AHAM	Association of Home Appliance Manufacturers			
AKWH	Annual Gross Electric Energy savings	kiloWatt-hours, kWh		
AKW	Average Hourly Summer Demand Savings	kW		
kW	Electric Demand	kiloWatts		
PD_O	Peak day gas savings	Ccf		

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

The average hourly demand savings for refrigerators, freezers and ice machines (winter and summer) are:

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

Lost Opportunity Gross Peak Demand Savings, Natural Gas

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

Changes from Last Version

Accessed Energy Star Spreadsheet, added Watersense Spray Valve.

References

[1] ENERGY STAR Commercial Kitchen Package for businesses and operators, http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=CKP Last Accessed Sept 6, 2016.

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

[3] 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] Actual full load hours should be used, when known, in the savings calculator in lieu of the default hours.

2.6.3 LOST OPPORTUNITY CUSTOM

Description of Measure

This measure may apply to any C&I Lost Opportunity installations whose scope may be considered custom or comprehensive and not covered by a prescriptive measure.

Savings Methodology

Energy and demand savings are calculated on a custom basis for each customer's specific situation. Savings are calculated as the difference between baseline energy usage/peak demand and the energy use/peak demand after implementation of the custom measure. Energy savings estimates should be calibrated against billing or metered data where possible to test the reasonableness of energy savings. Also, the energy and demand savings analysis must be reviewed for reasonableness by either a third party consulting engineer or a qualified in-house engineer.

The methodology for determining gas peak day savings is provided in Appendix 1.

Note that the demand savings methodologies below provide a gross, reasonable estimate based on available information. Final reported values are adjusted based on realization rates provided in Appendix 3.

Electric demand savings methodologies are categorized as follows:

1. Temperature dependent measures (HVAC measures that vary with ambient temperature)

2. Non-temperature dependent measures (process, lighting, time control)

3. Whole building performance.

Temperature dependent measures:

Savings from individual temperature dependent measures are typically determined by either full load hour analysis or bin temperature analysis:

Full Load Hour Analysis

Summer and winter demand savings are calculated using an appropriately derived seasonal peak coincidence factor. Coincident factors for various measures (and/or end use) are provided in Appendix 1. Demand savings will be determined by multiplying the connected load kW savings by the appropriate coincidence factor.

Temperature Bin Analysis

A correlation was done between seasonal peak hours and outside air temperatures. Using this information the methodology was developed as described below. Typically either Bridgeport or Hartford weather data is used for the analysis.

• The summer seasonal peak demand savings shall be the difference between the weighted average demand of the top temperature bins that capture the majority of the ISO-NE summer seasonal peak hours in the previous three years, for the base and "efficient" cases. All hours above 80 degrees will be used for Bridgeport and 84 degrees will be used for Hartford.

• The winter seasonal peak demand savings shall be the difference between the weighted average demand of the bottom temperature bins that capture the majority of the ISO-NE winter seasonal peak hours in the previous three years, for the base and "efficient" cases. All hours below 30 degrees will be used for Bridgeport and 26 degrees will be used for Hartford.

Non-temperature-dependent measures:

Demand savings for measures that are not temperature-dependent will be determined by either the coincidence factors from Appendix 1 or the average estimated week day (WD) savings over the summer or winter seasonal peak period. A custom coincidence factor may also be used for measures or end uses that are not identified in Appendix 1. However, the analysis determining the custom coincidence factor must be performed or approved by a qualified in house engineer.

The average summer/winter seasonal peak demand savings shall be determined as follows:

$$SKW = \frac{Annual\ kWh\ savings\ (WD - June, July, August)}{Equipment\ \ Run\ hours\ (WD - June, July, August)} \times \left(\frac{Run\ hours\ during\ 12pm - 6pm\ WD}{6} \right)$$

$$WKW = \frac{Annual\ kWh\ savings\ (WD - December, January)}{Equipment\ \ Run\ hours\ (WD - December, January)} \times \left(\frac{Run\ Hours\ during\ 4pm - 9pm\ WD}{5} \right)$$

Note that the average demand savings methodology should only be used when the coincident factor methodology cannot or is not practicable.

Whole Building Performance:

Whole building performance shall be determined using a computer simulation model. Approved software and modeling requirements are specified by the program administrators.

The methodology for determining the seasonal peak demand savings will depend on the computer simulation output capabilities. If the model can provide the demand for the coldest and hottest hours of the year and the month when they occur, then that data will be used to determine demand savings.

The summer seasonal peak demand savings will be the difference between the peak demand (whole building) from the base and design models during the hours as described in the temperature dependent section above. This assumes the hottest hours occur during June through August. If the hottest hour methodology cannot be used then the demand savings shall be determined by taking the difference in the peak demand between the base and design models for the summer month (June through August) with the highest cooling load in the base model. If neither of these methods can be used then in house engineering must review the project/model to determine an acceptable method.

The winter seasonal peak demand savings will be the difference between the peak demand (whole building) from the base and design models during the coldest hours as described in the temperature dependent section above. This assumes the coldest hours occur during December or January. If the coldest hour methodology cannot be used then the demand savings shall be determined by taking the average winter (December, January) peak demand from the base model and subtracting the average winter (December, January) peak demand from the design model.

Baseline:

Baseline efficiencies for individual measures are based on code or federal standard. If there is no applicable code requirement, the assumption would be that no installation of any energy saving measure unless there was a study based on a statistically valid sample of similar installations to support a different baseline.

If projects are initiated after the new code adoption then IECC 2012 TABLE C407.5.1(1) must be used to evaluate the energy savings, otherwise the baseline for whole building performance is ASHRAE 90.1-2007 with the 2008 supplement Addenda. Modeling shall be performed in accordance with Appendix G in ASHRAE 90.1.

Nomenclature

Symbol	Description	Units	Values	Comments
WD	Week Days	Days		

Changes from Last Version

Updated to reference to IECC 2012 in the event Connecticut adopts IECC 2012 in the next PSD year.

Clarified the parameters of any baseline other than code

2.6.4 COMMERCIAL CLOTHES WASHERS

Description of Measure

The installation of an ENERGY STAR Commercial Clothes Washer.

Savings Methodology

Savings for this measure are calculated using the appropriate water heating and dryer fuel source. The basis of the savings is the Consortium for Energy Efficiency (CEE) savings calculator (Ref [1]). The usage per load by fuel source for baseline (Federal Standard) and ENERGY STAR units were calculated based on (Ref [1]). Using the average loads per year the annual savings are calculated. Number of annual loads will either be based on the CEE default calculator default values (Laundromats (2,190 loads per year) or multi-family (1,241 Loads per year)) or project specific information for any facility type. Installed energy use will be based on the installed modified energy factor. Note that the Federal Standard and ENERGY STAR requirements changed in 2013. There are now separate Federal Standard levels for front loading and top loading washers. The CEE savings calculator (Ref [1]) used for this measure was modified based on the new Federal Standard and ENERGY STAR requirements.

Inputs

Symbol	**Description**	**Units**
N	Number of units	
	Water heating fuel source (Electric, natural gas, propane, oil)	
	Dryer Fuel Source (none, electric, natural gas, propane)	
	Type of facility (Laundromat or Multi-family)	
MEF_i	Modified Energy Factor - installed	$ft^3/kWh/cycle$
LDS	Average number of loads per week	loads/wk
WK	Average number of weeks per year	wk/yr

Nomenclature

Symbol	**Description**	**Units**	**Values**	**Comments**
AKWH	Annual electric energy savings	kWh		
$AKWH_O$	Annual electric energy savings - other	kWh		
$AKWH_W$	Annual electric energy savings – water heating	kWh		
$ABTU_O$	Annual Btu savings - other	Btu		
$ABTU_W$	Annual Btu savings – water heating	Btu		
ACCF	Annual natural gas savings - total	Ccf		
$ACCF_O$	Annual natural gas savings - other	Ccf		
$ACCF_W$	Annual natural gas savings – water heating	Ccf		
APG	Annual propane savings - total	Gallons		
APG_O	Annual propane savings - other	Gallons		
APG_W	Annual propane savings – water heating	Gallons		
AOG_W	Annual Oil savings – water heating	Lbs/h		
$DKWH_b$	Dryer kWh per load - baseline	kWh/ld	0.872/ 0.698	Note [1]
$DKWH_{es}$	Dryer kWh per load – ENERGY STAR	kWh/ld	0.634	Note [1]
$DRBTU_b$	Dryer Btu - baseline	Btu/ld	2,969/ 2,376	Note [1]
$DRBTU_{es}$	Dryer Btu – ENERGY STAR	Btu/ld	2,160	Note [1]
AGW	Annual water savings	Gallons/year		
Gal_b	Gallons of water - baseline	Gallons	26.35/ 17.1	Note [1]

Symbol	Description	Units	Values	Comments
Gal_{es}	Gallons of water – ENERGY STAR	Gallons	13.95	Note [1]
LDS	Average number of Loads per week	Loads/wk		Input, Note [2]
MEF_i	Modified energy Factor - installed	ft^3/kWh/cycle		Input
MEF_{es}	Modified energy factor – ENERGY STAR	ft^3/kWh/cycle	2.2	Note [1]
N	Number of units			Input
PD_W	Peak day factor – water heating		0.00321	Appendix 1
PD	Peak day savings	Ccf		
WK	Average Weeks per year	Wk/yr		Input
$WKWH_b$	Washer kWh per load - baseline	kWh/ld	0.116/ 0.093	Note [1]
$WKWH_{es}$	Washer kWh per load – ENERGY STAR	kWh/ld	0.085	Note [1]
$WHKWH_b$	Hot Water kWh per load - baseline	kWh/ld	0.949/ 0.760	Note [1]
$WHKWH_{es}$	Hot Water kWh per load – ENERGY STAR	kWh/ld	0.690	Note [1]
$WHBTU_b$	Hot Water Btu - baseline	Btu/ld	3,246/ 2,597	Note [1]
$WHBTU_{es}$	Hot Water Btu – ENERGY STAR	Btu/ld	2,361	Note [1]

Lost Opportunity Gross Energy Savings, Electric

Electric savings will be calculated in three pieces. Electric dryer and water heating savings are present only if the heat element fuel source is electric.
Annual savings = Washer savings + Water heating savings + Dryer Savings

$$AKWH = AKWH_{O-washer} + AKWH_{O-eletricdryer} + AKWH_{W-electric}$$

$$AKWH = N \times LDS \times WK \times \left[\begin{array}{l} \left(WKWH_b - WKWH_{es} \times \frac{MEF_{es}}{MEF_i} \right) + \left(WHKWH_b - WHKWH_{es} \times \frac{MEF_{es}}{MEF_i} \right) \\ + \left(DKWH_b - DKWH_{es} \times \frac{MEF_{es}}{MEF_i} \right) \end{array} \right]$$

Lost Opportunity Gross Energy Savings, Fossil Fuel

Fossil fuel savings will be calculated in two pieces. Fossil fuel dryer and water heating savings are only present if the heat element fuel source is fossil fuel.

Annual savings = Water heating savings + Dryer Savings

$$ABTU = ABTU_{O-FossilFueldryer} + ABTU_{W-fossilfuel}$$

$$ABTU_W = N \times LDS \times WK \times \left(WHBTU_b - WHBTU_{es} \times \frac{MEF_{es}}{MEF_i} \right)$$

$$ABTU_O = N \times LDS \times WK \times \left(DRBTU_b - DRBTU_{es} \times \frac{MEF_{es}}{MEF_i} \right)$$

Savings by fuel source:

Water Heating

$$ACCF_W = \frac{ABTU_W}{102{,}900 Btu/ccf}$$

$$AOG_W = \frac{ABTU_W}{138{,}690 Btu/Gal}$$

$$APG_W = \frac{ABTU_W}{91{,}330 Btu/Gal}$$

Dryer

$$ACCF_O = \frac{ABTU_O}{102{,}900 Btu/ccf}$$

$$APG_O = \frac{ABTU_O}{91{,}330 Btu/Gal}$$

Lost Opportunity Gross Energy Savings, Example

A new Laundromat installs 25 new ENERGY STAR front loading washing machines that have an MEF of 2.2. The Laundromat has natural gas water heat and gas dryers. What are the energy savings?

Electric savings:

$$AKWH = N \times LDS \times WK \times \left[\left(WKWH_b - WKWH_{es} \times \frac{MEF_{es}}{MEF_i} \right) + \left(WHKWH_b - WHKWH_{es} \times \frac{MEF_{es}}{MEF_i} \right) + \left(DKWH_b - DKWH_{es} \times \frac{MEF_{es}}{MEF_i} \right) \right]$$

Dryer and Water heater electric usage = 0
N=25
LDS x WK = 2,190 (default loads per year)
$WKWH_b$ = 0.093 kWh/ld
$WKWH_{es}$ = 0.085 kWh/ld
MEF_{es} = 2.2
MEF_i = 2.2

$$AKWH = 25 \times 2{,}190 \times \left[\left(0.093 - 0.085 \times \frac{2.2}{2.2} \right) + (0-0) + (0-0) \right] = 438 kWh$$

Natural Gas savings:

$$ABTU = ABTU_{O-FossilFueldryer} + ABTU_{W-fossilfuel}$$

$$ABTU_W = N \times LDS \times WK \times \left(WHBTU_b - WHBTU_{es} \times \frac{MEF_{es}}{MEF_i} \right)$$

$$ABTU_W = 25 \times 2{,}190 \times \left(2{,}597 - 2{,}361 \times \frac{2.2}{2.2} \right) = 12{,}921{,}000 Btus$$

$$ACCF_W = \frac{ABTU_W}{102{,}900 Btu/ccf} = \frac{12{,}921{,}000 Btus}{102{,}900 Btu/ccf} = 125.6 Ccfs$$

$$ABTU_O = N \times LDS \times WK \times \left(DRBTU_b - DRBTU_{es} \times \frac{MEF_{es}}{MEF_i} \right)$$

$$ABTU_O = 25 \times 2{,}190 \times \left(2{,}376 - 2{,}160 \times \frac{2.2}{2.2}\right) = 11{,}826{,}000 Btus$$

$$ACCF_O = \frac{ABTU_O}{102{,}900 Btu/ccf} = \frac{11{,}826{,}000 Btus}{102{,}900 Btu/ccf} = 115 Ccfs$$

$$ACCF = ACCF_O + ACCF_{Wl} = 125.6 + 115 = 240.6 Ccfs$$

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

Assumed to be zero.

Lost Opportunity Gross Peak Day Savings, Natural gas

$$PD = \frac{ACCF_O}{365 days/yr} + PD_W \times ACCF_W$$

Lost Opportunity Gross Peak Day Savings, Example

$$PD = \frac{ACCF_O}{365 days/yr} + PD_W \times ACCF_W = PD = \frac{115}{365 days/yr} + 0.00321 \times 125.6 = 0.72 Ccfs$$

Non Energy Benefits

ENERGY STAR washers use less water than the base unit.

Water savings:

$$AGW = N \times LDS \times WK \times \left(GAL_b - GAL_{es} \times \frac{MEF_{es}}{MEF_i}\right)$$

Changes from Last Version

No changes.

References

[1] http://www.ceeforum.org/sites/default/files/CEE_CommCW_SpecSavingsCalc_2011.xls (modified based on 2013 Fed Standard and ENERGY STAR requirements)

Notes

[1] Baseline (top loading/front loading) and ENERGY STAR usage values used in energy savings calculation tool on website identified in Ref [1]

[2] Default loads per year for Laundromats and Multi-family from Ref [1]

2.7 ENVELOPE

2.7.1 COOL ROOF

Description of Measure

Install a qualifying cool roof surface with high reflectance (Note [4]) and high emittance (Note [5]).

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 (Note [6]) are the same as 90.1-200. 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	-17000	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 Energy Savings, Fossil Fuel

$$F_H = -17000$$
$$ABTU_H = F_H \times A_{ac}$$
$$ABTU_H = -17000 \times A_{ac}$$
$$ACCF_H = \frac{ABTU_H}{102{,}900\ btu/Ccf}$$
$$AOG_H = \frac{ABTU_H}{138{,}690\ btu/gal}$$
$$APG_H = \frac{ABTU_H}{91{,}330\ btu/gal}$$

Reminder: *Increasing the reflectance of a roof causes an increase in heating energy usage (thus the negative factor above) because it will decrease the temperature of the roof which will result in higher heating loads.*

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:

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

$$WKW_C = 0$$

Changes from Last Version

Converted the Heating factor to units of btu/ft^2, so the lost opportunity fossil fuel savings will be in the correct units. Note on measure applicability going forward.

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.

[4] Reflectance – Solar reflectance is the portion of the sun's radiation that is reflected by the surface.

[5] Emittance – Emittance is the ability of a surface to radiate heat.

[6] If new code is adopted cool roof savings will be determined on a project-by-project basis

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 existing operating hours of the fixtures being replaced. Note [1].

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
kW_B	Existing fixture connected kW	
kW_A	Replacement Fixture connected kW	
	Hours of operation (if available)	

Nomenclature

Item	Description	Units	Values	Comments
AKWH	Annual Gross Electric Energy savings	kWh		
CF_L	Lighting Coincidence Factor from Appendix 1			Appendix 1
CF_{os}	Occupancy Sensor Coincidence Factor from Appendix 1			Appendix 1
COP	Coefficient of Performance		3.5	
F	Fraction of lighting energy that must be removed by the facility's cooling system.			
G	Estimated lighting energy heat to space based on modeling		0.73	Note [3]
H	Facility lighting hours of use	Hours		Site specific or Appendix 5
HVAC	Heating, Ventilation and Air Conditioning			
kW	Fixture input	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		
S_{os}	Energy savings from use of occupancy sensors, if applicable	kWh		
S_c	Energy savings from reduced cooling load	kWh		
SKW	Seasonal Summer Peak Summer Demand Savings	kW		
W_n	Input watts for fixture type n	Watts		
WKW	Seasonal Winter Peak Summer Demand Savings	kW		

Retrofit Gross Energy Savings, Electric

$$AKWH = S_r + S_{OS} + S_C$$

Calculation of savings due to fixture retrofit

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

kW_B = The total power usage of the lighting fixtures that are being replaced, kW (For EISA qualifying bulbs 75% of the actual wattage is used for baseline, see Note [1]).
kW_A = The total power usage of the new lighting fixtures that are being installed, kW.
H = Facility lighting hours of use (site specific or Appendix 5)

Calculation of savings due to occupancy sensors

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

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

Calculation of savings to remove excess heat produced by the new lighting fixtures. This is due to the reduced cooling required as the result of putting the new lighting in place.

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

F = Fraction of annual kWh energy savings that must be removed by the cooling system. If the HVAC system includes an economizer, then F = 0.35. Otherwise, use Table 1 below:
COP = 3.5 (Note [2])

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

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

<u>Retrofit Gross Energy Savings, Fossil Fuel</u>

Space heating energy consumption will increase due to reduced lighting load (cooler lighting fixtures).

Annual Oil Savings = -0.0007129 MMBtu per annual kWh saved and
Annual gas savings = -0.0003649 MMBtu per kWh. See (Ref [3]).

<u>Retrofit Gross Seasonal Peak Demand Savings, Electric (Winter and Summer)</u>

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

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

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

G = 0.73 (Note [3])

COP = 3.5 (Note [2])

Non Energy Benefits

O&M savings due to the installation of new equipment.

Changes from Last Version

No changes.

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 is from "Calculating Lighting and HVAC Interactions," ASHRAE Journal 11-93 as used by KCPL.

[3] Massachusetts Technical Reference Manual, 2012 Program Year, page 170

Notes

[1] To account for the Energy Independence and Security Act of 2007 the baseline for existing (installed) General Service bulbs shall be based on high efficiency incandescent bulbs (such as halogen). Therefore, if the existing incandescent bulb is not a halogen, 75% of actual installed wattage is used for the baseline calculation. 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.

[2] Estimated based on Connecticut Code.

[3] An analysis was conducted by Wood, Byk, and Associates, 829 Meadowview Road, Kennett Square, PA 19348, an engineering firm which was utilized to provide technical support for C&LM programs. The analysis was based on a DOE-2 default analysis and information was provided to David Bebrin (CL&P) on August 17, 2007.

3.1.2 REFRIGERATOR LED

Description of Measure

The replacement of older 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 from more efficient lighting.

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			Note [1]
EER	Energy Efficiency Ratio			Note [1]
AKW	Kilowatts, average demand savings for both summer and winter	kW		
L	Ballast location factor			
N	Number of lights			
h	Lighting annual run hours			
ΔkW	Reduction in power for each light	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). Note [1]
If existing EER's are available then ACOP = Average EER/3.413
Where Average EER = Full Load EER/0.85

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

For open case refrigerators, the coefficient of performance and ballast location factor values shown above must be used. Only lighting savings are claimed and no "refrigeration" savings.

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). Note [1]
If existing EER's are available then COP = EER/3.413
Coincidence Factors (CF) for refrigeration is assumed to be the same for both winter and summer.

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

Changes from Last Version

Added note on open case refrigerators

Notes

[1] Refrigeration interactive factors are based on communication with the Nicholas Group, P.C. The EER and COP values are derived from ASHRAE handbook [2009 ASHRAE Handbook – Fundamentals, 2.3 (13)] for refrigeration equipment as well as experience from submitted projects.

3.2 HVAC & WATER HEATING

3.2.1 WATER SAVING MEASURES

Description of Measure

This measure replaces existing pre-rinse spray valves, shower heads and faucet aerators with units that have an average flow rate of 1.6 gpm (or less), 2.0 gpm and 1.5 gpm respectively.

Savings Methodology

Spray valve savings are based on the results of a replacement program in California (Ref[1]). Showerhead and faucet aerator savings are based on Ref [2]).

Inputs

Symbol	Description	Units
	Number of Spray Valves	
	Number of Showerheads	
	Number of Faucet Aerators	

Nomenclature

Symbol	Description	Units	Values	Comments
$AKWH_w$	Annual Gross Electric Energy savings – water heating	kWh		Ref [1]
$ACCF_w$	Annual natural gas consumption- water heating	Ccf		Ref [1]
gpm	Gallons per minute			
PD_W	Peak Day Savings	Ccf		
PDF_w	Peak Day Factor – water heating		0.00321	Appendix 1

Retrofit Gross Energy Savings, Electric

If hot water is supplied via an electric water heater then energy savings are:

Spray Valves	
Facility Type	**$AKWH_W$ per Spray Valve**
Grocery	126 kWh
Non-grocery	957 kWh

Showerheads/Faucet Aerators (Note [1])	
Type	**$AKWH_W$ per Unit**
Showerhead	475 kWh
Aerator	309 kWh

Retrofit Gross Energy Savings, Fossil Fuel

If hot water is supplied via a gas water heater then annual energy savings are:

Spray Valves	
Facility Type	**$ACCF_W$ per Spray Valve**
Grocery	5.3 CcF (5.5 Therms)
Non-grocery	40.8 CcF (42 Therms)

Showerheads/Faucet Aerators (Note [1])	
Type	**$ACCF_W$ per Unit**
Showerhead	25.3 CcF (26 Therms)
Aerator	16.5 CcF (17 Therms)

Retrofit Gross Seasonal Peak Demand Savings, Electric (Winter and Summer)

Assumed to be zero.

Retrofit Gross Peak Day Savings, Natural Gas

$$PD_W = PDF_W \times ACCF_W = 0.00321 \times ACCF_W$$

Spray Valves	
Facility Type	**PD_W per Spray Valve**
Grocery	0.0172 CcF
Non-grocery	0.1310 CcF

Showerheads/Faucet Aerators (Note [1])	
Type	**PD_W per Unit**
Showerhead	0.0811 CcF
Aerator	0.0530 CcF

Non Energy Benefits

Water savings are estimated to be:

Spray Valves	
Facility Type	**Gallons per year**
Grocery	1,496
Non-grocery	8,603

Showerheads/Faucet Aerators (Note [1])	
Type	**Gallons per year**
Showerhead	3,650
Aerator	5,460

Changes from Last Version

No changes.

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. Table 3-9 page 26

[2] Federal Energy Management Program (FEMP) Energy Cost Calculator for Faucets and Showerheads. http://www1.eere.energy.gov/femp/technologies/eep_faucets_showerheads_calc.html

Notes

[1] Savings for showerheads and faucet aerators are based on the default usage assumed in Ref [2]. On average, faucets are assumed to run 30 minutes per day, 260 days per year. Showerheads are assumed to run 20 minutes per day, 365 days per year. Ref [2] and actual usage values should be used, when known, in lieu of default savings values.

3.2.2 PIPE INSULATION

Description of Measure

Installation of insulation on bare hydronic supply heating pipes located in unconditioned spaces.

Savings Methodology

Savings were determined using 3E Plus v4.1 software (Ref [1]) with 50°F ambient temperature and 180°F fluid temperature. If the difference between the actual average ambient temperature and fluid temperature varies significantly from this difference (130°F), the savings should be scaled using linear interpolation. The hourly heat loss savings per linear foot for various pipe and insulation sizes/material are provided in Table 1 below.

Table1: Hourly Heat Loss Savings per Linear Foot of Pipe Insulation

Pipe Material	Nominal Pipe Size (In)	Insulation Material	Insulation Thickness 0.5(in)	Insulation Thickness 1.0(in)	Insulation Thickness 1.5 (in)	Insulation Thickness 2.0 (in)
			HL Savings Btu/hr/ft	HL Savings Btu/hr/ft	HL Savings Btu/hr/ft	HL Savings Btu/hr/ft
Copper	0.5	Polyethylene foam tube	40	47	50	52
	0.75	Polyethylene foam tube	50	57	61	63
	1.0	Polyethylene foam tube	62	73	77	79
	1.25	Polyethylene foam tube	76	88	96	98
	1.5	Polyethylene foam tube	86	103	109	113
	2.0	Polyethylene foam tube	110	127	135	139
	0.5	Mineral fibers	46	52	54	55
	0.75	Mineral fibers	57	63	66	68
	1.0	Mineral fibers	71	79	82	84
	1.25	Mineral fibers	86	96	102	103
	1.5	Mineral fibers	97	111	115	119
	2.0	Mineral fibers	123	137	142	145
Steel	0.5	Polyethylene foam tube	47	54	57	59
	0.75	Polyethylene foam tube	59	66	71	73
	1.0	Polyethylene foam tube	74	84	88	91
	1.25	Polyethylene foam tube	91	103	111	113
	1.5	Polyethylene foam tube	103	120	126	130
	2.0	Polyethylene foam tube	132	149	156	160
	0.5	Mineral fibers	54	59	62	63
	0.75	Mineral fibers	67	72	75	77
	1.0	Mineral fibers	82	91	94	96
	1.25	Mineral fibers	101	111	117	118
	1.5	Mineral fibers	114	128	132	136
	2.0	Mineral fibers	144	158	164	167

Inputs

Symbol	Description	Units
	Nominal Pipe size diameter	Inches
	Insulation Material	
	Insulation Thickness	Inches
L	Length of Insulation	Linear foot
	Heating Fuel Type(Oil, Gas)	

Nomenclature

Symbol	Description	Units	Values	Comments
ACCF	Annual Natural Gas Savings	Ccf		
EFLH	Equivalent heating full load hours for the facility type	hours	Appendix 5	
HL	Heat loss savings per linear foot of pipe	Btu/ft/hr	Table 1	
L	Length of pipe being insulated	Linear ft		
AFUE	Annual Fuel Utilization Efficiency, estimated boiler efficiency		0.80	
PD	Peak day savings natural gas	Ccf		

Retrofit Gross Energy Savings, Fossil Fuel

Annual Gas Heating Savings

$$ACCF = \frac{HL \times EFLH}{(102{,}900 \times 0.80)} \times L$$

Annual Oil Heating Savings

$$AOG = \frac{HL \times EFLH}{(138{,}690 \times 0.80)} \times L$$

Retrofit Gross Energy Savings, Example

One inch (1”) thick polyolefin C1427-04 insulation was installed on 100 feet un-insulated hot water heating supply pipe (copper). The pipe nominal size is 1 inch and is located in unconditioned space of an office/retail type business. What are the energy savings resulting from adding the insulation?

Based on these data and using table1 above, the corresponding HL heat loss savings is 73 Btu/ft/hr. The length of pipe being insulated L=100 ft. Using Appendix 5, (hours of use), heating EFLH for an office/retail is 1248. Using the savings formula:

$$ACCF = \frac{HL \times EFLH}{(102{,}900 \times 0.80)} \times L = \frac{73 \times 1248}{(102{,}900 \times 0.80)} \times 100 = 110.7Ccf$$

Retrofit Gross Peak Day Savings, Natural Gas

$$\mathrm{PD} = \frac{\mathrm{ACCF}}{\mathrm{EFLH}} \times 24$$

Changes from Last Version

No changes.

References

[1] NAIMA, 3E Plus software tool, Version 4.1, Released 2012.

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 in the residential section of this document (Measure 4.2.9).

Changes from Last Version

No changes.

3.2.4 DUCT INSULATION

Description of Measure

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

Savings Methodology

The savings were determined using 3E Plus v4.1 software (Ref [1]). The savings are based on insulating existing bare ducting with R-6 insulation (Ref [2]). Savings presented in table 1 below are for example purposes only and should only be used when the parameters (inputs) match the inputs here (like average air supply/return temperatures are 130deg F/ 65deg F for heating). For all other scenarios, the 3E software or a similar methodology should be used to develop estimates of the appropriate energy savings under actual conditions.

Table 1: Assumed temperature conditions

Duct Location	Season	Ambient Temp (°F)	Supply Air Temp (°F)	Return Air Temp (°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 hour per ft² of insulation

	$BTUH_b$ (Bare)		$BTUH_a$ (Insulated R-6)	
Duct Location	Heating Btu/hr/ft²	Cooling Btu/hr/ft²	Heating Btu/hr/ft²	Cooling Btu/hr/ft²
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
	Heating Fuel /Heating system type (Elect Heat Pump, Gas Furnace, …)

Nomenclature

Symbol	Description	Units	Values	Comments
$AKWH_C$	Annual gross electric cooling savings	kWh		
$AKWH_H$	Annual gross electric heating savings	kWh		
$BTUH_{ca}$	Cooling heat transfer rate of insulated ducting	Btu/hr/ft^2	Table 2	
$BTUH_{cb}$	Cooling heat transfer rate of un-insulated ducting	Btu/hr/ft^2	Table 2	
$BTUH_{ha}$	Heating heat transfer rate of insulated ducting	Btu/hr/ft^2	Table 2	
$BTUH_{hb}$	Heating heat transfer rate of un-insulated ducting	Btu/hr/ft^2	Table 2	
COP_H	Coefficient of Performance of heating equipment	Unitless	1.0 for Elect furnace 2.0 for Heat Pump 3.0 for Ground Source Heat Pump	
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

Annual gross electric heating savings for electrically heated buildings:

$$AKWH_H = \frac{(BTUH_{hb} - BTUH_{ha}) \times EFLH \times A}{3412 \times COP_H}$$

Annual gross electric cooling savings for building equipped with Central AC or Heat pump:

$$AKWH_C = \frac{(BTUH_{cb} - BTUH_{ca}) \times EFLH \times A}{3412 \times 3.5}$$

Where:
3412 = converts Btu to kWh
3.5 = estimated cooling equipment efficiency, COP

Retrofit Gross Energy Savings, Fossil Fuel

Annual gross gas savings Gas heated buildings:

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

Where:
0.80 = estimated heating equipment efficiency

Retrofit Gross Energy Savings, Example

R-6 Insulation was installed on 100 ft^2 of bare supply ducting located in the basement of a small retail store. This system is utilizes a heat pump and provides both heating and cooling. What are the savings?

Annual gross electric heating savings:

$$AKWH_H = \frac{(BTUH_{hb} - BTUH_{ha}) \times EFLH \times A}{3412 \times 2}$$

From Table 2: $BTUH_{hb}$=132.34
From Table 2: $BTUH_{ha}$=12.04
From Appendix 5: EFLH heating=1248 hr
A= 100 ft^2
From Nomenclature table: COP_H for Heat pump = 2.0

$$AKWH_H = \frac{(132.34 - 12.04) \times 1248 \times 100}{3412 \times 2} = 2200.09 kWh$$

Annual gross electric cooling savings:

$$AKWH_C = \frac{(BTUH_{cb} - BTUH_{ca}) \times EFLH \times A}{3412 \times 3.5}$$

From table 2 $BTUH_{cb}$=25.22
From table 2 $BTUH_{ca}$=2.73
From Appendix 5 EFLH cooling=797
A= 100 ft^2

$$AKWH_C = \frac{(25.22 - 2.73) \times 797 \times 100}{3412 \times 3.5} = 150.10 kWh$$

<u>Retrofit Gross Seasonal Peak Demand Savings, Electric (Winter and Summer)</u>

Currently, no demand savings are claimed for this measure.

<u>Changes from Last Version</u>

Added reference [2]

<u>References</u>

[1] NAIMA, 3E Plus software tool, Version 4.1, Released 2012.

[2] Minimum Duct Insulation R-Value, Table 6.8.2B, ASHRAE Standard 90.1 – 2010.

3.2.5 SET BACK THERMOSTAT

Description of Measure

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

Savings Methodology

Savings estimates below are based on computer simulation models (Ref [1]). Seven models were developed assuming different occupancy schedules. A 10 degree setback for unoccupied periods is assumed for both heating and cooling modes. A relationship between hours of occupancy and savings was developed from these models based on installed capacity (kW-electric heating, Tons-cooling, MBh-gas heat). Savings will only be realized if the facility currently maintains a constant temperature for both occupied and unoccupied periods.

There are no electric demand savings since savings occur during off peak periods. Peak day savings are calculated using a peak day factor (0.0477) calculated for setback thermostats. A temperature bin analysis was used to calculate the reduction for the temperature bins during set back period. The sum load reductions from the coldest 24 hours were divided by the total sum of load reduction for the entire year

Inputs

Symbol	Description	Units
CAP	Output capacity of gas heating equipment	MBh
Hrs	Occupied Hours per week	Hrs
Tons	Installed Cooling Capacity	Tons
Nr	Nameplate Rating of baseboard electric resistance heat	kW (Note [2])

Nomenclature

Symbol	Description	Units	Values	Comments
ACCF	Annual Natural Gas Savings	Ccf		
AKWH	Annual Gross Electric Energy savings	kWh		
CAP	Output capacity of gas heating equipment	MBh		Input
Hrs	Occupied Hours per week	Hours		Input
MBh	Thousands of Btu per hour			
Nr	Nameplate Rating of baseboard electric resistance heat	kW		Input
PDF	Peak Day Factor		0.0477	
PD	Peak Day Savings	Ccf		
SF_{CCF}	CcF savings factor	Ccf/MBh		Note [1]
$SF_{kWh,H}$	kWh savings factor – electric heat	kWh/kW		Note [1]
$SF_{kWh,C}$	kWh savings factor – cooling	kWh/Ton		Note [1]
Tons	Installed cooling capacity	Tons		Input

Retrofit Gross Energy Savings, Electric

Heating (Applicable only if the facility has an existing electric resistance heat)

$$SF_{kWh,H} = 239.48 - (1.5569 \times Hrs)$$

$$AKWH_H = Nr \times SF_{kWh,H} = Nr \times (239.48 - 1.5569 \times Hrs)$$

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

$$SF_{kWh,C} = 167.01 - (1.0929 \times Hrs)$$

$$AKWH_C = Tons \times SF_{kWh,C} = Tons \times [167.01 - (1.0929 \times Hrs)]$$

Retrofit Gross Energy Savings, Fossil Fuel

Heating (Applicable only if the facility has an existing gas heat)

$$SF_{CCF} = 2.79 - (0.0181 \times Hrs)$$

$$ACCF = CAP \times SF_{CCF} = CAP \times [2.79 - (0.0181 \times Hrs)]$$

Retrofit Gross Seasonal Peak Demand Savings, Electric (Winter and Summer)

There are no demand savings since savings occurs during off peak periods

Retrofit Gross Peak Day Savings, Natural gas

$$PD = PDF \times ACCF = 0.0477 \times ACCF$$

Changes from Last Version

No changes.

References

[1] Trane System Analyzer version 6.1

Notes

[1] Ref [1] to model a number of different occupancy schedules. These results were used to develop a correlation between occupancy schedule and energy savings. These equations are used to adjust savings for different occupancy schedules.

[2] If nameplate kW is not available for electric baseboard use 200 watts per foot for baseboards < 3 feet and 250 watts per foot for all others. These values are based on research of typical existing equipment.

3.2.6 STEAM TRAP REPLACEMENT

Description of Measure

This measure replaces steam traps that are leaking or have failed open in commercial and industrial applications. It is applicable to thermostatic, mechanical or thermodynamic traps and not applicable to venturi/orifice traps (Ref [1]).

Savings Methodology

The savings estimates below are based on Napier's equation, which provides steam loss through orifices at various pressures. The steam flows derived from the Napier's equation are adjusted down based on whether the trap is leaking or failed open. Not all steam energy will be lost to the environment.

Inputs

Symbol	Description
P	Steam Pressure (psig)
D	Orifice diameter (in)
EFLH	Equivalent full load hours (hrs)

Nomenclature

Symbol	Description	Units	Values	Comments
ACCF	Annual natural gas savings	Ccf	102,900 Btu	
D	Orifice diameter	Inches		
Eff	Boiler efficiency	%	80%	
EFLH	Equivalent full load hours	Hours	See below	Note [1] Note [2]
h_{fg}	Specific Enthalpy of Evaporation	Btu/ lb_m	Varies based on pressure.	
Lb_m	Steam flow through orifice	lb_m/hr		
L_f	Steam loss adjustment factor	%	50% for failed traps. 12.5% for leaking traps.	
P	Gauge Pressure	psig		
Pa	Absolute pressure	psia	Gauge pressure in psig + Atmospheric pressure (14.696)	
PD	Peak day natural gas savings	Ccf		

Retrofit Gross Energy Savings, Fossil Fuel

Step 1 – Use Napier's equation to determine the steam flow rate in the orifice (Ref [2]).

$$lb_m = 24.24 \times P_a \times D^2$$

Where, lb_m = Steam flow rate, lb/hr
P_a = Absolute pressure, psia
D = Diameter of the orifice, in

Table 1: Enthalpy of Steam by Pressure (Ref [3])

Gauge Pressure (psig)	Absolute Pressure (psia)	Specific Enthalpy of Evaporation (Btu/lb)
2	16.70	966.07
5	19.70	960.54
10	24.70	952.56
15	29.70	945.68
25	39.70	934.09
50	64.70	912.06
75	89.70	895.16
100	114.70	881.04
125	139.70	868.68
150	164.70	857.58
200	214.70	837.95
250	264.70	820.68
300	314.70	805.03

Step 2 – Using the following equation estimate annual savings based on the steam loss (Step 1), specific enthalpy of evaporation (Table 1), equivalent full load hours, adjustment factors and boiler efficiency:

$$ACCF = \frac{lb_m \times h_{fg} \times EFLH \times L_f}{Eff \times 102{,}900}$$

<u>Retrofit Gross Peak Day Savings, Natural Gas</u>

$$PD = \frac{ACCF \times 24}{EFLH}$$

Where,

EFLH = Site specific hours if available

If unknown,

EFLH = 7,752 for process steam (Note [1])

EFLH = 3,763 for heating steam coil applications (Note [2])

EFLH = 5,376 for heating steam distribution applications

<u>Changes from Last Version</u>

No Changes

References

[1] Steam Efficiency Improvement, Boiler Efficiency Institute, Alabama, 1987.

[2] Steam Pressure Reduction: Opportunities and Issues, Energy Efficiency and Renewable Energy, U.S. Department of Energy, Washington DC, 2005.

[3] Steam Tables, Spirax Sarco, 2013. < http://www2.spiraxsarco.com/esc/Ss_Properties.aspx > Last accessed on Oct 10, 2013.

3.2.7 BLOWER DOOR TEST (SMALL C&I)

Description of Measure

This measure is for verifying infiltration reduction of older residential type construction, less than 5,000 ft^2, used for commercial occupancy (predominantly small business customers). Blower Door test equipment must be used to verify infiltration reduction.

Savings Methodology

The savings methodology is based on seven pilot projects conducted under CL&P's small business air sealing pilot program in Connecticut (Note [1]). Actual blower door tests were conducted at these sites. DOE-2 simulation and billing analyses were also performed for the pilot projects. The results were reviewed and verified by the utility engineers. The average energy savings per CFM reduction were estimated from the results of the projects and then converted to the appropriate fuels using unit conversions. The cooling savings per CFM and demand savings are from residential blower door measure (Measure 4.4.4). The savings would be reviewed with customer billing data by utility staff.

Inputs

Symbol	Description
CFM_{pre}	Infiltration before air sealing at 50 Pa
CFM_{post}	Infiltration after air sealing at 50 Pa
	Heating fuel type (e.g. electric resistive, HP, gas, oil, etc…)
	Heating distribution type (e.g. forced air with fan, HP, etc…)

Nomenclature

Symbol	Description	Units	Values	Comments
$AKWH_C$	Annual gross electric energy savings - Cooling	kWh		
$AKWH_H$	Annual gross electric energy savings - Heating	kWh		
CFM_{post}	Infiltration after air sealing measured with the house being negatively pressurized to 50 Pa relative to outdoor conditions.	CFM		
CFM_{pre}	Infiltration before air sealing measured with the house being negatively pressurized to 50 Pa relative to outdoor conditions.	CFM		
PDF_H	Natural gas peak day factor, Heating		0.00977	Appendix 1
PD_H	Natural gas peak day savings, Heating	CCF		
SKW_C	Seasonal Summer peak demand savings - Cooling	kW		
WKW_H	Seasonal Winter peak demand savings - Heating	kW	0	

Retrofit Gross Energy Savings, Electric

Table 1: Retrofit electric savings per CFM reduction (at 50 Pa)

Measure	Symbol	Energy Savings	Units
Electric Resistance Heating	$BD_{Heating}$	2.53	kWh
Heat Pump Heating	$BD_{Heating}$	1.26	kWh
Geothermal Heating	$BD_{Heating}$	0.84	kWh
Air Handler (fan)	BD_{AH}	0.025	kWh
Cooling (Central Air)	$BD_{Cooling}$	0.059	kWh

For electric resistive, heat pump or geothermal heating systems,

$$AkWH_H = BD_{Heating} \times (CFM_{Pre} - CFM_{Post})$$

For fossil fuel heating with air handler unit,

$$AkWH_H = BD_{AH} \times (CFM_{Pre} - CFM_{Post})$$

For homes with central air cooling,

$$AkWH_C = BD_{Cooling} \times (CFM_{Pre} - CFM_{Post})$$

Retrofit Gross Energy Savings, Fossil Fuel

Table 2: Retrofit fossil fuel savings per CFM reduction (at 50 Pa)

Measure	Symbol	Energy Savings	Units
Fossil fuel heating			
Natural Gas heating	BD_{NG}	0.11	CCF
Propane heating	$BD_{propane}$	0.12	Gallons
Oil heating	BD_{Oil}	0.07	Gallons

For homes with natural gas heating system,

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

For homes with oil heating system,

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

For homes with propane heating system,

$$APG_H = BD_{propane} \times (CFM_{Pre} - CFM_{Post})$$

Retrofit Gross Seasonal Peak Demand Savings, Electric (Winter and Summer)

Table 3: Demand savings per CFM reduction

Measure	Symbol	Energy Savings	Units
Electric Resistance and Heat Pump	BD_{WKW}	0.00117	kW
Geothermal Heat Pump	BD_{WKW}	0.00039	kW
Central AC and Heat Pump	BD_{SKW}	0.00009	kW

$$WKW_H = BD_{WKW} \times (CFM_{Pre} - CFM_{Post})$$

$$SKW_C = BD_{SKW} \times (CFM_{Pre} - CFM_{Post})$$

Note: *The demand savings are from the residential measure 4.4.4 Infiltration Reduction Testing (Blower Door Test).*

Retrofit Gross Peak Day Savings, Natural Gas

For homes with natural gas heating system,

$$PD_H = ACCF_H \times PDF_H$$

Changes from Last Version

None

Notes

[1] As part of CL&P's Small Business Energy Advantage (SBEA) Air Sealing Pilot, in 2012 EcoSmart Energy Services conducted air sealing, blower door tests, DOE-2 modeling and billing analysis on seven older residential type construction, both balloon and platform framing, that are used for commercial occupancy in Connecticut. The above energy savings per CFM are based on the pilot projects.

3.2.8 ADD SPEED CONTROL TO ROOFTOP UNIT FAN

Description of Measure

This measure installs speed control on existing constant speed rooftop unit evaporator/ventilation fans. In most cases the control method will include a variable frequency drive but the speed settings will be staged based on heating, cooling and ventilation modes.

Savings Methodology

The savings are determined via spreadsheet and are based on the inputs below and the following assumptions:

1) Full load cooling and heating hours from appendex 5
2) 13% of the fan hours are assumed to be in free cooling -Based onlocal temperature bins
3) 25% of heating/cooling equivalent full load hours are assumed to be in stage 2 –(Based on local temperature bins)
4) 75% of heating/cooling equivalent full load hours are assumed to be in stage 1 (50% output)
5) To calculate the fan hours in stage one, the equivalent full load heating/ cooling are multiplied by (75% from above) then divided by 50% capacity.

Reference 1 is for information only.

Inputs

Symbol	Description
H	Fan run hours
$EFLH_C$	Equivalent full load cooling hours
$EFLH_H$	Equivalent full load heating hours
SP1	Stage 1 fan speed
SP2	Stage 2 fan speed
SPV	Ventilation only fan speed
HP	Fan motor nameplate horsepower
LF	Fan Motor load factor
EF_M	Motor Efficiency

Nomenclature

Symbol	Description	Units	Values	Comments
AKW	Annual Summer and Winter Seasonal peak demand savings	kW		
AKWH	Annual gross electric energy savings	kWh		
$AKWH_E$	Annual gross electric energy consumption-Existing System	kWh		
$AKWH_R$	Annual gross electric energy consumption- After Retrofit	kWh		
EF_M	Motor Efficiency	%		
$EFLH_C$	Equivalent full load cooling hours	Hours		(Appendix 5)
$EFLH_H$	Equivalent full load heating hours	Hours		(Appendix 5)
H	Total fan run hours	Hours		(Appendix 5)
H_1	Fan run hours at stage 1	Hours		See spreadsheet
H_2	Fan run hours at stage 2	Hours		See spreadsheet
H_V	Fan run hours in ventilation only mode	Hours		Hours when no heating or cooling
H_O	Fan run hours in free cooling mode	Hours		13% of total

Symbol	Description	Units	Values	Comments
				fan hours
HP	Fan motor nameplate horsepower	Horsepower		
KW_E	Existing Fan kW	kW		
LF	Fan motor load factor	%	80%	
SP1	Stage 1 fan speed	%	75%	
SP2	Stage 2 fan speed	%	90%	
SPV	Ventilation only fan speed	%	40%	
	Fan Savings Exponent		2.7	Note [1]

Retrofit Gross Energy Savings, Electric

$AKWH = AKWH_E - AKWH_R$

$AKWH_E = KW_E * H$

$$KW_E = \frac{0.746 \times HP \times LF}{EF_M}$$

$$AKWH_R = \frac{KW_E \times SP1^{2.7} \times H_1}{0.97} + \frac{KW_E \times SP2^{2.7} \times H_2}{0.97} + \frac{KW_E \times SP1^{2.7} \times H_O}{0.97} + \frac{KW_E \times SPV^{2.7} \times H_V}{0.97}$$

Retrofit Gross Seasonal Peak Demand Savings, Electric (Winter and Summer)

$$AKW = KW_E - \left(\frac{KW_E \times SP2^{2.7}}{0.97} \right)$$

It is assumed that the fan will be running at stage 2 speed during the summer/winter peak demand period and is 100% coincident.

Changes from Last Version

Add Note regarding 2.7 exponent for fan savings
Clarified savings methodology
Add fan motor load factor assumption

References

[1] Advanced Rooftop Control (ARC) Retrofit: Field-Test Results, PNNL-22656, Pacific Northwest National Laboratory, July 2013.

Notes

[1] Exponent for fan saving that adjust ideal fan law vale of 3.0 to account for fan, motor and VFD efficiency

3.2.9 COMMERCIAL KITCHEN HOOD CONTROLS

Description of Measure

This measure if for the installation of controls to reduce airflow in commercial kitchen exhausts hoods. These systems can also control the airflow in dedicated make-up air units associated with the kitchen exhaust hoods. Savings are achieved by reducing the air flow of the exhaust and make-up air fans when cooking is not taking place under the hoods. Significant fan energy savings can be achieved along with reductions in heating and air conditioning loads.

Typically these systems will be retrofit to existing exhaust hoods or installed. Systems may also be installed during construction of a new commercial kitchen.

Savings Methodology

The energy savings are calculated using a custom spreadsheet based on site specific input for all projects. Savings are based on hours of kitchen operation, size of exhaust and make-up air fans, size of the kitchen, ventilation rate and oversize factor of the exhaust hoods, cooling and heating efficiencies and outside air temperatures. Adjustments can be made to the savings based on how much conditioned air the exhaust fans are pulling for the facility (is the kitchen area closed off from the dining area, are there make-up air fans incorporated in the exhaust hoods or in close proximity?).

Fan energy savings are estimated based on empirical data from studies of existing installations at a variety of types of facilities.

Heating and air conditioning savings are estimated using temperature bin data, along with an estimate of how much conditioned air is being exhausted.

Summer seasonal peak electric demand savings are assumed to be zero as most commercial kitchens are assumed to be operating during the summer seasonal peak period.

Natural gas peak day savings are calculated using the peak day factor for furnace/boiler of 0.0152 from measure 2.2.6 since the savings for this measure are consistent with the furnace/boiler savings profile.

The baseline for this measure is a kitchen exhaust system without variable speed fan controls.

Inputs

Symbol	Description	Units
Hr	Hours of Operation	hrs
HP_{EF}	Horsepower of Exhaust Fans	HP
HP_{MA}	Horsepower of Make-up Air Fans	HP
N_{EF}	Number of Exhaust Fans	
N_{MA}	Number of Make-up Air Fans	
EER	Cooling System Efficiency	Btu/watt-hr
HEFF	Heating System Efficiency	%
VR	Kitchen Ventilation Rate	CFM/ft^2
A	Kitchen Area	Ft^2
OF	Ventilation over size Factor	%
PR	Power Reduction	%
FR	Flow Reduction	%
MEff	Motor Efficiency	%
LF	Motor Load Factor	%
MHDD	Modified Heating Degree Days	^oF-day
CDD	Modified Cooling degree Days	^oF-day

Changes from Last Version

No changes

3.3 OTHER

3.3.1 CUSTOM MEASURE

Description of Measure

This measure may apply to any C&I Retrofit installations whose scope may be considered custom or comprehensive and not covered by a another specific measure.

Savings Methodology

Energy and demand savings are calculated on a custom basis for each customer's specific situation. Savings are calculated as the difference between baseline energy usage/peak demand and the energy use/peak demand after implementation of the custom measure. Energy savings estimates should be calibrated against billing or metered data where possible to test the reasonableness of energy savings. Also, the energy and demand savings analysis must be reviewed for reasonableness by either a third party consulting engineer or a qualified in-house engineer.

The methodology for determining gas peak day savings is provided in Appendix 1.

Note that the demand savings methodologies below provide a gross, reasonable estimate based on available information. Final reported values are adjusted based on realization rates provided in Appendix 3.

Electric demand savings methodologies are categorized as follows:

1. Temperature dependent measures (HVAC measures that vary with ambient temperature)

2. Non-temperature dependent measures (process, lighting, time control)

3. Computer simulation modeled measures (may include both 1 and 2)

Temperature dependent measures:

Savings from individual temperature dependent measures are typically determined by either full load hour analysis or bin temperature analysis:

Full Load Hour Analysis

Summer and winter demand savings are calculated using an appropriately derived seasonal peak coincidence factor. Coincident factors for various measures (and/or end use) are provided in Appendix 1. Demand savings will be determined by multiplying the connected load kW savings by the appropriate coincidence factor.

Temperature Bin Analysis

Temperature Bins shall be designated in 2 degree Fahrenheit increments.

- The summer seasonal peak demand savings shall be the difference between the weighted average demand of the top temperature bins that capture the majority of the ISO-NE summer seasonal peak hours in the previous three years, for the base and "efficient" cases. All hours above 80 degrees will be used for Bridgeport and 84 degrees will be used for Hartford.

- The winter seasonal peak demand savings shall be the difference between the weighted average demand of the bottom temperature bins that capture the majority of the ISO-NE winter seasonal peak hours in the previous three years, for the base and "efficient" cases. All hours below 30 degrees will be used for Bridgeport and 26 degrees will be used for Hartford.

Non-temperature-dependent measures:

Demand savings for measures that are not temperature-dependent will be determined by either the coincidence factors from Appendix 1 or the average estimated week day (WD) savings over the summer or winter seasonal peak period. A custom coincidence factor may also be used for measures or end uses that are not identified in Appendix 1. However, the analysis determining the custom coincidence factor must be performed or approved by a qualified in house engineer.

The average summer/winter seasonal peak demand savings shall be determined as follows:

$$SKW = \frac{Annual\ kWh\ savings\ (WD - June, July, August)}{Equipment\ \ Run\ hours\ (WD - June, July, August)} \times \left(\frac{Run\ hours\ during\ 12pm - 6pm\ WD}{6} \right)$$

$$WKW = \frac{Annual\ kWh\ savings\ (WD - December, January)}{Equipment\ \ Run\ hours\ (WD - December, January)} \times \left(\frac{Run\ Hours\ during\ 4pm - 9pm\ WD}{5} \right)$$

Note that the average demand savings methodology should only be used when the coincident factor methodology cannot or is not practicable.

Computer Simulation Modeling:

For certain unique or complex projects including those with interactive effects performance shall be determined using a computer simulation model. Approved software and modeling requirements are specified by the program administrators.

The methodology for determining the seasonal peak demand savings will depend on the computer simulation output capabilities. If the model can provide the demand for the coldest and hottest hours of the year and the month when they occur, then that data will be used to determine demand savings.

The summer seasonal peak demand savings will be the difference between the peak demand (whole building) from the base and design models during the hours as described in the temperature dependent section above. This assumes the hottest hours occurs during June through August. If the hottest hour methodology cannot be used then the demand savings shall be determined by taking the difference in the peak demand between the base and design models for the summer month (June through August) with the highest cooling load in the base model. If neither of these methods can be used then in house engineering must review the project/model to determine an acceptable method.

The winter seasonal peak demand savings will be the difference between the peak demand (whole building) from the base and design models during the coldest hours as described in the temperature dependent section aboveof . This assumes the coldest hours occurs during December or January. If the coldest hour methodology cannot be used then the demand savings shall be determined by taking the average winter (December, January) peak demand from the base model and subtracting the average winter (December, January) peak demand from the design model.

Baseline:

The baseline efficiency is the efficiency of the existing equipment being replaced in the measure.

Nomenclature

Symbol	Description	Units	Values	Comments
WD	Week Days	Days		

Changes from Last Version

No changes

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 the 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 (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 per year		
h	Hours per year the cover are in use	Hours/yr		
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 (Ref [1])

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

Retrofit Gross Seasonal Peak Demand Savings, Electric (Winter and Summer)

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

Changes from Last Version

No changes.

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 either shuts off or reduces the speed of 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 fan speed or the number of hours 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 speed or run-hours. The off hours, power reduction factors and power factor are stipulated values based on vendor experience. Fans with two speed controllers are assumed to operate at approximately 52% speed when on the low speed setting. This assumption is based on data provided by one of the controller manufacturers.

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			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			
PSC	Permanent Split Capacitor motor			
r	Adjustment factor for two speed controllers		1 or 0.86	
V	Volts of existing fans			
h	Fan off hours after measure installation			

Retrofit Gross Energy Savings, Electric

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

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

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

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

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 or if the volt/amp readings were taken after fans were replaced, then DP = 0. See Note [1].

Pf = estimated to be 0.65.

h = 3,000. See Note [2].

r= 1 for on/off controllers and 0.86 for two speed controllers.

ACOP = 2.03 for freezers and 2.69 for coolers (used for interactive affects). See Note [3].

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:

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

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

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

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 or if the volt/amp readings were taken after fans were replaced, then DP = 0. See Note [1].

Pf = estimated to be 0.65

r= 1 for on/off controllers and 0.86 for two speed controllers.

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

No changes.

References

[1] 2010 ASHRAE Handbook - Refrigeration. Retail Food Store Refrigeration and Equipment, Chapter 15, Figure 24.

Notes

[1] Power reduction factors of existing fans are based on correspondence with a National Resource Management (NRM) representative, March 3 and June 6 of 2011. If motors are being replaced concurrently with this measure then savings calculation for this measure should be coordinated with 3.4.3 to ensure the ending point of one measure (fan power/hours) is the starting point for the other.

[2] Fan off hours after measure installation (h) is based on correspondence with Nick Gianakas, Nicholas Group, P.C., June 27, 2010.

[3] Refrigeration interactive factors are derived from Reference [1] and correspondence with Nick Gianakas, Nicholas Group,P.C., June 27, 2010.

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.

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 (used for interactive affects)		Estimate from existing EER when available per Note [4], otherwise: Freezers: 2.03 Coolers: 2.69	Notes [4], [3]
AKWH	Annual Gross Electric Energy savings	kWh		
CF	Seasonal peak demand coincident factor for refrigeration (Same for Summer and Winter)			Appendix 1
COP	Coefficient of Performance (used to calculate interactive affects)		Freezers: 1.72 Coolers: 2.29	
DP	Power reduction factor		PSC motors: 0.40 Shaded pole motors:0.65	Note [1]
EER	Energy Efficiency Ratio			
h	Hours of operation	hours	With existing controls: 5,500 Without controls: 8,500	Note [2]
N	Number of fans			
Pf	Power factor of existing fans		0.65	Estimated
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:

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

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:

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

Changes from Last Version

No changes.

References

[1] 2010 ASHRAE Handbook - Refrigeration. Retail Food Store Refrigeration and Equipment, Chapter 15, Figure 24

Notes

[1] Power reduction factors of existing fans are based on correspondence with a National Resource Management (NRM) representative on March 3 and June 6 of 2011.

[2] Fan off hours after measure installation (h) is based on correspondence with Nick Gianakas, Nicholas Group,P.C., June 27, 2010. If fan controls are being installed concurrently with this measure then savings calculation for this measure should be coordinated with 3.4.2 to ensure the ending point of one measure (fan power/hours) is the starting point for the other.

[3] Refrigeration interactive factors are derived from Reference [1] and correspondence with Nick Gianakas, Nicholas Group,P.C., June 27, 2010.

[4] If existing EER's are available then ACOP = Average EER/3.413
Average EER = Full Load EER/0.85

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 based on vendor experience (See Note [1]). They are applicable to all store types and sizes.

Inputs

Symbol	Description
A	Amperage
N	Number of Door heaters
V	Volts
	Type: Cooler or Freezer

Nomenclature

Symbol	Description	Units	Values	Comments
A	Amperage of door heater			
AKW	Annual summer and winter electric demand savings	kW		
AKWH	Annual Gross Electric Energy savings	kWh		
CF	Seasonal peak demand coincident factor for refrigeration (Same for Summer and Winter)		Appendix 1	
h	Heater off hours after measure installation	hours	Coolers: 6,500 Freezers: 4,070	Note [1]
kW	KiloWatts			
N	Number of heaters			
Pf	Power Factor		1	Note [2]
V	Volts of door heater			

Retrofit Gross Energy Savings, Electric

$$AKWH = \frac{N \times V \times A \times Pf \times h}{1000 \, {}^{W}\!/_{kW}}$$

Retrofit Gross Seasonal Peak Demand Savings, Electric (Winter and Summer)

$$AKW = \frac{CF \times N \times V \times A \times Pf}{1000 \, {}^{W}\!/_{kW}}$$

Changes from Last Version

No changes.

Notes

[1] Heater off hours after measure installation for freezers and refrigerators are based on correspondence with a National Resource Management (NRM) representative, June 8, 2011. For the purposes of electric demand savings calculations, CF for refrigeration is assumed to be the same for both winter and summer.

[2] Assumes single phase power.

3.4.5 VENDING MACHINE CONTROLS

Description of Measure

This measure relates to the installation of new controls on existing refrigerated beverage vending machines, non-refrigerated snack vending machines, and glass front refrigerated coolers.

Controls can significantly reduce the energy consumption of vending machine and refrigeration systems.

This measure covers two separate methods of on/off control of vending machines. In one method the vending machine is controlled by occupancy sensors. The second method controls operation based on a set time schedule.

Qualifying controls must power down these systems during scheduled periods or periods of inactivity but, in the case of refrigerated machines, must always maintain a cool product that meets customer expectations.

This measure should not be applied to ENERGY STAR qualified vending machines, as they already have built-in controls.

Inputs

Symbol	Description
Equipment Type	Type of Vending Machine
$HOURS_{after}$	Hours vending machine turned on after measure installation
N	Number of vending machines
A	Amperage of vending machine (if available)
V	Voltage of Vending machine

Nomenclature

Symbol	Description	Units	Values	Comments
A	Amperage of vending machine	amps		
AKWH	Annual Gross Electric Energy Savings	kWh		
ESF	Energy Savings Factor			Tables 2 & 3
Equipment Type	Type of Vending Machine			
$HOURS_{after}$	Hours vending machine turned on after measure installation			
$HOURS_{before}$	Hours vending machine turned on before measure installation	hrs	8,760	
N	Number of vending machines			
PF	Power factor		0.85	
SKW	Summer Demand Savings	kW	0	
V	Volts of vending machine	volts		
$WATTS_{base}$	Connected kW of the controlled equipment	W		Table 1
WKW	Winter Demand Savings	kW	0	

Retrofit Gross Energy Savings, Electric

$AKWH = WATTS_{base} /1000 \times HOURS \times ESF \times N$

Where:

$WATTS_{base}$ = connected kW of the controlled equipment; see Table 1 below for default values by connected equipment type:

or where amperage and voltage are known using the following calculation;

= V x A x PF

1,000 = conversion factor (W/kW)

HOURS = operating hours of the connected equipment; in most cases it is assumed that the equipment operates 24 hours per day, 365 days per year or 8760.

ESF = Energy Savings Factor; represents the percent reduction in annual kWh consumption of the equipment controlled; see Table 2 below for Occupancy Based Controls by equipment type, and Table 3 below for Time Schedule Based Controls by equipment type.

Table 1: Connected Wattage of Vending Machines

Equipment Type	**$WATTS_{base}$ (Ref[1])**
Refrigerated Beverage Vending Machines	400
Non-Refrigerated Snack Vending Machines	85
Glass Front Refrigerated Coolers	460
Custom Calculation	V x A x PF

Table 2: Occupancy Based Controls

Equipment Type	**Energy Savings Factor (ESF) (Ref[1])**
Refrigerated Beverage Vending Machines	46%
Non-Refrigerated Snack Vending Machines	46%
Glass Front Refrigerated Coolers	30%

Table 3: Time Schedule Based Controls

Equipment Type	**Energy Savings Factor (ESF)**
All	$\left(1 - \frac{HOURS_{after}}{HOURS}\right) \times 0.45$ [Note 2]

Retrofit Gross Seasonal Peak Demand Savings, Electric (Winter and Summer)

SKW = 0
WKW = 0

Retrofit of Occupancy Controls on Refrigerated Beverage Vending Machine, Example

Add occupancy sensors to two (2) exiting soda vending machine where amperage and voltage is unknown.

AKWH = $WATTS_{base} /1000 \times HOURS \times ESF \times N$

From Table 1 Wattsbase = 400 W
From table 2 ESF= 0.46

AKWH = 400/ 1000 x 8760 x 0.46 x 2 = 3,224 kWh

Retrofit of on/off timer on a Glass Refrigerated Cooler, Example

Add a timer to an existing cooler. Electric input to cooler is measured at 120 volt and 4.2 Amps. Timer will shut the cooler of for 11 hours per day.

AKWH = $WATTS_{base}$ */1000 x HOURS x ESF x N*

$Watts_{base}$*= V x A x PF= 120 x4.2 x 0.85 = 428 W*

$$ESF = \left(1 - \frac{HOURS_{after}}{HOURS}\right) \text{ x } 0.45$$

$HOURS_{after}$ = 8760 – (365 x11) = 4,745 hrs

$$ESF = \left(1 - \frac{4745hrs}{8760hrs}\right) \text{ x } 0.45 \quad = 0.2065$$

AKWH = 428/1000 x 8760 x 0.2065 x 1= 774 kWh

Changes from Last Version

No Changes.

References

[1] USA Technologies Energy Management Product Sheets, July 2006; cited September 2009. <http://www.usatech.com/energy_management/energy_productsheets.php>

Notes

[1] Assumed that the peak period is coincident with periods of high traffic diminishing the demand reduction potential of occupancy based or time schedule based controls.

[2] The 45% factor to account for compressor cycling is based on NRM field experience and email communication with Nick Gianakos, June 27, 2010.

3.4.6 ADD DOORS TO OPEN REFRIGERATED DISPLAY CASES

Description of Measure

Installation of glass doors on open refrigerated display cases.

The savings from this measure are based on an ASHRAE research project (Ref [1]) that compared the energy consumption of a new open refrigerated display case to that of a new refrigerated display case with glass doors. CL&P/UI engineering utilized Ref [1] data (Table 7) in the analysis that provided the savings factors below. A site inspection of a completed installation by utility staff identified a gap (approx ¼") between the doors that allowed infiltration between the case and the store. This analysis assumes that the losses from the gap are equivalent to the energy consumed by the door heat in Table 7 of Ref [1].

Inputs

Symbol	Description
L	Length of display case

Nomenclature

Symbol	Description	Units	Values	Comments
$ACCF_H$	Annual Gross Natural Energy Savings	Ccf/yr		
AKWH	Annual Gross Electric Energy Savings	kWh/yr		
AOG_H	Annual Savings for Oil Heat	Gal/yr		
APG_H	Annual Savings for Propane Heat	Gal/yr		
L	Length of display case	Feet		
PD_H	Peak day gas savings	Ccf		
SF_{AKWH}	Electric Energy Savings Factor	kWh/Foot		
SF_{ACCF}	Heating Savings Factor	Ccf/Foot		
SF_{PD}	Peak Day Savings Factor	Ccf/Foot		
SF_{SKW}	Summer Demand Savings Factor	kW/Foot		
SF_{WKW}	Winter Demand Savings Factor	kW/Foot		
SKW	Summer Demand Savings	kW	0	
WKW	Winter Demand Savings	kW		

Retrofit Gross Energy Savings, Electric

Table 1 Electric Savings Factors			
Door Type	SF_{SKW}	SF_{WKW}	SF_{AKWH}
Door Heater	0	0.029	202.7
Gap	0	0.029	202.7

$AKWH = L \times SF_{AKWH}$

Note: The SF values depend on whether there is a gap between the doors or there are door heaters. It is assumed that the losses from the gap are equivalent to the energy consumed by the door heat so therefore they are the same for electric savings.

Retrofit Gross Seasonal Peak Demand Savings, Electric (Winter and Summer)

$SKW = L \times SF_{SKW}$

$WKW = L \times SF_{WKW}$

Retrofit Gross Energy Savings, Fossil Fuel

Table 2 Natural Gas Savings Factors		
Door Type	SF_{ACCF}	SF_{PD}
Door Heater	23.8	0.145
Gap	12.7	0.077

Note: The SF values depend on whether there is a gap between the doors or there are door heaters.

$ACCF_H = L \times SF_{ACCF}$

$AOG_H = L \times SF_{ACCF} \times 0.742$

$APG_H = L \times SF_{ACCF} \times 1.1267$

Retrofit Gross Peak Day Savings, Natural Gas

$PD_H = L \times SF_{PD}$

Changes from Last Version

No Changes.

References

[1] ASHRAE Research Project 1402 - "Comparison of Vertical Display Cases: Energy and Productivity of Glass Doors Versus Open Vertical Display Cases. by Brian A. Fricke, Ph.D and Bryan R. Becker, Ph.D, P.E. 18-Dec-2009

RESIDENTIAL

4.1 LIGHTING

4.1.1 LIGHT BULB

Description of Measure

Lighting savings defined in this section are for the replacement of low efficiency screw-based light bulbs with high efficiency screw-based bulbs of equivalent lumen output. This also includes luminaires with screw-based connections. Examples of efficient lighting technologies may include Solid State Lighting (SSL), Light Emitting Diode (LED), Induction Lamps, and Compact Fluorescent Lamps (CFL).

Savings Methodology

The following assumptions are made to calculate savings for bulbs:

- Measure lives vary according to the type of bulb and its rated lifetime hours (found in Appendix 4)
- The baseline for all bulbs is a screw-base incandescent bulb

Direct install bulbs are different than "retail bulbs" because their installation is performed or verified (in the situation that the builder installs the bulbs) by a professional home energy assessor. Actual rated bulb wattage and location of both the existing and replacement bulbs 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, globe bulbs, and candelabra based bulbs. (See Compact Fluorescent Lamp in Glossary, Section 1.6). LED down light savings are separate from other Non-General Service LEDs as the directionality of a down light gives the LED technology an efficiency advantage over non-directional technologies.

Certain General Service bulbs are required to comply with EISA standards according to Table 5 (Note [9]). The baseline for these bulbs at the reduced savings level is based on high-efficiency incandescent bulbs (such as halogen) having 75% of the wattage of the previous (non-EISA compliant) bulb (Ref [4]). This baseline change is being phased in throughout the 2012-2015 program years and will impact the Watt ratio component of the savings calculation (see Note [7]). Watt ratios given in Tables 2, 2A, and 3 reflect the equivalent value of savings taken over the lifetime of the bulb. Please refer to Note [9] for further details.

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. If this input is not collected then an assumed $Watt_{ratio}$ is used instead.	Watts
Location	Location of direct install bulb. See Table 1 for available options.	
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 for Non-General Service bulbs.	Hours

Nomenclature

Symbol	Description	Units	Values	Comments
AKWH	Annual Electric Energy Savings	kWh/yr		Calculated
CF_S	Average summer seasonal peak coincidence factor for Residential (Lighting)	unit-less	13.0.%	Appendix 1, Ref [3]
CF_w	Average winter seasonal peak coincidence factor for Residential (Lighting)	unit-less	20.0%	Appendix 1, Ref [3]
h_d	Daily hours of use, by room type for direct install. For Lost Opportunity or Retail, use "Unknown" as the room type.	Hours per day	Table 1 for all known locations Retail: 2.90	Ref [4]
LI	Corresponding to the Low Income sector			
Lifetime	The measure life of the bulb	Years	Lifetime	The measure life of the bulb
LKWH	Lifetime Electric Energy Savings	kWh		Calculated
Lumens	Lumen output of installed or purchased light bulb. This input is optional.		310-2600	Lumen output of installed or purchased light bulb.
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)	Optional Input	Direct install only
$Watt_{ratio}$	Wattage ratio between low efficiency bulb and high efficiency bulb. Defined as $Watt_{pre}/Watt_{post}$, or if $Watt_{pre}$ unknown, an assumed value.	unit-less	Tables 2, 2A,3	Tables 2, 2A for Retrofit, Table 3 for Retail
WKW	Winter Demand Savings	kW		Calculated

Retrofit Gross Energy Savings, Electric

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

$$AKWH = 1.04 \times \frac{Watt_\Delta \times h_d \times 365}{1000}$$

1.04 is an average energy factor due to lighting interactive effect Ref [7]

$$LKWH = AKWH \times Lifetime$$

Please refer to Table 1 for the correct hours of use per day by location (h_d):

Table 1: Hours of Use per Day by Location (h_d)*

Location	*All Customers*
	h_d
Bedroom	*2.3*
Bathroom	*2.0*
Den/Office†	*3.5*
Garage†	*1.9*
Hallway†	*1.9*
Kitchen	*4.2*
Living Room†	*3.5*
Dining Room	*3.0*
Exterior	*5.8*
Basement†	*1.9*
Closet†	*1.9*
Other	*1.9*
Household†	*2.9*

* Ref [4]
† Note [2, 10]

Please refer to Table 2 for the appropriate $Watt_{ratio}$ to be used in calculations.

Table 2: Retrofit and Direct Install $Watt_{ratio}$ Values

Existing Bulb	New High Efficiency Bulb			† $Watt_{ratio}$ (EISA Compliant)	Notes
	Install Type	*Bulb Type*	*Bulb*	*All Bulbs $Watt_{ratio}$*	
Incandescent, Known wattage	General Service	Both Non-Low Income and Low-Income	CFL/LED/ Induction	For CFLs, see Table 2A For LEDs, see Table 2B	Note [1]
Incandescent, Known wattage	Non-General Service	Both Non-Low Income and Low-Income	CFL/LED/ Induction	$\frac{Watt_{pre}}{Watt_{post}}$	Note [5]
Incandescent, Unknown wattage	General Service	Both Non-Low Income and Low-Income	CFL/LED/ Induction	For CFLs, see Table 2A For LEDs, see Table 2B	Ref [2] Ref [1]
Incandescent, Unknown wattage	Non-General Service	Non-Low Income	CFL/Non-Directional LED/ Induction	4.00	Ref [2]
Incandescent, Unknown wattage	Non-General Service	Non-Low Income	Directional/ Downlight LED	5.00	Ref [2]
Incandescent, Unknown wattage	Non-General Service	Low Income	CFL/LED/ Induction	3.40	Ref [1]

† For High Efficiency bulb types not listed use the $Watt_{ratio}$ values for CFL bulbs

Table 2A presents the Watt ratios to be used for bulbs impacted by EISA standards. Please note that Lumen ranges are provided for reference.

Table 2A: $Watt_{ratio}$ Values for CFL General Service Bulbs, Existing Incandescent Wattage

New High Efficiency Bulb		2014 $Watt_{ratio}$ (EISA Compliant)		Notes
$Lumen_{post}$ Range	***CFL Bulbs: Approximate Equivalent Wattage***	***Known Wattage:***	***Unknown Wattage:***	
		CFL Bulbs $Watt_{ratio}$		
Above 2600 or below 310	Above 30W or below 9W	$\frac{Watt_{pre}}{Watt_{post}}$	Non-Low Income: 4.0 Low Income: 3.4	Ref [1,2]
310-2600	9W- <30W	$\frac{0.75 \times Watt_{pre}}{Watt_{post}}$	Non-Low Income: 3.0 Low-Income: 2.55	Ref [1,2], Notes [1,6,9]

Table 2B: $Watt_{ratio}$ Values for LED General Service Bulbs, Existing Incandescent Wattage

New High Efficiency Bulb		2014 $Watt_{ratio}$ (EISA Compliant)		Notes
$Lumen_{post}$ Range	***LED Bulbs: Approximate Equivalent Wattage***	***Known Wattage:***	***Unknown Wattage:***	
		LED Bulbs $Watt_{ratio}$		
Above 2600 or below 310	Above 30W or below 6W	$\frac{Watt_{pre}}{Watt_{post}}$	4.0	
310-2600	6W - <30W	$\frac{0.75 \times Watt_{pre}}{Watt_{post}}$	3.4	Ref [6] Notes [1,6,9]

Retrofit Gross Energy Savings, Example

Example 1. A 60-Watt General Service incandescent bulb is replaced with a 10-Watt General Service LED bulb in the living room of a Non-Low Income home by direct install in 2017. What are the annual savings?

Using the equations from above:

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

$$AKWH = 1.04 \times \frac{Watt_{\Delta} \times h_d \times 365}{1000}$$

This bulb is affected by the EISA standards. From Table 1 we obtain h_d for the Non-Low Income location given. Tables 2 and 2A provide the appropriate $Watt_{ratio}$. Since $Watt_{pre}$ is known we can calculate directly:

$$Watt\Delta = \left(.75 \times \frac{60\ Watts}{20\ Watts} - 1\right) \times 10\ Watts$$

$$Watt\Delta = 35\ Watts$$

$$AKWH = 1.04 \times (35\ Watts) \times 3.5 \frac{hrs}{day} \times 365 \frac{days}{year} \div 1000\ W/kw$$

$$AKWH = 46.5 \frac{kwh}{yr}$$

Example 2. A 19-Watt General Service LED bulb is installed in the kitchen of a Low-Income home by direct install. The wattage of the incandescent bulb that was replaced is not known. What are the annual savings?

Using the equations from above:

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

$$AKWH = 1.04 \times \frac{Watt_{\Delta} \times h_d \times 365}{1000}$$

This bulb is affected by the EISA standards. From Table 1 we obtain h_d for the Low-Income location given. Table 2A provides the $Watt_{ratio}$ to be used in calculations for unknown $Watt_{pre}$:

$$Watt_{\Delta} = (3.4 - 1) \times 10\ Watts$$

$$Watt_{\Delta} = 35\ Watts$$

$$AKWH = 1.04 \times (35\ Watts) \times 3.5\frac{hrs}{day} \times 365\frac{days}{year} \div 1000\ W/kw$$

$$AKWH = 46.5\frac{kwh}{yr}$$

Retrofit Gross Seasonal Peak Demand Savings, Electric (Winter and Summer)

$$SKW = 1.05 \times \frac{Watt_{\Delta} \times CF_S}{1000}$$

$$WKW = \frac{Watt_{\Delta} \times CF_W}{1000}$$

1.05 is an average capacity factor due to lighting interactive effect Ref [7

Note: General Service Bulbs affected by EISA compliance will utilize the same calculation methodology as described for annual and lifetime savings.

Values for CF_s and CF_w can be found in Appendix 1 as the Residential; Lighting Coincidence Factors.

Retrofit Gross Peak Demand Savings, Example

Example 3. A 60-Watt General Service incandescent bulb is replaced with a 15-Watt General Service LED bulb in the living room of a Non-Low Income home. What are the savings?

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

$$Watt_{\Delta} = 30.0\,Watts$$

$$SKW = 1.05 \times 30.0\,Watts \times 0.130 \div 1000\,{}^{W}\!/_{kW}$$

$$SKW = 0.00409\,kW$$

$$WKW = 30.0\,Watts \times 0.20 \div 1000\,{}^{W}\!/_{kW}$$

$$WKW = 0.006kW$$

Lost Opportunity Gross Energy Savings, Electric

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

$$AKWH = 1.04 \times \frac{Watt_{\Delta} \times h_d \times 365}{1000}$$

If the location of the installed bulb is known, use the value from Table 1. Otherwise, use h_d = 2.9 ("Unknown" from Table 1, as it cannot be verified where a purchased bulb is installed).

Please refer to Table 3 for the appropriate $Watt_{ratio}$ to be used in all Lost Opportunity, Residential New Construction, and Retail Product calculations.

Table 3: Lost Opportunity and Retail $Watt_{ratio}$ Values

Bulb†	$Watt_{ratio}$	**Notes**
CFL	3.6	Ref[8] Note [11]
LED	3.7	Ref[8] Notes [11]

† For bulb types not listed use the $Watt_{ratio}$ values for CFL bulbs

Lost Opportunity Gross Energy Savings, Example

Example 4. What are the electric energy savings when a 12.5 Watt LED is purchased through a retailer?

$$Watt_{\Delta} = (3.7 - 1) \times 12.5\,Watts$$

$$Watt_{\Delta} = 33.75\,Watts$$

$$AKWH = 1.04 \times (32.5Watts) \times 2.9\,{}^{hrs}\!/_{day} \times 365\,{}^{days}\!/_{year} \div 1000W/kw$$

$$AKHW = 37.15\,{}^{kWh}\!/_{yr}$$

Example 5. What are the electric energy savings from an 11-Watt LED bulb rated for 15,000 hours purchased through a retailer?

$$Watt\Delta = (3.7 - 1) \times 11\ Watts$$
$$Watt\Delta = 29.7$$

$$AKWH = 1.04 \times (29.7\ Watts) \times 2.9\ {}^{hrs}/_{day} \times 365\ {}^{days}/_{year} \div 1000\ {}^{Watts}/_{Watt-hr}$$

$$AKHW = 32.7\ {}^{kWh}/_{yr}$$

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

$$SKW = 1.05 \times \frac{Watt_{\Delta} \times CF_S}{1000}$$

$$WKW = \frac{Watt_{\Delta} \times CF_W}{1000}$$

Note: General Service Bulbs affected by EISA compliance will utilize the same calculation methodology as described for annual and lifetime savings.

Lost Opportunity Gross Peak Demand Savings, Example

Example 6. What are the electric energy savings when a 12.5-Watt LED is purchased through a retailer in 2017?

$Watt_{\Delta} = (3.7\text{-}1)\times 12.5$ Watts
$Watt_{\Delta} = 33.8$ Watts

$$SKW = 1.05 \times 33.8\ Watts \times 0.13 \div 1000\ W/_{kW}$$
$$SKW = 0.0046\ kW$$

$$WKW = 33.8 Watts \times 0.20 \div 1000\ W/_{kW}$$
$$WKW = 0.0067\ kW$$

Non Energy Benefits

Table 4: One time O&M benefit per bulb (Note [4]) and Lighting Interactive effect Note (10):

Bulb Type	O&M Benefit $/Bulb (note4)	Lighting Interactive Effect Penalty $/Kwh (note 10)
General Service CFL bulb	$ 1.50	$ - 0.048
Non-General Service CFL bulb	$ 5.00	
LED General Service bulb	$ 3.00	
LED Non-General Service bulb	$ 10.80	
LED Directional/Downlight	$ 7.50	

Changes from Last Version

Updated Table 3 based on R154 Lighting study. Updated O&M benefits based on Ref[11] Recalculated interactive effects table based on new fuel prices note[10].

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 5-17, page 56.

[3] NMR Group Inc., Northeast Residential Lighting Hour-of Use Study, May 5, 2014, Table ES-7, page XVIII.

[4] NMR Group Inc., Northeast Residential Lighting Hour-of Use Study, May 5, 2014, Table 3.8, page 53.

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

[6] ENERGY STAR Certified Light Bulbs, website, last accessed February 6, 2014. http://www.energystar.gov/productfinder/product/certified-light-bulbs/results

[7] CT Residential Lighting interactive effect NMR Group Inc Dec 2014 Table 1 Page 2

[8] NMR Group Inc.,Connecticut LED Lighting Study Report (R154), January 28, 2016, pg 30.

[9] Weekly Heating Oil and Propane Prices (October – March) <https://www.eia.gov/dnav/pet/PET_PRI_WFR_DCUS_SCT_W.htm>, last accessed Sept 12, 2016.

[10] Residential Natural Gas Prices, <http://www.eia.gov/dnav/ng/ng_pri_sum_dcu_SCT_m.htm> , last accessed Sept 12, 2016.

[11] California LED Workpaper Update Study, August 28, 2015. Tables A5 & A7

Notes

[1] The Watt ratio is modified to reflect the (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 EISA federal standard requires incandescent bulbs to use 75% of the wattage of standard General Service incandescent bulbs.

[4] One time O&M benefits are based on the avoided expense of replacement incandescent bulbs over the lifetime of the new bulb. Replacement assumptions and Incandescent bulb prices from Ref[11]

[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 an analysis of Ref [3].

[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.

[8] Years at full and reduced level are based on the implementation schedule of EISA compliance (Ref [2]).

[9] Table 5 shows the EISA schedule and number of years at full savings level for certain General-Service bulbs, all programs, for the benefit of the reader:

Table 5: EISA Schedule and Number of Years at Full Savings Level for Certain General-Service Bulbs, All Programs

Lumen Ranges	**Approximate CFL Wattage within lumen range**	**Year EISA standard becomes effective**	**Baseline Implementation Year (BIY)**	**Number of Years at Full Savings Level (YR_{full}) in Each PSD Year**			
				2012	2013	2014	2015
1490–2600	23W to 30W	2012	2013	1	0	0	0
1050–1489	18W to <23W	2013	2014	2	1	0	0
310–749, 750–1049	9W to <18W	2014	2015	3	2	1	0

The weighted average Watt ratios presented in this measure serve as a means to simplify calculation of annual and lifetime savings. Values presented for General Service CFL bulbs in the EISA Lumen range are based on a 4 year lifetime while those presented for General Service LED bulbs are based on a 10 year lifetime (from Appendix 1).

For 2015 the EISA standard for General Service bulbs, 25% greater efficiency, has been fully implemented so adjustments to watt ratios are not needed. Therefore for baseline for existing bulbs is 75% for the existing bulb wattage (note 3).

[10] The Lighting interactive effect penalty was based on the results from CT Residential Lighting Interactive Effects Memo completed by NMR Group Inc. December 20, 2014 Table shown for illustrative purposes

Lighting interactive effect penalty						
Fuel Type	Fuel Mix Assumptions	factor btu/kwh (note1)	Efficiency	IE Net fuel consumption /kWh	IE cost$/kwh	IE Average fuel cost /kwh
oil	0.50	1902	0.7	0.02	0.05	$0.023
propane	0.05	1902	0.7	0.03	0.07	$0.004
gas	0.30	1902	0.75	0.02	0.04	$0.011
electric	0.15	1902	1.5	0.37	0.07	$0.010
Fuel Rates (Note 12)				Average IE cost/kwh		**$0.048**
Electric	0.18	$/kwh				
Oil	2.3	$/gal				
Gas	1.5	$/100 ccf				
Propane	2.5	$/gal				

[11] Watt ratios in table 3 developed using the delta watts in ref [3] and installed bulb data from Connecticut Retail Products Programs

[12] Lighting Interactive Effect Penalty calculated using 2015-2016 Average Cost of Oil, Propane, and Natural Gas from Rev[9] and Rev[10]. Electricity Cost/kwh is a standard utility assumption.

4.1.2 LUMINAIRE

Description of Measure

Replacement of low efficiency hardwired or portable luminaires/lighting fixtures with luminaires/lighting fixtures 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 that meets ENERGY STAR specifications, and consists of all 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.

High efficiency Lighting products are those that meet the ENERGY STAR specification for Luminaires.

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 (e.g. from ceiling fans) 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, as well as any other technology not specifically referenced in this document.

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 [1]
CF_W	Average winter seasonal peak coincidence factor	unit-less		Appendix A, Ref [1]
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			
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.	unit-less	Table 2	Defined as: $Watt_{ratio} = \frac{Watt_{pre}}{Watt_{post}}$
WKW	Winter Demand Savings	kW		Calculated

Retrofit Gross Energy Savings, Electric

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

$$AKWH = 1.04 \times \frac{Watt_{\Delta} \times h_d \times 365}{1000}$$

1.04 is an average energy factor due to lighting interactive effect Ref [4]

Table 1: Hours of Use per Day by Location, Direct Install [Ref 2]

Location	*All Customers*
	h_d
Bedroom	*2.3*
Bathroom	*2.0*
Den/Office †	*3.5*
Garage †	*1.9*
Hallway †	*1.9*
Kitchen	*4.2*
Living Room †	*3.5*
Dining Room	*3.0*
Exterior	*5.8*
Security Exterior	*11.4* ††
Basement †	*1.9*
Closet †	*1.9*
Other	*1.9*
Household †	***2.9***

† Note [2, 6]
†† Note [1]

† † Note [1] Table **2: $Watt_{ratio}$ Values for Luminaires, both Retrofit and Lost Opportunity Installs**

Existing Wattage	Technology	$Watt_{ratio}$	Notes
Unknown	Fluorescent Torchieres	3.40	Note [5]
	Retail CFL Fixture	3.948	Ref [3], Table 5-19, p. 57
	Retail LED Fixture	4.00	
	†CFL/LED Directional/Downlight	See 4.1.1 Light Bulbs, Table 3	
Known	All	$Watt_{ratio} = \frac{Watt_{pre}}{Watt_{post}}$	

† CFL/LED Directional/Downlight products are treated as a lighting product. See Table 3 in measure 4.1.1 Lighting for details

Retrofit Gross Energy Savings, Example

Example 1: A 60-Watt ceiling fixture is replaced with a 15-Watt LED pin based fixture in the bathroom of a home by direct install.

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

$$Watt_{\Delta} = 45\,Watts$$

$$AKWH = 1.04 \times (45\,Watts) \times 2.00\,{}^{hrs}\!/_{day} \times 365\,{}^{days}\!/_{year} \div 1000\,{}^{Watts}\!/_{kWh}$$

$$AKHW = 34.2\,{}^{kWh}\!/_{yr}$$

Example 2: An existing fixture is replaced with a 18-Watt equivalent LED fixture in the living room of a low-income home by direct install. The existing wattage is not known. What are the energy savings?

$$Watt_{\Delta} = (4-1) \times 15\,Watts$$

$$Watt_{\Delta} = 45\,Watts$$

$$AKWH = 1.04 \times (45\,Watts) \times 3.50\,{}^{hrs}\!/_{day} \times 365\,{}^{days}\!/_{year} \div 1000\,{}^{Watts}\!/_{kWh}$$

$$AKHW = 59.8\,{}^{kWh}\!/_{yr}$$

Retrofit Gross Seasonal Peak Demand Savings, Electric (Winter and Summer) Note [1]

$$SKW = 1.05 \times Watt_{\Delta} \times CF_S \div 1000\,{}^{W}\!/_{kW}$$

$$WKW = Watt_{\Delta} \times CF_W \div 1000\,{}^{W}\!/_{kW}$$

1.05 is an average capacity factor due to lighting interactive effect Ref [4]

Retrofit Gross Peak Demand Savings, Example

Example 3: A 60-Watt ceiling fixture is replaced with a 15-Watt LED fixture in the bathroom of a home by direct install.

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

$$Watt_{\Delta} = 45\,Watts$$
$$SKW = 1.05 \times 45\,Watts \times 0.13 \div 1000\,{}^{W}\!/_{kW}$$
$$SKW = 0.0061\,kW$$
$$WKW = 45\,Watts \times 0.20 \div 1000\,{}^{W}\!/_{kW}$$
$$WKW = 0.009\,kW$$

Example 4: An existing fixture is replaced with a 18-Watt equivalent LED fixture in the living room of a low-income home by direct install. The existing wattage is not known. What are the peak demand savings?

$$Watt_{\Delta} = (4-1) \times 18\,Watts$$
$$Watt_{\Delta} = 54\,Watts$$
$$SKW = 1.05 \times 53\,Watts \times 0.13 \div 1000\,{}^{W}\!/_{kW}$$
$$SKW = 0.0074\,kW$$
$$WKW = 54\,Watts \times 0.20 \div 1000\,{}^{W}\!/_{kW}$$
$$WKW = 0.011\,kW$$

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

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

$$AKWH = 1.04 \frac{Watt_{\Delta} \times h_d \times 365\,{}^{days}\!/_{yr}}{1000\,{}^{W}\!/_{kW}}$$

Please refer to Table 2 for $Watt_{ratio}$ values.

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

Example 5: A 26-Watt ceiling fixture (using two 13 Watt LEDs) is purchased through a retailer.

$$Watt_{\Delta} = (4-1) \times 26\,Watts$$
$$Watt_{\Delta} = 78\,Watts$$

$$AKWH = 1.04 \times (78 watts) \times 3.0\,{}^{h}\!/_{day} \times 365\,{}^{days}\!/_{yr} \div 1000W/kw = 88.8\,{}^{kWh}\!/_{yr}$$

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

$$SKW = 1.05 \times Watt_{\Delta} \times CF_S \div 1000\,{}^{W}\!/_{kW}$$
$$WKW = Watt_{\Delta} \times CF_W \div 1000\,{}^{W}\!/_{kW}$$

Lost Opportunity Gross Peak Demand Savings, Example

Example 6: A 26-Watt LED ceiling fixture is purchased through a retailer. What are the peak demand savings?

$$SKW = 1.05 \times 78\ Watts \times 0.13 \div 1000 \, {}^{W}\!/_{kW}$$
$$SKW = 0.00106 kW$$

$$WKW = 78 Watts \times 0.20 \div 1000 \, {}^{W}\!/_{kW}$$
$$WKW = 0.0156\ kW$$

Non Energy Benefits

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

Type	Benefit	Lighting Interactive Effect Penalty $/Kwh (note7)
Hardwired Indoor	$ 5.00	$ 0.048
Portable – Table Lamp	$ 3.00	
Portable – Torchiere	$ 3.00	
Hardwired Exterior	$ 5.00	
Security Exterior	$ 5.00	

Changes from Last Version

Updated table 4 based on new Gas, Oil and Propane Prices. Inserted assumed Fuel Prices into interactive effects table note[8].

References

[1] NMR Group Inc., Northeast Residential Lighting Hour-of Use Study, May 5, 2014, Table ES-7,page XVIII

[2] Reference 1, Table ES-5, page XIII.

[3] Nexus Market Research (NMR), Residential Lighting Markdown Impact, January 20, 2009. Table 5-19, page 57, and Table 5-15, page 51.

[4] CT Residential Lighting interactive effect NMR group Inc Dec 2014 Table 1 Page 2

[5] California LED Workpaper Update Study, August 28, 2015. Tables A6 & A8

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Notes

[1] The "Security Exterior" 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. Security Exterior install locations do not claim Summer Peak savings, since hours of operation are outside Summer Peak boundaries

[2 The "Other" location (Ref [1, 2]) includes any other interior location not included in Table 2.

[3] One time O&M benefits are based on the avoided expense of replacement incandescent bulbs over the lifetime of the new bulb. Replacement assumptions and Incandescent bulb prices from Ref[5]

[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.

[6] The h_d values for "Den/Office" and "Living Room" tie to "Living Space", and values for Garage", "Hallway", "Basement" and" Closet" tie to "Other" in Ref [1] per NMR Group.

[7] The Lighting interactive effect penalty was based on the results from CT Residential Lighting interactive effect completed by NMR Group Inc December 2014 Table for illustrative purposes

Lighting interactive effect penalty						
Fuel Type	Fuel Mix Assumptions	factor btu/kwh (note1)	Efficiency	IE Net fuel consumption /kWh	IE cost$/kwh	IE Average fuel cost /kwh
oil	0.50	1902	0.7	0.02	0.05	$0.023
propane	0.05	1902	0.7	0.03	0.07	$0.004
gas	0.30	1902	0.75	0.02	0.04	$0.011
electric	0.15	1902	1.5	0.37	0.07	$0.010
Fuel Rates (Note 8)				Average IE cost/kwh		**$0.048**

Fuel Rates (Note 8)		
Electric	0.18	$/kwh
Oil	2.3	$/gal
Gas	1.5	$/100 ccf
Propane	2.5	$/gal

[8] Lighting Interactive Effect Penalty calculated using 2015-2016 Average Cost of Oil, Propane, and Natural Gas from Rev[5] and Rev[6]. Electricity Cost/kwh is a standard utility assumption.

4.2 HVAC

4.2.1 ENERGY EFFICIENT CENTRAL AC

Description of Measure

Installation of an energy efficient central air conditioning (AC) system and replacement of a working inefficient AC system.

Savings Methodology

Lost Opportunity Measure:

- Lost Opportunity savings are the difference in energy use between a baseline new model (Note [3]), and the chosen high efficiency new model, continuing for the Effective Useful Life (EUL) from Appendix 4.

Retrofit Measure:

- Uses the same methodology as a Lost Opportunity measure.
- In the case of early retirement of a working unit where the unit would have otherwise been installed until failure, lifetime "Retirement" savings are claimed additional to the lifetime "Lost Opportunity" savings (see Section 1.4).
- Retirement savings are the difference in energy use between the older unit (Note [2]) and a baseline new model (Note [3]), continuing for the Remaining Useful Life (RUL) from Appendix 4.

Savings are based on the Central Air Conditioning Impact and Process 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).

Inputs

Symbol	**Description**	**Units**
$CAP_{C,i}$	Installed cooling capacity of new unit	Tons
EER_i	Installed EER of new unit	Btu/Watt-hr

Nomenclature

Symbol	**Description**	**Units**	**Values**	**Comments**
$AKWH_C$	Annual electric energy savings - cooling	kWh		
ASF	Annual Savings factor	kWh/ton	362	Ref [1]
$CAP_{C,i}$	Installed cooling capacity	Tons		Input
DSF	Seasonal demand savings factor	kW/ton	0.45	Ref [1]
EER_b	Baseline EER, representing baseline new model	Btu/Watt-hr	11	Note [1]
EER_e	Existing EER of removed unit	Btu/Watt-hr	Use 8 if existing EER is not known	Note [2]
EER_i	Installed EER of new efficient unit	Btu/Watt-hr		Input
EUL	Effective Useful Life	Years	18	Appendix 4
$LKWH_C$	Lifetime electric energy savings - cooling	kWh		
RUL	Remaining Useful Life	Years	5	Appendix 4
SKW_C	Summer Seasonal Demand savings-cooling	kW		
$\ldots_{Retire}$	Associated with Retirement			
$\ldots_{Lost\ Opp}$	Associated with Lost Opportunity			

Retrofit Gross Energy Savings, Electric

Reminder: Retrofit savings are the sum of Retirement savings and Lost Opportunity savings. This section presents the Retirement portion of savings while the Lost Opportunity portion of the savings is presented further on in this measure. To obtain the lifetime savings, the following formula should be used:

$$LKWH_{C,\ Total} = AKWH_{C,\ Retire} \times RUL + AKWH_{C,\ Lost\ Opp} \times EUL$$

Retirement Component:

$$AKWH_{C,\ Retire} = ASF \times CAP_{C,i} \times \left(1 - \frac{EER_e}{EER_b}\right)$$

The equation simplifies when the existing EER is not known:

$$AKWH_{C,Retire} = 362\ {}^{kwh}/_{Ton} \times CAP_{C,i} \times \left(1 - \frac{8}{11}\right) = 98.73 \times CAP_{C,i}$$

Retrofit Gross Energy Savings, Example

An existing working central A/C is replaced by an energy efficient unit. The new installed unit has a 3 ton cooling capacity, at 13.0 EER. What are the annual energy savings?

To calculate the lost opportunity component, use the equation from “Lost Opportunity”:

$$AKWH_{C,Lost\ Opp} = 362\ {}^{kwh}/_{Ton} \times CAP_{C,i} \times \left(\frac{EER_i}{11} - 1\right)$$

Input the new unit’s cooling capacity and rated EER:

$$AKWH_{C,Lost\ Opp} = 362\ {}^{kwh}/_{Ton} \times 3\ tons \times \left(\frac{13}{11} - 1\right) = 197.45\ kWh$$

Because the existing unit is verified to be in working condition, use the Retirement equation to calculate annual Retirement savings (a constant times the new unit’s cooling capacity):

$$AKWH_{C,Retire} = 98.73 \times CAP_{C,i}$$

$$AKWH_{C,Retire} = 98.73 \times 3 = 296.19\ kWh$$

Retrofit Gross Seasonal Peak Demand Savings, Electric (Winter and Summer)

Reminder: Retrofit savings are the sum of Retirement savings and Lost Opportunity savings. This section presents the Retirement portion of savings while the Lost Opportunity portion of the savings is presented further on in this measure.

Retirement Component:

$$SKW_{C,\ Retire} = DSF \times CAP_{C,i} \times \left(1 - \frac{EER_e}{EER_b}\right)$$

The equation simplifies when the existing EER is not known:

$$SKW_{C,Retire} = 0.45\ {}^{kwh}/_{Ton} \times CAP_{C,i} \times \left(1 - \frac{8}{11}\right) = 0.123 \times CAP_{C,i}$$

Note: There is no need to apply a coincidence factor as coincidence is already factored into the demand equation.

Retrofit Gross Peak Demand Savings, Example

What are the summer demand savings for the above retrofit example?

Using the equation for Lost Opportunity summer demand savings, input the size and efficiency of the new unit:

$$SKW_{C,Lost\ Opp} = 0.45\ {}^{kwh}/_{Ton} \times CAP_{C,i} \times \left(\frac{EER_i}{11} - 1\right)$$

$$SKW_{C,Lost\ Opp} = 0.45\ {}^{kwh}/_{Ton} \times 3 \times \left(\frac{13}{11} - 1\right) = 0.245\ kW$$

Using the equation for Retirement summer demand savings, input the cooling capacity in tons:

$$SKW_{C,Retire} = 0.123 \times CAP_{C,i}$$

$$SKW_{C,Retire} = 0.123 \times 3 = 0.369\ kW$$

Lost Opportunity Gross Energy Savings, Electric

$$AKWH_{C,LostOpp} = ASF \times CAP_{C,i} \times \left(\frac{EER_i}{EER_b} - 1\right)$$

$$AKWH_{C,Lost\ Opp} = 362\ {}^{kwh}/_{Ton} \times CAP_{C,i} \times \left(\frac{EER_i}{11} - 1\right)$$

Lost Opportunity Gross Energy Savings, Example

A rebate is provided for the installation of a new energy efficient unit. The old unit is unknown. The new installed unit has a 3 ton cooling capacity, 13.0 EER. What are the annual savings?

To calculate annual savings, use the Lost Opportunity equation:

$$AKWH_{C,Lost\ Opp} = 362\ {}^{kwh}/_{Ton} \times CAP_{C,i} \times \left(\frac{EER_i}{11} - 1\right)$$

Input the new unit's cooling capacity and rated EER:

$$AKWH_{C,Lost\ Opp} = 362\ {}^{kwh}/_{Ton} \times 3\ tons \quad \times \left(\frac{13}{11} - 1\right) = 197.45\ kWh$$

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

$$SKW_{C,LostOpp} = DSF \times CAP_{C,i} \times \left(\frac{EER_i}{EER_b} - 1\right)$$

$$SKW_{C,Lost\ Opp} = 0.45\ {}^{kwh}/_{Ton} \times CAP_{C,i} \times \left(\frac{EER_i}{11} - 1\right)$$

Note: There is no need to apply a coincidence factor as coincidence is already factored into the demand equation

Lost Opportunity Gross Peak Demand Savings, Example

A rebate is provided for the installation of a new energy efficient unit. The old unit is unknown. The new installed unit has a 3 ton cooling capacity, 13.0 EER. What are the annual demand savings?

Using the equation for Lost Opportunity demand savings,

$$SKW_{C,Lost\ Opp} = 0.45\ {}^{kwh}/_{Ton} \times CAP_{C,i} \times \left(\frac{EER_i}{11} - 1\right)$$

Input the size and efficiency of the new unit:

$$SKW_{C,Lost\ Opp} = 0.45\ {}^{kwh}/_{Ton} \times 3 \times \left(\frac{13}{11} - 1\right) = 0.245\ kW$$

Changes from Last Version

No Changes.

References

[1] Central Air conditioning Impact and Process Evaluation, NMR 05/30/ 2014.

Notes

[1] Ref [1], NMR Central Air conditioning Impact and Process Evaluation pages I to III. “Because there were no instances of early replacement of CAC units in the monitoring sample, the baseline for estimating savings is the minimum standard for new installations, namely 11 EER.”

[2] EER for the existing unit is 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 (Ref [1], page ES-1 gives the ratio 11 EER / 14 SEER). 8 EER is used as the estimated existing efficiency.

4.2.2 HEAT PUMP

Description of Measure

Installation of an energy efficient air source heat pump and replacement of a working, less efficient electric heating system, including heat pumps and electric resistance heating.

Savings Methodology

Lost Opportunity Measure:

- Lost Opportunity savings are the difference in energy use between a baseline new model (Note [2]), and the chosen high efficiency new model, continuing for the Effective Useful Life (EUL) from Appendix 4.

Retrofit Measure:

- Uses the same methodology as a Lost Opportunity measure.
- In the case of early retirement of a working unit where the unit would have otherwise been installed until failure, lifetime "Retirement" savings are claimed additional to the lifetime "Lost Opportunity" savings (see Section 1.4).
- Retirement savings are the difference in energy use between the older unit (Note [1]) and a baseline new model (Note [2]), continuing for the Remaining Useful Life (RUL) from Appendix 4.

The savings methodology presented here is for heating only; cooling savings from an efficient heat pump are the same as the cooling savings for an efficient central air conditioner, as presented in measure 4.2.1 of this manual.

Note: the savings here do not apply to a Ductless Heat Pump; see Measure 4.2.12 for Ductless Heat Pump methodology.

Inputs

Symbol	Description	Units
$CAP_{H,i}$	Installed Heating Capacity	Btu/hr
$HSPF_e$	Heating Season Performance Factor of existing unit (AHRI-Verified)	Btu/Watt-hr
$HSPF_i$	Heating Season Performance Factor, installed unit (AHRI-Verified)	Btu/Watt-hr
	Existing heating system type	

Nomenclature

Symbol	Description	Units	Values	Comments
AKWH	Annual Electric Energy Savings	kWh		
$CAP_{H,i}$	Installed Heating Capacity	Btu/hr		Input
$EFLH_H$	Heating Equivalent Full-Load Hours	Hours	1349	Note [3]
$HSPF_b$	Heating Season Performance Factor, Baseline, representing baseline new model	Btu/ Watt-hr	8.2	Note [1]
$HSPF_e$	Heating Season Performance Factor, Existing (AHRI-Verified)	Btu/ Watt-hr	Use 6.8 if HSPF existing is not known; 3.41 for electric resistance heat	Note [2]
$HSPF_i$	Heating Season Performance Factor, Installed (AHRI-Verified)	Btu/ Watt-hr		Input
SKW	Summer Demand Savings	kW		
WKW	Winter Demand Savings	kW		

Retrofit Gross Energy Savings, Electric

Reminder: Retrofit savings are the sum of Retirement savings and Lost Opportunity savings. This section presents the Retirement portion of savings while the Lost Opportunity portion of the savings is presented further on in this measure. To obtain the lifetime savings, the following formula should be used:

$$LKWH_{C,\ Total} = AKWH_{C,\ \mathrm{Retire}} \times RUL + AKWH_{C,\ Lost\ Opp} \times EUL$$

Early Retirement component:

$$AKWH_{H,Retire} = EFLH_H \times CAP_{H,i} \times \left(\frac{1}{HSPF_e} - \frac{1}{HSPF_b}\right) \times \frac{1}{1000 \, {}^{W}\!/_{kW}}$$

The equation simplifies when the existing HSPF is not known:

$$AKWH_{H,Retire} = 1349 \, {}^{hrs}\!/_{yr} \times CAP_{H,i} \times \left(\frac{1}{6.8} - \frac{1}{8.2}\right) \times \frac{1}{1000} = 0.03281 \times CAP_{H,i}$$

Cooling: If the unit also provides cooling, calculate savings as presented in Central AC measure (4.2.1).

Retrofit Gross Energy Savings, Example

A new air source heat pump with both heating and cooling capacity of 36,000 Btu/hr, $HSPF_i$ of 9.00, SEER of 15.50, and EER of 13.0 is installed in a home to replace an old working heat pump with heating capacity of 36,000 Btu/hr, and $HSPF_e$ of 6.

To calculate the lost opportunity component for heating, use the equation from "Lost Opportunity":

$$AKWH_{H,\ LostOpp} = EFLH_H \times CAP_{H,i} \times \left(\frac{1}{HSPF_b} - \frac{1}{HSPF_i}\right) \times \frac{1}{1000}$$

Input the HSPF and heating capacity of the new heat pump:

$$AKWH_{H,LostOpp} = 1349 \, {}^{hrs}\!/_{yr} \times 36{,}000 \times \left(\frac{1}{8.2} - \frac{1}{9.0}\right) \times \frac{1}{1000} = 526 \ kWh$$

Because the existing unit is verified to be in working condition, use the Retirement equation to calculate annual Retirement savings, using the capacity of the new unit and HSPF of the existing unit.

$$AKWH_{H,\ \mathrm{Retire}} = EFLH_H \times CAP_{H,i} \times \left(\frac{1}{HSPF_e} - \frac{1}{HSPF_b}\right) \times \frac{1}{1000 \, {}^{W}\!/_{kW}}$$

$$AKWH_{H,Retire} = 1349 \, {}^{hrs}\!/_{yr} \times CAP_{H,i} \times \left(\frac{1}{6.8} - \frac{1}{8.2}\right) \times \frac{1}{1000} = 1{,}219 \ kWh$$

Because the HP also provides cooling, calculate cooling savings as presented in the Central AC measure (4.2.1).

Retrofit Gross Seasonal Peak Demand Savings, Electric (Winter and Summer)

Heating: WKW= 0; Note [4]

Cooling: If the unit also provides cooling, calculate demand savings as presented in Central AC measure (4.2.1).

Lost Opportunity Gross Energy Savings, Electric

$$AKWH_{H,LostOpp} = EFLH_H \times CAP_i \times \left(\frac{1}{HSPF_b} - \frac{1}{HSPF_i}\right) \times \frac{1}{1000}$$

$$AKWH_{H,LostOpp} = 1349 \, {}^{hrs}\!/_{yr} \times CAP_i \times \left(\frac{1}{8.2} - \frac{1}{HSPF_i}\right) \times \frac{1}{1000}$$

Cooling: If the unit also provides cooling, calculate savings as presented in Central AC measure (4.2.1).

Lost Opportunity Gross Energy Savings, Example

A rebate is provided for the installation of a new air source heat pump with an installed cooling capacity of 36,000 Btu/hr and HSPF of 9. What are the annual electric heating and cooling savings?

Using the Lost Opportunity equation, input the capacity and HSPF of the new unit:

$$AKWH_{H,LostOpp} = 1349\ {}^{hrs}/_{yr} \times CAP_i \times \left(\frac{1}{8.2} - \frac{1}{HSPF_i}\right) \times \frac{1}{1000}$$

$$AKWH_{H,LostOpp} = 1349\ {}^{hrs}/_{yr} \times 36{,}000 \times \left(\frac{1}{8.2} - \frac{1}{9.0}\right) \times \frac{1}{1000} = 526\ kWh$$

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

Heating: WKW= 0; Note [4]
Cooling: If the unit also provides cooling, calculate demand savings as presented in Central AC measure (4.2.1).

Changes from Last Version

No Change

References

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

[2] National Climatic Data Center, Divisional Data Select, http://www7.ncdc.noaa.gov/CDO/CDODivisionalSelect.jsp

[3] 1989 ASHRAE Fundamentals, Chapter 28: Energy Estimating Methods, page 28.2 Fig. 1: Correction Factor versus Degree-Days

[4] 1989 ASHRAE Fundamentals, 24.6 Table 1: Climatic Conditions for the United States: Connecticut: Hartford, Brainard Field.

[5] McQuiston, Faye C.; Jerald D. Parker; Jeffrey D. Spitler. Heating, Ventilating, and Air Conditioning: Analysis and Design, Fifth Edition, Chapter 7: Space Heating Load, page 192. ISBN 0-471-35098-2.

Notes

[1] The federal minimum standard for heat pumps is HSPF 8.2, as of Jan 1, 2015.

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

[3] Equivalent Full Load Hours estimated as follows:

$$EFLH_H = \left(\frac{24 \times HDD \times AF}{T_{OC} - T_{IC}}\right) = \left(\frac{24 \times 5885 \times 0.64}{70 - 3}\right) = 1349 \text{ hr/yr}$$

Where:
24 = conversion between degree-days to degree-hours
HDD = 5885 = 30-year average annual degree days, data from Ref [2] for CT, Jan 1979 to Dec 2008
AF = 0.64 = ASHRAE degree day correction factor to account for occupant behavior from Ref [3]
T_{OC} = 3° F = outdoor heating design temperature for Hartford, Brainard Field at 99% level from Ref [4]
T_{OC} = 70° F = indoor heating design temperature, Ref [5].

[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.

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)” (Reference [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 efficiencies (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	1,569	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	326	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		0.59	Appendix 1
CF_H	Coincidence Factor, residential heating		0.50	Appendix 1
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	0.71	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 (ENERGY STAR Tier 1) Reference [2]

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

$$AKWH_C = \left(AC_b - AC_i\right)$$

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

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

$$AKWH_H = \left(AH_b - AH_i\right)$$

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

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

$$AKWH = AKWH_C + AKWH_H$$

Lost Opportunity Gross Energy Savings, Example

A 3 ton closed loop geothermal heat pump is installed with an EER of 20.2 and COP of 4.2. What are the energy savings?

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

$$AKWH_C = 3 \times 326 \times \left(\frac{17.2}{14.1} - \frac{17.2}{20.2}\right) = 360kWh$$

$$AKWH_H = 3 \times 1{,}569 \times \left(\frac{3.9}{3.3} - \frac{3.9}{4.2}\right) = 1{,}192kWh$$

$$AKWH = 360 + 1{,}192 = 1{,}552kWh$$

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

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

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

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

Changes from Last Version

Removed R7 Reference. Minor edits to equation units.

References

[1] HVAC Systems in an ENERGY STAR Home: Owning & Operating Costs (Update 2008), CDH Energy Corp, 2008, Tables 3 and 4.
[2] ENERGY STAR Tier 1 Geothermal Heat Pumps Key Product Criteria. http://www.energystar.gov/index.cfm?c=geo_heat.pr_crit_geo_heat_pumps. Last accessed on October 23, 2013.

4.2.6 ELECTRONICALLY COMMUTATED MOTOR

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.	
	Heating fuel type	

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)

$$WKW_H = PkW_H \times CF_H$$

$$WKW_H = 0.18 \times 0.50 = 0.09 kW$$

$$SKW_C = PkW_C \times CF_C$$

$$SKW_C = 0.16 \times 0.75 = 0.12 kW$$

Lost Opportunity Gross Peak Day Savings, Natural Gas

$$PD_H = ACCF \times PDF_H$$

$$PD_H = -10.8 \times 0.00977 = -0.106 ccf$$

Changes from Last Version

No changes.

References

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

Notes

[1] The Wisconsin study 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; other advanced sealing techniques can be used to achieve 2009 IECC duct sealing requirements (Ref [3a]), or if projects are initiated after the new code adoption, 2012 IECC Duct Sealing requirements (Ref [3b]).

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]). For all duct sealing, savings may be subject to a final analysis which may include a billing analysis, calibration, engineering models, or other applicable methods.

Advanced Duct Sealing (ADS) is a special case of duct sealing that satisfies IECC 2009 (Ref [3a]) or 2012 requirements (Ref [3b]). One of the methods approved in IECC 2009 or 2012 for verification of performance must be used following ADS and well documented (See Notes [1], [2]).

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**
A	Heated area served by system (required only for ADS measures)
CFM_{Pre}	Verified air leakage rate at 25 Pa before duct sealing
CFM_{Post}	Verified air leakage rate after duct sealing at 25 Pa (not required for ADS savings)
	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**
A	Heated area served by system	ft^2	Actual	
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 leakage rate before duct sealing at 25Pa	CFM	Actual	Note [1]
CFM_{Post}	Air leakage rate after duct sealing at 25 Pa	CFM	Actual	Note [2]
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	per cfm		Ref [1]

Retrofit Gross Energy Savings, Electric

Table 1: Electric Duct Blaster Savings, kWh per CFM Reduction at 25 Pa (Note [3])

	$REM_{Heating}$ for Heating			**REM_{AH}**	**$REM_{Cooling}$**
	Electric Forced Air	Heat Pumps	Geothermal	Heating Fan (Note [3])	Central AC Cooling
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,

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

Retrofit Gross Energy Savings, Fossil Fuel

Table 2: Fossil Fuel Duct Blaster Savings per CFM Reduction at 25 Pa (Note [4])

	Heating (MMBtu)	Gallons Oil – Gallons (**REM_{Oil}**)	Natural Gas – Ccf (**REM_{NG}**)	Gallons Propane – Gallons (**$REM_{Propane}$**)
Savings per CFM Reduction	*0.035*	0.252	0.340	0.383

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,

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

Retrofit Gross Energy Savings, Example

Duct sealing at 25 Pa was performed in a 2400 ft^2 1960’s ranch style home in Hartford. The home is primarily heated by a natural gas furnace and cooled by Central AC. The outside duct leakage readings at 25 Pa showed CFM_{Pre} of 850 and CFM_{Post} of 775. What are the energy savings for this home?

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

Using the equation for gas heating savings:

$$ACCF_H = REM_{NG} \times (CFM_{Pre} - CFM_{Post})$$
$$ACCF_H = 0.340 \times (850 - 775)$$
$$ACCF_H = 25.5\ Ccf$$

Using the equation for electric heating fan savings,

$$AKWH_H = REM_{AH} \times (CFM_{Pre} - CFM_{Post})$$
$$AKWH_H = 1.100 \times (850 - 775)$$

$$AKWH_H = 82.5\ kWh$$

Using the equation for Central AC savings,

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

<u>Retrofit Gross Seasonal Peak Demand Savings, Electric (Winter and Summer)</u>

Table 3: Electric Duct Blaster Savings, kW per CFM Reduction at 25 Pa (Note [3])

	REM_{WKW} for Heating				**REM_{SKW}**
	Electric Forced Air	Heat Pump	Geothermal	Everything Else	Central AC Cooling
Savings per CFM Reduction	0.0158	0.0158	0.0053	0	0.0023

$$WKW_H = REM_{WKW} \times (CFM_{Pre} - CFM_{Post})$$
$$SKW_C = REM_{SKW} \times (CFM_{Pre} - CFM_{Post})$$

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

<u>Retrofit Gross Seasonal Peak Demand Savings, Natural Gas</u>

$$PD_H = ACCF_H \times PDF_H$$

<u>Retrofit Gross Peak Demand Savings, Example</u>

Duct sealing at 25 Pa was performed in a 2400 ft^2 1960's ranch style home in Hartford. The home is primarily heated by heat pump and cooled by Central AC. The outside duct leakage readings at 25 Pa showed CFM_{Pre} of 850 and CFM_{Post} of 775. What are the peak demand savings for this home?

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

$$WKW_H = REM_{WKW} \times (CFM_{Pre} - CFM_{Post})$$
$$WKW_H = 0.0158 \times (850 - 775)$$
$$WKW_H = 1.19\ kW$$

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

$$SKW_C = REM_{SKW} \times (CFM_{Pre} - CFM_{Post})$$
$$SKW_C = 0.0023 \times (850 - 775)$$
$$SKW_C = 0.173\ kW$$

If the home in this example has a Natural Gas furnace instead of a heat pump, what are the natural gas peak day savings?

Using the formula for Peak Day Natural Gas,

$$PD_H = ACCF_H \times PDF_H$$
$$PD_H = 25.5 \times 0.00977 = 0.249\ Ccf$$
$$PD_H = 0.249\ Ccf$$

Changes from Last Version

Added the 2012 IECC requirements

References

[1] REM/Rate™ version 12.99 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 & United Illuminating, August 2010.

[2] Residential Central AC Regional Evaluation, ADM Associates, Inc., Final Report, November 2009.

[3a] 2009IEEC 403.2.2 Duct sealing. pages 30 & 31 ISBN978-1-5800-742-8.

[3b] 2012 IEEC 403.2.2 Duct Sealing pg R33 & R34 ISBN978-1-60983-091-5

Notes

[1] If the duct leakage to the outside has been measured and verified prior to performing ADS (such as CFM_{post} from a recent duct blaster test), this value shall be used for CFM_{pre}. If this value is not available, use the following: $CFM_{pre} = 0.195 \, {}^{CFM}\!/_{sqft} \times A$, based on the average CFM_{pre} from all Home Energy Solutions duct sealing projects in 2011.

[2a] Actual measured air flow CFM to outside shall be used for CFM_{post} whenever possible. In the case of ADS, if air flow to the outside is unavailable but the 2009 IECC specification has been met, CFM_{post} may be calculated based on the heated area served by the system.

[2b] Actual measured air flow CFM to outside shall be used for CFM_{post} whenever possible. In the case of ADS, if air flow to the outside is unavailable but the 2012 IECC specification has been met, CFM_{post} may be calculated based on the heated area served by the system: CFMpost=0.04 X A.

[3] Fan energy savings are only to be captured for forced-air systems with an air handling unit (fan).

[4] Fossil fuel savings include estimated expected system efficiency of 75% including combustion and distribution

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 by:

- 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 (or new construction).

In addition to electric savings, ductless heat pumps provide energy savings and environmental benefits that are not captured through C&LM Programs in situations where they are used to displace fossil fuel. Because C&LM does not take credit for fuel switching savings, the estimates of fossil fuel savings and emissions reductions are not presented here. However they can be derived based on the above assumptions and equations.

Note: The savings here are not to be applied to a heat pump with ducting. Only systems without ducts are addressed by this measure.

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
N	Number of zones
	Primary existing heating fuel type

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]

Symbol	Description	Units	Value	Comments
EE_H	Efficiency conversion factor, heating		0.171	Ref [1]
$HSPF_B$	Heating Season Performance Factor, Baseline	Btu/Watt-hr	8.2 – Lost Opportunity	Ref[2]
$HSPF_E$	Heating Season Performance Factor, Existing	Btu/Watt-hr	3.413 – Retrofit	Note [1]
$HSPF_I$	Heating Season Performance Factor, Installed	Btu/Watt-hr		Input
N	Number of ductless heat pump zones (or heads)		1 zone = 0.75 2 zones = 1.25 3 or more zones = 1.50	Input
$SEER_B$	Seasonal Energy Efficiency Ratio, Baseline	Btu/Watt-hr	14.0– Lost Opportunity	Ref[2]
$SEER_E$	Seasonal Energy Efficiency Ratio, Existing	Btu/Watt-hr	10.1 – Retrofit	Note [1]
$SEER_I$	Seasonal Energy Efficiency Ratio, Installed	Btu/Watt-hr		Input
SKW	Summer Demand Savings	kW		
WKW	Winter Demand Savings	kW		

Retrofit Gross Energy Savings, Electric

Heating

For Hartford: $$AKWH_H = N \times CAP_H \times \left(\frac{1}{HSPF_E} - \frac{1}{HSPF_I} \right) \times \frac{1}{EE_H} \times AA_H \times \frac{1}{1000}$$

For Bridgeport: $$AKWH_H = N \times CAP_H \times \left(\frac{1}{HSPF_E} - \frac{1}{HSPF_I} \right) \times \frac{1}{EE_H} \times CC_H \times \frac{1}{1000}$$

Cooling

For Hartford: $$AKWH_C = N \times CAP_C \times \left(\frac{1}{SEER_E} - \frac{1}{SEER_I} \right) \times \frac{1}{EE_C} \times AA_C \times \frac{1}{1000}$$

For Bridgeport: $$AKWH_C = N \times CAP_C \times \left(\frac{1}{SEER_E} - \frac{1}{SEER_I} \right) \times \frac{1}{EE_C} \times CC_C \times \frac{1}{1000}$$

Retrofit Gross Energy Savings, Example

An 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. The system has two zones. What are the annual electric heating and cooling savings?

Using the equation for annual electric heating savings,

$$AKWH_H = N \times CAP_H \times \left(\frac{1}{HSPF_E} - \frac{1}{HSPF_I} \right) \times \frac{1}{EE_H} \times AA_H \times \frac{1}{1000}$$

$$AKWH_H = 1.25 \times 24{,}000 \times \left(\frac{1}{3.413} - \frac{1}{11} \right) \times \frac{1}{0.1714} \times 130 \times \frac{1}{1{,}000} = 4{,}609\ kWh$$

Using the equation for annual electric cooling savings,

$$AKWH_C = N \times CAP_C \times \left(\frac{1}{SEER_E} - \frac{1}{SEER_I} \right) \times \frac{1}{EE_C} \times AA_C \times \frac{1}{1000}$$

$$AKWH_C = 1.25 \times 28{,}000 \times \left(\frac{1}{10.1} - \frac{1}{22} \right) \times \frac{1}{0.037} \times 3.1 \times \frac{1}{1000} = 157\ kWh$$

<u>Retrofit Gross Seasonal Peak Demand Savings, Electric (Winter and Summer)</u>

Winter Demand Savings:

For Hartford: $$WKW = N \times CAP_H \times \left(\frac{1}{HSPF_E} - \frac{1}{HSPF_I} \right) \times \frac{1}{EE_H} \times BB_H \times \frac{1}{1000}$$

For Bridgeport: $$WKW = N \times CAP_H \times \left(\frac{1}{HSPF_E} - \frac{1}{HSPF_I} \right) \times \frac{1}{EE_H} \times DD_H \times \frac{1}{1000}$$

Summer Demand Savings:

For Hartford: $$SKW = N \times CAP_C \times \left(\frac{1}{SEER_E} - \frac{1}{SEER_I} \right) \times \frac{1}{EE_C} \times BB_C \times \frac{1}{1000}$$

For Bridgeport: $$SKW = N \times CAP_C \times \left(\frac{1}{SEER_E} - \frac{1}{SEER_I} \right) \times \frac{1}{EE_C} \times DD_C \times \frac{1}{1000}$$

<u>Retrofit Gross Peak Demand Savings, Example</u>

An 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. The system has 2 zones. What are the annual summer and winter demand savings?

Using the equation for summer demand savings,

$$SKW = N \times CAP_C \times \left(\frac{1}{SEER_E} - \frac{1}{SEER_I} \right) \times \frac{1}{EE_C} \times BB_C \times \frac{1}{1000}$$

$$SKW = 1.25 \times 28{,}000 \times \left(\frac{1}{10.1} - \frac{1}{22} \right) \times \frac{1}{0.037} \times 0.0017 \times \frac{1}{1000} = 0.086\ kW$$

Using the equation for winter demand savings,

$$WKW = N \times CAP_H \times \left(\frac{1}{HSPF_E} - \frac{1}{HSPF_I} \right) \times \frac{1}{EE_H} \times BB_H \times \frac{1}{1000}$$

$$WKW = 1.25 \times 24000 \times \left(\frac{1}{3.413} - \frac{1}{11} \right) \times \frac{1}{0.171} \times 0.019 \times \frac{1}{1000} = 0.674\ kW$$

Lost Opportunity Gross Energy Savings, Electric

Heating

For Hartford: $$AKWH_H = N \times CAP_H \times \left(\frac{1}{HSPF_B} - \frac{1}{HSPF_I} \right) \times \frac{1}{EE_H} \times AA_H \times \frac{1}{1000}$$

For Bridgeport: $$AKWH_H = N \times CAP_H \times \left(\frac{1}{HSPF_B} - \frac{1}{HSPF_I} \right) \times \frac{1}{EE_H} \times CC_H \times \frac{1}{1000}$$

Cooling

For Hartford: $$AKWH_C = N \times CAP_C \times \left(\frac{1}{SEER_B} - \frac{1}{SEER_I} \right) \times \frac{1}{EE_C} \times AA_C \times \frac{1}{1000}$$

For Bridgeport: $$AKWH_C = N \times CAP_C \times \left(\frac{1}{SEER_B} - \frac{1}{SEER_I} \right) \times \frac{1}{EE_C} \times CC_C \times \frac{1}{1000}$$

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

Winter Demand Savings:

For Hartford: $$WKW = N \times CAP_H \times \left(\frac{1}{HSPF_B} - \frac{1}{HSPF_I} \right) \times \frac{1}{EE_H} \times BB_H \times \frac{1}{1000}$$

For Bridgeport: $$WKW = N \times CAP_H \times \left(\frac{1}{HSPF_B} - \frac{1}{HSPF_I} \right) \times \frac{1}{EE_H} \times DD_H \times \frac{1}{1000}$$

Summer Demand Savings:

For Hartford: $$SKW = N \times CAP_C \times \left(\frac{1}{SEER_B} - \frac{1}{SEER_I} \right) \times \frac{1}{EE_C} \times BB_C \times \frac{1}{1000}$$

For Bridgeport: $$SKW = N \times CAP_C \times \left(\frac{1}{SEER_B} - \frac{1}{SEER_I} \right) \times \frac{1}{EE_C} \times DD_C \times \frac{1}{1000}$$

Non Energy Benefits

Resource benefit from installing ductless heat pump to displace fossil fuel is $94.note (4)

Ductless Heat Pump customers have reported high levels of satisfaction. Ref [1]

Changes from Last Version

Removed customer benefits
Added note on customer fuel switching benefits calculations

References

[1] Ductless Mini Pilot Study, Final Report, KEMA, June 2009, Pages vi, vii, 4-15 and 4-18.

[2] 10 CFR 430.32 -2015 Ch. II

Notes

[1] The minimum heating efficiency standard set by federal government effective January 1, 2015 for ductless heat pumps is 8.2 HSPF and cooling efficiency is 14.0 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] The Connecticut Utilities do not claim any fuel switching savings however, annual fuel-switching customer monetary benefits can be calculated using the electrical savings calculated from the Ductless Heat Pump measure, the current cost of fuel (oil, gas, and propane), and equipment efficiencies. The Connecticut Utilities have a spreadsheet in order to make fuel switching calculations for demonstrational purposes.

4.2.13 PACKAGE TERMINAL HEAT PUMP

Description of Measure

Installation of new energy efficient packaged terminal heat pump

Savings Methodology

The savings methodology for a package terminal heat pump (PTHP) is calculated from baseline efficiencies in Ref [1].

Lost Opportunity Measure:

- Lost Opportunity savings are the difference in energy use between a baseline new model and the chosen high efficiency new model, continuing for the Effective Useful Life (EUL) from Appendix 4.

Retrofit Measure:

- Uses the same methodology as a Lost Opportunity measure;
- In the case of early retirement of a working unit where the unit would have otherwise been installed until failure, lifetime "Retirement" savings are claimed additional to the lifetime "Lost Opportunity" savings (see Section 1.4).
- Retirement savings are the difference in energy use between the older unit and a baseline new model, continuing for the Remaining Useful Life (RUL) from Appendix 4.

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	1349	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	362.0	Ref [2]
S_{kW}	Average Peak kW Savings per unit size	kW/Ton	0.45	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

$$AKWH_H = HR \times EFLH_H \times CAP_C \times \left(\frac{1}{COP_E} - \frac{1}{COP_B}\right) \times \frac{1}{3412}$$

$$\text{Where, } COP_B = 2.9 - \left(0.026 \times CAP_C \times \frac{1}{1{,}000}\right)$$

b) For replacement of electric resistive system, use the following equation

$$AKWH_H = HR \times EFLH_H \times CAP_C \times \left(1 - \frac{1}{SA \times COP_B}\right) \times \frac{1}{3412}$$

$$\text{Where, } COP_B = 2.9 - \left(0.026 \times CAP_C \times \frac{1}{1{,}000}\right)$$

Cooling

$$AKWH_C = S_{kWh} \times CAP_C \times \left(\frac{EER_B}{EER_E} - 1\right) \times \frac{1}{12{,}000}$$

$$AKWHc = 362.0 \times CAP_C \times \left(\frac{EER_B}{EER_E} - 1\right) \times \frac{1}{12{,}000}$$

$$\text{Where, } EER_B = 10.8 - \left(0.213 \times CAP_C \times \frac{1}{1{,}000}\right)$$

Reminder: *For working unit, claim additional lost opportunity savings*.

Retrofit Gross Energy Savings, Example

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

$$AKWH_H = HR \times EFLH_H \times CAP_C \times \left(\frac{1}{COP_E} - \frac{1}{COP_B}\right) \times \frac{1}{3412}$$

$$\text{Where, } COP_B = 2.9 - \left(0.026 \times 12{,}000 \times \frac{1}{1{,}000}\right) = 2.59$$

$$AKWH_H = 0.6 \times 1349 \times 12{,}000 \times \left(\frac{1}{2.5} - \frac{1}{2.59}\right) \times \frac{1}{3{,}412} = 39.55\ kWh$$

Cooling

$$AKWHc = 362.0 \times CAP_C \times \left(\frac{EER_B}{EER_E} - 1\right) \times \frac{1}{12{,}000}$$

$$\text{Where, } EER_B = 10.8 - \left(0.213 \times CAP_C \times \frac{1}{1{,}000}\right)$$

$$EER_B = 10.8 - \left(0.213 \times 12{,}000 \times \frac{1}{1{,}000}\right) = 8.24$$

$$AKWH_C = 362.0 \times 12{,}000 \times \left(\frac{8.24}{7.8} - 1\right) \times \frac{1}{12{,}000} = 20.42kW$$

Reminder: *For working unit, claim additional lost opportunity savings.*

Retrofit Gross Seasonal Peak Demand Savings, Electric (Winter and Summer)

WKW = 0; Note [3]

$$SKW_C = S_{kW} \times CAP_C \times \left(\frac{EER_B}{EER_E} - 1\right) \times \frac{1}{12{,}000}$$

$$SKW_C = 0.45 \times CAP_C \times \left(\frac{EER_B}{EER_E} - 1\right) \times \frac{1}{12{,}000}$$

$$\text{Where, } EER_B = 10.8 - \left(0.213 \times CAP_C \times \frac{1}{1{,}000}\right)$$

Retrofit Gross Peak Demand Savings, Example

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

$$SKW_C = 0.45 \times CAP_C \times \left(\frac{EER_B}{EER_E} - 1\right) \times \frac{1}{12{,}000}$$

$$\text{Where, } EER_B = 10.8 - \left(0.213 \times 12{,}000 \times \frac{1}{1{,}000}\right) = 8.24$$

$$SKW_C = 0.45 \times 12{,}000 \times \left(\frac{8.24}{7.8} - 1\right) \times \frac{1}{12{,}000} = 0.025kW$$

Lost Opportunity Gross Energy Savings, Electric

Heating

$$AKWH_H = HR \times EFLH_H \times CAP_C \times \left(\frac{1}{COP_B} - \frac{1}{COP_I}\right) \times \frac{1}{3412}$$

$$\text{Where, } COP_B = 3.2 - \left(0.026 \times CAP_C \times \frac{1}{1{,}000}\right)$$

Cooling

$$AKWH_C = 362.0 \times CAP_C \times \left(\frac{EER_I}{EER_B} - 1 \right) \times \frac{1}{12{,}000}$$

$$\text{Where, } EER_B = 12.3 - \left(0.213 \times CAP_C \times \frac{1}{1{,}000} \right)$$

Lost Opportunity Gross Energy Savings, Example

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

$$AKWH_H = HR \times EFLH_H \times CAP_C \times \left(\frac{1}{COP_B} - \frac{1}{COP_I} \right) \times \frac{1}{3412}$$

$$\text{Where, } COP_B = 3.2 - \left(0.026 \times 12{,}000 \times \frac{1}{1{,}000} \right) = 2.88$$

$$AKWH_H = 0.6 \times 1349 \times 12{,}000 \times \left(\frac{1}{2.88} - \frac{1}{3.6} \right) \times \frac{1}{3412} = 197.7kWh$$

Cooling

$$AKWH_C = 357.6 \times CAP_C \times \left(\frac{EER_I}{EER_B} - 1 \right) \times \frac{1}{12{,}000}$$

$$\text{Where, } EER_B = 12.3 - \left(0.213 \times 12{,}000 \times \frac{1}{1{,}000} \right) = 9.74$$

$$AKWH_C = 362.0 \times 12{,}000 \times \left(\frac{12.5}{9.74} - 1 \right) \times \frac{1}{12{,}000} = 102.6kWh$$

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

WKW= 0

$$SKW_C = 0.45 \times CAP_C \times \left(\frac{EER_I}{EER_B} - 1 \right) \times \frac{1}{12{,}000}$$

$$\text{Where, } EER_B = 12.3 - \left(0.213 \times CAP_C \times \frac{1}{1{,}000} \right)$$

Lost Opportunity Gross Peak Demand Savings, Example

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

$$SKW_C = 0.45 \times CAP_C \times \left(\frac{EER_I}{EER_B} - 1 \right) \times \frac{1}{12{,}000}$$

$$\text{Where, } EER_B = 12.3 - \left(0.213 \times CAP_C \times \frac{1}{1{,}000}\right)$$

$$EER_B = 12.3 - \left(0.213 \times 12{,}000 \times \frac{1}{1{,}000}\right) = 9.74$$

$$SKW_C = 0.45 \times 12{,}000 \times \left(\frac{12.5}{9.74} - 1\right) \times \frac{1}{12{,}000} = 0.128kW$$

Changes from Last Version

No Changes

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] $EFLH_H$ =1,349 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.

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		

Retrofit Gross Energy Savings, Electric

Cooling savings (Note [1])

$$AKWH_C = 64.37 \times \frac{CAP_C}{12{,}000\,{}^{BTU}\!/_{ton}}$$

Heating Savings

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, cooling savings per CFM reduction is 1.059 kWh. Therefore, for 39.34 kWh savings, there is 37.15 CFM reduction.

$$CFM_{Savings} = \frac{39.34}{1.059} = 37.15\,{}^{CFM}\!/_{ton}$$

Using 4.2.9 duct sealing savings and based on system type the savings can be summarized in Table3 below

Table 3: Savings calculation

System Type	$AKWH_C$	$AKWH_H$
Central AC	$64.37 \times \frac{CAP_C}{12{,}000}$	
Heat Pump	$64.37 \times \frac{CAP_C}{12{,}000}$	$142.9 \times \frac{CAP_C}{12{,}000}$
Geothermal Heat pump	$64.37 \times \frac{CAP_C}{12{,}000}$	$92.25 \times \frac{CAP_C}{12{,}000}$
Furnace (fan Electric Savings)		$40.86 \times \frac{CAP_C}{12{,}000}$

Retrofit Gross Energy Savings, Fossil Fuel

$$ACCF_H = 13.3 \times \frac{CAP_C}{12{,}000}$$

$$AOG_H = 9.3 \times \frac{CAP_C}{12{,}000}$$

$$APG_H = 14.2 \times \frac{CAP_C}{12{,}000}$$

Retrofit Gross Energy Savings, Example

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,

$$AKWH_C = 64.37 \times \frac{CAP_C}{12{,}000}$$

$$AKWH_C = 64.37 \times \frac{36{,}000}{12{,}000} = 193.1kWh$$

Using the equation for heating fan energy,

$$AKWH_H = 40.86 \times \frac{CAP_C}{12{,}000}$$

$$AKWH_H = 40.86 \times \frac{36{,}000}{12{,}000} = 122.58kWh$$

Using the equation for natural gas heating,

$$ACCF_H = 13.3 \times \frac{CAP_C}{12{,}000}$$

$$ACCF_H = 13.3 \times \frac{36{,}000}{12{,}000} = 39.9ccf$$

Retrofit 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:

$$WKW = 0.587 \times \frac{CAP_C}{12{,}000}$$

Retrofit Gross Peak Day Savings, Natural Gas

$$PD_H = ACCF_H \times PDF_H$$

Retrofit Gross Peak Demand Savings, Example

A 1980's home has a 36,000 Btu (3 tons) heat pump system. Quality installation and verification is performed on the system. 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

No Changes

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. 2011. 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, revised June 1 , 2013.

Notes

[1] The average new residential central air conditioners use 357.6 kWh per ton annually (Ref [1]).
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;
Total cooling savings	= 18% x 357.6 x tons =64.37 $AKWH_c$/ton

$$Ton = \frac{CAP_C}{12{,}000\ {}^{BTU}\!/_{ton}}$$

$$AKWH_C = 64.37 \times \frac{CAP_C}{12{,}000\ {}^{BTU}\!/_{ton}}$$

4.2.15 DUCT INSULATION

Description of Measure

Installation of insulation with an R-value greater than or equal to 6 on un-insulated 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), under typical conditions listed in Note [1].

Cooling savings should be reported for homes equipped with central AC using the same duct being insulated.

Note: A duct insulation project should be custom if the actual conditions vary significantly from the typical case presented in this measure (temperature conditions in Note [1], R-value about 6). In such a situation, the 3E Plus tool (Ref [2]) and a similar methodology should be used to develop estimates of the appropriate energy savings.

For all duct sealing, savings may be subject to a final analysis which may include a billing analysis, calibration, engineering models, or other applicable methods.

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	various	Tables 2 & 3	Ref [2]
DI_C	Annual Cooling Savings per square foot	various	Tables 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		

Symbol	Description	Units	Values	Comments
WPF	Winter Peak Factor	W/kWh	0.570	Ref [1]

Retrofit Gross Energy Savings, Electric

Table 1: Annual Savings per ft^2 for homes with Heat Pump or Central AC

Duct location	Heating		Cooling	
	DI_H	Unit	DI_C	Unit
Supply basement	13.05	kWh/ ft^2	0.7721	kWh/ ft^2
Return basement	3.150	kWh/ ft^2	0.2327	kWh/ ft^2
Supply Attic	14.46	kWh/ ft^2	1.425	kWh/ ft^2
Return Attic	4.194	kWh/ ft^2	0.8209	kWh/ ft^2

Heating savings, Electric Heat Pumps:

$$AKWH_H = DI_H \times A$$

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 ft^2 for homes with fossil fuel

Duct location	Heating Savings per ft^2	
	DI_H	Unit
Supply basement	0.1187	MMbtu/ ft^2
Return basement	0.02866	MMbtu/ ft^2
Supply Attic	0.1316	MMbtu/ ft^2
Return Attic	0.03816	MMbtu/ ft^2

For homes with a natural gas furnace,

$$ACCF_H = \frac{DI_H \times A}{0.10290}$$

For homes with an oil furnace,

$$AOG_H = \frac{DI_H \times A}{0.13869}$$

For homes with a propane furnace,

$$APG_H = \frac{DI_H \times A}{0.09133}$$

Reminder*: cooling savings can be claimed for homes equipped with central AC*

Retrofit Gross Energy Savings, Example

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?

$$ACCF_H = \frac{DI_H \times A}{0.10290}$$

$$ACCF_H = \frac{0.1187 \times 50\ ft^2}{0.10290} = 57.68\,Ccf$$

Since the house is equipped with central AC, there are cooling savings too:

$$AKWH_C = DI_C \times A$$

$$AKWH_C = 0.7721 \times 50\text{ft}^2 = 38.61\,\text{kWh}$$

Retrofit Gross Seasonal Peak Day Savings, Electric (Winter and Summer)

Winter seasonal peak demand (kW) will be claimed for homes equipped with a Heat Pump:

$$WKW = \frac{WPF \times DI_H \times A}{1{,}000\,{}^{W}\!/_{kW}}$$

Summer seasonal peak demand (kW) will be claimed for homes equipped with Central AC:

$$SKW = \frac{SPF \times DI_C \times A}{1{,}000\,{}^{W}\!/_{kW}}$$

Retrofit Gross Peak Day Savings, Natural Gas

For homes with a natural gas furnace,

$$PD_H = ACCF_H \times PDF_H$$

Retrofit Gross Peak Demand Savings, Example

What are the peak demand savings for the above retrofit example?
Using the formula for Peak Day Natural Gas:

$$PD_H = ACCF_H \times PDF_H$$

$$PD_H = 57.68 \times 0.00977 = 0.564\,Ccf$$

Cooling demand savings may also be claimed:

$$SKW = \frac{SPF \times DI_C \times A}{1{,}000\,{}^{W}\!/_{kW}}$$

$$SKW = \frac{0.017 \times 0.7721 \times 50\,ft^2}{1{,}000\,{}^{W}\!/_{kW}} = 0.000656\,kW$$

Changes from Last Version

No changes.

References

[1] Evaluation of the Weatherization Residential Assistance Partnership (WRAP) and Helps Programs, conducted by KEMA, September 2010, table ES-9 page 1-11.

[2] North American Insulation Manufacturers Association (NAIMA), 3E Plus software tool, Version 4.1, Released 2012

Notes

[1] **Assumed Temperature Conditions**

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

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 (Note [2]). 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.

Energy savings resulting from the removal of units in working condition are calculated as follows:

Lost Opportunity Measure:

- Lost Opportunity savings are the difference in energy use between a baseline new model (Note [1]) and the chosen high efficiency new model, continuing for the Effective Useful Life (EUL) from Appendix 4.

Retrofit Measure:

- Uses the same methodology as a Lost Opportunity measure;
- In the case of early retirement of a working unit, where the unit would have otherwise been installed until failure, lifetime "Retirement" savings are claimed additional to the lifetime "Lost Opportunity" savings (see Section 1.4).
- Retirement savings are the difference in energy use between the older unit and a baseline model (Note [1]), continuing for the Remaining Useful Life (RUL) 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
A	Heated area served by boiler	ft^2
$AFUE_I$	AFUE-installed	%

Nomenclature

Symbol	Description	Units	Values	Comments
A	Heated area served by boiler	ft^2	ft^2 = 2000 if unknown	Input Note [2]
$ABTU_H$	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 4.5.7)
$AFUE_B$	Annual Fuel Utilization Efficiency, Baseline	%	82% - Gas/Propane 84% - Oil	Note [1]
$AFUE_E$	Annual Fuel Utilization Efficiency, Existing	%	Table 2 (if known)	Ref [1]
$AFUE_I$	Annual Fuel Utilization Efficiency, Installed	%		Input
EUL	Effective Useful Life			Appendix 4

Symbol	Description	Units	Values	Comments
HF	Heating Factor based on age of home	Btu/ ft^2/ Yr	Table 1 Use 33,300 if unknown	Ref [1] Note [2]
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		
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	If unknown, use default HF value	Input Note [2]
YR_e	Year existing boiler installed	Years		Input

Lost Opportunity Gross Energy Savings, Fossil Fuel

Table 1: Residential Heating Factor (Ref [1]

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
Unknown	33,300

Table 2: Existing AFUE (Ref [1], Note[1])

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 2012	80%	80%
2013 to present, or unknown (baseline)	82%	84%

Savings by heating fuel:

$$ABTU_H = A \times HF \times \left(\frac{1}{AFUE_B} - \frac{1}{AFUE_I} \right)$$

$$ACCF_H = \frac{ABTU_H}{102{,}900 \, {}^{Btu}/_{Ccf}}$$

$$AOG_H = \frac{ABTU_H}{138{,}690 \, {}^{Btu}/_{Gal}}$$

$$APG_H = \frac{ABTU_H}{91{,}330 \, {}^{Btu}/_{Gal}}$$

Water Heating Savings by water heating fuel:

$$ABTU_W = ADHW \times \left(\frac{1}{AFUE_b} - \frac{1}{AFUE_i} \right)$$

$$ACCF_W = \frac{ABTU_W}{102{,}900 \, {}^{Btu}/_{Ccf}}$$

$$ACCF_W = \frac{ABTU_W}{138{,}690 \, {}^{Btu}/_{Ccf}}$$

$$ACCF_W = \frac{ABTU_W}{91{,}330 \, {}^{Btu}/_{Ccf}}$$

Lost Opportunity Gross Energy Savings, Example

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 83 percent.

From Table 1:
HF = 33,300
From example:
$AFUE_I$= 83% or 0.83
$AFUE_B$= 82% or 0.82 (baseline value)

$$ABTU_H = 2{,}000 \times 33{,}300 \times \left(\frac{1}{0.82} - \frac{1}{0.83} \right)$$

$$ABTU_H = 978{,}354 \; Btu$$

$$ACCF_H = \frac{975{,}534 \; Btu}{102{,}900 \, {}^{Btu}/_{Ccf}}$$

$$ACCF_H = 9.5 \; Ccf$$

Water Heating:

$$ABTU_W = 11{,}197{,}132 \times \left(\frac{1}{0.82} - \frac{1}{0.83} \right)$$

$$ABTU_W = 164{,}486 \; Btu$$

$$ACCF_W = \frac{164{,}486 \; Btu}{102{,}900 \, {}^{Btu}/_{Ccf}}$$

$$ACCF_W = 1.6 \; Ccf$$

Total:

$$ACCF = ACCF_H + ACCF_W$$

$$ACCF = 9.5 \, {}^{Ccf}/_{yr} + 1.6 \, {}^{Ccf}/_{yr}$$

$$ACCF = 11.1 \, {}^{Ccf}/_{yr}$$

Lost Opportunity Gross Seasonal Peak Demand Savings, Natural Gas

$$PD_H = ACCF_H \times PDF_H$$
$$PD_W = ACCF_W \times PDF_W$$

Lost Opportunity Gross Peak Demand Savings, Example

For the same example as above:

$$PD_H = 9.5 \times 0.00977$$
$$PD_H = 0.09\ Ccf$$
$$PD_W = 1.6 \times 0.00321$$
$$PD_W = 0.005\ Ccf$$

Total:

$$PD = PD_H + PD_W$$
$$PD = 0.09 + 0.005$$
$$PD = 0.095\ Ccf$$

Retrofit Gross Energy Savings, Fossil Fuel

Reminder: Retrofit savings are the sum of Retirement savings and Lost Opportunity savings. This section presents the Retirement portion of savings.

Tables 1 and 2 are used to estimate the heating load and existing boiler efficiency of the home, based on age.

$$ABTU_H = A \times HF \times \left(\frac{1}{AFUE_E} - \frac{1}{AFUE_B} \right)$$

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:

$$ACCF_W = \frac{ABTU_W}{102{,}900\,{}^{Btu}/_{Ccf}}$$

$$AOG_W = \frac{ABTU_W}{138{,}690\,{}^{Btu}/_{Gal}}$$

$$APG_W = \frac{ABTU_W}{91{,}330\,{}^{Btu}/_{Gal}}$$

Retrofit Gross Energy Savings, Example

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 1 and 2:
HF = 33,300 (from Table 1)
$AFUE_E$= 70% or 0.70 (from Table 2)
$AFUE_B$= 82% or 0.82 (baseline value)

Reminder: *Retrofit savings do not depend on the efficiency of the new installed unit.*

$$ABTU_H = 2{,}000 \times 33{,}300 \times \left(\frac{1}{0.70} - \frac{1}{0.82}\right)$$

$$ABTU_H = 13{,}923{,}345\ Btu$$

$$ACCF_H = \frac{13{,}923{,}345\ Btu}{102{,}900\,{}^{Btu}/_{Ccf}}$$

$$ACCF_H = 135\ Ccf$$

Water Heating:

$$ABTU_W = 11{,}197{,}132 \times \left(\frac{1}{0.70} - \frac{1}{0.82}\right)$$

$$ABTU_H = 2{,}340{,}864\ Btu$$

$$ACCF_W = \frac{2{,}340{,}864\ Btu}{102{,}900\,{}^{Btu}/_{Ccf}}$$

$$ACCF_W = 23\ Ccf$$

$$Total:$$

$$ACCF = ACCF_H + ACCF_W$$

$$ACCF = 135 + 23$$

$$ACCF = 158\ Ccf$$

Retrofit Gross Peak Day Savings, Natural Gas

$$PD_H = ACCF_H \times PDF_H$$

If Boiler also provides DHW:

$$PD_W = ACCF_W \times PDF_W$$

Retrofit Gross Peak Demand Savings, Example

For same example as above:

$$PD_H = 135 \times 0.00977$$
$$PD_H = 1.32\ Ccf$$

$$PD_W = 23 \times 0.00321$$
$$PD_W = 0.07\ Ccf$$

$$PD = PD_H + PD_W$$
$$PD = 1.39\ Ccf$$

Changes from Last Version

No changes.

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 September 26, 2013.

Notes

[1] The baseline values are based in reference [1] efficiencies for 2011.

[2] Default values are based on defined CT reference home as determined from historical actuals.

4.2.17a BOILER alternate methodology

Description of Measure

Installation of an energy-efficient boiler.

Savings Methodology

The fossil fuel savings for this measure are calculated using a linear regression based on verified data from a recent evaluation of heating equipment in Massachusetts (Ref [2]). 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.
Energy savings resulting from the removal of units in working condition are calculated as follows:

Lost Opportunity Measure:

- Lost Opportunity savings are calculated according to a regression on installed AFUE based on verified savings data from Ref [2]. A regression was used rather than the usual reciprocal formula because of differences in boiler performance at varying efficiencies (e.g. failure to consistently achieve proper temperatures for condensing in all installations).

Retrofit Measure:

- Uses the same methodology as a Lost Opportunity measure;
- In the case of early retirement of a working unit, where the unit would have otherwise been installed until failure, lifetime “Retirement” savings are claimed additional to the lifetime “Lost Opportunity” savings (see Section 1.4).
- Retirement savings are the difference in energy use between the older unit and a baseline model (Note [1]), continuing for the Remaining Useful Life (RUL) from Appendix 4.

Inputs

Symbol	Description	Units
	Heating Fuel (Natural gas, oil, propane)	
$AFUE_E$	AFUE, existing (if available)	%
$AFUE_I$	AFUE, installed	%

Nomenclature

Symbol	Description	Units	Values	Comments
A	Heated area served by boiler	ft^2	2000	Note [2]
$ABTU_H$	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 4.5.7)
$AFUE_B$	Annual Fuel Utilization Efficiency, Baseline	%	85%	Note [1]
$AFUE_E$	Annual Fuel Utilization Efficiency, Existing	%	80%	Note [4]
$AFUE_I$	Annual Fuel Utilization Efficiency, Installed	%		Input
EUL	Effective Useful Life			Appendix 4
HF	Average heating factor based on home’s heat load	Btu/ ft^2	46,400	Note [3]
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		
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

Lost Opportunity Gross Energy Savings, Fossil Fuel

Savings by heating fuel:

$$ABTU_H = 102{,}241{,}440 \times AFUE_I - 86{,}909{,}340$$

$$ACCF_H = \frac{ABTU_H}{102{,}900\ ^{Btu}/_{Ccf}}$$

$$AOG_H = \frac{ABTU_H}{138{,}690\ ^{Btu}/_{Gal}}$$

$$APG_H = \frac{ABTU_H}{91{,}330\ ^{Btu}/_{Gal}}$$

Water Heating Savings by water heating fuel:

$$ABTU_W = 11{,}360{,}160 \times AFUE_I - 9{,}652{,}020$$

$$ACCF_W = \frac{ABTU_W}{102{,}900\ ^{Btu}/_{Ccf}}$$

$$ACCF_W = \frac{ABTU_W}{138{,}690\ ^{Btu}/_{Ccf}}$$

$$ACCF_W = \frac{ABTU_W}{91{,}330\ ^{Btu}/_{Ccf}}$$

Lost Opportunity Gross Energy Savings, Example

A boiler is installed in a natural gas heated home. The installed boiler has efficiency (AFUE) of 90 percent.

From example:
$AFUE_I$= 90% or 0.90

$$ABTU_H = 102{,}241{,}440 \times AFUE_I - 86{,}909{,}340$$

$$ABTU_H = 5{,}107{,}956\ Btu$$

$$ACCF_H = \frac{5{,}107{,}956\ Btu}{102{,}900\ ^{Btu}/_{Ccf}}$$

$$ACCF_H = 49.6\ Ccf$$

Water Heating:

$$ABTU_W = 11{,}360{,}160 \times AFUE_I - 9{,}652{,}020$$

$$ABTU_W = 572{,}124\ Btu$$

$$ACCF_W = \frac{572{,}124\ Btu}{102{,}900\ ^{Btu}/_{Ccf}}$$

$$ACCF_W = 5.6\ Ccf$$

Total:

$$ACCF = ACCF_H + ACCF_W$$
$$ACCF = 49.6\ {}^{Ccf}\!/_{yr} + 5.6\ {}^{Ccf}\!/_{yr}$$
$$ACCF = 55.2\ {}^{Ccf}\!/_{yr}$$

Lost Opportunity Gross Seasonal Peak Demand Savings, Natural Gas

$$PD_H = ACCF_H \times PDF_H$$
$$PD_W = ACCF_W \times PDF_W$$

Lost Opportunity Gross Peak Demand Savings, Example

For the same example as above:

$$PD_H = 49.6 \times 0.00977$$
$$PD_H = 0.485\ Ccf$$
$$PD_W = 5.6 \times 0.00321$$
$$PD_W = 0.018\ Ccf$$

Total:

$$PD = PD_H + PD_W$$
$$PD = 0.485 + 0.018$$
$$PD = 0.503\ Ccf$$

Retrofit Gross Energy Savings, Fossil Fuel

Reminder: Retrofit savings are the sum of Retirement savings and Lost Opportunity savings. This section presents the Retirement portion of savings.

Tables 1 and 2 are used to estimate the heating load and existing boiler efficiency of the home, based on age.

$$ABTU_H = A \times HF \times \left(\frac{1}{AFUE_E} - \frac{1}{AFUE_B} \right)$$
$$ABTU_H = 2{,}000 \times 46{,}400 \times \left(\frac{1}{AFUE_E} - \frac{1}{0.85} \right)$$

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:

$$ABTU_W = ADHW \times \left(\frac{1}{AFUE_E} - \frac{1}{AFUE_B} \right)$$

$$ABTU_W = 11{,}197{,}312 \times \left(\frac{1}{AFUE_E} - \frac{1}{0.85} \right)$$

Water Heating Savings by water heating fuel:

$$ACCF_W = \frac{ABTU_W}{102{,}900\ {}^{Btu}\!/\!_{Ccf}}$$

$$AOG_W = \frac{ABTU_W}{138{,}690\ {}^{Btu}\!/\!_{Gal}}$$

$$APG_W = \frac{ABTU_W}{91{,}330\ {}^{Btu}\!/\!_{Gal}}$$

Retrofit Gross Energy Savings, Example

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, but the existing boiler AFUE is unknown.

From example:
$AFUE_E$= 80% or 0.80 (default value)
$AFUE_B$= 85% or 0.85 (baseline value)

Reminder: *Retrofit savings do not depend on the efficiency of the new installed unit.*

$$ABTU_H = 2{,}000 \times 46{,}400 \times \left(\frac{1}{0.80} - \frac{1}{0.85} \right)$$

$$ABTU_H = 6{,}823{,}589\ Btu$$

$$ACCF_H = \frac{6{,}823{,}589\ Btu}{102{,}900\ {}^{Btu}\!/\!_{Ccf}}$$

$$ACCF_H = 66.3\ Ccf$$

Water Heating:

$$ABTU_W = 11{,}197{,}132 \times \left(\frac{1}{0.80} - \frac{1}{0.85} \right)$$

$$ABTU_H = 823{,}319\ Btu$$

$$ACCF_W = \frac{823{,}319\ Btu}{102{,}900\ {}^{Btu}\!/_{Ccf}}$$

$$ACCF_W = 8.0\ Ccf$$

$$Total:$$

$$ACCF = ACCF_H + ACCF_W$$

$$ACCF = 66.3 + 8.0$$

$$ACCF = 74.3\ Ccf$$

Retrofit Gross Peak Day Savings, Natural Gas

$$PD_H = ACCF_H \times PDF_H$$

If Boiler also provides DHW:

$$PD_W = ACCF_W \times PDF_W$$

Retrofit Gross Peak Demand Savings, Example

For same example as above:

$$PD_H = 66.3 \times 0.00977$$

$$PD_H = 0.65\ Ccf$$

$$PD_W = 8.0 \times 0.00321$$

$$PD_W = 0.03\ Ccf$$

$$PD = PD_H + PD_W$$

$$PD = 0.68\ Ccf$$

Changes from Last Version

No Changes

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 September 26, 2013.

[2] Cadmus Group, “High Efficiency Heating Equipment Impact Evaluation Final Report”, March 2015. Massachusetts.

Notes

[1] The baseline value is based on recent market data in Connecticut.

[2] Default value selected based on recent data from Reference [2]. This evaluation reported an average size of 2000 sq. ft. for homes with boilers in Massachusetts.

[3] Default value selected based on recent data from Reference [2]. This evaluation reported increased heating loads for homes with boilers in Massachusetts, and the previous default assumption of 38,700 Btu/ft^2 has correspondingly been increased by 20%.

[4] The value of 80% is based on verified data from Reference [2], Table 4, and should be used except in situations where either actual nameplate ratings or actual efficiency test data are available.

4.2.18 FURNACE

Description of Measure

Installation of a warm air or forced-air energy efficient furnace

Savings Methodology

The fossil fuel savings for this measure are calculated using the same methodology as the 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 as follows:

Lost Opportunity Measure:

- Lost Opportunity savings are the difference in energy use between a baseline new model and the chosen high-efficiency new model, continuing for the Effective Useful Life (EUL) from Appendix 4.

Retrofit Measure:

- Uses the same methodology as a Lost Opportunity measure;
- In the case of early retirement of a working unit where the unit would have otherwise been installed until failure, lifetime "Retirement" savings are claimed additional to the lifetime "Lost Opportunity" savings (see Section 1.4).
- Retirement savings are the difference in energy use between the older unit and a baseline new model, continuing for the Remaining Useful Life (RUL) 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
A	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	ft^2 = 2000 if unknown	Input Note [3]
$ABTU_H$	Annual Btu savings – heating	Btu		
$ACCF_H$	Annual natural gas savings –heating	Ccf	102,900 Btu	
$AFUE_B$	AFUE of baseline furnace		0.80 (Gas or Propane) 0.83 (Oil)	Table 2, Note [1]
$AFUE_E$	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	

Symbol	Description	Units	Values	Comments
APG_H	Annual gas savings—heating	Ccf	102,900 Btu	
EUL	Effective Useful Life			Appendix 4
HF	Heating Factor based on age of home	Btu/ft^2	Table 1 Use 33,300 if unknown	Note [3]
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
YR_h	Year of home construction	Years	If unknown, use default HF	Input Note [3]
YR_e	Year existing furnace installed	Years		Input

Lost Opportunity Gross Energy Savings, Fossil Fuel

Table 1: Residential Heating Factor (Ref [1], Note [2])

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
Unknown	33,300

Table 2: Existing AFUE (Ref [1])

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 2013	78%	80%
2014 to present	80%	83%
Unknown	78%	80%

$$ABTU_H = A \times HF \times \left(\frac{1}{AFUE_B} - \frac{1}{AFUE_I} \right)$$

Savings by heating fuel:

$$ACCF_H = \frac{ABTU_H}{102{,}900 \, {}^{Btu}\!/_{Ccf}}$$

$$AOG_H = \frac{ABTU_H}{138{,}690 \, {}^{Btu}\!/_{Gal}}$$

$$APG_H = \frac{ABTU_H}{91{,}330 \, {}^{Btu}\!/_{Gal}}$$

Lost Opportunity Gross Energy Savings, Example

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 Table 1:
HF = 33,300
From example:
$AFUE_I$= 95% or 0.95
$AFUE_B$= 80% or 0.80 (baseline value)

$$ABTU_H = 2{,}000 \times 33{,}300 \times \left(\frac{1}{0.80} - \frac{1}{0.95} \right)$$

$$ABTU_H = 13{,}144{,}737\ Btu$$

$$ACCF_H = \frac{13{,}144{,}737\ Btu}{102{,}900\ {}^{Btu}\!/_{Ccf}}$$

$$ACCF_H = 127.7\ Ccf$$

Lost Opportunity Gross Peak Day Savings, Natural Gas

$$PD_H = ACCF_H \times PDF_H$$

Lost Opportunity Gross Peak Demand Savings, Example

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?

$$PD_H = 127.7 \times 0.00977$$

$$PD_H = 1.2\ CCF$$

Retrofit Gross Energy Savings, Fossil Fuel

Reminder: Retrofit savings are the sum of Retirement savings and Lost Opportunity savings. This section presents the Retirement portion of savings.

Using the Tables 1 and 2, the home's heating load and existing furnace efficiency can be estimated.

$$ABTU_H = A \times HF \times \left(\frac{1}{AFUE_E} - \frac{1}{AFUE_B} \right)$$

Savings by heating fuel:

$$ACCF_H = \frac{ABTU_H}{102{,}900\ {}^{Btu}\!/_{Ccf}}$$

$$AOG_H = \frac{ABTU_H}{138{,}690\ {}^{Btu}\!/_{Gal}}$$

$$APG_H = \frac{ABTU_H}{91{,}330\ {}^{Btu}\!/_{Gal}}$$

Reminder: *For electric savings for energy efficient fan motors, see measure 4.2.6 (ECM).*

Retrofit Gross Energy Savings, Example

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 1 and 2:
HF = 33,300 (Table 1)
$AFUE_E$= 68% or 0.68 (Table 2)
$AFUE_B$= 80% or 0.80 (baseline value)

$$ABTU_H = 2{,}000 \times 33{,}300 \times \left(\frac{1}{0.68} - \frac{1}{0.80}\right)$$

$$ABTU_H = 14{,}691{,}177\ Btu$$

$$ACCF_H = \frac{14{,}691{,}177\ Btu}{102{,}900\ {}^{Btu}\!/_{Ccf}}$$

$$ACCF_H = 142.8\ Ccf$$

Retrofit Gross Peak Day Savings, Natural Gas

$$PD_H = ACCF_H \times PDF_H$$

Retrofit Gross Peak Demand Savings, Example

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?

$$PD_H = 142.8 \times 0.00977$$

$$PD_H = 1.4\ CCF$$

Changes from Last Version

No changes.

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 September 26, 2013.

Notes

[1] The baseline values are based in reference [1] efficiencies for 2011.

[2] The Heating Factor from reference [1] was decreased to account for set-back savings based on the ENERGY STAR tool set-back assumptions.

[3] Default values are based on defined CT reference home as determined from historical actuals and forecasted mix of installations.

4.2.18a FURNACE alternate methodology

Description of Measure

Installation of a warm air or forced-air energy efficient furnace.

Savings Methodology

The fossil fuel savings for this measure are calculated using the same methodology as the ENERGY STAR furnace calculator, located on the ENERGY STAR Website (Ref [1]), with average heating factor and area based on a recent evaluation of heating equipment in Massachusetts (Ref [2]). 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 as follows:

Lost Opportunity Measure:

- Lost Opportunity savings are the difference in energy use between a baseline new model and the chosen high-efficiency new model, continuing for the Effective Useful Life (EUL) from Appendix 4.

Retrofit Measure:

- Uses the same methodology as a Lost Opportunity measure;
- In the case of early retirement of a working unit where the unit would have otherwise been installed until failure, lifetime "Retirement" savings are claimed additional to the lifetime "Lost Opportunity" savings (see Section 1.4).
- Retirement savings are the difference in energy use between the older unit and a baseline new model, continuing for the Remaining Useful Life (RUL) from Appendix 4.
- When the AFUE of the existing furnace is unknown, Table 1 may be used to obtain an estimate of AFUE based on the year the existing furnace was installed.

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)	
$AFUE_E$	AFUE, existing (if available)	%
$AFUE_I$	AFUE, installed	%

Nomenclature

Symbol	Description	Units	Values	Comments
A	Average area heated by furnaces	ft^2	1800	Note [2]
$ABTU_H$	Annual Btu savings – heating	Btu		
$ACCF_H$	Annual natural gas savings –heating	Ccf		
$AFUE_B$	AFUE of baseline furnace		0.85	Note [1]
$AFUE_E$	AFUE of existing furnace		0.78 if unknown	Note [4]
AOG_H	Annual oil savings – heating	Gallons		
APG_H	Annual propane savings –heating	Gallons		
EUL	Effective Useful Life			Appendix 4
HF	Average heating factor based on home's heat load	Btu/ft^2	30,600	Note [3]
PD_H	Natural gas peak day savings – heating	Ccf		
PDF_H	Natural gas peak day factor –heating		0.00977	Appendix 2

Symbol	Description	Units	Values	Comments
RUL	Remaining Useful Life			Appendix 4

Lost Opportunity Gross Energy Savings, Fossil Fuel

$$ABTU_H = A \times HF \times \left(\frac{1}{AFUE_B} - \frac{1}{AFUE_I} \right)$$

$$ABTU_H = 1{,}800 \times 30{,}600 \times \left(\frac{1}{0.85} - \frac{1}{AFUE_I} \right)$$

$$ABTU_H = 64{,}800{,}000 - \frac{55{,}080{,}000}{AFUE_I}$$

Savings by heating fuel:

$$ACCF_H = \frac{ABTU_H}{102{,}900 \, {}^{Btu}/_{Ccf}}$$

$$AOG_H = \frac{ABTU_H}{138{,}690 \, {}^{Btu}/_{Gal}}$$

$$APG_H = \frac{ABTU_H}{91{,}330 \, {}^{Btu}/_{Gal}}$$

Lost Opportunity Gross Energy Savings, Example

An 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?

Constant values:
HF = 30,600
A = 1,800
From example:
$AFUE_I$= 95% or 0.95
$AFUE_B$= 85% or 0.85 (baseline value)

$$ABTU_H = 1{,}800 \times 30{,}600 \times \left(\frac{1}{0.85} - \frac{1}{AFUE_I} \right)$$

$$ABTU_H = 64{,}800{,}000 - \frac{55{,}080{,}000}{AFUE_I}$$

$$ABTU_H = 6{,}821{,}052 \ Btu$$

$$ACCF_H = \frac{6{,}821{,}052 \ Btu}{102{,}900 \, {}^{Btu}/_{Ccf}}$$

$$ACCF_H = 66.3 \ Ccf$$

Lost Opportunity Gross Peak Day Savings, Natural Gas

$$PD_H = ACCF_H \times PDF_H$$

Lost Opportunity Gross Peak Demand Savings, Example

An 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?

$$PD_H = 66.3 \times 0.00977$$
$$PD_H = 0.6\ Ccf$$

Retrofit Gross Energy Savings, Fossil Fuel

Reminder: Retrofit savings are the sum of Retirement savings and Lost Opportunity savings. This section presents the Retirement portion of savings.

$$ABTU_H = A \times HF \times \left(\frac{1}{AFUE_E} - \frac{1}{AFUE_B}\right)$$
$$ABTU_H = 1{,}800 \times 30{,}600 \times \left(\frac{1}{AFUE_E} - \frac{1}{0.85}\right)$$
$$ABTU_H = \frac{55{,}080{,}000}{AFUE_E} - 64{,}800{,}000$$

Savings by heating fuel:

$$ACCF_H = \frac{ABTU_H}{102{,}900\ {}^{Btu}\!/_{Ccf}}$$
$$AOG_H = \frac{ABTU_H}{138{,}690\ {}^{Btu}\!/_{Gal}}$$
$$APG_H = \frac{ABTU_H}{91{,}330\ {}^{Btu}\!/_{Gal}}$$

Reminder: *For electric savings for energy efficient fan motors, see measure 4.2.6 (ECM).*

Retrofit Gross Energy Savings, Example

An existing natural gas furnace with unknown AFUE was installed in 1985. What are the annual retirement fossil fuel savings for the replacement of this furnace?

Reminder: *Retrofit savings do not depend on the efficiency of the new installed unit.*

$AFUE_E$= 78% or 0.78 (default value)
$AFUE_B$= 85% or 0.85 (baseline value)

$$ABTU_H = 1{,}800 \times 30{,}600 \times \left(\frac{1}{0.78} - \frac{1}{0.85}\right)$$

$$ABTU_H = 5{,}815{,}385\ Btu$$

$$ACCF_H = \frac{5{,}815{,}385\ Btu}{102{,}900\ ^{Btu}/_{Ccf}}$$

$$ACCF_H = 56.5\ Ccf$$

Retrofit Gross Peak Day Savings, Natural Gas

$$PD_H = ACCF_H \times PDF_H$$

Retrofit Gross Peak Demand Savings, Example

An existing natural gas furnace was installed in 1985. What are the retirement peak day natural gas savings?

$$PD_H = 56.5 \times 0.00977$$

$$PD_H = 0.6\ Ccf$$

Changes from Last Version

No Changes

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 September 26, 2013.

[2] Cadmus Group, "High Efficiency Heating Equipment Impact Evaluation Final Report", March 2015. Massachusetts.

Notes

[1] The baseline value is based on recent market data in Connecticut.

[2] An existing default value confirmed by data from CT Single Family Potential study.

[3] Default value selected based on recent data from Reference [2]. This evaluation reported an annual heating load of 584 therms or 58.4 MMBtu for Massachusetts homes. Dividing by the average size of 1800 sq. ft and multiplying by a degree-day factor of 92% (based on climate differences between Connecticut and Massachusetts), yields a factor close to the existing table factor of 30,600 Btu/ft^2.

[4] The value of 78% is based on verified data from Reference [2], Table 4, and should be used except in situations where either actual nameplate ratings or actual efficiency test data are available.

4.2.19 BOILER RESET CONTROLS

Description of Measure

Retrofit installation of control to automatically reset boiler water temperature based on outdoor or return water temperature. The measure is assumed to be applied to existing non-condensing boiler systems.

Savings Methodology

Savings is based on Home Energy Services Impact Evaluation by the Cadmus Group for the Gas and electric Program Administrators of Massachusetts (Ref 1)

Inputs

Symbol	Description
	Number of Gas Fired Boilers

Nomenclature

Symbol	Description	Units	Values	Comments
$ACCF_H$	Annual natural gas savings heating	Ccf/yr	45	Ref [1]
PDF_H	Natural Gas Peak day factor		.00977	Appendix 1
PD_H	Natural Gas peak day savings - heating	Ccf/yr	0.439	Ref [1]

Retrofit Gross Annual Savings, Fossil Fuel

45 Ccf per year

Retrofit Gross Peak Day Savings, Natural Gas

0.439 Ccf per boiler control

Non Energy Benefits

Not applicable.

Changes from Last Version

No changes.

References

[1] The Cadmus Group, Inc. (2012) Home Energy Services Impact Evaluation. Prepared for the Electric and Gas Program Administrators of Massachusetts

4.2.20 ECM CIRCULATING PUMP

Description of Measure

Retrofit installation of an Electronically Commutated Motor circulating pump to replace an existing circulating pump on a residential hydronic heating system.

Savings Methodology

Savings is based on Impact Evaluation of the ECM circulator Pump Pilot Program by the Cadmus Group for the Gas and Electric Program Administrators of Massachusetts (Ref [1])

Inputs

Symbol	Description
	Number of ECM Circulator Pumps

Nomenclature

Symbol	Description	Units	Values	Comments
AKWH	Annual Electric energy savings	kWh/yr	285	Ref [1]
SKW	Seasonal Summer Peak Savings	kW	0	
WKW	Seasonal Winter Peak Savings	kW	0.056	Ref [1]
CF_H	Seasonal Winter Peak Coincidence Factor		1.0	Appendix 1

Retrofit Gross Annual Savings, Electric

285 kWh per year

Retrofit Gross Seasonal Peak Demand Savings, Electric

Cooling

$SKW_C = 0$

Heating

$WKW_H = 0.056$ kW

Non Energy Benefits

Not applicable.

Changes from Last Version

No changes.

References

[1] The Cadmus Group, Inc. (2012) Impact Evaluation of the 2011-2012ECM Circulator Pump Pilot Program. Prepared for the electric and Gas Program Administrators of Massachusetts.

4.2.21 WI FI THERMOSTAT

Description of Measure

This measure is the replacement of an existing residential thermostat with a Wi Fi Enabled Thermostat.

Savings Methodology

The savings from this measure are based on the savings differential from the baseline thermostat to the new a Wi Fi Enabled Thermostat. Assumed Baselines are as follows:

	Baseline	**Comments**
HES	Manual	
HES-IE	Manual	

Inputs

Symbol	**Description**	**Units**
	No of units installed	

Nomenclature

Symbol	**Description**	**Units**	**Comments**
$AKWH_C$	Annual Gross Electric Energy Savings - Cooling	kWh/yr	Reference [1], [2]
$AKWH_H$	Annual Gross Electric Energy Savings - Heating	kWh/yr	
$AKWH_{H-ER}$	Annual Gross Electric Energy Savings – Heating – Electric Resistance	kWh/yr	
$AKWH_{H-HP}$	Annual Gross Electric Energy Savings – Heating – Heat Pump	kWh/yr	
$AKWH_{H-GHP}$	Annual Gross Electric Energy Savings – Heating – Ground Source Heat Pump	kWh/yr	
$ACCF_H$	Annual Gross Natural Gas Energy Savings - Heating	Ccf/yr	Reference [1]
AGO_H	Annual Gross Oil Energy Savings - Heating	Gal/yr	
AGP_H	Annual Gross Propane Energy Savings - Heating	Gal/yr	
SKW	Summer Demand Savings - Cooling	kW	Note [4]
WKW	Winter Demand Savings	kW	Note [4]

Gross Energy Savings, Electric

	$AKWH_C$	$AKWH_H$	$AKWH_{H-ER}$	$AKWH_{H-HP}$	$AKWH_{H-GHP}$	**Comments**
HES	104.0		637.5	318.7	212.5	Reference [1]
HES-IE	104.0		637.5	318.7	212.5	Reference [1]

Gross Seasonal Peak Demand Savings, Electric (Winter and Summer)

None (see Note [4])

Gross Energy Savings, Fossil Fuels

	$ACCF_H$	AGO_H	AGP_H	**Comments**
HES	84.5	66.7	95.3	Reference [1]
HES-IE	84.5	66.7	95.3	Reference [1]

Changes from Last Version

Removed Behavioral energy savings

References

[1] The Cadmus Group, Inc. - "Wi-Fi Programmable Thermostat Pilot Program Evaluation – Part of the Massachusetts 2011 Residential Retrofit and Low Income Program Area Evaluation", Sept. 2012

[2] The Cadmus Group, Inc. - "Wi-Fi Programmable Thermostat Pilot Program Evaluation – Part of the Massachusetts 2011 Residential Retrofit and Low Income Program Area Evaluation", Sept. 2012. Per page 18, paragraph 3, it states that there is no difference in electric savings between sites with a programmable thermostat baseline and sites with a manual thermostat baseline.

Notes

[1] Savings is based on thermostat alone with no behavioral component (messages, demand response, etc.).

[2] Direct install is based on site verification that the customer has an in-home Wi Fi network

[3] Assumes a 15 yr. measure life

[4] CT is not claiming any kW Demand reductions at this time and will revisit this after the evaluation of any CT specific Wi Fi Thermostat Program.

4.2.22 CLEAN TUNE AND TEST

Description of Measure

Clean test and tune performed on boilers or furnaces by cleaning and adjusting burner, and cleaning heat exchanger

Savings Methodology

The fossil fuel savings for this measure are based on equipment tune-ups by adjusting the burner and cleaning the heat exchanger; therefore, the efficiency improves.

Inputs

Symbol	Description	Units
	Heating Fuel (Natural gas, oil, propane)	

Nomenclature

Symbol	Description	Units	Values	Comments
A	Heated area served by boiler or furnace	ft^2	2000	Note [1]
$ABTU_H$	Annual Btu savings - heating	Btu/yr		
ACCF	Annual natural gas savings	Ccf/yr		
$ACCF_H$	Annual natural gas savings -heating	Ccf/yr		
$AFUE_E$	Annual Fuel Utilization Efficiency, Existing	%	80%	Note [3]
HF	Average heating factor based on home's heat load	Btu/ ft^2	46,400	Note [2]
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		
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
ESF	Energy Savings factor		0.02	Ref[1]

Gross Energy Savings, Fossil Fuel

$$ABTU_H = A \times HF \times (\frac{1}{AFUE_E}) \times ESF$$

$$ABTU_H = 2{,}000 \times 46{,}400 \times \left(\frac{1}{.80}\right) \times 0.02 = 2{,}320{,}000\,Btu$$

Savings by heating fuel:

$$ACCF_H = \frac{2{,}320{,}000}{102{,}900} = 22.5\,CCF$$

$$AOG_H = \frac{2{,}320{,}000}{138{,}690} = 16.7\,Gal$$

$$APG_H = \frac{2{,}320{,}000}{91{,}330} = 25.4\,Gal$$

Peak Day Savings, Natural Gas

$$PD_H = ACCF_H \times PDF_H$$
$$PD_H = 22.5\,CCF \times 0.00977 = 0.219\ Ccf$$

Changes from Last Version

"area (A) served by boiler or furnace"
Measure life in appendix 4

References

[1] ESF 2% value was used compared to 5% used in the New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs – Residential, Multi-Family, and Commercial/Industrial Measures
Version 3,Issue Date - June 1, 2015. page 98.

[2]Cadmus Group, "High Efficiency Heating Equipment Impact Evaluation Final Report", March 2015. Massachusetts.

Notes

[1] Default value selected based on recent data from Reference [2]. This evaluation reported an average size of 2000 sq. ft. for homes with boilers in Massachusetts.

[2] Default value selected based on recent data from Reference [2]. This evaluation reported increased heating loads for homes with boilers in Massachusetts, and the previous default assumption of 38,700 Btu/ft^2 has correspondingly been increased by 20%.

[3] The value of 80% is based on verified data from Reference [2], Table 4, and should be used except in situations where either actual nameplate ratings or actual efficiency test data are available.

4.3 APPLIANCES AND CONSUMER GOODS

4.3.6 ROOM AIR CONDITIONER

Description of Measure

Savings detailed below cover the purchase of a high efficiency room air conditioner and the replacement of an inefficient room air conditioner in working condition.

Savings Methodology

Lost Opportunity Measure:

- Lost Opportunity savings are the difference in energy use between a baseline model (Note [2]), and the chosen high efficiency new model, continuing for the Effective Useful Life (EUL) from Appendix 4.
- The Retail measure is a Lost Opportunity-only methodology, as the existing unit is not verified.

Retrofit Measure:

- Uses the same methodology as a Lost Opportunity measure.
- In the case of early retirement of a working unit where the unit would have otherwise been installed until failure, lifetime "Retirement" savings are claimed additional to the lifetime "Lost Opportunity" savings (see Section 1.4).
- Retirement savings are the difference in energy use between the older unit and a baseline model, continuing for the Remaining Useful Life (RUL) from Appendix 4. See Notes [1,2]

Table 1: Energy Specifications (Note [3])

Product Size in CAP_C (Btu/hr)	**2000 EER_b Federal Standard (Ref [3])**	
Type:	*Window*	*Sleeve*
<8,000	11.0	10.0
8,000 - 13,999	10.9	9.6
14,000 - 19,999	10.7	9.3
>20,000	9.4	9.4

Inputs

Symbol	**Description**	**Required For**
EER_e	Energy Efficiency Ratio of existing unit	Retirement
EER_i	Energy Efficiency Ratio of new unit	Lost Opportunity
$CAP_{C,e}$	Rated cooling capacity of existing unit, in Btu/hr	Retirement
$CAP_{C,i}$	Rated cooling capacity of new unit, in Btu/hr	Lost Opportunity
	Brand and Model of existing unit	Retirement
	Brand and Model of new installed unit	Lost Opportunity

Nomenclature

Symbol	**Description**	**Units**	**Values**	**Comments**
$AKWH_C$	Annual electric energy savings - cooling	kWh/yr	Calculated	
$CAP_{C,i}$	Rated cooling capacity of new installed unit	Btu/hr		
$CAP_{C,e}$	Rated cooling capacity of (old) existing unit	Btu/hr	Actual as rated; Use $CAP_{C,i}$ if unknown	
CF_S	Summer Seasonal Peak Coincidence Factor	unitless	Appendix 1	
EER_b	Energy Efficiency Ratio, representing baseline new model	Btu/ Watt-hr	2014Federal Standard level from Table 1	Note [2]
EER_i	Energy Efficiency Ratio of new installed unit	Btu/ Watt-hr	Actual as rated	

Symbol	Description	Units	Values	Comments
EER_e	Energy Efficiency Ratio of existing unit	Btu/ Watt-hr	Actual as rated Use 8.86 if unknown	Note [1]
EUL	Effective Useful Life: Measure life of the new unit	years	Appendix 4	
EFLH	Annual Equivalent Full Load Hours	hr/yr	272	Ref [1]
$LKWH_C$	Lifetime electric energy savings - cooling	kWh	Calculated	
RUL	Remaining Useful Life: remaining number of years the existing unit would have operated until failure.	years	Appendix 4	
SKW_C	Summer Seasonal Demand savings-cooling	kW	Calculated	
Sleeve	Unit without louvered sides			Note [3]
Window	Unit with louvered sides			
$\ldots_{Retire}$	Associated with Retirement			
$\ldots_{Lost\ Opp}$	Associated with Lost Opportunity			

Lost Opportunity Gross Energy Savings, Electric

$$AKWH_{C,LostOpp} = EFLH \times CAP_{C,i} \times \left(\frac{1}{EER_b} - \frac{1}{EER_i}\right) \div 1000 \, {}^{W}\!/_{kW}$$

Lost Opportunity Gross Energy Savings, Example

Example 1: A 6,000 Btu/hr window AC unit at 11.7 EER is purchased through a retail promotion; what are the savings?

Use size and EER of the installed unit, and the federal standard EER for the installed unit's size (Table 1):

$$AKWH_{C,Lost\ Opp} = 272 \, {}^{kwh}\!/_{Ton} \times 6{,}000 \times \left(\frac{1}{11} - \frac{1}{11.7}\right) \div 1000 = 8.9 \, kWh$$

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

$$SKW_{C,LostOpp} = CF_s \times CAP_{C,i} \times \left(\frac{1}{EER_b} - \frac{1}{EER_i}\right) \div 1000 \, {}^{W}\!/_{kW}$$

Lost Opportunity Gross Peak Demand Savings, Example

Example 2: A 6,000 Btu/hr window AC unit at 11.7 EER is purchased through a retail promotion; what are the demand savings?

Use size and EER of the installed unit, and the federal standard EER for the installed unit's size (Table 1):

$$SKW_{C,Lost\ Opp} = .303 \, {}^{kwh}\!/_{Ton} \times 6{,}000 \times \left(\frac{1}{11} - \frac{1}{11.7}\right) \div 1000 = 0.01 kW$$

Retrofit Gross Energy Savings, Electric

Reminder: Retrofit savings are the sum of Retirement savings and Lost Opportunity savings. This section presents the Retirement portion of savings. To obtain lifetime savings the following formula can be used:

$$LKWH_{Total} = \left(AKWH_{Retire} \times RUL\right) + \left(AKWH_{LostOpp} \times EUL\right)$$

Retirement Component:

$$AKWH_{C,Retire} = EFLH \times CAP_{C,e} \times \left(\frac{1}{EER_e} - \frac{1}{EER_b}\right) \div 1000 \, {}^{W}\!/_{kW}$$

Retrofit Gross Energy Savings, Example

Example 3: An existing window air conditioner rated 5,900 Btu/hr 8 EER and verified to be in working condition is replaced with a 6,000 Btu/hr unit at 11.7 EER. What are the energy savings?

Lost Opportunity Savings: using the size and EER of the installed (new) unit as well as the federal standard EER for the rated size (from Table 1) yields:

$$AKWH_{C,Lost\ Opp} = 272\ {}^{kwh}/_{Ton} \times 6{,}000 \times \left(\frac{1}{11} - \frac{1}{11.7}\right) \div 1000 = 8.9\ kWh$$

Retirement Savings: using the size and EER of the existing (old) unit as well as the federal standard EER for the existing unit's rated size (from Table 1) yields:

$$AKWH_{C,Retire} = 272\ {}^{kwh}/_{Ton} \times 5{,}900 \times \left(\frac{1}{8.0} - \frac{1}{11}\right) \div 1000 = 54.7\ kWh$$

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

Reminder: Retrofit savings are the sum of Retirement savings and Lost Opportunity savings. This section presents the Retirement portion of savings. To obtain total savings the following formula can be used:

$$Peak\ Demand\ Savings_{Total} = \frac{(Peak\ Demand\ Savings_{Retire} \times RUL) + (Peak\ Demand\ Savings_{LostOpp} \times EUL)}{EUL}$$

Retirement Component:

$$SKW_{C,Retire} = CF_s \times CAP_{C,e} \times \left(\frac{1}{EER_e} - \frac{1}{EER_b}\right) \div 1000\ {}^{W}/_{kW}$$

Retrofit Gross Peak Demand, Example

Example 4: An existing window air conditioner rated 5,900 Btu/hr 8 EER and verified to be in working condition is replaced with a 6,000 Btu/hr unit at 11.7 EER. What are the energy savings?

Lost Opportunity: using the size and EER of the installed (new) unit as well as the federal standard EER for the rated size (from Table 1) yields:

$$SKW_{C,Lost\ Opp} = .303\ {}^{kwh}/_{Ton} \times 6{,}000 \times \left(\frac{1}{11} - \frac{1}{11.7}\right) \div 1000 = 0.01 kW$$

Retirement: using the size and EER of the existing (old) unit as well as the federal standard EER for the existing unit's rated size (from Table 1) yields:

$$SKW_{Retire} = 0.303\ {}^{kwh}/_{Ton} \times 5{,}900 \times \left(\frac{1}{8} - \frac{1}{11}\right) \div 1000 = 0.061 kW$$

Changes from Last Version

No Changes.

References

[1] RLW Coincidence Factor Study: Room Air Conditioners, Prepared for: Northeast Energy Efficiency Partnerships' New England Evaluation and State Program Working Group, June 23, 2008, page iv.

[2] Consortium for Energy Efficiency. CEE Super-Efficient Appliances Initiative: High Efficiency Specifications for Room Air Conditioners, Effective January 1, 2003.

[3] Federal Register, 78 FR 42389 (July 17, 2013).. Energy Conservation Program: Energy Conservation Standards for Residential Room Air Conditioner. Published August 15, 2013, Compliance date June 1, 2014.

Notes

[1] The EER and capacity of the existing unit should be looked up in the CEC database or equivalent source by brand and model number. If the EER of the old air conditioner is unknown, use 8.86 EER, based on Ref [5], page vi, which identified baseline efficiencies for room ACs replaced with ductless heat pumps.

[2] The EER of the baseline unit is at the 2014 Federal Standard level (Table 1); Lost Opportunity at the installed unit's size, and Retirement at the existing unit's size.

[3] ENERGY STAR defines a "Through the Wall (TTW)" unit as "A RAC [Room Air Conditioner] without louvered sides," also referred to as a "built-in" or sleeve unit. "Window" units in this measure are defined as those with louvered sides. This measure does not explicitly cover Casement (width-constrained) or Reverse Cycle (i.e. heat pump) units.

4.3.7 CLOTHES WASHER

Description of Measure

Savings detailed below cover the purchase of a standard size high efficiency clothes washer and the replacement of an inefficient clothes washer in working condition.

Savings Methodology

Lost Opportunity Measure:

- Lost Opportunity savings are the difference in energy use between a baseline model and the chosen high efficiency new model, continuing for the Effective Useful Life (EUL) from Appendix 4.
- The Retail measure is a Lost Opportunity-only methodology only. Savings are claimed for a mix of fuels when the hot water/dryer fuel type combinations are not known as shown in Note [5].
- The ENERGY STAR New Home measure is a special Lost-Opportunity-only measure, where the hot water/dryer fuel type is known but the current ENERGY STAR level is used as the baseline.

Retrofit Measure:

- Uses the same methodology as a Lost Opportunity measure.
- In the case of early retirement of a working unit where the unit would have otherwise been installed until failure, lifetime "Retirement" savings are claimed additional to the lifetime "Lost Opportunity" savings (See Section 1.4).
- Retirement savings are the difference in energy use between the older unit and a baseline model and continue for the Remaining Useful Life (RUL) from Appendix 4. See Notes [1,4].

Energy savings for clothes washers come from three sources (Note [3]):

1. *Machine energy savings* (electricity used to run the washer itself): always electric energy.
2. *Water Heater savings*, reduced hot water use is claimed for the water heater fuel used in the home.
3. *Dryer savings*, 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.

No demand savings have been identified for this measure.

Inputs

Symbol	Description	Required for:
Axis Orientation	Existing unit's configuration: Front Loading (Horizontal Axis) or Top Loading (Vertical Axis)	Note [2]; not used for savings
Dryer Type	Type of dryer to be used with the new installed unit: Electric, Gas, or None	All except Retail
MEF_i	Modified Energy Factor of new installed unit	Lost Opportunity
Cap_e	Compartment Capacity of existing unit in Cubic ft.	Retirement
Cap_i	Compartment Capacity of new installed unit in Cubic ft.	Lost Opportunity
WF_i	Water Factor of new installed unit (Used for calculating water savings)	Lost Opportunity
WH Fuel	Water heating fuel	All except Retail
	Brand and Model of existing unit	Retirement
	Brand and Model of new installed unit	Lost Opportunity

Nomenclature

Symbol	Description	Units	Values	Comments
ACCF	Annual natural gas energy savings	Ccf/yr	Calculated	
AKWH	Annual electric energy savings	kWh/yr	Calculated	
AOG_W	Annual energy savings for oil Water Heater	Gal Oil/yr	Calculated	
APG_W	Annual energy savings for propane Water Heater	Gal Propane/yr	Calculated	
AWG	Annual Gallons of water saved	Gal/Year	Calculated	
Cap_e	Compartment capacity of existing clothes washer	cubic feet, ft^3	Actual; use Cap_i if unknown	
Cap_i	Compartment capacity of new installed clothes washer	cubic feet, ft^3	Actual as found	
Cycles/yr	Average number of loads of laundry per year	Cycles/yr	Residential: 295	Ref [4]
EAKWH	Equivalent total annual electric equivalent energy reduction calculated directly from a model's MEF: the sum of Machine, Water Heater, and Clothes Dryer components	kWh/yr	Calculated	Definition of MEF. Used in derivation only
EF	Water Heating Efficiency for fossil fuel water heaters	unitless	0.62	Ref [6]
EUL	Effective Useful Life: Measure life of installed unit.	years	Appendix 4	
$L\ldots_{total}$	Total gross lifetime energy or water savings	various	Calculated	
$IMEF_b$	Integrated Modified Energy Factor (IMEF) of baseline new model	ft^3/kWh/cycle	New Home: 2.38 All Others: 1.84	Note [1], Note [7]
$IMEF_e$	Integrated Modified Energy Factor (IMEF) of existing unit	ft^3/kWh/cycle	1.29	Note [4]
$IMEF_i$	Integrated Modified Energy Factor (IMEF) of new installed unit	ft^3/kWh/cycle	Actual as rated	
RUL	Remaining Useful Life: remaining number of years the existing unit would have operated until failure	years	Appendix 4	
IWF_b	Integrated Water Factor (WF): gallons of water needed per ft^3 of laundry, baseline new model	gal/ft^3 · cycle	New Home:3.7 All others: 4.7	Note [1], Note [7]
IWF_e	Integrated Water Factor for existing unit	gal/ft^3 · cycle	6.5	Note [4]
IWF_i	Integrated Water Factor for installed unit	gal/ft^3 · cycle	Actual as found	
$\ldots_D$	Associated with Clothes Dryer energy component		Fuel-specific	
$\ldots_{lost\ opp}$	Associated with Lost Opportunity			
$\ldots_M$	Associated with Machine energy component		Fuel-specific	
$\ldots_{retire}$	Associated with Retirement			
$\ldots_{turn\text{-}in}$	Associated with Turn-in Program			

Symbol	Description	Units	Values	Comments
…w	Associated with Water Heating component		Fuel-specific	

Lost Opportunity Gross Energy Savings, Electric

Savings are based on the capacity of the existing unit and are the sum of three components (discussed previously):

1. *Machine energy savings*: always electric energy.
2. *Water Heater savings*: for the fuel that is used in the home's water heater.
3. *Dryer savings*: claimed for the fuel that is used in the dryer.

Electric energy savings are presented in Table 1. Refer to Table 2 for Fossil Fuel energy savings. If the fuel type is unknown, use the unknown equation only once as it accounts for machine energy, water heating savings, and dryer savings. If the fuel type is known, claim each component separately as needed.

Table 1: Lost Opportunity Savings Summary by Savings Component, Electric Fuel (Note [3,5])

Savings Component	Known Fuel Type	Unknown Fuel Type †
Machine Energy	$AKWH_{M,LostOpp} 15.63 \times Cap_i \times (\frac{1}{IMEF_b} - \frac{1}{IMEF_i})$	$AKWH_{m,LostOpp} = 263.65 \times Cap_i \times (\frac{1}{IMEF_b} - \frac{1}{IMEF_i})$
Water Heater	$AKWH_{M,LostOpp} = 36.875 \times Cap_i \times (\frac{1}{IMEF_b} - \frac{1}{IMEF_i})$	
Clothes Dryer	$AKWH_{m,LostOpp} = 242.49 \times Cap_i \times (\frac{1}{IMEF_b} - \frac{1}{IMEF_i})$	

† *This equation accounts for machine energy, water heater, and clothes dryer electric savings.*

Lost Opportunity Gross Energy Savings, Fossil Fuel

Savings are based on the capacity of the existing unit and are the sum of three components (discussed previously):

1. *Machine energy savings*: always electric energy. This component is always claimed.
2. *Water Heater savings*: for the fuel that is used in the home's water heater. If fuel type is unknown claim savings for all fuels. If fuel type is known, claim savings only for the fuel type.
3. *Dryer savings*: claimed for the fuel that is used in the dryer. If fuel type is unknown, claim savings for all fuels. If fuel type is known, claim savings only for the fuel type.

Fossil Fuel savings are presented in Table 2. Refer to Table 1 for Electric Energy savings.

Table 2: Lost Opportunity Savings Summary by Savings Component and Fossil Fuel (Note [3])

Savings Component	Known Fuel Type	Unknown Fuel Type †††
Water Heater: Natural Gas ††	$ACCF_{W,LostOpp} = 1.972 \times Cap_i \times (\frac{1}{IMEF_b} - \frac{1}{IMEF_i})$	$ACCF_{LostOpp} = 1.226 \times Cap_i \times \left(\frac{1}{1.84} - \frac{1}{IMEF_i}\right)$
Water Heater: Oil††	$AOG_{W,LostOpp} = 1.46 \times Cap_i \times (\frac{1}{IMEF_b} - \frac{1}{IMEF_i})$	$AOG_{LostOpp} = .744 \times Cap_i \times \left(\frac{1}{1.84} - \frac{1}{IMEF_i}\right)$
Water Heater: Propane††	$APG_{w,LostOpp} = 2.222 \times Cap_i \times \left(\frac{1}{IMEF_b} - \frac{1}{IMEF_i}\right)$	$APG_{LostOpp} = .189 \times Cap_i \times \left(\frac{1}{1.84} - \frac{1}{IMEF_i}\right)$
Clothes Dryer (Gas Only)	$ACCF_{w,LostOpp} = 8.037 \times Cap_i \times (\frac{1}{IMEF_b} - \frac{1}{IMEF_i})$	$ACCF_{LostOpp} = .723 \times Cap_i \times (\frac{1}{1.84} - \frac{1}{IMEF_i})$

†† *Existing Water heater efficiency is assumed to be 62%*
††† *Electric savings for unknown fuel types uses the equation from Table 1.*

Non Energy Benefits

Lost Opportunity Water Savings: these savings are also applicable to unknown fuel conditions**:**

$$AWG_{LostOpp} = Cap_i \times 295 \frac{cycles}{yr} \times (IWF_b - IWF_i) \frac{gal}{ft^3 \cdot cycle}$$

Retirement Water Savings: (Note [6])

$$AWG_{Retire} = 531\ gal/yr \times Cap_e$$

Lost Opportunity Gross Energy Savings, Example

Example 1: Calculate the savings for a 3.00 ft^3 capacity clothes washer purchased through a retail promotion. The unit has an IMEF of 2.22 and an IWF of 3.5.

Since this is a retail purchase and the fuel type is unknown, the unknown equations are used. Note that the baseline is 1.84IMEF and 4.7 IWF.

Machine Energy: Use the equation for unknown electric savings (Table 1). Use $IMEF_b = 1.84$, $IMEF_i = 2.22$, and $Cap_i=3$. This calculation accounts for all electric savings, including water heater and dryer:

$$AKWH_{LostOpp} = 263.65 \times 3.00ft^3 \times (\frac{1}{1.84} - \frac{1}{2.22})$$
$$AKWH_{LostOpp} = 73.399 \frac{kWh}{yr}$$

Water Heater Savings: In this example the water heater fuel is unknown. Therefore 3 calculations will be performed using the equations for unknown fossil fuel conditions (Table 2). Use $IMEF_i$=2.22.

Natural Gas:

$$ACCF_{LostOpp} = 1.226 \times 3\ ft^3 \times \left(\frac{1}{1.84} - \frac{1}{2.22}\right)$$
$$ACCF_{LostOpp} = 0.342\ ccf/yr$$

Oil:

$$AOG_{LostOpp} = .744 \times 3\ ft^3 \times \left(\frac{1}{1.84} - \frac{1}{2.22}\right)$$
$$AOG_{LostOpp} = 0.208 \frac{gal}{yr}$$

Propane:

$$APG_{LostOpp} = .189 \times 3\ ft^3 \times \left(\frac{1}{1.84} - \frac{1}{2.22}\right)$$
$$APG_{LostOpp} = .053 \frac{gal}{yr}$$

Clothes Dryer Savings: Use the equation for unknown fossil fuel savings (Table 2) to calculate additional gas savings. Electric dryer savings are already accounted for in the Machine Energy calculation.

APG

$$ACCF_{LostOpp} = .723 \times Cap_i \times (\frac{1}{1.84} - \frac{1}{2.22})$$
$$ACCF_{LostOpp} = .202\ Ccf/yr$$

Non-Electric Benefit: Additionally, water savings are calculated as a non-electric benefit:

$$AWG_{LostOpp} = Cap_i \times 295 \frac{cycles}{yr} \times (IWF_b - IWF_i) \frac{gal}{ft^3 \cdot cycle}$$
$$AWG_{LostOpp} = 3\ ft^3 \times 295 \frac{cycles}{yr} \times (4.7 - 3.5) \frac{gal}{ft^3 \cdot cycle}$$
$$AWG_{LostOpp} = 1062\ gal/yr$$

Example 2: What are the energy savings from installing a new 3.81 ft^3 clothes washer with IMEF of 3.21 and IWF of 2.5in an ENERGY STAR New Home? The home has a gas hot water heater and a gas clothes dryer.

Since the fuel types are known, use the equations for known fuel type. Note that the baseline for ENERGY STAR New Home is $IMEF_b$=2.38, $IMEF_i$=3.21, IWF_b=3.7, IWF_i=2.9, and Cap_i=3.81:

Machine Energy: Table 1 provides the equation for known fuel type:

$$AKWH_{LostOpp} = 15.63 \times 3.81\, ft^3 \times (\frac{1}{2.38} - \frac{1}{3.21})$$

$$AKWH_{LostOpp} = 6.47\, kwh/yr$$

Water Heater Savings: In this example the water heating fuel is natural gas; use the known fuel type equation from Table 2:

$$ACCF_{LostOpp} = 1.972 \times 3.81 ft^3 \times (\frac{1}{2.38} - \frac{1}{3.21})$$

$$ACCF_{LostOpp} = 0.816 \frac{Ccf}{yr}$$

Clothes Dryer: In this example the dryer fuel is gas; use the known fuel type equation from Table 2:

$$ACCF_{LostOpp} = 8.037 \times 3.81\, ft^3 \times (\frac{1}{2.38} - \frac{1}{3.21})$$

$$ACCF_{LostOpp} = 3.327\, Ccf/yr$$

Non-Electric Benefits: In addition, water savings are calculated as a non-electric benefit:

$$AWG_{LostOpp} = Cap_i \times 295 \frac{cycles}{yr} \times (WF_b - WF_i) \frac{gal}{ft^3 \cdot cycle}$$

$$AWG_{LostOpp} = 3.81\, ft^3 \times 295 \frac{cycles}{yr} \times (3.7 - 2.5) \frac{gal}{ft^3 \cdot cycle}$$

$$AWG_{LostOpp} = 1349\, gal/yr$$

<u>Retrofit Gross Energy Savings, Electric</u>

Reminder: Retrofit savings are the weighted sum of Retirement savings and Lost Opportunity savings. This section presents the Retirement portion of savings. To obtain lifetime savings the following formula can be used:

$$LKWH_{Total} = (AKWH_{Retire} \times RUL) + (AKWH_{LostOpp} \times EUL)$$

Retirement Component: Savings are based on the capacity of the existing unit and are the sum of the previously discussed three components:

1. *Machine energy savings*: always electric energy. This component is always claimed.

2. *Water Heater savings*: for the fuel that is used in the home's water heater.

3. *Dryer savings*: claimed for the fuel that is used in the dryer.

Table 3: Retirement Savings; Summary by Fuel Type and Savings Component (Note [3])

Fuel Type	Savings Component		
	Machine Energy	**Water Heater**	**Clothes Dryer**
Electric	$AKWH_{M,retire} = 3.828 \times Cap_e$	$AKWH_{M,retire} = 12.03 \times Cap_e$	$AKWH_{D,retire} = 52.497 \times Cap_e$
Gas		$ACCF_{W,retire} = .643 * Cap_e$	$ACCF_{D,Retire} = 1.741 \times Cap_e$
Oil		$AOG_{W,retire} = .477 \times Cap_e$	
Propane		$APG_{W,Retire} = .724 \times Cap_e$	

<u>Retrofit Gross Energy Savings, Fossil Fuel</u>

Refer to Table 3 for the equation to calculate savings, depending on the fossil fuel of each component.

<u>Retrofit Gross Energy Savings, Example</u>

Example 3: In an existing home, a 3.00 ft^3 capacity unit is installed with an MEF of 2.22 and a WF of 4.2. 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 (unknown existing efficiency, but verified to be in working condition). What are the total savings?

Lost Opportunity Savings: use $Cap_i = 3$, $IMEF_b = 1.84$, $IMEF_i = 2.22$, $IWF_b = 4.7$, $IWF_i = 3.5$, and equations from Tables 1 and 2 to calculate savings for each savings component and fuel type:

Machine Energy: Use the equation from Table 1 for known fuel type. This is always electric:

$$AKWH_{M,LostOpp} = 15.63 \times 3\,ft^3 \times (\frac{1}{1.84} - \frac{1}{2.22})$$
$$AKWH_{M,LostOpp} = 4.362\frac{kwh}{yr}$$

Water Heater: Use the equation from Table 2 for known fuel type (in this example, gas):

$$ACCF_{LostOpp} = 1.972 \times 3\,ft^3 \times (\frac{1}{1.84} - \frac{1}{2.22})$$
$$ACCF_{LostOpp} = .550\frac{Ccf}{day}$$

Clothes Dryer: Use the equation from Table 2 for known fuel type (in this example, gas):

$$AKWH_{LostOpp} = 242.49 \times 3ft^3 \times (\frac{1}{1.84} - \frac{1}{2.22})$$
$$AKWH_{LostOpp} = 67.675\frac{Kwh}{yr}$$

Non-Electric Benefit: In addition, water savings are calculated as a non-electric benefit:

$$AWG_{LostOpp} = Cap_i \times 295 \frac{cycles}{yr} \times (WF_b - WF_i) \frac{gal}{ft^3 \cdot cycle}$$

$$AWG_{LostOpp} = 3ft^3 \times 295 \frac{cycles}{yr} \times (4.7 - 3.5) \frac{gal}{ft^3 \cdot cycle}$$

$$AWG_{LostOpp} = 1062\ gal/yr$$

Retirement Savings: use Cap_i=3 to calculate savings and equations from Table 3 for each savings component and fuel type:

Machine Energy: Use the equation from Table 3 (machine energy is always electric energy):

$$AKWH_{M,retire} = 3.828 \times Cap_e$$
$$AKWH_{M,retire} = 3.828 \times 3\ ft^3$$
$$AKWH_{M,retire} = 11.484 \frac{kwh}{yr}$$

Water Heater: Use the equation from Table 3 for a gas water heater:

$$ACCF_{W,retire} = .643 \times Cap_e$$
$$ACCF_{W,retire} = .643 \times 3\ ft^3$$
$$ACCF_{W,retire} = 1.929\ Ccf/yr$$

Clothes Dryer: Use the equation from Table 3 for an electric clothes dryer:

$$AKWH_{D,retire} = 52.497 \times Cap_e$$
$$AKWH_{D,retire} = 52.497 \times 3\ ft^3$$
$$AKWH_{D,retire} = 157.5\ kwh/yr$$

Non Electric Benefit: Water Savings may also be calculated:

$$AWG_{retire} = 531 \frac{gal}{ft^3 \cdot yr} \times Cap_e$$
$$AWG_{retire} = 531 \frac{gal}{ft^3 \cdot yr} \times 3\ ft^3$$
$$AWG_{retire} = 1593 \frac{gal}{yr}$$

<u>Non Energy Benefits</u>

New units may have additional useful features and controls, do a better job cleaning, use less detergent, and leave less water weight remaining in the clean items.

Changes from Last Version

No changes

References

[1] ENERGY STAR Program Requirements Product Specification for Clothes Washers: Eligibility Criteria, Version 5.1. Effective January 1, 2011. Tier 1 effective July 1, 2009, Tier 2 effective January 1, 2011.

[2] U.S. DOE Energy Conservation Standards Rulemaking Framework Document for Residential Clothes Washers, August 21, 2009.

[3] 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.

[4] DOE Federal Test Procedure 10 CFR 430, Appendix J2, as of March 7, 2015.

[5] Consortium for Energy Efficiency (CEE) Super-Efficient Home Appliances Initiative (SEHA): High efficiency specification for residential clothes washers. January 1, 2011.

[6] ENERGY STAR Program Requirements Product Specification for Clothes Washers: Eligibility Criteria, Version 7.1. Effective March 7,2015.

Notes

[1] The MEF and WF of the baseline unit are at 2009 ENERGY STAR Version 5.1 Tier 1 level, which does not depend on any categories. New Construction is a special case, where the baseline must be current ENERGY STAR level (Ref [6]).

[2] According to the Engineering Analysis section of Ref [2], "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.). Therefore, if the existing unit is front-loading, the "retirement" portion may not be claimed (Note [2]).

[3] The ENERGY STAR Calculator tool (Ref [3]) 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 below are derived from those average consumptions and reflect the average weight each component contributes to total energy use:

Table 4: Proportions for Equivalent Energy Proportions

Measure	**Machine Proportion**	**Water Heater Proportion**	**Clothes Dryer Proportion**
Lost Opportunity	5.3%	12.5%	82.2%
Retirement	5.6%	17.6%	76.8%

Deriving the Lost Opportunity Portion (Tables 1 &2)

First calculate the difference in equivalent total electric energy from one model to another, based on MEF:

$$EAKWH_{LostOpp} = Cap_i \times 295\frac{cycles}{yr} \times \left(\frac{1}{IMEF_b} - \frac{1}{IMEF_i}\right)$$

The equivalent total kWh is split into its components according to the proportions in Note [3]:

Machine Energy (All):

$$AKWH_M, LostOpp = 5.3\% \times EAKWH_{LostOpp} = AKWH_{M,LostOpp} = 15.63 \times Cap_i \times (\frac{1}{IMEF_b} - \frac{1}{IMEF_i})$$

Electric Water Heater:

$$AKWH_M, LostOpp = 12.5\% \times EAKWH_{LostOpp} = AKWH_{M,LostOpp} = 36.875 \times Cap_i \times (\frac{1}{IMEF_b} - \frac{1}{IMEF_i})$$

Electric Clothes Dryer:

$$AKWH_{d,LostOpp} = 82.2\% \times EAKWH_{LostOpp} = AKWH_{m,LostOpp} = 242.49 \times Cap_i \times (\frac{1}{IMEF_b} - \frac{1}{IMEF_i})$$

For Fossil Fuels, a conversion from kWh is required:

Gas Water Heater:

$$ACCF_{W,LostOpp} = \frac{12.5\% \times 3412\,{}^{Btu}/_{kWh} \times EAKWH_{LostOpp}}{102{,}900\,{}^{Btu}/_{Ccf} \times 0.62} = ACCF_W, LostOpp = 1.972 \times Cap_i \times (\frac{1}{IMEF_b} - \frac{1}{IMEF_i})$$

Oil Water Heater:

$$AOG_{W,LostOpp} = \frac{12.5\% \times 3412\,{}^{Btu}/_{kWh} \times EAKWH_{LostOpp}}{138{,}690\,{}^{Btu}/_{Gal} \times 62\%} = AOG_{W,LostOpp} = 1.46 \times Cap_i \times \left(\frac{1}{IMEF_b} - \frac{1}{IMEF_i}\right)$$

Propane Water Heater:

$$AOG_{W,LostOpp} = \frac{12.5\% \times 3412\,{}^{Btu}/_{kWh} \times EAKWH_{LostOpp}}{91{,}330\,{}^{Btu}/_{Gal} \times 62\%} = APG_{w,LostOpp} = 2.222 \times Cap_i \times \left(\frac{1}{IMEF_i} - \frac{1}{IMEF_b}\right)$$

Gas Clothes Dryer:

$$ACCF_{D,LostOpp} = \frac{82.2\% \times 3412\,{}^{Btu}/_{kWh} \times EAKWH_{LostOpp}}{102{,}900\,{}^{Btu}/_{Gal}} = ACCF_{w,LostOpp} = 8.037 \times Cap_i \times (\frac{1}{IMEF_b} - \frac{1}{IMEF_i})$$

Deriving the Retirement Portion: (Table 3)

First, the equivalent total annual kWh is calculated, using baseline and standard values:

$$EAKWH_{LostOpp} = Cap_i \times 295\frac{cycles}{yr} \times \left(\frac{1}{IMEF_e} - \frac{1}{IMEF_b}\right)$$

$$EAKWH_{LostOpp} = Cap_i \times 295\frac{cycles}{yr} \times \left(\frac{1}{1.29} - \frac{1}{1.84}\right) = 68.356 \times Cap_i$$

The equivalent total kWh is split into its components according to values in Table 5:

Machine Energy (All Fuels): $AKWH_{M,retire} = 5.6\% \times EAKWH_{retire} = 3.828 \times Cap_e$

Electric Water Heater: $AKWH_{W,retire} = 17.6\% \times EAKWH_{retire} = 12.03 \times Cap_e$

Electric Clothes Dryer: $AKWH_{D,retire} = 76.8\% \times EAKWH_{retire} = 52.497 \times Cap_e$

For Fossil Fuels, a conversion from kWh is required:
Gas Water Heater:

$$ACCF_{W,Retire} = \frac{17.6\% \times 3412 \, {}^{Btu}\!/_{kWh} \times EAKWH_{Retire}}{102{,}900 \, {}^{Btu}\!/_{Ccf} \times 62\%} = .643 * Cap_e$$

Oil Water Heater:

$$AOG_{W,Retire} = \frac{17.6\% \times 3412 \, {}^{Btu}\!/_{kWh} \times EAKWH_{Retire}}{138{,}690 \, {}^{Btu}\!/_{Gal} \times 62\%} = .477 \times Cap_e$$

Propane Water Heater:

$$AOG_{W,Retire} = \frac{17.6\% \times 3412 \, {}^{Btu}\!/_{kWh} \times EAKWH_{Retire}}{91{,}330 \, {}^{Btu}\!/_{Gal} \times 62\%} = .724 \times Cap_e$$

Gas Clothes Dryer:

$$ACCF_{D,Retire} = \frac{76.8\% \times 3412 \, {}^{Btu}\!/_{kWh} \times EAKWH_{retire}}{102{,}900 \, {}^{Btu}\!/_{Gal}} = 1.741 \times Cap_e$$

[4] For early retirement cases where the MEF and WF of the existing unit is unknown, the existing unit efficiency is estimated to be at the level of the 2015 Federal Standard: 1.844 MEF and 6.54.7 WF (Ref [6]). Listed below are MEF and WF values for relevant standards:

Level	**IMEF**	**IWF**	**Reference**
2015 Federal Standard, Residential Clothes washers. Front-loading	1.84	4.7	[4]
2015 Federal Standard, Residential Clothes washers. Top-loading	1.29	6.5	[4]
CEE Tier 1 / ENERGY STAR	2.38	3.7	[1],[5],[6]
CEE Tier 2	2.74	3.2	[5]
CEE Tier 3	2.92	3.2	[5]

[5] When the hot water and dryer fuels are both unknown, the following fuel mix is estimated typical for Connecticut. Savings are claimed for all fuel types according to the following percentages; this weighting has been done by multiplying every individual Lost Opportunity component of every fuel by its respective percentage and only the resultant equations have been listed in the body of the measure:

Water Heater Fuel				**Clothes Dryer Fuel**	
Electric	Gas	Oil	Propane	Electric	Gas
15%	25.5%	51%	8.5%	91%	9%

Derivation of equation for Lost Opportunity Electric Savings:
The electric savings are the sum of the machine energy, the water heater energy, and the clothes dryer energy. The machine energy is: . $AKWH_{M,LostOpp} = 15.63 \times Cap_i \times (\frac{1}{IMEF_b} - \frac{1}{IMEF_i})$This is because all of the machine energy savings are electric.
The water heater energy is 15% of $AKWH_{M,LostOpp} = 36.875 \times Cap_i \times (\frac{1}{IMEF_b} - \frac{1}{IMEF_i})$, which is $AKWH_{W,LostOpp} = 5.53 \times Cap_i \times (\frac{1}{IMEF_b} - \frac{1}{IMEF_i})$.

The clothes washer energy savings is 91% of $AKWH_{m,LostOpp} = 242.49 \times Cap_i \times (\frac{1}{IMEF_b} - \frac{1}{IMEF_i})$, which is $AKWH_{m,LostOpp} = 220.67 \times Cap_i \times (\frac{1}{IMEF_b} - \frac{1}{IMEF_i})$.

Adding these equations together results in 15.63+5.53+242.49=263.65resulting in:
$AKWH_{m,LostOpp} = 263.65 \times Cap_i \times (\frac{1}{IMEF_b} - \frac{1}{IMEF_i})$.

[6] Non Energy benefits for the retirement component simplifies as follows

$$AWG_{retire} = Cap_e \times 295 \frac{cycles}{yr} \times (IWF_b - IWF_i) \frac{gal}{ft^3 \cdot cycle}$$

$$AWG_{retire} = Cap_e \times 295 \frac{cycles}{yr} \times (6.5 - 4.7) \frac{gal}{ft^3} = 531 \times Cap_e$$

[7] The IMEF and IWF of the baseline unit are at ENERGY STAR Version 7.1 level, which does not depend on any categories. New Construction is a special case, where the baseline must be current ENERGY STAR level (Ref [

4.3.8 DISHWASHER

Description of Measure

Savings detailed below cover the purchase of a high efficiency standard size residential dishwasher and the replacement of an inefficient dishwasher in working condition.

Savings Methodology

Lost Opportunity Measure:

- Lost Opportunity savings are the difference in energy use between a baseline model and the chosen high efficiency new model, continuing for the Effective Useful Life (EUL) from Appendix 4.
- The Retail measure is a Lost Opportunity-only methodology, as the existing unit is not verified, and savings are claimed for a mix of fuels when the hot water fuel type is not known (Note [1]).
- The ENERGY STAR New Home measure is a special Lost-Opportunity-only measure, where the hot water fuel type is known.

Retrofit Measure:

- Uses the same methodology as a Lost Opportunity measure.
- In the case of early retirement of a working unit where the unit would have otherwise been installed until failure, lifetime "Retirement" savings are claimed additional to the lifetime "Lost Opportunity" savings (see Section 1.4).
- Retirement savings are the difference in energy use between the older unit (Note [4]) and a baseline model (Note [3]), a deemed value, continuing for the Remaining Useful Life (RUL) from Appendix 4.

Dishwashers are rated for the kWh energy use per year, and hot water usage per cycle. Savings, based on equations derived in Note [2], come from two sources:

1. *Machine energy savings* (electricity used to run the machine and during standby mode): always electric energy.
2. *Water Heater savings*, due to the reduction in hot water use: may only be claimed for the fuel that is used in the home's water heater.

Inputs

Symbol	Description	Required for
WH Fuel	Water Heater fuel type	All (When unknown, use fuel mix, Note [1])
E_i	Rated kWh/yr of new unit	Lost Opportunity
GPC	Rated gallons of water per cycle of new unit	Lost Opportunity
	Brand and Model of existing unit	Verification purposes only (not used for savings)
	Brand and Model of new installed unit	Lost Opportunity

Nomenclature

Symbol	Description	Units	Values	Comments
$AKWH_M$	Annual gross machine electric savings. Includes motor, heater, dryer, and standby energy.	kWh/yr	calculated	Notes [1], [3]
$AKWH_W$	Annual gross energy savings for an electric water heater	kWh/yr	calculated	Notes [1], [3]
AKWH	Annual gross electric savings	kWh/yr		
AOG	Annual gross energy savings for an oil water heater.	Gal/yr	calculated	Notes [1],[3]
APG	Annual gross energy savings for a propane water heater.	Gal/yr	calculated	Notes [1],[3]
Cycles/yr	Average number of loads of dishes per year	Cycles/yr	Residential: 215	Ref [1]
E_b	Annual Rated kWh usage of baseline unit	kWh/yr	307	Ref [6]
E_e	Annual Rated kWh usage of existing unit	kWh/yr	371	Note [4]
E_i	Annual Rated kWh usage of new installed unit	kWh/yr	Actual	
EF	Efficiency for fossil fuel Water Heaters	Unitless		Ref [5]

Symbol	Description	Units	Values	Comments
GPC_b	Estimated Gallons of Water per cycle of baseline unit	Gal/cycle	5.0	Ref [6], Note [4]
GPC_i	Rated Gallons of Water per cycle of installed unit	Gal/cycle	As found	
$\ldots_{retire}$	Associated with Retirement component.			
$\ldots_{lost\ opp}$	Associated with Lost Opportunity component.			

Lost Opportunity Gross Energy Savings, Electric

Savings shown in Table 1 are the electric savings portions of two components:

1. *Machine energy savings*: always electric energy. This component is always claimed.
2. *Water Heater savings*: for the fuel that is used in the home's water heater.

Table 1: Lost Opportunity Electric Savings Equations

Savings Component	*Known Fuel Type*	*Unknown Fuel Type†*
Machine Energy	$AKWH_{M,lostopp} = 126\,{}^{kWh}\!/_{yr} - \left(E_i - \left(36.17 \times GPC_i\right)\right)$	$AKWH_{lostopp} = 153\,{}^{kWh}\!/_{yr} - \left(E_i - \left(30.74 \times GPC_i\right)\right)$
Water Heater	$AKWH_{W,lostopp} = 181\,{}^{kWh}\!/_{yr} - \left(36.17 \times GPC_i\right)$	

† *This equation accounts for both machine energy and electric water heater savings.*

Lost Opportunity Gross Energy Savings, Fossil Fuel

Savings shown in Table 2 are the fossil fuel savings portions of two components:

1. *Machine energy savings*: always electric energy. Savings presented in Table 1.
2. *Water Heater savings*: for the fuel that is used in the home's water heater. If the fuel type is unknown, claim savings for all fuels. If the fuel type is known, claim savings only for the fuel type.

Table 2: Lost Opportunity Fossil Fuel Savings Equations

Savings Component	Fuel Type	Known Fuel Type	Unknown Fuel Type
Water Heater	Gas	$ACCF_{lostopp} = 9.670\,{}^{Ccf}\!/_{yr} - \left(1.934 \times GPC_i\right)$	$ACCF_{lostopp} = 2.466\,{}^{Ccf}\!/_{yr} - \left(0.4932 \times GPC_i\right)$
	Oil	$AOG_{lostopp} = 7.175\,{}^{Gal}\!/_{yr} - \left(1.435 \times GPC_i\right)$	$AOG_{lostopp} = 3.659\,{}^{Gal\,Oil}\!/_{yr} - \left(0.7319 \times GPC_i\right)$
	Propane	$APG_{lostopp} = 10.90\,{}^{Gal}\!/_{yr} - \left(2.179 \times GPC_i\right)$	$APG_{lostopp} = 0.9265\,{}^{Gal}\!/_{yr} - \left(0.1852 \times GPC_i\right)$

Lost Opportunity Gross Energy Savings, Example

Example 1: A new unit is purchased through a retail promotion, rated for total energy of 190 kWh/yr and total water use of 2.9 Gallons/cycle. The water heater fuel is unknown. What are the savings?

The water heating fuel type is not known. Machine energy (electric energy from Table 1) and water heating savings (use the unknown fuel equations from Tables 2) are claimed as follows:

Machine Energy: Use the unknown fuel type equation from Table 1. Note that electric water heating savings are accounted for in the equation below and do not need to be calculated separately:

$$AKWH_{lostopp,fuel\,mix} = 153\,{}^{kWh}\!/_{yr} - \left[E_i - \left(30.74 \times GPC_i\right)\right]$$

$$AKWH_{lostopp,fuel\,mix} = 153\,{}^{kWh}\!/_{yr} - \left[190\,{}^{kWh}\!/_{yr} - \left(30.74 \times 2.9\right)\right] = 52.1\,{}^{kWh}\!/_{yr}$$

Water Heating Savings: Use the unknown fuel type equations from Table 2:

Natural Gas:

$$ACCF_{lostopp} = 2.466 \,{}^{Ccf}\!/_{yr} - (0.4932 \times GPC_i)$$
$$ACCF_{lostopp} = 2.466 \,{}^{Ccf}\!/_{yr} - (0.4932 \times 2.9) = 1.036 \,{}^{Ccf}\!/_{yr}$$

Oil:
$$AOG_{lostopp} = 3.659 \,{}^{Gal\,Oil}\!/_{yr} - (0.7319 \times GPC_i)$$
$$AOG_{lostopp} = 3.659 \,{}^{Gal\,Oil}\!/_{yr} - (0.7319 \times 2.9) = 1.54 \,{}^{Gal\,Oil}\!/_{yr}$$

Propane:
$$APG_{lostopp} = 0.9265 \,{}^{Gal}\!/_{yr} - (0.1852 \times GPC_i)$$
$$APG_{lostopp} = 0.9265 \,{}^{Gal}\!/_{yr} - (0.1852 \times 2.9) = 0.389 \,{}^{Gal\,Propane}\!/_{yr}$$

Non-Electric Benefits: Water savings are claimed:
$$AWG_{lostopp} = \left(5.0 \,{}^{Gal}\!/_{cycle} - GPC_i\right) \times 215 \,{}^{cycles}\!/_{yr}$$
$$AWG_{lostopp} = \left(5.0 \,{}^{Gal}\!/_{cycle} - 2.9\right) \times 215 \,{}^{cycles}\!/_{yr} = 452 \,{}^{Gal\,Water}\!/_{yr}$$

Retrofit Gross Energy Savings, Electric

Reminder: Retrofit savings are the weighted sum of Retirement savings and Lost Opportunity savings. This section presents the Retirement portion of savings. To obtain lifetime savings the following formula can be used:
$$LKWH_{Total} = (AKWH_{\text{Retire}} \times RUL) + (AKWH_{LostOpp} \times EUL)$$

Retirement Component:
Savings shown in Table 3 are the electric savings of two components:

3. *Machine energy savings*: always electric energy. This component is always claimed.
4. *Water Heater savings*: for the fuel that is used in the home's water heater.

Table 3: Retirement Electric Savings Equations (Note [4], Table 4a, Table 4b)

Savings Component	Fuel Type	Known Fuel Type	Unknown Fuel Type††
Machine Energy	Electric	35 kWh/yr	39.5 kWh/yr
Water Heater	Electric	29 kWh/yr	

†† *This equation accounts for both machine energy and electric water heater savings.*

Retrofit Gross Energy Savings, Fossil Fuel

Reminder: Retrofit savings are the sum of Retirement savings and Lost Opportunity savings. This section presents the Retirement portion of savings. To obtain lifetime savings the following formula can be used:
$$LKWH_{Total} = (AKWH_{\text{Retire}} \times RUL) + (AKWH_{LostOpp} \times EUL)$$

Retirement Component:
Equations shown in Table 4 are the fossil fuel savings portions of two components:

1. *Machine energy savings*: always electric energy. Savings presented in Table 1.
2. *Water Heater savings*: for the fuel that is used in the home's water heater. If the fuel type is unknown, claim savings for all fuels. If the fuel type is known, claim savings only for the fuel type.

Table 4: Retirement Fossil Fuel Savings Equations (Note [4], Table 4a, Table 4b)

Savings Component	Fuel Type	Known Fuel Type	Unknown Fuel Type
Water Heater	Gas	1.547 Ccf/yr	0.394 Ccf/yr
	Oil	1.148 Gal/yr	0.585 Gal/yr
	Propane	1.738 Gal/yr	0.148 Gal/yr

Retrofit Gross Energy Savings, Example

What are the savings for a dishwasher installed in an existing home to replace a working unit? The new unit is rated for total energy of 190 kWh/yr and total water use of 2.9 Gallons/cycle. The home has a propane water heater.

Savings for this example consist of both lost opportunity and retirement components:

Lost Opportunity (use rated Energy and water use for new installed unit)**:**

Machine Energy Savings: Use the equation for machine energy savings from Table 1:

$$AKWH_{M,lostopp} = 126\,{}^{kWh}\!/_{yr} - \left[E_i - (36.17 \times GPC_i)\right]$$

$$AKWH_{M,lostopp} = 126\,{}^{kWh}\!/_{yr} - \left[190 - (36.17 \times 2.9)\right]$$

$$AKWH_{M,lostopp} = 40.89\,{}^{kWh}\!/_{yr}$$

Water Heating Savings: Use the appropriate equation for known fuel type from Table 2:

$$APG_{lostopp} = 10.90\,{}^{Gal}\!/_{yr} - (2.179 \times GPC_i)$$

$$APG_{lostopp} = 10.90\,{}^{Gal}\!/_{yr} - (2.179 \times 2.9)$$

$$APG_{lostopp} = 4.58\,{}^{Gal\,Propane}\!/_{yr}$$

Non Electric Benefits: Water savings are claimed as follows:

$$AWG_{lostopp} = \left(5.0\,{}^{Gal}\!/_{cycle} - 2.9\right) \times 215\,{}^{cycles}\!/_{yr} = 452\,{}^{Gal\,Water}\!/_{yr}$$

Retirement Savings:

Machine Energy Savings: Use the equation for machine energy savings from Table 3:

$AKWH_{\text{Retire}} = 35\ {}^{\text{kWh}}/_{\text{yr}}$

Water Heating Savings: Use the appropriate known fuel type equation from Table 4:

$AKWH_{\text{Retire}} = 1.738\ {}^{\text{Gal}}/_{\text{yr}}$

Non Electric Benefits: Water savings are claimed as follows:

$$AWG_{retire} = 172\,{}^{Gal}\!/_{yr}$$

Non Energy Benefits (Quantified)

Lost Opportunity Water Savings (all units):

Water savings assume gallons per cycle baseline (GPC_b) value of 5.0 resulting in the equation:

$$AWG_{lostopp} = \left(5.0\,{}^{Gal}\!/_{cycle} - GPC_i\right) \times 215\,{}^{cycles}\!/_{yr}$$

Retirement Water Savings (all units):

Water savings for retirement assume gallons per cycle baseline of 5.0 and existing usage (GPC_e) of 5.8 resulting in the equation:

$$AWG_{retire} = 172\,{}^{Gal}\!/_{yr}$$

Changes from Last Version

No changes.

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.

[6] Federal Register 10 CFR Parts 429 and 430, Energy Conservation Program: Energy Conservation Standards for Residential Dishwashers. Published May 30, 2012, effective May 30, 2013. Table I.1.

[7] Market Impact Analysis on the Potential Revision of the ENERGY STAR Criteria for Dishwashers, June 10, 2005

[8] ENERGY STAR Criteria for Dishwashers as of March 2, 2006.

Notes

[1] Most of the savings for high efficiency dishwashers come from water heating. When the hot water fuel is unknown, water heating savings are claimed for all fuel types according to the following percentages:

Water Heater Fuel (typical fuel mix estimated for Connecticut)			
Electric	Gas	Oil	Propane
15%	25.5%	51%	8.5%

The total savings using this fuel mix are calculated as a percent of savings for known fuels as follows:

$$AKWH_{fuel\,mix} = (100\% \times AKWH_M) + (15\% \times AKWH_W)$$

$$ACCF_{fuel\,mix} = (25.5\% \times ACCF_W)$$

$$AOG_{fuel\,mix} = (51\% \times AOG_W)$$

$$AOG_{fuel\,mix} = (8.5\% \times APG_W)$$

[2] For E = total rated energy use, a = Water Heater component of usage, b = Machine component of usage, the energy usage is characterized by the equation $E = a + b$. Each usage component is derived as follows:

a. Water Heater Component:

Water Heating Assumptions (Ref [1])					
% Hot Water Supplied	Average Cycles/yr of Dishwasher	Temperature Rise	Specific Heat of Water	Water Heater Efficiency	
				Electric	Fossil Fuel (Ref [5])
100%	215	70°F	8.2 Btu/Gal-°F	100%	62%

Estimate Annual Btu energy usage to heat the hot water used by the dishwasher:

$$Annual\ Hot\ Water\ Btu\ Usage = 100\% \times 215\,{}^{Cycles}\!/_{yr} \times 8.2\,{}^{Btu}\!/_{Gal-°F} \times 70\,°F \times GPC_W$$

$$Annual\ Hot\ Water\ Btu\ Usage = 123{,}410\,{}^{Btu-cycles}\!/_{Gal-yr} \times GPC_W$$

Using the following equation to convert annual Hot Water energy from Btu to each fuel type:

$$Annual\ Water\ Heating\ Usage = \frac{Annual\ Hot\ Water\ Btu\ Usage}{Fuel\ Conversion\,{}^{Btu}\!/_{unit} \times EF}$$

Electric Water Heater usage:

$$Annual\ Electric\ Water\ Heating\ Usage, kWh = \frac{123{,}410 \times GPC_W}{3412\,{}^{Btu}\!/_{kWh}}$$

$$Annual\ Electric\ Water\ Heating\ Usage, kWh = 36.17 \times GPC_W$$

Gas Water Heater usage:

$$Annual\ Gas\ Water\ Heating\ Usage = \frac{123{,}410 \times GPC_W}{102{,}900\,{}^{Btu}\!/_{Ccf} \times 0.62}$$

$$Annual\ Gas\ Water\ Heating\ Usage = 1.934 \times GPC_W$$

Oil Water Heater usage:

$$Annual\ Oil\ Water\ Heating\ Usage = \frac{123{,}410 \times GPC_W}{138{,}690\,{}^{Btu}\!/_{Gal\ Oil} \times 0.62}$$

$$Annual\ Oil\ Water\ Heating\ Usage = 1.435 \times GPC_W$$

Propane Water Heater usage:

$$Annual\ Propane\ Water\ Heating\ Usage = \frac{123{,}410 \times GPC_W}{91{,}330\,{}^{Btu}\!/_{Gal\ Propane} \times 0.62}$$

$$Annual\ Propane\ Water\ Heating\ Usage = 2.179 \times GPC_W$$

b. Machine Component:

Estimate electric Machine energy use (b) by subtracting the water heating energy in kWh (a) from the unit’s total rated kWh usage (E)

$$Annual\ Machine\ kWh\ Usage = E - \left(36.17\,{}^{kWh}\!/_{Gal-yr} \times GPC_W\right)$$

[3] The Lost Opportunity baseline unit is represented by the 2013 Federal Standard (Ref [6]). Baseline Energy usage for the Machine and Water Heater Components is shown in Table 3.

[4] Energy Factor (EF) was not rated until the 1994 Federal Standard. The Maximum Energy and Water Use criteria replaced the EF in the 2009 ENERGY STAR criteria, and the 2010 Federal Standard followed suit. The annual kWh energy use criterion differs from the EF in that it also includes standby energy use. The approximate relationship between the two types of criteria is (standby power use additional to this):

$$Annual\ kWh\ Energy\ Use = \frac{215\,{}^{cycles}\!/_{yr}}{EF}.$$

The typical existing unit is represented the 2001 ENERGY STAR level at 0.58 EF, based on high market penetration in 2004 (Ref [7]), with equivalent energy use of 371 kWh/yr. Because there was no specification for water use prior to 2009, the typical existing unit water usage is estimated to be the same as the 2009 ENERGY STAR (5.8 Gal/cycle) level.

Table 3: Energy Specifications and Usage Components (values in brackets are estimated)

Level (with effective date)	EF	Total Energy Use Rating	Hot Water Use Rating	Energy Usage Components (Calculated from equations in Note [2])					Ref
				Machine Energy	Water Heating				
					Electric	Gas	Oil	Propane	
	N/A	kWh/yr	Gal/ Cycle	kWh/yr	kWh/yr	Ccf/ yr	Gal/ yr	Gal/ yr	
May 14, 1994 Federal Standard	0.46	[467]	[7.3]	203	264	14.12	10.48	15.91	[8]
Jan 1, 2001 ENERGY STAR (existing)	**0.58**	**[371]**	**[5.8]**	**161**	**210**	**11.22**	**8.323**	**12.64**	**[8]**
2007 ENERGY STAR	0.65	[331]	[5.8]	121	210	11.22	8.323	12.64	[8]
2010 Federal Standard	N/A	355	6.5	120	235	12.57	9.328	14.16	[2]
2009 ENERGY STAR	N/A	324	5.8	114	210	11.22	8.323	12.64	[3]
2013 Federal Standard	**N/A**	**307**	**5.0**	**126**	**181**	**9.670**	**7.175**	**10.90**	**[6]**
2012 ENERGY STAR	N/A	295	4.25	141	154	8.220	6.099	9.261	[4]
2012 CEE Tier 1	0.75	295	4.25	141	154	8.220	6.099	9.261	[2]

Table 4a: Derivation of Deemed Savings for Retirement Savings – Known Fuel Type

Derivation	***Deemed Savings***
$AKWH_{M,lostopp} = \left[371\, {}^{kWh}\!/_{yr} - (36.17 \times 5.8)\right] - 126\, {}^{kWh}\!/_{yr}$	*35 kWh/yr*
$AKWH_{W,lostopp} = (36.17 \times 5.8) - 181\, {}^{kWh}\!/_{yr}$	*29 kWh/yr*
$ACCF_{lostopp} = (1.934 \times 5.8) - 9.670\, {}^{Ccf}\!/_{yr}$	*1.547 Ccf/yr*
$AOG_{lostopp} = (1.435 \times 5.8) - 7.175\, {}^{Gal}\!/_{yr}$	*1.148 Gal/yr*
$APG_{lostopp} = (2.179 \times 5.8) - 10.90\, {}^{Gal}\!/_{yr}$	*1.738 Gal/yr*

Table 4b: Derivation of Deemed Savings for Retirement Savings – Unknown Fuel Type

Derivation (using deemed savings from known fuel type and methodology from Note [1])	***Deemed Savings***
$AKWH_{lostopp,fuel\,mix} = 35.2\, {}^{kWh}\!/_{yr} + \left(15\% \times 28.8\, {}^{kWh}\!/_{yr}\right)$	*39.5 kWh/yr*
$ACCF_{lostopp,fuel\,mix} = \left(25.5\% \times 1.547\, {}^{Ccf}\!/_{yr}\right)$	*0.394 Ccf/yr*
$AOG_{lostopp,fuel\,mix} = \left(51\% \times 1.148\, {}^{Gal}\!/_{yr}\right)$	*0.585 Gal/yr*
$APG_{lostopp,fuel\,mix} = \left(8.5\% \times 1.738\, {}^{Gal}\!/_{yr}\right)$	*0.148 Gal/yr*

4.3.9 REFRIGERATOR

Description of Measure

Savings detailed below cover the replacement of a full size refrigerator with a new energy efficient model, the installation of an energy efficient refrigerator in a home, and the permanent removal of a non-primary refrigerator from service

Savings Methodology

Lost Opportunity Measure:
- Lost Opportunity savings are the difference in energy use between a baseline model of the same size and category as the installed unit, and the chosen high efficiency new model, continuing for the Effective Useful Life (EUL) from Appendix 4.
- The Retail measure is a Lost Opportunity-only methodology, as the existing unit is not verified.

Retrofit Measure:
- Uses the same methodology as a Lost Opportunity measure.
- In the case of early retirement of a working unit where the unit would have otherwise been installed until failure, lifetime "Retirement" savings are claimed additional to the lifetime "Lost Opportunity" savings (see Section 1.4).
- Retirement savings are the difference in energy use between the older unit and a baseline model of the same size and category as the older unit, continuing for the Remaining Useful Life (RUL) from Appendix 4. See Note [5] for exceptions.
- The Turn-in measure (permanent removal of a working non-primary unit that will not be replaced with a new unit) is a special case where savings are claimed as the existing unit's rated annual energy usage.

Only Full-Sized Refrigerators are considered in this measure (Total volume of 7.75 cubic feet or greater). The efficiency of a refrigerator model is rated on the annual energy usage in kWh, which varies according to size, configuration, and features. A "Site/Lab Factor" (Ref [1], pages 7-2 and 7-3) is applied to the consumption for each newer unit (from 2004 on) before taking the difference between energy usage levels for savings calculations.

Inputs

Symbol	Description	Required for
AV_i	Adjusted Volume of new installed unit	Lost Opportunity
E_e	Actual unadjusted rated kWh energy usage for the existing unit	Retirement
E_i	Actual rated kWh energy usage for the new installed unit	Lost Opportunity
V_e	Total Nominal Volume of existing unit	Retirement
$Year_e$	Year of existing (old) model	Retirement – only if usage is unknown
	Configuration of existing refrigerator (See Table 1 for options)	Retirement
	Configuration of new refrigerator (See Table 1 for options)	Lost Opportunity
	Brand and Model of existing refrigerator	Retirement
	Brand and Model of new installed refrigerator	Lost Opportunity

Nomenclature

Symbol	Description	Units	Values	Comments
$AKWH_{retire}$	Gross annual Retirement savings	kWh/yr	Calculated	
$AKWH_{lost\ opp}$	Gross annual Lost Opportunity savings	kWh/yr	Calculated	
$AKWH_{turn\text{-}in}$	Gross annual Turn-in savings	kWh/yr	Calculated	
AV_i	Adjusted Volume of new installed unit	ft^3	Actual as rated	Note [3]
AV_e	Adjusted Volume of existing unit	ft^3	Actual as rated If AV_e unknown: $AV_e = (1.319 \times V_e) - 2.491$	Note [2]
E_b	Electric energy usage of baseline new unit, calculated separately for 'Retirement' and 'Lost Opportunity'	kWh/yr	Calculated	Note [4], Table [2]
E_e	Unadjusted electric energy usage of existing unit			Note [1]
$E_{fed\ std}$	Electric energy usage of 2014Federal Standard unit, varies according to size and category	kWh/yr	Calculated separately for 'Retirement' and 'Lost Opportunity'	Note [4], Table 1, Ref [9]
E_i	Electric energy usage of new installed unit	kWh/yr	Actual	
EUL	Effective Useful Life: Measure life of installed unit.	years	Appendix 4	
$LKWH_{total}$	Total gross lifetime electric energy savings	kWh	Calculated	
PF_S	Summer Peak Factor	W/ kWh	0.1834	Ref [1]
PF_W	Winter Peak Factor	W/ kWh	0.1031	Ref [1]
RUL	Remaining Useful Life: remaining number of years the existing unit would have operated until failure	years	Appendix 4	
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_e	Total Nominal Volume of existing unit	ft^3	Actual as found	
WKW	Winter electric demand savings	kW		
$Year_e$	Year of Manufacture of existing unit	Yr	Actual; if unknown, estimate based on age.	Note [1]
$\ldots_{retire}$	Associated with Retirement			
$\ldots_{lost\ opp}$	Associated with Lost Opportunity			
$\ldots_{turn\text{-}in}$	Associated with Turn-in Program			

Lost Opportunity Gross Energy Savings, Electric

$$AKWH_{lost\,opp} = SLF_{new} \times \left(E_{b,LostOpp} - E_i\right)$$

Where:

SLF_{new} = 0.881

E_i = Rated energy usage of the new installed unit (if not given lookup from ENERGY STAR website (Note [3])

$E_{b,LostOpp}$ = $E_{fed\ std}$ (Baseline energy usage of new unit)

$E_{fed\ std}$ = Calculated based on the configuration and adjusted volume of the new unit (Note [3]).

AV_i = Adjusted volume of new unit. See Note [2] for details.

How to Calculate $E_{b,LostOpp}$ and $E_{fed\ std}$:

1. Use Table 1 to select the equation for $E_{fed\ std}$ corresponding to the new unit's configuration.
2. Use the adjusted volume of the new unit (AV_i) in this equation (Note [3]). Calculate $E_{fed\ std}$.
3. Use the result for $E_{b,LostOpp}$.

Table 1: Federal Standard Energy Use (kWh/yr) for Full-Size Refrigerators (Ref [9], Note[3])

Configuration (use "Any" if unknown)	Defrost	Automatic Ice Maker	Through-the-Door Ice	$E_{fed\ std}$ (2014) (Ref[9])
Refrigerator-freezers and refrigerators other than all-refrigerators.	Manual	Any	Any	7.99AV + 225.0
All-refrigerators—manual defrost.	Manual	Any	Any	6.79AV + 193.6
Refrigerator-freezers—defrost	Partial automatic	Any	Any	7.99AV + 225.0
Refrigerator-freezers—with top-mounted freezer	Automatic	No	No	8.07AV + 233.7
Built-in refrigerator-freezer—with top-mounted freezer	Automatic	No	No	9.15AV + 264.9
Refrigerator-freezers—with top-mounted freezer	Automatic	Yes	No	8.07AV + 317.7
Built-in refrigerator-freezers—with top-mounted freezer	Automatic	Yes	No	9.15AV + 348.9
All-refrigerators	Automatic	Any	Any	7.07AV + 201.6
Built-in All-refrigerators—	Automatic	Any	Any	8.02AV + 228.5
Refrigerator-freezers—with side-mounted freezer	Automatic	No	No	8.51AV + 297.8
Built-In Refrigerator-freezers—with side-mounted freezer	Automatic	No	No	10.22AV + 357.4
Refrigerator-freezers—with side-mounted freezer	Automatic	Yes	No	8.51AV + 381.8
Built-In Refrigerator-freezers—with side-mounted freezer	Automatic	Yes	No	10.22AV + 441.4
Refrigerator-freezers—with bottom-mounted freezer	Automatic	No	No	8.85AV + 317.0
Built-In Refrigerator-freezers—with bottom-mounted freezer	Automatic	No	No	9.40AV + 336.9
Refrigerator-freezers—with bottom-mounted freezer	Automatic	Yes	No	8.85AV + 401.0
Built-In Refrigerator-freezers— with bottom-mounted freezer	Automatic	Yes	No	9.40AV + 420.9
Refrigerator-freezer— with bottom-mounted freezer	Automatic	Yes	Yes	9.25AV + 475.4
Built-in refrigerator-freezer— with bottom-mounted freezer	Automatic	Yes	Yes	9.83AV + 499.9
Refrigerator-freezers—with top-mounted freezer	Automatic	Yes	Yes	8.40AV + 385.4
Refrigerator-freezers—with side-mounted freezer	Automatic	Yes	Yes	8.54AV + 432.8
Built-In Refrigerator-freezers—with side-mounted freezer	Automatic	Yes	Yes	10.25AV + 502.6

Lost Opportunity Gross Energy Savings, Example

Example 1: A new 25.25 ft^3 refrigerator with a side-by-side configuration, automatic defrost, and through-the-door ice service is purchased through a retail promotion. The ENERGY STAR lists Adjusted Volume of 31.3925 ft^3, and rated annual energy usage = 469 kWh/yr. What are the energy savings?

$$AKWH_{lostopp} = 0.881 \times (E_{b,LostOpp} - E_i)$$

$E_i = 469\ ^{kWh}/_{yr}$

$E_{b,p}$ = determined as follows:

Determine $E_{fed\ std}$:

Select the appropriate equation from Table 1 and calculate $E_{fed\ std}$ using AV_i = 31.3925 ft^3:

$$E_{b\ lost\ opp} = E_{fed\ std} = 8.54 \times AV_i + 432.8$$

$$E_{fed\ std,Lostop} = 8.54 \times 31.3925 + 432.8 = 701.kWh$$

$$AKWH_{Lostopp} = 0.881 \times (701 - 469) = 204.\,kWh/yr$$

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

$$WKW_{lostopp} = AKWH_{lostopp} \times PF_W / 1000\, {}^{W}\!/_{kW}$$

$$SKW_{lostopp} = AKWH_{lostopp} \times PF_S / 1000\, {}^{W}\!/_{kW}$$

Lost Opportunity Gross Peak Demand Savings, Example

Example 2: What are the demand savings for Example 1?

From Example 1 the energy savings are $AKWH_{lost\ opp} = 204\, {}^{kWh}\!/_{yr}$:

Winter Peak Savings:

$$WKW_{lostopp} = AKWH_{lostopp} \times PF_W / 1000\, {}^{W}\!/_{kW}$$

$$WKW_{Lostopp} = 204 \times \frac{0.1031}{1000} = 0.021\ kW$$

Summer Peak Savings:

$$SKW_{lostopp} = AKWH_{lostopp} \times PF_S / 1000\, {}^{W}\!/_{kW}$$

$$SKW_{Lostopp} = 204 \times \frac{0.1834}{1000} = 0.037\ kW$$

Retrofit Gross Energy Savings, Electric

Reminder: Retrofit savings are the weighted sum of Retirement savings and Lost Opportunity savings. This section presents the Retirement portion of savings. To obtain lifetime savings the following formula can be used:

$$LKWH_{Total} = (AKWH_{Retire} \times RUL) + (AKWH_{LostOpp} \times EUL)$$

Retirement Component:

$$AKWH_{retire} = E_e - (SLF_{new} \times E_{b,\,retire})$$

Where:

SLF_{new} = 0.881

E_e = Rated energy usage of the existing unit. If not given use Note [1] to estimate this value.

$E_{b,Retire}$ = Baseline energy usage.equals $E_{fed\ std\ for\ the}$ same size and configuration as the existing unit. Since configuration of units may differ, retirement is determined separately from lost opportunity as follows:

> $E_{b\ Retire} = E_{fed\ std}$
>
> $E_{fed\ std}$ = Calculated based on the configuration and adjusted volume of the existing unit (Note [3]).
>
> AV_e = Adjusted volume of existing unit. If not given use Note [2] to estimate this value.

How to Calculate $E_{bRetire}$ ($E_{bRetire} = E_{fed\ std}$):

1. Use Table 1 to select the equation for $E_{fed\ std}$ corresponding to the existing unit's configuration.
2. Use the adjusted volume of the existing unit (AV_e) in this equation (Note[3]). Calculate $E_{fed\ std}$.
3. Use the result for $E_{b,}$

Turn-in Measure: For refrigerator turn-in the savings are equal to the energy usage of the unit being turned in.

$AKWH_{turn-in} = E_e$

Retrofit Gross Energy Savings, Example

Example 3: Calculate energy savings for replacing a 1998 model in working condition in an existing home with an unknown energy usage. The existing model has a total volume of 18.00 ft^3 with a top-mount freezer and without through-the-door ice service. The new installed model is an 18.11 ft^3 Refrigerator with top-mount freezer and automatic defrost without through-the-door ice service. The ENERGY STAR website lists Adjusted Volume of 20.77 ft^3 and rated annual energy use of 311 kWh/yr.

Total energy savings for this example are the combination of Lost Opportunity and Retirement savings as follows:

Lost Opportunity Component:

$$AKWH_{lostopp} = SLF_{new} \times \left(E_{b,LostOpp} - E_i\right)$$

Use:
SLF_{new} = 0.881
E_i = 311 $^{kWh}/_{yr}$
$E_{b,LostOpp}$ = determined as follows:

Determine $E_{fed\ std}$:
Select the appropriate equation from Table 1 and calculate $E_{fed\ std}$ using AV_i = 20.77 ft^3:

$$E_b = E_{fed\ std,} = 8.07 \times 20.77 + 233.7 = 401. \text{ kWh}$$

$$AKWH_{lostopp} = 0.881 \times \left(E_{b,\,lostopp} - E_i\right)$$

$$AKWH_{Lostopp} = 0.881 \times (401 - 311) = 80\ kWh/yr$$

Retirement Component:

$AKWH_{retire} = E_e - (SLF_{new} \times E_b)$

Use:
SLF_{new} = 0.881
E_e = this value is unknown and must be estimated based on the age of the existing unit (per Note [1]):

Determine E_e:
Use V_e = 18.00 ft^3 and Note [1] to estimate energy use for a unit manufactured in 1998:

$$E_e = V_e \times \left(4440.6 - \left(2.2035 \times Year_e\right)\right)$$

$$E_e = 18.00 ft^3 \times \left(4440.6 - \left(2.2035 \times 1998\right)\right) = 684 \, {}^{kWh}\!/_{yr}$$

$E_{b,e}$ = the federal standard usage and is determined as follows:

Determine $E_{fed\ std}$:
Select the appropriate equation from Table 1

$$E_{fed\ std,Lostop} = 8.07 \times AVe + 233.7$$

Determine AV_e: Since AV_e is unknown, nominal volume (V_e = 18.00 ft^3) is used to calculate AV_e:

$$AV_e = \left(1.319 \times V_e\right) - 2.491$$

$$AV_e = \left(1.319 \times 18.00\ ft^3\right) - 2.491 = 21.251\ ft^3$$

Use the value for AV_e to find the federal standard usage for retirement ($E_{fed\ std,\ retire}$):

$E_{fed\ std,Lostop} == 8.07 \times 21.251 + 233.7 = 405\ kwh$

Use the value for $E_{fed\ std,\ retire}$ to find the energy usage baseline ($E_{b,Retire}$):

$E_{b\ ,lost\ opp} = 405\ kWh/yr$

Use the calculated baseline usage and the existing usage to determine the retirement component:

$$AKWH_{retire} = E_e - (0.881 \times E_{b,\ retire})$$

$$AKWH_{retire} = 684 - 0.881 \times 405 = 327kWh/yr$$

Retrofit Gross Peak Demand Savings, Electric, Winter and Summer

Reminder: Retrofit savings are the sum of Retirement savings and Lost Opportunity savings. This section presents the Retirement portion of savings. To obtain total savings the following formula can be used:

$$Peak\ Demand\ Savings_{Total} = \frac{(Peak\ Demand\ Savings_{Retire} \times RUL) + (Peak\ Demand\ Savings_{LostOpp} \times EUL)}{EUL}$$

Retirement Component:

$$WKW_{retire} = AKWH_{retire} \times PF_W / 1000 \, W/_{kW}$$
$$SKW_{retire} = AKWH_{retire} \times PF_S / 1000 \, W/_{kW}$$

Turn-in:

$$WKW_{turn-in} = AKWH_{turn-in} \times PF_W / 1000 \, W/_{kW}$$
$$SKW_{turn-in} = AKWH_{turn-in} \times PF_S / 1000 \, W/_{kW}$$

Retrofit Gross Peak Demand Savings, Example

Example 4: What are the demand savings for Example 3?

Because the existing unit is verified to be in working condition, the retrofit savings are made up of both a Lost Opportunity component and an Early Retirement component. Using the results of Example 3:

$AKWH_{lost\ opp} = 80 \, ^{kWh}/_{yr}$
$AKWH_{retire} = 327 \, ^{kWh}/_{yr}$

Lost Opportunity Component:

$$WKW_{lostopp} = AKWH_{lostopp} \times PF_W / 1000 \, W/_{kW}$$
$$SKW_{lostopp} = AKWH_{lostopp} \times PF_S / 1000 \, W/_{kW}$$

$$WKW_{lost\,opp} = 80 \, ^{kWh}/_{yr} \times 0.1031 / 1000 \, W/_{kW} = 0.008\,\text{kW}$$

$$SKW_{lost\,opp} = 80 \, ^{kWh}/_{yr} \times 0.1834 / 1000 \, W/_{kW} = 0.015\text{kW}$$

Retrofit Component:

$$WKW_{retire} = AKWH_{retire} \times PF_W / 1000 \, W/_{kW}$$
$$SKW_{retire} = AKWH_{retire} \times PF_S / 1000 \, W/_{kW}$$

$$WKW_{retire} = 327\,{}^{kWh}\!/_{yr} \times 0.1031/1000\,{}^{W}\!/_{kW} = 0.034\text{kW}$$

$$SKW_{retire} = 327\,{}^{kWh}\!/_{yr} \times 0.1834/1000\,{}^{W}\!/_{kW} = 0.060\,\text{kW}$$

Changes from Last Version

No changes.

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] Consortium for Energy Efficiency (CEE) Super-Efficient Home Appliances Initiative (SEHA) High-efficiency Specifications for Refrigerators, Effective September 2014.

[4] California Energy Commission (CEC) Appliance Database.
Online historical appliance database: http://www.energy.ca.gov/appliances/database/historical_excel_files/
Online current (meeting minimum standards) appliance database: http://www.appliances.energy.ca.gov/

[5] ENERGY STAR Residential Refrigerators and Freezers Specification: ENERGY STAR Version 5.0 specification. Effective date: September 15, 2014.
http://www.energystar.gov/index.cfm?c=revisions.res_refrig_spec . Last Accessed November 6, 2012.

[6] Federal Register, Vol. 76, No. 179. 10 CFR Part 430. Energy Conservation Program: Energy Conservation Standards for Residential Refrigerators, Refrigerator-Freezers, and Freezers. Published September 15, 2011, Effective November 14, 2011, Compliance date September 15, 2014.

[7] ENERGY STAR Refrigerators Website, last accessed July 25, 2012:
http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=RF

Notes

[1] The unadjusted annual energy usage of the existing unit is usually found in the CEC database (Ref [5]) or an equivalent source by brand and model number. If the existing unit kWh usage is unknown, it may be estimated with the following equations, using the nominal total volume of the unit and the estimated year of manufacture:

Table 2: Calculating Existing Energy Usage Based on Year and Nominal Total Volume

Date of Manufacture	*Equation to Calculate Existing Energy usage*	*Reference*
1978 to current year	$E_e = V_e \times (4440.6 - (2.2035 \times Year_e))$	*[5]*
Before 1978	$E_e = V_e \times (82\,{}^{kWh}\!/_{ft^3})$	*[5]*

Equations are based on average rated usage of full size standard refrigerators found in the CEC Database (Ref [5]) from 1978 to 2003

[2] The definition of Adjusted Volume is the following equation: $AV = V_{fresh} + (1.63 \times V_{frozen})$, where fresh refers to the main refrigerator compartment, and frozen refers to the freezer compartment. Adjusted Volume of the existing unit may be estimated using the following: an analysis of data from Ref [5] showed the following strong relationship between Volume and Adjusted Volume for standard size Refrigerator-Freezer units: $AV_e = (1.319 \times V_e) - 2.491$. For All-Refrigerators, the Adjusted Volume (AV) is the same as the nominal

volume (no freezer compartment). Please refer to the Department of Energy test procedure Pt. 430, Subpt. B, App. A1, Sections 5.3 and 6 for details. http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-part430-subpartB-appA1.pdf

[3] Energy use and Adjusted Volume ratings for new installed ENERGY STAR units may be obtained through the ENERGY STAR website, Ref [8]. Because of the complexity of the 2013 ENERGY STAR Version 5.0 specification (Ref [6]) and 2014 Federal Standard (Ref [7]), the details of these specifications are not listed here but may be obtained directly from the final reference documents.

[4] Consortium for Energy Efficiency, Super Efficient Home Appliances Initiative, Revised January 2007,(Refrigerator section updated in September 2014).

[5] Exceptions to standard calculations for replacement of existing units may occur in the following special situations:

a. If the annual kWh usage of the existing unit is already less than or equal to the baseline level ($E_e \leq E_b$), no retirement savings may be claimed.
b. If the annual kWh usage of existing unit is less than the baseline level but greater than the annual kWh usage of the new installed unit ($E_i < E_e < E_b$), the lost opportunity component of savings may still be claimed, but the existing unit Annual kWh usage must be used for the baseline rather than 2014 Federal Standard.
c. If new unit Annual kWh is greater than or equal to the existing unit kWh ($E_e \leq E_i$), regardless of size, no savings may be claimed.

4.3.10 CLOTHES DRYER

Description of Measure

Savings detailed below cover the purchase of an Energy Star high efficiency clothes dryer.

Savings Methodology

Lost Opportunity Measure:

- Lost Opportunity savings are the difference in energy use between a baseline model and the chosen high efficiency new model, continuing for the Effective Useful Life (EUL) from Appendix 4.
- The Retail measure is a Lost Opportunity-only methodology.

No demand savings have been identified for this measure.

Inputs

Symbol	Description	Required for:
Dryer Type	Type of dryer to be used with the new installed unit: Electric, Gas, or Propane	All
CEFi	Combined Energy Factor of new installed unit	Lost Opportunity
Cap_i	Compartment Capacity of new installed unit in Cubic ft.	Lost Opportunity
	Brand and Model of new installed unit	Lost Opportunity

Nomenclature

Symbol	Description	Units	Values	Comments
ACCF	Annual natural gas energy savings	Ccf/yr	Calculated	
AKWH	Annual electric energy savings	kWh/yr	Calculated	
APG	Annual propane energy savings	Gal Propane/yr	Calculated	
Cap_i	Compartment capacity of new installed clothes dryer	cubic feet, ft^3	Actual as found	
N_{Cycles}	Average number of loads of laundry per year	Cycles/yr	Residential: 322	Note [3]
EUL	Effective Useful Life: Measure life of installed unit.	years	Appendix 4	
CEF_b	Combined Energy Factor (CEF) of baseline new model	lb/kWh/cycle	Refer to tableI.1 Note[1,2]	Note [1,2]
CEF_i	Combined Energy Factor (CEF) of new installed unit	lb/kWh/cycle	Actual as rated	
$\ldots_{lost\ opp}$	Associated with Lost Opportunity			

Table 1._Residential Clothes Dryer 2015 Program Standards

Product class	CEF *lb/kWh*	Comments
Vented or Ventless Electric, Standard (4.4 cubic feet (ft^3) or greater capacity)	3.11	Note [1]
Vented Gas	2.84	Note [2]

Lost Opportunity Gross Energy Savings, Electric

Electric savings for an electric dryer are based on the installed unit capacity and combined energy factor, the savings algorithm are explained in details in note2 .

$$\text{AKWH}_{\text{LostOpp}} = 2 \times (Cap_i - 1) \times \left(\frac{1}{CEF_b} - \frac{1}{CEF_i}\right) \times N_{\ Cycles}$$

$$\text{AKWH}_{\text{LostOpp}} = 2 \times (Cap_i - 1) \times \left(\frac{1}{CEF_b} - \frac{1}{CEF_i}\right) \times 322$$

Lost Opportunity Gross Energy Savings, Fossil Fuel

Gas savings for gas dryer are based on installed unit capacity and combined energy factor CEF

$$\text{ACCF}_{\text{LostOpp}} = 2 \times (Cap_i - 1) \times \left(\frac{1}{CEF_b} - \frac{1}{CEF_i}\right) \times Cycles/yr \times {}^{3412}/_{102900}$$

$$\text{ACCF}_{\text{LostOpp}} = 2 \times (Cap_i - 1) \times \left(\frac{1}{CEF_b} - \frac{1}{CEF_i}\right) \times 322 \times 0.033$$

Propane savings for propane dryer are based on installed unit capacity and combined energy factor CEF

$$\text{APG}_{\text{LostOpp}} = 2 \times (Cap_i - 1) \times \left(\frac{1}{CEF_b} - \frac{1}{CEF_i}\right) \times Cycles/yr \times {}^{3412}/_{91330}$$

$$\text{APG}_{\text{LostOpp}} = 2 \times (Cap_i - 1) \times \left(\frac{1}{CEF_b} - \frac{1}{CEF_i}\right) \times 322 \times 0.037$$

Lost Opportunity Gross Energy Savings, Example

Example 1: Calculate the savings for a 7.3 ft^3 capacity electric clothes purchased through a retail promotion. The unit has a CEF of 3.93.

Since this is an electric clothes dryer purchase through retailer, the electric lost opportunity savings formula is used for saving calculation

$$\text{AKWH}_{\text{LostOpp}} = 2 \times (Cap_i - 1) \times \left(\frac{1}{CEF_b} - \frac{1}{CEF_i}\right) \times 322 = 2 \times (7.3 - 1) \times \left(\frac{1}{3.11} - \frac{1}{3.93}\right) \times 322 = 272\ kWh$$

Non Energy Benefit:

New units may have additional useful features and controls, such wrinkle prevention, filter cleaning indicators, newer units use less energy therefore less CO2 emissions.

Changes from last version

No changes

Reference

[1] On August 24, 2011, amended standards were issued for residential clothes dryers. The full text of the amended standard is available in the Code of Federal Regulations, 10 CFR 430.32(h)(3)PDF. It is also in the Electronic Code of Federal Regulations.

[2] ENERGY STAR Program Requirements, Product Specification for Clothes Dryers, Effective January 1,2015; www.energystar.gov/sites/default/files/specs//ENERGY%20STAR%20Final%20Version%201%200%20Clothes%20Dryers%20Program%20Requirements.pdf

Notes

[1] The electric baseline CEF was derived in the ENERGY STAR Version 1.0 (Ref [2]), analysis by multiplying 2015 Federal Standard (Ref [1], by the average change in gas dryers' assessed CEF between Appendix D1 and Appendix D2: 3.73 - (3.73 x 0.166)
[2] The gas baseline CEF was derived in the ENERGY STAR Version 1.0 (Ref [2]), analysis by multiplying 2015 standard by the average change in gas dryers' assessed CEF between Appendix D1 and Appendix D2: 3.30 - (3.30 x 0.139)
[3] Weighted average of 322 clothes washer cycles per year based on the Efficiency Vermont 2014 Technical Resource Manual clothes washer measure characterization.

4.3.12 FREEZER

Description of Measure

Savings detailed below cover the replacement of a full size freezer with a new energy efficient model, the installation of an energy efficient freezer in a home, and the permanent removal of a freezer from service.

Savings Methodology

Lost Opportunity Measure:

- Lost Opportunity savings are the difference in energy use between a baseline model of the same size and category as the installed unit, and the chosen high efficiency new model (Note [4]), continuing for the Effective Useful Life (EUL) from Appendix 4.
- The Retail measure is a Lost Opportunity-only methodology, as the existing unit is not verified.

Retrofit Measure:

- Uses the same methodology as a Lost Opportunity measure.
- In the case of early retirement of a working unit where the unit would have otherwise been installed until failure, lifetime “Retirement” savings are claimed additional to the lifetime “Lost Opportunity” savings (see Section 1.4).
- Retirement savings are the difference in energy use between the older unit (Note [1]) and a baseline model (Note [2]) of the same size and category as the older unit, continuing for the Remaining Useful Life (RUL) from Appendix 4. See Note [3] for exceptions.
- The Turn-in measure (permanent removal of a working non-primary unit that will not be replaced with a new unit) is a special case where savings are claimed as the existing unit’s rated annual energy usage.

Only full-sized Freezers are considered in this measure (Total volume of 7.75 cubic feet or greater). The efficiency of a freezer is rated on the annual energy usage in kWh, which varies according to size, configuration, and features (Note [3]). Savings are calculated as the difference in unadjusted rated annual energy usage between two levels.

Inputs

Symbol	Description	Required for
E_e	Actual (unadjusted) rated kWh consumption of (old) existing model	Retirement
E_i	Actual rated kWh consumption of new installed model	Lost Opportunity
V_e	Volume of existing (old) model	Retirement
V_i	Volume of new installed model	Lost Opportunity
$Year_e$	Year of existing (old) model	Retirement – only if usage is unknown
	Category of existing freezer (See Table 1 for options)	Retirement
	Category of new installed freezer (See Table 1 for options)	Lost Opportunity
	Brand and Model of existing freezer	Retirement
	Brand and Model of new installed freezer	Lost Opportunity

Nomenclature

Symbol	Description	Units	Values	Comments
AV_e	Adjusted Volume of existing model	ft^3	$AV_e = 1.73 \times V_e$	
AV_i	Adjusted Volume of new installed model	ft^3	$AV_i = 1.73 \times V_i$	
V_e	Total volume of existing model	ft^3	Actual	
V_i	Total volume of new installed model	ft^3	Actual	
E_b	Annual electric energy usage of baseline new unit	kWh/yr	All: $E_{fed\ std}$	Note [2], Table 1

Symbol	Description	Units	Values	Comments
E_e	Annual electric energy usage of existing model	kWh/yr	Actual If E_e unknown: Use V_e and/or $year_e$ and Table 3 to estimate E_e	Note [1]
$E_{fed\ std}$	Electric energy usage of Federal Standard unit, varies according to size and category	kWh/yr	Calculated separately for "Retirement" and "Lost Opportunity"	Table 1
E_i	Electric energy usage of new installed unit	kWh/yr	As rated	
AKWH	Gross annual electric energy 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]
$\ldots_{turn\text{-}in}$	Associated with Turn-in Program			
$\ldots_{lost\ opp}$	Associated with Lost Opportunity			
$\ldots_{retire}$	Associated with Retirement			

Lost Opportunity Gross Energy Savings, Electric

$$AKWH_{lostopp} = E_{b,lostopp} - E_i$$

Where:
E_i = Rated energy usage of the new installed unit (if not given lookup per Note [1])
$E_{b,\ lost\ opp}$ = Baseline energy usage. Use Table 1 and AV_i to calculate this value.

1. Convert installed volume (V_i) to adjusted volume (AV_i): $AV_i = 1.73 \times V_i$ (Note [4])
2. $E_{b,\ lost\ opp}$ will equal $E_{fed\ std}$ for all scenarios.

Table 1: Energy Specifications: Maximum Energy Use (Ref [2,4])

Configuration	$E_{fed\ std}$
Upright freezers with manual defrost	5.57 x AV + 193.7
Upright freezers with automatic defrost W/O automatic Ice make	8.62 x AV + 228.3
Upright freezers with automatic defrost and with automatic ice maker	8.62 x AV + 312.3
Chest freezers and all other freezers except compacts	7.29 x AV + 107.8

Lost Opportunity Gross Energy Savings, Example

Example 1: Calculate savings for a 16.0 cubic foot upright freezer with manual defrost purchased through a retail promotion. Rated energy usage is 320 kWh/yr.

$$AKWH_{lostopp} = E_{b,lostopp} - E_i$$

$E_i = 320\ ^{kWh}/_{yr}$
$E_{b,\ lost\ opp}$ = determined as follows:

Determine AV_i: convert installed volume (V_i = 16.0 ft^3) to AV_i):

$$AV_i = 1.73 \times V_i$$

$$AV_i = 1.73 \times 16.0 ft^3 = 27.68 ft^3$$

Determine $E_{fed\ std}$: using the configuration of the unit, select the equation for $E_{fed\ std}$ (this is a retail purchase) from Table 1. Then use AV_i to calculate $E_{b,lost\ opp}$:

$E_{b,lost\ opp}$= 5.57x AVi +193.7
$E_{b,lost\ opp}$= 5.57x 27.68 +193.7=347.9 kwh/yr

Calculate savings using $E_{b,\ lost\ opp}$ = 347.9 $^{kWh}/_{yr}$ and E_i = 320 $^{kWh}/_{yr}$:

$$AKWH_{lostopp} = E_{b,lostopp} - E_i$$

$AKWH_{Lost\ Opp}$ =347.9-320=27.9 kwh/yr

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

$$WKW_{lostopp} = AKWH_{lostopp} \times PF_W / 1000\ ^W\!/_{kW}$$

$$SKW_{lostopp} = AKWH_{lostopp} \times PF_S / 1000\ ^W\!/_{kW}$$

Lost Opportunity Gross Peak Demand Savings, Example

Example 2: What are the peak savings for Example 1?

From Example 1 the energy savings are $AKWH_{lost\ opp}$ = 27.9$^{kWh}/_{yr}$:

Winter Peak Savings:

$$WKW_{lostopp} = AKWH_{lostopp} \times PF_W / 1000\ ^W\!/_{kW}$$

WKW=27.9 x 0.1031/1000 w/kw=0.0029

Summer Peak Savings:

$$SKW_{lostopp} = AKWH_{lostopp} \times PF_S / 1000\ ^W\!/_{kW}$$

SKW=27.9 x 0.1834/1000 w/kw=0.0051 kw

Retrofit Gross Energy Savings, Electric

Reminder: Retrofit savings are the weighted sum of Retirement savings and Lost Opportunity savings. This section presents the Retirement portion of savings. To obtain lifetime savings the following formula can be used:

$$LKWH_{Total} = (AKWH_{\mathrm{Retire}} \times RUL) + (AKWH_{LostOpp} \times EUL)$$

$$AKWH_{retire} = E_e - E_{b,retire}$$

Where:

E_e = Rated energy usage of the existing unit. If unknown, lookup using $Year_e$, V_e, and equations per Note [1].

$E_{b,\ retire}$ = Baseline energy usage. Use Table 1 and AV_e to calculate this value.

1. Convert existing volume (V_e) to adjusted volume (AV_e): $AV_e = 1.73 \times V_e$ (Note [4])
2. $E_{b,\ retire}$ will equal $E_{fed\ std}$ for all scenarios.

Turn-in measure:

$$AKWH_{turn-in} = E_e$$

Retrofit Gross Energy Savings, Example

Example 3: Calculate energy savings for replacing a 1997 model manual defrost chest freezer in working condition in an existing home if the rated usage of the existing model is unknown. The old unit's volume is 12.86 ft^3. The new unit is a chest freezer and has a volume of 12.9 ft^3 and a rated energy use of 256 kWh/yr.

Total energy savings for this example are the combination of Lost Opportunity and Retirement savings as follows:

Lost Opportunity Component:

$$AKWH_{lostopp} = E_{b,lostopp} - E_i$$

$E_i = 256\ ^{kWh}/_{yr}$

$E_{b,\ lost\ opp}$ = determined as follows:

Determine AV_i: convert installed volume (V_i = 12.9 ft^3) to AV_i :

$$AV_i = 1.73 \times V_i$$

$$AV_i = 1.73 \times 12.9 ft^3 = 22.317 ft^3$$

Determine $E_{fed\ std}$: using the configuration of the unit, select the equation for $E_{fed\ std}$ from Table 1. Then use AV_i to calculate $E_{b,lost\ opp}$:

$E_{b,lost\ opp}$= 7.29 x AV +107.8

$E_{b,lost\ opp}$= 7.29 x 22.317 +107.8 =270.5 kwh/yr

Calculate savings using $E_{b,\ lost\ opp}$ = 270.5 $^{kWh}/_{yr}$ and E_i = 256 $^{kWh}/_{yr}$:

$$AKWH_{lostopp} = E_{b,lostopp} - E_i$$

$AKWH_{lost\ opp}$ =270.5-256=14.5 kwh/yr

Retirement Component:

$$AKWH_{retire} = E_e - E_{b,retire}$$

E_e = Existing energy usage is unknown; it must be estimated:

Determine E_e:

Use $Year_e$ = 1997, V_e = 12.86ft^3, and the equation from Note [1] to calculate E_e:

$$E_e = (3142.6 - (1.5579 \times Year_e)) \times V_e$$

$$E_e = (3142.6 - (1.5579 \times 1997)) \times 12.86 ft^3 = 405\ ^{kWh}/_{yr}$$

$E_{b,retire}$ = the retirement baseline usage based on AV_e and configuration of the existing unit. For

Determine $E_{b,\ retire}$: first, calculate AV_e:

$$AV_e = 1.73 \times V_e$$

$$AV_e = 1.73 \times 12.86 ft^3 = 22.2478 ft^3$$

Use the equation for $E_{fed\ std}$ for chest freezers from Table 1. In this example $E_{b,\ retire} = E_{fed\ std}$:

$E_{fed\ std}$= 7.29 x 22.2478+107.8 =270 kwh

Calculate savings using E_e= 405 $^{kWh}/_{yr}$ and $E_{b,\ retire}$ = 270 $^{kWh}/_{yr}$:

$AKWH_{retire}$ = $E_e - E_{b,retire}$ =405-270=135 kwh/yr

Retrofit Gross Peak Demand Savings, Electric, Winter and Summer

Reminder: Retrofit savings are the sum of Retirement savings and Lost Opportunity savings. This section presents the Retirement portion of savings. To obtain total savings the following formula can be used:

$$Peak\ Demand\ Savings_{Total} = \frac{(Peak\ Demand\ Savings_{\mathrm{Retire}} \times RUL) + (Peak\ Demand\ Savings_{LostOpp} \times EUL)}{EUL}$$

Retirement Component:

$$WKW_{retire} = AKWH_{retire} \times PF_W / 1000 \, {}^{W}\!/_{kW}$$
$$SKW_{retire} = AKWH_{retire} \times PF_S / 1000 \, {}^{W}\!/_{kW}$$

Turn-in:

$$WKW_{turn-in} = AKWH_{turn-in} \times PF_W / 1000 \, {}^{W}\!/_{kW}$$
$$SKW_{turn-in} = AKWH_{turn-in} \times PF_S / 1000 \, {}^{W}\!/_{kW}$$

Retrofit Gross Peak Demand Savings, Example

Example 4: What are the demand savings for Example 3?

Because the existing unit is verified to be in working condition, the retrofit savings are made up of both a Lost Opportunity component and an Early Retirement component. Using the results of Example 3:
$AKWH_{lost\ opp}$ = 14.5 $^{kWh}/_{yr}$
$AKWH_{retire}$= 135 $^{kWh}/_{yr}$

Lost Opportunity Component:

$$WKW_{lost\,opp} = AKWH_{lost\,opp} \times PF_W / 1000 \, {}^{W}\!/_{kW}$$
$$SKW_{lost\,opp} = AKWH_{lost\,opp} \times PF_S / 1000 \, {}^{W}\!/_{kW}$$

WKW=14.5 x 0.1031/1000 w/kw=0.0014 kW

SKW=14.5 x 0.1834/1000 w/kw=0.0026 kW

Retirement Component:

$$WKW_{retire} = AKWH_{retire} \times PF_W / 1000 \, {}^{W}\!/_{kW}$$
$$SKW_{retire} = AKWH_{retire} \times PF_S / 1000 \, {}^{W}\!/_{kW}$$

WKW=135 x 0.1031/1000 w/kw=0.0139 kW

SKW=135 x 0.1834/1000 w/kw=0.0247 kW

Changes from Last Version

No Changes.

References

[1] KEMA, Evaluation of the Weatherization Residential Assistance Partnership and Helps Programs (WRAP/Helps), September 10, 2010

[2] California Energy Commission (CEC) Appliance Database.
Online historical appliance database: http://www.energy.ca.gov/appliances/database/historical_excel_files/
Online current (meeting minimum standards) appliance database: http://www.appliances.energy.ca.gov/

[3] Federal Register, Vol. 76, No. 179. 10 CFR Part 430. Energy Conservation Program: Energy Conservation Standards for Residential Refrigerators, Refrigerator-Freezers, and Freezers. Published September 15, 2011, Effective November 14, 2011, Compliance date September 15, 2014.

[4] Nexus Market Research, Inc. Impact, Process, and Market Study of the Connecticut Appliance Retirement Program: Overall Report, December 23, 2005. Table ES.4, Page 3.

Notes

[1] The unadjusted annual energy usage of the existing unit can usually be found in the CEC database (Ref [5]) or equivalent source by brand and model number.

If actual usage of the existing unit is unknown, the equations in Table 3, below, may be used to estimate the energy usage of the existing unit, based on its known volume and estimated age. The following equations are based on average rated usage of models from Ref [5] added between 1978 and 2003.

Table 3: Equations to estimate existing energy usage if unknown

Category	Units 1978 and newer, Estimated E_e	Units prior to 1978, Estimated E_e (capped at 1978 levels)
Upright freezers with manual defrost	$(2797.8-(1.382\times Year_e))\times V_e$	$(64.204\times V_e)$
Upright freezers with automatic defrost	$(4974.3-(2.461\times Year_e))\times V_e$	$(108.46\times V_e)$
Chest freezers and all other freezers except compacts	$(3142.6-(1.5579\times Year_e))\times V_e$	$(61.074\times V_e)$

[2] The baseline new model is represented by the 2014 Federal Standard level (Table 1). Because in many cases the installed energy efficient unit does not share the same size and category as the existing unit, the Federal Standard energy usage, $E_{fed\ std}$, must be calculated separately for Lost Opportunity (using the Adjusted Volume and category of the new installed unit) and Retirement (using the Adjusted Volume and category of the existing unit).

[3] Exceptions to standard calculations for replacement of existing units may occur in the following special situations:

a. If the annual kWh usage of the existing unit is already less than or equal to that of the baseline level ($E_e \leq E_b$), no retirement savings may be claimed.
b. If the annual kWh usage of the existing unit is less than that of the baseline level but greater than that of the new installed unit ($E_i < E_e < E_b$), the lost opportunity component of savings may still be claimed, but the existing unit Annual kWh usage must be used for the baseline rather than Federal Standard.
c. If annual kWh usage of the new installed unit greater than or equal to that of the existing unit ($E_e \leq E_i$), regardless of size, no savings may be claimed.

4.3.13 DEHUMIDIFIER

Description of Measure

Savings detailed below cover the purchase of a high efficiency dehumidifier.

Savings Methodology

Lost Opportunity Measure:

- Lost Opportunity savings are the difference in energy use between a baseline model (Note [4]) based on the capacity of the installed unit, and the chosen high efficiency new model (Note [1]), continuing for the Effective Useful Life (EUL) from Appendix 4.
- The Retail measure is a Lost Opportunity-only methodology, as the existing unit is not verified.

Retrofit Measure:

- Uses the same methodology as a Lost Opportunity measure.
- In the case of early retirement of a working unit where the unit would have otherwise been installed until failure, lifetime "Retirement" savings are claimed additional to the lifetime "Lost Opportunity" savings (see Section 1.4).
- Retirement savings are the difference in energy use between the older unit (Note [2]) and a baseline model (Note [4]) based on the capacity of the existing unit, continuing for the Remaining Useful Life (RUL) from Appendix 4.

Energy usage for dehumidifiers depends on the capacity and the rated Energy Factor.

Inputs

Symbol	Description
Cap_i	Capacity of the new installed unit, in pints/day
Cap_e	Capacity of the (old) existing unit, in pints/day
EF_i	Energy Factor of the new installed unit
EF_e	Energy Factor of the (old) existing unit
	Make and Model of (old) existing unit
	Make and Model of new installed unit

Nomenclature

Symbol	Description	Units	Values	Comments
days/yr	Equivalent Annual Days per year equaling 1620 hrs/yr	days/yr	67.5	Ref [4]
$EF_{b,\ lost\ opp}$	Energy Factor of baseline new unit based on size of new unit	L/kWh	2012 Federal Standard	Table 1 , Note [4]
$EF_{b,\ retire}$	Energy Factor of baseline new unit based on size of existing unit	L/kWh	2012 Federal Standard	Table 1 , Note [4]
EF_e	Energy Factor of (old) existing unit	L/kWh	actual	Note [2]
EF_i	Energy Factor of new installed unit	L/kWh	actual	
$size_e$	Capacity of the (old) existing unit	pints/day	actual	
$size_i$	Capacity of the new installed unit	pints/day	actual	

Lost Opportunity Gross Energy Savings, Electric

$$AKWH_{lostopp} = Cap_i \times 0.473 \, {}^{Liters}\!/_{pint} \times 67.5 \, {}^{days}\!/_{yr} \times \left(\frac{1}{EF_{b,lostopp}} - \frac{1}{EF_i} \right)$$

Table 1 provides the corresponding Energy Factor baselines based on the capacity of the unit:

Table 1: Energy Factor Baseline ($EF_{b, lost\ opp}$ and $EF_{b, retire}$)

Capacity (Pints/day)	2012 EF Federal Standard (Ref [5])
≤ 25	**1.35**
> 25 to ≤ 35	
> 35 to ≤ 45	**1.50**
> 45 to ≤ 54	**1.60**
> 54 to < 75	**1.70**
≥ 75 to ≤ 185	**2.5**

Lost Opportunity Gross Energy Savings, Example

Example 1: A 64 pint/day unit with an energy factor of 1.9 is purchased through a retail promotion. What are the energy savings?

$$AKWH_{lostopp} = Cap_i \times 0.473 \, {}^{Liters}\!/_{pint} \times 67.5 \, {}^{days}\!/_{yr} \times \left(\frac{1}{EF_{b,lostopp}} - \frac{1}{EF_i} \right)$$

Use:
Cap_i = 64 pints/day
$EF_{b,lost\ opp}$ = 1.70 (from Table 1)
EF_i = 1.9

Calculate $AKWH_{lost\ opp}$:

$$AKWH_{lostopp} = 64 \, {}^{pints}\!/_{day} \times 0.473 \, {}^{Liters}\!/_{pint} \times 67.5 \, {}^{days}\!/_{yr} \times \left(\frac{1}{1.7} - \frac{1}{1.9} \right) = 126.5 \, {}^{kWh}\!/_{yr}$$

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

$$SKW_{lostopp} = \frac{AKWH_{lostopp}}{1620 \, {}^{hrs}\!/_{yr}}$$

No winter demand savings shall be claimed (Note [3]).

Lost Opportunity Gross Peak Demand Savings, Example

Example 2: What are the demand savings from Example 1?

$$SKW_{lostopp} = \frac{AKWH_{lostopp}}{1620 \, {}^{hrs}\!/_{yr}}$$

Use:
$AKWH_{lost\ opp} = 126.5 \, {}^{kWh}/_{yr}$

$$SKW_{lostopp} = \frac{126.5 \, {}^{kWh}\!/_{yr}}{1620 \, {}^{hrs}\!/_{yr}} = 0.0781 \, kW$$

Retrofit Gross Energy Savings, Electric

Reminder: Retrofit savings are the weighted sum of Retirement savings and Lost Opportunity savings. This section presents the Retirement portion of savings. To obtain lifetime savings the following formula can be used:

$$LKWH_{Total} = \left(AKWH_{\text{Retire}} \times RUL\right) + \left(AKWH_{LostOpp} \times EUL\right)$$

$$AKWH_{retire} = Cap_e \times 0.473\,{}^{Liters}/_{pint} \times 67.5\,{}^{days}/_{yr} \times \left(\frac{1}{EF_e} - \frac{1}{EF_{b,\,retire}}\right)$$

Refer to Table 1 for the corresponding $EF_{b,\,retire}$ based on the capacity of the unit.

Retrofit Gross Energy Savings, Example

Example 3: A working 30 pint/day unit with an unknown EF_e is replaced in an existing home with a high efficiency 30 pint/day unit with an EF_i of 1.85 Liters/kWh. What are the energy savings?

Total energy savings for this example are the combination of Lost Opportunity and Retirement savings as follows:

Lost Opportunity Component:

$$AKWH_{lost\,opp} = Cap_i \times 0.473\,{}^{Liters}/_{pint} \times 67.5\,{}^{days}/_{yr} \times \left(\frac{1}{EF_{b,lost\,opp}} - \frac{1}{EF_i}\right)$$

Use:
Cap_i = 30 pints/day
EF_i = 1.85 Liters/kWh
$EF_{b,\text{ lost opp}}$ = 1.35 (from Table 1)

Calculate $AKWH_{lost\,opp}$ component:

$$AKWH_{lost\,opp} = 30\,{}^{pints}/_{day} \times 0.473\,{}^{Liters}/_{pint} \times 67.5\,{}^{days}/_{yr} \times \left(\frac{1}{1.35} - \frac{1}{1.85}\right) = 191.8\,{}^{kWh}/_{yr}$$

Retirement Component:

$$AKWH_{retire} = Cap_e \times 0.473\,{}^{Liters}/_{pint} \times 67.5\,{}^{days}/_{yr} \times \left(\frac{1}{EF_e} - \frac{1}{EF_{b,\,retire}}\right)$$

Use:
Cap_e = 30 pints/day
EF_e = unknown; using Cap_e = 30 pints/day, the 2007 $EF_{fed\,std}$ from Table 2 = 1.20 (Note [2])
$EF_{b,\,retire}$ = 1.35 ($Cap_e = Cap_i$, therefore $EF_{b,lost\,opp} = EF_{b,retire}$)

Calculate $AKWH_{retire}$ component:

$$AKWH_{retire} = 30\,{}^{pints}/_{day} \times 0.473\,{}^{Liters}/_{pint} \times 67.5\,{}^{days}/_{yr} \times \left(\frac{1}{1.2} - \frac{1}{1.35}\right) = 88.7\,{}^{kWh}/_{yr}$$

Retrofit Gross Peak Demand Savings, Electric, Winter and Summer

Reminder: Retrofit savings are the sum of Retirement savings and Lost Opportunity savings. This section presents the Retirement portion of savings. To obtain total savings the following formula can be used:

$$Peak\ Demand\ Savings_{Total} = \frac{\left(Peak\ Demand\ Savings_{\text{Retire}} \times RUL\right) + \left(Peak\ Demand\ Savings_{LostOpp} \times EUL\right)}{EUL}$$

$$SKW_{retire} = \frac{AKWH_{retire}}{1620 \, {}^{hrs}/_{yr}}$$

No winter demand savings shall be claimed (Note [3]).

Retrofit Gross Peak Demand Savings, Example

Example 4: What are the demand savings for Example 3?

Because the existing unit is verified to be in working condition, the retrofit savings are made up of both a Lost Opportunity component and an Early Retirement component. Using the results of Example 3:
$AKWH_{lost\ opp} = 191.8 \, {}^{kWh}/_{yr}$
$AKWH_{retire} = 88.7 \, {}^{kWh}/_{yr}$

Lost Opportunity Component:

$$SKW_{lost\,opp} = \frac{191.8 \, {}^{kWh}/_{yr}}{1620 \, {}^{hrs}/_{yr}} = 0.1184 \, {}^{kWh}/_{yr}$$

Retirement Component:

$$SKW_{retire} = \frac{88.7 \, {}^{kWh}/_{yr}}{1620 \, {}^{hrs}/_{yr}} = 0.0547 \, {}^{kWh}/_{yr}$$

Changes from Last Version

No changes.

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] ENERGY STAR Dehumidifiers website, last accessed August 2, 2012. http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=DE

[5] Federal Register Volume 74, No 66, published April 8, 2009, Part II, DOE, 10 CFR Part 340, Energy Conservation Program: Energy Conservation Standards for Certain Consumer Products (Dishwashers, Dehumidifiers, Microwave Ovens, and Electric and Gas Kitchen Ranges and Ovens) and for Certain Commercial and Industrial Equipment (Commercial Clothes Washers), Final Rule, effective October 1, 2012. Page 16042, Table I.1.

Notes

[1] The Energy Factor for new installed ENERGY STAR units may be obtained through the ENERGY STAR website, Ref [4].

[2] If the Energy Factor of the existing unit is unknown, it shall be based on the 2007 Federal Standard EF listed in Table 2 for the existing unit's capacity. If the capacity of the existing unit is unknown, the capacity of the new unit shall be used.

Table 2: Energy Specifications: Energy Factor (EF)

Capacity (Pints/day)	2007 Federal Standard (Ref [3])	2008 ENERGY STAR (Ref [2])	2012 Federal Standard (Ref [5])	2012 ENERGY STAR (Ref [1])
≤ 25	1.00	1.20	1.35	1.85
> 25 to ≤ 35	1.20	1.40		
> 35 to ≤ 45	1.30	1.50	1.50	
> 45 to ≤ 54	1.30	1.60	1.60	
> 54 to < 75	1.50	1.80	1.70	
≥ 75 to ≤ 185	2.25	2.50	2.5	2.80

[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] The baseline new model is represented by the 2012 Federal Standard level shown in Table 1. Because in many cases the installed energy efficient unit does not share the same capacity as the existing unit, the baseline energy usage, must be calculated separately for Lost Opportunity (using the capacity of the new installed unit) and Retirement (using the capacity of the existing unit).

4.3.14 ELECTRONICS

Description of Measure

Purchase of a new ENERGY STAR qualified electronics equipment. Electronics equipment includes:

- Blu-Ray player
- Computer Monitor (Displays)
- Cordless Phones
- Desktop Computers
- DVD player
- Home Theatre in a Box Systems
- Laptop Computers
- Room Air Cleaners
- Set-top Boxes & Cable Boxes
- Sound Bars

Televisions***Savings Methodology***

The savings estimates in the Table 1 below are for ENERGY STAR qualified electronics equipment versus conventional equipment. (References [1] & [2]).
Note: *No demand savings have been identified for this measure*

Inputs

Symbol	Description	Units
	No of units purchased	

Nomenclature

Symbol	Description	Units	Values	Comments
AKWH	Annual Electric Energy Savings	kWh		Table 1
SKW	Summer Demand Savings	kW	0	
WKW	Winter Demand Savings	kW	0	

Lost Opportunity Gross Energy Savings, Electric

The savings estimates in the following table are for ENERGY STAR qualified electronics equipment versus conventional equipment.

Table 1: ENERGY STAR Electronics Annual Savings

Electronics Equipment	**Energy Savings AKWH**	**Comments**
Blu-Ray player	8	Reference [1]
Computer Monitor (Displays)	14	Reference [2]
Cordless Phones	26	Savings based on the difference between a conventional cordless phone (37.1 kWh) and an ENERGY STAR unit (11.5 kWh). Ref [1]
Desktop Computers	77	Reference [2]
DVD player	19	Reference [1]
Home Theatre in a Box	18	Reference [3]
Laptop Computers	24	Reference [2]
Room Air Cleaners	227	Reference [3]
Set-top Boxes & Cable Boxes	54	Reference [1]
Sound Bars	71	Reference [3]
Televisions	43	Savings based on the difference between a 40” conventional TV and an ENERGY STAR unit. Ref [1]

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

WKW = 0
SKW = 0

No demand savings are claimed for this measure.

Changes from Last Version

No Changes

References

[1] Savings Estimate for ENERGY STAR Qualified Consumer Electronics, ENERGY STAR Consumer Electronics Calculator, ENERGY STAR <www.energystar.gov> Last accessed on July 24, 2013.

[2] Savings Estimate for ENERGY STAR Qualified Office Equipment, ENERGY STAR Office Equipment Savings Calculator, ENERGY STAR <www.energystar.gov> Last accessed on July 24, 2013.

[3] EPA Next Gen Product Analysis_10.9.14.xlsx. Last Accessed on July 1, 2015

4.3.15 ADVANCED POWER STRIPS

Description of Measure

Installing an advanced power strip.

Savings Methodology

Deemed savings based on advanced smart trip feature to eliminate the stand by losses to eliminate standby power loss from various electronic products commonly used in the home. Baseline is the conventional power surge protector or no power strips and peripherals on.

Inputs

Symbol	Description	Units
	No of units	

Nomenclature

Symbol	Description	Units	Values	Comments
AKWH	Annual Electric Energy Savings	kWh		Ref[1]
SKW	Summer Demand Savings	kW		Ref[2]
WKW	Winter Demand Savings	kW		Ref[2]
CFs	summer seasonal peak coincidence factor		0.73	Ref[2]
CFw	winter seasonal peak coincidence factor		1.0	Ref[2]

Gross Energy Savings, Electric

AKWH = 79 kwh

Gross Seasonal Peak Demand Savings, Electric (Winter and Summer)

$SKW = .017 \times .73 = .012\ kW$
$WKW = .017 \times 1\ kW$ = .017 kW

Changes from Last Version

Measure Life updated in Appendix 4

References

[1] Ecos 2009 Smart plug Strips
[2] Estimated using demand allocation methodology described in Cadmus demand impact model (2012) prepared for Massachusetts Program Administrators.

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. High-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. 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 (Note [2]). Current UDRH values are based on the 2011 RNC study (Ref [1]).

Inputs

Symbol	Description
REM	REM simulation file submitted by an HERS rater

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.

The savings are based on an "average" home built in Connecticut as determined by a baseline evaluation and used as a baseline home UDRH (Reference [1]). ***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, Electric

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.

Changes from Last Version

No changes.

References

[1] Connecticut 2011 Baseline Study of Single-Family Residential New Construction, Final Report, Oct 1, 2012, NMR Group, Inc., KEMA, Inc., Cadmus and Dorothy Conant.

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] The UDRH is based on data collected through evaluations, and baseline levels are prescriptive code values or those established from the most recent baseline studies available and program administrator field experience.

4.4.4 INFILTRATION REDUCTION TESTING (BLOWER DOOR TEST)

Description of Measure

Blower Door Test equipment is used to verify infiltration reduction.

Savings Methodology

REM/Rate (Ref [1]), a residential energy analysis, code compliance and rating software, was used to simulate energy use in a typical home before and after infiltration reduction (CFM air leakage at 50 Pascals pressure difference). The average energy savings in MMBtu and kWh were estimated from the results of the REM/Rate simulations, then converted to the appropriate fuels using unit conversions and assumed distribution losses. The demand savings were also based on the REM simulation.

This methodology is used to estimate infiltration savings only when savings are a result of sealing surfaces that provide direct separation between conditioned and non-conditioned space. For multi-family units (defined as more than 4 units) that share a common boundaries or connecting hallways, either a guarded blower door test should be performed by pressurizing all adjacent units to isolate the leakage to the outside, or the leakage of the entire structure should be measured using a single test. If an unguarded test of a unit is performed (i.e. individual units or sections of a building are tested) that result should be corrected using the adjustment equation below. This equation adjusts for inter-unit leakage through shared surfaces. For all blower door testing, savings may be subject to a final analysis which may include a billing analysis, calibration, engineering models, or other applicable methods.

Note: these savings are based on envelope reductions only and should not be applied to duct sealing reductions which are addressed as a separate measure (Measure 4.2.9).

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
REM	Savings factor in energy units per CFM reduction based on REM/Rate simulation			
SKW	Summer Demand Savings	kW		
WKW	Winter Demand Savings	kW		
BF	Blower door CFM reduction Factor		1	SF
			Calculated	MF

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
Cooling (Room AC: Window, Sleeve, or PTAC) (Note [1])	$REM_{Cooling}$	0.0168	kWh

For Electric Resistive, Heat Pump or Geothermal Heating Systems,

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

For Fossil Fuel heating with air handler unit,

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

For homes with cooling,

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

Retrofit Gross Energy Savings, Fossil Fuel

Table 2: Retrofit Fossil Fuel Savings per CFM Reduction (at 50 Pa)

Measure		Energy Savings	Units
Fossil Fuel Heating		0.012	MMBtu
Natural Gas	REM_{NG}	0.117	Ccf
Propane	$REM_{Propane}$	0.131	Gal
Oil	REM_{Oil}	0.087	Gal

For homes with natural gas heating system,

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

For homes with oil heating system,

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

For homes with propane heating system,

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

Retrofit Gross Energy Savings, Example

A blower door test was performed in a 2400 ft^2, 1940's Cape Cod style home in Hartford, heated primarily by an oil boiler and cooled by Room AC. 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?

Oil Heating savings may be calculated using the following equation:

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

$$AOG_H = 0.087 \times (1850 - 1575) \times 1 = 23.9 \, {}^{\text{Gal-Oil}}/_{\text{yr}}$$

Cooling savings may also be claimed as follows:

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

$$AKWH_C = 0.0168 \times (1850 - 1575) \times 1 = 4.62 \, {}^{kWh}\!/_{yr}$$

Retrofit Gross Seasonal Peak Demand Savings, Electric (Winter and Summer)

Table 3: Demand Savings, kW per CFM Reduction

Electric Resistance and Heat Pump	Geothermal - Retrofit	Central AC and HP	Room AC (Note [2])
REM_{WKW}	REM_{WKW}	REM_{SKW}	REM_{SKW}
0.00117	0.00039	0.00009	0.00002

$$WKW_H = REM_{WKW} \times (CFM_{Pre} - CFM_{Post}) \text{ x BF}$$
$$SKW_C = REM_{SKW} \times (CFM_{Pre} - CFM_{Post}) \text{ x BF}$$

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

For homes with natural gas heating system,

$$PD_H = ACCF_H \times PDF_H$$

Retrofit Gross Peak Demand Savings, Example

For the above Retrofit example, what is the summer demand savings for this home?

$$SKW_C = REM_{SKW} \times (CFM_{Pre} - CFM_{Post}) \text{ x BF}$$
$$SKW_C = 0.00002 \times (1850 - 1575) \times 1 = 0.0055 \text{ kW}$$

Changes from Last Version

No changes

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/Rate™ was performed by C&LM Planning team, Northeast Utilities, August 2008.

[2] Nexant Market Research, Inc., “Market Assessment for ENERGY STAR Room Air Conditioners in Connecticut,” Cambridge, MA, 2007, pp. 17,18

[3] RLW Analytics, “Final Report: Coincidence Factor Study: Residential Room Air Conditioners,” Middletown, CT, 2008, p. iv, p. 22

[4] ADM Associates, Inc., "Residential Central AC Regional Evaluation," Sacramento, CA, 2009, pp. 4-4

[5] Technical Report: Multifamily Envelope Leakage Model O. Faakye & D. Griffiths Consortium for Advanced Residential Buildings February 2014

Notes

[1] Reference 5 formula on page 24 was used:

Calculated Blower door CFM reduction = BF × Measured CFM (Unguarded Blower Door)

BF = 0.8610 + A + B − 0.0044 x C − 0.0002xD + 0.0012 x F-0.0054x G

Where,

A = ClimateZone_5a: -0.0423

B =Ductwork Location: Conditioned Space: 0.0511
Ductwork Location: Unconditioned Space: 0.2700
Ductless Location: 0

C = Door Area (ft^2)

D = Shared Surface Area (ft^2)

F = Envelope Perimeter (ft) is used to describe the sum of all the lengths of the edges of the unit, common and exterior surfaces

G = Age (years)*

*The dominant weighing factor on the blower door factor equation is the age of the building. As the age of the house increases the blower door factor will tend to decrease to an unreasonable small number. In order to calculate a fair amount of savings it may be necessary to cap the age at a low number on a project-by-project basis.

[2] Room Air Conditioning cooling savings are derived from factors found in Ref [2,3,4].

4.4.8 WINDOW REPLACEMENT

Description of Measure

Installation of ENERGY STAR window to replace existing single pane window that is 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 / Heating system type	
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			
$\ldots_{es}$	ENERGY STAR			Ref[6]
$\ldots_{HP}$	Heat Pump Heating Only			

Symbol	Description	Units	Values	Comments
$\ldots_R$	Electric Resistance Heating Only			
$\ldots_{RAC}$	Room Air Conditioners (Cooling Only)			Note [3]

Retrofit Gross Energy Savings, Electric

Table 1: Annual Electric Energy Usage (Note [2])

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	5.57	1.49

$$A = \frac{D_H \times D_W}{144 \, {}^{in^2}\!/_{ft^2}}$$

Heating (Electric Resistive Heating and Heat Pump, Note [1]):

$$AKWH_{H,R} = (AEH_b - AEH_{es}) \times A$$

$$AKWH_{H,HP} = \frac{(AEH_b - AEH_{es})}{2} \times A$$

Example, for going from a baseline to an Energy Star window:

$$AKWH_{H,R} = (22.02 - 5.66) \times A$$

$$AKWH_{H,R} = 16.36 \times A$$

$$AKWH_{H,HP} = \frac{(22.02 - 5.66)}{2} \times A$$

$$AKWH_{H,HP} = 8.18 \times A$$

Cooling (CAC Only):

$$AKWH_{C,CAC} = (AEH_b - AEH_{es}) \times A$$

$$AKWH_{C,CAC} = (2.57 - 1.49) \times A$$

$$AKWH_{C,CAC} = 1.08 \times A$$

Cooling (Room A/C Only): (Note [3])

$$AKWH_{C,RAC} = (28.3\%) \times AKWH_{C,CAC}$$

$$AKWH_{C,RAC} = 0.305 \times A$$

Retrofit Gross Energy Savings, Fossil Fuel

Table 2: Annual Fossil Fuel Energy Usage

Window Type	AGU (Ccf/ft²)	AOU (gal/ft²)	APG_H (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:

Natural Gas:

$$ACCF_H = (AGU_b - AGU_{es}) \times A$$
$$ACCF_H = (1.08 - 0.28) \times A$$
$$ACCF_H = 0.80 \times A$$

Oil:

$$AOG_H = (AOU_b - AOU_{es}) \times A$$
$$AOG_H = (0.80 - 0.20) \times A$$
$$AOG_H = 0.60 \times A$$

Propane:

$$APG_H = (APU_b - APU_{es}) \times A$$
$$APG_H = (1.21 - 0.31) \times A$$
$$APG_H = 0.90 \times A$$

Retrofit Gross Energy Savings, Example

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.

$$A = \frac{24\,in \times 36\,in}{144 \, {}^{sqin}\!/\!{}_{sf}} = 6\,sq\,ft$$

$$AKWH_H = 16.36 \, {}^{kWh}\!/\!{}_{sf} \times 6\,sqft = 98\,kWh$$
$$AKWH_C = 1.08 \, {}^{kWh}\!/\!{}_{sf} \times 6\,sqft = 6.5\,kWh$$

Retrofit Gross Seasonal Peak Demand Savings, Electric (Winter and Summer)

If home has electric resistance heat:

$$WKW = AKWH_{H,R} \times \frac{PFW}{1000 \, {}^{W}\!/\!{}_{kW}} = 16.36 \, {}^{kWh}\!/\!{}_{ft^2} \times A \times \frac{0.570 \, {}^{W}\!/\!{}_{kWh}}{1000 \, {}^{W}\!/\!{}_{kW}} = 0.0093 \, {}^{kW}\!/\!{}_{ft^2} \times A$$

If home has a heat pump: (Note [1])

$$WKW = AKWH_{H,HP} \times \frac{PFW}{1000} = \frac{0.0093}{2} \times A = 0.00465 \times A$$

If home has central air conditioning: (Note [2])

$$SKW_{C,CAC} = \left(0.0046 \, {}^{kW}\!/\!{}_{sf} - 0.0025 \, {}^{kW}\!/\!{}_{sf}\right) \times CF_S \times A$$
$$SKW_{C,CAC} = 0.0012 \, {}^{kW}\!/\!{}_{sf} \times A$$

If home has one or more room air conditioners: (Note [3])

$$SKW_{C,RAC} = (25.1\%) \times SKW_{C,CAC}$$

$$SKW_{C,RAC} = 0.00031 \,{}^{kW}\!/_{sf} \times A$$

Retrofit Gross Peak Day Savings, Natural Gas

$$PD_H = ACCF_H \times PDF_H$$

Retrofit Gross Peak Demand Savings, Example

For the above example with electric resistance heat and central air, demand savings are as follows:

$$WKW = 0.0093 \,{}^{kW}\!/_{sf} \times 6\,ft^2 = 0.056kW$$

$$SKW_{CAC} = 0.0012 \,{}^{kW}\!/_{sf} \times 6\,ft^2 = 0.0072kW$$

Changes from Last Version

No changes.

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

[3] Nexant Market Research, Inc., “Market Assessment for ENERGY STAR Room Air Conditioners in Connecticut,” Cambridge, MA, 2007, pp. 17,18

[4] RLW Analytics, “Final Report: Coincidence Factor Study: Residential Room Air Conditioners,” Middletown, CT, 2008, p. iv, p. 22

[5] ADM Associates, Inc., “Residential Central AC Regional Evaluation,” Sacramento, CA, 2009, pp. 4-4

[6] ENERGY STAR Program Requirements for Residential Windows, Doors, and Skylights – Partner Commitments, January 1, 2016

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 one-half those of 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.

[3] Room Air Conditioning cooling savings are derived from factors found in Ref [3,4, and 5].

4.4.9 THERMAL ENCLOSURE

Description of Measure

New homes that meet or exceed the RESNET Grade 1 High Performance insulation standard. In addition, homes must have at least R-40 ceiling insulation and R-21 above grade wall insulation and must have a mechanical ventilation system.

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. For rated homes, savings from this measure are superseded by REM savings.*

Savings were calculated for both electric and fossil fuels based on REM/Rate modeling of homes with the insulation standards required by this measure compared to the Baseline new home (Ref [1]).

Inputs

Symbol	Description	Units
A	Surface area above grade of conditioned space	ft^2
	System/Fuel Type (Electric Resistive, Heat Pump, air handler, Central A/C, Gas, Oil, Propane, etc...)	

Nomenclature

Symbol	Description	Units	Values	Comments
A	Surface area above grade of conditioned space	ft^2		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 ft^2	kW/ft^2	0.00004	Note [1]
REM_{WKW}	Modeled Winter kW per ft^2	kW/ft^2	0.00039	Note [1][2]
SKW	Summer Demand Savings	kW		
WKW	Winter Demand Savings	kW		

Lost Opportunity Gross Energy Savings, Electric

Table 1 - Electric Savings per ft^2 (Note [1])

System Type	Symbol	Energy Savings	Units
Electric Resistance	REM_H	0.910	kWh/ ft^2
Heat Pump Heating	REM_H	0.530	kWh/ ft^2
Ground source Heat Pump Heating	REM_H	0.295	kWh/ ft^2
Air Handler (fan) Heating	REM_F	0.018	kWh/ ft^2
Cooling	REM_C	0.008	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,

$$AKWH_C = REM_C \times A$$

Lost Opportunity Gross Energy Savings, Fossil Fuel

Table 2 - Fossil Fuel Savings per ft^2 (Note [1])

Heating Fuel	Symbol	Energy Savings	Units
Fossil Fuel Savings		0.0039	MMBtu/ft^2
Natural Gas	REM_G	0.0354	Ccf/ ft^2
Oil	REM_O	0.0279	Gal/ ft^2
Propane	REM_P	0.0392	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,

$$APG_H = REM_P \times A$$

Lost Opportunity Gross Energy Savings, Example

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 ft^2. What are the annual energy savings?

$$ACCF_H = REM_G \times A = 0.0354 \times 1{,}100 = 39\ Ccf$$

Additional electric savings claimed for air handling system,

$$AKWH_H = REM_F \times A = 0.018 \times 1{,}100 = 19\ kWh$$

Additional cooling savings claimed for central AC system,

$$AKWH_C = REM_C \times A = 0.008 \times 1{,}100 = 9kWh$$

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

$$PD_H = ACCF_H \times PDF_H$$

Lost Opportunity Gross Peak Demand Savings, Example

Insulation was installed in a new home. The insulation meets the RESNET Grade 1 High Performance insulation standard. The home is equipped with a natural gas furnace and a central AC. The total floor area of conditioned space is 1,500 ft^2. What are the peak demand savings (electric and natural gas)?

Summer demand savings,

$$WKW_H = REM_{WKW} \times A = 0.0004 \times 1{,}100 = 0.43\ kW$$

$$SKW_C = REM_{SKW} \times A = 0.00004 \times 1{,}100 = 0.05\ kW$$

Natural gas peak day savings,

$$PD_H = ACCF_H \times PDF_H = 53 \times 0.00977 = 0.52\ Ccf$$

Non Energy Benefits

Increased personal comfort.

Changes from Last Version

No changes.

References

[1] NMR Group Inc., Connecticut 2011 Baseline Study of Single- Family Residential New Construction, October 1 , 2012.

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] Winter Demand Savings (kW) only apply for Electric Resistance, Heat Pump and Ground Source Heat Pump heating systems.

4.4.10 INSTALL STORM WINDOW

Description of Measure

Installation of storm window to augment existing single pane window that is 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 zero.
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
	Primary existing heating fuel type	

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]
$AKWH_H$	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

$$A = \frac{D_H \times D_W}{144 \, {}^{in^2}/_{ft^2}}$$

Heating (Electric Resistive Heating and Heat Pump, Note [1])**:**

$$AKWH_{H,R} = \left(AEH_b - AEH_{dp}\right) \times A$$

$$AKWH_{H,R} = (22.02 - 10.79) \times A$$

$$AKWH_{H,R} = 11.23 \times A$$

$$AKWH_{H,HP} = 5.62 \times A$$

<u>Retrofit Gross Energy Savings, Fossil Fuel</u>

Table 2: Annual Gas Energy Usage

Window Type	AGU (kWh/ft^2)	AOU (gal/ft^2)	APG (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:
Gas:

$$ACCF_H = (AGU_b - AGU_{dp}) \times A = (1.08 - 0.53) \times A$$

$$ACCF_H = 0.55 \times A$$

Oil:

$$AOG_H = (AOU_b - AOU_{dp}) \times A = (0.80 - 0.39) \times A$$

$$AOG_H = 0.41 \times A$$

Propane

$$APG_H = (APU_b - APU_{dp}) \times A = (1.21 - 0.59) \times A$$

$$APG_H = 0.62 \times A$$

Retrofit Gross Energy Savings, Example

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 resistance heat:

$$WKW = AKWH_{H,R} \times \frac{PFW}{1000\,{}^{W}\!/_{kW}} = 11.23\,{}^{kWh}\!/_{ft^2} \times A \times \frac{0.570\,{}^{W}\!/_{kWh}}{1000\,{}^{W}\!/_{kW}} = 0.0064\,{}^{kW}\!/_{ft^2} \times A$$

If home has a heat pump: (Note [1])

$$WKW = \frac{AKWH_{H,R}}{2} \times \frac{PFW}{1000\,{}^{W}\!/_{kW}} = \frac{0.0064\,{}^{kW}\!/_{ft^2}}{2} \times A = 0.0032\,{}^{kW}\!/_{ft^2} \times A$$

$$SKW = 0$$

Retrofit Gross Peak Demand Savings, Example

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

No changes.

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

Thermal barrier applied to attic hatch, attic stairs, or whole house fan.

Savings Methodology

The energy savings are estimated in two parts: conductive savings and infiltration reduction savings. 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 infiltration savings if not included in blower door measure.*

Inputs

Symbol	Description	Units
	Type of attic penetration being insulated.	
	Was the infiltration reduction included in blower door measurements?	
	Heating fuel /Heating system type (Electric resistive, Heat Pump, Gas…)	

Nomenclature

Symbol	Description	Units	Values	Comments
A	Total area of thermal barrier	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 (Fossil fuel)	%	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	Table 1	
R_i	Effective R-value - installed	ft^2hr^oF/Btu	Table 1	
WKW_H	Winter Seasonal Demand Savings - Heating	kW	Table 5	

Retrofit Gross Energy Savings, Electric

$$ABTU = ABTU_{Conductive} + ABTU_{Infiltration}$$

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	$ABTU_{Infiltration}$
Attic Hatch	154,876
Attic pull down Stairs	533,461
Whole House Fan	243,195

Reminder: *Only include infiltration savings if not included in blower door measure.*

Annual Electric Savings:

$$AKWH_H = AKWH_{Conductive} + AKWH_{Infiltration}$$

$$kWh = \frac{Btu}{3{,}412 Btu / kWh}$$

Table 3: Annual Electric Savings

Insulation Measure	$AKWH_{Conductive}$ For Electric Resistive	$AKWH_{Infiltration}$ For Electric Resistive	$AKWH_{Conductive}$ For Heat pump	$AKWH_{Infiltration}$ For Heat pump
Attic Hatch	81	45	40.5	22.5
Attic pull down Stairs	151	156	75.5	78
Whole House Fan	71	71	35.5	35.5

Reminder: *Only include infiltration savings if not included in blower door measure.*

<u>Retrofit Gross Energy Savings, Fossil Fuel</u>

Using savings from Tables 1 and 2 and an equipment efficiency of 75%, the fossil fuel savings are as follows. Savings by fuel type:

Gas: $ACCF_H = \frac{ABTU_H}{75\% \times 102{,}900 \, {}^{Btu}/_{Ccf}}$

Oil: $AOG_H = \frac{ABTU_H}{75\% \times 138{,}690 \, {}^{Btu}/_{Gal}}$

Propane: $APG_H = \frac{ABTU_H}{75\% \times 91{,}330 \, {}^{Btu}/_{Gal}}$

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)

Table 5: Winter Demand Savings

Insulation Measure	$WKW_{H\ Conductive}$ For Electric Resistive	$WKW_{H\ Infiltration}$ For Electric Resistive	$WKW_{H\ Conductive}$ For Heat Pump	$WKW_{H\ Infiltration}$ For Heat Pump
Attic Hatch	0.05	0.03	0.02	0.01
Attic pull down Stairs	0.09	0.09	0.04	0.04
Whole House Fan	0.04	0.04	0.02	0.02

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

No changes.

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].
Baseline assumptions
$R_{existing}$ = 0.61 + 0.47 + 0.61 = 1.69 for hatch and stairs
$R_{existing}$ = 0.61 + 0.10 + 0.61 = 1.32 for fan.
Where:
3/8” particle board = R 0.47
Air film = 0.61

[2] 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.

4.4.13 INFILTRATION REDUCTION (PRESCRIPTIVE)

Description of Measure

Prescriptive infiltration reduction measures not validated by Blower Door testing, such as 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 (4.4.4) 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 directly between conditioned space and unconditioned space 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 claimed since cooling energy savings are not quantified.

A weatherization project should be custom only if it 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.
	Heating system type

Nomenclature

Symbol	Description	Units	Values	Comments
$\cdots_{gasket}$	Installation of air sealing gasket on an electric outlet	per gasket	Tables 1, 2	Ref [1], p. 1-11, Table ES 9
$\cdots_{door\ kit}$	Installation of Door Sweep or Door Kit	per sweep	Tables 1, 2	Ref [1], p. 1-11, Table ES 9
$\cdots_{sealing}$	Foot of Caulking, Sealing, or Polyethylene Tape	per foot	Tables 1, 2	Ref [1], p. 1-11, Table ES 9
$\cdots_{wx}$	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		0.75	
PDF_H	Peak Day Factor - Gas Heating		0.00977	Appendix 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	AOG	APG
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
Window & Door Weatherization	fuel per linear foot	0.524	0.374	0.571

Retrofit Gross Seasonal Peak Demand Savings, Electric (Winter and Summer)

$$WKW = AKWH_H \times PF_W / 1000\ {}^{W}/_{kW}$$

Retrofit Gross Peak Day Savings, Natural Gas

$$PD_H = ACCF_H \times PDF_H$$

Non Energy Benefits

Increased personal comfort and decreased draftiness.

Changes from Last Version

No changes.

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

Installation of insulation in walls that separates conditioned space and unconditioned space (including unconditioned basements, attics, and crawl spaces).

Savings Methodology

Energy savings are calculated using parallel flow method based on a typical 2x4 wall. Factors 7/12 and -4are 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
GF	Ground Factor; Percent of unconditioned space walls above grade (rounded to nearest %)	%

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		
GF	**Above Grade**: Adjustment for a wall between conditioned and ambient space which is 100% above grade (0 % below grade). This includes cold (uninsulated or open) crawl spaces and cantilever floors.		1.0	Note [3]
	Mixed Grade: Adjustment for a wall between conditioned and ambient space which is between 31% and 99% above grade (inclusive) on average.		0.75	Note [3]
	Below Grade: Adjustment for a wall between conditioned and ambient space which is between 0% and 30% above grade (inclusive) on average e.g. a typical below grade basement.		0.60	Notes [3]
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	^{0}F-day	5,885	Ref [2]
PDF_H	Peak Day Factor - Heating		0.00977	Appendix 1

Symbol	Description	Units	Values	Comments
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		
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
…CAC	Central Air Conditioner			
…RAC	Room Air Conditioners (Cooling Only)			Note [1]

<u>Retrofit Gross Energy Savings, Electric</u>

Effective R-value,

$$R_{existing} = \left(\frac{7}{12} \times R_{pre}\right) + 4$$

$$R_{new} = \left(\frac{7}{12} \times R_{post}\right) + 4$$

Heating Savings,

$$ABTU_H = \left(\frac{1}{R_{existing}} - \frac{1}{R_{new}}\right) \times HDD \times 24 \times F_{Adj} \times A \times GF$$

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 (Central A/C only), and above grade walls

$$AKWH_{C,CAC} = \left(\frac{1}{R_{existing}} - \frac{1}{R_{new}}\right) \times \Delta T_{Bin} \times A \times \frac{1}{SEER_B \times 1{,}000}$$

Cooling Savings (Room A/C only), and above grade walls (Note[1])

$$AKWH_{C,RAC} = (28.3\%) \times AKWH_{C,CAC}$$

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%*

Retrofit Gross Energy Savings, Example

Wall insulation in a house is upgraded from R-6 to a total of R-13. The total square feet insulation added is 100. The wall is above grade and the home is heated by electric resistance heating system and has a central AC. What are the annual electric energy savings?

$$R_{existing} = \left(\frac{7}{12} \times R_{pre}\right) + 4 = \left(\frac{7}{12} \times 6\right) + 4 = 7.5$$

$$R_{new} = \left(\frac{7}{12} \times R_{post}\right) + 4 = \left(\frac{7}{12} \times 13\right) + 4 = 11.6$$

Using the equation for heating savings,

$$ABTU_H = \left(\frac{1}{R_{existing}} - \frac{1}{R_{new}}\right) \times HDD \times 24 \times F_{Adj} \times A \times GF$$

$$ABTU_H = \left(\frac{1}{7.5} - \frac{1}{11.6}\right) \times 5885 \times 24 \times 0.64 \times 100 \times 1$$

$$ABTU_H = 425{,}993\ Btu$$

Heating savings for electric resistance system,

$$AKWH_{H,R} = \frac{ABTU_H}{3{,}412}$$

$$AKWH_{H,R} = \frac{ABTU_H}{3{,}412}$$

$$AKWH_{H,R} = \frac{ABTU_H}{3{,}412} = 124.8\ kWh$$

Using the equation for cooling savings,

$$AKWH_C, CAC = \left(\frac{1}{R_{existing}} - \frac{1}{R_{new}}\right) \times \Delta T_{bin} \times A \times \frac{1}{SEER_B \times 1000}$$

$$AKWH_{C,CAC} = \left(\frac{1}{7.5} \times \frac{1}{11.6}\right) \times 3{,}888 \times 100 \times \frac{1}{13 \times 1{,}000} = 1.4\ kWh$$

Retrofit Gross Seasonal Peak Demand Savings, Electric (Winter and Summer)

For homes with electric resistance heat,

$$WKW = \frac{AKWH_H(Electric\_Resistance)}{1{,}000} \times WPF$$

$$WKW = \frac{AKWH_H(Electric\_Resistance)}{1{,}000} \times 0.57$$

For homes with heat pump,

$$WKW = \frac{AKWH_H}{1{,}000} \times 0.57$$

For Central A/C only,

$$SKW_{CAC} = CF \times \left(\frac{1}{R_{existing}} - \frac{1}{R_{new}}\right) \times \Delta T_{Summer} \times A \times \frac{1}{EER_B \times 1{,}000}$$

For Room A/C only, (Note [1])

$$SKW_{RAC} = (25.1\%) \times SKW_{CAC}$$

Retrofit Gross Peak Day Savings, Natural Gas

$$PD_H = ACCF_H \times PDF_H$$

Retrofit Gross Peak Demand Savings, Example

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?

$$WKW = \frac{AKWH_H(Electric\_Resistance)}{1{,}000} \times 0.57$$

From the previous example, $AKWH_H = 124.8\ kWh$, therefore,

$$WKW = \frac{124.8}{1{,}000} \times 0.57 = 0.071\ kW$$

Using the equation,

$$SKW_{CAC} = CF \times \left(\frac{1}{R_{existing}} - \frac{1}{R_{new}}\right) \times \Delta T_{Summer} \times A \times \frac{1}{EER_B \times 1{,}000}$$

.

$$SKW_{CAC} = 0.59 \times \left(\frac{1}{7.5} - \frac{1}{11.6} \right) \times 20.5 \times 100 \times \frac{1}{11 \times 1{,}000} = 0.0052\, kW$$

Changes from Last Version

Corrected Ref [2], "30 year average"

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 year 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.
[5] Nexant Market Research, Inc., "Market Assessment for ENERGY STAR Room Air Conditioners in Connecticut," Cambridge, MA, 2007, pp. 17,18
[6] RLW Analytics, "Final Report: Coincidence Factor Study: Residential Room Air Conditioners," Middletown, CT, 2008, p. iv, p. 22
[7] ADM Associates, Inc., "Residential Central AC Regional Evaluation," Sacramento, CA, 2009, pp. 4-4

Notes

[1] Room Air Conditioning cooling savings are derived from factors found in Ref [5,6,7].
[2] Calculated the $R_{effective}$ of un-insulated wall assembly based on see Table below

	Cavity	Framing
Outside air film	0.17	0.17
Lapped Wood Siding	0.80	0.80
Sheathing ¼"	0.31	0.31
Air space 3.5" / or framing	1.00	4.38
Gypsum Board (drywall ½")	0.45	0.45
Interior air film	0.68	0.68
Total R	3.41	6.79
Relative Area % based on 2x4 16" OC	0.75	0.25
R effective whole wall assembly	4	

The above R values can be found at :http://www.allwallsystem.com/design/RValueTable.html.
[3] Grade Factors were developed using REMrate software
.

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	ft²hrºF/Btu
R_{post}	Insulation R-value after upgrade	ft²hrºF/Btu
A	Total gross area of ceiling insulation	ft²

Nomenclature

Symbol	Description	Units	Values	Comments
A	Total gross area of ceiling insulation	ft²		
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 (Fossil fuel)	%	75%	Estimated
F_{adj}	ASHRAE adjustment factor		0.64	Ref [1]
HDD	Heating Degree Days, CT state average	^{0}F-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	ft²hrºF/Btu	Calculated	
R_{new}	Effective R-value after upgrade	ft²hrºF/Btu	Calculated	
R_{pre}	Existing Insulation R-value	ft²hrºF/Btu	Input	
R_{post}	Insulation R-value after upgrade	ft²hrºF/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]
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

Symbol	Description	Units	Values	Comments
$\ldots_{H,R}$	Electric Resistance Heating			
$\ldots_{H,HP}$	Heat Pump Heating			
$\ldots_{C,CAC}$	Central A/C cooling			
$\ldots_{C,RAC}$	Room A/C cooling			Note [1]

<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 (Central A/C only),

$$AKWH_{C,CAC} = \left(\frac{1}{R_{existing}} - \frac{1}{R_{new}} \right) \times \Delta T_{Bin} \times A \times \frac{1}{SEER_B \times 1{,}000}$$

Cooling Savings (Room A/C only), Note [1]

$$AKWH_{C,RAC} = (28.3\%) \times AKWH_{C,CAC}$$

<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: *System Efficiency is 75%*

<u>Retrofit Gross Energy Savings, Example</u>

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;

$$R_{new} = R_{post} - 2$$

$$R_{new} = 60 - 2 = 58$$

$$ABTU_H = \left(\frac{1}{R_{existing}} - \frac{1}{R_{new}} \right) \times HDD \times 24 \times F_{Adj} \times A$$

$$ABTU_H = \left(\frac{1}{7.5} - \frac{1}{58} \right) \times 5{,}885 \times 24 \times 0.64 \times 1000 = 10{,}493{,}969\ Btu$$

$$AKWH_{H,R} = \frac{ABTU_H}{3{,}412\ ^{Btu}/_{kWh}}$$

$$AKWH_{H,R} = \frac{10{,}493{,}969\ Btu}{3{,}412\ ^{Btu}/_{kWh}} = 3075\ kWh$$

$$AKWH_C, CAC = \left(\frac{1}{R_{existing}} - \frac{1}{R_{new}} \right) \times \Delta T_{bin} \times A \times \frac{1}{SEER_B \times 1000}$$

$$AKWH_{C,CAC} = \left(\frac{1}{7.5} - \frac{1}{58} \right) \times 3{,}888 \times 1{,}000 \times \frac{1}{13 \times 1{,}000} = 35 kWh$$

<u>Retrofit Gross Seasonal Peak Demand Savings, Electric, Winter, and Summer</u>

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 A/C only or heat pump providing cooling,

$$SKW_{C,CAC} = CF \times \left(\frac{1}{R_{existing}} - \frac{1}{R_{new}} \right) \times \Delta T_{Summer} \times A \times \frac{1}{EER_B \times 1{,}000}$$

$$SKW_{C,CAC} = CF \times \left(\frac{1}{R_{existing}} - \frac{1}{R_{new}} \right) \times 20.5 \times A \times \frac{1}{11 \times 1{,}000}$$

For Homes with Room A/C only, (Note [1])

$$SKW_{C,RAC} = (25.1\%) \times SKW_{C,CAC}$$

Retrofit Gross Peak Day Savings, Natural Gas

$PDF_H = 0.00977$

$$PD_H = ACCF_H \times PDF_H$$

Retrofit Gross Peak Demand Savings, Example

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 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,

$$SKW_{C,CAC} = CF \times \left(\frac{1}{R_{existing}} - \frac{1}{R_{new}} \right) \times \Delta T_{Summer} \times A \times \frac{1}{EER_B \times 1{,}000}$$

$$SKW_{C,CAC} = 0.59 \times \left(\frac{1}{7.5} - \frac{1}{58} \right) \times 20.5 \times 1000 \times \frac{1}{11 \times 1{,}000}$$

$$SKW_{C,CAC} = 0.127 kW$$

Changes from Last Version

Corrected Ref [2], “30 year average”

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 year average.

[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.

[5] Nexant Market Research, Inc., “Market Assessment for ENERGY STAR Room Air Conditioners in Connecticut,” Cambridge, MA, 2007, pp. 17,18

[6] RLW Analytics, “Final Report: Coincidence Factor Study: Residential Room Air Conditioners,” Middletown, CT, 2008, p. iv, p. 22

[7] ADM Associates, Inc., “Residential Central AC Regional Evaluation,” Sacramento, CA, 2009, pp. 4-4

Notes

[1] Room Air Conditioning cooling savings are derived from factors found in Ref [5,6,7].

4.4.16 FLOOR INSULATION

Description of Measure

Installation of insulation in a floor that separates conditioned space and unconditioned space (including unconditioned basements, unconditioned garages, and crawl spaces).

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 with an adjustment to account for floors over tempered space.

Note: *This measure is only applicable to floors over unconditioned spaces where the walls of the unconditioned space are not insulated (Note [1]). This measure only has heating savings associated with it.*

Inputs

Symbol	Description	Units
R_{pre}	Existing Insulation R-value	ft^{2}hr°F/Btu
R_{post}	Insulation R-value after upgrade	ft^{2}hr°F/Btu
A	Total gross area of ceiling insulation	ft^2
GF	Ground Factor; Percent of unconditioned space walls above grade (rounded to nearest %)	%

Nomenclature

Symbol	Description	Units	Values	Comments
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		
GF	**Above Grade**: Adjustment for a floor over unconditioned space which is 100% above grade (0 % below grade). This includes cold (uninsulated or open) crawl spaces and cantilever floors.		1.0	Note [2]
	Mixed Grade: Adjustment for a floor over unconditioned space which is between 31% and 99% above grade (inclusive) on average.		0.75	Note [2]
	Below Grade: Adjustment for floors over unconditioned space which is between 0% and 30% above grade (inclusive) on average e.g. a typical below grade basement.		0.60	Note [2]
EF	Heating system efficiency (Fossil fuel)	%	75%	Estimated
F_{adj}	ASHRAE adjustment factor		0.64	Ref [1]
HDD	Heating Degree Days, CT state average	^{0}F-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^{2}hr°F/Btu	Calculated	

Symbol	Description	Units	Values	Comments
R_{new}	Effective R-value after upgrade	ft^{2}hr°F/Btu	Calculated	
R_{pre}	Existing Nominal Insulation R-value	ft^{2}hr°F/Btu	Input	
R_{post}	Insulation Nominal R-value after upgrade	ft^{2}hr°F/Btu	Input	
WKW	Winter Peak Demand Savings	kW		
WPF	Winter Peak Factor	W/ kWh	0.57	Ref [4]
$\ldots_{H,R}$	Electric Resistance Heating			
$\ldots_{H,HP}$	Heat Pump Heating			

<u>Retrofit Gross Energy Savings, Electric</u>

$$ABTU_H = \left(\frac{1}{R_{existing}} - \frac{1}{R_{new}}\right) \times HDD \times 24 \times F_{Adj} \times A \times GF$$

Where:

$$R_{(existing)} = 0.55 \times R_{(pre)} + 3.9$$

$$R_{(new)} = 0.55 \times R_{(post)} + 3.9$$

For Electric Resistance Heating Savings,

$$AKWH_{H,R} = \frac{ABTU_H}{3{,}412\ {}^{Btu}\!/\!_{kWh}}$$

For Heat Pump,

$$AKWH_{H,HP} = \frac{AKWH_{H,R}}{2}$$

<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**: System Efficiency is 75%*

<u>Retrofit Gross Energy Savings, Example</u>

R-19 insulation is added to the floor over an unconditioned basement in a house. The basement walls are primarily mixed grade. The total square feet insulation added is 1000 and the floor does not have any existing insulation. The home is heated by electric resistance heating system. What are the annual electric energy savings?

Step 1: Calculate the effective R-values ($R_{existing}$ and R_{new}):

Determine $R_{(existing):}$

$$R_{(existing)} = 0.55 \times R_{(pre)} + 3.9$$

$$R_{(existing)} = 0.55 \times 0 + 3.9 = 3.9$$

Determine $R_{(new)}$:

$$R_{(new)} = 0.55 \times R_{(post)} + 3.9$$

$$R_{(new)} = 0.55 \times 19 + 3.9 = 14.35$$

Step 2: Determine the Ground Factor (GF) and calculate savings:

Since the basement below the floor is primarily mixed grade, the GF = 0.75

$$ABTU_H = \left(\frac{1}{R_{existing}} - \frac{1}{R_{new}} \right) \times HDD \times 24 \times F_{Adj} \times A \times GF$$

$$ABTU_H = \left(\frac{1}{3.9} - \frac{1}{14.35} \right) \times 5{,}885 \times 24 \times 0.64 \times 1000 \times 0.75 = 12{,}658{,}980.43 Btu$$

$$AKWH_{H,R} = \frac{ABTU_H}{3{,}412 \, {}^{Btu}/_{kWh}}$$

$$AKWH_{H,R} = \frac{12{,}658{,}980.43}{3{,}412} = 3{,}710.1 kWh$$

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,

$$WKW = \frac{AKWH_{H,HP}}{1{,}000} \times 0.57$$

Retrofit Gross Peak Day Savings, Natural Gas

$$PD_H = ACCF_H \times PDF_H$$

Retrofit Gross Peak Demand Savings, Example

R-19 insulation is added to the floor over an unconditioned basement in a house. The basement walls are primarily mixed grade. The total square feet insulation added is 1000 and the floor does not have any existing insulation. The home is heated by electric resistance heating system. 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, $AKWH_{H,R}$ = 3957.5 kWh. Therefore,

$$WKW = \frac{3710.1}{1{,}000} \times 0.57 = 2.11kW$$

Changes from Last Version

Edited Ref [2] so that it a lines with the rest of the degree day references in the PSD.
Input note[2] on Grade Factors.

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 year average. http://www7.ncdc.noaa.gov/CDO/CDODivisionalSelect.jsp

[3] Evaluation of WRAP and Helps Programs, KEMA, 2010, Table ES-8, page 1-10.

Notes

[1] This measure applies to all floors over unconditioned space including floors over unconditioned basements, floors over unconditioned garages, floors over crawl spaces and cantilever floors. These energy savings estimates are based on an analysis assuming that the walls of the unconditioned space are not insulated. A custom energy savings analysis would have to be developed if the walls of that unconditioned space were insulated (even partially).[2] Grade Factors were developed using REMrate software

[2] Grade Factors were developed using REMrate software

4.4.17 NEW CONSTRUCTION DUCT AND ENVELOPE TESTING

Description of Measure

Duct Blaster and Blower Door Testing of New Homes that exceed the 2009 International Energy Conservation Code (IECC) or if Connecticut chooses to adopt the new code, 2012 International Energy Conservation Code (IECC) requirements for Duct and Envelope Sealing.

Savings Methodology

Savings from this measure shall only be claimed if both measured duct leakage and envelope air infiltration levels are at or below specified code compliance levels or levels found in CT Baseline Study (Ref [1]).

Compliant envelope infiltration rate is 5.8 air changes per hour.

Compliant duct leakage per CFM per 100 square feet of conditioned space is based on the test method used and the CT Baseline Study:

Test method	Compliance Rate (CFM25 per 100 ft^2)
Rough-In Air Handler Installed	13.3
Rough-In Air Handler Not Installed	8.9
Post-Construction Leakage to Outside	17.7
Post Construction Total Duct Leakage	26.6

Base level CFM rates for Code compliance for both air infiltration and duct leakage must be calculated for each home based of the area and volume of the conditioned space.

REM/Rate (Ref [2]), a residential energy analysis, code compliance and rating software, was used to simulate energy use in a typical home for reductions in duct leakage and air infiltration compared code requirements (CFM air leakage at 25Pascals pressure difference for Ducts and 50 Pascals pressure difference for envelope). The average energy savings in MMBtu and kWh were estimated from the results of the REM/Rate simulations then converted to the appropriate fuels using unit conversions and assumed distribution losses. The demand savings were also based on the REM simulation.

Note: Electric and Fossil Fuel Savings for both Duct and Envelope Tightness are added together to determine the total savings for home. **New homes without duct work can qualify for a reduced incentive if the measured envelope air leakage rate is at or below the specified level**.

Inputs

Symbol	Description
A	Conditioned Floor Area
CFM25	Post Construction verified duct leakage rate at 25 Pa
CFM50	Post Construction verified envelope leakage rate at 50 Pa
V	Volume of Condition Space
	Heating Fuel Type (Electric Resistive, HP, Gas, Oil, Propane, etc….)
	Heating System Distribution Type (Forced air with fan, heat pump, resistive, radiator, etc..)
H	Average Ceiling height of Conditioned Space

Nomenclature

Symbol	Description	Units	Values	Comments
A	Conditioned Floor Area	ft^2	Actual	
$ACCF_{HD}$	Annual Natural Gas Savings – Duct Sealing	Ccf/yr		
$ACCF_{HE}$	Annual Natural Gas Savings – Envelope Sealing	Ccf/yr		
$AKWH_{HD}$	Annual Electric Savings, Heating – Duct Sealing	kWh/yr		
$AKWH_{HE}$	Annual Electric Savings, Heating – Envelope Sealing	kWh/yr		

$AKWH_{CD}$	Annual Electric Savings, Cooling – Duct Sealing	kWh/yr		
$AKWH_{CE}$	Annual Electric Savings, Cooling – Envelope Sealing	kWh/yr		
AOG_{HD}	Annual Oil Savings – Duct Sealing	Gal/yr		
AOG_{HE}	Annual Oil Savings – Envelope Sealing	Gal/yr		
AOP_{HD}	Annual Propane Savings – Duct Sealing	Gal/yr		
AOP_{HE}	Annual Propane Savings – Envelope Sealing	Gal/yr		
$CFM25_{test}$	Verified Duct Leakage rate at 25 Pa	CFM	Actual	
$CFM25_{base}$	Code required Leakage rate per 100 Square feet	CFM	Compliance Rate x A/100	See Savings Methodology Section
$CFM50_{test}$	Verified envelope air leakage rate at 50 Pa	CFM	Actual	
$CFM50_{base}$	Code Required Maximum Air Infiltration at 50 Pa	CFM	5.8 x V ÷60	
H	Average height of Conditioned space	ft	Actual Use 8ft if unknown	
PD_{HD}	Natural Gas Peak Day Savings- Heating –Duct Sealing	Ccf/day		
PD_{HE}	Natural Gas Peak Day Savings- Heating –Envelope Sealing	Ccf/day		
PDF_{H}	Natural gas peak day factor –Heating		0.00977	Appendix 1
SKW_{CD}	Summer Demand Savings – Duct Sealing	kW		
SKW_{CE}	Summer Demand Savings – Envelope Sealing	kW		
WKW_{HD}	Winter Demand Savings – Duct Sealing	kW		
WKW_{HE}	Winter Demand Savings – Envelope Sealing	kW		
V	Volume of conditioned space	Ft^3	A x H	

Lost Opportunity Gross Energy Savings, Electric

The two components of savings are:

1. Duct Sealing @ 25Pa (Table 1)
2. Blower Door @ 50Pa (Table 2)

For each component the baseline leakage rate must be calculated as follows:

Calculation of Baseline Leakage Rates

$$CFM\,25_{Base} = \left(\frac{Compliance\ Rate \times A}{100} \right)$$

$$CFM\,50_{Base} = \left(\frac{5.8 \times V}{60} \right) \quad Where:$$

$$V = A \times H \qquad (use\ H = 8\,ft\ if\ unknown)$$

Table 1: Electric Savings, kWh per CFM Reduction (Duct Sealing) at 25 Pascal (Note [2])

System Type	Equation (See Measure 4.2.9 for details)
Electric Forced Air	$AKWH_{HD} = 7.693 \times (CFM\,25_{Base} - CFM\,25_{Test})$
Heat Pumps	$AKWH_{HD} = 3.847 \times (CFM\,25_{Base} - CFM\,25_{Test})$
Geothermal	$AKWH_{HD} = 2.564 \times (CFM\,25_{Base} - CFM\,25_{Test})$
Heating Fan (Note [2])	$AKWH_{HD} = 1.100 \times (CFM\,25_{Base} - CFM\,25_{Test})$
Central AC Cooling	$AKWH_{CD} = 1.059 \times (CFM\,25_{Base} - CFM\,25_{Test})$

Table 2: Electric Savings, kWh per CFM Reduction (Blower Door) at 50 Pascal

System Type	Equation (See Measure 4.4.4 for details)
Electric Forced Air	$AKWH_{HE} = 2.638 \times (CFM50_{Base} - CFM50_{Test})$
Heat Pumps	$AKWH_{HE} = 1.319 \times (CFM50_{Base} - CFM50_{Test})$
Geothermal	$AKWH_{HE} = 0.879 \times (CFM50_{Base} - CFM50_{Test})$
Heating Fan (Note [2])	$AKWH_{HE} = 0.060 \times (CFM50_{Base} - CFM50_{Test})$
Central AC Cooling	$AKWH_{CE} = 0.0593 \times (CFM50_{Base} - CFM50_{Test})$
Cooling (Room AC: Window, Sleeve, or PTAC) (Note [1])	$AKWH_{CE} = 0.0168 \times (CFM50_{Base} - CFM50_{Test})$

Lost Opportunity Gross Energy Savings, Fossil Fuel

The two components of savings are:

1. Duct Sealing @ 25Pa (Table 3)
2. Blower Door @ 50Pa (Table 4)

For each component the baseline leakage rate must be calculated as shown in the previous section.

Table 3: Fossil Fuel Savings per CFM Reduction (Duct Sealing) at 25 Pascal

Fuel Type	Equation (See Measure 4.2.9 for details)
Natural gas	$ACCF_{HD} = 0.340 \times (CFM25_{Base} - CFM25_{Test})$
Oil	$AOG_{HD} = 0.252 \times (CFM25_{Base} - CFM25_{Test})$
Propane	$APG_{HD} = 0.383 \times (CFM25_{Base} - CFM25_{Test})$

Table 4: Fossil Fuel Savings per CFM Reduction (Blower Door) at 50 Pascal

Fuel Type	Equation (See Measure 4.4.4 for details)
Natural gas	$ACCF_{HE} = 0.117 \times (CFM50_{Base} - CFM50_{Test})$
Oil	$AOG_{HE} = 0.087 \times (CFM50_{Base} - CFM50_{Test})$
Propane	$APG_{HE} = 0.131 \times (CFM50_{Base} - CFM50_{Test})$

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

The two components of savings are:

1. Duct Sealing @ 25Pa (Table 5)
2. Blower Door @ 50Pa (Table 4)

For each component the baseline leakage rate must be calculated as shown in the previous section.
Reminder: *Demand savings are based on design load calculation in REM software hence there is no need to use coincidence factors*

Table 5: Winter and Summer Demand Savings per CFM Reduction (Duct Sealing) at 25 Pascal

System Type	Equation (See Measure 4.2.9 for details)
Electric Forced Air	$WKW_{HD} = 0.0158 \times (CFM25_{Base} - CFM25_{Test})$
Heat Pumps	$WKW_{HD} = 0.0158 \times (CFM25_{Base} - CFM25_{Test})$
Geothermal	$WKW_{HD} = 0.0053 \times (CFM25_{Base} - CFM25_{Test})$
All Others	$WKW_{HD} = 0$
Central AC Cooling	$SKW_{CD} = 0.0023 \times (CFM25_{Base} - CFM25_{Test})$

Table 6: Winter and Summer Demand Savings per CFM Reduction (Blower Door) at 50 Pascal

System Type	Equation (See Measure 4.4.4 for details)
Electric Forced Air	$WKW_{HE} = 0.00117 \times (CFM50_{Base} - CFM50_{Test})$
Heat Pumps	$WKW_{HE} = 0.00117 \times (CFM50_{Base} - CFM50_{Test})$
Geothermal	$WKW_{HE} = 0.00039 \times (CFM50_{Base} - CFM50_{Test})$
All Others	$WKW_{HE} = 0$
Central AC Cooling	$SKW_{CE} = 0.00009 \times (CFM50_{Base} - CFM50_{Test})$
Room AC Cooling (Note [1])	$SKW_{CE} = 0.00002 \times (CFM50_{Base} - CFM50_{Test})$

<u>Lost Opportunity Gross Peak Demand Savings, Natural Gas</u>

For homes with Natural Gas heating only, the two components of savings are:

1. Duct Sealing @ 25Pa (PD_{HD})
2. Blower Door @ 50Pa (PD_{HE})

$$PD_H = ACCF_H \times PDF_H$$

$$Therefore;$$

$$PD_{HD} = ACCF_{HD} \times 0.00977$$

$$PD_{HE} = ACCF_{HE} \times 0.00977$$

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

Verification testing was done on new 2,000 ft^2 home with 9 ft. ceilings and central air conditioning. The home is heated by a gas furnace. Testing results of Post-Construction Leakage to Outside were as follows:

- Duct Blaster Test measured 100 CFM at 25 Pascals.
- Blower Door Test measured 1000 CFM at 50 Pascals.

Calculation of Baseline Leakage Rate:

$$CFM\,25_{Base} = \left(\frac{Compliance\ Rate \times A}{100}\right) = \left(\frac{17.7 \times 2{,}000}{100}\right) = 354\ CFM\,25_{Base}$$

$$CFM\,50_{Base} = \left(\frac{5.8 \times V}{60}\right) = \left(\frac{5.8 \times 18{,}000}{60}\right) = 1{,}740\ CFM\,50_{Base}$$

$Where:$

$$V = A \times H = 2{,}000\,ft^2 \times 9\,ft = 18{,}000\,ft^3$$

Heating Savings

Heating savings consist of both gas and electric (heating fan) savings for Duct and Envelope:

Duct:

$$ACCF_{HD} = 0.340 \times (CFM\,25_{Base} - CFM\,25_{Test})$$
$$ACCF_{HD} = 0.340 \times (354 - 100) = 86.4\ ccf$$
$$AKWH_{HD} = 1.100 \times (CFM\,25_{Base} - CFM\,25_{Test})$$
$$AKWH_{HD} = 1.100 \times (354 - 100) = 279.4\ {}^{kWh}\!/_{yr}$$

Envelope:

$$ACCF_{HE} = 0.340 \times (CFM\,50_{Base} - CFM\,50_{Test})$$
$$ACCF_{HE} = 0.117 \times (1{,}740 - 1{,}000) = 86.6\ ccf$$
$$AKWH_{HE} = 0.060 \times (CFM\,50_{Base} - CFM\,50_{Test})$$
$$AKWH_{HE} = 0.060 \times (1{,}740 - 1000) = 44.4\ {}^{kWh}\!/_{yr}$$

Total Gas Heating Savings = $ACCF_{HD} + ACCF_{HE} = 86.4\ ccf + 86.6\ ccf = 173.0\ ccf$

Total Electric Heating Savings = $AKWH_{HD} + AKWH_{HE} = 279.4\ {}^{kWh}\!/_{yr} + 44.4\ {}^{kWh}\!/_{yr} = 323.8\ {}^{kWh}\!/_{yr}$

Cooling Savings

Cooling savings consist of electric savings for Duct and Envelope:

Duct:

$$AKWH_{CD} = 1.059 \times (CFM\,25_{Base} - CFM\,25_{Test})$$
$$AKWH_{CD} = 1.059 \times (354 - 100) = 269.0\ {}^{kWh}\!/_{yr}$$

Envelope:

$$AKWH_{CE} = 0.0593 \times (CFM\,50_{Base} - CFM\,50_{Test})$$
$$AKWH_{CE} = 0.0593 \times (1{,}740 - 1000) = 43.9\ {}^{kWh}\!/_{yr}$$

Total Electric Cooling Savings = $AKWH_{CD} + AKWH_{CE} = 269.0\ {}^{kWh}\!/_{yr} + 43.9\ {}^{kWh}\!/_{yr} = 312.9\ {}^{kWh}\!/_{yr}$

Demand Savings

Demand Savings consist of electric (summer) savings for the central air conditioner and Gas Peak Day savings for the gas furnace. These savings apply for both duct and envelope components:

Duct:

$$PD_{HD} = ACCF_{HD} \times 0.00977$$

$$PD_{HD} = 86.4 \times 0.00977 = 0.844 \, {ccf}/{day}$$

$$WKW_{HD} = 0$$

$$SKW_{CD} = 0.0023 \times \left(CFM25_{Base} - CFM25_{Test}\right)$$

$$SKW_{CD} = 0.0023 \times (354 - 100) = 0.584 \, kW$$

Envelope:

$$PD_{HE} = ACCF_{HE} \times 0.00977$$

$$PD_{HE} = 86.6 \times 0.00977 = 0.846 \, {ccf}/{day}$$

$$WKW_{HE} = 0$$

$$SKW_{CE} = 0.00009 \times \left(CFM50_{Base} - CFM50_{Test}\right)$$

$$SKW_{CE} = 0.00009 \times (1{,}740 - 1{,}000) = 0.066 \, kW$$

Total Gas Peak Day Savings = $PD_{HD} + PD_{HE} = (86.4 + 86.6) \times 0.00977 = 1.690 \, {ccf}/{day}$

Total Electric Winter Demand = 0

Total Electric Summer Demand = $SKW_{CD} + SKW_{CE} = 0.584 \, kW + 0.066 \, kW = 0.651 \, kW$

Changes from Last Version

No changes.

References

[1] Connecticut 2011 Baseline Study of Single-Family New Construction – Final Report, by NMR and KEMA, Oct 2012.

[2] 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/Rate™ was performed by C&LM Planning team, Northeast Utilities, August 2008.

[3] Nexant Market Research, Inc., "Market Assessment for ENERGY STAR Room Air Conditioners in Connecticut," Cambridge, MA, 2007, pp. 17,18

[4] RLW Analytics, "Final Report: Coincidence Factor Study: Residential Room Air Conditioners," Middletown, CT, 2008, p. iv, p. 22

[5] ADM Associates, Inc., "Residential Central AC Regional Evaluation," Sacramento, CA, 2009, pp. 4-4

Notes

[1] Room Air Conditioning cooling savings are derived from factors found in Ref [3,4,5].

[2] Fan savings are only captured for forced hot air systems with an air handling unit (fan).

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 electric energy adjustment is made when the home has a dishwasher.

Inputs

Symbol	Description
Dishwasher presence	Whether or not home has dishwasher
WH fuel	Type of fuel used in hot water heater.
T_{BR}	Temperature of hot water from tank before reset
T_{AR}	Temperature of hot water from tank after reset

Nomenclature

Symbol	Description	Units	Values	Comments
$ACCF_W$	Annual Gas Savings	Ccf/yr		
$AKWH_{noDW}$	Annual Electric Energy Savings – with no dishwasher	kWh/ yr		
$AKWH_{neg}$	Annual Electric Energy Savings – Dishwasher	kWh/ yr		Negative adjustment
$AKWH_W$	Annual Electric Energy Savings – Water Heating	kWh/ yr		
AOG_W	Annual Oil Savings	Gal/yr		
APG_W	Annual Propane Savings	Gal/yr		
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]
T_{BR}	Temperature of hot water from tank before reset	ºF		
T_{AR}	Temperature of hot water from tank after reset	ºF		
D_w	Density of water	lbs/gallon	8.3	

Retrofit Gross Energy Savings, Electric

Table 1: Hot Water Consumption of Clothes Washer

Number of cycles per year (Ref [2])	312
Water use per cycle (Note [1])	22.83
Percent Hot Water (Ref [1])	29%
Annual clothes washer hot water consumption (Gal) - W_{cw}	**2065.8**

Table 2: Hot Water Consumption of Dishwasher

Number of cycles per year (Ref [2])	215.0
Water use per cycle (Note [1])	4.34
Percent Hot Water (Ref [1])	100%
Annual dishwasher hot water consumption (Gal) - W_{dw}	**933.1**

Use the following equation to calculate total electricity saved per year at water heater for electric heat without dishwasher. The following savings are due to lowering of electric hot water heater temperature from T_{BR} to T_{AR}.

$$AKWH_{noDW} = \frac{D_w \times W_{cw} \times (T_{BR} - T_{AR})}{3412 \times EF_E} kWh$$

Where, EF =0.95, is the energy factor of the hot water system.

If the home has a dishwasher,

Negative adjustment to account for dishwasher preheater:

$$AKWH_{neg} = -\frac{D_w \times W_{dw} \times (T_{BR} - T_{AR})}{3412} kWh$$

Total electricity saved per year at water heater for electric heat with dishwasher:

$$AKWH_w = AKWH_{noDW} + AKWH_{neg}$$

If the before and after reset temperatures are unknown, use the following deemed savings. See Note [2].
Total electricity saved per year without dishwasher: 79.3 kWh
Total electricity saved per year with dishwasher: 45.3 kWh

Retrofit Gross Energy Savings, Fossil Fuel

Savings for Homes with Gas Water Heaters

$$ACCF_w = \frac{D_w \times W_{cw} \times (T_{BR} - T_{AR})}{102{,}900 \times EF_F} Ccf$$

Savings for Homes with Oil Hot Water Heaters

$$AOG_w = \frac{D_w \times W_{cw} \times (T_{BR} - T_{AR})}{138{,}690 \times EF_F} Gallons$$

Savings for Homes with Propane Water Heaters

$$APG_w = \frac{D_w \times W_{cw} \times (T_{BR} - T_{AR})}{91{,}330 \times EF_F} Gallons$$

Retrofit Gross Energy Savings, Example

What is the energy savings from lowering of electric hot water heater temperature from 140°F to 125 °F?

Using equation,

$$AKWH_{noDW} = \frac{D_w \times W_{cw} \times (T_{BR} - T_{AR})}{3412 \times EF_E} kWh$$

Where, EF =0.95, is the energy factor of the hot water system. Therefore, annual electric energy savings is

$$AKWH_{noDW} = \frac{8.3 \times 2065.8 \times (140 - 125)}{3412 \times 0.95} = 79.3 kWh$$

If the home has a dishwasher then a negative adjustment has to be made to account for dishwasher preheater:

$$AKWH_{neg} = -\frac{8.3 \times 933.1 \times (140 - 125)}{3412} = -34 kWh$$

Therefore, total electricity saved per year at water heater for electric heat with dishwasher:

$$AKWH_w = AKWH_{noDW} + AKWH_{neg}$$

$$AKWH_w = 79.3 - 34 = 45.3 kWh$$

Changes from Last Version

No changes.

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, 2013.

[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.

Notes

[1] Weighted average of ENERGY STAR and conventional water consumption from (Ref [2]).

[2] The deemed savings are calculated based on ‘before’ temperature at 140 F and the ‘reset’ temperature at 125F.

4.5.2 WATER HEATER WRAP

Description of Measure

Wrapping old electric hot water heaters with fiberglass insulation with an insulating blanket to reduce standby heat loss through the skin. Not valid for newer units which are already insulated with foam or units that are already wrapped in insulation.

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

No changes.

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 milder 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	
AWG	Annual Water Savings	Gal/yr	Calculated	
d_e	Median duration per event	minutes	8.3	Ref [4]
d_W	Density of water	lb/ Gal	8.31	
RE_E	Recovery Efficiency of Electric Water Heater		0.98	Ref [3]
RE_F	Recovery Efficiency of Fossil Fuel Water Heater		0.78 for SF 0.67 for MF	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, Note[3]
n_e	Average number of shower events per day per household		1.97	Ref [4],p144 Table 41, Note[3],
n_i	number of low flow showerheads installed		As found	Note[3]
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	
SH_W	Specific Heat of Water	BTU/lb-°F	1	
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

$$S_W = n_e \times d_e \times 365 \,{}^{days}\!/_{yr} \times r_g \times \left(gpm_{federal\,std} - gpm_{WaterSense}\right)/n_a$$

$$S_W = 1.97\ events \times 8.3\ {}^{\min}\!/_{event} \times 365\,{}^{days}\!/_{yr} \times 0.9344 \times \left(2.5\ gpm - 2.0\ gpm\right)/2.3$$

$$S_W = 1{,}212.3\,{}^{Gal}\!/_{showerhead\text{-}yr}$$

$$MMBtu\ Savings = \sqrt{n_i} \times \left(T_{shower} - T_{Supply}\right) \times d_W \times SH_W \times S_W / 10^6\,{}^{Btu}\!/_{MMBtu}$$ (See Note [2])

$$MMBtu\ Savings = \frac{\sqrt{n_i} \times \left(T_{shower} - T_{supply}\right)}{10^6\,{}^{Btu}\!/_{MMBtu}} \times d_W \times SH_W \times S_W / 10^6\,{}^{Btu}\!/_{MMBtu}$$

$$MMBtu\ Savings = \frac{\sqrt{n_i} \times \left(105^\circ F - 55^\circ F\right)}{10^6\,{}^{Btu}\!/_{MMBtu}} \times 8.31\,{}^{lb}\!/_{Gal} \times 1 \times 1{,}212.3\,{}^{Gal}\!/_{showerhead\text{-}yr}$$

$$MMBtu\ Savings = 0.504\,{}^{MMBtu}\!/_{showerhead} \times \sqrt{n_i}$$

$$AKWH = \frac{MMBtu\_Savings}{0.003412\,{}^{MMBtu}\!/_{kWh} \times RE_e} = \frac{0.504 \times \sqrt{n_i}}{0.003412 \times 0.98}$$

$$AKWH = 151\,{}^{kWh}\!/_{showerhead} \times \sqrt{n_i}$$

Retrofit Gross Energy Savings, Fossil Fuel

For Natural Gas:

$$ACCF = \frac{MMBTU\ Savings}{0.1029\,{}^{MMBtu}\!/_{CCF} \times RE_g} = \frac{0.504 \times \sqrt{n}}{0.1029 \times 0.78}$$

$$ACCF = 6.28 \times \sqrt{n}$$

For Oil:

$$AOG = \frac{MMBTU\ Savings}{0.138690\,{}^{MMBtu}\!/_{Gal-oil} \times RE_g} = \frac{0.504 \times \sqrt{n}}{0.138690 \times 0.78}$$

$$AOG = 4.65\,{}^{gal}\!/_{showerhead} \times \sqrt{n_i}$$

For Propane:

$$AOP = \frac{MMBTU\ Savings}{0.09133\,{}^{MMBtu}\!/_{Gal-propane} \times RE_g} = \frac{0.504 \times \sqrt{n}}{0.09133 \times 0.78}$$

$$AOP = 7.07\,{}^{gal}\!/_{showerhead} \times \sqrt{n_i}$$

Retrofit Gross Energy Savings, Example

Example 1: Two showerheads are replaced in bathrooms of a home which uses electric hot water heating. What are the savings per household per year?

Annual electric savings:

$$AKWH = 151\,{}^{kWh}\!/_{showerhead} \times \sqrt{n_i} = 151 \times \sqrt{2} = 213\,{}^{kWh}\!/_{yr}$$

Annual water savings:

$$AWG = 1{,}212.3 \, {}^{Gal}\!/_{showerhead\text{-}yr} \times \sqrt{n}_i = 1714 \, {}^{Gallons}\!/_{yr}$$

Example 2: Two showerheads are replaced in bathrooms of a home which uses gas hot water heating. What are the savings per household per year?

Annual gas savings:

$$ACCF = 6.28 \, {}^{CCF}\!/_{showerhead} \times \sqrt{n_i} = 6.28 \times \sqrt{2} = 8.9 \, {}^{CCF}\!/_{yr}$$

Annual water savings:

$$AWG = 1{,}212.3 \, {}^{Gal}\!/_{showerhead\text{-}yr} \times \sqrt{n}_i = 1714 \, {}^{Gallons}\!/_{yr}$$

Retrofit Gross Peak Day Savings, Natural Gas

$$PD_{WH} = ACCF \times PDF_{WH}$$

Non Energy Benefits

Annual water savings in gallons

$$AWG = 1{,}212.3 \, {}^{Gal}\!/_{showerhead\text{-}yr} \times \sqrt{n}_i$$

Changes from Last Version

Input instructions for multifamily (note[3])

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] Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 2.0, Created by Illinois Energy Efficiency Stakeholder Advisory Group, June 7, 2013, pg. 491.

[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.

[3] For a multi-family property, $n_{a,}$ $n_{i \text{ and }}$ n_e are given per dwelling / unit, then multiply the savings results by the number of unit / dwelling the measure is applied to.

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. 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	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	
DF	Drain Factor		0.795	Ref [3]
RE_E	Recovery Efficiency of Electric Water Heater		0.98	Ref [3]
RE_G	Recovery Efficiency of Fossil Fuel Water Heater		0.78 for SF 0.67 for MF	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], Note[4], Ref [4]
n_e	Median number of faucet events per day per household		42.9	Note [4], Ref [4]
n_i	number of aerators installed		As found	Note [4]
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	
SHW	Specific heat of water	Btu/(lb·°F)	1	
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

$$S_W = n_e \times d_e \times 365 \, {}^{days}/_{yr} \times r_g \times DF \times (gpm_{federal\ standard} - gpm_{Water\ Sense})/n_a$$

$$S_W = 42.9 \times 0.6167 \times 365 \, {}^{days}/_{yr} \times 0.9344 \times 0.795 \times (2.2\ gpm - 1.5\ gpm)/5.1$$

$$S_w = 985 \, {}^{Gal}/_{faucet\ yr}$$

$$MMBtu\ Savings = \sqrt{n} \times (T_{Faucet} - T_{Supply}) \times d_W \times SH_W \times S_W / 10^6 \, {}^{Btu}/_{MMBtu}$$ (See Note [2])

$$MMBtu\ Savings = \sqrt{n} \times (80°\mathrm{F} - 55°\mathrm{F}) \times 8.31 \, {}^{lb}/_{Gal} \times 1 \, {}^{Btu}/_{lb°\mathrm{F}} \times 985 \, {}^{Gal}/_{faucet\ yr} / 10^6 \, {}^{Btu}/_{MMbtu}$$

$$MMBtu\ Savings = 0.205 \, {}^{MMBtu}/_{faucet} \times \sqrt{n}$$

$$AKWH = \frac{MMBtu\ Savings}{0.003412 \, {}^{MMBtu}/_{kWh} \times RE_e} = \frac{0.205 \times \sqrt{n}}{0.003412 \, {}^{MMBtu}/_{kWh} \times .98}$$

$$AKWH = 61.2 \, {}^{kWh}/_{faucet} \times \sqrt{n}$$

Retrofit Gross Energy Savings, Fossil Fuel

Natural Gas:

$$ACCF = \frac{MMBtu\ Savings}{0.102900 \, {}^{MMBtu}/_{Ccf} \times RE_g} = \frac{0.205 \times \sqrt{n}}{0.102900 \, {}^{MMBtu}/_{Ccf} \times .78}$$

$$ACCF = 2.55 \times \sqrt{n}$$

Oil:

$$AOG = \frac{MMBtu\ Savings}{0.138690 \, {}^{MMBtu}/_{Gal\ oil} \times RE_g} = \frac{0.205 \times \sqrt{n}}{0.138690 \, {}^{MMBtu}/_{Gal\ oil} \times .78}$$

$$AOG = 1.89 \times \sqrt{n}$$

Propane:

$$AOP = \frac{MMBtu\ Savings}{0.09133 \, {}^{MMBtu}/_{Gal\ propane} \times RE_g} = \frac{0.205 \times \sqrt{n}}{0.09133 \, {}^{MMBtu}/_{Gal\ propane} \times .78}$$

$$AOP = 2.88 \times \sqrt{n}$$

Retrofit Gross Energy Savings, Example

Example 1. Two aerators are replaced in bathrooms of home which uses electric hot water heating. What are the total savings?

$AKWH = 61.2\ {}^{kWh}/_{faucet} \times \sqrt{2} = 87\ {}^{kWh}/_{yr}$

$Annual\ Gal\ Water\ Savings = S_W \times \sqrt{n} = 985\ {}^{Gal}/_{yr} \times \sqrt{2} = 1392\ {}^{Gal}/_{yr}$

Example 2. Two aerators are replaced in bathrooms of a home which uses gas hot water heating. What are the savings?

$ACCF = 2.65 \times 2 = 3.75\ {}^{Ccf}/_{yr}$

$Annual\ Gal\ Water\ Savings = S_W \times \sqrt{n} = 985\ {}^{Gal}/_{yr} \times \sqrt{2} = 1392\ {}^{Gal}/_{yr}$

Retrofit Gross Peak Day Savings, Natural Gas

$$PD_{WH} = ACCF \times PDF_{WH}$$

Non Energy Benefits

$Annual\ Gal\ Water\ Savings = S_W \times \sqrt{n} = 985\ {}^{Gal}/_{yr} \times \sqrt{n}$

Changes from Last Version

No changes.

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] Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 2.0, Created by Illinois Energy Efficiency Stakeholder Advisory Group, June 7, 2013, pg. 491.

[4] Aquacraft Water Engineering & Management. California Single Family Water Use Efficiency Study. June 1, 2011.

[5] Cadmus - Impact Evaluation: Home Energy Services—Income-Eligible and Home Energy Services Programs: Volume 2 (R16), Revised 7/2/14,

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] For a multi-family property, $n_{a,}$ $n_{i \text{ and}}$ n_e are given per dwelling / unit, then multiply the savings results by the number of unit / dweeling the measure is applied to.

4.5.7 FOSSIL FUEL WATER HEATER

Description of Measure

Installation of a high efficiency natural gas or propane tankless and storage water heaters.

Savings Methodology

Energy and demand savings calculations for a tankless or storage water heater are shown 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 4.2.17). 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	%

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	11,197,132	Note [1]
APG_W	Annual Propane savings – water heating	Gal		
EF_B	Energy Factor - Baseline		0.71	Note [2] and [3]
EF_I	Energy Factor - Installed			Note [3]
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	Note [1]

Lost Opportunity Gross Energy Savings, Fossil Fuel

$$ADHW = GPY \times 8.3\ {}^{lbs}\!/_{Gal} \times \left(T_{dhw} - T_{aiw}\right)$$

$$ADHW = 19{,}839\ {}^{Gal}\!/_{yr} \times 8.3\ {}^{lbs}\!/_{Gal} \times \left(125°F - 57°F\right)$$

$$ADHW = 11{,}197{,}132\ Btu$$

$$ABTU_W = ADHW \times \left(\frac{1}{EF_B} - \frac{1}{EF_I} \right)$$

$$ABTU_W = 11{,}197{,}132\ Btu \times \left(\frac{1}{0.71} - \frac{1}{EF} \right)$$

Savings by water heating fuel:

$$ACCF_W = \frac{ABTU_W}{102{,}900\ {}^{Btu}/_{Ccf}}$$

$$APG_W = \frac{ABTU_W}{91{,}330\ {}^{Btu}/_{Gal}}$$

Lost Opportunity Gross Energy Savings, Example

A natural gas water heater with an EF = 82% (0.82) is installed. What are the annual natural gas savings?

$$ABTU_W = 11{,}197{,}132\ Btu \times \left(\frac{1}{.71} - \frac{1}{.82} \right) = 2{,}115{,}569\ btu$$

$$ACCF_w = \frac{2{,}115569\ Btu}{102{,}900\ btu/Ccf} = 20.6\ Ccf$$

Lost Opportunity Gross Peak Day Savings, Natural Gas

$$PD_W = ACCF_W \times PDF_W$$

$$PD_W = ACCF_W \times 0.00321$$

Changes from Last Version

No Changes

Notes

[1] These values were developed using the Tool in Ref [1] for Hartford area weather data and a three bedroom house.

[2] Code of Federal Regulations, 10 CFR 430.32(d) as of March 7, 2015. Baseline is an average of the 50 gal. storage gas water heater and tankless water heater Energy Factors

[3] The energy factor (EF) is defined as the overall energy efficiency of a water heater based on the amount of hot water produced per unit of fuel consumed over a typical day. This includes recovery efficiency, standby losses and cycling losses (Source: www.energysavers.gov)

References

[1] Tool for Generating Realistic Residential Hot Water Event Schedules, Preprint, NREL, August 2010.

4.5.8 HEAT PUMP WATER HEATER

Description of Measure

Installation of a heat pump water heater.

Savings Methodology

Energy and demand savings calculations for a Heat Pump Water Heater are shown below. 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. Heating penalty and recovery adjustment accounts for the additional space heating loads due to extraction of heat from the air where the water heater is located.

Inputs

Symbol	Description	Units
	Number of units installed	
	Installed unit Energy factor	EF_i

Nomenclature

Symbol	Description	Units	Values	Comments
$ADHW$	Annual domestic hot water load	Btu	11,197,132	Note [2]
$AEDHW_W$	Annual electric energy savings	kWh/yr		
EF_b	Energy factor – Baseline		0.945	Ref [2]
EF_i	Energy factor - Installed			
GPH	Average gallons per hour during peak time	gph	1.96	Note [1]
GPY	Annual domestic hot water usage	Gal	19,839	Note [1]
$PDHW_s$	Peak hour hot water load - summer	Btu/hr	976	
$PDHW_w$	Peak hour hot water load - winter	Btu/hr	1,285	
SKW	Summer electric demand savings	kW		
T_{aiw}	Average annual incoming water temperature	ºF	57	Note [1]
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		
P	Heating penalty and recovery adjustment	%	90	Assumed

Lost Opportunity Gross Energy Savings, Electric=

For an installed Heat Pump Water Heater,

$$ADHW_W = GPY \times 8.3\frac{lbs}{gal} \times (T_{dhw} - T_{aiw}) \times 1\frac{Btu}{lb°F}$$

$$ADHW_W = 11{,}197{,}132\ Btu$$

$$AEDHW_W = 11{,}197{,}132\ Btu \times \frac{1}{3412\frac{Btu}{kwh}} \times (\frac{1}{EF} - \frac{1}{EF_i \times P})$$

$$AEDHW_W = 11{,}197{,}132\ Btu \times \frac{1}{3412\frac{Btu}{kwh}} \times \left(\frac{1}{0.945} - \frac{1}{EF_i \times 0.9}\right)$$

$$AEDHW_W = 3281.69 \times \left(\frac{1}{0.945} - \frac{1}{EF_i \times 0.9}\right)$$

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

For an installed Heat Pump Water Heater,

$$PDHW_s = GPH \times 8.3\frac{lbs}{gal} \times (T_{dhw} - T_{siw})$$

$$PDHW_s = 1.96\frac{gal}{hr} \times 8.3\frac{lbs}{gal} \times (125°F - 65°F) \times 1\frac{Btu}{lb°F} = 976\frac{Btu}{h}$$

$$SKW = PDHW_s \times \frac{1}{3412\frac{Btu}{kwh}} \times \left(\frac{1}{EF_b} - \frac{1}{EF_i \times P}\right)$$

$$SKW = 976\frac{Btu}{hr} \times \frac{1}{3412\frac{Btu}{kwh}} \times \left(\frac{1}{0.945} - \frac{1}{EF_i \times 0.9}\right)$$

$$SKW = 0.286 \times \left(\frac{1}{0.945} - \frac{1}{EF_i \times 0.9}\right)$$

$$PDHW_w = WPH \times 8.3\frac{lbs}{gal} \times (T_{dhw} - T_{siw}) \times 1\frac{Btu}{lb°F}$$

$$PDHW_w = 1.96\frac{gal}{hr} \times 8.3\frac{lbs}{gal} \times (125°F - 46°F) = 1{,}285\frac{Btu}{h}$$

$$WKW = PDHW_W \times \frac{1}{3412\frac{Btu}{kwh}} \times \left(\frac{1}{EF_b} - \frac{1}{EF_i \times P}\right)$$

$$WKW = 1{,}285\frac{Btu}{hr} \times \frac{1}{3412\frac{Btu}{kwh}} \times \left(\frac{1}{0.945} - \frac{1}{EF_i \times 0.9}\right)$$

$$WKW = 0.376 \times \left(\frac{1}{0.945} - \frac{1}{EF_i \times 0.9}\right)$$

Lost Opportunity Gross Energy Savings, Example

A Heat Pump Water heater with an energy factor of 2.7 is installed. What are the annual and peak day savings?

$$AEDHW_W = 11{,}197{,}132\ Btu \times \frac{1}{3412\frac{Btu}{kwh}} \times \left(\frac{1}{0.945} - \frac{1}{2.7 \times 0.9}\right)$$

$$\mathrm{AEDHW_W} = 2{,}122\ \mathrm{kwh}$$

$$SKW = 976\frac{Btu}{hr} \times \frac{1}{3412\frac{Btu}{kwh}} \times \left(\frac{1}{0.945} - \frac{1}{2.7 \times 0.9}\right)$$

$$SKW = 0.185\ kW$$

$$WKW = 1{,}285\frac{Btu}{hr} \times \frac{1}{3412\frac{Btu}{kwh}} \times \left(\frac{1}{0.945} - \frac{1}{2.7 \times 0.9}\right)$$

$$WKW = 0.244\ kW$$

Changes from Last Version

No Change

References

[1] Tool for Generating Realistic Residential Hot Water Event Schedules, Preprint, NREL, August 2010.

[2] Code of Federal Regulations, 10 CFR 430.32(d) as of March 7, 2015. Baseline Energy factor for a 50 gal Heat Pump Water Heater.

Notes

[1] These values were developed using the Tool in Ref [1] for Hartford area weather data and a three bedroom house.

4.5.9 PIPE INSULATION

Description of Measure

Installation of insulation on domestic hot water (DHW) pipes and or heating 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]. The savings should be limited to the first 6 linear feet of installed pipe insulation per water heater [4].

Inputs

Symbol	Description
Pipe Diameter	Pipe diameter , inches (savings are shown for ½" and ¾" pipes for domestic hot water, Savings are shown for 3/4",1",1 ½" and 2"pipes used for heating)
L	Length of pipe insulation, in feet.
	Hot water Fuel type (Electric resistive, Gas, Oil, Propane)
	Heating Fuel type (Gas, Oil, Propane)

Nomenclature

Symbol	Description	Units	Values	Comments
$ACCF_H$	Annual Gas Savings per linear foot, Heating	Ccf/ft		Table 4
$ACCF_W$	Annual Gas Savings per linear foot, domestic hot water	Ccf/ft		Table 3
AKW_H	Annual kWh Energy Savings coefficient, heating	kWh/ft		Table 2
AKW_W	Annual kWh Energy Savings coefficient, domestic hot water	kWh/ft		Table 1
$AKWH_H$	Annual Energy Savings, heating	kWh	Calculated	
$AKWH_W$	Annual Energy Savings, domestic hot water	kWh	Calculated	
AOG_H	Annual Oil Savings, Heating	Gal/ft		Table 4
AOG_W	Annual Oil Savings, domestic hot water	Gal/ft		Table 3
APG_H	Annual Propane Savings, Heating	Gal/ft		Table 4
APG_W	Annual Propane Savings, domestic hot water	Gal/ft		Table 3
PD_W	Peak Day savings, domestic hot water			
PDF_H	Peak Day Factor, Heating		0.00977	Appendix 1
PDF_W	Peak Day Factor, domestic hot water		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_H	Summer Seasonal Peak Demand Savings heating	kW		
SKW_W	Summer Seasonal Peak Demand Savings domestic hot water	kW		
WKW_H	Winter Seasonal Peak Demand Savings heating	kW		
WKW_W	Winter Seasonal Peak Demand Savings domestic hot water	kW		

Retrofit Gross Energy Savings, Electric

Table 1: Annual Electrical Savings per Linear Foot of Domestic Hot Water Pipe Insulation

Pipe Diameter (inches)	AKW_W (kWh/ft)
0.50	14.1
0.75	20.5

Annual Electric Domestic hot water savings can be calculated using the formula below, and using the values for AKW_W from Table 1.

$$AKWH_W = AKW_W \times L$$

Table 2: Annual Electrical Savings per Linear Foot of Heating Pipe Insulation

Pipe Diameter (inches)	AKW_H (kWh/ft)
0.75	12.9
1.00	16.0
1.25	19.6
1.50	22.2

Annual Electric heating savings can be calculated using the formula below, and using the value for AKW_H from Table 2.

$$AKWH_H = AKW_H \times L$$

Retrofit Gross Energy Savings, Fossil Fuel

Table 3: Annual Fossil Fuel Savings per Linear Foot of domestic hot water Pipe Insulation

Pipe Diameter (inches)	$ACCF_W$ (Ccf/ft)	AOG_W (Gallons/ft)	APG_W (Gallons/ft)
0.50	0.75	0.63	0.82
0.75	1.10	0.91	1.20

Annual Gas Domestic hot water savings can be calculated using the formula below and using the $ACCF_w$ coefficient in Table 3.

$$ACCF = ACCF_W \times L$$

Annual Oil Domestic hot water savings can be calculated using the formula below and using the AOG_w coefficient in Table 3.

$$AOG = AOG_W \times L$$

Annual Propane Domestic hot water savings can be calculated using the formula below and using the APG_w coefficient in Table 3.

$$APG = APG_W \times L$$

Table 4: Annual Fossil Fuel Savings per Linear Foot of Heating Pipe Insulation

Pipe Diameter (inches)	$ACCF_H$ (Ccf/ft)	AOG_H (Gallons/ft)	APG_H (Gallons/ft)
0.75	0.5	0.4	0.6
1.00	0.6	0.5	0.7
1.25	0.8	0.6	0.9
1.50	0.9	0.7	1.0

Annual Gas heating savings can be calculated using the formula below and using the $ACCF_H$ coefficient in Table 4:

$$ACCF = ACCF_H \times L$$

Annual Oil Heating savings can be calculated using the formula below and using the AOG_H coefficient in Table 4:

$$AOG = AOG_H \times L$$

Annual Propane Domestic hot water savings can be calculated using the formula below and using the APG_H coefficient in Table 4:

$$APG = APG_H \times L$$

Retrofit Gross Energy Savings, Example

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?

$$AOG = AOG_H \times L$$

$$AOG = 0.63\,{}^{Gal}\!/_{ft} \times 5\ ft = 3.15\,{}^{Gal}\!/_{yr}$$

Retrofit Gross Seasonal Peak Demand Savings, Electric (Winter and Summer)

For domestic Hot water the summer seasonal peak demand savings is:

$$SKW_W = \left(\frac{AKWH \times PF_S}{1000}\right)$$

For domestic Hot water the winter seasonal peak demand savings is:

$$WKW_W = \left(\frac{AKWH \times PF_S}{1000}\right)$$

For Heating summer seasonal peak demand"

$$SKW_H = 0$$

$$WKW_H = \left(\frac{AKWH \times 0.57}{1000}\right)$$

Retrofit Gross Peak Day Savings, Natural Gas

For Domestic Hot Water:

$$PD_W = ACCF \times PDF_W$$

For Heating:

$$PD_H = ACCF \times PDF_H$$

Retrofit Gross Peak Demand Savings, Example

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?

$$AKWH = 5\,feet \times 14.1\,{}^{kWh}\!/_{ft \cdot yr} = 70.5\,{}^{kWh}\!/_{yr}$$

$$SKW = \frac{\left(70.5\,kWh \times 0.1147\,{}^{W}\!/_{kWh}\right)}{1000\,{}^{W}\!/_{kW}} = 0.0081\,kW$$

$$WKW = \frac{\left(70.5\,kWh \times 0.1747\,{}^{W}\!/_{kWh}\right)}{1000\,{}^{W}\!/_{kW}} = 0.012\,kW$$

Changes from Last Version

No Changes

References

[1] NAIMA, 3E Plus software tool, Version 4.1, Released 2012.

[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.

[4] Cadmus .Impact Evaluation: DRAFT -Home Energy Services—Income-Eligible and Home Energy Services Programs: Volume 2 (R16), June 2, 2014.

Notes

[1] 3E Plus Inputs for Domestic hot water:

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 v4.01 (2012) 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%

4.5.10 SOLAR WATER HEATER

Description of Measure

Installation of solar water heater, to displace residential hot water load.

Savings Methodology

Savings for systems would be provided by contractors and would be calculated using Solar Pathfinder solar thermal tool (http://www.solarpathfinder.com/) or equivalent software. The energy savings calculations must be based on the SRCC "C" Mildly Cloudy Day rating, the number of occupants in the home, the size/number of storage tanks, and the efficiency of the back-up system. If feasible, savings should be calibrated to actual billing data.

Inputs

Symbol	Description
SPF	Solar Path finder software used to estimate the savings[1]

Lost Opportunity Gross Energy Savings, Electric

Based on the solar path finder report

Lost Opportunity Gross Energy Savings, Electric

Based on the solar path finder report

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

Based on the solar path finder report

Lost Opportunity Gross Peak Day Savings, Natural Gas

Based on the solar path finder report

Non Energy Benefits

Increases a home's value.

Changes from Last Version

No changes

References

Notes

[1] Solar Pathfinder is a residential energy analysis. This software calculates, hot water load, and energy savings using the site /array characteristics, shading factor, tank capacity and type, this software is widely used in sizing and estimating the savings from solar water heater.

4.6 OTHER

4.6.1 RESIDENTIAL CUSTOM

Description of Measure

This measure may apply to any project whose scope may be considered custom or comprehensive. Applicable measures may include the replacement of an inefficient HVAC system (or component) such as a fossil fuel furnace, boiler, heat pump, air conditioner, Home Performance with ENERGY STAR project measures, or any other project where interactive effects between two or more measures are present.

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, etc.). The analysis of the site-specific measures will be reviewed for reasonableness by a qualified internal program administrator or independent third party engineer. Whenever possible, site utility billing history must be utilized as appropriate.
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

In case where interactive effects between two or more measures are present, a comprehensive analysis must be conducted and fully documented, with assumptions and methodology clearly indicated.

Changes from Last Version

No changes.

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/>

4.6.2 BEHAVIORAL CHANGE

Description of Measure

This measure covers enrollment in a residential behavioral program or installation of a measure with a behavioral change component that is designed to encourage lower energy usage through behavioral messaging. These behavioral messages can be periodic normative reports or messages that present the customers with timely information on their energy usage and a call to action to reduce or save energy. Behavioral messages can be delivered through many avenues, including paper, email, and text messages.

Savings Methodology

Because the characteristics of behavioral programs make them amenable to robust, unbiased evaluation through randomized, controlled trials, and because Connecticut is expected to regularly evaluate its behavioral energy efficiency programs, use of evaluated savings estimates is recommended.

Evaluations should be conducted and savings calculated in accordance with the Department of Energy's SEE Action Recommendations, including but not limited to the use of a randomized controlled trial and a panel data model[1].

Savings are estimated by the difference between usage with the behavioral program and usage without the behavioral program. Usage without the behavioral program can be estimated by dividing adjusting actual usage by an adjustment factor based on the treatment effect to back out the effect of the program, or by application of a deemed savings value based on evaluation.

Inputs

Symbol	Description	Comments
Usage Electric	Annual Electric Energy Consumption	
Usage Gas	Annual Electric Energy Consumption	

Nomenclature

Symbol	Description	Units	Comments
AKWH-H	Annual Electric Energy Savings Heating	kWh	
AKWH-C	Annual Electric Energy Savings Cooling	kWh	
ACCF	Annual Gas Savings	CCF	
ATE	Average Treatment Effect		Input
Usage Electric	Annual Electric Consumption	kWh	Input
Usage Gas	Annual Gas Consumption	CCF	Input

UIL HERs program is introducing new customers over the three years; the methodology captures both savings from first year customers as well as incremental savings from repeat customers. It aligns savings and costs by plan year. It models a first year customer and the savings and attrition expected if they did not continue to receive reports. It then modeled this same customer in the second year with a percentage increase to the savings (to reflect continued participation) and the same attrition values.
The first year customer has the first year's savings as the annual savings, and the sum of the declining savings as the lifetime savings. The measure life is calculated by dividing the lifetime savings by the annual savings[2].

The second year the same customer receives the report the first year savings are the incremental savings between the upward adjusted savings percentage, and the second year savings counted in the Lifetime savings in the first year. As the program matures and additional evaluations become available this methodology may be refined.

Assumptions							
Presistence	1	0.71	0.4	0.3	0.1		
Percent savings			1.17%	First year			
			1.35	Second year adjustment for extension customers			
			1.58%	Maximum percentage of savings			

Changes from Last Version

No Changes

References

[1] Department of Energy, SEE Action, “Evaluation, Measurement, and Verification (EM&V) of Residential Behavior-Based Energy Efficiency Programs: Issues and Recommendations”. May 2012. Page xi.
[2]Evaluation of the Year 2 CL&P Pilot Customer Behavior Program (R2) August 2014.

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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	90.4%$_{(d,3)}$	77.0%$_{(d,4)}$	14.7%$_{(d,5)}$	13.3%$_{(d,6)}$
Manufacturing	67.1%$_{(d,3)}$	43.2%$_{(d,4)}$	19.8%$_{(d,5)}$	17.2%$_{(d,6)}$
Medical (Hospital)	74.0%$_{(d,3)}$	61.8%$_{(d,4)}$	23.9%$_{(d,5)}$	22.1%$_{(d,6)}$
Office	70.2%$_{(d,3)}$	53.9%$_{(d,4)}$	27.4%$_{(d,5)}$	29.6%$_{(d,6)}$
Other	47.6%$_{(d,3)}$	42.8%$_{(d,4)}$	2.4%$_{(d,5)}$	6.6%$_{(d,6)}$
Restaurant	77.5%$_{(d,3)}$	64.4%$_{(d,4)}$	14.7%$_{(d,5)}$	13.3%$_{(d,6)}$
Retail	79.5%$_{(d,3)}$	64.7%$_{(d,4)}$	14.7%$_{(d,5)}$	13.3%$_{(d,6)}$
University / College	65.0%$_{(d,3)}$	52.8%$_{(d,4)}$	28.3%$_{(d,5)}$	23.1%$_{(d,6)}$
Warehouse	72.7%$_{(d,3)}$	53.5%$_{(d,4)}$	24.6%$_{(d,5)}$	18.3%$_{(d,6)}$
School	59.9%$_{(d,3)}$	38.8%$_{(d,4)}$	20.9%$_{(d,5)}$	15.9%$_{(d,6)}$
Parking lot/Street Lighting	1.5%$_{(g)}$	66.9%$_{(g)}$		

Other Commercial and Industrial Measures		
Measure	Summer	Winter
Unitary A/C	82.0%$_{(c)}$	0.0%$_{(c)}$
Efficient Motors (cooling)	73.0%$_{(c)}$	60.0%$_{(c)}$
Efficient Motors (heating)	0.0%$_{(c)}$	80.0%$_{(c)}$
Refrigeration Controls	10.0%$_{(f)}$	10.0%$_{(f)}$
Air Compressors	77.0%$_{(h)}$	54.0%$_{(h)}$

Residential		
Measure	Summer	Winter
Lighting	13.0%$_{(i)}$	20.0%$_{(i)}$
Central A/C	59.0%$_{(b)}$	0.0%$_{(b)}$
Window A/C	30.3%$_{(e)}$	0.0%$_{(e)}$
Heating	0.0%$_{(f)}$	50.0%$_{(f)}$
Refrigeration	30.0%$_{(f)}$	21.0%$_{(f)}$
Water Heating Measures	10.0%$_{(f)}$	15.0%$_{(f)}$

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)

$$Peak\ Day\ Savings\ (residential\ heating) = 0.00977 \times Annual\ Heating\ Savings$$

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 in Reference [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,

$$Peak\ Factor = \frac{(1\ day) \times (120\ °F - 45.96\ °F)}{(365\ days) \times (120\ °F - 56.72\ °F)} = 0.00321$$

$$Peak\ Day\ Savings\ (residential\ water) = 0.00321 \times Annual\ Water\ Heating\ Savings$$

3) **Measures with daily constant savings:** 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.

$$Peak\ Day\ Savings = \frac{Annual\ Savings}{365\ days\ per\ year}$$

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

No Changes.

References

[1] Tool for Generating Realistic Residential Hot Water Event Schedules, Preprint, NREL, August 2010.

[b] Residential Central AC Regional Evaluation: Final Report, Prepared by ADM Associates, Inc., November 2009, Table 4-17, CT weighted average. Winter seasonal peak CF is assumed to be zero.

[c] 2005 Coincident Factor Study for UI & CL&P by RLW, January 2007, Table 5.

[d] Coincidence Factor Study Residential and Commercial Industrial Lighting Measures by RLW, Spring 2007.
[d, 1] N/A
[d, 2] N/A
[d, 3] Page VIII, Table i-11.
[d, 4] Page IX, Table i-12.
[d, 5] Page XII, Table i-17.
[d, 6] Page XII, Table i-18.

[e] Coincidence Factor Study, Residential Room Air Conditioners, Prepared by RLW, December 2007, Table 22, Hartford, CT seasonal CF. Winter seasonal peak CF is assumed to be zero.

[f] Estimated.

[g] UI analysis performed using historical seasonal peak hours (2010-2014).
[h] MA TRM for 2013 to 2015 program years, October 2012.
[i] NMR Group Inc., Northeast Residential Lighting Hour-of Use Study, May 5, 2014, Table ES-7, page XVIII.

APPENDIX 2. LOAD SHAPES

Load Shapes by End Use and Sector.

Load Shape	Winter Peak Energy %	Winter Off-Peak Energy %	Summer Peak Energy %	Summer Off-Peak Energy %
End Use	**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%

Winter is defined as October – May
Summer is defined as June – September
Peak is defined as 7:00 AM – 11:00 PM weekdays (no holidays)
Off-peak is defined 11:00 PM to 7:00 AM, plus all weekend and holiday hours.

Changes from Last Version

No changes.

APPENDIX 3. REALIZATION RATES

Gross Realization %				FR & SO		Net Realization % (Note 3)		
End-use	kWh	Winter Seasonal Peak kW	Summer Seasonal kW	Free-ridership	Spillover	kWh	Winter Seasonal Peak kW	Summer Seasonal Peak kW
Energy Conscious Blueprint								
Cooling	87.1%$_{(19)}$	108.0%$_{(19)}$	66.0%$_{(19)}$	29.5%$_{(d,1)}$	12.4%$_{(d,1)}$	**72.24%**	**89.5%**	**54.7%**
Custom	86.0%$_{(19)}$	91.0%$_{(19)}$	87.0%$_{(19)}$	22.5%$_{(d,1)}$	16.9%$_{(d,1)}$	**81.18%**	**85.9%**	**82.1%**
Heating	85.0%$_{(19)}$	108.0%$_{(19)}$	66.0%$_{(19)}$	23.7%$_{(d,1)}$	28.0%$_{(d,1)}$	**88.65%**	**112.6%**	**68.8%**
Lighting	116.0%$_{(19)}$	113.0%$_{(19)}$	121.0%$_{(19)}$	16.7%$_{(d,1)}$	2.4%$_{(d,1)}$	**99.41%**	**96.8%**	**103.7%**
Motors	86.0%$_{(19)}$	91.0%$_{(19)}$	87.0%$_{(19)}$	18.2%$_{(d,1)}$	7.1%$_{(d,1)}$	**76.45%**	**80.9%**	**77.3%**
Other	86.0%$_{(19)}$	45.0%$_{(19)}$	45.0%$_{(19)}$	18.2%$_{(d,1)}$	7.1%$_{(d,1)}$	**76.45%**	**40.0%**	**40.0%**
Process	69.3%$_{(19)}$	81.9%$_{(19)}$	78.7%$_{(19)}$	17.6%$_{(d,1)}$	0.9%$_{(d,1)}$	**57.69%**	**68.2%**	**65.6%**
Refrigeration	86.0%$_{(19)}$	91.0%$_{(19)}$	87.0%$_{(19)}$	3.6%$_{(d,1)}$	25.9%$_{(d,1)}$	**105.18%**	**111.3%**	**106.4%**
Energy Opportunities								
Cooling	101.0%$_{(b,1)}$	160.0%$_{(b,3)}$	116.0%$_{(b,2)}$	20.0%$_{(d,1)}$	0.0%$_{(d,1)}$	**80.8%**	**128.0%**	**92.8%**
Custom	101.0%$_{(b,1)}$	160.0%$_{(b,3)}$	116.0%$_{(b,2)}$	25.9%$_{(d,1)}$	1.8%$_{(d,1)}$	**76.7%**	**121.4%**	**88.0%**
Heating	101.0%$_{(b,1)}$	160.0%$_{(b,3)}$	116.0%$_{(b,2)}$	14.8%$_{(d,1)}$	0.0%$_{(d,1)}$	**86.1%**	**136.3%**	**98.8%**
Lighting	101.0%$_{(b,1)}$	160.0%$_{(b,3)}$	116.0%$_{(b,2)}$	10.8%$_{(d,1)}$	6.3%$_{(d,1)}$	**96.5%**	**152.8%**	**110.8%**
Motors	101.0%$_{(b,1)}$	160.0%$_{(b,3)}$	116.0%$_{(b,2)}$	11.5%$_{(d,1)}$	4.5%$_{(d,1)}$	**93.9%**	**148.8%**	**107.9%**
Other	101.0%$_{(b,1)}$	160.0%$_{(b,3)}$	116.0%$_{(b,2)}$	2.6%$_{(d,1)}$	0.0%$_{(d,1)}$	**98.4%**	**155.8%**	**113.0%**
Process	101.0%$_{(b,1)}$	160.0%$_{(b,3)}$	116.0%$_{(b,2)}$	6.9%$_{(d,1)}$	3.7%$_{(d,1)}$	**97.8%**	**154.9%**	**112.3%**
Refrigeration	101.0%$_{(b,1)}$	160.0%$_{(b,3)}$	116.0%$_{(b,2)}$	3.2%$_{(d,1)}$	0.0%$_{(d,1)}$	**97.8%**	**154.9%**	**112.3%**
Small Business Energy Advantage								
Cooling	96.2%$_{(c)}$	94.3%$_{(c)}$	89.9%$_{(c)}$	15.3%$_{(d,1)}$	0.2%$_{(d,1)}$	**81.7%**	**80.1%**	**76.3%**
Heating	96.2%$_{(c)}$	94.3%$_{(c)}$	89.9%$_{(c)}$	0.0%$_{(d,1)}$	0.0%$_{(d,1)}$	**96.2%**	**94.3%**	**89.9%**
Lighting	96.2%$_{(c)}$	94.3%$_{(c)}$	89.9%$_{(c)}$	3.8%$_{(d,1)}$	2.5%$_{(d,1)}$	**94.9%**	**93.1%**	**88.7%**
Custom	96.2%$_{(c)}$	94.3%$_{(c)}$	89.9%$_{(c)}$	0.3%$_{(d,1)}$	0.0%$_{(d,1)}$	**95.9%**	**94.0%**	**89.6%**
Other	96.2%$_{(c)}$	94.3%$_{(c)}$	89.9%$_{(c)}$	0.5%$_{(d,1)}$	0.2%$_{(d,1)}$	**95.9%**	**94.0%**	**89.6%**
Comp. Air	96.2%$_{(c)}$	94.3%$_{(c)}$	89.9%$_{(c)}$	0.3%$_{(d,1)}$	0.0%$_{(d,1)}$	**95.9%**	**94.0%**	**89.6%**
Refrigeration	96.2%$_{(c)}$	94.3%$_{(c)}$	89.9%$_{(c)}$	1.4%$_{(d,1)}$	0.0%$_{(d,1)}$	**94.9%**	**93.0%**	**88.6%**

Gross Realization %				FR & SO		Net Realization % (Note 3)		
End-use	kWh	Winter Seasonal Peak kW	Summer Seasonal kW	Free-ridership	Spillover	kWh	Winter Seasonal Peak kW	Summer Seasonal Peak kW
O&M								
PRIME	100.0%	100.0%	100.0%	0.0%	0.0%	**100.0%**	**100.0%**	**100.0%**
O&M	73%(e,1)	101%(e,1)	84%(e,1)	0.0%	0.0%	**73%**	**101%**	**84%**
Retro-com	74%(e,2)	90%(e,2)	113%(e,2)	0.0%	0.0%	**74%**	**90%**	**113%**
Load Management								
Load Response	100.0%	100.0%	100.0%	0.0%	0.0%	**100.0%**	**100.0%**	**100.0%**
Upstream Lighting								
CFL Linear Fluorescent	100.0%	100.0%	100.0%	26.0%(m)	0.0%	**74.0%(m)**	**74.0%(m)**	**74.0%(m)**
LED	100.0%	100.0%	100.0%	18.0%(m)	0.0%	**82.0%(m)**	**82.0%(m)**	**82.0%(m)**

CL&P & UI Commercial & Industrial Gas Realization Rates

Gross Realization %				FR & SO		Net Realization % (Note 3)		
End-use	Energy (CCF)	Peak Day (CCF)		Free-ridership	Spillover		Energy (CCF)	Peak Day (CCF)
Energy Conscious Blueprint								
Envelope	68.0%(19)	100%(19)		23.8%(d,2)	9.5%(d,2)		**58.3%**	**58.3%**
HVAC	96.0%(19)	100%(19)		23.8%(d,2)	9.5%(d,2)		**82.3%**	**82.3%**
Process	68.0%(19)	100%(19)		23.8%(d,2)	9.5%(d,2)		**58.3%**	**58.3%**
Water Heating	96.0%(19)	100%(19)		23.8%(d,2)	9.5%(d,2)		**82.3%**	**82.3%**
Energy Opportunities								
Controls	84.0%(b,1)	100.0%		30.0%(d,2)	31.0%(d,2)		**84.8%**	**101.0%**
HVAC	84.0%(b,1)	100.0%		30.0%(d,2)	31.0%(d,2)		**84.8%**	**101.0%**
Process	84.0%(b,1)	100.0%		30.0%(d,2)	31.0%(d,2)		**84.8%**	**101.0%**
O&M								
Overall Program	87%(e,3)	108%(e,3)		0.0%	0.0%		87%	108%
RCx								
Overall Program	60%(e,4)	72%(e,4)		0.0%	0.0%		60%	72%

CL&P & UI Residential Electric & Gas Realization Rates

Gross Realization %					FR & SO		Net Realization % (Note 4)		
Measure	kWh or (CCF)	Winter Seasonal Peak kW or (Peak Day CCF)	Summer Seasonal Peak kW	Installation Rate	Free-ridership	Spillover	kWh or (CCF)	Winter Seasonal Peak kW or (Peak Day CCF)	Summer Seasonal Peak kW
Home Energy Solutions/ Home Energy Solutions Income Eligible* • Realization Rates are Applicable to both program except as where noted below									
Other Measures	100.0%	100.0%	100.0%	100.0%	0.0%	0.0%	**100.0%**	**100.0%**	**100.0%**
HES Lighting LEDs (note 9)	100.0%	100.0%	100.0%	100.0%	10.0%	0.0%	**90.00%**	**90.00%**	**90.00%**
HES Lighting LEDs (note 9)	100.0%	100.0%	100.0%	100.0%	23.5%	0.0%	**76.50%**	**76.50%**	**76.50%**
Prescriptive Air Sealing (note 11)	56.5%(o)	56.5%(o)	56.5%(o)	100.0%	0.0%	0.0%	**56.5%**	**56.5%**	**56.5%**
Blower Door Air Sealing (note 12)	92.5%(o)	92.5%(o)	92.5%(o)	100.0%	0.0%	0.0%	**92.5%**	**92.5%**	**92.5%**
Duct Sealing (note 16)	92.5%(o)	92.5%(o)	92.5%(o)	100.0%	0.0%	0.0%	**92.5%**	**92.5%**	**92.5%**
HES Insulation (note 17)	68.8%(o)	68.8%(o)	68.8%(o)	100.0%	6.0%(s)	0.0%	**64.7.%**	**64.7.%**	**64.7.%**
HES-IE Insulation (note 17)	68.8%(o)	68.8%(o)	68.8%(o)	100.0%	0.0%(s)	0.0%	**68.8%**	**68.8%**	**68.8%**
HES Water Savings Measures	100.0%	100.0%	100.0%	100.0%	20.0%	0.0%	**80.0%**	**80.0%**	**80.0%**
HES Water Pipe Wrap	100.0%	100.0%	100.0%	100.0%	28.0%	0.0%	**72.0%**	**72.0%**	**72.0%**
Central AC/HP-CLP	100%(p)	100%(p)	100 %(p)	100.0%	42.0%(j)	0.0%	**58.0%**	**58%**	**5.8%**
Central AC/HP-UI	100%(p)	100%(p)	100%(p)	100.0%	26.0%(j)	0.0%	**74%**	**74%**	**74%**
Ductless Heat Pump – Single Family (note 15)	63.0%(o)	63.0%(o)	63.0%(o)	100.0%	0.0%	0.0%	**63.0%**	**63%**	**63%**
Ductless Heat Pump – Multi-Family (note 11)	52.0%(o)	52.0%(o)	52.0%(o)	100.0%	0.0%	0.0%	**52.0%**	**52%**	**52%**
Appliances (note 10)	94.3%(o)	94.3%(o)	94.3%(o)	100.0%	0.0%	0.0%	**94.3%**	**94.3%**	**94.3%**
Refrigerators (note 13)	100.0%	100.0%	100.0%	100.0%	0.0%	0.0%	**100.0%**	**100.0%**	**100.0%**
Windows (note 14)	100.0%	100.0%	100.0%	100.0%	0.0%	0.0%	**100.0%**	**100.0%**	**100.0%**
Water Heating (note 14)	100.0%	100.0%	100.0%	100.0%	0.0%	0.0%	**100.0%**	**100.0%**	**100.0%**
Heating System Retirement (note 10)	63.7%(o)	63.7%(o)	63.7%(o)	100.0%	0.0%	0.0%	**63.7%**	**63.7%**	**63.7%**

Heating System Replacement for Boiler and Gas alternate	100.0%	100.0%	100.0%	100.0%	0.0%	0.0%	**100.0%**	**100.0%**	**100.0%**
Gas Boiler (UIL Method) (note 18)	100.0%	100.0%	100.0%	100.0%	28.0%	0.0%	**72.0%**	**72.0%**	**72.0%**
Gas Furnace (UIL Method)(note 18)	100.0%	100.0%	100.0%	100.0%	28.0%	0.0%	**72.0%**	**72.0%**	**72.0%**
Gross Realization %					**FR & SO**		**Net Realization %** (Note 4)		
Measure	**kWh or (CCF)**	**Winter Seasonal Peak kW or (Peak Day CCF)**	**Summer Seasonal Peak kW**	**Installation Rate**	**Free-ridership**	**Spillover**	**kWh or (CCF)**	**Winter Seasonal Peak kW or (Peak Day CCF)**	**Summer Seasonal Peak kW**
Retail Products									
CFL Bulbs (Note 6)	100.0%	100.0%	100.0%	88.0%(i)	47.9%(k)	0.0%	**45.9%**	**45.9%**	**45.9%**
LED Bulbs (note 6)	100.0%	100.0%	100.0%	97.5%(i)	24.3%(k)	0.0%	**73.80%**	**73.80%**	**73.80%**
Portable Lamps	100.0%	100.0%	100.0%	70.0%(h,1)	3.1%(h,1)	6.0%(h,2)	**72.0%**	**72.0%**	**72.0%**
Torchiere	100.0%	100.0%	100.0%	70.0%(h,1)	3.1%(h,1)	6.0%(h,2)	**72.0%**	**72.0%**	**72.0%**
Hard Wired Fixtures	100.0%	100.0%	100.0%	80.0%(h,1)	3.1%(h,1)	6.0%(h,2)	**82.3%**	**82.3%**	**82.3%**
Ceiling Fans & Lights	100.0%	100.0%	100.0%	80.0%(h,1)	3.1%(h,1)	6.0%(h,2)	**82.3%**	**82.3%**	**82.3%**
CFL giveaway (Note 6)	100.0%	100.0%	100.0%	88%i)	47.0%(k)	0.0%	**46.64%**	**46.64%**	**46.64%**
NCP Heat Pump Hot Water Heater	100.0%	100.0%	100.0%	100.0%	0.0%	0.0%	**100.0%**	**100.0%**	**100.0%**
Freezer (note 20)	100.00 %	100.00%	100.00%	100%	30%	0.00%	**70.00%**	**70.00%**	**70.00%**
Clothes Washer (note 20)	100.00 %	100.00%	100.00%	100%	45%	0.00%	**55.00%**	**55.00%**	**55.00%**
Dryer (note 20)	100.00 %	100.00%	100.00%	100%	15%	0.00%	**85.00%**	**85.00%**	**85.00%**
Refrigerator (note 20)	100.00 %	100.00%	100.00%	100%	46%	0.00%	**54.00%**	**54.00%**	**54.00%**
Behavioral Programs									
Home Energy Reports	100.0%	100.0%	100.0%	100.0%	0.0%	0.0%	**100.0%**	**100.0%**	**100.0%**
Appliance Turn-In									
Refrigerator Recycling	100%	100%	100%	100%	31.0%(l)	0.0%	**69.0%**	**69.0%**	**69.0%**
Freezer Recycling	100%	100%	100%	100%	41.0%(l)	0.0%	**59.0%**	**59.0%**	**59.0%**

Changes from Last Version

Added new HES and HESIE Insulation, Water Saving, Pipe Wrap, Lighting Free Ridership values

Updated Retail Products CFL and LED Installation Rates and Free Ridership

Updated UI Residential Furnace and Boiler Free ridership

Updated ECB Realization Rates

Updated Retail Products Appliance free ridership values

References

[a] Global Energy Partners, Evaluation of The Energy Conscious Blueprint Program, August 4, 2011.
[a,1] Table ES-4.
[a,2] Table ES-5.
[a,3] Table ES-6.

[b] EMI, Evaluation of the Energy Opportunities Program: Program Year 2011, April 1, 2014.
[b,1] Page ES-5, Table 1-1.
[b,2] Page ES-6, Table 1-2.
[b,3] Page ES-6, Table 1-3.

[c] KEMA, Impact Evaluation of the Connecticut Small Business Energy Advantage Program, April 2014, Page 2, Table 2.

[d] Tetra Tech, 2011 C&I Electric & Gas Free-ridership and Spillover Study, October 5, 2012,
[d,1] Page 3-4, Table 3-5
[d,2] Page 3-5, Table 3-6.

[e] Michaels Energy & Evergreen Economics, Impact Evaluation of the Retrocommissioning, Operation and Maintenance, and Business Sustainability Challenge Programs, Report, Not dated.
[e,1] Page v, Table 6
[e,2] Page ii, Table 1.
[e,3] Page vi, Table 7
[e,4] Page ii, Table 2

[f] Nexant, Home Energy Solutions Evaluation, Final Report, March 2011.Page 3, Table E.1-1.

[g] KEMA, Evaluation of the Weatherization Residential Assistance Partnership (WRAP) and Helps Programs, September 10, 2010
[g,1] Page 1-13.
[g,2] Table ES-9, Page 1-11. Note [5]

[h] Point of Purchase Lighting Impact Evaluation, 2003
[h,1] Page 6, Table 2.
[h,2] Page 6, Table 2. Note [6]

[i] Connecticut LED Lighting Study Report (R154), January 28 2016, Pg 35, Table 21

[j] ADM Associates, Inc., Residential Central AC Regional Evaluation Free-Ridership Analysis, October 2009, Page 9.

[k] Free-ridership values negotiated between the EEB Consultants and Connecticut electric and gas utilities.

[l] NMR, Massachusetts Appliance Turn-in Program Impact Evaluation, June 15, 2011, Page 2, Table ES-3.

[m] KEMA, Process Evaluation of the 2012 Bright Opportunities Program Final Report, June 14, 2013, Page 1-11 Table 1-3.

[n] Massachusetts Technical Reference Manual (TRM), Program year 2012

[o] NMR and Cadmus, Impact Evaluation: Home Energy Services—Income-Eligible and Home Energy Services Programs: Volume 2 (R16), Review Draft, July 2, 2014.

[p] NMR and DNV GL, Central Air Conditioning Impact and Process Evaluation Final Report, October 8, 2014, Page III.

[q] NMR and DNV GL, Northeast Residential Lighting Hours-of-Use Study, May 5, 2014.

[r] D+R international LTD, 2015 D+R Connecticut HVAC Market Report, May 27, 2016

[s] NMR Group, Inc. HES/HES-IE Process Evaluation and Real Time Research, April 13,2016

[t] C20 impact evaluation of Energy Conscious Blueprint Program years 2012-2013, November 6, 2015. Tables 4-3 through 4-6

[u] ENERGY STAR 2015 Shipment data Unit Shipment and Market Penetration Report Calendar Year 2015 Summary < https://www.energystar.gov/ia/partners/downloads/unit_shipment_data/2015_USD_Summary_Report.pdf?593e-b9e5>

Notes

[1] Realization rates based on references [1], [2], [3] & [5] based on program. If study not available value set to 100%.

[2] Based on reference [4]. If study not available values set to 0.

[3] Net Realization = (Gross realization %) x (100% - Free ridership % + Spillover %)
UI caps net realization rate at 100%

[4] Net Realization = (Gross realization %) x (installation rate %) x (100% - Freeridership % + Spillover %)
UI caps net realization rate at 100%

[5] Figure of 73.1% is the ratio of the evaluated coincidence factor (.19) to the coincidence factor in use (.26). This method of incorporating the evaluation allows the use of a consistent 0.26 coincidence factor throughout lighting.

[6] The Installation rate is the average of the four year installation rates given in Ref[i]

[7] Installation rate is the average of the first-year installation rate and the lifetime installation rate; this is due to the 4-year measure life, halfway between 1-year and the 7-year measure life used in the study.

[8] Program realization rates used for increased precision when individual measure sample size is small.

[9] HES Free ridership values for Direct install LED's and CFL's are the result of a combination of the 2015 R86: Connecticut Residential LED Market Assessment and 2016 Connecticut Lighting Market Trends

[10] Weighted average of results from the draft HES evaluation [o].

[11] HES-IE results from the draft HES evaluation [o].

[12] HES results from the draft HES evaluation [o].

[13] The findings of the draft HES evaluation have been incorporated into the savings calculation for this measure.

[14] Realization rate in excess of 100% fixed to 100%.

[15] Pending final results from the draft HES evaluation, this realization rate incorporates results from [o], [f], and [g].

[16] Pending final results from the draft HES evaluation, this measure uses the HES realization rate for weatherization.

[17] Weighted average of study results incorporating the effect of changes to PSD calculations. Updated in 2016 for results of interactive effects

[18] UIL's Boiler and Furnace Free ridership values were determined using adjusted AFUE baselines. The adjusted baselines are the weighted average of AFUEs of units sold in CT in 2015, from [r] that did not meet program minimum performance levels.

[19] ECB Realization rates are based on the results in ref[t].for some categories the results were weighted and averaged in order to accommodate the previously established end use categories.

[20] Free ridership values from ref[u]

APPENDIX 4. LIFETIMES

Commercial and Industrial Lifetimes

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					
Automatic Photocell Dimming Systems	9(a)	10(a)	N/A	N/A	N/A
Bi-Level Switching (Demand Reduction)	10(a,*)	10(a,*)	N/A	N/A	N/A
CFLs	5(a)	N/A	N/A	N/A	N/A
Fixtures (LED & Fluorescent)	13(a)	15(a)	N/A	N/A	N/A
Fluorescent Lighting system power reduction controls	9(a,*)	N/A	N/A	N/A	N/A
Lamp and Ballast Conversions	13(a)	N/A	N/A	N/A	N/A
Lamp Replacement (LED)	N/A	N/A	8(l)	8(l)	N/A
Lamp Replacement (Fluorescent)	N/A	N/A	5(l)	5(l)	N/A
Upstream Lighting (LED)	8(l)	N/A	8(l)	8(l)	N/A
Upstream Lighting (Fluorescent)	5(l)	N/A	5(l)	5(l)	N/A
LEDs (screw-in bulbs)	8(l)	N/A	N/A	N/A	N/A
Occupancy Sensors	9(a)	10(a)	N/A	N/A	N/A
Re-circuiting and New Controls	10(a,*)	N/A	N/A	N/A	N/A
Remove Unnecessary Lighting Fixtures	5(l)	N/A	N/A	N/A	N/A
Reprogramming of EMS Controls	N/A	N/A	5(b,2)	N/A	8(l)
Sweep Controls / EMS Based Controls	10(a,*)	15(a,*)	N/A	N/A	N/A
Timer Switch	10(a,*)	N/A	N/A	N/A	N/A
Building Envelope					
Cool Roofs	N/A	15(c/14)	N/A	N/A	N/A
Insulation	20(c/19)	20(c/19)	N/A	N/A	N/A
Movable Window Insulation	10(l)	10(l)	N/A	N/A	N/A
New Windows	N/A	20(c/16)	N/A	N/A	N/A
Roof Spray Cooling	15(l)	15(l)	N/A	N/A	N/A
Window Film	10(c/18)	10(c/18)	N/A	N/A	N/A
Domestic Hot Water					
Energy-Efficient Motors	15(a)	20(a)	N/A	N/A	N/A
Faucet Aerators	10(j)	N/A	N/A	N/A	N/A
Gas Fired Water Heater	N/A	15(c/93)	N/A	N/A	N/A
Heat Pump Water Heater	10(c/143*)	10(c/143*)	N/A	N/A	N/A
Heat Recovery	15(l)	15(l)	N/A	N/A	N/A
Low Flow Showerhead	10(j)	N/A	N/A	N/A	N/A
Point-of-Use Water Heater	20(c/95)	20(c/95)	N/A	N/A	N/A
Pre-Rinse Spray Valve	5(h)	N/A	N/A	N/A	N/A
Solar Water Heater	20(l)	20(l)	N/A	N/A	N/A

Description	Retrofit	Lost Opportunity	Operations	Maintenance	RCx
Heating, Ventilating and Air Condition (HVAC) Systems					
2-Speed Motor Control in Rooftop units	$13_{(a,*)}$	$15_{(a,*)}$	N/A	N/A	N/A
Additional Pipe Insulation	$10_{(l)}$	$10_{(l)}$	N/A	N/A	N/A
Additional Vessel Insulation	$10_{(l)}$	$10_{(l)}$	N/A	N/A	N/A
Air Curtain	$15_{(l)}$	$15_{(l)}$	N/A	N/A	N/A
Air Distribution System Modifications & Conversions	$20_{(l)}$	$20_{(l)}$	N/A	N/A	N/A
Cool Thermal Storage	$15_{(l)}$	$15_{(l)}$	N/A	N/A	N/A
Cooling Tower Alternates	$13_{(l)}$	$15_{(c/45*)}$	N/A	N/A	N/A
Dehumidifiers	$13_{(l)}$	$15_{(l)}$	N/A	N/A	N/A
Duct Insulation	$20_{(a,**)}$	N/A	N/A	N/A	N/A
Duct Sealing	$18_{(c/31)}$	N/A	N/A	N/A	N/A
Duct Type Air Destratification System	$15_{(f*)}$	$15_{(f*)}$	N/A	N/A	N/A
Economizer - Air/Water	$7_{(a)}$	$10_{(a)}$	N/A	N/A	N/A
Electric Chillers	N/A	$23_{(a)}$	N/A	N/A	N/A
Electric Spot Radiant Heat	$10_{(l)}$	$10_{(l)}$	N/A	N/A	N/A
Energy-Efficient Motors	$15_{(a)}$	$20_{(a)}$	N/A	N/A	N/A
Energy-Efficient Packaged Terminal Units	N/A	$15_{(a)}$	N/A	N/A	N/A
Evaporative Cooling (unitary)	N/A	$15_{(a,*)}$	N/A	N/A	N/A
Gas Engine Chillers	N/A	$15_{(d)}$	N/A	N/A	N/A
Gas Fired Boiler (Condensing)	N/A	$15_{(l)}$	N/A	N/A	N/A
Gas Fired Boiler (Non-Condensing)	N/A	$20_{(c/24)}$	N/A	N/A	N/A
Gas Fired Radiant Heater	N/A	$15_{(l)}$	N/A	N/A	N/A
Gas Furnace	N/A	$20_{(c/24*)}$	N/A	N/A	N/A
High-Efficiency Unitary Equipment (A/C and Heat Pumps)	N/A	$15_{(a)}$	N/A	N/A	N/A
Low-Leakage Damper	$12_{(l)}$	$12_{(l)}$	N/A	$5_{(b,2)}$	N/A
Make-up Air Unit for Exhaust Hood	$15_{(l)}$	$15_{(l)}$	N/A	N/A	N/A
Outdoor Air Damper Adjustment or Modification	N/A	N/A	N/A	$5_{(b,2)}$	N/A
Paddle Type Air Destratification Fan	$15_{(f*)}$	$15_{(f*)}$	N/A	N/A	N/A
Plate/Heat Pipe Type Heat Recovery System	$14_{(c/27)}$	$14_{(c/27)}$	N/A	N/A	N/A
Repair Air Side Economizer	N/A	N/A	N/A	$5_{(b,2)}$	N/A
Repair Steam/Air Leaks	N/A	N/A	N/A	$5_{(b,2)}$	N/A
Replace Steam Traps	N/A	N/A	N/A	$6_{(g)}$	N/A
Rotary Type Heat Recovery System	$14_{(c/41)}$	$14_{(c/41)}$	N/A	N/A	N/A
Variable Speed Drives	$13_{(b,1)}$	$15_{(b,1)}$	N/A	N/A	N/A
VAV System Components	$13_{(l)}$	N/A	N/A	N/A	N/A
Water/Steam Distribution System Modifications & Conversions	$20_{(l)}$	$20_{(l)}$	N/A	N/A	N/A
Zoned Circulator Pump System	$15_{(l)}$	N/A	N/A	N/A	N/A
HVAC Controls					
Adjust Scheduling	N/A	N/A	$5_{(b,2)}$	N/A	$6_{(l)}$
Controls to Eliminate Simultaneous Heating and Cooling	$10_{(a)}$	N/A	$5_{(b,2)}$	N/A	$8_{(l)}$
Demand Control Ventilation - Multi Zone	$10_{(a)}$	$10_{(l)}$	N/A	N/A	N/A
Demand Control Ventilation - Single Zone	$10_{(a)}$	$10_{(l)}$	N/A	N/A	$8_{(l)}$
EMS/Linked HVAC Controls	$10_{(a)}$	$15_{(a)}$	N/A	N/A	$8_{(l)}$
Enthalpy Control Economizer	$7_{(a)}$	$10_{(a)}$	N/A	N/A	N/A

Description	Retrofit	Lost Opportunity	Operations	Maintenance	RCx
Modify HVAC Controls	$10_{(a)}$	N/A	N/A	N/A	$8_{(l)}$
New/Additional EMS Points	$10_{(a)}$	$15_{(a)}$	N/A	N/A	N/A
Programmable Thermostat	$8_{(a)}$	N/A	N/A	N/A	N/A
Repair HVAC Controls	N/A	N/A	N/A	$5_{(b,2)}$	N/A
Reprogramming of EMS Controls	N/A	N/A	$5_{(b,2)}$	N/A	$8_{(l)}$
Reset Setpoints	N/A	N/A	$5_{(b,2)}$	N/A	$6_{(l)}$
Single Zone Controls NOT Linked to other Controls	$10_{(a)}$	N/A	N/A	N/A	N/A
Time Clocks	$11_{(c/43)}$	N/A	N/A	N/A	N/A
Upgrade to dual/comparative Enthalpy Economizer	$10_{(a,*)}$	$10_{(a,*)}$	N/A	N/A	N/A
Refrigeration					
Additional Pipe Insulation - Refrigeration System	$11_{(c/83)}$	$11_{(c/83)}$	N/A	N/A	N/A
Additional Vessel Insulation - Refrigeration System	$11_{(c/83*)}$	$11_{(c/83*)}$	N/A	N/A	N/A
Adjust Scheduling	N/A	N/A	$5_{(b,2)}$	N/A	$8_{(l)}$
Ambient Subcooling	$15_{(c/85)}$	$15_{(c/85)}$	N/A	N/A	N/A
Auto Cleaning System for Condenser Tubes	$10_{(l)}$	$10_{(l)}$	N/A	N/A	N/A
Case Cover	$5_{(c/84)}$	$5_{(c/84)}$	N/A	N/A	N/A
Commercial Refrigeration Systems/Components	$15_{(c/85)}$	$15_{(c/85)}$	$3_{(l)}$	N/A	N/A
Demineralized Water for Ice	$10_{(l)}$	$10_{(l)}$	N/A	N/A	N/A
Electronically Commutated Motors	$15_{(c/85)}$	$15_{(c/85)}$	N/A	N/A	N/A
Heat Recovery from Refrigeration System	$10_{(c/80)}$	$13_{(l)}$	N/A	N/A	N/A
Hot Gas Bypass for Defrost or Regeneration	$10_{(l)}$	$10_{(l)}$	N/A	N/A	N/A
Industrial Refrigeration Systems/Components	$20_{(b,1)}$	$20_{(b,1)}$	$3_{(l)}$	N/A	N/A
Low Case HVAC Returns	$10_{(l)}$	$10_{(l)}$	N/A	N/A	N/A
Low Emissivity Ceiling Surface	$15_{(l)}$	$15_{(l)}$	N/A	N/A	N/A
Mechanical Subcooling	$15_{(c/85)}$	$15_{(c/85)}$	N/A	N/A	N/A
Motorized Insulated Doors	$8_{(c/75)}$	$8_{(c/75)}$	N/A	N/A	N/A
Open or Enclosed Display Cases	$12_{(c/76)}$	$12_{(c/76)}$	N/A	N/A	N/A
Adding Doors on Open Display Cases	$12_{(c/76*)}$	N/A	N/A	N/A	N/A
Oversized Condensers	$15_{(c/85)}$	$15_{(c/85)}$	N/A	N/A	N/A
Polyethylene Strip Curtain	$4_{(c/88)}$	$4_{(c/88)}$	N/A	N/A	N/A
Refrigeration Controls	$10_{(b,1)}$	$10_{(b,1)}$	$5_{(b,2)}$	N/A	$10_{(c/86)}$
Reset Setpoints	N/A	N/A	$5_{(b,2)}$	N/A	$8_{(l)}$
Vending Machine Occupancy Sensors	$5_{(b,1)}$	N/A	N/A	N/A	N/A
Process Equipment					
Add Regulator Valves in Compressed Air System	$10_{(l)}$	$10_{(l)}$	N/A	N/A	$10_{(c/86)}$
Air Compressor	$13_{(b,1)}$	$15_{(b,1)}$	N/A	N/A	N/A
Clothes Washer	N/A	$11_{(i)}$	N/A	N/A	N/A
Compressed Air Distribution and Storage Systems	$10_{(l)}$	N/A	N/A	N/A	N/A
Energy Efficient Transformers	$15_{(a,*)}$	$20_{(a,*)}$	N/A	N/A	N/A
Energy-Efficient Motors	$15_{(a)}$	$20_{(a)}$	N/A	N/A	N/A
Injection Molding Machine Jackets	$5_{(l)}$	N/A	N/A	N/A	N/A
Install Air Compressor No-Loss Condenser Drains	$10_{(l)}$	$10_{(l)}$	N/A	$5_{(b,2)}$	$10_{(c/86)}$
Interlock Air System Solenoid Valves with Machine Operation	$10_{(a,*)}$	$10_{(a,*)}$	N/A	N/A	$10_{(c/86)}$
Interlock Exhaust Fans with Machine Operations	$10_{(a,*)}$	$10_{(a,*)}$	N/A	N/A	$10_{(c/86)}$
Plastic Injection Molding Machine	$13_{(l)}$	$15_{(l)}$	N/A	N/A	N/A

Description	Retrofit	Lost Opportunity	Operations	Maintenance	RCx
PRIME	N/A	5(e)	N/A	N/A	N/A
Refrigerated Air Dryer	13(b,1)	15(b,1)	N/A	N/A	N/A
Repair Steam/Compressed Air Leaks	N/A	N/A	N/A	5(b,2)	N/A
Replace Steam Traps	N/A	N/A	N/A	6(g)	N/A
Variable Frequency Drives	13(b,1)	15(b,1)	N/A	N/A	N/A
Water treatment magnets	10(l)	N/A	N/A	N/A	N/A
Commercial Kitchen Equipment					
Convection Oven	N/A	12(c/20)	N/A	N/A	N/A
Dishwasher - Under Counter	N/A	10(k)	N/A	N/A	N/A
Dishwasher - Stationary Single Tank Door	N/A	15(k)	N/A	N/A	N/A
Dishwasher - Single Tank Conveyor	N/A	20(k)	N/A	N/A	N/A
Dishwasher - Multi Tank Conveyor	N/A	20(k)	N/A	N/A	N/A
Freezer	N/A	12(c/76)	N/A	N/A	N/A
Fryer	N/A	12(c/20)	N/A	N/A	N/A
Griddle	N/A	12(c/20)	N/A	N/A	N/A
Hot Food Holding Cabinet	N/A	12(c/23)	N/A	N/A	N/A
Ice Machine	N/A	12(c/82)	N/A	N/A	N/A
Refrigerator	N/A	12(c/76)	N/A	N/A	N/A
Steam Cooker	N/A	12(c/20)	N/A	N/A	N/A
Other					
Whole Building Performance	N/A	17(l)	N/A	N/A	N/A

Changes from Last Version

No Changes

References

[a] GDS Associates Inc., Measure Life Report, Residential and Commercial Industrial Lighting and HVAC Measures, June 2007, Table 2.
[a,*] This measure is similar to those in the report, so a measure life from Table 2 was used.
[a,**] This measure is similar to those in the report, so a measure life from Table 1 was used.

[b] Energy & Resource Solutions (ERS), Measure Life Study: prepared for The Massachusetts Joint Utilities, October 10, 2005.
[b,1] Table 1-1.
[b,2] Page 4-9.

[c] 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.
[c/#] Row #.
[c/#*] Similar measure to row #; row # used.

[d] Gas chiller measure life was set by the CT DPUC in their decision in Docket 05-07-14, in response to Public Act 05-01, “An Act Concerning Energy Independence”. Dec 28, 2005, Page 29, Table 4

[e] Energy & Resource Solutions (ERS), Process Reengineering for Increased Manufacturing Efficiency Program Evaluation, March 26, 2007, Page 1-5.

[f*] Efficiency Maine TRM, 3/5/07, Page 91. Similar measure.

[g] Energy and Environmental Analysis, Inc. Steam Traps Workpaper for PY2006-2008. Prepared for Southern California Gas Company, December 2006, Page 14, Section 9.1.

[h] Veritec Consulting, "Region of Waterloo Pre-Rinse Spray Valve Pilot Study Final Report", January, 2005, Executive Summary.

[i] Appliance Magazine. U.S. Appliance Industry: Market Share, Life Expectancy & Replacement Market, and Saturation Levels. January 2010. Page 10.

[j] GDS Associates, Inc. (2009). Natural Gas Energy Efficiency Potential in Massachusetts. Prepared for GasNetworks; Table B-2a.

[k] ENERGY STAR commercial kitchen equipment savings calculator.

[l] Estimated

Residential Lifetimes

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, Retrofit EUL**	**New Home & Retail, Lost Opportunity EUL**	**Comments**
Light Bulbs				
CFL, General Service	N/A	4	4	Notes [1], [2]
CFL, Non-General Service 6,000 hr	N/A	4	4	Note [1]
CFL, Non-General Service 7,000 hr	N/A	4	4	Note [1]
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]
CFL, Non-General Service, >15,000 hr	N/A	8	8	Note [1]
LED, Down light	N/A	8 (l)	8 (l)	Note [5]
LED, General Service	N/A	8(l)	8(l)	Note [5]
LED, Non-General Service, Non-Downlight	N/A	8(l)	8(l)	Note [5]

	Existing Home, Retirement RUL	**Existing Home, Retrofit EUL**	**New Home & Retail, Lost Opportunity EUL**	**Comments**
Luminaires				
CFL, Hardwired Indoor Fixture	N/A	8	8	Note[5]
CFL, Hardwired Exterior Fixture	N/A	6(e,1)	6(e,1)	
CFL, Portable Table Lamp	N/A	8(c,1)	8(c,1)	
CFL, Portable Torchiere	N/A	8(c,1)	8(c,1)	
CFL, Security Exterior	N/A	15(d,3)	15(d,3)	
LED, Portable Table Lamp	N/A	8(c,1)	8(c,1)	
LED, Portable Torchiere	N/A	8(c,1)	8(c,1)	
LED, Hardwired Exterior Fixture	N/A	8	8	Note[5]
LED, Hardwired Indoor Fixture	N/A	8	8	Note[5]
Heating, Ventilation, and Air-Conditioning (HVAC) systems				
Air Source Heat Pump	5(d)	18(c,1)	25(c,1)	
Boiler (Gas)	5(d)	20(a)	20(a)	
Boiler Reset Control	N/A	15(f)	N/A	
Central Air Conditioning System	5(d)	18(c,1)	25(c,1)	
Clean Tune and Test	N/A	2(k)	N/A	
Duct Blaster Test (New Construction)	N/A	N/A	25(c,1)	
Duct Insulation	N/A	20(c,1)	N/A	
Duct Sealing	N/A	20(c,1)	N/A	
Ductless Split Heat Pump	N/A	18(c,1)	N/A	
Electronically Commutated Motor (Fan)	N/A	18(c,1)	18(c,1)	
ECM Circulator Pump	N/A	15(g)	N/A	
Furnace (Gas)	5(d)	20(d)	20(d)	
Geothermal Heat Pump	N/A	18(c,1)	25(c,1)	
Package Terminal Heat Pump	5(d)	18(c,1)	N/A	
QIV, Air Source Heat Pump	N/A	18(c,1)	18(c,1)	
QIV, Boiler (Boiler Reset)	N/A	20(a)	20(a)	
QIV, Central Air Conditioning System	N/A	18(c,1)	18(c,1)	
QIV, Geothermal Heat Pump	N/A	18(c,1)	18(c,1)	
WiFi Thermostat	N/A	15 (h)	15 (h)	
Appliances				
Advanced Power Strips	N/A	5(j)	N/A	
Clothes Washers, Clothes Dryers	4(d)	11(a)	11(a)	
Dehumidifiers	4(d)	12(c,1)	12(c,1)	
Dish Washers	4(d)	10(a)	10(a)	
Freezers	4 (8) (d)	11(a)	11(a)	
Refrigerators	5 (10) (d)	12(a)	12(a)	
Room AC Units	4(d)	9(a)	9(a)	
Envelope				
Air Sealing and Weatherization (Non-Blower Door)	N/A	20(c,1)	N/A	
Blower Door	N/A	20(c,1)	25(c,1)	
Broken Window Repair	N/A	5(d)	N/A	
Insulating Attic Openings	N/A	25(c,1)	N/A	
Insulation	N/A	25(c,1)	N/A	
Storm Window Installation	N/A	20(c,1)	N/A	
Thermal Bypass	N/A	N/A	25(c,1)	
Window Replacement	N/A	25(c,1)	N/A	
Domestic Hot Water				
Flip and Faucet Aerators	N/A	5(d)	N/A	
Heat Pump Water Heater		10(b,4)	10(b,4)	

	Existing Home, Retirement RUL	Existing Home, Retrofit EUL	New Home & Retail, Lost Opportunity EUL	Comments
High Efficiency Storage Gas Water Heater		N/A	11(b,5)	
On Demand Tankless Gas Water Heater		20(b,2)	20(b,2)	
Pipe Insulation		15(d)	N/A	
Shower Head Low Flow	N/A	10(c,2)	N/A	
Water Heater Thermostat Setting (Existing Unit)	N/A	4(d)	N/A	
Water Heater Wrap	N/A	5(d)	N/A	
Solar Water Heating	N/A	20(i)	20(i)	
REM Savings (for ENERGY STAR Homes)				
Cooling	N/A	N/A	25(c,1)	
Dom. Water Heating	N/A	N/A	25(c,1)	
Heating	N/A	N/A	25(c,1)	
BOP (Builder Option Plan for ENERGY STAR homes)				
Cooling	N/A	N/A	25(c,1)	
Dom. Water Heating	N/A	N/A	25(c,1)	
Heating	N/A	N/A	25(c,1)	
Behavioral Programs				
Home Energy Reports	N/A	1+(d)	N/A	[5]

Changes from Last Version

CT&T Lifetime
Advanced power strips lifetime
New Residential LED Lifetimes

References

[a] Appliance Magazine. U.S. Appliance Industry: Market Share, Life Expectancy & Replacement Market, and Saturation Levels. January 2010. Page 10.
[b] California Public Utilities Commission, 2008 Database for Energy-Efficient Resources, December 16, 2008. http://www.deeresources.com/deer0911planning/downloads/EUL_Summary_10-1-08.xls, last accessed May 31, 2011, Version 2008.2.05.
[b,1] Cell D135.
[b,2] Cell D146.
[b,3] Cell D141.
[b,4] Cell D143.
[b,5] Cell D145.
[c] GDS Associates Inc. Measure Life Report, Residential and Commercial Industrial Lighting and HVAC Measures, June 2007
[c,1] Table 1.
[c,2] Appendix C, pg. C-6
[d] NMR and Tetra tech Evaluation of the Year 2 CL&P Pilot Customer Behavior Program (R2), 8/8/2014; Hunt Alcott various reports[e] Nexus Market Research, Inc. (NMR). RLW Analytics, Inc. Residential Lighting Measure Life Study, June 4, 2008.
[e,1] Page 1, Table 1-2.
[f] The American Council for an Energy-Efficient Economy, Emerging Technologies Report, Page 2, May, 2006
[g] Rhode Island TRM, National Grid, 2012, Page M-76

[h] Environmental Protection Agency (2010). Life Cycle Cost Estimate for Programmable Thermostats. Accessed on 10/12/2011.
[i] Solar Thermal Systems Analysis, Tim Merrigan, National Renewable Energy Laboratory https://www1.eere.energy.gov/solar/pdfs/solar_tim_merrigan.pdf

[j] Plug Load –Smart Strips, 2015 Massachusetts TRM. Pg 162
[k] NYSERDA (New York State Energy Research and Development Authority), $mart Equipment Choices Database

Notes

[1] Based on Ref [d], Ref [b], and Ref [e]. References [d] and [b] 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 [e], Table 1-2, Page 1.

[4] LED Bulbs are rated at 25,000 hour life, but have been capped here to the fixture lifetime.

[5] Measure life has been defined as 8 years to account for more stringent EISA standards that take effect 1 January 2020

APPENDIX 5. HOURS OF USE

Commercial and Industrial Hours of Use and EFLH

(Note [1])

Facility Type	Lighting Hours	Cooling FLHrs	Heat Pump FLHrs*	HVAC Fan Motor Hours	CHWP & Cooling Towers (Note [2])	Heating Pumps (Note [2])
Auto Related	4,056	837	1,171	4,056	1,878	5,376
Bakery	2,854	681	1,471	2,854	1,445	5,376
Banks, Financial Centers	3,748	797	1,248	3,748	1,767	5,376
Church	1,955	564	1,694	1,955	1,121	5,376
College - Cafeteria	6,376	1,139	594	6,376	2,713	5,376
College - Classes/Administrative	2,586	646	1,537	2,586	1,348	5,376
College - Dormitory	3,066	709	1,418	3,066	1,521	5,376
Commercial Condos	4,055	837	1,172	4,055	1,877	5,376
Convenience Stores	6,376	1,139	594	6,376	2,713	5,376
Convention Center	1,954	564	1,695	1,954	1,121	5,376
Court House	3,748	797	1,248	3,748	1,767	5,376
Dining: Bar Lounge/Leisure	4,182	854	1,140	4,182	1,923	5,376
Dining: Cafeteria / Fast Food	6,456	1,149	574	6,456	2,742	5,376
Dining: Family	4,182	854	1,140	4,182	1,923	5,376
Entertainment	1,952	564	1,695	1,952	1,120	5,376
Exercise Center	5,836	1,069	728	5,836	2,518	5,376
Fast Food Restaurants	6,376	1,139	594	6,376	2,713	5,376
Fire Station (Unmanned)	1,953	564	1,695	1,953	1,121	5,376
Food Stores	4,055	837	1,172	4,055	1,877	5,376
Gymnasium	2,586	646	1,537	2,586	1,348	5,376
Hospitals	7,674	1,308	270	7,674	3,180	5,376
Hospitals / Health Care	7,666	1,307	272	7,666	3,177	5,376
Industrial - 1 Shift	2,857	681	1,470	2,857	1,446	5,376
Industrial - 2 Shift	4,730	925	1,003	4,730	2,120	5,376
Industrial - 3 Shift	6,631	1,172	530	6,631	2,805	5,376
Laundromats	4,056	837	1,171	4,056	1,878	5,376
Library	3,748	797	1,248	3,748	1,767	5,376
Light Manufacturers	2,857	681	1,470	2,857	1,446	5,376
Lodging (Hotels/Motels)	3,064	708	1,418	3,064	1,521	5,376
Mall Concourse	4,833	938	978	4,833	2,157	5,376
Manufacturing Facility	2,857	681	1,470	2,857	1,446	5,376
Medical Offices	3,748	797	1,248	3,748	1,767	5,376
Motion Picture Theatre	1,954	564	1,695	1,954	1,121	5,376
Multi-Family (Common Areas)	7,665	1,306	273	7,665	3,177	5,376
Museum	3,748	797	1,248	3,748	1,767	5,376
Nursing Homes	5,840	1,069	727	5,840	2,520	5,376
Office (General Office Types)	3,748	797	1,248	3,748	1,767	5,376
Office/Retail	3,748	797	1,248	3,748	1,767	5,376

Facility Type	Lighting Hours	Cooling FLHrs	Heat Pump FLHrs*	HVAC Fan Motor Hours	CHWP & Cooling Towers (Note [2])	Heating Pumps (Note [2])
Parking Garages & Lots	4,368	878	1,094	4,368	1,990	5,376
Penitentiary	5,477	1,022	817	5,477	2,389	5,376
Performing Arts Theatre	2,586	646	1,537	2,586	1,348	5,376
Police / Fire Stations (24 Hr)	7,665	1,306	273	7,665	3,177	5,376
Post Office	3,748	797	1,248	3,748	1,767	5,376
Pump Stations	1,949	563	1,696	1,949	1,119	5,376
Refrigerated Warehouse	2,602	648	1,533	2,602	1,354	5,376
Religious Building	1,955	564	1,694	1,955	1,121	5,376
Residential (Except Nursing Homes)	3,066	709	1,418	3,066	1,521	5,376
Restaurants	4,182	854	1,140	4,182	1,923	5,376
Retail	4,057	837	1,171	4,057	1,878	5,376
School / University (Ref [1])	2,187	594	1,637	2,187	1,205	5,376
Schools (Jr./Sr. High) (Ref [1])	2,187	594	1,637	2,187	1,205	5,376
Schools (Preschool/Elementary) (Ref [1])	2,187	594	1,637	2,187	1,205	5,376
Schools (Technical/Vocational) (Ref [1])	2,187	594	1,637	2,187	1,205	5,376
Small Services	3,750	798	1,247	3,750	1,768	5,376
Sports Arena	1,954	564	1,695	1,954	1,121	5,376
Town Hall	3,748	797	1,248	3,748	1,767	5,376
Transportation	6,456	1,149	574	6,456	2,742	5,376
Warehouse (Not Refrigerated)	2,602	648	1,533	2,602	1,354	5,376
Waste Water Treatment Plant	6,631	1,172	530	6,631	2,805	5,376
Workshop	3,750	798	1,247	3,750	1,768	5,376

Changes from Last Version

No Changes

References

[1] "CT & MA Utilities 2004-2005 Lighting Hours of Use for School Buildings Baseline Study", Final Report, September 7, 2006, by RWL Analytics.

Notes

[1] The hours listed in table are default hours to be used when site specific hours are not available. These hours have been developed over the years and are taken into account during program evaluations. Any errors, whether positive or negative, are trued up in the realization rates. Significant changes to this table will only be done if the evaluation contractor provides "going forward" realization rates along with updated hours.

[2] Since it is common to have redundant pumps, the hours provided above are estimated based on full operation of only the pumps(s) required to maintain system flow (lead pump(s)). Therefore, lag pump(s) have 0 hours of operation even if the pumps are typically alternated. For example, if a system had two 10hp pumps but only one was required to operate at any given time to maintain system flow (lead/lag), then the EFLH's would be based on one 10hp pump.

APPENDIX 6. NON-ENERGY IMPACTS

Residential Non-energy Impacts

The Companies currently quantify and count a number of Non-Energy Impacts ("NEIs") in the Total Resource Cost Test, including water, non-embedded emissions, and non-resource (e.g. lower maintenance) savings. A growing body of evidence suggests that consumers consider NEIs in the choice to adopt energy efficiency measures. NEIs have been estimated at 50-300 percent of annual household energy savings (Reference 1). Many jurisdictions across the United States have quantified numerous NEIs and they include them in the Total Resource Cost Testing. For 2017, the Companies support improvements to their cost-effectiveness methodology to account for all benefits derived from energy-efficiency measures and programs. As such, the Companies will begin to incorporate additional Non-Energy Impacts that were identified and quantified through an independent third party evaluation of the HES and HES-IE programs (Reference 2). Additional NEIs that will be incorporated in 2017 include higher comfort, noise reduction, lower maintenance, increased safety, and increased home value. The NEIs will be incorporated into the Total Resource Cost test for HES, HES-IE, and HVAC. Going forward, the Companies will work to identify and quantify (through evaluation studies) additional NEIs that can be included in other programs including NEIs for C&I programs.

Table 1: Non-Energy Impacts[1]

	HES	HES-IE	Rebate	MF
Comfort	0.25	0.17	0.31	0.14
Outside Noise	0.04	0.05	0.06	
Appliance Noise	0.05	0.06	0.15	
Maintenance	0.07	0.08	0.18	0.15
Home Value	0.12	0.07	0.24	0.09
Home Appearance	0.03	0.06	0.04	
Home Safety	0.05	0.07	0.05	0.21
Lighting quality	0.08	0.14		
Complaints	0	0	0	0.08
Total	**0.69**	**0.70**	**1.03**	**0.67**

[1]The annual customer bill savings are multiplied by the factors in Table 1 to estimate the Non-Energy Impacts. The Non-Energy Impact is an annual benefit that is multiplied over the life of the measure. For example, if a utility customer implements an energy saving measure through the HES program, the annual Non-energy benefit is 69 cents for every dollar saved. The annual benefit is credited every year for the life (Appendix: 4) of the measure.

References

[1] Valuation of Non-Energy Benefits to Determine Cost-Effectiveness of Whole House Retrofit Programs: A Literature Review. Jennifer Thorne Amann, May 2006.

[2] NMR Group, Inc. Submitted to Connecticut Energy Efficiency Fund Board, Eversource, and United Illuminating. Project R4 HES/HES-IE Process Evaluation and R31 Real-Time Research. April 13, 2016. Available at: http://www.energizect.com/sites/default/files/R4_HES-HESIE%20Process%20Evaluation%2C%20Final%20Report_4.13.16.pdf.

APPENDIX 7. 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 ft^2	kWh/ft^2/ yr
AEH	Annual Electric Heating Usage per ft^2	kWh/ft^2/ yr
AF/BI	Air foil / backward inclined fan	
AFUE	Annual Fuel Utilization Efficiency	
AGU	Annual Gas Usage per ft^2	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 ft^2	gal/ft^2/yr
APG	Annual Propane Savings	Gallon/yr
APU	Annual Propane Usage per ft^2	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	
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	

Symbol	Description (See Note [1])	Units
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 ft^2 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	
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	

Symbol	Description (See Note [1])	Units
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	
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 Btu per hour	1000 Btu/hr
MEF	Clothes Washer Modified Energy Factor	ft^3/kWh/ cycle
MMBtu	One Million of British Thermal Units	1,000,000 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
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

Symbol	Description (See Note [1])	Units
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
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	

Subscripts

Symbol	Description (See Note [1])	Units
…A	Actual/installed Unit	
…a	After PRIME	
…b	Baseline Unit	
…BD	Blower Door flow rate reading performed at 50 Pa	Cubic Feet per Minute
…Bin	Temperature BIN hours	
…C	Cooling	
. . . CAC	Central Air Conditioning	
…CDH	From CDH HVAC study	
…d	number of hours that piece of equipment is expected to operate per Day	h
…Δ	Delta	
…dp	Double pane window	
…door kit	Door kit, Door sweep	
…DS	Duct Sealing flow rate reading performed at 25 Pa	Cubic Feet per Minute
…E	Electric energy	
…e	Existing (unit, production rate, etc.)	
…es	ENERGY STAR	
…ES 09	ENERGY STAR 2009 unit	
…fed std	Federal Standard unit	
…G	Natural Gas	
…gasket	Air sealing gasket	
…h	Based on billing history	
…H	Heating	
…HP	Heat Pump	
…HVAC	HVAC motor	
…hw	Hard Wired light fixtures	
…i	incoming	
…i	Installed Unit	
…ic	Interactive Cooling	
…L	Lighting	
…LI	Low Income sector	
…LO	Lost Opportunity measure	
…lpd	Lighting Power Density	
…lt	Life Time	
…M	Motors	
…N	Non-HVAC applications	
…NLI	Non-Low Income sector	
…O	Oil	
…O	Others	
…os	Occupancy Sensors	
…P	Process	
…P	Propane	
…post	Final Reading	
…pre	Initial Reading	
…R	Electric Resistance	
…R	Refrigeration	
…ratio	Ratio between low efficiency value and high efficiency value	
…retire	Retirement portion	

Symbol	Description (See Note [1])	Units
$\cdots_{retro}$	Retrofit portion	
$\cdots_{retrofit}$	Retrofit portion	
$\cdots_{S}$	Summer	
$\cdots_{sealing}$	Caulking, sealing, polyethylene tape	foot
$\cdots_{total}$	Total, Sum	
$\cdots_{W}$	Water Heating	
$\cdots_{wop}$	Without PRIME	
$\cdots_{wp}$	With PRIME	
$\cdots_{wt}$	Winter	
$\cdots_{wx}$	Weatherstrip, repair	
$\cdots_{y}$	number of hours that piece of equipment is expected to operate per Year	h

Changes from Last Version

No changes.

Notes

[1] Many of these terms have more complete definitions in the Glossary section.

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