Connecticut’s 2022 Program Savings Document

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SECTION ONE: INTRODUCTION

1.1 PURPOSE

This Program Savings Documentation (PSD) manual provides detailed, comprehensive documentation of resource and non-resource savings corresponding to the Energy Efficiency Fund programs and individual Conservation and Load Management (C&LM) program technologies. Savings calculations detailed in the PSD manual are used by Eversource Energy of Connecticut (Eversource), The United Illuminating Company (United Illuminating), Connecticut Natural Gas Corporation (CNG), and The Southern Connecticut Gas Company (SCG), hereinafter referred to as (the Companies). The PSD manual fulfills the former Connecticut Department of Public Utility Control's (DPUC) requirement for the Companies to develop a Technical Reference Manual.[1]

The Companies have worked together during the past several years to develop common engineering assumptions and impact factors for all types of energy-efficient measures and the PSD manual is a compilation of these continued efforts. In addition, the results of program impact evaluations have been incorporated by the Companies. Thus, all C&LM savings claims are traceable through cross-references to the current PSD manual. The PSD manual is reviewed annually, and is updated to reflect changes in technologies, baselines, measured savings, evaluation recommendations, and impact factors. This document is the nineteenth update to the PSD manual (2022 PSD manual).

The C&LM savings calculations in the 2022 PSD manual represent typical energy-efficient 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.

1.2 FORWARD CAPACITY MARKET

In June 2006, the Federal Energy Regulatory Commission (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), the operator of the region's bulk power system and wholesale electricity markets, was made responsible for projecting the energy needs of the New England region three years in advance and then holding an annual auction to purchase power resources to satisfy the region's future needs.

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1 Docket No. 03-11-01PH02, DPUC Review of CL&P and UI Conservation and Load Management Plan for Year 2004 – Phase II, Jul. 28, 2004. The DPUC is now called the Connecticut Public Utilities Regulatory Authority (PURA).

In response to ISO-NE's solicitation for proposals for the Forward Capacity Auction (FCA), Eversource and United Illuminating submitted new demand side resource projects, including energy efficiency that will decrease electric demand. Per ISO-NE's requirements, detailed Project Qualification Packages that include Measurement and Verification (M&V) Plans must be 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 2022 PSD manual provides the basis of any demand reduction value calculations submitted by Eversource and United Illuminating in the FCM.

1.3 ORGANIZATION

Energy efficiency and demand management measures in the 2022 PSD manual are grouped by primary sector and reflect how programs and measures are organized within the programs. Commercial and industrial (C&I) measures are also categorized as either "Lost Opportunity" or "Retrofit." The main sections of the 2022 PSD manual are as follows:

- Section 1: Introduction.
- Section 2: C&I Lost Opportunity.
- Section 3: C&I 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 used in the 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 natural gas lost opportunity savings.
- **Non-Energy Impacts.** Describes any impacts 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 are presented in this section.

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

1.4 BACKGROUND

In 1999, the State Legislature created the Energy Efficiency Board (EEB), to guide and assist Connecticut's electric and natural gas distribution companies in the development and implementation of cost-effective energy conservation programs and market transformation initiatives.[2] The Connecticut Energy Efficiency Fund (Fund) 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 Fund programs. Fund programs are administrated by the Companies and are designed to realize the Fund's three primary objectives:

1. **Advance the efficient use of energy.** 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.** 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 US Environmental Protection Agency (EPA) regulates "criteria" air pollutants under the Clean Air Act's National Ambient Air Quality Standards (NAAQS). The EPA calls them criteria air pollutants because the agency regulates them by developing human health-based and/or environmentally-based criteria (science-based guidelines) for setting permissible levels.

[2] Conn. Gen. Stat. § 16-245m. The original name was the Energy Conservation Management Board.

Fund programs have significantly reduced two NAAQS criteria pollutants emitted in the process of generating electricity: sulfur dioxide and nitrogen dioxide. Carbon dioxide and other greenhouse gases (GHGs), such as methane, are also emitted during the process. GHGs are linked to global warming and climate change. 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 Companies have developed Fund programs that support the state's environmental initiatives to reduce these air pollutants, as well as fine particulate and ozone emissions.

3. **Promote Economic Development and Energy Security.** 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 Fund programs is available at the following websites:

- Connecticut's statewide energy information portal: www.energizect.com
- Eversource: www.eversource.com
- United Illuminating: www.uinet.com
- CNG: www.cngcorp.com
- SCG: www.soconngas.com
- EEB: www.energizect.com/connecticut-energy-efficiency-board

1.5 PROGRAM SAVINGS

Consistent with Public Act 13-298, Public Act 11-80 § 33, and Connecticut General Statute § 16-245m(d)(4), the EEB 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 Fund programs. The results of these evaluations are incorporated into the 2022 PSD manual through changes to savings algorithms and/or realization rates which are used to adjust savings.

The savings results presented in the 2022 PSD 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. 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 Two for load shapes for various end-use savings.** Load shapes are used to assign the proper value of energy savings resulting from the implementation of energy efficiency and demand management measures to the corresponding time of day when those savings are realized.

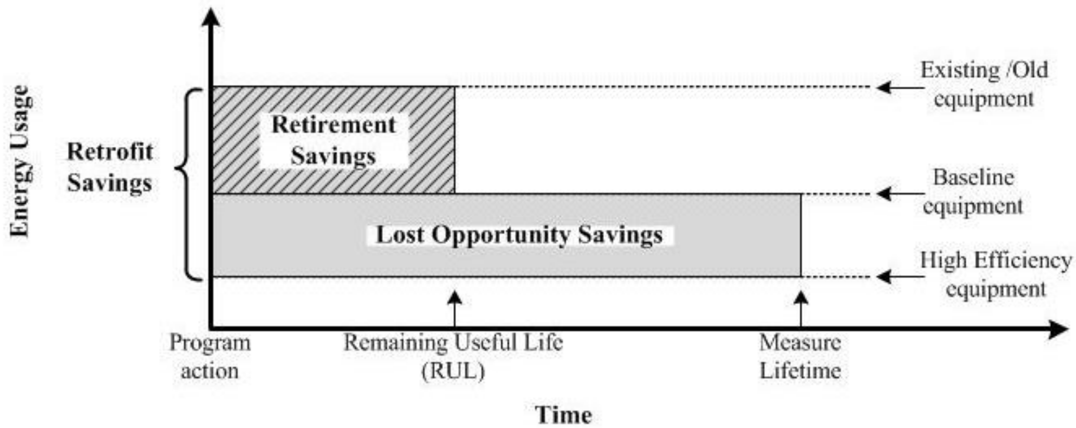
TYPES OF SAVINGS

Energy efficiency measures are generally limited to two types:

- **Retirement.** Where less efficient measures are replaced before the end of their useful life with energy-efficient measures; and
- **Lost Opportunity.** Where new measures are installed that are more efficient than a baseline or standard.

Many energy efficiency measures consist of both Retirement Savings and Lost Opportunity Savings. This is illustrated in *Figure A* below.

Figure A: Retrofit, Retirement & Lost Opportunity Savings



Some measures may utilize a two-part lifetime savings calculation. For example, in an Early Retirement case, where the existing unit (e.g., a unit using lower efficiency, out-of-date technology) would have been operating until failure and early retirement is stimulated by the program measure; **Retirement 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 a Fund 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 Savings apply to the portion of savings resulting from choosing a high-efficiency product to replace the retired product over a standard efficiency (baseline) 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; however, they are ignored because they are assumed to be short lived.

IECC CODE CHANGE

Where applicable, the 2022 PSD manual's values have been revised to reference the 2021 International Energy Conservation Code (2021 IECC). If a project permit is issued before this code is adopted by the State, the previous code (2015 IECC) should be referenced.

PEAK SAVINGS

The values for electric demand savings (both winter and summer) in the 2022 PSD manual are given based on the following definitions:

- A "Seasonal Peak" reduction is based on the average peak reduction for a measure during the ISO-NE definition for a Seasonal Peak Demand Resource; when the real-time system hourly load is equal to or greater than 90% 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 to late afternoon on Summer Season weekdays, or for the Winter Season, in the early evening.

Electric peak demand savings is calculated on a measure-by-measure basis. Coincidence factors are multiplied by the connected load savings of the measure in order to obtain the peak demand savings. See *Appendix One* 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 24-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 One*.

NON-ENERGY IMPACTS

In addition to direct electric and natural gas benefits, some measures have other non-energy impacts (NEIs). Where appropriate, these are defined in the 2022 PSD manual. NEIs may be included in the Total Resource Cost Test and include resource impacts (e.g., water) and non-resource impacts (e.g., operation and maintenance (O&M), comfort, etc.).

SAVINGS ADJUSTMENT FACTORS

The savings for the C&LM measures defined in the 2022 PSD manual are Gross Savings. Impact factors are applied to the Gross Savings to calculate the Net Savings (final). Gross Savings estimates (based on known technical parameters) represent 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 the hours of use, differences in efficiency, differences in power consumption, etc. Gross Savings is an estimate of expected customer savings; however, it does not include program attribution factors such as free-ridership.

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 installation rates, free-ridership, and spillover. The equation for Net Savings is as follows:

Net Savings = Gross Savings x Realization Rate x Installation Rate x (1 + Spillover – Free Ridership)

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 realization rates may be used in addition to or instead of the aforementioned impact factors to align calculated savings with observed savings values.

For instance, a billing analysis may show observed savings from a refrigerator removal program to be 60% of the Gross Savings (calculated). In this case, the differences may be attributable to a combination of factors, including refrigerators that are not being used, 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% realization rate would be applied to the Gross Savings (calculated) to correct the calculation.

Realization rates can be applied to specific measures or across programs depending on their source. Since 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 Three contains a list of program specific realization rates. These 2022 PSD manual rates have been updated based on recently completed studies.

COMMON ENERGY CONVERSIONS

Energy conversions used in the 2022 PSD manual that convert energy to a specific fuel type are summarized in *Figure B* below.

Table B: Energy Conversion Factors

To Obtain:	Multiply:	By:
Btu	MMBtu	1,000,000
ccf of natural gas	MMBtu	1/0.1029
ccf of natural gas	Therm	1/1.029
Gallon of oil (No. 2)	MMBtu	1/0.138690

To Obtain:	Multiply:	By:
Gallon of propane	MMBtu	1/0.09133
kWh (electric)	MMBtu	1/0.003412
kWh (electric)	Btu	1/3412
Ton (air conditioning)	Btu/h	1/12000

SAVINGS CALCULATIONS

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

1.6 GLOSSARY

The Glossary provides definitions of the energy efficiency terms used in the 2022 PSD manual. Note that some of these terms may have alternative or multiple definitions some of which may be outside the context of the 2022 PSD manual. Only definitions pertaining to the 2022 PSD 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 the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (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. For Lost Opportunity measures, the baseline is determined by the applicable code or standard practice, whichever is more stringent.[3] *Contrast with Compliance Efficiency.*

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 energy efficiency programs determine cost effectiveness using the Utility Cost Test (i.e., Electric System and the Natural Gas System), the Modified Utility Cost Test, or Total Resource Test. Energy efficiency efforts are cost effective if the benefit-cost ratio is greater than or equal to 1.0. Currently, the Companies use the following three benefit-cost tests:

1. The **Utility Cost Test** includes the value of utility-specific benefits and program costs associated with those benefits. For example, the Utility Cost Test includes energy-avoided costs from electric and natural gas conservation measures and programs; and all program costs associated with acquiring those benefits. The Utility Cost Test does not include a participant's out-of-pocket costs, the costs or benefits associated with oil

[3] See *Energy Efficiency Program Impact Evaluation Guide*, SEE Action, Dec. 2012 and *ISO-NE Manual for Measurement and Verification, Revision 6*, Jun. 2014.

or propane savings, or any indirect or societal impacts, such as reductions in emissions or NEIs (e.g., water savings).

2. The **Modified Utility Cost Test** includes all benefits and costs included in the Utility Cost Test, with the addition of oil and propane-avoided costs, and program costs associated with acquiring oil and propane savings. The Modified Utility Cost Test currently applies only to residential programs that save oil or propane.

3. The **Total Resource Cost Test** includes all energy and non-energy benefits, such as water savings and emissions, and participant benefits such as maintenance, property value, and comfort improvements. In addition, the Total Resource Cost Test includes all costs associated with acquiring savings. This includes program costs and participant out-of-pocket costs.

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.

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 natural gas-driven chillers.

Coincident Demand: Demand of a measure that occurs at the same time as some other peak (e.g., building peak, system peak, etc.). In the context of the 2022 PSD manual, coincident demand is a measure of demand savings that is coincident with ISO-NE'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 with 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® or ASHRAE.

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 based on an average daily temperature over a base temperature of 65°F. *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 measure heating energy demand and indicate how far the average daily temperature fell below 65°F. Similarly, CDDs, which measure cooling energy demand, indicate how far the average daily temperature was above 65°F.

Demand: The average electric power requirement (i.e., 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 the installation of an energy efficiency measure. This reduction is usually expressed as kW and is measured at the customer's meter. *See discussion under Peak Demand Savings.*

Demand Resources: ISO-NE 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-NE 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 distributed 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 (i.e., 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 BCR 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 (EIA) emissions data for fossil fuels. Emissions reductions for electric conservation can be estimated using ISO-NE marginal emissions factors which are published annually.

<u>Emittance</u>: 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.

<u>End Use</u>: Refers to a category of measures with similar load shapes. There are several different acceptable industry standards for defining end-use categories. Examples of end uses include: cooling, heating, lighting, refrigeration, water heating, motors, process, and others.

<u>Energy Conservation</u>: Energy or peak demand reduction resulting from changes in customer behavior(s) or program action(s).

<u>Energy Efficiency</u>: Reducing energy usage without a notable reduction in functional performance.

<u>Energy Efficiency Ratio (EER)</u>: A performance rating of electrically-operated cooling equipment during peak periods (*defined as a 95°F outside temperature, 80°F indoor temperature, and an indoor relative humidity of 50%*). EER is the total cooling output in Btus divided by the total electrical energy input in watt hours during the same period.

<u>Equivalent Full Load Hours (EFLH)</u>: 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.

<u>Evaluation Studies</u>: 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 the Companies' program administrators to modify the programs and savings estimates.

<u>Free-Rider</u>: A C&LM program participant who would have installed or implemented an energy efficiency measure even in the absence of program marketing or incentives.

<u>Free-Ridership</u>: The fraction (usually expressed as a percent) of gross program savings that would have occurred in the absence of a C&LM program.

<u>Gross Savings</u>: A savings estimate, calculated from objective technical factors. Gross Savings is an estimate of what a participant is expected to achieve, given the conservation measures being installed. The Gross Savings do not include impact factors.

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

<u>Heating Seasonal Performance Factor (HSPF)</u>: 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.

<u>High Efficiency</u>: High-efficiency equipment uses less energy than standard equipment.

<u>Impact Evaluation</u>: A study that assesses the energy, demand, and non-electric impacts associated with energy efficiency measures or programs.

<u>Impact Factor</u>: A number (usually expressed as a percent) used to adjust the Gross Savings in order to reflect the savings observed by an impact study.

<u>Installation Rate</u>: The fraction of the recorded products that are installed. For example, some screw-in LED bulbs are bought as spares and will not be installed until another one burns out.

<u>Lighting Power Density (LPD)</u>: 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.

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

<u>Load Shape</u>: The time-of-use pattern of a customer's electrical energy consumption or measure. Load shapes are defined as follows based on ISO-NE definitions:

- **<u>Summer On-Peak</u>:** 7 a.m. to 11 p.m., weekdays, during the months of June through September, except ISO-NE holidays;
- **<u>Summer Off-Peak</u>:** All other hours during the months of June through September (includes weekends and holidays);
- **<u>Winter On-Peak</u>:** 7 a.m. to 11 p.m., weekdays, during the months of October through May, except ISO-NE holidays; and
- **<u>Winter Off-Peak</u>:** All other hours during the months of October through May (includes weekends and holidays).

Because the value of avoided energy varies throughout the year, load shapes are used to allocate energy savings into specific time periods in order to better reflect its time-dependent value.

<u>Lost Opportunity</u>: 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."*

<u>Market Effect</u>: A long-term 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.

<u>MMBtu</u>: Millions of British Thermal Units.

<u>Measure</u>: 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.

<u>Measure Cost</u>: 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 measures. For retrofit measures, the 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 the 2022 PSD manual, primary end-use categories include: cooling, heating, lighting, motors, process, refrigeration, water heating, and other.

Natural Gas System (Benefit-Cost Ratio) Test: A ratio used to assess the cost effectiveness of energy efficiency programs and measures 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 tool used to screen natural gas measures and programs in Connecticut. Energy efficiency programs and measures are cost effective if the BCR 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. Net-to-gross ratios include elements of free-ridership and spillover.

Non-Electric Impacts: Quantifiable impacts (beyond electric savings) that are the result of the installation of a measure. Fossil fuel and water savings, O&M savings, and increases in productivity are examples of Non-Electric Impacts. Non-Electric Impacts can be negative (i.e., increased maintenance or increased fossil fuel usage resulting from a measure). Non-Electric Impacts may also include non-quantifiable impacts that are difficult to quantify, such as increased comfort. "Non-Energy Impacts" is a subset of Non-Electric Impacts that does not include fossil fuel savings or costs.

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*).

One Hundred Cubic Feet (ccf): 100 Cubic feet of gas; used to measure a quantity of natural gas.

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 their participation. Free-riders are a subset of this group.

Peak Day Factor: Multipliers that are used to calculate peak day reductions based on annual natural gas energy savings.

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

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

<u>Peak Demand Savings</u>: 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 One. 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 ISO-NE, is equal to or greater than 90% of the most recent 50/50 system peak load forecast, as determined by ISO-NE, for the applicable summer or winter season.

- **On-Peak Hours** are hours 1:00 to 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 and Demand Savings.*

<u>Peak Factor</u>: 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.

<u>Realization of Savings</u>: 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.

<u>Retrofit</u>: 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: (1) where the retirement part is additional to the lost opportunity part until the end of the Remaining Useful Life (RUL), and (2) after which lost opportunity savings continue until the last year of the retrofit measure's Effective Useful Life (EUL). *Contrast "Lost Opportunity."*

<u>R-Value</u>: 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 as degree Fahrenheit square feet hours per Btu ($ft^2 \cdot °F \cdot h/Btu$).

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

<u>Sector</u>: A system for grouping customers with similar characteristics. For the purpose of the 2022 PSD manual, the sectors are C&I, Small Business (SMB), Residential, Non-Limited Income (NLI), and Limited Income (LI).

<u>Spillover</u>: Savings attributable to a C&LM program, but in addition to the program's Gross (tracked) Savings. Spillover includes the effects of: (a) participants who install additional energy-efficient measures as a result of what they learned in the C&LM program; or (b) non-participants who install or influence the installation of energy-efficient measures as a result of being influenced by the C&LM program.

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

U-Value: A measure of the heat transmission through a material (such as insulation) or system. The lower the U-Value, the greater resistance to heat flow and the better its insulation value.

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

SECTION TWO: 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 with Design Lighting Consortium (DLC) or ENERGY STAR® approved lighting equipment.

Note: If a project permit is issued before 2021 IECC code is adopted by the State, the previous code (2015 IECC) should be referenced.

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 the installation of occupancy sensors and residential fixtures as applicable (see **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 LPDs based on 2021 IECC standards and additional efficiency code requirements; choose the appropriate table. The current 2021 IECC 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 controls.

Exterior Lighting: The default baseline for exterior lighting is ASHRAE 90.1-2019. 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 G* for the applicable lighting zone. Trade-offs are allowed only among exterior lighting applications listed in *Table G*. The lighting zone for the building exterior is determined from *Table H*.

INPUTS

Table A: Inputs

Symbol	Description	Units
Allowable LPD	Allowable LPD from 2021IECC	Watts/ft^2
	Total fixture connected kW	kW
	Facility illuminated area	ft^2

NOMENCLATURE

Table B: 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 One*
CF_{os}	Occupancy sensor coincidence factor			*Appendix One*
CF_{hw}	Residential lighting coincidence factor			*Appendix One*
COP	Coefficient of performance		4.5	See **Note [3]**
$DeltaW_{hw}$	Delta Watts of hardwired fluorescent fixtures in residential areas as calculated per *Section 4.1.1* of the 2022 PSD manual			
F	Fraction of lighting energy that must be removed by the facility's cooling system			
G	Estimated lighting energy heat		0.73	See **Note [1]**
H	Facility lighting—Hours of use	hrs		Site specific; Use *Appendix Five* only when site-specific assumptions do not exist.
$HVAC_{INTH}$	Heating, ventilation, and air conditioning	MMBtu/kWh	-0.000329	**Ref [9]**
kW	Electric demand	kW		
LPD	Lighting power density	$Watts/ft^2$		
N	Fixture number			

S_c	Energy savings from reduced cooling load	kWh		
S_{hw}	Energy savings from installation of hardwired fluorescent fixtures in residential areas	kWh		
S_{lpd}	Energy savings due to lower LPD	kWh		
S_{int}	Interior energy savings	kWh		
S_{ext}	Exterior energy savings	kWh		
W	Fixture input wattage	Watts		
$W_{allowance}$	Baseline W for exterior fixture lighting power	Watts		
W_n	Input Watts for fixture Type n	Watts		

LOST OPPORTUNITY GROSS ENERGY SAVINGS, ELECTRIC

Interior lighting:

$$S_{int} = S_{lpd} + S_{hw} + S_c$$

Calculation of savings due to lower LPD:

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

Allowable LPD, in W/ft^2, is the value of Watts per ft^2 from ASHRAE for the facility type divided by 1,000. The building area LPDs from the 2021 IECC are provided in the tables below. Refer to 2021 IECC for the space-by-space method. When using the space-by-space method to calculate the LPD, an increase in a space's power allowances can be used, in accordance with 2021 IECC 405.3.2(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 (see **Note [4]**).

Explanation of numerical constants:

- 1,000 converts watts to kW (1/1,000 is the conversion).

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

- Refer to the 2022 PSD manual's *Measure 4.1.1: Lighting* 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 hardwired 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:

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

- **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 C*.
- **COP** = 4.5 (see **Note [3]**).

Table C: Fraction of Annual kWh Energy Savings that Must Be Removed by 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 D: Lighting Power Densities Using the Building Area Method – IECC 2021 Standard Section C405.3.2(1), see Ref [5] and Section C406.3 Additional Efficiency Options, see Ref [6]

Building Area Type (see Note [2])	Standard LPD (W/ft^2)	Additional Efficiency Option (W/ft^2)
Automotive facility	0.75	0.68
Convention center	0.64	0.58
Court house	0.79	0.72
Dining: bar lounge/leisure	0.80	0.72
Dining: cafeteria/fast food	0.76	0.69
Dining: family	0.71	0.64
Dormitory	0.53	0.48
Exercise center	0.72	0.65
Fire station	0.56	0.51
Gymnasium	0.76	0.69
Health care clinic	0.81	0.73
Hospital	0.96	0.87
Hotel/motel	0.56	0.51
Library	0.83	0.75
Manufacturing facility	0.82	0.74
Motion picture theatre	0.44	0.40
Multifamily	0.45	0.41
Museum	0.55	0.50
Office	0.64	0.58
Parking garage	0.18	0.17
Penitentiary	0.69	0.63
Performing arts theatre	0.84	0.76
Police/fire station	0.66	0.60
Post office	0.65	0.59
Religious building	0.67	0.61
Retail	0.84	0.76
School/university	0.72	0.65
Sports arena	0.76	0.69
Town hall	0.69	0.63
Transportation	0.50	0.45
Warehouse	0.45	0.41
Workshop	0.91	0.82

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:

a. First LPD value applies if no less than 30% of conditioned floor area is in a daylight zone. Automatic daylighting controls shall be installed in daylight zones and shall meet the requirements of Section C405.2.2.3. In all other cases, the second LPD value applies.

b. No less than 70% 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.

Table E: Lighting Power Densities Using the Space-By Space Method – 2021 IECC section C405.3.2(2); Interior Lighting Power Allowances: Space-By-Space Method (See Ref [8])

Common Space Types[a]	LPD (watts/ft^2)
Atrium	
Less than 40 feet in height	0.48
Greater than 40 feet in height	0.60
Audience seating area	
In an auditorium	0.61
In a gymnasium	0.23
In a motion picture theater	0.27
In a penitentiary	0.67
In a performing arts theater	1.16
In a religious building	0.72
In a sports arena	0.33
Otherwise	0.33
Automotive (see Vehicular maintenance area)	
Banking activity area	0.61
Breakroom (See Lounge/breakroom)	
Classroom/lecture hall/training room	
In a penitentiary	0.89
Otherwise	0.71
Computer room, data center	0.94
Conference/meeting/multipurpose room	0.97
Convention Center—exhibit space	0.61
Copy/print room	0.31
Corridor	
In a facility for the visually impaired (and not used primarily by the staff)[b]	0.71
In a hospital	0.71
Otherwise	0.41
Courtroom	1.20
Dining area	
In bar/lounge or leisure dining	0.86
In cafeteria or fast food dining	0.40

Common Space Types[a]	LPD (watts/ft²)
In a facility for the visually impaired (and not used primarily by the staff)[b]	1.27
In family dining	0.60
In a penitentiary	0.42
Otherwise	0.43
Dormitory—living quarters[c, d]	0.50
Electrical/mechanical room	0.43
Emergency vehicle garage	0.52
Facility for the visually impaired[b]	
In a chapel (and not used primarily by the staff)	0.70
In a recreation room (and not used primarily by the staff)	1.77
Fire Station—sleeping quarters[c]	0.23
Food preparation area	1.09
Guestroom[c, d]	0.41
Gymnasium/fitness center	
In an exercise area	0.90
In a playing area	0.85
Healthcare facility	
In an exam/treatment room	1.40
In an imaging room	0.94
In a medical supply room	0.62
In a nursery	0.92
In a nurse's station	1.17
In an operating room	2.26
In a patient room[c]	0.68
In a physical therapy room	0.91
In a recovery room	1.25
Laboratory	
In or as a classroom	1.11
Otherwise	133.00
Laundry/washing area	0.53
Library	
In a reading area	0.96
In the stacks	1.18
Loading dock, interior	0.88
Lobby	
For an elevator	0.65
In a facility for the visually impaired (and not used primarily by the staff)[b]	1.69

Common Space Types[a]	LPD (watts/ft²)
In a hotel	0.51
In a motion picture theater	0.23
In a performing arts theater	1.25
Otherwise	0.84
Locker room	0.52
Lounge/breakroom	
In a healthcare facility	0.42
Otherwise	0.59
Manufacturing facility	
In a detailed manufacturing area	0.80
In an equipment room	0.76
In an extra-high-bay area (greater than 50 feet floor-to-ceiling height)	1.42
In a high-bay area (25–50 feet floor-to-ceiling height)	1.24
In a low-bay area (less than 25 feet floor-to-ceiling height)	0.86
Museum	
In a general exhibition area	0.31
In a restoration room	1.10
Office	
Enclosed	0.74
Open plan	0.61
Parking area, interior	0.15
Pharmacy area	1.66
Performing arts theater—dressing room	0.41
Post office—sorting area	0.76
Religious buildings	
In a fellowship hall	0.54
In a worship/pulpit/choir area	0.85
Restroom	
In a facility for the visually impaired (and not used primarily by the staff[b]	1.26
Otherwise	0.63
Retail facilities	
In a dressing/fitting room	0.51
In a mall concourse	0.82
Sales area	1.05
Seating area, general	0.23
Stairwell	0.49
Sports arena—playing area	

Common Space Types[a]	LPD (watts/ft^2)
For a Class I facility[e]	2.94
For a Class II facility[f]	2.01
For a Class III facility[g]	1.30
For a Class IV facility[h]	0.86
Storage room	0.38
Transportation facility	
At a terminal ticket counter	0.51
In a baggage/carousel area	0.39
In an airport concourse	0.25
Vehicular maintenance area	0.60
Warehouse—storage area	
For medium to bulky, palletized items	0.33
For smaller, hand-carried items	0.69
Workshop	1.26

For SI: 1 foot = 304.8 mm, 1 watt per square foot = 10.76 w/m2.

a. In cases where both a common space type and a building area specific space type are listed, the building area specific space type shall apply.

b. A 'Facility for the Visually Impaired' is a facility that is licensed or will be licensed by local or state authorities for senior long-term care, adult daycare, senior support or people with special visual needs.

c. Where sleeping units are excluded from lighting power calculations by application of Section R404.1, neither the area of the sleeping units nor the wattage of lighting in the sleeping units is counted.

d. Where dwelling units are excluded from lighting power calculations by application of Section R404.1, neither the area of the dwelling units nor the wattage of lighting in the dwelling units is counted.

e. Class I facilities consist of professional facilities; and semiprofessional, collegiate, or club facilities with seating for 5,000 or more spectators.

f. Class II facilities consist of collegiate and semiprofessional facilities with seating for fewer than 5,000 spectators; club facilities with seating for between 2,000 and 5,000 spectators; and amateur league and high school facilities with seating for more than 2,000 spectators.

g. Class III facilities consist of club, amateur league and high school facilities with seating for 2,000 or fewer spectators.

h. Class IV facilities consist of elementary school and recreational facilities; and amateur league and high school facilities without provision for spectators.

Exterior Lighting

Calculation of savings due to lower lighting power:

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

Watts as tabulated per Tables E, F, and G, based on IECC 2021 (for 2022 PSD manual update):

H = Hours of Use

Table F: Exterior Lighting Zones, see Ref [4]

Lighting Zone	Description
1	Developed areas of national parks, state parks, forest land, and rural areas
2	Areas predominantly consisting of residential zoning, neighborhood business districts, light industrial with limited nighttime use, and residential mixed-use areas
3	All other areas not classified as Lighting Zone 1, 2, or 4
4	High-activity commercial districts in major metropolitan areas as designated by the local land use planning authority

Table G: Exterior Lighting Power Allowances – 2021 IECC Standard Section C405.5.2(2), see Ref [7]

				Power Allowance			
Category		Space	Units	Zone 1	Zone 2	Zone 3	Zone 4
Base Site Allowance			W	500	600	750	1,300
Tradable Surfaces	Uncovered parking Areas	Parking areas and drives	W/ft2	0.03	0.04	0.06	0.08
	Building grounds	Walkways less than 10 feet wide	W/Linear Foot	0.5	0.5	0.6	0.7
	Building grounds	Walkways 10 feet wide or greater	W/ft2	0.10	0.10	0.11	0.14
	Building grounds	Dining areas	W/ft2	0.65	0.65	0.75	0.95
	Building grounds	Stairways	W/ft2	0.6	0.7	0.7	0.7
	Building grounds	Pedestrian tunnels	W/ft2	0.12	0.12	0.14	0.21
	Building grounds	Landscaping	W/ft2	0.04	0.05	0.05	0.05
	Building entrances and exits	Pedestrian and vehicular entrances and exits	W/Linear Foot (door width)	14	14	21	21
	Building entrances and exits	Entry canopies	W/ft2	0.20	0.25	0.40	0.40
	Building entrances and exits	Loading docks	W/ft2	0.35	0.35	0.35	0.35
	Sales canopies	Canopies (free standing and attached)	W/ft2	0.40	0.40	0.6	0.7
	Outdoor sales	Open areas (including vehicle sales lots)	W/ft2	0.20	0.20	0.35	0.50
	Outdoor sales	Street frontage for vehicle sales lots in addition to "Open Area" allowance	W/Linear Foot	-	7	7	21

Power Allowance						
Category		Units	Zone 1	Zone 2	Zone 3	Zone 4
Non-Tradable Surfaces	Building facades-ft^2 allowance	W/ft² of gross above-grade wall area	-	0.075	0.113	0.15
	Automated Teller Machines (ATMs)/night depositories	W per location	135 W plus 45 W per add ATM	135 W plus 45 W per add ATM	135 W plus 45 W per add ATM	135 W plus 45 W per add ATM
	Entrances and gatehouse inspection stations at guarded facilities	W/ft² of covered and uncovered area	0.5	0.5	0.5	0.5
	Loading areas for law enforcement, fire, ambulance, and other emergency vehicles	W/ft² of covered and uncovered area	0.35	0.35	0.35	0.35
	Drive-up windows and doors	W/drive-through	200	200	200	200
	Parking near 24-Hour retail entrances	W/main entry	400	400	400	400

Lost Opportunity Gross Energy Savings, Fossil Fuel

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

- Annual Oil Savings = -0.000162279 MMBtu per annual kWh saved; and
- Annual Natural Gas Savings = -0.000162279 MMBtu per kWh. See **Ref [3]**.

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

Lost Opportunity Gross Seasonal Peak Demand Savings, Electric (winter and summer)

$$KW_{summer} = \left((CF_L \times (Allowable\ LPD - Actual\ LPD) \times A) + CF_{hw} \times \frac{\sum DeltaW_{hw}}{1000} \right) \times \left(1 + \frac{G}{COP}\right)$$

$$KW_{winter} = \left((CF_L \times (Allowable\ LPD - Actual\ LPD) \times A) + CF_{hw} \times \frac{\sum DeltaW_{hw}}{1000} \right)$$

- **CF_L** and is the lighting (CF_L) coincidence factor (summer/winter) taken from *Appendix One*.
- **Allowable LPD**, in kW/ft^2 = the value of Watts per ft^2 from the 2018 IECC for the facility type divided by 1,000.
- **Actual LPD**, in kW/ft^2 = Total Fixture Wattage (kW) divided by the Lighted Area, ft^2.
- **A** = is calculated for each project, either from architectural drawings or by physical measurement.
- **CF_{hw}** is the residential lighting coincidence factor (summer/winter) from *Appendix One*.
- **$DeltaW_{hw}$** = Delta watts of hardwired fluorescent fixtures in residential areas as calculated per *Measure 4.1.1* of the 2022 PSD manual.
- **G** = 0.73.
- **COP** = 4.5. See **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

- Updated tables with new 2021 IECC requirements.
- Updated reference to 2021 IECC.

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 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] DNV KEMA (2014) Retrofit Lighting Controls Measures Summary of Findings, Final Report, pp. 5-26, see Table 12.

[4] 2021 IECC, Table C405.5.2 (1) Exterior Lighting Zones.

[5] 2021 IECC, Table C405.3.2 (1) Interior Lighting Power Allowances: Building Area Method.

[6] 2021 IECC, Section C406.3 Reduced Lighting Power by more than 10 percent.

[7] 2021 IECC, Table C405.5.2 (2) Lighting Power Allowances for Building Exteriors.

[8] 2021 IECC, Table C405.3.2(2) Interior Lighting Power Allowances: Space-By-Space Method.

[9] DNV GL (2017). Impact Evaluation of PY2015 Massachusetts Commercial and Industrial Upstream Lighting Initiative.

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] DNV GL (2017). Impact Evaluation of PY2015 Massachusetts Commercial and Industrial Upstream Lighting Initiative. DNVGL_2017_Upstream_Lighting_Impact_Evaluation.

[4] 2021 IECC requires certain space types to have occupancy sensors. Savings for these occupancy sensors required by code therefore cannot be claimed. Refer to 2021 IECC C405.2.1.1 for details.

2.1.2 UPSTREAM LIGHTING

Description of Measure

This section describes the savings methodology for ENERGY STAR or Design Lights Consortium (DLC) certified lighting products incentivized through an upstream model.

Savings Methodology

The individual bulb or fixture's delta watts are based on the Bright Opportunities Program, an upstream lighting initiative in Massachusetts (**Ref [1]**). Delta Watts are defined as the pre-installation, or baseline wattage, minus the post-installation wattage. The final annual energy savings (i.e., kWh) is modified to suit Connecticut program rules. All lighting products should be either ENERGY STAR (**Ref [2]**) or DLC (**Ref [3]**).

Inputs

Table A: Inputs

Symbol	Description	Units
N	No. of units sold at the point of sale	
	Product type	
	Facility type	
	Lighting Controls Type	

Nomenclature

Table B: Nomenclature

Item	Description	Units	Values	Comments
AKWH	Annual energy savings	kWh		
LTKWH	Lifetime energy savings	kWh		
Lifetime	Equipment lifetime	Years		*Appendix 4*
ΔW	Delta Watts	Watts		*Table C*, **Note [1]**
H	Hours of use	Hours		*Appendix Five*
SKW	Summer demand savings	kW		
WKW	Winter demand savings	kW		
CF_S	Summer lighting coincidence factor			*Appendix One*
CF_W	Winter lighting coincidence factor			*Appendix One*

Item	Description	Units	Values	Comments
$HVAC_{INTC}$	HVAC interactivity multiplier, cooling		1.024	**Ref [4]**
D_{INT}	Demand savings factor		1.152	**Ref [4]**
$HVAC_{INTH}$	HVAC interactivity multiplier, heating	MMBtu/kWh	-0.000329	**Ref [5]**
		%	Savings Factor varies by Type of Controls: see *Table D*	**Ref [1] and Ref [2]**
ΔW_{total}		Watts	ΔW_{total}= $\Delta W_{fixture}$ without controls + LED controlled X Savings Factor	*Table C*

Table C: Delta Watts, see Ref [1]

Product	Product Type	Δ Watts[1]	LED Controlled Watts W_{ctrl}[2] (Where applicable)	Δ Watts fixture and controls Δ Watts total (Where applicable)
BR20/PAR20	Screw-in LEDs	28.1		
BR20/PAR30	Screw-in LEDs	38.1		
BR40/PAR38	Screw-in LEDs	44.2		
MR16	Screw-in LEDs	22.1		
A-line, 75/100W	Screw-in LEDs	30.5		
Decoratives	Screw-in LEDs	13.6		
LED retrofit kit, <25W	Screw-in LEDs	38.4		
LED retrofit kit, >25W	Screw-in LEDs	56.6		
Stairwell kit, low-output w/sensor	LED stairwell kits	19.2		
Stairwell kit, mid-output w/sensor	LED stairwell kits	40.0		
G24 LED	Screw-in LEDs	15.3		
G23 LED	Screw-in LEDs	8.4		
T8 TLED, 4ft	Linear LEDs	13.8		
T8 TLED, 2ft	Linear LEDs	6.9		

Product	Product Type	Δ Watts[1]	LED Controlled Watts W_{ctrl}[2] (Where applicable)	Δ Watts fixture and controls Δ Watts total (Where applicable)
A-line, 40/60W	Screw-in LEDs	21.7		
2x4 LED fixture standard	Linear LEDs	33.0		
2x4 LED fixture premium	Linear LEDs	37.0		
2x2 LED fixture standard	Linear LEDs	29.0		
2x2 LED fixture premium	Linear LEDs	33.0		
1x4 LED fixture standard	Linear LEDs	16.0		
1x4 LED fixture premium	Linear LEDs	20.0		
2x4 LED fixture standard w/ one control	Linear LEDs w/controls		46.0	44.0
2x4 LED fixture standard w/ dual controls	Linear LEDs w/controls		46.0	50.5
2x4 LED fixture standard w/ NLC or LLC controls	Linear LEDs w/controls		46.0	55.5
2x4 LED fixture premium w/ one control	Linear LEDs w/controls		40.6	46.7
2x4 LED fixture premium w/ dual controls	Linear LEDs w/controls		40.6	52.4
2x4 LED fixture premium w/ NLC or LLC controls	Linear LEDs w/controls		40.6	56.9
2x2 LED fixture standard w/ one control	Linear LEDs w/controls		32.7	36.8
2x2 LED fixture standard w/ dual controls	Linear LEDs w/controls		32.7	41.4
2x2 LED fixture standard w/ NLC or LLC controls	Linear LEDs w/controls		32.7	45.0
2x2 LED fixture premium w/ one control	Linear LEDs w/controls		30.0	40.2
2x2 LED fixture premium w/ dual controls	Linear LEDs w/controls		30.0	44.4
2x2 LED fixture premium w/ NLC or LLC controls	Linear LEDs w/controls		30.0	47.7
1x4 LED fixture standard w/ one control	Linear LEDs		34.5	24.3

Product	Product Type	Δ Watts[1]	LED Controlled Watts W_{ctrl}[2] (Where applicable)	Δ Watts fixture and controls Δ Watts total (Where applicable)
	w/controls			
1x4 LED fixture standard w/ dual controls	Linear LEDs w/controls		34.5	29.1
1x4 LED fixture standard w/NLC or LLC controls	Linear LEDs w/controls		34.5	32.9
1x4 LED fixture premium w/ one control	Linear LEDs w/controls		30.5	27.3
1x4 LED fixture premium w/ dual controls	Linear LEDs w/controls		30.5	31.6
1x4 LED fixture premium w/ NLC or LLC controls	Linear LEDs w/controls		30.5	34.9
T5 LED	Linear LEDs	20.0		
U-bend LED	Linear LEDs	23.4		
High/low bay 50-99W	High bay/low bay	174.0		
High/low bay 100-199W	High bay/low bay	229.0		
High/low bay ≥ 200W	High bay/low bay	334.0		
LED high/low bay 20-99 w/ one control standard[3]	High bay/low bay		73.1	191.5
LED high/low bay 20-99 w/ dual controls standard	High bay/low bay		73.1	201.8
LED high/low bay 20-99 w/ NLC or LLC controls standard	High bay/low bay		73.1	209.8
LED high/ low bay 20-99 w/ one control premium	High bay/low bay		75.5	192.1
LED high/ low bay 20-99 w/ dual controls premium	High bay/low bay		75.5	202.7
LED high/low bay 20-99 w/ NLC or LLC controls premium	High bay/low bay		75.5	211.0
LED high/low bay 100-199 w/ one control standard	High bay/low bay		145.8	264.0
LED high/low bay 100-199 w/ dual controls standard	High bay/low bay		145.8	284.4

Product	Product Type	Δ Watts[1]	LED Controlled Watts W_{ctrl}[2] (Where applicable)	Δ Watts fixture and controls Δ Watts total (Where applicable)
LED high/low bay 100-199 w/ NLC or LLC controls standard	High bay/low bay		145.8	300.4
LED high/low bay 100-199 w/ one control Premium	High bay/low bay		148.0	264.5
LED high/low bay 100-199 w/ dual controls premium	High bay/low bay		148.0	285.2
LED high/low bay 100-199 w/ NLC or LLC controls premium	High bay/low bay		148.0	301.5
LED high/low bay >200 w/ one control standard	High bay/low bay		246.0	393.0
LED high/low bay >200 w/ dual controls standard	High bay/low bay		246.0	427.5
LED high/low bay >200 w/ NLC or LLC controls standard	High bay/low bay		246.0	454.5
LED high/low bay >200 w/ one control premium	High bay/low bay		243.0	392.3
LED high/low bay >200 w/ dual controls premium	High bay/low bay		243.0	426.3
LED high/low bay > 200 w/ NLC or LLC controls premium	High bay/low bay		243.0	453.1
Exterior 20-99 w/ one control standard	Exterior LEDs	101.5	56.0	114.9
Exterior 20-99 w/ one control premium	Exterior LEDs	101.5	58.8	115.6
Exterior 100-199 w/ one controls standard	Exterior LEDs	176.5	135.0	208.9
Exterior 100-199 w/ one controls premium	Exterior LEDs	176.5	147.9	212.0
Exterior >200 w/ one controls standard	Exterior LEDs	231.5	301.6	303.9
Exterior >200 w/ one control premium	Exterior LEDs	231.5	300.0	303.5
1x4 LED troffer retrofit kit – premium	Linear LEDs	37.3	38.5	
1x4 LED troffer retrofit kit w/ one control – premium	Linear LEDs		38.5	46.5
1x4 LED troffer retrofit kit w/ dual controls – premium	Linear LEDs		38.5	51.9
1x4 LED troffer retrofit kit w/ NLC or LLC	Linear LEDs		38.5	56.2

Product	Product Type	Δ Watts[1]	LED Controlled Watts W_{ctrl}[2] (Where applicable)	Δ Watts fixture and controls Δ Watts total (Where applicable)
controls – premium				
1x4 LED troffer retrofit kit - standard	Linear LEDs	29.5	35.3	
1x4 LED troffer retrofit kit w/ one control - standard	Linear LEDs		35.3	38.0
1x4 LED troffer retrofit kit w/ dual controls - standard	Linear LEDs		35.3	42.9
1x4 LED troffer retrofit kit w/ NLC or LLC control - standard	Linear LEDs		35.3	46.8
2x2 LED troffer retrofit kit – premium	Linear LEDs	19.6	27.0	
2x2 LED troffer retrofit kit w/ one control – premium	Linear LEDs		27.0	26.1
2x2 LED troffer retrofit kit w/ dual controls – premium	Linear LEDs		27.0	29.9
2x2 LED troffer retrofit kit w/ NLC or LLC controls – premium	Linear LEDs		27.0	32.8
2x2 LED troffer retrofit kit - standard	Linear LEDs	18.1	25.3	
2x2 LED troffer retrofit kit w/ one control - standard	Linear LEDs		25.3	24.2
2x2 LED troffer retrofit kit w/ dual controls - standard	Linear LEDs		25.3	27.7
2x2 LED troffer retrofit kit w/ NLC or LLC controls - standard	Linear LEDs		25.3	30.5
2x4 LED troffer retrofit kit - premium	Linear LEDs	56.2	28.0	
2x4 LED troffer retrofit kit w/ one control- premium	Linear LEDs		28.0	62.9
2x4 LED troffer retrofit kit w/ dual controls - premium	Linear LEDs		28.0	66.8
2x4 LED troffer retrofit kit w/ NLC or LLC controls – premium	Linear LEDs		28.0	69.9
2x4 LED troffer retrofit kit – standard	Linear LEDs	53.5	26.0	
2x4 LED troffer retrofit kit w/ one control - standard	Linear LEDs		26.0	59.7

Product	Product Type	Δ Watts[1]	LED Controlled Watts W_{ctrl}[2] (Where applicable)	Δ Watts fixture and controls Δ Watts total (Where applicable)
2x4 LED troffer retrofit kit w/ dual control - standard	Linear LEDs		26.0	63.4
2x4 LED troffer retrofit kit w/ NLC or LLC control - standard	Linear LEDs		26.0	66.2
LED ambient/strip/wrap	Linear LEDs	21.8		
Mogul high bay	High bay/low bay	283.6		
Mogul low bay	High bay/low bay	191.0		
Mogul Ext 175W	Exterior LEDs	141.9		
Mogul Ext 250W	Exterior LEDs	184.9		
Mogul Ext 400W	Exterior LEDs	283.3		
LED tubes, 3ft	Linear LEDs	12.0		
LED tubes, 8ft	Linear LEDs	25.1		
Parking garage, 20-99W - standard	Exterior LEDs	122.9		
Parking garage, 20-99W - premium	Exterior LEDs	130.5		
Parking garage, 100-199W - standard	Exterior LEDs	249.4		
Parking garage, 100-199W - premium	Exterior LEDs	253.9		
Parking garage, ≥ 200W - standard	Exterior LEDs	561.6		
Parking garage, ≥200W – premium	Exterior LEDs	583.1		

1 For bulbs dimmed based on a schedule or occupancy add an additional 15% delta watts.

2 Based on median value of DLC v5.0 and v5.1 qualified products list as of 10/22/21.

3 Upper end of wattage range is assumed to be 99.99. The wattage range for all other product categories assumes a similar level of precision.

Lost Opportunity Gross Energy Savings, Electric

Interior Lighting

$$AKWH = \frac{N \times \Delta W \times H \times HVAC_{INTC}}{1000}$$

Exterior Lighting

$$AKWH = \frac{N \times \Delta W \times H}{1000}$$

Where:

- **N** = No. of units.
- **ΔW** = Delta Watts per unit.
- **H** = Hours of Use are based on facility type in *Appendix Five*.
- **$HVAC_{INTC}$ =** HVAC interactivity multiplier, cooling.

Lost Opportunity Gross Seasonal Peak Demand Savings, Electric (winter and summer)

$$SKW = \frac{N \times \Delta W \times CF_S \times D_{INT}}{1000}$$

$$WKW = \frac{N \times \Delta W \times CF_W}{1000}$$

Lost Opportunity Gross Savings, Example

Example: *A MR16 LED bulb is sold to be installed in a small office at retail and incentivized through the Upstream Lighting program. For this bulb, the Delta Watts per bulb from Massachusetts Bright Opportunities Program is 22.1 W. The small office Hours of Use from Appendix Five (3,595) are used. For the Demand Savings, the Office Coincidence Factors from Appendix One of 70.2% (summer) and 53.9% (winter) are used.*

$$AKWH = \frac{N \times \Delta W \times H \times HVAC_{INTC}}{1000\frac{W}{kW}} = \frac{1 \times 22.1\ W \times 3{,}595 \times 1.024}{1000\frac{W}{kW}}$$
$$= 81.35\ kWh$$

$$LTKWH = AKWH \times Lifetime = 81.35 \times 4 = 325.42\ kWh$$

$$SKW = \frac{N \times \Delta W \times CF_{S\times} D_{INT}}{1000\frac{W}{kW}} = \frac{1 \times 22.1 \times 98.4\% \times 1.152}{1000\frac{W}{kW}} = 0.024\ kW$$

$$WKW = \frac{N \times \Delta W \times CF_w}{1000\frac{W}{kW}} = \frac{1 \times 22.1 \times 85.6\%}{1000\frac{W}{kW}} = 0.018\ kW$$

Description of lighting control types:

- **Occupancy sensor.** Reduces lighting operating hours by switching off lighting in unoccupied spaces.
- **Daylight dimming control.** – Reduces lighting output to a set level or reduces lighting operating hours in response to natural daylighting using continuous, stepped, or on/off dimming capability.
- **High-end trim.** Reduces lighting output of individual lights or groups of lights to a set level continuously. Must have the ability to set a maximum light level.
- **Dual occupancy and daylight dimming controls.** Combines the capabilities of occupancy and daylight sensors, allowing lighting fixtures to respond to occupancy and daylight.
- **Networked lighting controls or luminaire level lighting controls.** A networked lighting control system consists of an intelligent network of individually addressable luminaires and control devices. Networked lighting controls and luminaire level lighting controls are defined according to the DLC Networked Lighting Controls definition, which requires systems to have fixture networking capabilities, individual addressability, occupancy sensing, daylight harvesting, high-end trim, flexible zoning, continuous dimming, scheduling, and cybersecurity. The network ability allows building managers to group lights with specific zonal control and scheduling strategies, energy monitoring and high-end trim resulting in a higher savings capability. While DLC listing is not a requirement for any control type characterized in this measure, programs should consider eligibility requirements that ensure quality product is installed.

Lighting Controls Gross Energy Savings, Electric

$$S_{tot} = S_{ctrl} + S_{cool}$$

$$S_{ctrl} = \frac{W_{ctrl} \times H \times (SF_{EE} - SF_{Base})}{1{,}000\ W/kW}$$

$$S_{cool} = \frac{S_{ctrl} \times F}{COP}$$

Description of variable inputs:

- **W_{ctrl}** (W) is the facility lighting load that is controlled by the lighting control system. This value is site-specific.
- **H** (hours/yr) is the total operating hours of the controlled lighting circuit before the lighting controls are installed. This value is calculated on a site-specific basis; if no site-specific assumptions exist, use *Appendix Five*.

- **SF_{EE}** (%) is the average annual reduction in electric consumption achieved by a particular control measure type in the installed condition. Savings factors for various automated lighting control types are specified in *Table D*.

- **SF_{Base}** (%) is the average annual reduction in electric consumption achieved by a particular control measure type in the baseline condition. Savings factors for various automated lighting control types are specified in *Table D*; for upstream lighting assume no controls were installed, the baseline savings factor is 0%.

Table D: Savings Factor by Lighting Control Type

Lighting Control Type	Savings Factor (SF)
Networked Lighting Controls (NLC) or Luminaire-Level Lighting Controls (LLLC)	49% **Ref [1]**
Dual Occupancy and Daylight Dimming Controls	38% **Ref [2]**
Any One Control Strategy Savings Factor	24% **Ref [2]**
No Lighting Controls	0%
Note: Maximum of only one control strategy available for Exterior.	

- **S_{cool}** (kWh) does not apply to exterior lighting measures.

- **F** (%) is the fraction of energy savings due to the reduced cooling required as the result of reducing lighting operating hours and/or fixture illumination through lighting controls. For interior upstream lighting measures assume F = 0.35. For exterior upstream lighting controls measure F = 0.

Heating Penalty

Heating Penalty in MMBtu:

$$MMBTU = AKWH \times HVAC_{INTH}$$

Where,

$$HVAC_{INTH} = -0.000329\ MMBTU\ per\ kWh$$

Changes from Last Version

- Updated Hours of Use, CFs, and CFw in the example based on the C1635 Study.

- Added the heating penalty equation.
- Updated the lighting controls savings.

References

[1] C&I Upstream Lighting Program. Mass Saves. Available at: *https://www.masssave.com/en/learn/partners/upstream-lighting/*, last accessed Mar. 20, 2019.

[2] ENERGY STAR Certified Light Bulbs, Available at: http://www.energystar.gov/productfinder/product/certified-light-bulbs/results, last accessed May 22, 2018.

[3] Design Lights Consortium product lists. Available at: https://www.designlights.org/qpl.

[4] DNV GL (2020). C1635 Impact Evaluation of PY 2016 & 2017 Energy Opportunities (EO) Program.

[5] DNV GL (2017). Impact Evaluation of PY2015 Massachusetts Commercial and Industrial Upstream Lighting Initiative.

Notes

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

[2] Design Lights Consortium product lists. Available at: https://www.designlights.org/qpl.

2.1.3. INTERIOR LIGHTING CONTROLS

Description of Measure

Installation of new occupancy sensors or daylighting sensors and controls on a new or existing lighting system. Lighting control types covered by this measure include wall, ceiling, fixture mounted or integrated controls, as well as Luminaire Level Lighting Controls (LLLCs) or Networked Lighting Controls (NLCs), which may have additional high-end trim and networking capabilities.

Savings Methodology

Energy and seasonal peak demand savings are calculated for the installation of lighting controls using an energy savings factor based on the installed control type. These systems save energy and peak demand by shutting off power to lighting fixtures when the space is unoccupied or illumination is not required. They also save energy and demand by reducing power to lighting systems to correct for over-illumination due to excessive lamp output or the presence of daylight. Installation of lighting controls reduces the cooling load and provides additional savings, which are also calculated in this measure.

This measure only applies to interior lighting controls that are in addition to those required by 2021 IECC C405.2. Exterior lighting controls are not covered by this measure.

Inputs

Table A: Inputs

Symbol	Description	Units
Controlled LPD	Facility controlled LPD	Watts/ft^2
kW_{ctrl}	Total fixture connected kW	kW
A	Facility illuminated and controlled area	ft^2
H	Facility lighting —Hours of use	Hours/year

Nomenclature

Table B: Nomenclature

Item	Description	Units	Values	Comments
A	Facility illuminated area	ft^2	Input	Site-specific
CF_{OS}	Occupancy sensor coincidence factor	-		*Appendix One*
COP	Coefficient of performance	-	4.5	**Note [2]**

F	Fraction of lighting energy that must be removed by the facility's cooling system	-	*Table D*	**Ref [3]**
G	Estimated lighting energy heat to space based on modeling	-	0.73	**Ref [4], Note [1]**
H	Facility lighting —Hours of use	Hours/year	Input	Site-specific; Use *Appendix Five* only when site-specific assumptions do not exist.
LPD	Lighting power density	Watts/ ft^2	Input	Site-specific
S_{cool}	Annual energy savings from reduced cooling load	kWh		Calculated
S_{ctrl}	Annual energy savings from use of interior lighting controls	kWh		Calculated
S_{tot}	Annual gross electric energy savings	kWh		Calculated
SF	Lighting controls savings factor	%	*Table C*	**Ref [1], Ref [2]**
SKW	Summer demand savings	kW		Calculated
WKW	Winter demand savings	kW		Calculated
Lifetime	Measure life of the fixture	Years	12.2	**Ref [5] ,Note[5]**
LKWH	Lifetime electric energy savings	kWh		Calculated

Description of lighting control types:

- **Occupancy sensors.** Reduces lighting operating hours by switching off lighting in unoccupied spaces.
- **Daylight dimming controls.** Reduces lighting output to a set level or reduces lighting operating hours in response to natural daylighting using continuous, stepped, or on/off dimming capability.
- **High end trim.** Reduces lighting output of individual lights or groups of lights to a set level continuously. Must have the ability to set a maximum light level.
- **Dual occupancy and daylight dimming controls.** Combines the capabilities of occupancy and daylight sensors, allowing lighting fixtures to respond to occupancy and daylight.
- **Networked lighting controls** and **luminaire-level lighting controls.** A networked lighting control system consists of an intelligent network of individually addressable luminaires and control devices. LLLCs and NLC are defined according to the DLC Networked Lighting Controls definition, which requires systems to have fixture networking capabilities, individual addressability, occupancy sensing, daylight harvesting, high-end trim, flexible zoning, continuous dimming, scheduling, and cybersecurity. The network ability allows building managers to group lights with specific zonal control and scheduling strategies, energy monitoring and high-end trim resulting in a higher savings capability. While DLC listing is not a requirement for any control type

characterized in this measure, programs should consider eligibility requirements that ensure quality product is installed.

Lost Opportunity Gross Energy Savings, Electric

$$S_{tot} = S_{ctrl} + S_{cool}$$

$$S_{ctrl} = \frac{A_{ctrl}\,(ft^2) \times LPD_{ctrl}\,(W/ft^2) \times H \times (SF_{EE} - SF_{Base})}{1{,}000\ W/kW}$$

$$S_{cool} = S_{ctrl} \times \frac{F}{COP}$$

Description of variable inputs:

- **A_{ctrl}** (ft^2) is the controlled lighting building area and calculated (measured) for each project, either from architectural drawings or by physical measurement.
- **Controlled LPD** (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.
- **H** (hours/yr) is the total operating hours of the controlled lighting circuit before the lighting controls are installed. This value is calculated on a site-specific basis; if no site-specific assumptions exist, use *Appendix Five*.
- **SF_{EE}** (%) is the average annual reduction in electric consumption achieved by a particular control measure type in the installed condition. Savings factors for various automated lighting control types are specified in *Table C*.
- **SF_{Base}** (%) is the average annual reduction in electric consumption achieved by a particular control measure type in the baseline condition. Savings factors for various automated lighting control types are specified in *Table C*; if no lighting controls were installed (or required by code), the baseline savings factor is 0%.

Table C: Energy Savings Factor by Lighting Control Type

Lighting Control Type	Savings Factor (SF)
Networked lighting controls (NLCs) and luminaire-level Lighting controls (LLLCs)	49% **Ref [1]**
Dual occupancy and daylight dimming controls	38% **Ref [2]**

Combination of high-end trim and daylight dimming	35% **Note [4]**
Combination of high-end trim and occupancy sensors	33% **Note [4]**
High-end trim	27% **Ref [1]**
Daylight dimming	28% **Ref [2]**
Occupancy sensors	24% **Ref [2]**
No lighting controls	0%

- **F** (%) is the fraction of energy savings due to the reduced cooling required as the result of reducing lighting operating hours and/or fixture illumination through lighting controls. If the HVAC system includes an economizer, then F = 0.35. Otherwise, use *Table D*.

Table D: Fraction of Energy Savings due to Reduced Cooling from the HVAC System, see Ref [3]

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

Explanation of numerical constants:

- 1,000 converts watts to kW (1/1,000 is the conversion).
- **COP** = 4.5. See **Note [2]**.

Lost Opportunity Gross Energy Savings, Fossil Fuel

Space heating energy consumption will increase due to reduced lighting operating hours.

- Annual Oil Savings = -0.000162279 MMBtu per annual kWh saved; and
- Annual Natural Gas Savings = -0.000162279 MMBtu per kWh. See **Ref [3]**.

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

$$SkW = \frac{A_{ctrl}\,(ft^2) \times LPD_{ctrl}\,(W/ft^2) \times (SF_{EE} - SF_{Base}) \times CF_{OS} \times (1 + G/COP)}{1{,}000\ W/kW}$$

$$WkW = \frac{A_{ctrl}\,(ft^2) \times LPD_{ctrl}\,(W/ft^2) \times (SF_{EE} - SF_{Base}) \times CF_{OS}}{1{,}000\ W/kW}$$

Description of variable inputs:

- **A_{ctrl}** (ft^2) is the controlled lighting building area and calculated (measured) for each project, either from architectural drawings or by physical measurement.
- **Controlled LPD** (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.
- **SF_{EE}** (%) is the average annual reduction in electric consumption achieved by a particular control measure type in the installed condition. Savings factors for various automated lighting control types are specified in *Table C*.
- **SF_{Base}** (%) is the average annual reduction in electric consumption achieved by a particular control measure type in the baseline condition. Savings factors for various automated lighting control types are specified in *Table C*; if no lighting controls were installed, the baseline savings factor is 0%.
- **CF_{OS}** is the occupancy sensor coincidence factors (summer/winter) taken from *Appendix One*. See **Note [3].**

Explanation of numerical constants:

- **G** = 0.73. See **Note [1]**.
- **COP** = 4.5. See **Note [2]**.

Changes from Last Version

- Added new measure.

References

[1] DLC and Northwest Energy Efficiency Alliance (NEEA), "Energy Savings from Networked Lighting Control (NLC) Systems with and without LLLC", Energy Solutions, Sep. 24 2020.

[2] Williams, A., B. Atkinson, K. Garesi, E. Page, and F. Rubinstein. 2012. "Lighting Controls in Commercial Buildings." The Journal of the Illuminating Engineering Society of North America 8 (3): 161-180.

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

[4] DNV GL (2017). *Impact Evaluation of PY2015 Massachusetts Commercial and Industrial Upstream Lighting Initiative*. DNVGL_2017_Upstream_Lighting_Impact_Evaluation.

[5] DNV (2021). *Connecticut C2014 C&I Lighting Saturation and Remaining Potential – Phase One Results and Recommendations*.

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] Estimated based on 2015 Connecticut Code. 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 Aug. 17, 2007.

[3] It is assumed that the occupancy sensor coincidence factors (summer/winter) taken from Appendix One would apply to all control types.

[4] Savings factors for the combination of high-end trim with daylight dimming and high-end trim with occupancy sensors were calculated based on savings factors from the individual controls from **Ref [2]**.

[5] The measure life for interior lighting controls is assumed to be the adjusted measure lifetime (AML) for LED fixtures from the Connecticut C2014 study, based on the assumption that the controls are integrated with the fixture.

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.

Note: If a project permit is issued before 2021 IECC code is adopted by the State, the previous code (2015 IECC) should be referenced.

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 the chiller's demand (kW) and consumption (kWh) for each temperature BIN (**Note [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 (i.e., chilled water pumps, condenser water pumps, and cooling tower fans).

Inputs

Table A: Inputs

Symbol	Description	Units
H_{OH}	Facility occupancy hours per week (on and off-peak)	Hr/week
	Chiller plant availability per month	Y or N
$L_{100°F,\ Unocc}$	Peak cooling load @100°F (occupied)	Tons
$L_{100°F,\ Occ}$	Peak cooling load @100°F (unoccupied)	Tons
T_{Econ}	Economizer set point	°F
$L_{Econ,\ Occ,\ OAT+}$	Load at economizer set point + (occupied)	Tons
$L_{Econ,\ Unocc,\ OAT+}$	Load at economizer set point + (unoccupied)	Tons
$L_{Econ,\ Occ,\ OAT-}$	Load at economizer set point - (occupied)	Tons
$L_{Econ,\ Unocc,\ OAT-}$	Load at economizer set point - (unoccupied)	Tons
$L_{0°F,\ Occ}$	Load at @ 0°F outside air temp (occupied)	Tons
$L_{0°F,\ Unocc}$	Load at @ 0°F outside air temp (unoccupied)	Tons
$L_{T\ Bin}$	Load @ Temperature Bin	Tons
CAP	Chiller(s) capacity at ARI rating	Tons
F_{L1}	Chiller load percentage relative to ARI rated capacity	%

	Condenser – air or water-cooled	
$EFF_{kW/ton}$	Chiller efficiency	kW/ton
	Compressor type	
EFF_{PL}	ARI-part load efficiency @ 100% load, @ 75% load, @ 50% load, and @ 25% load	**Note [2]**
	Primary chilled water pump	BHP
	Secondary chilled water pump	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

Table B: 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			

Outputs

Table C: Nomenclature

Symbol	Description	Units
S_{kW}	Summer Peak Demand Savings	kW
W_{kW}	Winter Peak Demand Savings	kW
A_{kWh}	Annual Energy Savings	kWh

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 positive displacement (screw, scroll, and reciprocating); and
    - Air cooled.
- Speed, constant, or variable.
- Auxiliary equipment:
    - Chilled water pumps;
    - Cooling tower pumps;
    - Cooling tower fans; and
    - 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; and
- Un-occupied hours the chiller is operated each week.

Load profile:

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

***Savings calculations*:**

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 D*, and again for the proposed chillers, and the difference determines the kWh and 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. Multifamily building chiller installations are variable flow chillers and shall apply the savings prescribed in Path B.

Table D: Baseline Efficiencies for Electric[1] Chillers, see Note [3]

Equipment Type	Size Category (tons)	Units	Path A[2]		Path B[3]	
			Full Load[4]	IPLV[4]	Full Load[4]	IPLV[4]
Air cooled	<150	EER	≥ 10.100	≥ 13.700	≥ 9.700	≥ 15.800
	≥150	EER	≥ 10.100	≥ 14.100	≥ 9.700	≥ 16.100
Water cooled positive displacement	< 75	kW/ton	≤ 0.750	≤ 0.600	≤0 .780	≤ 0.500
	≥ 75 & < 150	kW/ton	≤ 0.720	≤ 0.560	≤ 0.750	≤ 0.490
	≥ 150 & < 300	kW/ton	≤ 0.660	≤ 0.540	≤ 0.680	≤ 0.440
	≥ 300 & <600	kW/ton	≤ 0.610	≤ 0.520	≤ 0.625	≤ 0.410
	≥ 600	kW/ton	≤ 0.560	≤ 0.500	≤ 0.585	≤ 0.380
Water cooled centrifugal	<150	kW/ton	≤ 0.610	≤ 0.550	≤ 0.695	≤ 0.440
	≥ 150 & < 300	kW/ton	≤ 0.610	≤ 0.550	≤ 0.635	≤ 0.400
	≥ 300 & < 400	kW/ton	≤ 0.560	≤ 0.520	≤ 0.595	≤ 0.390
	≥ 400	kW/ton	≤ 0.560	≤ 0.500	≤ 0.585	≤ 0.380

[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] Rated based on **Note [2]**.

Table E: 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	10.100	12.265	14.797	14.878
	≥ 150	EER	10.100	12.648	15.258	15.134
Water cooled positive displacement	< 75	kW/ton	0.750	0.639	0.534	0.776
	≥ 75 & < 150	kW/ton	0.720	0.596	0.498	0.728
	≥ 150 & < 300	kW/ton	0.660	0.574	0.480	0.713
	≥ 300 & < 600	kW/ton	0.610	0.556	0.464	0.662
	≥ 600	kW/ton	0.560	0.534	0.446	0.636
Water cooled centrifugal	< 150	kW/ton	0.610	0.565	0.521	0.616
	≥ 150 & < 300	kW/ton	0.610	0.565	0.521	0.616
	≥ 300 & < 400	kW/ton	0.560	0.536	0.494	0.565
	≥ 400 & ≤ 600	kW/ton	0.560			
	≥600	kW/ton	0.560	0.515	0.475	0.547

Table F: 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	9.7	14.145	17.065	17.359
	≥ 150	EER	9.7	14.442	17.422	17.481
Water cooled positive displacement	< 75	kW/ton	0.78	0.530	0.443	0.682
	≥ 75 & < 150	kW/ton	0.75	0.518	0.432	0.692
	≥ 150 & < 300	kW/ton	0.68	0.467	0.390	0.587
	≥ 300 & < 600	kW/ton	0.625	0.435	0.364	0.548
	≥ 600	kW/ton	0.585	0.403	0.337	0.508
Water cooled centrifugal	< 150	kW/ton	0.695	0.547	0.377	0.405
	≥ 150 & < 300	kW/ton	0.635	0.497	0.343	0.368
	≥ 300 & < 400	kW/ton	0.595	0.486	0.335	0.349
	≥ 400 & < 600	kW/ton	0.585			
	≥ 600	kW/ton	0.585	0.474	0.327	0.338

Savings Calculation Algorithm

For buildings with one chiller, the spreadsheet calculation methodology is summarized below:

1. Get chiller load at outdoor temperature bin, $L_{T\ Bin}$:

If $T_{T\ Bin} > T_{Econ}$, then

For Occupied Periods,

$$L_{T\ Bin} = L_{Econ,\ Occ,\ OAT+} + \frac{L_{100°F} - L_{Econ,\ Occ,\ OAT+}}{100 - T_{Econ,\ OAT}} \times (T_{T\ Bin} - T_{Econ})$$

If $T_{T\ Bin} = T_{Econ}$, then

$$L_{T\ Bin} = \frac{L_{Econ,\ Occ,\ OAT+} + L_{Econ,\ Occ,\ OAT-}}{2}$$

If $T_{T\ Bin} < T_{Econ}$, then

$$L_{T\ Bin} = L_{0°F} + \frac{L_{Econ,\ Occ,\ OAT-} - L_{0°F}}{T_{Econ - 0°F}} \times (T_{T\ Bin} - 0°F)$$

2. Repeat $L_{T\ Bin}$ calculations for unoccupied periods and sum with occupied load values for each bin.

3. Determine chiller load percentage relative to ARI rated capacity, $L_{P1,\ Bin}$:

$$F_{L1,\ Bin} = \frac{L_{T\ Bin}}{CAP}$$

4. Using AHRI IPLV ratings at 100%, 75%, 50%, and 25%, kW/ton values are interpolated in 1/100 increments from 0 to 100% loading. For baseline equipment, IPLV values are referenced from code requirements as defined in *Table D*. For the new, energy efficiency equipment, efficiency values are from the AHRI certification.

5. Using values from the interpolation table, a kW/ton value ($EFF_{\frac{kW}{ton},\ Bin}$) is then assigned at each temperature bin ($T_{T\ Bin}$) based on chiller load percentage ($F_{L1,\ Bin}$). These values are used to determine chiller power draw ($kW_{Chiller,\ Bin}$) at each bin:

$$kW_{Chiller,\ Bin} = EFF_{\frac{kW}{ton},\ Bin} \times L_{T\ Bin}$$

6. Bin Hours (H_{Bin}) are a function of user-specified equipment operating hours (H_{OH}) and TMY3 database hours based on specified weather location. Annual energy consumption for is calculated for each bin based on bin-specific equipment power draws and associated bin hours (H_{Bin}):

$$kWh_{Chiller,\ Bin} = kW_{Chiller,\ Bin} \times H_{Bin}$$

7. Energy consumption from each bin is summed to determine annual energy consumption:

$$kWh_{Chiller,\ Ann.\ Use} = \sum kWh_{Chiller,\ Bin}$$

8. Energy consumption is compared between baseline chiller and efficient chiller to determine annual energy savings:

$$kWh_{Chiller,\ Ann.\ Use} = kWh_{Chiller,\ Ann.\ Use,\ Base} - kWh_{Chiller,\ Ann.\ Use,\ Base}$$

9. Summer Peak Demand Savings (S_{kW}) is determined for both the baseline chiller and efficient chiller by adding energy consumed in bins where outdoor temperature is greater than 80°F and then averaging across total bin hours in the range. The difference in kW represents Summer Peak Demand Savings:

$$S_{kW} = \frac{\left(\sum_{80°F-Max} kWh_{Chiller,\ Base,\ Bin} - \sum_{80°F-Max} kWh_{Chiller,\ EE\ ,\ Bin}\right)}{\sum_{80°F-Max} H_{Bin}}$$

10. Winter Peak Demand Savings (W_{kW}) is determined for both the baseline chiller and efficient chiller by adding energy consumed in bins where outdoor temperature is less than 30ºF and then averaging across total bin hours in the range. The difference in kW represents Winter Peak Demand Savings:

$$W_{kW} = \frac{\left(\sum_{30°F-Min} kWh_{Chiller,\ Base,\ Bin} - \sum_{30°F-Min} kWh_{Chiller,\ EE\ ,\ Bin}\right)}{\sum_{30°F-Min} H_{Bin}}$$

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 peak demand. There are no ISO-NE winter peak demand savings.

Non-Energy Impacts

Because the baseline and high-efficiency technology are the same for electric chillers, the majority of the projects have zero NEIs.

Changes from Last Version

- Added description of spreadsheet calculation methodology.

Notes

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

[2] Either EER for air cooled or kW/ton for water cooled. Part-load performance based on AHRI 550/590.

[3] Developed using typical chiller part load curves and the baseline efficiencies in *Table D*. The table is based on 2021 IECC Table C403.3.2(3).

2.2.2 UNITARY AIR CONDITIONERS (A/C) AND HEAT PUMPS

Description of Measure

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

Note: If a project permit is issued before 2021 IECC code is adopted by the State, the previous code (2015 IECC) should be referenced.

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 2021 IECC standard efficiency options.

Inputs

Table A: 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
$SEER_i$	Seasonal Energy Efficiency Ratio ("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

Table B: 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	%	.44	*Appendix One*
$CF_{C,MF}$	Seasonal summer cooling coincidence factor for Multifamily applications	%	.59	*Appendix One*
COP_b	High-temperature COP, heat pumps ≥ 65,000 Btu/hr – 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/hr – baseline	Btu/watt-hr		**Note [1]**
EER_i	EER, ≥ 65,000 Btu/hr – installed	Btu/watt-hr		Input

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 < 65,000 Btu/hr.*

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/hr. There are two paths for complying with the ASHRAE 90.1 2019 Standards: (1) the Baseline Efficiencies (Table C) and (2) Additional Efficiencies (Table D).*

Table C: Baseline Efficiencies – Unitary and Split System-A/C 2021 IECC, see 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 (split system)	13.0 SEER (split system)
	14.0 SEER (single package)	14.0 SEER (single package)
≥ 65,000 and < 135,000	11.2 EER	11.0 EER
	12.8 IEER	12.6 IEER
≥ 135,000 and < 240,000	11.0 EER	10.8 EER
	12.4 IEER	12.2 IEER
≥ 240,000 and < 760,000	10.0 EER	9.8 EER
	11.6 IEER	11.4 IEER
≥ 760,000	9.7 EER	9.5 EER
	11.2 IEER	11.0 IEER
If applicable, compare against federal requirement and use more stringent value.		

Table D: Baseline Efficiencies –Unitary and Split System Heat Pumps—2021 IECC, see Note [2]

Size (Btu/h)	Cooling Mode		Heating Mode @ 47°F db/43°F wb
	Units with Electric Resistance or No Heating Section	Units with Heating Section Other Than Electric Resistance	
< 65,000, split systems	14.0 SEER	14.0 SEER	8.2 HSPF
< 65,000, single package	14.0 SEER	14.0 SEER	8.0 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
If applicable, compare against federal requirement and use more stringent value.			

Lost Opportunity Gross Energy Savings, Example

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 is the measure's 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 Five*, the cooling equivalent full load hours for an office are 797 hours. EERb from *Table D* is 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.*

Lost Opportunity Gross Peak Demand Savings, Example

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 is the unit's seasonal peak savings?*

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

Note: *From Appendix One, the seasonal coincidence factor for cooling = 0.44.*

EER_b from *Table D* = 11 EER:

$$SKW_C = 120{,}000 \times \left(\frac{1}{11} - \frac{1}{12.5}\right) \times \frac{kW}{1000\ W} \times 0.44 = .576\ kW$$

$$WKW_H = 0$$

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

Changes from Last Version

- Updated references from 2018 IECC to 2021 IECC.
- Updated SKW_C value and examples.

Notes

[1] *Table C* above is based on 2021 IECC (CT Code), see Table C403.3.2(1).

[2] *Table D* above is based on 2021 IECC (CT Code), see Table C403.3.2(4).

2.2.3 WATER AND GROUND SOURCE HEAT PUMPS

Description of Measure

High-efficiency water source, ground water source, and ground-coupled heat pump units.

Note: If a project permit is issued before 2021 IECC code is adopted by the State, the previous code (2015 IECC) should be referenced.

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

Table A: 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 (as certified by AHRI which uses standard ISO 13256-1)	Btu/watt-hr
COP_i	COP – installed (s certified by AHRI which uses a standard ISO 13256-1)	

Nomenclature

Table B: 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	%	82%	*Appendix One*
CF_H	Seasonal summer heating coincidence factor	%	82%	*Appendix One*
CF_C (MF)	Seasonal summer cooling coincidence factor (Multifamily)	%	59%	**Ref [2]**
CF_H (MF)	Seasonal summer heating coincidence factor (Multifamily)	%	100%	**Ref [2]**
COP_b	High-temperature COP, heat pumps 65,000 Btu/h-baseline			**Ref [1]**
COP_i	COP – installed			Input
COP_e	COP – existing			Input
EER_b	EER – baseline	Btu/watt-hr		**Ref [1]**
EER_i	EER – installed	Btu/watt-hr		Input
EER_e	EER – existing	Btu/watt-hr		Input
$EFLH_C$	Equivalent full load hours - cooling	Hrs		*Appendix Five*
$EFLH_H$	Equivalent full load hours - heating	Hrs		*Appendix Five*
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 C: Baseline Efficiencies, see Note [1]

Type	Cooling Capacity Btu/hr	EER_b	COP_b
Water source heat pump (closed loop within a building, served by boiler and cooling tower)	< 17,000	12.2	4.3
Water source heat pump (closed loop within a building, served by boiler and cooling tower)	≥ 17,000 and < 135,000	13.0	4.3
Ground water heat pump (water used by the heat pump is in contact with the ground)	< 135,000	18.0	3.7
Ground loop heat pump (water used by the heat pump is isolated from contact with the ground)	< 135,000	14.1	3.2

Lost Opportunity Gross Energy Savings, Example

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 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 Five*, the cooling equivalent full load hours for an office are 797 hours. The EER_b from *Table C* is 14.1:

$$AKWHc = 125{,}000 \times \left(\frac{1}{14.1} - \frac{1}{15.0} \right) \times \frac{kW}{1000W} \times 797 = 423.94$$

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 Five*, the heating equivalent full load hours for an office are 1,248 hours. The COP_b from *Table C* is 3.2:

$$AKWH_H = 99{,}000 \times \left(\frac{1}{3.2} - \frac{1}{3.5} \right) \times \frac{1}{3.412} \times \frac{kW}{1000W} \times 1248 = 969.94$$

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:

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

If supplemental heating systems, such as fossil fuel equipment, are present on site, they will kick on during peak winter days when the heat pump unit cannot operate efficiently at such low temperatures. In this case, winter peak demand savings are 0.

Lost Opportunity Gross Peak Demand Savings, Example

Example: *A ground loop water-to-air-source 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 One*, the seasonal coincidence factor for cooling = 0.82. The EER_b from *Table C* is 14.1:

$$SKWc = 0.82 \times 125{,}000 \times \left(\frac{1}{14.1} - \frac{1}{15.0}\right) \times \frac{kW}{1000W} = 0.44kW$$

Heating:

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

WKWH = 0 if supplemental heating system is present or
if boiler-fed hot water loop supplies heating side of water-source heat pump.

The seasonal coincidence factor is assumed to be the same as the summer factor = 0.82. The COP_b from *Table C* is 3.2:

$$WKW_H = 0.82 \times 99{,}000 \times \left(\frac{1}{3.2} - \frac{1}{3.5}\right) \times \frac{1}{3.412} \times \frac{kW}{1000W} = 0.64kW$$

Early Retirement or Retrofit Gross Energy Savings, Electric

Cooling:

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

Heating:

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

Early Retirement or Retrofit Gross Peak Demand Savings, Electric

Cooling:

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

Heating:

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

Changes from Last Version

- Revised IECC references from to remove reference to CT building code.
- Added information regarding AHRI certification.

References

[1] *Table C* is based on the 2021 IECC's Table C403.3.2(14).

[2] *TRC. X1941: Multifamily Impact Evaluation, PSD Savings Review,* July 2021.

2.2.4 DUAL ENTHALPY CONTROLS

This measure is discontinued based on the recommendation of the impact study - *Cadmus, C1634 Impact Evaluation of PY 2016 & 2017 Energy Conscious Blueprint Program.*

2.2.5 DEMAND CONTROL VENTILATION

Description of Measure

Upgrade to HVAC system to control outside air flow based on CO_2 levels. The proposed system monitors the CO_2 in the spaces or return air and reduces 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, and 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 are 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* in the 2022 PSD manual) since the savings for this measure are consistent with the furnace/boiler savings profile. The baseline for this measure is a system with no CO_2 ventilation control.

Inputs

Table A: 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

- **Note (1)** added in regard to virus spread, such as COVID-19.

Notes

[1] Refer to ASHRAE suggestions in the future related to spread of viruses such as COVID -19.
Per ASHRAE (Position Document on infectious Aerosols, published April 2020, page 10) "to increase outdoor air ventilation by disabling DCV and opening outdoor air dampers to 100% as indoor and outdoor conditions permit in the buildings that remained open."
Here is the link to this document: https://www.ashrae.org/file%20 library/about/position%20documents/pd_ infectious aerosols 2020.pdf.

2.2.6 NATURAL GAS FIRED BOILERS AND FURNACES

Description of Measure

This measure encourages the installation of high-efficiency, natural gas-fired, hydronic heating boilers and furnaces.

Note: If a project permit is issued before 2021 IECC code is adopted by the State, the previous code (2015 IECC) should be referenced.

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 based on Industry Standard Practice (ISP) baseline per **Ref [1]**. If the boiler is used for domestic hot water, in addition to heating, the project should be handled as a custom measure (See *Measure 2.6.3: Lost Opportunity Custom* in the 2022 PSD manual).

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

Table A: Inputs

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

Nomenclature

Table B: Nomenclature

Symbol	Description	Units	Values	Comments
ACCF	Gross annual energy savings	ccf		
AFUE	Annual Fuel Utilization Efficiency			
CAP	Installed boiler or furnace output capacity	Btu/hr		
EFLH	Equivalent full load hours	Hours	*Appendix Five*	
E_t	Thermal efficiency	%		
E_c	Combustion efficiency	%		
OF	Oversize factor			**Note [2]**
PD	Gross peak day natural gas savings			
ηb	Base case efficiency	Percent		
	Furnace (120,000 Btu/hr or greater)	Percent	Unknown existing venting or new construction: 85% Et Existing condensing stack: 90% Et Existing non-condensing stack: 80% Et, or code	**Ref [1]**
	Furnace (Less than 120,000 Btu/hr)	Percent	85% AFUE	**Ref [1]**
	Boilers, small (<300 MBH)	Percent	92% AFUE	**Ref [1]**
	Boilers, medium (300 MBH to 2,500 MBH)	Percent	90% E_t	**Ref [1], Note [4]**
	Boilers, large (>2,500 MBH)	Percent	90% E_c	**Ref [1]**
	Steam (<300 MBH)	Percent	82% AFUE	**Ref [1] Note [4]**
	Steam (>300 MBH)	Percent	82% E_t	**Ref [1] Note [4]**
	Cast iron sectional hot water (<300 MBH)	Percent	82% AFUE	**Ref [1] Note [4]**
	Cast iron sectional hot water (300 MBH – 2,500 MBH)	Percent	82% E_t	**Ref [1] Note [4]**
	Cast iron sectional hot water (>2,500 MBH)	Percent	82% E_c	**Ref [1]**
ηp	Proposed case efficiency	Percent		

Lost Opportunity Gross Energy Savings, Fossil Fuel

Heating savings:

$$ACCF = \left[\frac{CAP}{OF} \times \left(\frac{EFLH}{102{,}900\frac{Btu}{ccf}}\right) x \left(\frac{1}{\eta_b} - \frac{1}{\eta_p}\right)\right]$$

Lost Opportunity Gross Peak Day Savings, Natural Gas

Conventional (non-condensing) boiler peak day natural gas savings (CCF):

$$PD = 0.0152 \times ACCF$$

Condensing boiler peak day natural gas savings (CCF):

$$PD = 0.0133 \times ACCF$$

Furnace peak day natural gas savings (CCF):

$$PD = 0.0152 \times ACCF$$

Changes from Last Version

- Updated boilers and furnaces baseline rating per **Ref [1].**
- Updated efficiency units for select boilers.

References

[1] DNV, CT X1931-1 Industry Standard Practice Boilers and Furnaces, Dec. 10, 2021.

Notes

[1] Peak day factors and full load hours were developed by third-party engineers (Fuss & O'Neill, Manchester, Conn.) in 2008 using a temperature BIN analysis. The engineering analysis was provided to Eversource (natural gas), CNG, and SCG 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 OF for multiple boiler and furnace installations 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 90.1 and 2021 IECC minimum efficiency requirements are based on input capacity.

[4] Adopted efficiency units consistent with IECC 2021 Code instead of combustion efficiency because AHRI database indicates that Ec is not readily available for some equipment.

2.2.7 NATURAL GAS RADIANT HEATERS

Description of Measure

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

Note: If a project permit is issued before 2021 IECC code is adopted by the State, the previous code (2015 IECC) should be referenced.

Savings Methodology

Energy savings is estimated to be 25% of the consumption of a conventional natural 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

Table A: Inputs

Symbol	Description
CAP	Installed heating capacity in Btu/hr
	Facility type

Nomenclature

Table B: 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 C, Appendix Five*	**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:

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

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

Occupancy Category	Equivalent Full-Load Heating Hours
Warehouse, storage, and 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

- Update references from 2018 IECC to 2021 IECC.

References

[1] ASHRAE Technical Paper No. 4643, "*Evaluation of an Infrared Two-Stage Heating System in a*

Commercial Application," 2003, Conclusions, p. 138.

[2] 2021 IECC, Table C403.3.2(5), for warm air unit heaters, gas fired.

Notes

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

[2] In the case of a single-heater installation, the OF is 1.0. In the case of a multiple-heater installation, the total heater output capacity shall be used and the OF is 1.1.

[3] The EFLH range is shown in *Table C*. The magnitude of the EFLHs in each occupancy category considers both hours occupied and internal heat release equipment. Refer to *Appendix Five* for occupancy categories not listed in *Table C*.

2.2.8 NATURAL GAS-FIRED DOMESTIC HOT WATER HEATERS

Description of Measure

Installation of high-efficiency, natural gas-fired, storage-type, domestic hot water heaters > 75,000 Btu/hr.

Note: If a project permit is issued before 2021 IECC code is adopted by the State, the previous code (2015 IECC) should be referenced.

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 a natural gas storage water heater (> 75,000 Input Btu/hr) as specified in 2021 IECC (**Ref [1]**).

Based on facility type and square footage, *Table C* (**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 natural 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 domestic hot water (DHW) load; and
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]**); and
3. Hot water set point is 130°F.

Inputs

Table A: 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 in square feet	ft^2
	Building occupancy type	

Nomenclature

Table B: 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 C*	**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], Note [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 heater's natural gas usage:

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

Table C: Annual Base Case Gas Usage Rate by Occupancy Type, see Ref [2], Note [2]

Building Occupancy Category	Annual Base Case Gas Usage Rate, E_b (ccf/ft^2)
Education	0.068
Enclosed and strip malls	0.137
Food sales	0.043
Food service	0.382
Health care	0.232
Inpatient health care	0.334
Lodging	0.258
Mercantile	0.103
Multifamily low-rise	0.193
Multifamily high-rise	0.176
Office	0.047
Other	0.023

Public assembly	0.02
Public order and safety	0.209
Retail (other than mall)	0.024
Service	0.147
Warehouse and storage	0.028
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:

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

Ref [1], Note [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 (gallons of 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 natural gas savings using the following equation:

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

Lost Opportunity Gross Energy Savings, Example

Example: *A 50,000 square foot inpatient health care facility installs a new energy-efficient natural gas storage type DHW heater with the following ratings*:

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

What is the annual energy savings?

Calculate annual base case DHW natural gas usage:

$$CCF_{W,b} = A \times E_b = 50{,}000 \times 0.334 = 16{,}700\ ccf$$

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:

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

$$H = \frac{\left(8{,}760\ {}^{hr}/_{yr} \times 341 \times 1{,}000\right) - \left(16{,}700 \times 102{,}900\ {}^{Btu}/_{CCF}\right)}{(341 \times 1{,}000) - \frac{1{,}475}{0.80}} = 3{,}741$$

<u>Calculate annual building hot water usage (gallons of hot water consumed/yr)</u>:

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

$$GPY_W = \frac{\left(16{,}700 \times 102{,}900\ {}^{Btu}/_{CCF} \times 0.8\right) - (1{,}475 \times 3{,}741)}{75 \times 8.33\ {}^{Btu}/_{Gal{}^\circ F}} = 2{,}191{,}638$$

<u>Calculate annual natural gas savings using the following equation</u>:

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

$$ACCF_W = 16{,}700 - \frac{\left(2{,}191{,}638 \times 75 \times 8.33\ {}^{Btu}/_{Gal{}^\circ F} + 1{,}044 \times 3{,}741\right)}{102{,}900\ {}^{Btu}/_{CCF} \times 0.91} = 2{,}036$$

<u>Lost Opportunity Gross Peak Day Savings, Natural Gas</u>

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

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

$$PD = 2{,}036 \times 0.0032 = 6.5$$

<u>Changes from Last Version</u>

- Updated reference from 2018 IECC to 2021 IECC.

References

[1] 2021 IECC, Table C404.2.

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

[3] Tool for Generating Realistic Residential Hot Water Event Schedules, Reprint, NREL, Aug. 2010.

Notes

[1] For instantaneous hot water heaters, the SLR = 0.

[2] Multifamily Low- and High-Rise Annual Base Case Gas Usage Rate, Eb (ccf/ft^2) calculated by dividing RECS Annual household site end use consumption by fuel in the Northeast - averages 2015, Natural Gas, Water Heating (213 ccf/unit for low rise and 147 ccf/unit for high rise) by Average Square Footage Per Multifamily Housing Unit (1,105 ft^2 for low-rise and 834 ft^2 for high-rise).

2.2.9 VARIABLE REFRIGERANT FLOW (VRF) HVAC SYSTEM

Description of Measure

Installation of a large high-efficiency air-sourced Variable Refrigerant Flow (VRF) HVAC system for commercial and residential applications.

Note: If a project permit is issued before 2021 IECC code is adopted by the State, the previous code (2015 IECC) should be referenced.

Savings Methodology

Savings are custom calculated for each VRF installation based on the specific equipment specifications and operating profile. A temperature BIN model is utilized to develop usage and periodic demand. Customer specific information is used to determine a load profile for the air-sourced VRF system. Based on the VRF's performance characteristics energy (kWh) and Demand (kW) usage is calculated for the proposed case, while 2019 ASHRAE Code (**Note [1]**) specifications are used to calculate baseline usage. A VRF spreadsheet calculates the difference between the baseline and the proposed consumption (kWh, kW) to determine savings.

Inputs

Table A: Inputs

Symbol	Description	Units
	Facility occupancy hours per week (on- and off-peak)	Hr/Week
	Unit ID	
	Manufacturer/outdoor unit model	
	Indoor unit type (ducted, non-ducted, or mixed)	
	VRF classification (Heat recovery, no heat recovery, or cooling only)	
	Heating capacity (≥ 65,000 Btu/hr)	Btu/hr
	Cooling capacity (≥ 65,000 Btu/hr)	Btu/hr
	EER	Btu/watt-hr
	IEER	Btu/watt-hr
	High-temperature COP	
	Low-temperature COP	

Nomenclature

Table B: Nomenclature

Symbol	Description	Units	Values	Comments
EER	Energy Efficiency Ratio	Btu/watt-hr		
IEER	Integrated Energy Efficiency Ratio	Btu/watt-hr		
COP	Coefficient of performance			

Lost Opportunity Gross Energy Savings, Electric

Equipment:

Each VRF is characterized by:

- Indoor Unit type:
  - Ducted;
  - Non-ducted; and
  - Mixed.
- VRF Classification:
  - No VRF heat recovery;
  - VRF heat recovery; and
  - Cooling only.
- Heat and Cooling Capacity, Btuh.
- Cooling Efficiency:
  - EER; and
  - IEER.
- Heating Efficiency:
  - High temp COP; and
  - Low temp COP.

Operating profile:

The customer's cooling load profile, for each temperature BIN, is characterized by:

- Occupied hours the VRF is operated each week; and
- Un-occupied hours the VRF is operated each week.

Savings calculation:

With the above information 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 VRF meeting the baseline efficiencies, *Table C*, and again for the proposed VRF, and the difference determines the kWh and kW savings for each period. These are summed to yield the total savings.

Table C: Baseline Efficiencies – Electronically Operated Variable-Refrigerant-Flow and Applied Heat Pumps see Note [1]

Size (Cooling)	Cooling Mode			Heating Mode	
	VRF Multi-split System		VRF Multi-split System with Heat Recovery	Heating Mode @ 47°F db/43°F wb	Heating Mode @ 17°F db/15°F wb
	Cooling Only	Heating & Cooling			
≥ 65,000 Btu/h and < 135,000 tBu/h	11.2 EER	11.0 EER	10.8 EER	3.3 COP	2.25 COP
	15.5 IEER	14.6 IEER	14.4 IEER		
≥ 135,000 Btu/h and < 240,000 Btu/h	11.0 EER	10.6 EER	10.4 EER	3.2 COP	2.05 COP
	14.9 IEER	13.9 IEER	13.7 IEER		
≥ 240,000	10.0 EER	9.5 EER	9.3 EER	3.2 COP	2.05 COP
	13.9 IEER	12.7 IEER	12.5 IEER		

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 and winter peak demand.

Non-Energy Impacts

Because the baseline and high-efficiency technology are the same for electric VRF, the majority of the projects have zero non-electric benefits (Non-Energy Impacts).

Changes from Last Version

- Modified *Table C* to include “Cooling Only” values.
- Updated 2016 ASHRAE code references to 2019 (IECC 2021 references ASHRAE 90.1 2019).

Notes

[1] *Table C* above is based on the 2019 ASHRAE Code, Table 6.8.1-10. 6.8.1-10.

2.2.10 COMMERCIAL HEAT PUMP WATER HEATERS (CHPWH)

Description of Measure

Installation of a new efficient, commercial heat pump water heater (CHPWH), the baseline would be an electric resistance water heater (**Ref [4]**).

Retrofit: Currently installed electric resistance water heater.

Savings Methodology

Energy and demand savings calculations for a CHPWH are based on usage difference between new installed CHPWH and electric resistance water heater as shown below. The savings are based on the algorithm derived from a custom spreadsheet. CHPWH selection criteria are in accordance with ENERGY STAR certification (**Ref [1]**). The savings represent electric savings.

Inputs

Table A: Inputs

Symbol	Description	Units
N	Number of units installed	
CAPH,i	Heat input capacity of proposed (installed) CHPWH	kW
CAPW,i	Water storage capacity of proposed (installed) CHPWH	Gallons
A	Building floor area served by water heater	ft^2
Coph	Rated COP (Coefficient of Performance)	
	Building occupancy type	

Nomenclature

Table B: Nomenclature

Symbol	Description	Units	Comments
$\mathrm{AKW}H$	Annual Energy Savings	kWh/yr	
AWG	Annual Hot Water Usage	Gal/Yr	
SKW	Summer Demand Savings	kW	
WKW	Winter Demand Savings	kWh	
$\mathrm{AKW}H_{\mathrm{B}}$	Annual electric energy usage of base case CHPWH	kWh/yr	**Ref [1]**
$\mathrm{AKW}H_{\mathrm{I}}$	Annual electric usage of proposed(installed) CHPWH	kWh/yr	**Ref [1]**
CAPH,b	Heat Input capacity of base case CHPWH	kW	
CAPH,i	Heat Input capacity of proposed (installed) CHPWH	kW	
CAPW,b	Water storage capacity of base case CHPWH	Gallons	
CAPW,i	Water storage capacity of proposed (installed) CHPWH	Gallons	
Eb	Annual base case gas energy usage rate (per ft^2)	$ccf/ft^2/yr$	*Table C* ***Ref [2], Note [1]***
EEb	Annual base case electric energy usage rate (per ft^2)	$kWh/ft^2/yr$	
A	Building floor area	ft^2	
ηb	Thermal efficiency of gas furnace	%	**80% Ref [3]**

Lost Opportunity Gross Energy Savings

Calculate annual base case CHWPH's electric energy usage rate (EEB): $kWh/ft^2/yr$

$$EEB = Eb \times \eta b \times \frac{102900}{3413}$$

(Where Eb is derived from *Table C* based on occupancy type).

Table C: Annual Base Case Gas Usage Rate (Eb) by Occupancy Type, see Ref [2], Note [2]

Building Occupancy Category	Annual Base Case Gas Usage Rate, Eb (ccf/ft^2)
Education	0.068
Enclosed and strip malls	0.137
Food sales	0.043
Food service	0.382
Health care	0.232
Inpatient health care	0.334
Lodging	0.258
Mercantile	0.103
Multifamily low-rise	0.193
Multifamily high-rise	0.176
Office	0.047
Other	0.023
Outpatient health care	0.038
Public assembly	0.02
Public order and safety	0.209
Retail (other than mall)	0.024
Service	0.147
Vacant	0.013
Warehouse and storage	0.028

Calculate annual electric energy usage of base case CHPWH: $AKWH_B$ (kWh/yr):

$$AKWHB = A \times E_{eb}$$

Calculate annual electric energy usage of proposed (installed) CHPWH: $AKWH_I$ (kWh/yr):

$$AKWHI = \frac{AKWHB}{COPh}$$

Calculate annual electric energy savings of CHPWH: $AKWH$ (kWh/yr):

$$AKWH = AKWHB - AKWHI$$

Calculate annual hot water usage of CHPWH: AWG (Gal/yr):

$$AWG = (AKWHb \times 3413) \div (75 \times 8.33)$$

$$SKW = 0 \ \& \ WKW = 0$$

Lost Opportunity Gross Energy Savings, Example

Example: *A 119 gallon capacity ENERGY STAR certified (A.0 SMITH) CHPWH was sold for a grocery store of 5,000 square feet. CHPWH is qualified with an industry-leading 4.2 COP and dual 6 kW heating elements provide additional heating capability for periods of high demand.*

For electric savings:

Eb is derived from *Table C* based on building type (food sales in this example).

$$E_{EB} = Eb \times \eta b \times \frac{102900}{3413}$$

$$E_{EB} = 0.043 \text{ x } 80\% \text{x } \frac{102900}{3413}$$

= 1.037 kWh/FT2

$$AKWHB = A \times E_{eb}$$

= 5,000 ×1.037 kWh/yr

= 5,186 kWh/yr

$$AKWH_I = \frac{AKWHB}{COPh}$$

$$= \frac{5186}{4.2}$$

=1235 kWh/yr

$$AKWH = AKWH_B - AKWH_I$$

= 5,186 -1235

=3,951 kWh Annual Savings

Changes from Last Version

- New measure added.

References

[1] Commercial Heat Pump Water Heater (CHPWH) ENERGY STAR Criteria to get qualified for CHWHP measure https://www.energystar.gov/products/water_heaters/commercial_water_heaters/key_product_criteria

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

[3] 2021 IECC, Table C404.2.

[4] Code of Federal Regulations at 10 CFR 431.110 https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-431/subpart-G/subject-group-ECFR4c2d09a7e7a11ca/section-431.110.

Notes

[1] Multifamily Low- and High-Rise Annual Base Case Gas Usage Rate, Eb (ccf/ft^2) calculated by dividing RECS Annual household site end use consumption by fuel in the Northeast - averages 2015, natural gas, water heating (213 ccf/unit for low rise and 147 ccf/unit for high rise) by average square footage per multifamily housing unit (1,105 ft^2 for low-rise and 834 ft^2 for high-rise).

2.2.11 ECM CIRCULATING PUMP

Description of Measure

Retrofit installation of an Electronically Commutated Motor (ECM) circulating pump to replace an existing non-ECM circulating pump used to circulate hydronic heating system or hot water system for Commercial building application.

Savings Methodology

Savings is based are based on Cadmus Study conducted for single-phase circulator pumps up to 3 horsepower (HP) used in commercial and industrial buildings within Massachusetts and Connecticut. **Ref [1]**

Inputs

Table A: Inputs

Symbol	Description
	Number of installed ECM circulator pumps
	Size of pump (horsepower)
	Circulator pump application: hydronic heating or hot water system

Nomenclature

Table B: Nomenclature

Symbol	Description	Units	Values	Comments
AKWH	Annual electric energy savings	kWh/yr	Varies by size and application	See *Table D*
SKW	Seasonal summer peak savings	kW	Varies by size and application	See *Table D*
WKW	Seasonal winter peak savings	kW	Varies by size and application	See *Table D*
CF_H	Seasonal winter peak coincidence factor		1.0	*Appendix One*
HOU	Average Run time for commercial application	Hr/Yr	Varies by application: • Hydronic Heating=2,745 • Hot water =6,248	*Table 4 in **Ref [1]***
ACP	Average Circulator Pump size	HP	Varies	*Based on CT sales data, **Ref [1]*** *Table 3*

Retrofit Gross Annual Savings, Electric

Using the annual savings equation provided in **Ref [1]**, and using the average circulator pump "ACP" size below:

Table C: Average Circulator Pump Size

Pump Size	Average Hydronic Heating Size	Average Hot Water Size
$\leq$ 1HP	0.187	0.186
> 1HP	1	1

The savings are as follow:

- *Hydronic heating ≤ 1 HP:*

$$\mathrm{AKWH} = 1{,}222 \times \mathrm{HP_{rated}} + 103$$

Using average size of hydronic heating circulator pump = 0.187 HP therefore:

$$AKWH = 1{,}222 \times ACP + 103 = 1{,}222 \times 0.187 + 103 = 331.5\ kWh$$

- *Hot water ≤ 1 HP:*

$$AKWH = 2{,}780 \times HP_{rated} + 233$$

Using average size of hot water circulator pump = 0.187 HP therefore:

$$AKWH = 2{,}780 \times ACP + 233 = 2{,}780 \times 0.187 + 233 = 752.9\ kWh$$

- *Hydronic heating > 1 HP:*

$$AKWH = 1{,}325$$

Using average size of hydronic heating circulator pump = 1 HP therefore:

$$AKWH = 1{,}222 \times ACP + 103 = 1{,}222 \times 1 + 103 = 1{,}325\ kWh$$

- *Hot water > 1 HP:*

$$AKWH = 2{,}780 \times HP_{rated} + 233$$

Using average size of hot water circulator pump = 1 HP therefore:

$$AKWH = 2{,}780 \times ACP + 233 = 2{,}780 \times 1 + 233 = 3{,}013\ kWh$$

Retrofit Gross Seasonal Peak Demand Savings, Electric

- *Hydronic heating ≤ 1 HP*:

$$SKW = 0\ kW$$

$$WKW = \frac{AKWH}{HOU} = \frac{331.51}{2,745} = 0.121\ kW$$

- *Hot water ≤ 1 HP*:

$$SKW = \frac{AKWH}{HOU} = \frac{725.86}{6,248} = 0.120\ kW$$

$$WKW = \frac{AKWH}{HOU} = \frac{725.86}{6,248} = 0.120\ kW$$

- *Hydronic heating > 1 HP*:

$$SKW = 0\ kW$$

$$WKW = \frac{AKWH}{HOU} = \frac{1,325}{2,745} = 0.483\ kW$$

- *Hot water > 1 HP*:

$$SKW = \frac{AKWH}{HOU} = \frac{3,013}{6,248} = 0.482kW$$

$$WKW = \frac{AKWH}{HOU} = \frac{3,013}{6,248} = 0.482kW$$

The energy and seasonal peak demand savings can be summarized in Table D below:

Table D: Energy and Peak Demand Savings

Pump Size	Annual Savings-Hydronic Heating	SKW -Hydronic Heating	WKW - Hydronic Heating	Annual Savings-Hot Water	SKW -Hot Water	WKW - Hot Water
≤1 HP	331.5	0	0.121	752.9	0.120	0.120
>1 HP	1,325.0	0	0.483	3,013.0	0.482	0.482

Changes from Last Version

- New measure.

References

[1] The Cadmus Group (2017). Circulator Pump Technical Memo: Cadmus_2017_Circulator_Pump_Technical_Memo

2.3 MOTORS AND TRANSFORMERS

2.3.1 LOW VOLTAGE DRY TYPE DISTRIBUTION TRANSFORMERS

Description of Measure

Measure discontinued in 2017 due to implementation of a new Federal Energy Standard (**Ref [1]**) which makes potential savings negligible to support incentives for this program.

Savings Methodology

Not applicable (see above). Savings had been based on Consortium for Energy Efficiency (CEE) Tier level efficiency requirements; however, the CEE Initiative has been suspended.

Changes from Last Version

- Measure discontinued.

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 VARIABLE FREQUENCY DRIVES

Description of Measure

Addition of variable frequency drives (VFDs) to control a fan or pump system in an 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 [an Air Foil (AF), Backward Inclined (BI), and Forward Curved (FC)] with or without inlet guide vanes or a constant speed/flow centrifugal pump. ASHRAE default performance curves (**Ref [1]**) are used 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

Table A: Inputs

Symbol	Description
BHP	Brake horsepower
EFFi	Installed motor efficiency
H	Annual hours of operation
	Fan type

Nomenclature

Table B: Nomenclature

Symbol	Description	Units	Values	Comments
AF	Air foil fan			Fan type
AKWH	Gross annual electric energy savings	kWh		

BHP	System brake horsepower	HP		**Note [2]**
BI	Backward incline fan			Fan type
CHWP	Chilled water pump			
CV	Constant volume fan			
EFF_i	Motor efficiency – installed	%		
FC	Forward curved fan			Fan type
H	Annual hours of operation			Site specific or default, *Appendix Five*
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 2-XX*	
$SF_{kW,S}$	Summer seasonal demand savings based on typical load profile for application	(kW/HP)	*Table 2-XX*	
$SF_{kW,W}$	Summer seasonal demand savings based on typical load profile for application	(kW/HP)	*Table 2-XX*	
SKW	Seasonal summer peak savings	kW		
WKW	Seasonal winter peak savings	kW		
HP	Nominal horsepower			
LF	Load factor		0.65	**Ref [2]**

Lost Opportunity Gross Energy Savings, Electric

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

***Note**: Refer to Table C for the appropriate SF_{kWh}.*

Table C: 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
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.

[2] Lawrence Berkeley National Laboratory, and Resource Dynamics Corporation. (2008). "Improving Motor and Drive System Performance; A Sourcebook for Industry". U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy. Golden, CO: National Renewable Energy Laboratory, or https://www.energy.gov/sites/prod/files/2014/04/f15/amo_motors_sourcebook_web.pdf.

<u>Notes</u>

[1] The constants in *<u>Table C</u>* 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] Use equipment specific BHP if available, else BHP = Nominal HP x 65% LF. **Ref [2]**.

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, and labor) and optimize flow in order to improve the efficiency of the manufacturing process. The savings calculations are based on **Ref [1]** and **[Ref 2]**. 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); and

2. Producing more products over the same time period reduces losses in the manufacturing equipment consumption (e.g., such as less idle time and an increase in motor efficiency).

This measure is intended for facilities that increase the production efficiency (i.e., more widgets per unit time). Facilities where the production efficiency remains constant, such that Na and Ne are equal, should not use this measure. Instead, these should be treated as custom projects.

The PRIME process also reduces waste. Since this is very site dependent, it is not considered in this calculation. For projects with natural gas savings, the calculations will be done on a case-by-case basis for each customer's specific manufacturing process(es).

Inputs

Table A: Inputs

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

Nomenclature

Table B: Nomenclature

Symbol	Description	Units	Values	Comments
AKWH	Annual electric energy savings	kWh		
EKWH	Estimated annual electric usage with an 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 affected by PRIME	%		Input
PD	Annual electric energy usage dependent on production quantity	kWh		
SF	Savings factor	%		**Ref [1]**
$..._{wop}$	Without PRIME			
$..._{wp}$	With PRIME			

Lost Opportunity Gross Energy Savings, Electric

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

Estimated annual consumption with increase in productivity without PRIME:

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

$$IND_{wop} = 0.41 \times PPA \times KWH_h$$

$$HR_{wop} = 0.41 \times PPA \times KWH_h \times \frac{N_a}{N_e}$$

Estimated annual consumption with increase in productivity with PRIME:

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

$$IND_{wp} = 0.41 \times PPA \times KWH_h$$

$$HR_{wp} = 0.41 \times PPA \times KWH_h$$

$$PD_{wp} = 0.18 \times PPA \times KWH_h \times \frac{N_a}{N_e} \times (1 - SF)$$

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

Savings algorithms come directly from **Ref [1, 2]**.

Lost Opportunity Gross Energy Savings, Example

Example: *A manufacturing plant that has an annual electricity consumption of 1,000,000 kWh (KwH_h) 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:

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

$$IND_{wop} = 0.41 \times 0.25 \times 1{,}000{,}000 = 102{,}500\ kWh$$

$$HR_{wop} = 0.41 \times 0.25 \times 1{,}000{,}000 \times \frac{330}{300} = 112{,}750\ kWh$$

$$PD_{wop} = 0.18 \times 0.25 \times 1{,}000{,}000 \times \frac{330}{300} = 49{,}500\ kWh$$

$$EKWH_{wop} = 102{,}500 + 112{,}750 + 49{,}500 = 264{,}750\ kWh$$

Estimated annual consumption with increase in productivity with PRIME:

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

***INDwp** = 0.41 x 0.25 x 1,000,000 = 102,500 kWh*

HRwp = 0.41 x 0.25 x 1,000,000 = 102,500 kWh

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

$$PD_{wp} = 0.18 \times 0.25 \times 1{,}000{,}000 \times \frac{330}{300} \times (1 - 0.045) = 47{,}272.5\ kWh$$

EKWHwp = 102,500 + 102,500 + 47,272.5 = 252,272.5 kWh

AKWHo = **264,750 - 252,272.5 = 12,477.5 kWh**

Lost Opportunity Gross Seasonal Peak Demand Savings, Electric (winter and summer)

- **SKW** = 0; and
- **WKW** = 0.

Non-Energy Impacts

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] Energy & Resource Solutions. *PRIME Program Evaluation*, Mar. 26, 2007, Section 4.

[2] *Business and Energy Sustainability Program Impact Evaluation Energy & Resource Solutions*, Sep. 3, 2018, Tables 4-5.

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 Food Service (CFS) Equipment Calculator on the ENERGY STAR Training Centre website (**Ref [1]**) or the Food Technology Service Center (FTSC) for the California Energy Wise program (**Ref [2]**). Note that deemed savings based on default values from ENERGY STAR Commercial Kitchen Equipment savings calculator and California Energy Wise Commercial Kitchen Energy Savings Calculator as referenced. The peak electric and natural gas demand savings are calculated as specified below. The baselines from which savings are calculated are provided in *Table A* below.

Table A: Savings Baseline

Equipment	Baseline
Dishwasher	Conventional unit per **Ref [1]** calculator
Freezer	**Ref [3]**
Fryer	Conventional unit per **Ref [1]** and **Ref [2]** calculator
Griddle	Conventional unit per **Ref [2]** calculator
Hot food holding cabinet	Conventional unit per **Ref [2]** calculator
Ice machine	**Ref [1]**
Oven	Conventional unit per **Ref [1]** and **Ref [2]** calculator
Refrigerator	**Ref [3]**
Steam cooker	Conventional unit per **Ref [2]** calculator
WaterSense pre-rinse spray valve	See *3.2.1: Water-Saving Measures*

Nomenclature

Table B: 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 natural gas savings	ccf		

Table C: Commercial Kitchen Equipment Deemed Savings Ref [4]

Measure	ccf	ccf/day	kWh	kW
Commercial electric deck ovens **Ref [4] & Note (3)**			7,519	0.858
Electric combination oven **Ref [2]**			15,095	1.723
Electric convection oven (full size) **Ref [1]**			2001	0.228
Electric convection oven (half size) **Ref [1]**			244	0.027
Electric dishwasher high temp – door type **Ref [1]**			11,863	1.354
Electric dishwasher high temp – multi-tank conveyor **Ref [1]**			27,408	3.129
Electric dishwasher high temp – pot, pan, utensil **Ref [1]**			3,311	0.378
Electric dishwasher high temp – single tank conveyor **Ref [1]**			9,212	1.052
Electric dishwasher high temp – under counter **Ref [1]**			3,171	0.362
Electric dishwasher low temp – door type **Ref [1]**			16,153	1.844
Electric dishwasher low temp – multi-tank conveyor **Ref [1]**			18,811	2.147
Electric dishwasher low temp – single-tank conveyor **Ref [1]**			13,626	1.555
Electric dishwasher low temp – under counter **Ref [1]**			2,540	0.29
Electric fryer - standard vat **Ref [2]**			2,976	0.34
Electric fryer - large vat **Ref [2]**			2,841	0.324
Electric griddle – up to 36” **Ref [4]**			3,965	0.453
Electric griddle – over 36” **Ref [4]**			7,930	0.905
Electric hot food holding cabinets – full size **Ref [2]**			2,737	0.312
Electric hot food holding cabinets – ¾ size **Ref [2]**			1,095	0.125

Measure	ccf	ccf/day	kWh	kW
Electric hot food holding cabinets – half size **Ref [2]**			1,095	0.125
Electric ice machine, remote cond./split unit, continuous 1,750 lb/day **Ref [2]**			3,641	0.416
Electric ice machine, self-contained 200 lb/day **Ref [2]**			805	0.092
Electric ice making, head 0-500 lb/day **Ref [2]**			1,117	0.127
Electric ice machine, remote cond./split unit, batch 1,250 lb/day **Ref [2]**			2,601	0.296
Electric steam cooker **Ref [2]**			30,156	3.442
Energy-efficient commercial conveyor broilers, < 20" wide **Ref [4] & Note [3]**	1,113	3.049	7,144	0.816
Energy-efficient commercial conveyor broilers, 20-26" wide **Ref [4] & Note [3]**	1,879	5.148	6,403	0.731
Energy-efficient commercial conveyor broilers, > 26" wide **Ref [4] & Note [3]**	3,072	8.416	23,849	2.722
Energy-efficient commercial underfired broiler **Ref [4] & Note [3]**	212		N/A	N/A
Freezer, glass door, self-contained (< 15 cubic ft) **Ref [1]**			427	0.05
Freezer, glass door, self-contained (15-29.9 cubic ft) **Ref [1]**			681	0.08
Freezer, glass door, self-contained (30-49.9 cubic ft) **Ref [1]**			541	0.06
Freezer, glass door, self-contained (50+ cubic ft) **Ref [1]**			589	0.07
Freezer, solid door, self-contained (< 15 cubic ft) **Ref [1]**			256	0.03
Freezer, solid door, self-contained (15-29.9 cubic ft) **Ref [1]**			269	0.03
Freezer, solid door, self-contained (30-49.9 cubic ft) **Ref [1]**			1062	0.12
Freezer, solid door, self-contained (50+ cubic ft) **Ref [1]**			1486	0.17
Gas combination oven **Ref [2]**	912	2.5		
Gas convection oven **Ref [2]**	295	0.8		
Gas conveyor oven **Ref [2]**	731	2		
Gas dishwasher high temp – door type **Ref [1]**	285	0.781	4,840	0.553
Gas dishwasher high temp – multi-tank conveyor **Ref [1]**	656	1.796	11,230	1.282
Gas dishwasher high temp – pot, pan, utensil **Ref [1]**	85	0.234	1,204	0.137
Gas dishwasher high temp – single-tank conveyor **Ref [1]**	173	0.473	4,948	0.565
Gas dishwasher high temp – under counter **Ref [1]**	44	0.12	2,089	0.238
Gas dishwasher low temp – door type **Ref [1]**	654.75	1.794		

Measure	ccf	ccf/day	kWh	kW
Gas dishwasher low temp – multi-tank conveyor **Ref [1]**	762.42	2.089		
Gas dishwasher low temp – single-tank conveyor **Ref [1]**	528.65	1.448	584	0.067
Gas dishwasher low temp – under counter **Ref [1]**	102.82	0.282		
Gas fryer – large vat **Ref [7]**	435	1.2		
Gas fryer - standard vat **Ref [7]**	531	1.5		
Gas griddle with 3 ft countertop width **Ref [2]**	313	0.9		
Gas pre-rinse spray valve **Ref [2]**	94	0.3		
Gas rack oven **Ref [2]**	1,748	4.8		
Gas steamer **Ref [2]**	3,066	8.4		
Induction Cooktop **Ref [6]**			15,960	1.82
On-demand commercial electric hand wrap machine **Ref [4] & Note [3]**			990	0.11
Refrigerated chef bases, 35-54" **[Ref 5]**			1,051	0.11
Refrigerated chef bases, 55-73" **[Ref 5]**			1,637	0.18
Refrigerated chef bases, 74-89" **[Ref 5]**			1,986	0.21
Refrigerated chef bases, 90-120" **[Ref 5]**			2,673	0.29
Refrigerator, solid door, self-contained (< 15 cubic ft) **Ref [1]**			170	0.0194
Refrigerator, solid door, self-contained (15-29.9 cubic ft) **Ref [1]**			230	0.03
Refrigerator, solid door, self-contained (30-49.9 cubic ft) **Ref [1]**			818	0.093
Refrigerator, solid door, self-contained (50+ cubic ft) **Ref [1]**			376	0.04
Refrigerator, glass door, self-contained (< 15 cubic ft) **Ref [1]**			69	0.01
Refrigerator, glass door, self-contained (15-29.9 cubic ft) **Ref [1]**			113	0.01
Refrigerator, glass door, self-contained (30-49.9 cubic ft) **Ref [1]**			883	0.101
Refrigerator, glass door, self-contained (50+ cubic ft) **Ref [1]**			1,212	0.138
Ultra-low temp freezers **Ref [4] & Note [3]**			5,737	0.655

Lost Opportunity Gross Seasonal Peak Demand Savings, Electric (winter and summer)

The average hourly demand savings for (winter and summer) is:

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

Lost Opportunity Gross Peak Demand Savings, Natural Gas

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

Changes from Last Version

- Updated savings based on CT X-1931 Final Report.

References

[1] ENERGY STAR Commercial Kitchen Package for businesses and operators, available online at: https://energy.gov/eere/femp/energy-and-cost-savings-calculators-energy-efficient-products, last accessed Jun. 3, 2018.

[2] California Energy Wise Commercial Kitchen Energy Savings Calculators, Available online at: https://caenergywise.com/calculators/, last accessed Jul. 30, 2019.

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

[4] Sep. 10, 2019 memo, *2020 PSD Manual Foodservice Equipment Update Recommendations Memo* from Energy Solutions.

[5] 2020 California electronic Technical Reference Manual (eTRM), available online at: https://www.caltf.org/etrm-overview.

[6] Vollrath HIDC/HIMC Induction Range Comparison Appliance Test Report, FSTC Report #501311088-R0, Food Service Technology Service, Dec 2013. https://www.caenergywise.com/report-library/cooktops/Vollrath_HIDC-HIMC_Induction_Range_Comparison.pdf.

[7] https://cmadmin.energystar.gov/sites/default/files/asset/document/CFS_calculator_03-02-2021.xlsx.

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 ENERGY STAR savings calculator, in lieu of the default hours.

[3] kW savings numbers are calculated based on PSD AKW savings equation:

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

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 natural gas peak day savings is provided in *Appendix One*.

Note: *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 Three.*

Savings are calculated as the difference between baseline energy usage/peak demand and the energy use/peak demand after implementation of the custom measure. The analyses for temperature and non-temperature dependent measures should use a regression or bin analysis method and normalize for independent variables such as temperature, production, etc.

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 One*. 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°C will be used for Bridgeport and 84°F 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°C will be used for Bridgeport and 26°F will be used for Hartford.

Non-temperature dependent measures:

Demand Resource Seasonal Peak Hours are those hours in which the actual, Real-Time hourly load for Monday through Friday on non-holidays, during the months of June, July, August, December, and January, as determined by ISO-NE, is equal to or greater than 90% of the most recent 50/50 system peak load forecast, as determined by ISO-NE, for the applicable summer or winter season. However, the analysis determining the custom coincidence factor must be performed or approved by a qualified in-house engineer.

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

$$SKW = \frac{Annual\ kWh\ savings\ (WD - June, July, Augsut)}{Equipment\ Run\ Hours\ (WD - June, July, August)} \times \left(\frac{DR\ Seasonal\ Peak\ Hours}{6}\right)$$

$$WKW = \frac{Annual\ kWh\ savings\ (WD - December, January)}{Equipment\ Run\ Hours\ (WD - December, January)} \times \left(\frac{DR\ Seasonal\ Peak\ Hours}{5}\right)$$

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

Demand Resource (DR) Seasonal Peak Hours are determined by ISO-NE (*see above for definition*).

Whole building performance:

Whole building performance shall be determined using a computer simulation model. Approved software and modeling requirements are specified by the Companies' 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 hottest hours as described in the temperature dependent section above. This assumes the hottest hours occur during June, July, and August. If the hottest hour methodology cannot be used then the demand savings shall be determined by taking the average summer (i.e., June, July, and August) peak demand from the base model and subtracting the average summer (i.e., June, July, and August) peak demand from the design model.

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 (i.e., December and January) peak demand from the base model and subtracting the average winter (i.e., December and January) peak demand from the design model.

Baseline:

Baseline efficiencies for individual measures are based on code or federal standards. 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 2021 IECC Table C407.5.1(1) must be used to evaluate the energy savings or as applicable codes and standards.

Nomenclature

Table A: Nomenclature

Symbol	Description	Units	Values	Comments
WD	Weekdays	Days		

Changes from Last Version

- No changes.

2.6.4 COMMERCIAL CLOTHES WASHERS

Description of Measure

The installation of an ENERGY STAR certified 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 CEE savings calculator (**Ref [1]**). The usage per load by fuel source for baseline (Federal Standard) and ENERGY STAR certified 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 (i.e., laundromats (*2,190 loads per year*) or multifamily (*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: *The Federal Standard and ENERGY STAR certified 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 certified requirements.*

Inputs

Table A: Inputs

Symbol	Description	Units
N	Number of units	
	Water heating fuel source (i.e., electric, natural gas, propane, or oil)	
	Dryer fuel source (i.e., none, electric, natural gas, or propane)	
	Type of facility (i.e., laundromat or multifamily)	
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

Table B: Nomenclature

Symbol	Description	Units	Values	Comments
AKWH	Annual electric energy savings	kWh		
ΔKW	Peak demand savings	kW		
$AKWH_O$	Annual electric energy savings – other	kWh		
$AKWH_W$	Annual electric energy savings – water heating	kWh		

$ABTU_O$	Annual Btu savings – other	Btu		
CF	Summer Peak Coincident Factor for measure		0.029	**Note [3]**
$ABTU_W$	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]**
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 One*
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]**
WKBTU	Washer KBtu per load - baseline	KBtu/ld	2,597	**Note [1]**
$WHKWH_b$	Water heater kWh per load - baseline	kWh/ld		**Note [1]**
$WHBTU_b$	Water heater Btu per load - baseline	KBtu/ld		**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

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

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

Summer Coincident Peak KW Savings Algorithm

ΔkW = ΔkWh/Hours * CF

Where,

Hours = Assumed run hours of clothes washer = 265. 7 N**ote [3]**

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 a fossil fuel.

Annual Savings = Washer Savings + Water Heating Savings + Dryer Savings

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

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

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

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

Example: *A new commercial laundromat installs 25 new ENERGY STAR certified front-loading washing machines that have a Modified Energy Factor of 2.2. The laundromat has natural gas water heat and gas dryers. What are the energy savings?*

Electric savings:

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

- 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; and
- MEF_i = 2.2.

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

<u>Natural gas savings</u>:

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

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

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

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

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

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

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

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

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

- 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 impacts:

ENERGY STAR certified 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

- Revised Nomenclature table.
- Added $WHKWH_b$ and $WHBTU_b$ to *Table B: Nomenclature*.
- Added Summer Coincident Peak kW Savings Algorithm.

References

[1] Available at: Modified based on 2016 October Federal Standard and ENERGY STAR requirements. https://energy.mo.gov/sites/energy/files/energy-star-appliance-calculator.xlsx

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 multifamily applications from **Ref [1]**.

[3] Values of CF and Hours from Mid Atlantic Technical Reference Manual Version 10, April 2020.

SECTION THREE: 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, and reduced cooling load. The baseline is the wattage and existing operating hours of the fixtures being replaced (see **Note [1]**).

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

Inputs

Table A: Inputs

Symbol	Description	Units
kW_B	Existing fixture connected kW	
kW_A	Replacement fixture connected kW	
	Hours of operation (if available)	

Nomenclature

Table B: Inputs

Item	Description	Units	Values	Comments
AKWH	Annual gross electric energy savings	kWh		
CF_L	Lighting coincidence factor from *Appendix One*			*Appendix One*
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]**

Item	Description	Units	Values	Comments
H	Facility lighting, hours of use	Hours		Site Specific or *Appendix Five*
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			
S_r	Energy savings due to lighting retrofit	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

$$AKWH = S_r + S_C$$

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 Energy Independence and Security Act (EISA)-qualifying bulbs, 75% of the actual wattage is used for the 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 Five*).

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:

$$S_C = \frac{S_r \times F}{COP}$$

- **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 C*.
- **COP** = 3.5 (**Note [2]**).

Table C: Fraction of Lighting Energy that Must Be Removed by Facility's Cooling System (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

Retrofit Gross Energy Savings, Fossil Fuel

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

- Annual Oil Savings = -0.000162279 MMBtu per annual kWh saved; and
- Annual Natural Gas Savings = -0.000162279 MMBtu per kWh. See (**Ref [3]**).

Retrofit Gross Seasonal Peak Demand Savings, Electric (winter and summer)

$$SKW = CF_L \times (\sum kW_B - \sum kW_A) \times \left(1 + \frac{G}{COP}\right)$$

$$WKW = CF_L \times (\sum kW_B - \sum kW_A)$$

- **CF_L** is the lighting (CF_L) coincidence factors (summer/winter) taken from *Appendix One*.
- **G** = 0.73 (**Note [3]**).

- **COP** = 3.5 (**Note [2]**).

Non-Energy Impacts

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

Changes from Last Version

- Removed references to occupancy sensors.

References

[1] DNV KEMA (2014), *Retrofit Lighting Controls Measures Summary of Findings: Final Report*, pp. 5-26, see Table 12.

[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, pp. 11-93 as used by KCPL.

[3] DNV GL (2017). *Impact Evaluation of PY2015 Massachusetts Commercial and Industrial Upstream Lighting Initiative*. DNVGL_2017_Upstream_Lighting_Impact_Evaluation.

Notes

[1] To account for the EISA of 2007, the baseline for existing (installed) General Service bulbs shall be based on high-efficiency incandescent bulbs (such as halogens). 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 EISA of 2007.

[2] Estimated based on 2015 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 (Eversource) on Aug. 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

Table A: 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	
Per ΔkW	Reduction in power for each light	kW

Nomenclature

Table B: 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 One*

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

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

- **COP** = 2.03 for freezers and 2.69 for coolers (used for interactive effects) (see **Note [1]**).
- If existing EERs 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) (see **Note [1]**).
- If existing EERs 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

- No changes.

Notes

[1] Refrigeration interactive factors are based on communications 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.

3.1.3 INTERIOR LIGHTING CONTROLS

Description of Measure

Installation of new occupancy sensors or daylighting sensors and controls on a new or existing lighting system. Lighting control types covered by this measure include wall, ceiling, fixture mounted or integrated controls, as well as Luminaire Level Lighting Controls (LLLCs) or Networked Lighting Controls (NLC), which may have additional high-end trim and networking capabilities.

Savings Methodology

Energy and seasonal peak demand savings are calculated for the installation of lighting controls using an energy savings factor based on the installed control type. These systems save energy and peak demand by shutting off power to lighting fixtures when the space is unoccupied or illumination is not required. They also save energy and demand by reducing power to lighting systems to correct for over-illumination due to excessive lamp output or the presence of daylight. Installation of lighting controls reduces the cooling load and provides additional savings, which are also calculated in this measure.

Inputs

Table A: Inputs

Symbol	Description	Units
W_{ctrl}	Controlled fixture connected wattage	W
H	Facility lighting —Hours of use	Hours/year

Nomenclature

Table B: Inputs

Item	Description	Units	Values	Comments
CF_{OS}	Occupancy sensor coincidence factor	-		*Appendix One*
COP	Coefficient of performance	-	3.5	**Note [2]**
F	Fraction of lighting energy that must be removed by the facility's cooling system	-	*Table D*	**Ref [3]**
G	Estimated lighting energy heat to space based on modeling	-	0.73	**Ref [4], Note [3]**
H	Facility lighting —Hours of use	Hours/year	Input	Site-specific; Use *Appendix Five* only when site-specific

				assumptions do not exist.
W_{ctrl}	Facility controlled lighting wattage load	W	Input	Site-specific
S_{cool}	Annual energy savings from reduced cooling load	kWh		Calculated
S_{ctrl}	Annual energy savings from use of interior lighting controls	kWh		Calculated
S_{tot}	Annual gross electric energy savings	kWh		Calculated
SF	Lighting controls savings factor	%	*Table C*	**Ref [1], Ref [2]**
SKW	Summer demand savings	kW		Calculated
WKW	Winter demand savings	kW		Calculated
Lifetime	Measure life of the fixture	Years	7	**Ref [5, 4], Note[5]**
LKWH	Lifetime electric energy savings	kWh		Calculated

Description of lighting control types:

- **Occupancy sensor.** Reduces lighting operating hours by switching off lighting in unoccupied spaces.
- **Daylight dimming control.** Reduces lighting output to a set level or reduces lighting operating hours in response to natural daylighting using continuous, stepped, or on/off dimming capability.
- **High-end trim.** Reduces lighting output of individual lights or groups of lights to a set level continuously. Must have the ability to set a maximum light level.
- **Dual occupancy and daylight dimming controls.** Combines the capabilities of occupancy and daylight sensors, allowing lighting fixtures to respond to occupancy and daylight.
- **Networked lighting control and luminaire level lighting controls.** A networked lighting control system consists of an intelligent network of individually addressable luminaires and control devices. LLLCs and NLC are defined according to the DLC Networked Lighting Controls definition, which requires systems to have fixture networking capabilities, individual addressability, occupancy sensing, daylight harvesting, high-end trim, flexible zoning, continuous dimming, scheduling, and cybersecurity. The network ability allows building managers to group lights with specific zonal control and scheduling strategies, energy monitoring and high-end trim resulting in a higher savings capability. While DLC listing is not a requirement for any control type characterized in this measure, programs should consider eligibility requirements that ensure quality product is installed.

Retrofit Gross Energy Savings, Electric

$$S_{tot} = S_{ctrl} + S_{cool}$$

$$S_{ctrl} = \frac{W_{ctrl} \times H \times (SF_{EE} - SF_{Base})}{1{,}000\ W/kW}$$

$$S_{cool} = \frac{S_{ctrl} \times F}{COP}$$

Description of variable inputs:

- **W_{ctrl}** (W) is the facility lighting load that is controlled by the lighting control system. This value is site-specific.
- **H** (hours/yr) is the total operating hours of the controlled lighting circuit before the lighting controls are installed. This value is calculated on a site-specific basis; if no site-specific assumptions exist, use *Appendix Five*.
- **SF_{EE}** (%) is the average annual reduction in electric consumption achieved by a particular control measure type in the installed condition. Savings factors for various automated lighting control types are specified in *Table C*.
- **SF_{Base}** (%) is the average annual reduction in electric consumption achieved by a particular control measure type in the baseline condition. Savings factors for various automated lighting control types are specified in *Table C*; if no lighting controls were installed, the baseline savings factor is 0%.

Table C: Savings Factor by Lighting Control Type

Lighting Control Type	Savings Factor (SF)
Networked lighting controls (NLC) and luminaire-level lighting controls (LLLC)	49% **Ref [1]**
Luminaire-level lighting controls (LLLC)	49% **Ref [1]**
Dual occupancy and daylight dimming controls	38% **Ref [2]**
Combination of high-end trim and occupancy sensors	33% **Note [4]**
High-end trim	27% **Ref [1]**
Daylight dimming	28% **Ref [2]**
Occupancy sensors	24% **Ref [2]**
No lighting controls	0%

- **F** (%) is the fraction of energy savings due to the reduced cooling required as the result of reducing lighting operating hours and/or fixture illumination through lighting controls. If the HVACsystem includes an economizer, then F = 0.35. Otherwise, use *Table D*.

Table D: Fraction of Energy Savings due to Reduced Cooling from the HVAC System, see Ref [3]

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

Explanation of numerical constants:

- 1,000 converts watts to kW (1/1,000 is the conversion).
- **COP** = 3.5. See **Note [2]**.

Retrofit Gross Energy Savings, Fossil Fuel

Space heating energy consumption will increase due to reduced lighting operating hours.

- Annual Oil Savings = -0.000162279 MMBtu per annual kWh saved; and
- Annual Natural Gas Savings = -0.000162279 MMBtu per annual kWh saved. See **Ref [3]**.

$$SkW = \frac{W_{ctrl} \times (SF_{EE} - SF_{Base}) \times CF_{OS} \times (1 + G/COP)}{1{,}000\ W/kW}$$

$$WkW = \frac{W_{ctrl} \times (SF_{EE} - SF_{Base}) \times CF_{OS}}{1{,}000\ W/kW}$$

Retrofit Gross Seasonal Peak Demand Savings, Electric (winter and summer)

Description of variable inputs:

- **CF_{OS}** is the occupancy sensor coincidence factors (summer/winter) taken from *Appendix One*. See **Note [3].**
- **W_{ctrl}** (W) is the facility lighting load that is controlled by the lighting control system. This value is site-specific.
- **SF_{EE}** (%) is the average annual reduction in electric consumption achieved by a particular control measure type in the installed condition. Savings factors for various automated lighting control types are specified in *Table C*.
- **SF_{Base}** (%) is the average annual reduction in electric consumption achieved by a particular control measure type in the baseline condition. Savings factors for various automated lighting control types are specified in *Table C;* if no lighting controls were installed, the baseline savings factor is 0%.

Explanation of numerical constants:

- **G** = 0.73. See **Ref [5], Note [1]**
- **COP** = 3.5. See **Note [2]**

Changes from Last Version

- Added new measure.

References

[1] DLC and Northwest Energy Efficiency Alliance (NEEA), "Energy Savings from Networked Lighting Control (NLC) Systems with and without LLLC", Energy Solutions, Sept 24 2020.

[2] Williams, A., B. Atkinson, K. Garesi, E. Page, and F. Rubinstein. 2012. "Lighting Controls in Commercial Buildings." The Journal of the Illuminating Engineering Society of North America 8 (3): 161-180.

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

[4] DNV GL (2017). *Impact Evaluation of PY2015 Massachusetts Commercial and Industrial Upstream Lighting Initiative*. DNVGL_2017_Upstream_Lighting_Impact_Evaluation.

[5] DNV (2021). *Connecticut C2014 C&I Lighting Saturation and Remaining Potential – Phase One Results and Recommendations*.

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] Estimated based on 2015 Connecticut Code. 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 Aug. 17, 2007.

[3] It is assumed that the occupancy sensor coincidence factors (summer/winter) taken from Appendix One would apply to all control types.

[4] Savings factors for the combination of high-end trim with daylight dimming and high-end trim with occupancy sensors were calculated based on savings factors from the individual controls from **Ref [2]**.

[5] The measure life for interior lighting controls is assumed to be the adjusted measure lifetime (AML) for LED fixtures from the Connecticut C2014 study, based on the assumption that the controls are integrated with the fixture.

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. If existing information not available, use default existing conditions based on the DOE's online savings calculator: https://www.energy.gov/eere/femp/energy-cost-calculator-faucets-and-showerheads-0#output.

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

Table A: Inputs

Symbol	Description	Units
	Number of spray valves	
	Number of showerheads	
	Number of faucet aerators	

Nomenclature

Table B: 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		

Retrofit Gross Energy Savings, Electric

If hot water is supplied via an electric water heater, then energy savings are as shown in *Table C below:*

Table C: Energy Savings – Electric Water Heater (Spray Valves and Aerators)

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	507 kWh
Aerator	309 kWh

Retrofit Gross Energy Savings, Fossil Fuel

If hot water is supplied via a natural gas water heater, then annual energy savings are as shown in *Table D below*:

Table D: Energy Savings – Natural Gas Water Heater (Spray Valves and Aerators)

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	27.2 ccf (28 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

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

Table E: Retrofit Gross Peak Day Savings (Spray Valves and Aerators)

Spray Valves	
Facility Type	**$AKWH_W$ per Spray Valve**
Grocery	0.0172 ccf
Non-grocery	0.1310 ccf
Showerheads/Faucet Aerators (Note [1])	
Type	**$AKWH_W$ per Unit**
Showerhead	0.0811 ccf
Aerator	0.0530 ccf

Non-Energy Impacts

Water savings are estimated to be:

Table F: Non-Energy Impacts (Spray Valves and Aerators)

Spray Valves	
Facility Type	**Gallons per Year**
Grocery	1,496
Non-grocery	8,603
Showerheads/Faucet Aerators (Note [1])	
Type	**Gallons per Year**
Showerhead	3,900
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), Feb. 21, 2007, p. 26, see Table 3-9.

[2] Federal Energy Management Program ("FEMP") Energy Cost Calculator for Faucets and Showerheads. Available online at: https://www.energy.gov/eere/femp/energy-cost-calculator-faucets-and-showerheads-0.

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, DHW and Chilled water 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 ("HL") savings per linear foot for various pipe and insulation sizes/material are provided in *Table A*. For parameter values not listed in the 2022 PSD manual, heat loss values will be calculated using 3E Plus.

Table A: 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
	3.0	Polyethylene foam tube	156	184	195	201
	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
	3.0	Mineral fibers	173	196	205	209

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
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
	3.0	Polyethylene foam tube	187	215	226	232
	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
	3.0	Mineral fibers	204	227	236	240

Inputs

Table B: Inputs

Symbol	Description	Units
In	Nominal pipe size diameter	Inches
	Insulation material	
	Insulation thickness	Inches
L	Length of insulation	Linear foot
	Heating fuel type (oil, natural gas)	

Nomenclature

Table C: Nomenclature

Symbol	Description	Units	Values	Comments
ACCF	Annual natural gas savings	CCF		
EFLH	Equivalent heating full load hours for the facility type	Hours	*Appendix Five*	Multifamily chillers should use CHWP and cooling towers EFLH in *Appendix Five*
HL	Heat loss savings per linear foot of pipe	Btu/ft/hr	*Table A*	
L	Length of pipe being Insulated	Linear ft		
AFUE	Annual Fuel Utilization Efficiency, estimated boiler efficiency		0.80	Use site-specific AFUE, if available. If unknown, use default
PD	Peak day savings natural gas	ccf		
Hours	Hours assumed for multifamily DHW **Ref [2]**	Hours	8,760	

Retrofit Gross Energy Savings, Fossil Fuel

Annual natural 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

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 is the energy savings resulting from adding the insulation?*

Based on the data and using *Table A*, the corresponding HL savings is 73 Btu/ft/hr. The length of pipe being insulated L = 100 ft. Using *Appendix Five* (hours of use), the heating EFLH for an office/retail space is 1,248.

Using the savings formula:

$$ACCF = \frac{HL \times EFLH}{102{,}900 \times 0.80} \times L = \frac{73 \times 1248}{102{,}900 \times 0.80} \times 100 = 110.7 \text{ ccf}$$

Retrofit Gross Peak Day Savings, Natural Gas

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

Changes from Last Version

- Provided additional direction for AFUE variable.
- Added 3E+ simulation values for 3" diameter pipe.
- Updated based on *X1931 Report*.

References

[1] NAIMA, 3E Plus software tool, Version 4.1, Rel. 2012. Last accessed Aug 2021.

[2] R1705/R1609 Multifamily Baseline and Weatherization Study, available online at: https://www.energizect.com/sites/default/files/R1705-1609%20MF%20Baseline%20Weatherization%20Study_Final%20Report_10.10.19.pdf.

3.2.3 DUCT SEALING

Description of Measure

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

Savings Methodology

Refer to the duct sealing measure in the Residential Section of the 2022 PSD manual (*Measure 4.2.5*).

Changes from Last Version

Updated savings factors are based on the report “Analysis of Energy Savings for Building Envelope Infiltration Reductions and Duct Leakage to Outside Reductions,” Draft Report, Aug 3, 2021, MaGrann Associates.

3.2.4 DUCT INSULATION

Description of Measure

Installation of R-6 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 *Tables A* and *B* 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 130°F/65°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 A: 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 B: Heat Transfer Rates per Hour per ft² of Insulation

Duct Location	$BTUH_b$ (Bare)		$BTUH_a$ (Insulated R-6)	
	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

Table C: Inputs

Symbol	Description
A	Insulation area in square feet
	Heating fuel/Heating system type (e.g., electric heat pump, natural gas furnace)

Nomenclature

Table D: 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 B*	
$BTUH_{cb}$	Cooling heat transfer rate of un-insulated ducting	$Btu/hr/ft^2$	*Table B*	
$BTUH_{ha}$	Heating heat transfer rate of insulated ducting	$Btu/hr/ft^2$	*Table B*	
$BTUH_{hb}$	Heating heat transfer rate of un-insulated ducting	$Btu/hr/ft^2$	*Table B*	
COP_H	Coefficient of performance of heating equipment	Unit-less	1.0 for electric furnace 2.4 for heat pump 3.0 for ground-source heat pump	Use site-specific heating system COP if available. If unknown, use default values in values column
EFLH	Equivalent heating or cooling full-load hours for the facility type	Hours	*Appendix Five*	
A	Insulation area in square feet			
ACCF	Annual natural gas savings	ccf		

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 A/C or heat pump:

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

- Where: **3,412** = converts Btu to kWh
- **3.5** = Use site-specific cooling system COP if available. If unknown, use default of 3.5 for Central A/C or heat pump.

Retrofit Gross Energy Savings, Fossil Fuel

Annual gross natural gas savings, natural gas heated buildings:

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

Where:

Use site-specific heating system efficiency if available. If unknown, use default of 80% for boilers, 78% for natural gas and propane furnaces, and 76% for oil furnaces.

- For natural gas conversions use 102,900 Btu/ccf;
- For oil conversions use 138,690 Btu/gallon; and
- For propane conversions use 91,330 Btu/gallon.

Retrofit Gross Energy Savings, Example

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 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 B:* $BTUH_{hb}$ =132.34;
- From *Table B*: $BTUH_{ha}$ =12.04;
- From *Appendix Five*: EFLH heating = 1,248 hr;
- A = 100 ft^2; and
- From Nomenclature *Table C*: COP_H for heat pump = 2.0.

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

Annual gross electric cooling savings:

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

- From *Table B*: $BTUH_{cb}$ = 25.22;
- From *Table B*: $BTUH_{ca}$ = 2.73;
- From *Appendix Five*: EFLH cooling = 797; and
- A = 100 ft^2.

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

Retrofit Gross Seasonal Peak Demand Savings, Electric (winter and summer)

Currently no demand savings are claimed for this measure.

Changes from Last Version

- Updated GSHP COP.

References

[1] NAIMA, 3E Plus software tool, Version 4.1, Rel. 2012. Last Accessed Aug 2021.

[2] Minimum Duct Insulation R-Value, Table 6.8.2-2, ASHRAE Standard 90.1 – 2013.

3.2.5 COMMERCIAL ADVANCED THERMOSTATS

Description of Measure

This measure involves replacement of an existing manual or programmable thermostats with an ENERGY STAR certified smart thermostat. This measure applies to small commercial buildings. A smart thermostat is a thermostat that can be controlled remotely with a phone, tablet, or other internet-connected devices. It allows users to create automatic and programmable temperature settings based on daily schedules, weather conditions, and heating and cooling needs. Using features like learning, scheduling, geofencing, by diagnosing problems with the HVAC system, and by reminding users of when it's time to perform HVAC system maintenance, a smart thermostat ensures that the HVAC system runs efficiently and that the controlled space is heated or cooled only as much as needed, reducing heating and cooling energy consumption.

Savings Methodology

The measure energy savings are calculated using deemed energy savings factors based on study results **[1].** Building space heating and space cooling energy intensities (Btu/square foot **Note [1])** were estimated for based on Commercial Buildings Energy Consumption Survey [2]. The estimated energy intensities were then multiplied with deemed savings factors to estimate per square foot heating and cooling savings (**Note [2]).**

Inputs

Table A: Inputs

Symbol	Description	Units
A	Building floor area in square feet	ft^2

Nomenclature

Table B: Nomenclature

Symbol	Description	Units	Values	Comments
$AKWH_{H-ER}$	Annual gross electric energy savings – heating (electric resistance)	kWh		
$AKWH_{H-HP}$	Annual gross electric energy savings – heating (heat pump)	kWh		
$AKWH_{C}$	Annual gross electric energy savings - cooling	kWh		
ACCF	Annual natural gas savings	ccf		
AOG	Annual oil savings	gallons		
APG	Annual propane savings	gallons		
A	Building conditioned area served by thermostat	ft^2		Input

Retrofit Gross Energy Savings, Electric

Heating (applicable only if the facility has an existing electric resistance heating system) **Note [3]**:

$$AKWH_H = 0.4561\left(\frac{kWh}{ft^2}\right) \times A\,(ft^2)$$

Heating (applicable only if the facility has an existing heat pump heating system) **Note [3]**:

$$AKWH_H = 0.1425\left(\frac{kWh}{ft^2}\right) \times A\,(ft^2)$$

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

$$AKWH_C = 0.0234\left(\frac{kWh}{ft^2}\right) \times A\,(ft^2)$$

Retrofit Gross Energy Savings, Fossil Fuel

Heating (applicable only if the facility has an existing natural gas heating system):

$$ACCF = 0.0178\left(\frac{ccf}{ft^2}\right) \times A\,(ft^2)$$

Heating (applicable only if the facility has an existing oil heating system):

$$AOG = 0.0134\left(\frac{gallons}{ft^2}\right) \times A\,(ft^2)$$

Heating (applicable only if the facility has an existing propane heating system):

$$APG = 0.0201\left(\frac{gallons}{ft^2}\right) \times A\,(ft^2)$$

If site-specific building conditioned area per thermostat information is not available, the following deemed savings values should be used for direct install **Note [4]**:

	$AHWH_c$	$AHWH_{H-ER}$	$AHWH_{H-HP}$	ACCF	AOG	APG
When heating fuel and cooling system is known (Direct Install)	58.6	1,140.3	356.4	44.5	33.5	50.1

For midstream programs, the following savings values should be used **Note [5]**:

	AKWH	ACCF	AOG	APG
When heating fuel and cooling system is unknown (Midstream, E-commerce, etc.)	181.1	12.6	11.8	11.0

Retrofit Gross Seasonal Peak Demand Savings, Electric (winter and summer)

- Assumed to be zero until additional information is available.

Changes from Last Version

- New measure.

References

[1] Navigant. Wi-Fi Thermostat Impact Evaluation--Secondary Research Study, prepared for Massachusetts Program Administrators and EEAC Consultants, September 20, 2018.

[2] US Energy Information Administration Commercial Buildings Energy Consumption Survey (CBECS), 2012 CBECS Data End-Use Consumption, Table E4 and Table E7. https://www.eia.gov/consumption/commercial/data/2012/index.php?view=consumption

[3] Cadmus, Memorandum: EUL analysis of Residential Smart Communicating Thermostat—Vendor A and B, February 1, 2019. https://www.caetrm.com/media/reference-documents/SWHC039-01_A8_-_EUL_Analysis.pdf

Notes

[1] Energy intensities in 2012 CBECS Data End-Use Consumption, Table E7 are based on commercial buildings located in New England.

[2] Energy savings factors of 4.5% and 2% are used for heating and cooling, respectively based on **Ref [1]**.

[3] Heating electric savings are derived based on conversion of natural gas heating savings to electric heating savings (therm to kWh) multiplied by the equipment efficiency.

For electric resistance heating, $kWh_{savings} = \frac{(therm_{savings} \times 29.3 \times 0.85)}{1}$, where 29.3 is therm to kWh conversion factor, 0.85 is the natural gas furnace efficiency and 1 is the electric resistance heating efficiency.

For heat pump heating, $kWh_{savings} = \frac{(therm_{savings} \times 29.3 \times 0.85)}{3.2}$, where 29.3 is therm to kWh conversion factor, 0.85 is the natural gas furnace efficiency and 3.2 is the heat pump COP.

[4] Estimated based on deemed building conditioned area of 2,500 square feet per thermostat.

[5] Heating primary fuel type for midstream savings calculation was estimated to be 14% electric (37% of the 14% was estimated to be heat pump heating and 63% of the 14% was estimated to be electric resistance heating), 28% natural gas, 35% fuel oil, and 22% propane, based on **Ref [2]** Table B38, heating equipment, number of buildings for New England.

3.2.6 STEAM TRAP REPLACEMENT

Description of Measure

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

Savings Methodology

The savings estimates below are based on the Grashof Equation (more information on the Grashof Equation can be found in **Ref [2]**) which provides steam loss through orifices at various pressures). The steam flows derived from the Grashof 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

Table A: Inputs

Symbol	Description
P	Steam pressure (psig)
D	Orifice diameter (In)
EFLH	Equivalent full load hours (Hrs)

Nomenclature

Table B: Nomenclature

Symbol	Description	Units	Values	Comments
ACCF	Annual natural gas savings	ccf	102,900 Btu	
D	Orifice diameter	Inches		
Eff	Boiler efficiency	%	Use site-specific boiler efficiency if available; if boiler efficiency is unknown, use default of Linkage control = 83.2% Parallel Positioning = 84.2 Parallel Positioning and O_2 Trim = 85%	**Ref [6]**
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		
CR	Condensate return factor	%	100.0% no condensate return line; 36.3% condensate return line system	**Ref [4]**

L_f	Steam loss adjustment factor	%	55% for failed traps. 26% for leaking traps	**Ref [4]**
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 Grashof's Equation to determine the steam flow rate in the orifice (**Ref [2]**):*

$$lb_m = \frac{3600\frac{sec}{hr} \times \pi \times D^2 \times P_a^{0.97} \times 0.7}{60\ \frac{lb_m}{in^{.06} lb^{.97} hr} \times 4} = 32.99 \times D^2 \times P_a^{0.97}$$

- Where, lb_m = Steam flow rate, lb/hr;
- P_a = Absolute pressure in steam trap line, psia; and
- D = Diameter of the orifice, in
    - 0.97 = empirically derived factor in Grashof Equation;
    - 60 = empirically derived factor in Grashof Equation; and
    - 0.7 = discharge coefficient (70%).

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

Gauge Pressure (psig)	Absolute Pressure (psia)	Specific Enthalpy of Evaporation (Btu/lb)
2	16.7	966.0
5	19.7	960.5
10	24.7	952.5
15	29.7	945.6
25	39.7	934.0
50	64.7	911.9
75	89.7	895.0
100	114.7	880.9
125	139.7	868.5
150	164.7	857.4
200	214.7	837.8
250	264.7	820.6
300	314.7	804.9

Step 2 – Using the following equation estimate annual savings based on the steam loss (Step 1), specific enthalpy of evaporation (Table 3-W), equivalent full load hours, adjustment factors, and boiler efficiency:

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

Retrofit Gross Peak Day Savings, Natural Gas

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

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]**); and
- **EFLH** = 5,376 for heating steam distribution applications and multifamily common areas (**Ref [5]**).

Changes from Last Version

- Formatting updates in description narrative.
- Updated direction for boiler efficiency variable.

References

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

[2] E. A. Avallone, T. Baumeister III and A. M. Sadegh, *Marks' Standard Handbook for Mechanical Engineers*, New York: McGraw-Hill, 2007.

[3] Steam System Modeler Tool (SSMT), U.S. Department of Energy, 2015, available online at: https://www4.eere.energy.gov/manufacturing/tech_deployment/amo_steam_tool/propSaturated last accessed on May 26, 2021.

[4] *Steam Trap Evaluation Phase 2*, Massachusetts Program Administrators and Energy Efficiency Advisory Council, Mar. 8, 2017.

[5] *TRC. X1941: Multifamily Impact Evaluation, PSD Savings Review,* July 2020.

[6] MA20C05-G-STBE Steam Trap and Boiler Efficiency Research, Massachusetts Program Administrators and Energy Efficiency Advisory Council, Oct. 20, 2020.

Notes

[1] Estimated.

[2] Estimated.

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. For multifamily buildings, this measure should only be used for projects that conduct a whole building leakage test. Projects that test individually dwelling units should use the Infiltration Reduction Blower Door measure.

Savings Methodology

The savings methodology is based on seven pilot projects conducted under Eversource'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 Eversource 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 the 2022 PSD manual's *Measure 4.4.2: Residential Blower Door*. The savings would be reviewed with customer billing data by the Companies' staff.

Inputs

Table A: 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, natural gas, oil, etc.)
	Heating distribution type (e.g., forced air with fan, HP, etc.)

Nomenclature

Table B: 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 One*
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	
ACCFH	Annual gross fossil fuel savings (natural gas heating)	ccf		
AOGH	Annual gross fossil fuel energy savings (oil)	ccf		
APGH	Annual gross fossil fuel energy savings (propane)	ccf		

Retrofit Gross Energy Savings, Electric

Table C: Retrofit Electric Savings per CFM Reduction (at 50 Pa)

Measure	Symbol	Energy Savings	Units
Electric resistance heating	$BD_{Heating}$	2.840	kWh
Heat pump heating	$BD_{Heating}$	1.257	kWh
Geothermal heating	$BD_{Heating}$	0.861	kWh
Air handler (fan)	BD_{AH}	0.112	kWh
Cooling (central A/C)	$BD_{Cooling}$	0.0169	kWh

For electric resistive, heat pump, or geothermal heating systems:

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

For fossil fuel heating with air handler unit:

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

For homes with central A/C air cooling:

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

Retrofit Gross Energy Savings, Fossil Fuel

Table D: Retrofit Fossil Fuel Savings per CFM Reduction (at 50 Pa)

Measure	Symbol	Energy Savings	Units
Fossil fuel heating		0.012	MMBtu
Natural gas heating	BD_{NG}	0.118	ccf
Propane heating	$BD_{propane}$	0.133	Gallons
Oil heating	BD_{Oil}	0.087	Gallons

For homes with natural gas heating system:

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

For homes with oil heating system:

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

For homes with propane heating system:

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

Retrofit Gross Seasonal Peak Demand Savings, Electric (winter and summer)

Table E: Demand Savings per CFM Reduction

Measure	Symbol	Energy Savings	Units
Electric resistance and heat pump	BD_{WKW}	0.00124	kW
Geothermal heat pump	BD_{WKW}	0.00038	kW
Central A/C and heat pump	BD_{SKW}	0.00008	kW
Room A/C cooling		0.00002	kW

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

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

Note: *The demand savings are from the Residential Measure 4.4.2—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

- Updated savings factors based on new study **Ref [1]**.

Notes

[1] "Analysis of Energy Savings for Building Envelope Infiltration Reductions and Duct Leakage to Outside Reductions" by MaGrann Assoc., Aug. 3, 2021.

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 and ventilation fans. In most cases the control method will include a VFD, 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. [H] Full load cooling and heating hours from *Appendix Five*.
2. [H_0] 13% of the fan hours are assumed to be in free cooling; based on local temperature BINs.
3. [H_2] 25% of heating/cooling equivalent full-load hours are assumed to be in Stage 2 (based on local temperature BINs).
4. [H_1] 75% of heating/cooling equivalent full-load hours are assumed to be in Stage 1 (50% output). To calculate the fan hours in stage one, the equivalent full load heating/cooling are multiplied by (75% from above) then multiplied by 50% capacity.
5. $H_v = H – (H_0 + H_1 + H_2)$.

Ref [1] is for information only.

Inputs

Table A: 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

Table B: 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 Five*
$EFLH_H$	Equivalent full load heating hours	Hours		*Appendix Five*
H	Total fan run hours	Hours		*Appendix Five*
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 or free cooling
H_O	Fan run hours in free cooling mode	Hours		13% of total fan hours
HP	Fan motor nameplate horsepower	Horsepower		
KW_E	Existing fan kW	kW		
LF	Fan motor load factor	%		**Note [2], Ref [2]**
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]**
	VFD efficiency		0.97	

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

- Added variable definition for VFD efficiency.

References

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

[2] Lawrence Berkeley National Laboratory, and Resource Dynamics Corporation. (2008). "Improving Motor and Drive System Performance; A Sourcebook for Industry". U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Golden, CO: National Renewable Energy Laboratory, or https://www.energy.gov/sites/prod/files/2014/04/f15/amo_motors_sourcebook_web.pdf.

Notes

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

[2] Provide field measure LF if known, otherwise default to 65% for HVAC VFDs.

3.2.9 COMMERCIAL KITCHEN HOOD CONTROLS

Description of Measure

This measure is 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 retrofitted to existing exhaust hoods. 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 (e.g., 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 the 2022 PSD manual’s *Measure 2.2.6*; as 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

Table A: 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 oversize 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.

3.2.10 DEMAND CONTROL VENTILATION

Description of Measure

Upgrade to HVAC system to control outside air flow based on CO_2 levels. The proposed system monitors the CO_2 in the spaces or return air and reduces 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, and 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 are 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* in the 2022 PSD manual) since the savings for this measure are consistent with the furnace/boiler savings profile. The baseline for this measure is a system with no CO_2 ventilation control.

Inputs

Table A: 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

- Note (1) added in regard to virus spread such as COVID 19.

Notes

[1] Refer to ASHRAE suggestions in the future related to spread of viruses such as Covid -19.

Per ASHRAE (Position Document on infectious Aerosols, published April 2020, page 10) “to increase outdoor air ventilation by disabling DCV and opening outdoor air dampers to 100% as indoor and outdoor conditions permit in the buildings that remained open.”

Document available at: https://www.ashrae.org/file%20 library/about/position%20documents/pd_ infectious aerosols 2020.pdf.

3.3 OTHER

3.3.1 CUSTOM MEASURES

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 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 natural gas peak day savings is provided in *Appendix One*.

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 Three*. Electric demand savings methodologies are categorized as follows:

1. Temperature dependent measures (i.e., HVAC measures that vary with ambient temperature).
2. Non-temperature dependent measures (e.g., process, lighting, and 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 One*. 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°F will be used for Bridgeport and 84°F 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°F will be used for Bridgeport and 26°F will be used for Hartford.

<u>Non-Temperature-Dependent Measures</u>

Demand savings for measures that are not temperature-dependent will be determined by either the coincidence factors from Appendix One or the average estimated weekday (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 *<u>Appendix One</u>*. 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: *The average demand savings methodology should only be used when the coincident factor methodology cannot be used or is not practicable.*

<u>Computer Simulation Modeling</u>

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 Companies' 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 average summer (June, July, and August) peak demand from the base model and subtracting the average summer (June, July, and August) peak demand from the design 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 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 and January) peak demand from the base model and subtracting the average winter (December and January) peak demand from the design model. If neither of these methods can be used, then in-house engineering must review the project/model to determine an acceptable method.

Baseline

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

Nomenclature

Table A: Nomenclature

Symbol	Description	Units	Values
WD	Weekdays	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

Table A: Inputs

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

Nomenclature

Table B: Nomenclature

Symbol	Description	Units	Values	Comments
AKWH	Annual gross electric energy savings	kWh/yr		
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 C: Savings Factor Based on Case Temperature (Ref [1])

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

Inputs

Table A: Inputs

Symbol	Description
A	Amperage
EER	Energy Efficiency Ratio of refrigeration units
N	Number of fans
V	Volts

Nomenclature

Table B: Nomenclature

Symbol	Description	Units	Values	Comments
A	Amperage of existing fans			
ACOP	Average coefficient of performance			
AKWH	Annual gross electric energy savings	kWh		
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		Seasonal peak kW calculated using the average hourly usage over entire year

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			
CF	Seasonal peak demand coincident factor for refrigeration (same for summer and winter)			*Appendix One*

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 EERs are available, then ACOP = Average EER/3.413; and
- Average EER = Full Load EER/0.85.

<u>Retrofit Gross Seasonal Peak Demand Savings, Electric (winter and summer)</u>

<u>If the fan motors are single-phase or three-phase, then calculate the demand savings as follows</u>:

$$AKW = \frac{AKWH}{8760} xCF$$

<u>Changes from Last Version</u>

- Added CF to the kW calculations.
- Defined CF in *Table B*.

<u>References</u>

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

<u>Notes</u>

[1] Power reduction factors of existing fans are based on correspondence with a National Resource Management (NRM) representative, Mar. 3 and Jun. 6 of 2011. If motors are being replaced concurrently with this measure, then savings calculations for this measure should be coordinated with *Measure 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 Gianakos, Nicholas Group, P.C., Jun. 27, 2010.

[3] Refrigeration interactive factors are derived from **Ref [1]** and correspondence with Nick Gianakos, Nicholas Group, P.C., Jun. 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 (see **[Ref 2]**).

Inputs

Table A: Inputs

Symbol	Description
A	Amperage
EER	Energy Efficiency Ratio of refrigeration units
N	Number of fans
V	Volts

Nomenclature

Table B: Nomenclature

Symbol	Description	Units	Values	Comments
A	Amperage of existing fans			
ACOP	Average coefficient of performance (used for interactive effects)		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 One*
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			
W	Fan motor power draw	Watts		**Note [5]**

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 or three-phase then calculate demand savings as follows:

$$AKW = \frac{AKWH}{8760 \, \frac{Hrs}{yr}} \times CF$$

Changes from Last Version

- Updated note to direct use of manufacturer stated W instead of calculated value if available in literature.

References

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

[2] *Becker, B.R, and Fricke B.A., High Efficiency Evaporator Fan Motors for Commercial Refrigeration Applications, Purdue Labs, 2016, available online at: https://docs.lib.purdue.edu/cgi/viewcontent.cgi?article=2588&context=iracc.*

Notes

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

[2] Fan off hours after measure installation (h) is based on correspondence with Nick Gianakos, Nicholas Group, P.C., Jun. 27, 2010. If fan controls are being installed concurrently with this measure, then savings calculation for this measure should be coordinated with *Measure 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 **Ref [1]** and correspondence with Nick Gianakos, Nicholas Group, P.C., Jun. 27, 2010.

[4] If existing EERs are available, then ACOP = Average EER/3.413; Average EER = Full Load EER/0.85.

[5] If available in manufacturer literature, W to be used in place of V x A x PF for single-phase motors and in place of "V x A x PF x $\sqrt{3}$ " for 3-phase motors.

3.4.4 DOOR HEATER CONTROLS

Description of Measure

Installation of an on/off or micro-pulse 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 their doors whose purpose is to prevent condensation from forming.

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

Table A: Inputs

Symbol	Description
A	Amperage
N	Number of door heaters
V	Volts
	Type: Cooler or freezer

Nomenclature

Table B: Nomenclature

Symbol	Description	Units	Values	Comments
A	Amperage of door heater			
ACOP	Average Coefficient of Performance (cooler or freezer)			
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 One*	
h	Heater off-hours after measure installation	Hours	On/Off :2786 Micro-pulse: 4196	**Note [1]**
kW	Kilowatts			

N	Number of heaters			
Pf	Power factor		1	**Note [2]**
V	Volts of door heater			

Retrofit Gross Energy Savings, Electric

$$AKWH = \frac{N \times V \times A \times Pf \times h}{1000 \, {}^{W}\!/_{kW}} \text{ x } \left[1 + \frac{1}{ACOP}\right]$$

Retrofit Gross Seasonal Peak Demand Savings, Electric (winter and summer)

$$AKW = \frac{AKWH}{8760 \, \frac{Hrs}{yr}}$$

Changes from Last Version

- Revised AKWH equation.

Notes

[1] Heater off hours after measure installation for freezers and refrigerators are based on update to: https://cadmusgroup.com/wp-content/uploads/2016/02/NEEP-CRL_Report_FINAL_clean.pdf?submissionGuid=cb214243-bab8-479a-a4c4-.

[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. In the second method, controls operation are 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

Table A: 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

Table B: Nomenclature

Symbol	Description	Units	Values	Comments
A	Amperage of vending machine	amps		
AKWH	Annual gross electric energy savings	kWh		
ESF	Energy savings factor			*Table D* and *Table E*
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 C*
WKW	Winter demand savings	kW	0	

Retrofit Gross Energy Savings, Electric

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

Where:

- **$WATTS_{base}$** = connected kW of the controlled equipment; see *Table C* 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/year or 8760; and
- **ESF** = Energy Savings Factor; represents the percent reduction in annual kWh consumption of the equipment controlled; see *Table D* below for occupancy-based controls by equipment type, and *Table E* below for time schedule-based controls by equipment type.

Table C: Connected Wattage of Vending Machines

Equipment Type	$WATTS_{base}$
Refrigerated beverage vending machines	400 (**Ref [1]**)
Non-refrigerated snack vending machines	80 (**Ref [1]**)
Glass front refrigerated coolers	400 (**Ref [2]**)
Custom calculation	V x A x PF

Table D: Occupancy-Based Controls

Equipment Type	Energy Savings Factor (ESF)
Refrigerated beverage vending machines	46% (**Ref [1]**)
Non-refrigerated snack vending machines	25% (**Ref [1]**)
Glass front refrigerated coolers	35% (**Ref [2]**)

Table E: Time Schedule-Based Controls

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

Retrofit Gross Seasonal Peak Demand Savings, Electric (winter and summer) Note [1]

- **SKW** = 0; and
- **WKW** = 0.

Retrofit of Occupancy Controls on Refrigerated Beverage Vending Machine, Example

Add occupancy sensors to two existing soda vending machine where the amperage and voltage is unknown.

- AKWH = $WATTS_{base}$ /1,000 x HOURS x ESF x N.
- From *Table C*, Watts base = 400 W; From *Table D*, ESF = 0.46.
- AKWH = 400/ 1,000 x 8,760 x 0.46 x 2 = 3,223.7 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 volts 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*

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

$$\textbf{HOURS}_{\textbf{after}} = 8760 - (365 \text{ x} 11) = 4{,}745 \text{ hrs}$$

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

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

Changes from Last Version

- Example correction.

References

[1] Energy Misers – Vending Miser, available online at: https://www.energymisers.com/vendingmiser.php.

[2] Energy Misers - Cooler Misers, available online at: https://www.energymisers.com/coolermiser.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 NMR Group, Inc. field experience and e-mail communication with Nick Gianakos, Jun. 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. Eversource/United Illuminating engineering utilized Table 7 of **Ref [1]** in the analysis that provided the savings factors below. A site inspection of a completed installation by the Companies' 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

Table A: Inputs

Symbol	Description
L	Length of display case

Nomenclature

Table B: Nomenclature

Symbol	Description	Units
$ACCF_H$	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 natural 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
WKW	Winter demand savings	kW

Retrofit Gross Energy Savings, Electric

Table C: Electric and Gas Savings Factors for Coolers

Door Type	SF_{SKW}	SF_{WKW}	SF_{AKWH}	SF_{ACCF}	SF_{PD}
Door heater	0.0838	0.02083	160.681	24.389	0.14849
Gap	0.0838	0.02083	160.681	9.157	0.05575
No door heater + No gap	0.02232	0.05549	427.984	24.389	0.14849

Table D: Electric and Gas Savings Factors for Freezer

Door Type	SF_{SKW}	SF_{WKW}	SF_{AKWH}	SF_{ACCF}	SF_{PD}
Door heater	0.02352	0.04284	341.440	14.210	0.08651
Gap	0.02352	0.04284	341.440	26.716	0.16265
No door heater + No gap	0.04421	0.08055	641.939	26.716	0.16265

- **AKWH** = L x SF_{AKWH}
- ***Note:*** *The SF values depend on whether there is a gap between the doors or if 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 x* SF_{SKW}; and
- **WKW** = *L x* SF_{WKW}.

Retrofit Gross Energy Savings, Fossil Fuel

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

$$\mathbf{ACCF_H} = L \times SF_{ACCF}$$

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

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

Retrofit Gross Peak Day Savings, Natural Gas

$$\mathbf{PD_H} = L \times SF_{PD}$$

Changes from Last Version

- Table C and Table D are updated with electric and gas savings for coolers and freezers.

References

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

3.5 COMPRESSED AIR SYSTEMS

3.5.1 VARIABLE SPEED DRIVE-CONTROLLED AIR COMPRESSORS

Description of Measure

Installation of oil flooded rotary screw compressors with Variable Speed Drives (VSDs) instead of one with load-unload control. This measure applies only to air compressors that are ≥ 15 HP and ≤ 75 HP.

Savings Methodology

Load-unload controlled compressors have significant cycling losses. They work as follows: The compressor runs loaded, producing compressed air. Once the system reaches the maximum pressure setpoint, they unload or "cut-out." The system must release the compressed air from the oil separator and surrounding air lines just downstream of the compressor. The compressor then idles until system pressure drops to the minimum pressure setpoint, at which point it "cuts in" and reloads for the next cycle. Variable speed drive-controlled compressors avoid these cycling and idling losses.

The baseline is a typical load/unload compressor. The high efficiency replacement is an oil flooded, rotary screw compressor with VFD part load control.

The savings calculations are estimated based on a study of prescriptive compressed air **Ref [1]**, which used actual compressed air systems loading measurements and metered operation hours to estimate a savings factor.

Inputs

Table A: Inputs

Symbol	Description
HP	Air compressor nominal rated horsepower
H	Annual hours of operation

Nomenclature

Table B: Nomenclature

Symbol	Description	Units	Values	Comments
AKWH	Annual electric energy savings	kWh/yr		
SkW	Summer demand savings	kW		
WkW	Winter demand savings	kW		
HP	Air compressor nominal rated horsepower	HP		
SF	Savings factor	kW/HP	0.189	**Ref [1]**
CF_S	Summer coincidence factor			*Appendix One*

CF_W	Winter coincidence factor			*Appendix One*
H	Annual hours of operation			Site specific (must be provided on application form) or default, use *Table G*

Table C: Default Operations Hours of Compressed Air Systems

Shift	Hours	Notes
Single shift (8/5)	1,976	7 AM – 3 PM, weekdays, minus some holidays and scheduled down time
2-shift (16/5)	3,952	7AM – 11 PM, weekdays, minus some holidays and scheduled down time
3-shift (24/5)	5,928	24 hours per day, weekdays, minus some holidays and scheduled down time
4-shift (24/7)	8,320	24 hours per day, 7 days a week minus some holidays and scheduled down time

Lost Opportunity Gross Energy Savings, Electric

$$AKWH = HP \times H \times SF$$

Lost Opportunity Gross Seasonal Peak Demand Savings, Electric (winter and summer)

$$SkW = HP \times SF \times CF_S$$

$$WkW = HP \times SF \times CF_W$$

Changes from Last Version

- New measure.

References

[1] DNV KEMA (2015), Impact Evaluation of Prescriptive Chiller and Compressed Air Installations, pp. 8-11.

Notes

[1] In case sufficient site-specific information or/and metered data are available, custom savings calculation should be used to calculate more accurate savings.

3.5.2 HIGH EFFICIENCY REFRIGERATED AIR DRYERS

Description of Measure

Installation of cycling or Variable Frequency Drives (VFDs)-controlled refrigerated air dryers instead of non-cycling refrigerated dryers. This measure is applicable to single compressor systems only.

Savings Methodology

Refrigerated compressed air dryers use a refrigeration system to reduce the compressed air temperature below its dewpoint (about 35°F) to condense and remove moisture from a compressed air stream. The baseline condition is a compressed air system equipped with a non-cycling air dryer that uses hot gas bypass controls to modulate refrigeration capacity. Hot gas bypass requires constant refrigeration system operation at near-full input power. In contrast, a high efficiency air dryer cycles on and off or uses a VFD to modulate refrigeration capacity instead, which allows load reduction.

The savings calculation is based on a study of prescriptive compressed air **Ref [1]**, which used the actual compressed air systems loading measurements and metered operation hours to estimate a savings factor. This measure is not applicable for conversion from another type of dryer such as desiccant dryer to a refrigerated dryer.

Inputs

Table A: Inputs

Symbol	Description
CFM_{Dryer}	Full flow rated capacity of the refrigerated air dryer in cubic feet per minute (CFM)
H	Annual hours the compressed air system is pressurized

Nomenclature

Table B: Nomenclature

Symbol	Description	Units	Values	Comments
AKWH	Annual electric energy savings	kWh/yr		
SkW	Summer demand savings	kW		
WkW	Winter demand savings	kW		
CFM_{Dryer}	Full flow rated capacity of the refrigerated air dryer in cubic feet per minute (CFM)	CFM		Obtain from equipment's Compressed Air Gas Institute Datasheet
SF	Savings factor	kW/CFM	0.00554	**Ref [1]**
CF_S	Summer coincidence factor			*Appendix One*
CF_W	Winter coincidence factor			*Appendix One*
H	Annual hours of operation	Hrs/yr		**Site Specific** or default, use Table 3-JJJ

Table C: Default Operations Hours of Compressed Air Systems

Shift	Hours	Notes
Single shift (8/5)	1,976	7 AM – 3 PM, weekdays, minus some holidays and scheduled down time
2-shift (16/5)	3,952	7AM – 11 PM, weekdays, minus some holidays and scheduled down time
3-shift (24/5)	5,928	24 hours per day, weekdays, minus some holidays and scheduled down time
4-shift (24/7)	8,320	24 hours per day, 7 days a week minus some holidays and scheduled down time

Lost Opportunity Gross Energy Savings, Electric

$$AKWH = CFM_{Dryer} \times H \times SF$$

Lost Opportunity Gross Seasonal Peak Demand Savings, Electric (winter and summer)

$$SKW = CFM_{Dryer} \times SF \times CF_S$$

Changes from Last Version

- New measure.

References

[1] DNV KEMA (2015), Impact Evaluation of Prescriptive Chiller and Compressed Air Installations, pp. 8-11.

Notes

[1] In case sufficient site-specific information or/and metered data are available, custom savings calculation should be used to calculate more accurate savings.

3.5.3 EFFICIENT COMPRESSED AIR NOZZLES

Description of Measure

Replacement of standard air nozzle with high-efficiency nozzle in compressed air systems.

Savings Methodology

Engineered air nozzles entrain compressed air with surrounding air as it leaves the nozzle. This increases air flow volume with less compressed air use. The engineered air nozzles reduce the velocity of the resulting airflow but increase the mass flow of the air which improve the cooling and drying effect. The energy savings associated with the engineered air nozzles are due to the reduced compressor work. Efficient nozzles typically have the added benefits of noise reduction and improved safety in systems with greater than 30 psig.

The baseline condition is standard air nozzle. The high-efficiency air nozzle must meet the following specifications:

1. High-efficiency air nozzle must replace standard air nozzle.
2. High-efficiency air nozzle must meet SCFM rating at 80psig less than or equal to: 1/8” 11 SCFM, 1/4" 29 SCFM, 5/16” 56 SCFM, 1/2" 140 SCFM.
3. Manufacturer’s specification sheet of the high-efficiency air nozzle must be provided along with the make and model.

Inputs

Table A: Inputs

Symbol	Description
SCFM	Air flow through standard air nozzle
H	Annual hours of operation

Nomenclature

Table B: Nomenclature

Symbol	Description	Units	Values	Comments
AKWH	Annual electric energy savings	kWh/yr		
kW	Electric peak demand savings	kW		
SCFM	Air flow through standard nozzle	CFM		Use actual rated flow at 80 psi. If unknown use *Table D*
SCFM%Reduced	Percent in reduction of air loss per nozzle	%	0.5	**Note [1]**
EFF_{Comp}	Efficiency of air compressor	kW/CFM		Use *Table E*. If unknown, use 0.19 kW/CFM

MEF	Marginal efficiency factor per control type for air compressor	kW/Percent Load		Use *Table F*. If unknown, use 0.3%kW/%load
%USE	Percent of the system total annual pressurized hours during which the nozzle is in use	%	0.03	Site specific. If unknown, use 0.03
CF	Coincidence factor		0.95	
H	Annual hours of operation	Hrs/yr		Site specific or default or *Table C*

Table C: Default Operations Hours of Compressed Air Systems

Shift	Hours	Notes
Single shift (8/5)	1,976	7 AM – 3 PM, weekdays, minus some holidays and scheduled down time
2-shift (16/5)	3,952	7AM – 11 PM, weekdays, minus some holidays and scheduled down time
3-shift (24/5)	5,928	24 hours per day, weekdays, minus some holidays and scheduled down time
4-shift (24/7)	8,320	24 hours per day, 7 days a week minus some holidays and scheduled down time

Table D: Specific Flow Rates for Various Orifice Diameters, see Ref [1]

Pressure (psig)	Orifice Diameter (inches)					
	1/64	1/32	1/16	1/8	1/4	3/8
70	0.29	1.16	4.66	18.62	74.4	167.8
80	0.32	1.26	5.24	20.76	83.1	187.2
90	0.36	1.46	5.72	23.1	92	206.6
100	0.40	1.55	6.31	25.22	100.9	227
125	0.48	1.94	7.66	30.65	122.2	275.5

* Assuming 100% orifice flow for the standard nozzle in the baseline condition. If the orifice flow is <100%, the savings equation must be multiplied by the partial flow percentage.

Table E: kW/CFM Efficiencies for Several Air Compressor Types (EFF_{Comp}), see Ref [2]

Air Compressor Type	SAVE (kW/CFM)
Single-acting reciprocating air compressor	0.230
Double-acting reciprocating air compressor	0.155
Lubricant-injected rotary screw compressor	0.185
Lubricant-free rotary screw compressor	0.200
Centrifugal compressor	0.180
Average	**0.190**

Table F: Marginal Efficiency Factors per Control Type for Air Compressor Types (MEF), see Ref [3]

Control Type	Percent kW/Percent Load
Inlet valve modulated	0.31
Variable displacement	0.69
Variable speed drive	0.85

Retrofit Gross Energy Savings, Electric

$$AKWH = (SCFM \times \ SCFM\%\ Reduced) \times EFF_{Comp} \times MEF \times \%USE \times H$$

Retrofit Gross Peak Demand Savings, Electric

$$SKW = AKWH / H \times CF_S$$

Changes from Last Version

- New measure.

References

[1] US Department of Energy. Energy Tips – Compressed Air. August 2004. Available online: https://www.energy.gov/sites/prod/files/2014/05/f16/compressed_air3.pdf. Originally from Fundamentals of Compressed Air Systems Training offered by the Compressed Air Challenge®.

[2] Compressed Air Challenge "Fundamentals of Compressed Air Systems, "pp. 28-32.

[3] Compressed Air Challenge "Fundamentals of Compressed Air Systems," pp. 90-91.

[4] PA Consulting Group (2009), Business Programs: Measure Life Study. Prepared for State of Wisconsin Public Service Commission.

Notes

[1] Conservative estimate based on several manufacturers' technical specification sheets.

[2] In case sufficient site-specific information or/and metered data are available, custom savings calculation should be used to calculate more accurate savings.

3.5.4 COMPRESSED AIR LEAK DETECTION

Description of Measure

This measure covers the detection of compressed air losses through ultrasonic leak detection, and the repair of compressed air leaks.

Savings Methodology

Air leaks are common in compressed air systems, often wasting 20%-30% of the compressor's output. Air leak loss rate depend on the supply pressure in an uncontrolled system, as well as leak size quantity and time. This measure is applicable for general plant compressed air systems in manufacturing environments (70 to 125 psig).

Inputs

Table A: Inputs

Symbol	Description
H	Annual hours the compressed air system is pressurized

Nomenclature

Table B: Nomenclature

Symbol	Description	Units	Values	Comments
AKWH	Annual electric energy savings	kWh/yr		
kW	demand savings	kW		
NL	Number of detected leaks			
CFM_{Leak}	Flow rate loss per leak in cubic feet per minute (CFM)	CFM		Use *Table D*
EFF_{Comp}	Efficiency of air compressor	kW/CFM		Use *Table E*. If unknown, use 0.19 kW/CFM
MEF	Marginal efficiency factor per control type for air compressor	kW/Percent Load		Use *Table F*. If unknown, use 0.3%kW/%load
CF	Coincidence factor		0.845	**Ref [1]**
H	Annual hours the compressed air system is pressurized	Hrs/yr		Site specific or default values from *Table C*

Table C: Default Operations Hours of Compressed Air Systems

Shift	Hours	Notes
Single shift (8/5)	1,976	7 AM – 3 PM, weekdays, minus some holidays and scheduled down time
2-shift (16/5)	3,952	7AM – 11 PM, weekdays, minus some holidays and scheduled down time
3-shift (24/5)	5,928	24 hours per day, weekdays, minus some holidays and scheduled down time
4-shift (24/7)	8,320	24 hours per day, 7 days a week minus some holidays and scheduled down time

Table 1-K shows leakage rates for ideal orifices. Most gaps are irregular and sometimes ragged, which decreases the flow rate relative to the equivalent area.

Table D: CFM per Leak Size for Compressed Air Leaks, see Ref [2]

Pressure (psig)	Orifice Diameter (inches)					
	1/64	1/32	1/16	1/8	1/4	3/8
70	0.29	1.16	4.66	18.62	74.4	167.8
80	0.32	1.26	5.24	20.76	83.1	187.2
90	0.36	1.46	5.72	23.1	92	206.6
100	0.40	1.55	6.31	25.22	100.9	227
125	0.48	1.94	7.66	30.65	122.2	275.5

* For well-rounded orifices, values should be multiplied by 0.97 and by 0.61 for sharp ones.

Table E: kW/CFM Efficiencies for Several Air Compressor Types (EFF_{Comp}), see Ref [3]

Air Compressor Type	SAVE (kW/CFM)
Single-acting Reciprocating Air Compressor	0.230
Double-acting Reciprocating Air Compressor	0.155
Lubricant-injected Rotary Screw Compressor	0.185
Lubricant-free Rotary Screw Compressor	0.200
Centrifugal Compressor	0.180
Average	**0.190**

Table F: Marginal Efficiency Factors per Control Type for Air Compressor Types (MEF), see Ref [4]

Control Type	Percent kW/Percent Load
Inlet valve modulated	0.31
Variable displacement	0.69
Variable speed drive	0.85

Retrofit Gross Energy Savings, Electric

$$AKWH = NL \times CFM_{Leak} \times EFF_{Comp} \times MEF \times H$$

Retrofit Gross Peak Demand Savings, Electric

$$SKW = AKWH / H \times CFs$$

$$WKW = AKWH / H \times CFw$$

Changes from Last Version

- New measure.

References

[1] An average value derived from two coincidence factors that were developed through two separate studies. The 1st study is Aspen Systems Corporation, Prescriptive Variable Speed Drive Incentive Development Support for Industrial Air Compressors Executive Summary, Jun. 20, 2005. The 2nd study is KEMA, New Jersey's Clean Energy Program Energy Impact Evaluation and Protocol Review, Jul. 10, 2009.

[2] US Department of Energy. Energy Tips – Compressed Air. August 2004. Available online: https://www.energy.gov/sites/prod/files/2014/05/f16/compressed_air3.pdf. Originally from Fundamentals of Compressed Air Systems Training offered by the Compressed Air Challenge®.

[3] Compressed Air Challenge "Fundamentals of Compressed Air Systems," pp. 28-32.

[4] Compressed Air Challenge "Fundamentals of Compressed Air Systems," pp. 90-91.

SECTION FOUR: RESIDENTIAL

4.1 LIGHTING

4.1.1 LIGHTING

Description of Measure

Lighting savings are based on the replacement of low-efficiency light bulbs or luminaires with high-efficiency ENERGY STAR qualified LED bulbs or luminaires of equivalent lumen output.

Savings Methodology

The following assumptions are made to calculate savings for bulbs and luminaires. “Direct install” bulbs and luminaires are installed by vendors that have verified installation. “Retail” refers to bulbs and luminaires sold through retailers that do not have verified installation. Actual rated bulb wattage and location of both the existing and replacement bulbs is used to calculate savings for direct install. For retail, default (estimated) delta-watts and hours-of-use are used to calculate savings. There is a lighting interactive effect that applies to fossil fuel homes. Refer to *Table B: Nomenclature*.

Inputs

Table A: Inputs

Symbol	Description	Units
$Watt_{post}$	Rated wattage of installed or purchased high-efficiency bulb	Watts
$Watt_{pre}$	Rated wattage of low-efficiency bulb being replaced by direct install	Watts
Location	Location of direct install bulb. See *Table C* for available options	

Nomenclature

Table B: 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 One*, **Ref [3]**
CF_W	Average winter seasonal peak coincidence factor for residential (lighting)	unit-less	20.0%	*Appendix One*, **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 C* for all known locations *Retail Measure: 2.7*	**Ref [2]**
Lifetime	Measure life of the bulb	Years	Lifetime	*Appendix Four*
LKWH	Lifetime electric energy savings	kWh		Calculated
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. If $watt_{pre}$ is unknown, and assumed value	Watts (W)	Direct install: based on reported values. For retail or unknown direct install: 37.6 Watts (bulb) 37.6 Watts (luminaire)	Calculated
$Watt_{post}$	Rated wattage of high-efficiency bulb	Watts (W)	Input	
$Watt_{pre}$	Rated wattage of existing low-efficiency bulb	Watts (W)	Input	Direct install only
WKW	Winter demand savings	kW		Calculated
ABTU	Lighting interactive effect	Btu/kWh	-1,902	**Note [2]**

Retrofit and direct install savings calculation:

$$AKWH = 1.04 \times \frac{Watt_\Delta \times h_d \times 365}{1000} = 1.04 \times \frac{(Watt_{pre} - Watt_{post}) \times h_d \times 365}{1000}$$

Note: *1.04 is the average energy factor due to lighting interactive effect* ***Ref [1]****. Please refer to Table C for the correct hours of use per day by location (h_d).*

For unknown wattage, light bulbs:

$$(Watt\Delta = Watt_{pre} - Watt_{post} = 37.6\, watt)$$

For unknown wattage, luminaires:

$$(Watt\Delta = Watt_{pre} - Watt_{post} = 37.6\, Watt)$$

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

Location	All Customers
	h_d
Bedroom	2.1
Bathroom	1.7
Kitchen	4.1
Living room	3.3, **Ref [2]**
Dining room	2.8
Exterior	5.6
Other	1.7
Unknown	2.7, **Ref [2]**

Retrofit Gross Energy Savings, Example

Example: *A 45-Watt bulb is replaced with a 10-Watt LED bulb in the living room of a home by direct install. What is the annual savings?*

Using the equations from above:

$$\text{Watt}\Delta = Watt_{pre} - Watt_{post}$$

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

$$Watt\Delta = (45 - 10)$$

$$Watt\Delta = 35\, Watts$$

$$AKWH = 1.04 \times (35\, Watts) \times 3.3 \frac{hrs}{day} \times 365 \frac{days}{year} \div 1000 \frac{W}{kw}$$

$$AKWH = 43.844 \frac{kwh}{yr}$$

Retrofit Gross Seasonal Peak Demand Savings, Electric (winter and summer)

$$(Watt\Delta = Watt_{pre} - Watt_{post})$$

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

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

- 1.05 is an average capacity factor due to lighting interactive effect **Ref [7]**.
- Values for CF_S and CF_W can be found in *Appendix One* as the Residential Lighting Coincidence Factors.

Retrofit Gross Peak Demand Savings, Example

Example: *A 45-Watt bulb is replaced with a 10-Watt LED bulb in the living room of a home. What are the savings?*

$$\text{Watt}\Delta = Watt_{pre} - Watt_{post} = 45 - 10$$

$$Watt_{\Delta} = 35.0\ Watts$$

$$SKW = 1.05 \times 35.0\ Watts \times 0.130 \div 1000 \, {}^{W}\!/_{kW}$$
$$SKW = 0.005\ kW$$

$$WKW = 35.0\ Watts \times 0.20 \div 1000 \, {}^{W}\!/_{kW}$$
$$WKW = 0.007 kW$$

Lost Opportunity Gross Energy Savings (for rebate and upstream), Electric

For bulb/luminaire:

$$AKWH = 1.04 \times \frac{Watt_{\Delta} \times h_d \times 365}{1000} = 1.04 \times \frac{37.6 \times 2.7 \times 365}{1000}$$

$$AKWH = 38.54\ kWh$$

Lost Opportunity Gross Energy Savings, Example

Example: *What are the electric energy savings when any LED bulb is purchased through a retailer?*

$$\boldsymbol{AKWH} = 38.54\ kWh$$

Lost Opportunity Gross Peak Demand Savings, Example

For bulb/luminaire:

$$\boldsymbol{SKW} = 1.05 \times \frac{Watt_{\Delta} \times CFs}{1000} = 1.05 \times \frac{37.6 \times 0.13}{1000} = 0.0051\ kW$$

$$\boldsymbol{WKW} = \frac{Watt_{\Delta} \times CFw}{1000} = \frac{37.6 \times 0.20}{1000} = 0.0079\ k$$

Non-Energy Benefits

Table D: One-Time O&M Benefit per Bulb (see Note [1]) and Lighting Interactive Effects, see Note [2]

Bulb Type	O&M Benefit $/Bulb (Note 1)	Lighting Interactive Effect Penalty (Note 2)
LED bulb	$3.00	-1902 Btu/kWh. Only applies to fossil fuel-heated homes
LED luminaire	$4.00	

Changes from Last Version

- No change.

References

[1] *Connecticut Residential Lighting Interactive Effect*, NMR Group Inc., Dec. 2014, Table 1, p. 2.

[2] NMR Group Inc., Connecticut LED Lighting Study Report (R154), Jan. 28, 2016, p. 45.

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

Notes

[1] 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 [3].**

[2] The Lighting interactive effect penalty is based on the results from Connecticut Residential Lighting Interactive Effects Memo, Completed by NMR Group, Inc., Dec. 20, 2014. Penalty to be applied to non-electric benefits when planning.

4.1.2 CONNECTED LED LIGHTING

Description of Measure

This measure details the savings associated with connected LED lighting that allows for remote user control through Wi-Fi and/or a smart device. Using the remote controls, users can remotely turn the light on and off, adjust its brightness, and set a schedule for the light. Connected lighting controls savings are based on a reduction of operating hours and dimming. The savings for this measure are the estimated incremental control savings compared to a non-connected efficient lamp.

Savings Methodology

The following assumptions are made to calculate savings for connected LED lighting. "Direct install" bulbs and luminaires are installed by vendors that have verified installation. "Retail" refers to bulbs and luminaires sold through retailers that do not have verified installation. Actual rated bulb wattage and location of the bulbs is used to calculate savings for direct install. For retail, the actual rated bulb wattage and a default (estimated) hours-of-use are used to calculate savings. There is a lighting interactive effect that applies to fossil fuel homes. Refer to *Table B: Nomenclature*.

Inputs

Table A: Inputs

Symbol	Description	Units
$Watt_{controlled}$	Rated wattage of installed or purchased connected high-efficiency (LED) bulb.	Watts
Location	Location of direct install bulb. See *Table D* for available options.	

Nomenclature

Table B: 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 One*, **Ref [3]**
CF_W	Average winter seasonal peak coincidence factor for residential (lighting)	unit-less	20.0%	*Appendix One*, **Ref [3]**

hd	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 C* for all known locations	**Ref [2]**
Lifetime	Measure life of the bulb	Years	15	**Note [2]**
LKWH	Lifetime electric energy savings	kWh		Calculated
SF	Percentage of annual lighting energy saved by connected lighting controls	%	29%	**Ref [4]**
SKW	Summer demand savings	kW		Calculated
$Watt_{controlled}$	Rated wattage of installed or purchased connected high-efficiency (LED) bulb	Watts (W)	Input	
WKW	Winter demand savings	kW		Calculated
ABTU	Lighting interactive effect	Btu/kWh	-1,902	**Note [1]**

Retail and direct install savings calculation:

$$AKWH = 1.04 \times SF \times \frac{Watt_{controlled} \times h_d \times 365}{1000W/kW}$$

Note*: 1.04 is the average energy factor due to lighting interactive effect* ***Ref [1]****. Please refer to* *Table C* *for the correct hours of use per day by location (hd).*

Table C: Hours of Use per Day by Location (hd)

Location	All Customers
	Hd
Bedroom	2.1
Bathroom	1.7
Kitchen	4.1
Living room	3.3, **Ref [2]**
Dining room	2.8
Exterior	5.6
Other	1.7
Unknown	2.7, **Ref [2]**

Gross Energy Savings, Example

Example: *A 10-Watt connected LED bulb installed in the living room of a home by direct install. What is the annual savings?*

$$\mathrm{AKWH} = 1.04 \times \mathrm{SF} \times \frac{\mathrm{Watt_{controlled}} \times \mathrm{h_d} \times 365}{1000\ \mathrm{W/kW}}$$

$$\mathrm{AKWH} = 1.04 \times 29\% \times \frac{10\ \mathrm{Watts} \times 3.3\ \mathrm{hrs/day} \times 365\ \mathrm{days/year}}{1000\mathrm{W/kW}}$$

$$\mathrm{AKWH} = 3.6\ \mathrm{kWh/year}$$

Using the equations from above:

Gross Seasonal Peak Demand Savings, Electric (winter and summer)

$$\mathrm{SkW} = 1.05 \times \mathrm{SF} \times \frac{\mathrm{Watt_{controlled}} \times \mathrm{CF_S}}{1000\ \mathrm{W\backslash kW}}$$

$$\mathrm{WkW} = \mathrm{SF} \times \frac{\mathrm{Watt_{controlled}} \times \mathrm{CF}_W}{1000\ \mathrm{W\backslash kW}}$$

- 1.05 is an average capacity factor due to lighting interactive effect **Ref [7]**.
- Values for CFs and CFw can be found in *Appendix One* as the Residential Lighting Coincidence Factors.

Gross Peak Demand Savings, Example

Example: *A 10-Watt connected LED bulb in the living room of a home. What are the savings?*

$$\mathrm{SkW} = 1.05 \times \mathrm{SF} \times \frac{\mathrm{Watt_{controlled}} \times \mathrm{CF_S}}{1000\ \mathrm{W\backslash kW}}$$

$$\mathrm{SkW} = 1.05 \times 29\% \times \frac{10\ \mathrm{Watts} \times 13\%}{1000\ \mathrm{W\backslash kW}}$$

$$\mathrm{SkW} = 0.0004\ \mathrm{kW}$$

$$\mathrm{WkW} = \mathrm{SF} \times \frac{\mathrm{Watt_{controlled}} \times \mathrm{CF}_W}{1000\ \mathrm{W\backslash kW}}$$

$$\mathrm{WkW} = 29\% \times \frac{10\ \mathrm{Watts} \times 20\%}{1000\ \mathrm{W\backslash kW}}$$

$$\mathrm{WkW} = 0.0006\ \mathrm{kW}$$

Changes from Last Version

- Added new measure.

References

[1] *Connecticut Residential Lighting Interactive Effect*, NMR Group Inc., Dec. 2014, Table 1, p. 2.

[2] NMR Group Inc., Connecticut LED Lighting Study Report (R154), Jan. 28, 2016, p. 45.

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

[4] Navigant Consulting. Department of Energy Solid-State Lighting Program. Energy Savings Forecast of Solid-State Lighting in General Illumination Applications. December 2019.

[5] ENERGY STAR Program Requirements. Product Specification for Lamps (Light Bulbs). Eligibility Criteria 2.1.

Notes

[1] The Lighting interactive effect penalty is based on the results from Connecticut Residential Lighting Interactive Effects Memo, Completed by NMR Group, Inc., Dec. 20, 2014. Penalty to be applied to non-electric benefits when planning.

[2] A 15-year EUL cap has been deemed for most residential screw-base LED measures, as a result of measure persistence concerns and LED lifetime cap practices of other programs (in DC, IL, MA, MN, RI, VT, and WI). While connected lighting is less susceptible to persistence issues, they also have more electronic components than standard LED products and are therefore likely more subject to early failure. Therefore, the 15-year EUL cap is maintained for these measures.

4.1.3 OCCUPANCY SENSORS

Description of Measure

This measure details the savings associated with installing occupancy sensor(s) (hard-wired, fixture-, wall-, or ceiling-mounted) that switch lights off after a brief delay when they do not detect occupancy. Occupancy sensors reduce energy consumption by reducing the operating hours for lighting equipment in low occupancy areas, such as hallways, storage rooms, and restrooms. The savings for this measure are the estimated control savings compared to lighting fixtures being controlled by manual wall switches (no occupancy sensors).

Savings Methodology

The following assumptions are made to calculate savings for connected LED lighting. “Direct install” bulbs and luminaires are installed by vendors that have verified installation. “Retail” refers to bulbs and luminaires sold through retailers that do not have verified installation. Actual rated bulb wattage and location of the bulbs is used to calculate savings for direct install. For retail, the actual rated bulb wattage and a default (estimated) hours-of-use are used to calculate savings. There is a lighting interactive effect that applies to fossil fuel homes. Refer to *Table B: Nomenclature*.

Inputs

Table A: Inputs

Symbol	Description	Units
$Watt_{controlled}$	Rated wattage of installed or purchased connected high-efficiency (LED) bulb.	Watts
Location	Location of direct install bulb. See *Table D* for available options.	

Nomenclature

Table B: 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 One*, **Ref [3]**
CF_W	Average winter seasonal peak coincidence factor for residential (lighting)	unit-less	20.0%	*Appendix One*, **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 D* for all known locations	**Ref [2]**
Lifetime	Measure life of occupancy sensor	Years	10	**Ref [5]**
LKWH	Lifetime electric energy savings	kWh		Calculated
SF	Percentage of annual lighting energy saved by connected lighting controls	%	17%	**Ref [4]**
SKW	Summer demand savings	kW		Calculated
$Watt_{controlled}$	Rated wattage of installed or purchased connected high-efficiency (LED) bulb	Watts (W)	Input	
$Watt_{default}$	If $Watt_{controlled}$ is unknown, use this wattage.	Watts (W)	*Table C* for default wattage calculation	**Note [2], Ref [6]**
WKW	Winter demand savings	kW		Calculated
ABTU	Lighting interactive effect	Btu/kWh	-1,902	**Note [1]**

Retail and direct install savings calculation:

$$\text{AkWh} = 1.04 \times \text{SF} \times \frac{\text{Watt}_{\text{controlled}} \times h_{\text{d}} \times 365}{1000}$$

Note: *1.04 is the average energy factor due to lighting interactive effect* ***Ref [1]****. Please refer to Table D for the correct hours of use per day by location (hd).*

For unknown wattage:

Table C: Default Wattage Assumption

Number of lamps in space with control	Average lamp wattage	Connected unit kW
6.8	0.034	0.230

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

Location	All Customers
	Hd
Bedroom	2.1
Bathroom	1.7
Kitchen	4.1
Living room	3.3, **Ref [2]**
Dining room	2.8
Exterior	5.6
Other	1.7
Unknown	2.7, **Ref [2]**

Retrofit Gross Energy Savings, Example

Example: *A 10-Watt connected LED bulb installed in the living room of a home by direct install. What is the annual savings?*

$$\Delta kWh = 1.04 \times SF \times \frac{Watt_{controlled} \times h_d \times 365}{1000}$$

$$\Delta kWh = 1.04 \times 17\% \times 10 \text{ Watts} \times 1 \text{ kW} / 1{,}000 \text{ W} \times 3.3 \text{ hrs/day} \times 365 \text{ days/year}$$

$$\Delta kWh = 2.1 \text{ kWh/year}$$

Using the equations from above:

Retrofit Gross Seasonal Peak Demand Savings, Electric (winter and summer)

$$SkW = 1.05 \times SF \times \frac{Watt_{controlled} \times CF_S}{1000 \text{ W/kW}}$$

$$WkW = SF \times \frac{Watt_{controlled} \times CF_W}{1000 \text{ W/kW}}$$

- 1.05 is an average capacity factor due to lighting interactive effect **Ref [1]**.
- Values for CFs and CFw can be found in Appendix One as the Residential Lighting Coincidence Factors.

Retrofit Gross Peak Demand Savings, Example

Example: A 10-Watt connected LED bulb in the living room of a home. What are the savings?

$$SkW = 1.05 \times SF \times \frac{Watt_{controlled} \times CF_S}{1000\ W/kW}$$

$$SkW = 1.05 \times 17\% \times \frac{10\ Watt \times 13\%}{1000\ W/kW}$$

$$SkW = 0.0002\ kW$$

$$WkW = SF \times \frac{Watt_{controlled} \times CF_W}{1000\ W/kW}$$

$$WkW = 17\% \times \frac{10\ Watt \times 20\%}{1000\ W/kW}$$

$$WkW = 0.0003\ kW$$

Lost Opportunity Gross Energy Savings (for rebate and upstream), Electric

For bulb/luminaire:

$$AkWh = 1.04 \times SF \times \frac{Watt_{controlled} \times h_d \times 365}{1000}$$

$AkWh$ = 1.04 × 17% × 34 Watts × 1 kW / 1,000 W × 2.7 hrs/day × 365 days/year

$AkWh$ = 5.9 kWh/year

Lost Opportunity Gross Energy Savings, Example

Example: What is the annual electric energy savings when any LED bulb is purchased through a retailer?

AkWh = 5.9 kWh/year

Lost Opportunity Gross Peak Demand Savings, Example

For bulb/luminaire:

$$SkW = 1.05 \times SF \times \frac{Watt_{controlled} \times CF_S}{1000\ W/kW}$$

$$SkW = 1.05 \times 17\% \times \frac{34\ Watt \times 13\%}{1000\ W/kW}$$

$$SkW = 0.0007\ kW$$

$$WkW = SF \times \frac{Watt_{controlled} \times CF_W}{1000\ W/kW}$$

$$WkW = 17\% \times \frac{34\ Watt \times 20\%}{1000\ W/kW}$$

$$WkW = 0.0011\ kW$$

Changes from Last Version

- Added new measure.

References

[1] *Connecticut Residential Lighting Interactive Effect*, NMR Group Inc., Dec. 2014, Table 1, p. 2.

[2] NMR Group Inc., Connecticut LED Lighting Study Report (R154), Jan. 28, 2016, p. 45.

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

[4] Navigant Consulting. Department of Energy Solid-State Lighting Program. Energy Savings Forecast of Solid-State Lighting in General Illumination Applications. December 2019.

[5] GDS Associates Inc., Measure Life Report, Residential and Commercial Industrial Lighting and HVAC Measures, Jun. 2007, see Table 2.

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

Notes

[1] The Lighting interactive effect penalty is based on the results from Connecticut Residential Lighting Interactive Effects Memo, Completed by NMR Group, Inc., Dec. 20, 2014. Penalty to be applied to non-electric benefits when planning.

[2] Average of number of sockets in dining room, living space, bedroom, bathroom, and kitchen spaces and average connected wattage of lamps in dining room, living space, bedroom, bathroom, and kitchen spaces.

4.2 HVAC

4.2.1 ENERGY-EFFICIENT CENTRAL AIR CONDITIONING

Description of Measure

Installation of an energy-efficient Central Air Conditioning (Central A/C) system and replacement of a working inefficient A/C 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 Four*.

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 *Measure 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 Four*.

Savings are based on the Central A/C Impact and Process Evaluation (**Ref [1]**). This regional study metered the usage of recently installed residential A/C 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 EER.

Inputs

Table A: Inputs

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

Nomenclature

Table B: Nomenclature

Symbol	Description	Units	Values	Comments
$AKWH_C$	Annual electric energy savings, cooling	kWh		
ASF	Annual usage 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	11.2	**Note [1]**
EER_e	Existing EER of removed unit	Btu/Watt-hr	Use 11.2 (SEER 13) for lost opportunity. 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	11	**Note [3]**
$LKWH_C$	Lifetime electric energy savings, cooling	kWh		
RUL	Remaining useful life	Years	3.67	**Note [3]**
SKW_C	Summer seasonal demand savings, cooling	kW		
$\ldots_{Retire}$	Associated with retirement			
$\ldots_{Lost\ Opp}$	Associated with lost opportunity			
MAF	Multifamily adjustment factor		0.4	**Note [4]**

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:

For a single family:

$$AKWH_{C,Retire} = ASF \times CAP_{C,i} \times \left(1 - \frac{EERe}{11.2}\right)$$

For a multifamily:

$$AKWH_{C,Retire} = MAF \times ASF \times CAP_{C,i} \times \left(1 - \frac{EERe}{11.2}\right)$$

The equation simplifies when the existing EER is not known:

For a single family:

$$AKWH_{C,Retire} = 362\ {}^{kwh}/_{Ton} \times CAP_{C,i} \times \left(1 - \frac{8}{11.2}\right) = 103.42 \times CAP_{C,i}$$

For a multifamily:

$$AKWH_{C,Retire} = 0.4 \times 362\ {}^{kwh}/_{Ton} \times CAP_{C,i} \times \left(1 - \frac{8}{11.2}\right) = 41.37 \times CAP_{C,i}$$

Lost Opportunity Gross Energy Savings, Electric

For a single family:

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

$$AKWH_{C,Lost\ Opp} = 362\ {}^{kwh}/_{Ton} \times CAP_{C,i} \times \left(\frac{EER_i}{11.2} - 1\right)$$

For a multifamily:

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

$$AKWH_{C,Lost\ Opp} = 0.4 \times 362\ {}^{kwh}/_{Ton} \times CAP_{C,i} \times \left(\frac{EER_i}{11.2} - 1\right)$$

Retrofit Gross Energy Savings, Example

Example: A single family home has *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":

$$AKWH_{C,Lost\ Opp} = 362\ {}^{kwh}/_{Ton} \times CAP_{C,i} \times \left(\frac{EER_i}{11.2} - 1\right)$$

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

$$AKWH_{C,Lost\ Opp} = 362\,\frac{kwh}{Ton} \times 3\ tons \times \left(\frac{13}{11.2} - 1\right) = 174.53\ kWh$$

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):

$$AKWH_{C,Retire} = 103.42 \times CAP_{C,i}$$

$$AKWH_{C,Retire} = 103.42 \times 3$$

$$= 310.26\ kWh$$

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:

For single family:

$$SKW_{C,Retire} = 0.45\ {}^{kwh}/_{Ton} \times CAP_{C,i} \times \left(1 - \frac{8}{11.2}\right) = 0.129 \times CAP_{C,i}$$

The equation simplifies when the existing EER is not known.

For multifamily:

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

<u>The equation simplifies when the existing EER is not known</u>:

$$SKW_{C,Retire} = 0.40 \times 0.45 \, {}^{kwh}/_{Ton} \times CAP_{C,i} \times \left(1 - \frac{8}{11.2}\right)$$
$$= 0.051 \times CAP_{C,i}$$

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

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

$$SKW_{C,Lost\ Opp} = 0.45 \, {}^{kwh}/_{Ton} \times CAP_{C,i} \times \left(\frac{EER_i}{11.2} - 1\right)$$

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

<u>Retrofit Gross Peak Demand Savings, Example</u>

Example: *What are the summer demand savings for the above retrofit example?*

<u>Using the equation for Lost Opportunity Savings (summer demand), input the size and efficiency of the new unit</u>:

$$SKW_{C,Lost\ Opp} = 0.45 \, {}^{kwh}/_{Ton} \times CAP_{C,i} \times \left(\frac{EER_i}{11.2} - 1\right)$$

$$SKW_{C,Lost\ Opp} = 0.45 \, {}^{kwh}/_{Ton} \times 3 \times \left(\frac{13}{11.2} - 1\right) = 0.216 \, kW$$

<u>Using the equation for retirement summer demand savings, input the cooling capacity in tons</u>:

$$SKW_{C,Retire} = 0.129 \times CAP_{C,i}$$

$$SKW_{C,Retire} = 0.129 \times 3 = 0.386 kW$$

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

<u>For a single family</u>:

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

$$AKWH_{C,Lost\ Opp} = 362 \, {}^{kwh}/_{Ton} \times CAP_{C,i} \times \left(\frac{EER_i}{11.2} - 1\right)$$

For a multifamily:

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

$$AKWH_{C,Lost\ Opp} = 0.4 \times 362\ {}^{kwh}/_{Ton} \times CAP_{C,i} \times \left(\frac{EER_i}{11.2} - 1\right)$$

Lost Opportunity Gross Energy Savings, Example for a single-family unit

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 is the annual savings?*

To calculate annual savings, use the Lost Opportunity equation:

$$AKWH_{C,Lost\ Opp} = 362\ {}^{kwh}/_{Ton} \times CAP_{C,i} \times \left(\frac{EER_i}{11.2} - 1\right)$$

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

$$AKWH_{C,Lost\ Opp} = 362\ {}^{kwh}/_{Ton} \times 3\ tons \quad \times \left(\frac{13}{11.2} - 1\right) = 174.53\ kWh$$

Lost Opportunity Gross Seasonal Peak Demand Savings, Electric (winter and summer)

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

$$SKW_{C,Lost\ Opp} = 0.45\ {}^{kwh}/_{Ton} \times CAP_{C,i} \times \left(\frac{EER_i}{11.2} - 1\right)$$

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 for a single family unit

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:

$$SKW_{C,Lost\ Opp} = 0.45\ {}^{kwh}/_{Ton} \times CAP_{C,i} \times \left(\frac{EER_i}{11.2} - 1\right)$$

<u>Input the size and efficiency of the new unit</u>:

$$SKW_{C,Lost\ Opp} = 0.45\ {}^{kwh}/_{Ton} \times 3 \times \left(\frac{13}{11.2} - 1\right) = 0.216\ kW$$

<u>Changes from Last Version</u>

- Fixed typos in equation and made minor edits. Added missing MF factor (MAF=0.4) into some of the equations.
- Added notes to document the sources for Measure life changes and MAF adjustment factor.
- Fixed calculation errors in examples.

<u>References</u>

[1] *Central Air Conditioning Impact and Process Evaluation*, NMR Group, Inc., May 30, 2014.

<u>Notes</u>

[1] **Ref [1]**, *NMR Central Air Conditioning Impact and Process Evaluation*, pp. I to III. “Because there were no instances of early replacement of Central A/C 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]**, p. ES-1 gives the ratio 11.2 EER/13 SEER). 8 EER is used as the estimated existing efficiency.*

[3] Update based on R1706 RASS , For the early retirement X1931 ERS RUL is assumed 1/3 X 11 years = 3.67 years of the EUL when equipment specific information is not available.

[4] MAF is multifamily adjustment factor to account for average dwelling size smaller than single family.

X1931 ERS recommendations: “Add a 0.40 multiplier for multifamily buildings to the ASF to take into account lower kWh usage due to reduced square footage of units. The NMR study does not specify whether the study included both single and multifamily buildings. However, looking at Appendix D "Demographic Characteristics of Survey Respondents" the Home Ownership and Home square footage seems to indicate mostly single -family buildings. Divide the average square foots of a multifamily unit from R1705 R1609 (876) by the average single family square footage (2,191) in the Wi-Fi Programmable Thermostat Pilot Program Evaluation (2012/2013) (all single-family buildings) referenced in the Wi-Fi Thermostat measure to get a 0.40 multiplier.”

4.2.2 HEAT PUMP

Description of Measure

Installation of an energy-efficient ducted air source heat pump (ASHP) as replacement of a working, less-efficient electric heating system, including heat pumps and electric resistance heating or replacement of a fossil fuel-based heating system and Central A/C.

Savings Methodology

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 EUL from *Appendix Four*).

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 *Measure 1.5*).
- Retirement Savings are the difference in energy use between the older unit (**Note [2]**) and a baseline new model (**Note [1]**), continuing for the RUL from *Appendix Four*.

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 A/C, as presented in *Measure 4.2.1: Energy-Efficient Central A/C* of the 2022 PSD manual.

Note: *The savings here do not apply to a Ductless Heat Pump; see Measure 4.2.6 for Ductless Heat Pumps methodology.*

Inputs

Table A: Inputs

Symbol	Description	Units
$CAP_{H,i}$	Installed heating capacity AHRI verified, in the case the CAP_{Hi} is unknown, use the unit cooling CAP_{ci} X 0.9 [note5]	Btu/hr
$HSPF_e$	Heating Season Performance Factor, 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

Table B: Nomenclature

Symbol	Description	Units	Values	Comments
AKWH	Annual electric energy savings	kWh		
$CAP_{H,i}$	Installed heating capacity	Btu/hr	Varies by size	Input
$EFLH_H$	Heating equivalent full-load hours	Hours	862	**Note [3]**
EUL	Effective useful life	Years		*Appendix A4.2*
$HSPF_b$	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 site-specific pre-existing equipment HSPF value if known. • If installment year of preexisting system is known use: - 6.8 HSPF if preexisting ASHP system installed before 2006, - 7.7 HSPF if preexisting ASHP system installed, between 2006 -2014 - 8.2 HSPF if preexisting ASHP system installed after 2015. • If neither the HSPF nor installment year of preexisting system is known: - 7.7 HSPF. • If preexisting heating system is electric heat: - 3.14 HSPF	**Note [2]**
$HSPF_i$	Heating season performance factor, installed (AHRI-Verified)	Btu/Watt-hr		Input
RUL	Remaining useful life	Years		*Appendix A4.2*
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:

$$LKWH_{H,Total} = AKWH_{H,Retire} \times RUL + AKWH_{H,RLost\ Opp} \times EUL$$

Early Retirement component:

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

If replacing fossil fuel equipment:

$$\frac{1}{HSPF_e} = 0$$

Cooling: If the unit also provides cooling, calculate savings as presented in *Measure 4.2.1: Central A/C*.

Retrofit Gross Energy Savings, Example

***Example:** A new air-source heat pump with a heating capacity of 36,000 Btu/hr, $HSPF_i$ of 10, SEER of 17, 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 6.8.*

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:

$$AKWH_{H,LostOpp} = 862\ {}^{hrs}/_{yr} \times 36{,}000 \times \left(\frac{1}{8.2} - \frac{1}{10}\right) \times \frac{1}{1000} = 681.2\ kWh$$

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.

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

$$AKWH_{H,Retire} = 862\ {}^{hrs}\!/_{yr} \times 36{,}000 \times \left(\frac{1}{6.8} - \frac{1}{8.2}\right) \times \frac{1}{1000} = 779.1\ kWh$$

Because the heat pump also provides cooling; calculate cooling savings as presented in the *Measure 4.2.1: Energy-Efficient Central A/C*.

Retrofit Gross Seasonal Peak Demand Savings, Electric (winter and summer)

- **Heating: Note [4]:**
    - WKW= 0
- **Cooling:** If the unit also provides cooling, calculate demand savings as presented in *Measure 4.2.1: Energy-Efficient Central A/C*.

Lost Opportunity Gross Energy Savings, Electric

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

$$AKWH_{H,LostOpp} = 862\ {}^{hrs}\!/_{yr} \times CAP_{Hi} \times \left(\frac{1}{8.2} - \frac{1}{HSPF_i}\right) \times \frac{1}{1000}$$

Cooling: If the unit also provides cooling, calculate savings as presented in *Measure 4.2.1: Energy-Efficient Central A/C*.

Lost Opportunity Gross Energy Savings, Example

Example: *A rebate is provided for the installation of a new air source heat pump with an installed heating capacity of 36,000 Btu/hr and HSPF of 10. What are the annual electric heating and cooling savings?*

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

$$AKWH_{H,LostOpp} = 862\ {}^{hrs}\!/_{yr} \times CAP_i \times \left(\frac{1}{8.2} - \frac{1}{HSPF_i}\right) \times \frac{1}{1000}$$

$$AKWH_{H,LostOpp} = 862\ {}^{hrs}\!/_{yr} \times 36{,}000 \times \left(\frac{1}{8.2} - \frac{1}{10}\right) \times \frac{1}{1000} = 681.2\ kWh$$

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 *Measure 4.2.1: Energy-Efficient Central Air Conditioning*.

Changes from Last Version

- Updated wording in the case the CAP_{Hi} is unknown, use the unit cooling CAP_{ci} X 0.9.
- Updated the example with known CAPHI, new HSPF and SEER.
- Corrected reference to *Measure 4.2.6*.

References

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

[2] *1989 ASHRAE Fundamentals*, Chapter 28: Energy Estimating Methods, page 28.2, see Fig. 1: Correction Factor versus Degree-Days.

[3] Opinion Dynamics, New York Statewide Residential Gas High-Efficiency Heating Equipment Programs – Evaluation of 2009-2011 Programs, August 2014. p. 81.

Notes

[1] Federal minimum standard code compliant Heat Pump - 8.2 HSPF.

[2] Current US government established the federal minimum heating efficiency standard 10 CFR Part 430 - ENERGY CONSERVATION PROGRAM FOR CONSUMER PRODUCTS.

[3] The updated value (862 hours) is the average detached single family FLHH for Poughkeepsie, NY (from NY TRM) which is the closest NY weather station to CT. The NY FLH is based on billing data analysis of heating load and heating system nameplate capacities for 23,573 homes in 2014.

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

[5] The relation between heating and cooling capacity are sourced from an internal analysis of NEEP certified ASHP/DMSP units.

4.2.3 GEOTHERMAL HEAT PUMP

Description of Measure

Installation and commissioning of a high-efficiency closed loop ground source heat pump system.

Savings Methodology

Savings are determined using the engineering algorithm described below.

Note: *The savings baseline for lost opportunity is a code-compliant geothermal system. For retrofit, the baseline is site-specific electric cooling (Central A/C and/or heat pump) and site-specific electric heating system (electric resistance/HP) or fossil fuel heating system (boiler/furnace).*

Inputs

Table A: Inputs

Symbol	Description	Units
	Type of geothermal system (closed loop/DX) water-to-water or water-to-air note all calculation in this section are for ground source heat pump systems no water source heat pump calculation should be used in this section	
CAP_i	Installed cooling rated capacity	Tons
EER_i	EER - installed	Btu/Watt-hr
COP_i	COP - installed	

Nomenclature

Table B: Inputs

Symbol	Description	Units	Values	Comments
CAP_i	Installed rated cooling capacity	Btu/hr		
EER_i	Installed EER	Btu/Watt-hr		
COP_i	Installed COP			
CF_C	Coincidence Factor, residential cooling		0.69	**Ref [1]**
CF_H	Coincidence Factor, residential heating		0.50	*Appendix One*
$EFLH_H$	Effective full load hours, heating	Hours	862	**Ref [3]**
$EFLH_C$	Effective full load hours, cooling	Hours	470	**Ref [3]**
COP_b	Baseline COP		*Table C*	*2021 IECC*
COP_e	Coefficienct of Performance of preexisting electric heating system.			*input*

EER_b	Baseline EER		*Table C*	**Ref [3]**
EER_e				
SkW_C	Summer seasonal demand savings	kW		
WkW_H	Winter seasonal demand savings	kW		
$AkWh_C$	Annual cooling energy savings	kWh		
$AkWh_H$	Annual heating energy savings	kWh		

Lost Opportunity Gross Energy Savings, Electric

Table C: Baseline Efficiencies 2021 IECC, Ref [2]

System Type	EER_b	COP_b
Closed loop water-to-air	14.3	3.2
Closed loop water-to-water	15.1	2.5
DGX	15.0	3.5

Where:

$$AkWh_C = CAP_{C,i} \times EFLH_C \times \left(\frac{1}{EER_b} - \frac{1}{EER_i}\right) \times \frac{1}{1000}$$

Where:

$CAP_{C,i}$ = installed cooling capacity (kBtu/hr)

$$AkWh_H = CAP_{H,i} \times EFLH_H \times \left(\frac{1}{COP_b} - \frac{1}{COP_i}\right) \times \frac{1}{3{,}412}$$

$CAP_{H,i}$ = installed heating capacity (kBtu/hr). a cooling capcity can be used as a heating capacity if heating capacity unknown.

Lost Opportunity Gross Energy Savings, Example

Example: *A 3-ton closed loop water-to-water geothermal heat pump is installed with an EER of 20.2 and COP of 4.2. What are the energy savings?*

$$AkWh_C = 36{,}000 \times 470 \times \left(\frac{1}{15.1} - \frac{1}{20.2}\right) \times \frac{1}{1000} = 282.9\ kWh_C$$

$$AkWh_H = 36{,}000 \times 862 \times \left(\frac{1}{2.5} - \frac{1}{4.2}\right) \times \frac{1}{3{,}412} = 1472.5 kWh_H$$

Retrofit Gross Energy Savings, Electric

$$AkWh_C = CAP_{C,i} \times EFLH_C \times \left(\frac{1}{EER_e} - \frac{1}{EER_i}\right) \times \frac{1}{1000}$$

Where:

$CAP_{C,i}$ = installed cooling capacity (kBtu/hr)

EER_e = Energy efficiency ratio of preexisting electric cooling system

$$AkWh_H = CAP_{H,i} \times EFLH_H \times \left(\frac{1}{COP_e} - \frac{1}{COP_i}\right) \times \frac{1}{3{,}412}$$

Where:

- $CAP_{H,i}$ = installed heating capacity (kBtu/hr). Can be installed cooling capcity if unknown.
- COP_e = Coefiecient of Performance of preexisting electric heating system.
- if replacing electric resistance heating: $COP_e = 1$.
- If replacing fossil fuel equiment: $\frac{1}{COP_e} = 0$.

Lost Opportunity Gross Seasonal Peak Demand Savings, Electric (winter and summer)

Summer kW : $SkW_C = CAP_{C,i} \times \frac{1}{1000} \times \left(\frac{1}{EER_b} - \frac{1}{EER_i}\right) \times CF_C$

Where:

$CAP_{C,i}$ = installed cooling capacity (kBtu/hr)

EER_{eb} = Energy efficiency ratio of baseline cooling system see table 4-K

Winter kW : $WkW_H = CAP_{H,i} \times \frac{1}{3{,}412} \times \left(\frac{1}{COP_b} - \frac{1}{COP_i}\right) \times CF_H$

Where:

- $CAP_{H,i}$ = installed heating capacity (kBtu/hr). Can be installed cooling capcity if unknown.
- COP_b = Coefficienct of Performance of basline heating system, see *Table C*.

Retrofit Gross Seasonal Peak Demand Savings, Electric (winter and summer)

Summer kW:

$$SkW_C = CAP_{C,i} \times \frac{1}{1000} \times \left(\frac{1}{EER_e} - \frac{1}{EER_i}\right) \times CF_C$$

$CAP_{C,i}$ = installed cooling capacity (kBtu/hr)

EER_e = Energy efficiency ratio of prexisting cooling system

Winter kW :

$$WkW_H = CAP_{H,i} \times \frac{1}{3,412} \times \left(\frac{1}{COP_e} - \frac{1}{COP_i}\right) \times CF_H$$

Where:

- $CAP_{H,i}$ = installed heating capacity (kBtu/hr). Can be installed cooling capcity if unknown.
- COP_e = Coefficienct of Performance of preexisting electric heating system.

Changes from Last Version

- Updated baseline to ENERGY STAR V 3.1 tier 1 and removed the 2018 IECC.
- Updated the example calculation for baseline and formula subscript.
- Fixed retrofit savings formula from HSPF to COP since geothermal units are rated in COP not HSPF.
- Removed the retrofit fuel switching; awaiting approval for fuel switching programs.
- Added retrofit summer and winter kW.
- Updated **Ref [2]**.

References

[1] Aligns with other TRMs (NY and Mid-Atlantic) and based on more recent research by ERS.

[2] ENERGY STAR Tier 1 Geothermal Heat Pumps Key Product Criteria table 1.

https://www.energystar.gov/sites/default/files/specs/private/Geothermal_Heat_Pumps_Program_Requirements%20v3.1.pdf.

Accessed June 2, 2021.

[3] 2021 IECC.

4.2.4 ELECTRONICALLY COMMUTATED MOTOR HVAC FAN

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. This measure is only applicable to retrofit of existing fans.

Savings Methodology

Savings for this measure are calculated based on a typical home. These deemed savings are based on results **Ref [1]**. Demand savings were derived from interval data adjusted to historical ISO-NE seasonal peak hours and Normalized NOAA weather.

Inputs

Table A: Inputs

Symbol	Description	Units
N	Number of systems with ECMs installed	

Nomenclature

Table B: Nomenclature

Symbol	Description	Units	Values	Comments
$AKWH_H$	Annual electric energy savings during heating season	kWh/yr	84	**Ref [1]**
AKWHc	Annual electric energy savings during cooling season	kWh/yr	78	**Ref [1]**
PkW_C	kW savings – cooling mode	kW	0.129	**Ref [1], Note [2]**
PkW_H	kW savings – heating mode	kW	0.126	**Ref [1]**
SKW	Summer demand savings	kW		
WKW	Winter demand savings	kW		

Retrofit Net Energy Savings, Electric

$AKWH_H = 84$ kWh

$AKWH_C = 78$ kWh

$$AKWH = N \times (AKWH_H + AKWH_C)$$

Retrofit Net Demand Savings, Electric

$kW_w = 0.126$- kW

$kW_S = 0.129$kW

Changes from Last Version

- Noted that measure is only applicable to retrofit situations.
- Revised Savings based on **Ref [1]** values**.**

References

[1] *Evaluation of Retrofit Variable-Speed Furnace Fan Motors, January 2014, Report published by US Department of Energy,* available at*:* https://www.nrel.gov/docs/fy14osti/60760.pdf.

Notes

[1] kW savings are derived from using average kw savings from Table 6 and Table 8 of **Ref [1]** , converting them into Watts and multiplying with Coincidence Factor from *Table A1-3 of Appendix One*, CT PSD March, 2021.

4.2.5 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 (Pa) using standard duct blaster testing procedures and blower door; other advanced sealing techniques can be used. It is recommended to use mastic rather than foil tape to seal the leaky duct.

Savings Methodology

Duct improvements (sealing) should be verified with duct blaster test at 25 Pa using an approved test method. Notice 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.

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 A/C may only claim cooling savings.*

Inputs

Table A: Inputs

Symbol	Description	Units
A	Heated area served by system (required only for ADS measures)	A
CFM_{Pre}	Verified air leakage rate at 25 Pa before duct sealing	CFM_{Pre}
CFM_{Post}	Verified air leakage rate after duct sealing at 25 Pa (not required for ADS savings)	CFM_{Post}
	Heating fuel type (e.g., electric resistance, heat pump, natural gas, oil, propane, etc.)	
	Heating system distribution type (e.g., forced air with fan, heat pump, resistance, radiator, etc.)	

Nomenclature

Table B: 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 25 Pa	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 One*
REM	Savings modeled using Ekotrope RATER 4.0.0 software	per CFM		**Ref [1]**

Retrofit Gross Energy Savings, Electric

Table C: Electric Duct Blaster Savings, kWh per CFM Reduction at 25 Pa, see Note [3]

	$REM_{Heating}$ for Heating			REM_{AH}	$REM_{Cooling}$
	Electric Forced Air	Heat Pumps	Geothermal	Heating Fan (Note [3])	Central A/C Cooling
Savings per CFM reduction	13.494	5.971	4.089	0.883	1.780

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 A/C:

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

Retrofit Gross Energy Savings, Fossil Fuel

Table D: 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	0.058	0.415	0.559	0.630

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

Example: *Duct sealing at 25 Pa was performed in a 2,400 ft*^{2} *1960's ranch style home in Hartford, Conn. The home is primarily heated by a natural gas furnace and cooled by Central A/C. 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?* ***Note:*** *This home has fossil fuel, air handler (fan), and cooling savings.*

Using the equation for natural gas heating savings:

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

$$ACCF_H = 0.559 \times (850 - 775)$$

$$ACCF_H = 25.5\,Ccf \quad ACCF_H = 41.925Ccf$$

Using the equation for electric heating fan savings:

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

$$AKWH_H = 1.100 \times (850 - 775) \quad AKWH_H = 0.883 \times (850 - 775)$$

$$AKWH_H = 82.5\,kWh \quad AKWH_H = 66.225$$

Using the equation for Central A/C savings:

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

$$AKWH_C = 1.780 \times (850 - 775)$$

$$AKWH_C = 133.5kWh$$

Retrofit Gross Seasonal Peak Demand Savings, Electric (winter and summer)

Table E: 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 A/C Cooling
Savings per CFM reduction	0.0132	0.0132	0.0044	0.00	0.0015

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

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

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

Retrofit Gross Seasonal Peak Demand Savings, Natural Gas

$$PD_H = ACCF_H \times PDF_H$$

Retrofit Gross Peak Demand Savings, Example

Example: *Duct sealing at 25 Pa was performed in a 2,400 ft² 1960's ranch style home in Hartford, Conn. The home is primarily heated by a heat pump and cooled by Central A/C. 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:

($REM_{\mathbf{WKW}}$ = 0.0158 kW per CFM)

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

$$WKW_H = 0.0132 \times (850 - 775)$$

$$WKW_H = 0.99\ kW$$

Using the equation for summer demand savings (REMSKW = 0.0015 kW per CFM):

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

$$SKW_C = 0.0023 \times (850 - 775)\ SKW_C = 0.0015 \times (850 - 775)$$

$$SKW_C = 0.173\ kW\ SKW_C = 0.1125 kW$$

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:

$$PD_H = ACCF_H \times PDF_H$$

$$PD_H = 41.925 \times 0.00977\ Ccf$$

$$PD_H = 0.409\ Ccf$$

Changes from Last Version

- Revised savings factors based on the new study and simulation results, **Ref [1]**.
- Revised examples with new savings factors.

References

[1] Analysis of Energy Savings for Building Envelope Infiltration Reductions and Duct Leakage to Outside Reductions, MaGrann Associates, Aug. 3, 2021.

[2] Residential Central A/C Regional Evaluation, ADM Associates, Inc., Final Report, Nov. 2009.

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.

[2] 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.

4.2.6 HEAT PUMP – DUCTLESS

Description of Measure

Installation of an energy-efficient ductless air source heat pump as replacement of a working, less-efficient electric heating system, including ductless heat pumps and electric resistance heating or replacement of a fossil fuel-based heating system.

Savings Methodology

Savings methodology is based on *Ductless Mini-split Heat Pump Impact Evaluation*, Dec. 30, 2016, Cadmus (**Ref [1]**). Energy savings for DHPs are determined by:

- Savings based on equivalent full hours from the study; or
- By performing a custom analysis such as DOE-2 or Billing analysis [PRISM] (**Note [2] and [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.

A DHP installed in an existing home with electric resistance heating system is considered to have Retrofit Savings. A DHP installed in a home with fossil fuel heating system is considered to have Lost Opportunity Savings (or new construction).

Note: *The savings here are not to be applied to a heat pump with ducting. Only systems without ducts are addressed by this measure. The savings are independent of the number of zones (air handlers) installed.*

Inputs

Table A: Inputs

Symbol	Description
$HSPF_I$	Heating season performance factor, installed
$SEER_I$	Seasonal Energy Efficiency Ratio, installed
CAP_C	Nominal cooling capacity, Btu/hr
CAP_H	Nominal heating capacity, Btu/hr

Nomenclature

Table B: Nomenclature

Symbol	Description	Units	Values	Comments
1 Ton	Capacity, nominal tonnage	Tons	12,000 Btu/hr	Unit conversion
AKWH	Annual electric energy savings	kWh		
CAP_C	Nominal cooling capacity	Btu/hr		Input
CAP_H	Nominal heating capacity	Btu/hr		Input
$EFLH_H$	Equivalent full load hours, heating	hr	535	**Ref [2]**,
$EFLH_C$	Equivalent full load hours, cooling	hr	218	**Ref [1]**, p. 6
$HSPF_B$	Heating season performance factor, baseline	Btu/Watt-hr	8.2 – Lost Opportunity	**Ref [2]**
$HSPF_E$	Heating Season Performance Factor, existing	Btu/Watt-hr	- Site-specific pre-existing equipment HSPF for less efficient DHP units - 3.412 for electric resistance	**Note [1]**
$HSPF_I$	Heating Season Performance Factor, installed	Btu/Watt-hr		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		
SCF	Summer coincident factor		0.232	**Ref 3**
WKW	Winter demand savings	kW		
WCF	Winter coincidence factor		0.161	**Ref 3**

Retrofit Gross Energy Savings, Electric

Heating:

$$AKWH_H = CAP_H \times \left(\frac{1}{HSPF_E} - \frac{1}{HSPF_I}\right) \times EFLH_H \times \frac{1}{1000}$$

Cooling:

$$AKWH_C = CAP_C \times \left(\frac{1}{SEER_E} - \frac{1}{SEER_I}\right) \times EFLH_C \times \frac{1}{1000}$$

Retrofit Gross Energy Savings, Example

Example: *An energy-efficient DHP is installed in an existing home with electric resistance heat and existing cooling system with 10.1 SEER. 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:

$$AKWH_H = CAP_H \times \left(\frac{1}{HSPF_E} - \frac{1}{HSPF_I}\right) \times EFLH_H \times \frac{1}{1000}$$

$$AKWH_H = 24{,}000 \times \left(\frac{1}{3.413} - \frac{1}{11}\right) \times 535 \times \frac{1}{1{,}000} = 2{,}593.9\ kWh$$

Using the equation for annual electric cooling savings:

$$AKWH_C = CAP_C \times \left(\frac{1}{SEER_E} - \frac{1}{SEER_I}\right) \times EFLH_C \times \frac{1}{1000}$$

$$AKWH_C = 28{,}000 \times \left(\frac{1}{10.1} - \frac{1}{22}\right) \times 218 \times \frac{1}{1000} = 327 kWh$$

Retrofit Gross Seasonal Peak Demand Savings, Electric (winter and summer)

Winter demand savings:

WKW= 0

$$WKW = \frac{CAP_{H,5F}}{3.412} \times \left(1 - \frac{1}{COP_{H,5F}}\right) \times WCF$$

Summer demand savings:

$$SKW = CAP_C \times \left(\frac{1}{SEER_E} - \frac{1}{SEER_I}\right) \times SCF \times \frac{1}{1000}$$

Retrofit Gross Peak Demand Savings, Example

Example: *An energy-efficient DHP is installed in an existing home with electric resistance heat. The rated heating capacity is 24,000 Btu, rated cooling capacity is 24,000 Btu, installed HSPF is 11, the installed SEER is 22. What are the annual summer and winter demand savings?*

Using the equation for summer demand savings:

$$SKW = CAP_C \times \left(\frac{1}{SEER_E} - \frac{1}{SEER_I}\right) \times SCF \times \frac{1}{1000}$$

$$SKW = 24{,}000 \times \left(\frac{1}{10.1} - \frac{1}{22}\right) \times .232 \times \frac{1}{1000} = .30\ kW$$

Using the equation for winter demand savings:

$$WKW = CAP_H \times \left(\frac{1}{HSPF_E} - \frac{1}{HSPF_I}\right) \times WCF \times \frac{1}{1000}$$

$$WKW = 28{,}000 \times \left(\frac{1}{3.413} - \frac{1}{11}\right) \times .161 \times \frac{1}{1000} = 0.91$$

Lost Opportunity Gross Energy Savings, Electric

Heating:

$$AKWH_H = CAP_H \times \left(\frac{1}{HSPF_B} - \frac{1}{HSPF_I}\right) \times EFLH_H \times \frac{1}{1000}$$

Cooling:

$$AKWH_C = CAP_C \times \left(\frac{1}{SEER_B} - \frac{1}{SEER_I}\right) \times EFLH_C \times \frac{1}{1000}$$

Lost Opportunity Gross Seasonal Peak Demand Savings, Electric (winter and summer)

Winter demand savings:

$$WKW = CAP_H \times \left(\frac{1}{HSPF_B} - \frac{1}{HSPF_I} \right) \times WCF \times \frac{1}{1000}$$

Summer demand savings:

$$SKW = CAP_C \times \left(\frac{1}{SEER_B} - \frac{1}{SEER_I} \right) \times SCF \times \frac{1}{1000}$$

Changes from Last Version

- Updated the Equivalent Full Load Hours – Heating based on the *Ductless Mini-split Heat Pump Survey* (see **Ref [2]**).
- Updated SCF and WKW, **Ref [3].**
- Changed WKW savings for Retrofit Savings.

References

[1] *Ductless Mini-Split Heat Pump Study*, Final Report, Cadmus, Dec. 30, 2016, p. 5, see Table ES-3.

[2] Energy & Resource Solutions, "R1705 R1609 MF Baseline and Weatherization Opportunity Study," Oct. 10, 2019, p. 42, see Table 4-22, Available online at: https://www.energizect.com/sites/default/files/R1705-1609%20MF%20Baseline%20Weatherization%20Study_Final%20Report_10.10.19.pdf.

[3] CF value adapted from Cadmus "Ductless Mini-Split Heat Pump Impact Evaluation" , Table 7. (2016). Available online at: http://www.ripuc.ri.gov/eventsactions/docket/4755-TRM-DMSHP%20Evaluation%20Report%2012-30-2016.pdf. Since the CADMUS study defines CF only for on-peak hours, it required conversion to Seasonal Peak value. This was done by obtaining a regression between NE on-peak and seasonal-peak values from a 2011 KEMA Load shape study. See Table 0-5 ISO, values corresponding to Seasonal peak for NE-south coastal. This regression suggested using a 1.29 factor to convert to Seasonal Peak CF.

Notes

[1] The minimum heating efficiency standard set by the US government effective Jan. 1, 2015 for DHPs is 8.2 HSPF and cooling efficiency is 14.0 SEER.

[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. Available online at: 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 and 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. Available online at: http://www.doe2.com/.

4.2.7 PACKAGE TERMINAL HEAT PUMP

Description of Measure

Installation of a new energy-efficient packaged terminal heat pump.

Savings Methodology

The savings methodology for a package terminal heat pump (PTHP) is calculated from the 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 Four*.

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 *Measure 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 Four*.

Inputs

Table A: 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, baseline	Btu/Watt-hr
EER_I	Energy Efficiency Ratio, installed	Btu/Watt-hr
COP_B	Coefficient of performance, baseline	Btu/Watt-hr
COP_E	Coefficient of performance, existing	Watt/Watt
COP_I	Coefficient of performance, installed	Watt/Watt

Nomenclature

Table B: Nomenclature

Symbol	Description	Units	Values	Comments
1 Ton	Capacity, nominal tonnage	Tons	12,000 Btu/hr	Unit conversion
AKWH	Annual electric energy savings	kWh		
CAP_C	Cooling capacity	Btu/hr		Input
CAP_H	Heating capacity	Btu/hr		Input
COP_B	Coefficient of performance, baseline	Watt/Watt		**Ref [1]**
COP_I	Coefficient of performance, installed	Watt/Watt		Input
EER_B	Energy Efficiency Ratio, baseline	Btu/Watt-hr		**Ref [1]**
EER_I	Energy Efficiency Ratio, installed	Btu/Watt-hr		Input
$EFLH_H$	Heating equivalent full load hours	Hours	922 hours for uninsulated, pre-war buildings; 656 hours for buildings built prior to 1979; 510 hours for buildings built between 1979 and 2006; and 291 hours for buildings built after 2007	**Ref [3]**
$EFLH_C$	Cooling equivalent full load hours	Hours	626 hours for buildings built prior to 1979; 669 hours for buildings built between 1979 and 2006; and 812 hours for buildings built after 2007	**Ref [3]**
HR	Percent heating when heat pump is not in electric resistance back up		60%	**Note [1]**
PTHP	Packaged heat pump terminal			
SCF	Summer coincident factor		0.588	**Ref [4]**
SKW	Summer demand savings	kW		
WKW	Winter demand savings	kW	0	**Note [2]**

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

<u>Heating</u>:

<u>a) For replacement of a PTHP, use the following equations</u>:

$$AKWH_H = HR \times EFLH_H \times CAP_H \times \left(\frac{1}{COP_B} - \frac{1}{COP_I}\right) \times \frac{1}{3412}$$

$$\text{Where: } COP_B = 2.9 - \left(0.026 \times CAP_H \times \frac{1}{1{,}000}\right)$$

<u>b) For replacement of electric resistance system, use the following equations</u>:

$$AKWH_H = HR \text{ x } EFLH_H \text{ x } CAP_c \text{ x}\left(1 - \frac{1}{COP_B}\right) \times \frac{1}{3412})$$

$$\text{Where } COP_B = 2.9 - \left(0.026 \times CAP_H \times \frac{1}{1{,}000}\right)$$

<u>Cooling</u>:

$$AkWh_c = EFLH_C \times CAP_C \times \left(\frac{1}{EER_B} - \frac{1}{EER_I}\right) \times \frac{1}{1000}$$

$$\text{Where, } EER_B = 10.8 - \left(0.213 \times CAP_C \times \frac{1}{1{,}000}\right)$$

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

$$WKW = 0$$

$$SkW = CAP_C \times \left(\frac{1}{EER_B} - \frac{1}{EER_I}\right) \times \frac{1}{1000} \times SCF$$

$$Where, EER_B = 10.8 - \left(0.213 \times CAP_C \times \frac{1}{1{,}000}\right)$$

New Construction Project, Example

Example*:* *A PTHP is installed in a new construction project; the cooling capacity 12,000 Btu/hr, EER_I =12.5, and COP_I = 3.6.*

Annual Energy Savings:

Heating:

$$\mathrm{AKWH_H} = \mathrm{HR} \times \mathrm{EFLH_H} \times CAP_C \times \left(\frac{1}{COP_B} - \frac{1}{COP_I}\right) \times \frac{1}{3412}$$

$$COPB = 2.9\ (0.026 \times CAPH \times \frac{1}{1000}) = 2.588$$

$$AKWH_H = 0.6 \times 291 \times 12{,}000 \times \left(\frac{1}{2.588} - \frac{1}{3.6}\right) \times \frac{1}{3412} = 66.700\ kWh$$

Cooling:

$$AkWh_c = \mathrm{EFLH}_C \times CAP_C \times \left(\frac{1}{EER_B} - \frac{1}{EER_I}\right) \times \frac{1}{1000}$$

$$\text{Where } EER_B = 14 - \left(0.3 \times CAP_C \times \frac{1}{1000}\right) = 10.4$$

$$AkWh_c = 812 \times 12{,}000 \times \left(\frac{1}{10.4} - \frac{1}{12.5}\right) \times \frac{1}{1000} = 157.40\ kWh$$

Peak Demand Savings:

Heating:

WKW = 0

Cooling:

$$SkW = CAP_C \times \left(\frac{1}{EER_B} - \frac{1}{EER_I}\right) \times \frac{1}{1000} \times SCF$$

$$\text{Where } EER_B = -10.8 - \left(0.213 \times 12{,}000 \times \frac{1}{1000}\right) = 8.244$$

$$SkW = 12{,}000 \times \left(\frac{1}{8.244} - \frac{1}{12.5}\right) \times \frac{1}{1000} \times 0.588 = 0.291\ kW$$

Changes from Last Version

- Updated the EER_B and COP_b based on the IECC 2021.
- Revised EFLH and SCF values.
- Revised equations and examples to reflect new EFLH method.
- Removed SA values from *Table B* and removed corresponding Note.
- Removed reference to US DOE document and added IECC 2021 reference under **Ref (1)**.
- Revised EERb value in SKW (summer demand savings) per IECC 2021 and example with updated COP_b based on the IECC 2021.

References

[1] EER_B and COP_B varies per equipment based on IECC2021, Table C403.3.2(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 A/C Regional Evaluation*, ADM Associates Inc.," Tables 4-7 and 4-8, pp. 4-9.

[3] Hours adapted from NY TRM v7 Appendix G Poughkeepsie, NY location values which are based on DOE-2.2 simulations of a set of prototypical residential buildings defined in the following database: 004-2005 Database for Energy Efficiency Resources (DEER) Update Study, Final Report, Itron, Inc. Vancouver, WA. December 2005.

[4] Based on the C&I Unitary HVAC Load Shape Project Final Report, KEMA, 2011. Final values are presented in Metoyer, Jarred, "Report Revision Memo," KEMA, August 2011.

Notes

[1] HR = 60%, is percent heating when the heat pump is not in electric resistance back up, based on Hartford, Conn. BIN analysis.

[2] 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.

4.2.8 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]** and **Ref [3]**) and is recognized as an American National Standard. For new homes, the ENERGY STAR Inspection Checklist for National Programs Requirements V3.0 would be used (**Ref [4]** and **Ref [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; and
4. Installed with the proper amount of refrigerant.

Estimated savings potential (*Table A*) 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 A/C 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 A: QIV, Performed with New Residential A/C 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 QIV savings being estimated for this measure (*Table B*) are based on the low end of the range.

Table B: Estimated QIV Savings

	Cooling	Heating
Refrigerant charge	2%	
Airflow	2%	
Sizing	3%	
Duct sealing	15%	11%
Total	**22%**	**11%**

Inputs

Table C: Inputs

Symbol	Description
CAP_C	Nominal cooling capacity, Btu
Ton	Capacity of the equipment converted to tons

Nomenclature

Table D: Inputs

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 Two*
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]**):*

$$AkWHc = 79.64 \times \frac{CAPc}{12{,}000\,\frac{BTU}{Ton}}$$

Heating savings:

Using the results of 79.64 kWh duct sealing savings from the above equation and the relationship of savings factor of 1.78 from *Table C* in the 2022 PSD manual for *Measure 4.2.5: Duct Sealing*. Cooling savings per CFM reduction is 1.78 kWh. Therefore, for 79.64 kWh savings, there is a 44.74 CFM reduction.

$$CFM_{savings} = \frac{79.64}{1.78} = 44.74\ {}^{CFM}/_{ton}$$

Using *Measure 4.2.5*'s duct sealing savings factors and based on system type, the savings can be summarized in *Table E* below.

Table E: Savings Calculation

System Type	$AKWH_C$	$AKWH_H$
Central A/C	$AkWHc = 79.64 \times \frac{CAPc}{12{,}000\,\frac{BTU}{Ton}}$	
Heat pump	$AkWHc = 79.64 \times \frac{CAPc}{12{,}000\,\frac{BTU}{Ton}}$	$AkWHh = 267.15 \times \frac{CAPc}{12{,}000\,\frac{BTU}{Ton}}$
Geothermal heat pump	$AkWHc = 79.64 \times \frac{CAPc}{12{,}000\,\frac{BTU}{Ton}}$	$AkWHh = 182.95 \times \frac{CAPc}{12{,}000\,\frac{BTU}{Ton}}$
Furnace (fan electric savings)		$AkWHh = 39.50 \times \frac{CAPc}{12{,}000\,\frac{BTU}{Ton}}$

Retrofit Gross Energy Savings, Fossil Fuel

$$ACCF_H = 25.01 \times \frac{CAPc}{12{,}000\,\frac{BTU}{Ton}}$$

$$AOG_H = 25.01 \times \frac{CAPc}{12{,}000\,\frac{BTU}{Ton}}$$

$$APG_H = 28.19 \times \frac{CAPc}{12{,}000\,\frac{BTU}{Ton}}$$

Retrofit Gross Energy Savings, Example

Example: *A 1980's home has a combination natural gas furnace with a 36,000 Btu (3 tons) Central A/C system. QIV is performed on the systems. What are the energy savings?*

Using the equation for cooling savings:

$$AkWHc = 79.64\ \times \frac{CAPc}{12{,}000\,\frac{BTU}{Ton}}$$

$$AkWHc = 79.64\ \times \frac{36{,}000}{12{,}000\,\frac{BTU}{Ton}} = 238.9\ kWh$$

Using the equation for heating fan energy:

$$AkWHh = 39.50\ \times \frac{CAPc}{12{,}000\,\frac{BTU}{Ton}} = 39.50\ \times \frac{36{,}000}{12{,}000} = 118.52\ kwh$$

Using the equation for natural gas heating:

$$ACCFH = 25.01\ \times \frac{CAPc}{12{,}000\,\frac{BTU}{Ton}} = 25.01\ \times \frac{36{,}000}{12{,}000} = 75.03\ ccf$$

Retrofit Gross Seasonal Peak Demand Savings, Electric (winter and summer)

The new residential Central A/C uses 0.45kW per ton (**Ref [1]**). Therefore:

Annual Summer kW Savings = Percent Savings x0.45x Tons

$$SKW = 0.099\ \times \frac{CAPc}{12{,}000\,\frac{BTU}{Ton}}$$

<u>Using the CFM savings from Section 5 and peak savings per CFM from the 2022 PSD manual Measure 4.2.9, the winter demand savings for heat pumps only are as follows</u>:

$$WKW = 0.587 \times \frac{CAP_C}{12{,}000}$$

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

$$PD_H = ACCF_H \times PDF_H$$

<u>Retrofit Gross Peak Demand Savings, Example</u>

Example: *A 1980's home has a 36,000 Btu (3 tons) heat pump system. QIV is performed on the system. What are the summer and winter demand savings?*

<u>For cooling savings</u>:

$$SKW = 0.099 \times \frac{CAPc}{12{,}000 \frac{BTU}{Ton}}$$

$$SKW = 0.106 \times \frac{36{,}000}{12{,}000} = 0.32kW$$

$$SKW = 0.099 \times \frac{CAPc}{12{,}000 \frac{BTU}{Ton}}$$
$$= 0.099 \times \frac{36{,}000}{12{,}000 \frac{BTU}{Ton}}$$
$$= 0.297\ kW$$

<u>For heat pump savings</u>:

$$WKW = 0.587 \times \frac{CAP_C}{12{,}000}$$

$$WKW = 0.587 \times \frac{36{,}000}{12{,}000} = 1.76kW$$

Changes from Last Version

- *Updated the saving factors based on Measure 4.5.2 Duct Sealing.*
- Updated examples.
- Updated references.

References

[1] *Central Air Conditioning Impact and Process Evaluation*, NMR Group, Inc., May 30, 2014.

[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, Available online at: www.energystar.gov.

[5] ENERGY STAR Homes Inspection Checklist, Available online at: www.energystar.gov.

[6] ENERGY STAR Quality Installation, Revised Jun. 1, 2013, Available online at: http://www.energystar.gov/index.cfm?c=hvac_install.hvac_install_index.

Notes

[1] The average new residential Central A/C uses 362 kWh/Ton annually (**Ref [1]**).

Annual cooling kWh savings = Percent savings x 362 x Tons, where:

Annual cooling savings (Refrigerant Charge) = 2% x 362 x tons = 7.24x tons

Annual cooling savings (Airflow) = 2% x 362 x tons = 7.24x tons

Annual cooling savings (Sizing) = 3% x 362x tons = 10.86x tons

Annual cooling savings (Duct Sealing) = 15% x 362x tons = 54.3tons, where;

Total cooling savings = 22% x 362x tons = 79.64 $AKWH_c$/ton

$$Ton = \frac{CAP_C}{12{,}000\ ^{BTU}/_{ton}}$$

$$kWHc = 79.64 \times \frac{CAPc}{12{,}000\ \frac{BTU}{Ton}}$$

4.2.9 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 or 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 (i.e., supply basement, return basement, supply attic, and return attic), under typical conditions listed in **Note [1]**. Cooling savings should be reported for homes equipped with Central A/C 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 Insulation 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 A/C.*

Inputs

Table A: Inputs

Symbol	Description	Units
A	Surface area of duct area being insulated	ft^2
	System/fuel type (e.g., heat pump, natural gas furnace, oil furnace, Central A/C, 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 (e.g., forced air with fan, heat pump, resistance, radiator, etc.)	

Nomenclature

Table B: 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	*Table C* and *Table D*	**Ref [2]**
DI_C	Annual cooling savings per square foot	various	*Table C* and *Table D*	**Ref [2]**
PD_H	Natural gas peak day savings - heating	ccf		
PDF_H	Natural gas peak day factor - heating		0.00977	*Appendix Two*
SKW	Summer demand savings	kW		
SPF	Summer peak factor	W/kWh	0.017	**Ref [1]**
WKW	Winter demand savings	kW		
WPF	Winter peak factor	W/kWh	0.570	**Ref [1]**

Retrofit Gross Energy Savings, Electric

Table C: Annual Savings per ft² for Homes with Heat Pump or Central A/C

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 a heat pump providing cooling:

$$AKWH_C = DI_C \times A$$

Retrofit Gross Energy Savings, Fossil Fuel

Table D: Annual Savings per ft² for Homes with Fossil Fuel

Duct Location	Heating Savings per ft²	
	DI_H	Unit
Supply basement	0.1187	MMBtu/ ft²
Return basement	0.02866	MMBtu/ ft²
Supply attic	0.1316	MMBtu/ ft²
Return attic	0.03816	MMBtu/ ft²

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 A/C.*

Note: *When installing Duct Insulation with other Envelope measures and/or Duct Sealing measures reduce Annual Heating and Cooling savings by 16%.* ***Ref [3]***

Retrofit Gross Energy Savings, Example

Example: *A Cape Cod style home has a natural gas furnace. It is also equipped with a Central A/C system for cooling. Approximately 50 ft² 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 A/C, 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 A/C:

$$SKW = \frac{SPF \times DI_C \times A}{1{,}000\ ^{W}\!/_{kW}}$$

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

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

- Formatting changes.

References

[1] *Evaluation of the Weatherization Residential Assistance Partnership (WRAP) and Helps Programs,* conducted by KEMA, Sep. 2010, pp. 1-11, see Table ES-9.

[2] North American Insulation Manufacturers Association ("NAIMA"), 3E Plus software tool, Version 4.1, Rel. 2012.

[3] *Methodology for Estimated Energy Savings from Cost-Effective Air Sealing and Insulating,* United States Environmental Protection Agency, https://www.energystar.gov/campaign/seal_insulate/methodology, *last accessed Jun. 1, 2021.*

[1] **Table E: 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

4.2.10 BOILERS

Description of Measure

Installation of an energy-efficient boiler.

Savings Methodology

The fossil fuel savings for this measure are calculated using the equation from a boilers results Connecticut (**Ref [1]**). Hot water savings are also estimated. Hot water savings are calculated based on the hot water load used in *Water Heater: Measure 4.5.3*.

Energy savings resulting from the removal of units in working condition are calculated as follows:

Lost Opportunity measure:

Lost Opportunity savings are calculated according then installed AFUE based on verified savings data from **Ref [1]**.

Retrofit measure:

Retrofit measures use 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.

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 Four*.

Inputs

Table A: Inputs

Symbol	Description	Units
	Heating fuel (e.g., natural gas, oil, and propane)	
$AFUE_E$	AFUE, existing (if available)	%
$AFUE_I$	AFUE, installed	%

Nomenclature

Table B: Nomenclature

Symbol	Description	Units	Values	Comments
AF	Adjustment factor		0.98	Use for Condensing Boilers **Ref [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		
$ACCF_W$	Annual natural gas savings - water heating	ccf/yr		
ADHW	Annual domestic water heating load	Btu/yr	9,630,521	From *4.5.3: Water Heater Measure*
$AFUE_B$	Annual fuel utilization efficiency, baseline	%	85% Gas/Propane 84% Oil	**Ref (1)**
$AFUE_E$	Annual fuel utilization efficiency, existing	%	Actual Rated if unknown use 80%	
$AFUE_I$	Annual fuel utilization efficiency, installed	%		Input
EUL	Effective useful life			*Appendix Four*
HF	Average heating factor based on a home's heat load	Btu/ Year	85,200,000	**Ref [1]**
PD	Natural gas peak day savings	ccf/yr		
PD_H	Natural gas peak day savings – heating	ccf/yr		
PD_W	Natural gas peak day savings – water heating	ccf/yr		
PDF_H	Natural gas peak day factor – heating		0.00977	*Appendix One*
PDF_W	Natural gas peak day factor – water heating		0.00321	*Appendix One*
RUL	Remaining useful life			*Appendix Four*

Lost Opportunity Gross Energy Savings, Fossil Fuel

Savings by heating fuel:

$$ABTU_H = HF \times \left(\frac{1}{AFUE_B} - \frac{1}{AFUE_I x0.98} \right) = 85{,}200{,}000 \times \left(1/.85 - \frac{1}{AFUE_I x0.98} \right)$$

$$ACCF_H = \frac{ABTU_H}{102{,}900\ ^{Btu}/_{Ccf}}$$

$$AOG_H = \frac{ABTU_H}{138{,}690\,{}^{Btu}/_{Gal}}$$

$$APG_H = \frac{ABTU_H}{91{,}330\,{}^{Btu}/_{Gal}}$$

Water heating savings by water heating fuel:

$$ABTU_W = 9{,}630{,}521 \times \left(\frac{1}{AFUE_B} - \frac{1}{AFUE_I x 0.98}\right)$$

$$ACCF_W = \frac{ABTU_W}{102{,}900\,{}^{Btu}/_{Ccf}}$$

$$ACCF_W = \frac{ABTU_W}{138{,}690\,{}^{Btu}/_{Ccf}}$$

$$ACCF_W = \frac{ABTU_W}{91{,}330\,{}^{Btu}/_{Ccf}}$$

Lost Opportunity Gross Energy Savings, Example

Example: *A boiler is installed in a natural gas-heated home. The installed boiler has an* $AFUE_I$ *= 95% or 0.95.*

$$ABTU_H = 85{,}200{,}000 \times \left(\frac{1}{0.85} - \frac{1}{AFUE_I X 0.98}\right) = 85{,}200{,}000 \times \left(\frac{1}{0.85} - \frac{1}{0.95x0.98}\right)$$

$$ABTU_H = 8{,}720{,}793.58\ Btu$$

$$ACCF_H = \frac{8{,}720{,}793.58\ Btu}{102{,}900\,{}^{Btu}/_{Ccf}} ACCF_H = 84.8\ Ccf$$

Water heating:

$$ABTU_W = 9{,}630{,}521 \times \left(\frac{1}{AFUE_B} - \frac{1}{AFUE_I x 0.98}\right) = 9{,}630{,}521 \times \left(\frac{1}{.85} - \frac{1}{.95x0.98}\right)$$

$$ABTU_W = 985{,}749.7 Btu$$

$$ACCF_W = \frac{985{,}749.7 Btu}{102{,}900\,{}^{Btu}/_{ccf}}$$

$$ACCF_W = 9.6\ ccf$$

Total:

$$ACCF = ACCF_H + ACCF_W$$

$$ACCF = 83.8\ ^{ccf}/_{yr} + 9.6\ ^{ccf}/_{yr}$$

$$ACCF = 93.4\ ^{ccf}/_{yr}$$

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:

$$PD_H = 84.75 \times 0.00977$$
$$PD_H = 0.819\ Ccf$$

$$PD_W = 9.6 \times 0.00321$$
$$PD_W = 0.031\ ccf$$

Total:

$$PD = PD_H + PD_W$$

$$PD = 0.819 + 0.031$$

$$PD = 0.85\ ccf$$

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.*

$$ABTU_H = 85{,}200{,}000 \times \left(\frac{1}{AFUE_E} - \frac{1}{.85} \right)$$

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:

$$ABTU_W = ADHW \times \left(\frac{1}{AFUE_E} - \frac{1}{AFUE_B} \right)$$

$$ABTU_W = 9{,}630{,}521 \times \left(\frac{1}{AFUE_E} - \frac{1}{0.85} \right)$$

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

Example: *An existing natural gas boiler is being replaced with high-efficiency boiler, what are the early retirement savings? The existing boiler is used to heat domestic hot water in addition to heating, but the existing boiler AFUE is unknown.*

Example:

- $AFUE_E$ = 80% or 0.80 (default value); and
- $AFUE_B$ = 85% or 0.85 (baseline value).

Reminder: *Retrofit Savings do not depend on the efficiency of the new installed unit.*

$$ABTU_H = 85{,}200{,}000 \times \left(\frac{1}{0.80} - \frac{1}{0.85}\right)$$

$$ABTU_H = 6{,}264{,}706 BTU$$

$$ACCF_H = \frac{6{,}264{,}706 BTU}{102{,}900 \, {}^{BTU}/_{CCF}}$$

$$ACCF_H = 60.88 CCF$$

Water heating:

$$ABTU_W = 9{,}630{,}521 \times \left(\frac{1}{0.80} - \frac{1}{0.85}\right)$$

$$ABTU_W = 708{,}126.5 BTU$$

$$ACCF_W = \frac{708{,}126.5 BTU}{102{,}900 \, {}^{BTU}/_{CCF}}$$

$$ACCF_W = 6.88 CCF$$

Total:

$$ACCF = ACCF_H + ACCF_W$$

$$ACCF = 60.88 CCF + 6.88\ ccf$$

$$ACCF = 67.76\ ccf$$

Retrofit Gross Peak Demand Savings, Example

For same example as above:

$$PD_H = 60.88 \times 0.00977$$
$$PD_H = 0.595 Ccf$$

$$PD_W = 8.0 \times 0.00321$$
$$PD_W = 0.025\ Ccf$$

$$PD = PD_H + PD_W$$
$$PD = 0.62\ Ccf$$

Changes from Last Version

- None.

References

[1] *CT HVAC and Water Heating Process and Impact Evaluation Report*, West Hill Energy and Computing, R1614/R1613, Jul. 19, 2018.

4.2.11 FURNACES

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 results from the Furnace Results Memorandum (**Ref [1]**). 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 Four*.

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*); and
- 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 Four*.

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

Table A: Inputs

Symbol	Description	Units
	Heating fuel (e.g., natural gas, oil, and propane)	
AFUEE	AFUE, existing (if available)	%
AFUEI	AFUE, installed	%
CAP_H	Furnace input heating capacity	Btu/Hr

Nomenclature

Table B: Nomenclature

Symbol	Description	Units	Values	Comments
$ABTU_H$	Annual Btu savings – heating	Btu		
$ACCF_H$	Annual natural gas savings – heating	ccf		
$AFUE_B$	AFUE of baseline furnace		85% for natural gas or propane, 83% for oil	**Ref [1]**
$AFUE_E$	AFUE of existing furnace		Actual rated natural gas, propane, or oil 78% if unknown	**Ref [2]**, Table 4
AOG_H	Annual oil savings – heating	Gallons		
APG_H	Annual propane savings – heating	Gallons		
$EFLH_M$	Equivalent full load heating hours for multifamily homes	Hr	995	**Ref [3]**
EUL	Effective useful life		20	*Appendix Four*
HF	Average heating factor based on home's heat load	Btu/year	77,500,000	**Ref [1]**
PD_H	Natural gas peak day savings – heating	ccf		
PDF_H	Natural gas peak day factor – heating		0.00977	*Appendix Two*
RUL	Remaining useful life	years	7.33	*Appendix Four*
CAP_H	Multifamily input heating capacity	41,098	Btu/hr	**Ref [4]**

Lost Opportunity Gross Energy Savings, Fossil Fuel (single-family homes)

$$ABTU_H = 77{,}500{,}000 \times \left(\frac{1}{.85} - \frac{1}{AFUE_I}\right)$$

Lost Opportunity Gross Energy Savings, Fossil Fuel (multifamily homes)

$$ABTU_H = EFLH \quad H \times CAP \quad H \times \left(\frac{1}{.85} - \frac{1}{AFUE_I}\right)$$

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

Example: *A new natural gas furnace with an AFUE of 96% is installed. What are the annual fossil fuel savings? Constant values include:*

- $AFUE_I$ = 96% or 0.96; and
- $AFUE_B$ = 85% or 0.85 (baseline value).

$$ABTU_H = 77{,}500{,}000 \times \left(\frac{1}{0.85} - \frac{1}{0.96} \right)$$
$$ABTU_H = 10{,}447{,}305$$
$$ACCF_H = \frac{10{,}447{,}3015}{102{,}900 \ {}^{Btu}\!/\!{}_{Ccf}}$$
$$ACCF_H = 101.5 \ Ccf$$

Lost Opportunity Gross Peak Day Savings, Natural Gas

$$PD_H = ACCF_H \times PDF_H$$

Lost Opportunity Gross Peak Demand Savings, Example

Example: *A new natural gas furnace with an AFUE of 95% is installed. What are the peak day natural gas savings?*

$$PD_H = 101.5 \times 0.00977$$
$$PD_H = 0..992 \ Ccf$$

Retrofit Gross Energy Savings, Fossil Fuel (single-family homes)

Reminder*: Retrofit Savings are the sum of Retirement Savings and Lost Opportunity Savings. This section presents the Retirement portion of savings.*

$$ABTU_H = 77{,}500{,}000 \times \left(\frac{1}{AFUE_E} - \frac{1}{AFUE_B} \right)$$

$$ABTU_H = 77{,}500{,}000 \times \left(\frac{1}{AFUE_E} - \frac{1}{0.85} \right)$$

Retrofit Gross Energy Savings, Fossil Fuel (multifamily homes)

$$ABTU_H = EFLH_H \times CAP_H \times \left(\frac{1}{AFUE_E} - \frac{1}{AFUE_B} \right)$$

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: ECMs.*

Retrofit Gross Energy Savings, Example

Example: *An existing natural gas furnace with unknown AFUE. 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); and
- $AFUE_B$= 85% or 0.85 (baseline value).

$$ABTU_H = 77{,}500{,}000 \times \left(\frac{1}{0.78} - \frac{1}{0.85}\right)$$
$$ABTU_H = 8{,}182{,}504\ Btu$$
$$ACCF_H = \frac{8{,}182{,}504\ Btu}{102{,}900\ {}^{Btu}\!/\!{}_{Ccf}}$$
$$ACCF_H = 79.5\ Ccf$$

Retrofit Gross Peak Day Savings, Natural Gas

$$PD_H = ACCF_H \times PDF_H$$

Retrofit Gross Peak Demand Savings, Example

Example: *An existing natural gas furnace was installed in 1985. What are the retirement peak day natural gas savings?*

$$PD_H = 79.5 \times 0.00977$$
$$PD_H = 0.78\ Ccf$$

Changes from Last Version

- Added nomenclature.
- Added Multifamily specific algorithm.
- RUL number revised and Reference added for MF Heating Capacity in *Table B*.

References

[1] *CT HVAC and Water Heating Process and impact Evaluation Report*, West Hill Energy and Computing, R161/R 1613, Jul. 19, 2018.

[2] Cadmus Group, "*High Efficiency Heating Equipment Impact Evaluation Final Report*," Mar. 2015, MA.

[3] R1614-R1613, West Hill Energy and Computing (2018), *CT HVAC and Water Heating Process and Impact Evaluation Report*.

[4] R1705-R11609, Multifamily Baseline and Weatherization Opportunity Study, Oct. 10, 2019.

4.2.12 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 the Home Energy Services Impact Evaluation by the Cadmus Group for the Electric and Natural Gas Program Administrators of Massachusetts (**Ref [1]**).

Inputs

Table A: Inputs

Symbol	Description
	Number of gas-fired boilers

Nomenclature

Table B: 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 One*
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

- None.

References

[1] The Cadmus Group, Inc. *Home Energy Services Impact Evaluation*. Prepared for the Electric and Natural Gas Program Administrators of Massachusetts, 2012.

4.2.13 ECM CIRCULATING PUMP

Description of Measure

Retrofit installation of an Electronically Commutated Motor (ECM) circulating pump to replace an existing circulating pump on a residential hydronic heating system.

Savings Methodology

Savings is based on Connecticut's Impact Evaluation of Residential HVAC and Water Heater Process and Impact Evaluation (**Ref [1]**).

Inputs

Table A: Inputs

Symbol	Description
	Number of ECM circulator pumps
Heat pump motor	For multifamily: use the same savings as below per **Ref [2]**

Nomenclature

Table B: Nomenclature

Symbol	Description	Units	Values	Comments
AKWH	Annual electric energy savings	kWh/yr	68	**Ref [1]**
SKW	Seasonal summer peak savings	kW	0	
WKW	Seasonal winter peak savings	kW	0.024	**Ref [1]**
CF_H	Seasonal winter peak coincidence factor		1.0	*Appendix One*

Retrofit Gross Annual Savings, Electric

- 68 kWh per year for both single and multifamily.

Retrofit Gross Seasonal Peak Demand Savings, Electric

Cooling:

$$SKW_C = 0$$

Heating:

WKW_H = 0.024 kW for both single and MF

Changes from Last Version

- Used same savings values for both single and multifamily.

References

[1] *R1614/R1613 CT HVAC and Water Heater Process and Impact Evaluation,* West Hill Energy and Computing, EMI Consulting & Lexicon Energy Consulting, Jul. 19, 2018, p. 86.

[2] *X1941 Multifamily Impact Evaluation, TRC 2021 "Ensure projects use the ECM pump (not VFD) calculator".*

4.2.14 WIFI THERMOSTAT

Description of Measure

This measure is the replacement of an existing manual or programmable residential thermostat with an ENERGY STAR-qualified smart thermostat.

Savings Methodology

A communicating thermostat which allows remote set point adjustment and control via remote application. System requires an outdoor air temperature algorithm in the control logic to operate heating and cooling systems. The savings are per unit.

Table A: Assumed Baselines

Baseline	Comments
Manual or programmable	

Inputs

Table B: Inputs

Symbol	Description	Units
	Program channel whether it is: 1. Direct install (where heating fuel, heating system, and cooling system are known and verified). 2. Midstream, retailer (where heating fuel, heating system, and cooling system are not collected or unknown).	
	No. of units installed	

Nomenclature

Table C: Nomenclature

Symbol	Description	Units	Comments
$AKWH_C$	Annual gross electric energy savings - cooling	kWh/yr	**Ref [1]**, **Ref [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	**Ref [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

Table D: Gross Energy Savings, Electric (single-family)

	$AKWH_C$	$AKWH_{H-ER}$	$AKWH_{H-HP}$	$AKWH_{H-GHP}$	Comments
When heating fuel and cooling system is known (direct install)	64.0	637.5	318.7	212.5	**Ref [1]**
When heating fuel or cooling system is unknown (midstream, E-commerce, etc.). Additional gas, oil, propane savings from Measure 4.2.12, *Table B* should be claimed	25.0	NA	NA	NA	**Ref [5]**

Gross Seasonal Peak Demand Savings, Electric (winter and summer)

- None (see **Note [4]**).

Gross Energy Savings, Fossil Fuels

Table E: Gross Energy Savings, Fossil Fuels (single-family)

	$ACCF_H$	AGO_H	AGP_H	Comments
When heating fuel or cooling system is known (direct install)	30.2	22.4	34.1	**Ref [1]**
When heating fuel is unknown (midstream, E-commerce, etc.)	12.2	11.9	2.0	**Ref [5]**

Gross Peak Day Savings, Natural Gas

For direct install when the heating system is known:

$$PD_H = ACCF_H \times PDF_H \quad = 30.2X0.009770.295\ CCF$$

For midstream when the heating system is unknown:

$$PD_H = ACCF_H \times PDF_H \quad = 12.2\ x\ 0.00977 = 0.119\ ccf$$

Changes from Last Version

- No changes.

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*," Sep. 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*," Sep. 2012. Per p. 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.

[3] Navigant Consulting, "*Wi-Fi Thermostat Impact Evaluation--Secondary Research Study Memo*," 2018.

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-year measure life.

[4] Connecticut is not claiming any kW demand reductions at this time and will revisit this after the evaluation of any Connecticut-specific Wi-Fi Thermostat program.

[5] When existing fuel and cooling system are unknown, the savings are based on the NMR R1704 RASS saturation study reflecting the Central A/C penetration and fuel type in the state of Connecticut.

4.2.15 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

Table A: Gross Energy Savings, Fossil Fuels

Symbol	Description	Units
	Heating fuel (e.g., natural gas, oil, and propane)	

Nomenclature

Table B: Gross Energy Savings, Fossil Fuels

Symbol	Description	Units	Values	Comments
A	Heated area served by boiler or furnace	ft^2	2000 MF = 876	**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	%	For single family: AFUE Boiler= 80% for unknown, AFUE Furnace= 78% For multifamily: boiler AFUE = 88%, furnace AFUE = 92%	**Note [3]**
HF	Average heating factor based on home's heat load	Btu/ ft^2	38,750 for furnaces 42,600 for boilers	**Note [2]**

			MF = 20,300	
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 One*
PDF_W	Natural gas peak day factor – water heating		0.00321	*Appendix One*
ESF	Energy savings factor		0.02	**Ref [1]**

Gross Energy Savings, Fossil Fuel

$$ABTU_H = A \times HF \times (\frac{1}{AFUE_E}) \times ESF$$

$$ABTU_H = 2{,}000 \times 42600 \times \left(\frac{1}{.80}\right) \times 0.02 = 2{,}13{,}0000 Btu$$

Savings by heating fuel:

$$ACCF_H = \frac{2{,}1300000}{102{,}900} = 20.69 CCF$$

$$AOG_H = \frac{2{,}130000}{138{,}690} = 15.35 Gal$$

$$APG_H = \frac{2{,}13{,}0000}{91{,}330} = 23.32 Gal$$

Peak Day Savings, Natural Gas

$$PD_H = ACCF_H \times PDF_H$$

$$PD_H = 2220.69\ ccf \times 0.00977 = 0.219\ ccf\ 202ccf$$

Changes from Last Version

- No changes.
- $AFUE_E$ is 80% if unknown (for Boilers) & $AFUE_E$ is 78% if unknown (for Furnace) for single family is added to *Table B*.

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, Multifamily, and Commercial/Industrial Measures*, Version 3, Issue Date – Jun. 1, 2015, p. 98.

[2] Cadmus Group, "*High Efficiency Heating Equipment Impact Evaluation Final Report*", Mar. 2015. Massachusetts.

[3] Energy & Resource Solutions, "R1705 R1609 Multifamily Baseline and Weatherization Opportunity Study", Oct. 2019. Connecticut. https://www.energizect.com/sites/default/files/R1705-1609%20MF%20Baseline%20Weatherization%20Study_Final%20Report_10.10.19.pdf.

Notes

[1] Default value selected based on recent data from **Ref [2]**. This evaluation reported an average size of 2,000 sq. ft. for homes with boilers in Massachusetts. *Default multifamily value selected based on recent data from **Ref [3]**. This evaluation reported an average size of 876 sq. ft for multifamily units*

[2] Default value selected based on recent data from **Ref [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%. Default multifamily value calculated by scaling single-family Heating Factor and associated square footage by cited multifamily dwelling unit square footage from **Ref [3]**.

[3] The value of 80% and 78% is based on verified data from **Ref [2]**, Table 4, and Multifamily defaults are based on data from **Ref [3]**, see Table 4-27. Defaults should be used except in situations where either actual nameplate ratings or actual efficiency test data are available.

4.3 APPLIANCES

4.3.1 RESIDENTIAL APPLIANCES

Description of Measure

Installation of qualified appliances.

Savings Methodology

Energy savings for this Lost Opportunity measure are deemed. In the case of a retrofit, the savings calculator for ENERGY STAR-qualified appliances is located on the ENERGY STAR website (**Ref [1]**) and can be modified using the instructions in the Retrofit portion of the measure. Notice 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 natural gas demand savings are calculated as specified below. Refrigerator and freezer recycling savings are based on removing and properly recycling a secondary refrigerator or freezer in working condition, the summer and winter kW are obtained by dividing the annual kWh savings by 8,760 operating hours for the sake of establishing conservative peak demand.

Inputs

Table A: Inputs

Symbol	Description	Units
	No. of units purchased	

Nomenclature

Table B: Nomenclature

Symbol	Description	Units	Values	Comments
$ACCF_O$	Annual natural gas savings	ccf		
AKWH	Annual gross electric energy savings	kWh		
SKW	Average summer demand savings	kW		
WKW	Average winter demand savings	kW		
PD_O	Peak day gas savings	ccf		
EUL	Effective Useful Life: measure life of installed unit	years	*Appendix Four*	

Table C: Savings

	AKWH	SKW	WKW	Oil (Gal)	Propane (Gal)	Natural Gas (ccf)	Water (Gal)	Comments
Air cleaner/purifier	214	0.024	0.024					**Ref [1]**
Clothes washer, Tier I	88.1	0.009	0.012	0.14	0.44	0.29	823	**Note [1],] Ref [5]**
Clothes washer, Tier II	120.3	0.012	0.016	0.72	2.08	1.65	1795	**Note [1],** and **Ref [5]**
Clothes dryer (ENERGY STAR)	194	0.026	0.026					**Ref [2]**
Clothes dryer (hybrid)	412	0.05	0.05					**Ref [2]**
Clothes dryer (heat pump)	658	0.08	0.08					**Ref [2]**
Dehumidifier	229	0.007	0.00					**Ref [1]**
Dishwasher	11	0.00	0.00	0.16	0.16	0.01	87	**Note [1], Ref [5]**
Refrigerator Tier I (10% greater than ENERGY STAR)	59	0.007	0.006					**Ref [2]**
Refrigerator Tier II (15% greater than ENERGY STAR)	89	0.0105	0.008					**Ref [2]**
Room A/C	10.7	0.009	0.000					**Ref [2]**
Freezer, upright	44	0.005	0.004					**Ref [2]**
Freezer, chest	24	0.003	0.002					**Ref [2]**
Refrigerator recycling	794	0.09	0.09					**Ref [4]**
Freezer recycling	846	0.096	0.096					**Ref [4]**
Multifamily clothes washer (in unit)	27	0.003						**Ref [6]**
Multifamily clothes dryer	30	0.004						**Ref [6]**
Multifamily dishwasher	32	0.003						**Ref [6]**
Multifamily refrigerator	73	0.010						**Ref [6]**
Multifamily room A/C	13	0.011						**Ref [6]**

Retrofit Gross Energy Savings

1. Calculate Lost Opportunity Savings by using $AKWH_{Lost\ Opp}$ from *Table 4-XX*.
2. The retirement portion of the Retrofit ($AKWH_{retire}$) savings will be visible on the RESULTS sheet. For lifetime savings, use the below equation:

$$LKWH_{retrofit} = AKWH_{retire} \times RUL + AKWH_{LostOpp} \times EUL$$

Changes from Last Version

- Added refrigerator and freezer recycling measures.
- Updated savings for clothes washer and dish washers based on the RASS Draft Report (**Ref [5]**).

References

[1] R1973 Evaluation Studies.

[2] *Efficiency Vermont Technical Reference Manual*, last accessed on Aug. 30, 2018.

[3] ENERGY STAR Dehumidifiers website, last accessed Aug. 2, 2012, available online at: http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=DE E .

[4] *New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs*. Version 7, Issued Apr. 15, 2019, p. 44.

[5] The savings were prorated based on the new clothes washers loads and dishwasher cycles as recommended by the *R1706 Residential Appliance Saturation Survey and R1616/R1708 Residential Lighting Impact Saturation Studies*, Draft Report, Jun. 28, 2019, submitted by NMR Group, Inc.

[6] Multifamily appliances:

Energy & Resource Solutions, "*R1705 R1609 Multifamily Baseline and Weatherization Opportunity Study*," Oct. 2019, available online at: https://www.energizect.com/sites/default/files/R1705-1609%20MF%20Baseline%20Weatherization%20Study_Final%20Report_10.10.19.pdf.

Notes

[1] 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:

Table D: Estimated Fuel Mix

Water Heater Fuel				Clothes Dryer Heating Fuel		
Electric	**Gas**	**Oil**	**Propane**	**Electric**	**Gas**	**Propane**
30%	27%	41%	2%	93%	5%	2%

4.3.2 ELECTRONICS

Description of Measure

Purchase of a new ENERGY STAR qualified electronics equipment. Electronics equipment includes:

- Blu-Ray player;
- Computer monitors (displays);
- Cordless phones;
- Desktop computers;
- DVD player;
- Home theatre in a box systems;
- Laptop computers;
- Room air cleaners;
- Set-top boxes and cable boxes;
- Sound bars;
- Televisions; and
- Advanced power strips.

Savings Methodology

The savings estimates in *Table C* are for ENERGY STAR qualified electronics equipment versus conventional equipment (**Ref [1]** and **Ref [2]**).

Note: *No demand savings have been identified for this measure.*

Inputs

Table A: Inputs

Symbol	Description	Units
	No. of units purchased	

Nomenclature

Table B: Nomenclature

Symbol	Description	Units	Values	Comments
AKWH	Annual electric energy savings	kWh		*Table C*
SKW	Summer demand savings	kW	0	
WKW	Winter demand savings	kW	0	

Lost Opportunity Gross Energy Savings, Electric

The savings estimates in *Table C* are for ENERGY STAR qualified electronics equipment versus conventional equipment.

Table C: ENERGY STAR Electronics Annual Savings

Electronics Equipment	Energy Savings AKWH	Comments
Blu-ay player	4	ENERGY STAR calculator given in **Ref [1]** to find energy savings
Computer monitor (displays)	8	ENERGY STAR calculator given in **Ref [2]** to find energy savings
Cordless phones	4	ENERGY STAR calculator given in **Ref [1]** to find energy savings
Desktop computers	161	ENERGY STAR calculator given in **Ref [2]** to find energy savings
DVD player	6	ENERGY STAR calculator given in **Ref [1]** to find energy savings
Laptop computers	52	ENERGY STAR calculator given in **Ref [2]** to find energy savings
Televisions	30	ENERGY STAR calculator given in **Ref [1]** to find energy savings
Set-top boxes	69	**Ref [3]**
Sound bars	45	**Ref [4]**
Advanced power strips Tier I	117	**Ref [5]**
Advanced power strips Tier II (IR)	226	**Ref [5]**
Advanced power strips Tier II (IR-OS)	132	**Ref [5]**

Lost Opportunity Gross Seasonal Peak Demand Savings, Electric (winter and summer)

- WKW = 0;
- SKW = 0; and
- No demand savings are claimed for this measure.

Changes from Last Version

- Formatting changes.
- Updated advanced power strip values.
- Updated references.

References

[1] Savings Estimate for ENERGY STAR Qualified Consumer Electronics, ENERGY STAR Consumer Electronics Calculator, ENERGY STAR, last accessed on: Aug. 18, 2021. Available at: https://www.energystar.gov/sites/default/uploads/buildings/old/files/Consumer_Electronics_Calculator.xlsx

[2] Savings Estimate for ENERGY STAR Qualified Office Equipment, ENERGY STAR Office Equipment Savings Calculator, ENERGY STAR, last accessed on: Jul. 19, 2017. https://www.energystar.gov/sites/default/files/asset/document/Office%20Equipment%20Calculator.xlsx.

[3] Set Top Box Savings.xslx, last accessed on Jul. 26, 2017.

[4] Last accessed on: Aug 18, 2021, available online at: https://static1.squarespace.com/static/53c96e16e4b003bdba4f4fee/t/556d387fe4b0d8dc09b24c28/1433221247215/RPP+Methodology+for+Developing+UEC+Estimates_Final.pdf, (Sound bar Section).

[5] NMR Group, Inc., Advanced Power Strip Metering Study, *2018 NMR APS Metering Report,* 2018.

4.4 ENVELOPE

4.4.1 REM SAVINGS

Description of Measure

Residential Energy Modeling Savings for ENERGY STAR certified residential new construction.

Savings Methodology

An ENERGY STAR-certified Home must be certified through the Home Energy Rating System (HERS). ENERGY STAR certified Homes are limited to single-family homes or multifamily 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 (e.g., 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 lighting, thermal and mechanical efficiencies of the UDRH are set to baseline levels (**Note [2]**). Current UDRH values are based on the 2017 RNC Study (**Ref [1]**).

Inputs

Table A: Inputs

Symbol	Description
REM	REM simulation file submitted by HERS Rater

Lost Opportunity Gross Energy Savings, Electric

The UDRH report generates heating, cooling, lighting, and water heating consumption for the "as-built" home and the defined "base" home (i.e., *Table B*). The difference between those values is the energy savings. This savings is referred to as "REM" savings.

Table B: 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
Lighting	5.0	4.0	1.0

The REM savings above includes the effect of installing a programmable thermostat, so additional savings should not be claimed if one (or more) programmable thermostat(s) 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 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 (**Ref [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 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 – Gas.

Non-Energy Benefits

- Improves personal comfort and health. It also increases a home's durability and value.

Changes from Last Version

- Format changes.

References

[1] *R1602 Residential New Construction Program Baseline Study*, Dec. 5, 2017, NMR Group, Inc.

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/costs for new/existing single and multifamily 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.

4.4.2 INFILTRATION REDUCTION TESTING (BLOWER DOOR TEST)

Description of Measure

Blower Door Test equipment is used to verify infiltration reduction.

Savings Methodology

Energy modeling was conducted using Ekotrope RATER 4.0.0 software. Version 4.0.0 is the current version of the software. This tool is accredited by RESNET for HERS energy modeling and approved by the US Department of Energy for Section 45L tax credit verifications. The average energy savings in MMBtu and kWh were estimated from the results of the Ekotrope RATER simulations, then converted to the appropriate fuels using unit conversions and assumed distribution losses.

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 spaces. For multifamily units (defined as more than 4 units) that share 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 4.2.5).*

Inputs

Table A: Inputs

Symbol	Description
CFM_{Pre}	Infiltration before air sealing @ 50 Pa
CFM_{Post}	Infiltration after air sealing @ 50 Pa
	Heating fuel type (e.g., electric resistive, heat pump, natural gas, oil, propane, etc.)
	Heating system distribution type (e.g., forced air with fan, heat pump, resistive, radiator, etc.)

Nomenclature

Table B: 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
DLR50	Duct Leakage Reduction factor at 50 Pa			
PD_H	Natural gas peak day savings, heating	ccf		
PDF_H	Natural gas peak day factor, heating		0.00977	*Appendix One*
REM	Savings factor in energy units per CFM reduction based on Ekotrope RATER 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 C: Retrofit Electric Savings per CFM Reduction (at 50 Pa)

Measure	Symbol	Energy Savings	Units
Electric resistance heat	$REM_{Heating}$	2.840	kWh
Heat pump heating	$REM_{Heating}$	1.257	kWh
Geothermal heating	$REM_{Heating}$	0.861	kWh
Air handler heating (fan)	REM_{AH}	0.112	kWh
Cooling (central A/C only)	$REM_{Cooling}$	0.0594	kWh
Cooling (room A/C: window, sleeve, or PTAC) **Note [1]**	$REM_{Cooling}$	0.0169	kWh

For electric resistive, heat pump, or geothermal heating systems:

$$AKWH_H = REM_{\text{Heating}} \times (CFM_{Pre} - CFM_{Post} - DLR50) \times BF$$

$$DLR50 = 1.569 \times (LTO\ CFM25_{Pre} - LTO\ CFM25_{Post})$$

Where, LTO CFM25 are the pre- and post-measures duct blaster test results.

For Fossil Fuel heating with air handler unit:

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

For homes with cooling:

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

Retrofit Gross Energy Savings, Fossil Fuel

Table D: Retrofit Fossil Fuel Savings per CFM Reduction (at 50 Pa)

Measure	Symbol	Energy Savings	Units
Fossil fuel heating		0.012	MMBtu
Natural gas	REM_{NG}	0.118	ccf
Propane	$REM_{Propane}$	0.133	Gal
Oil	REM_{Oil}	0.087	Gal

For homes with natural gas heating system:

$$ACCF_H = REM_{NG} \times (CFM_{Pre} - CFM_{Post} - DLR50) \times BF$$

For homes with oil heating system:

$$AOG_H = REM_{Oil} \times (CFM_{Pre} - CFM_{Post} - DLR50) \times BF$$

For homes with propane heating system:

$$APG_H = REM_{\text{Propane}} \times (CFM_{Pre} - CFM_{Post} - DLR50) \times BF$$

Retrofit Gross Energy Savings, Example

Example: *A blower door test is performed in a 2,400 ft^2, 1940's Cape Cod style home in Hartford, Conn. The home is heated primarily by an oil boiler and cooled by a Room A/C. Blower door test equipment is used to measure the infiltration of the home at 50 Pa. The readings on the test equipment show CFM_{Pre} of 1,850 and CFM_{Post} of 1,575. No duct sealing measures are performed in between blower door tests. What are the electric and fossil fuel savings for this home?*

Oil heating savings may be calculated using the following equation:

$$AOG_H = REM_{Oil} \times (CFM_{Pre} - CFM_{Post} - DLR50) \text{ x BF}$$

$$AOG_H = 0.087 \times (1850 - 1575 - 0.00) \times 1 = 23.9\ {}^{\text{Gal-Oil}}/_{\text{yr}}$$

Cooling savings may also be claimed as follows:

$$AKWH_C = REM_{Cooling} \times (CFM_{Pre} - CFM_{Post} - DLR50) \text{ x BF}$$

$$AKWH_C = 0.0169 \times (1850 - 1575 - 0.00) \times 1 = 4.64\ {}^{kWh}/_{yr}$$

Retrofit Gross Seasonal Peak Demand Savings, Electric (winter and summer)

Table E: Demand Savings, kW per CFM Reduction (at 50 Pa)

Electric Resistance and Heat Pump	Geothermal - Retrofit	Central A/C and HP	Room A/C (Note [2])
REM_{WKW}	REM_{WKW}	REM_{SKW}	REM_{SKW}
0.00124	0.00038	0.00008	0.00002

$$WKW_H = REM_{WKW} \times (CFM_{Pre} - CFM_{Post} - DLR50) \text{ x BF}$$

$$SKW_C = REM_{SKW} \times (CFM_{Pre} - CFM_{Post} - DLR50) \text{ x BF}$$

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

Example: *For the above Retrofit example, what is the summer demand savings for this home?*

$$SKW_C = REM_{SKW} \times (CFM_{Pre} - CFM_{Post} - DLR50) \text{ x BF}$$

$$SKW_C = 0.00002 \times (1850 - 1575 - 0.00) \times 1 = 0.0055 \text{ kW}$$

Changes from Last Version

- Revised REM savings based on new study, **Ref [1]**.
- Updated equation to include duct leakage interactivity (DLR50).

References

[1] Analysis of Energy Savings for Building Envelope Infiltration Reductions and Duct Leakage to Outside Reductions, MaGrann Associates, Aug 3, 2021

[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, pp. iv, 22.

[4] ADM Associates, Inc., "*Residential Central A/C Regional Evaluation*," Sacramento, CA, 2009, pp. 4-4.

[5] O. Faakye & D. Griffiths, *Technical Report: Multifamily Envelope Leakage Model,* Consortium for Advanced Residential Buildings, Feb. 2014.

[6] *Estimating Energy Savings for Multifamily Air Sealing Measures*. Steven Winter Associates, Inc. Jul. 26, 2017.

Notes

[1] **Ref [5]** updated with results from **Ref [6]** were used.

[2] $$Calculated\ blower\ door\ CFM\ reduction = BF \times Measured\ CFM\ (Unguarded\ Blower\ Door\ Test)$$

$$BF = 0.7818\ - .0002 \times D + 0.0012 \times F$$

Where:

- **D** = Shared Surface Area (ft^2) between conditioned spaces.
- **F** = Envelope Perimeter (ft) is used to describe the sum of all the lengths of the edges of the unit, common and exterior surfaces.

[3] Room A/C cooling savings are derived from factors found in **Ref [2]**, **Ref [3]**, and **Ref [4]**.

4.4.3 WINDOW OR SLIDING GLASS DOOR REPLACEMENT

Description of Measure

Installation of an ENERGY STAR, or better, window/sliding glass door to replace an existing single pane or double pane window/sliding glass door that is between the conditioned space and the outdoors.

Savings Methodology

The measure's savings are calculated using the installed area of the replacement window and usage factors develop using RESFEN (**Ref [1]**) to model different window/sliding glass door types and heating fuels. The results of this analysis are shown in *Tables B* and *C*, which provide the annual usage based on existing conditions (window type). The energy savings are calculated by subtracting the heating fuel specific ENERGY STAR values from the existing conditions and then multiplying by the window/sliding glass door 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/sliding glass door is located in an unconditioned space such as an unheated porch, basement, or hallway.*

Inputs

Table A: Demand Savings, kW per CFM Reduction

Symbol	Description	Units
	Cooling system type of home	
	Heating fuel of home/heating system type	
D_H	Height of the window/sliding glass door	Inches
D_W	Width of the window/sliding glass door	Inches
U	Rated U Value of window/sliding glass door (not required for savings calculation)	Btu/ft^2 x h x ^{0}F

Nomenclature

Table B: Demand Savings, kW per CFM Reduction

Symbol	Description	Units	Values	Comments
A	Area of the window/sliding glass door	ft^2		
$ACCF_H$	Annual gas savings - heating	ccf/yr		
AEC	Annual electric cooling usage	$kWh/ft^2/yr$	*Table C*	**Note [2]**
AEH	Annual electric heating usage	$kWh/ft^2/yr$	*Table C*	**Note [2]**
AGU	Annual natural gas usage	$ccf/ ft^2/yr$	*Table D*	**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 D*	**Note [2]**
APG_H	Annual propane savings - heating	gallons/yr		
APU	Annual propane usage	$gal/ft^2/yr$	*Table D*	**Note [2]**
CF_S	Summer seasonal peak coincidence factor		0.59	*Appendix One*
D_H	Height of the window/sliding glass door	inch		
D_W	Width of the window/sliding glass door	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 One*
PD_H	Peak day savings - heating			
$..._b$	Baseline			
$..._{es}$	ENERGY STAR			**Ref [6]**
$..._{HP}$	Heat pump heating only			
$..._R$	Electric resistance heating only			
$..._{RAC}$	Room A/C (cooling only)			**Note [3]**

Retrofit Gross Energy Savings, Electric

Table C: Annual Electric Energy Usage (Note [2])

Window /Sliding Glass Door Type	AEH (kWh/ft^2)	AEC (kWh/ft^2)
Single pane ("leaky")	35.50	6.86
Single pane ("tight") (baseline)	32.96	6.76
Double pane (or single with storm)	28.69	6.34
ENERGY STAR - double pane	27.58	5.09
ENERGY STAR – triple pane	24.85	3.01

Savings by heating fuel:

$$A = \frac{D_H \times D_W}{144\ {in^2}/{ft^2}}$$

*Heating (electric resistance heating and heat pump, **Note [1]**):*

$$AKWH_{H,R} = 2 \times (AEH_b - AEH_{es}) \times A$$

$$AKWH_{H,HP} = (AEH_b - AEH_{es}) \times A$$

Example, for going from a baseline to an ENERGY STAR double pane window:

$$AKWH_{H,R} = 2 \times (32.96 - 27.58) \times A$$

$$AKWH_{H,R} = 10.76 \times A$$

$$AKWH_{H,HP} = (32.96 - 27.58) \times A$$

$$AKWH_{H,HP} = 5.38 \times A$$

Cooling (Central A/C Only):

$$AKWH_{C,CAC} = (AEC_b - AEC_{es}) \times A$$

$$AKWH_{C,CAC} = (6.76 - 5.09) \times A$$

$$AKWH_{C,CAC} = 1.67 \times A$$

*Cooling (Room A/C Only): (**Note [3]**):*

$$AKWH_{C,RAC} = (28.3\%) \times AKWH_{C,CAC}$$

$$AKWH_{C,RAC} = 0.417 \times A$$

Retrofit Gross Energy Savings, Fossil Fuel

Table D: Annual Fossil Fuel Energy Usage

Window/Sliding Glass Door Type	AGU (Ccf/ft^2)	AOU (gal/ft^2)	APU (gal/ft^2)
Single pane ("leaky")	2.76	1.99	3.02
Single pane ("tight") (baseline)	2.50	1.80	2.73
Double pane (or single with storm)	2.05	1.48	2.24
ENERGY STAR – double pane	1.95	1.40	2.13
ENERGY STAR – triple pane	1.67	1.20	1.82

Savings by heating fuel:

$$A = \frac{D_H \times D_W}{144 \, ^{in^2}/_{ft^2}}$$

Natural gas:

$$ACCF_H = (AGU_b - AGU_{es}) \times A$$

$$ACCF_H = (2.5 - 1.95) \times A$$

$$ACCF_H = 0.55 \times A$$

Oil:

$$AOG_H = (AOU_b - AOU_{es}) \times A$$

$$AOG_H = (1.80 - 1.40) \times A$$

$$AOG_H = 0.40 \times A$$

Propane:

$$APG_H = (APU_b - APU_{es}) \times A$$

$$APG_H = (2.73-2.13) \text{ X } A$$

$$APG_H = 0.60 \text{ X } A$$

Retrofit Gross Energy Savings, Example

Example: *A single-pane 24" x 36" window is replaced by an ENERGY STAR double-pane window in a home cooled by Central A/C and heated by electric resistance.*

$$A = \frac{24\,in \times 36\,in}{144\, {}^{sqin}/_{sf}} = 6\,sq\ ft$$

$$AKWH_H = 10.76 \times 6 = 64.56 \text{ kWh}$$

$$AKWH_C = 1.67 \times 6 = 10.02 \text{ kWh}$$

Retrofit Gross Seasonal Peak Demand Savings, Electric (winter and summer)

If home has electric resistance heat:

$$WKW = 10.76 \times A \times 0.570/1000$$

$$WKW = 0.0061 \times A$$

*If home has a heat pump (**Note [1]**):*

$$WKW = (0.0061/2) \times A$$

$$WKW = 0.0031 \times A$$

*If home has Central A/C (**Note [2]**):*

$$SKW_{C,CAC} = (0.0031-0.0025) \times A =$$

$$SKW_{C,CAC} .= 0.0006 \text{ X } A$$

*If home has one or more Room A/Cs (**Note [3]**):*

$$SKW_{C,CAC} .= 25.1\%) \times SKW_{C,CAC}$$

$$=0.0002 \times A$$

Retrofit Gross Peak Day Savings, Natural Gas

$$PD_H = ACCF_H \times PDF_H$$

Retrofit Gross Peak Demand Savings, Example

Example: *For the above example with electric resistance heat and Central A/C, demand savings are as follows:*

$$WKW = 0.0061 \times 6$$

$$WKW = 0.0366\ kW$$

$$SKW_{CAC} = 0.0006 \times 6$$

$$SKW_{CAC} = 0.0036\ kW$$

Changes from Last Version

- Updated savings factors based on new RESFEN 6.0 computer software simulation.

References

[1] Lawrence Berkeley National Laboratory, RESFEN 6.0 computer software, August 23, 2021, available online at http://windows.lbl.gov/software.

[2] KEMA, *Evaluation of the Weatherization Residential Assistance Partnership and Helps Programs (WRAP/Helps)*, Sep. 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, pp. iv and 22.

[5] ADM Associates, Inc., "*Residential Central A/C Regional Evaluation*," Sacramento, CA, 2009, pp. 4-4.

[6] ENERGY STAR Program Requirements for Residential Windows, Doors, and Skylights – Partner Commitments, Jan. 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 equal to one-half those of resistance heat demand savings.

[2] The usage values were developed for different fuel types and windows/sliding glass doors using RESFEN from **Ref [1]**. The values from that analysis are shown in the tables.

[3] Room A/C cooling savings are derived from factors found in **Ref [3]**, **Ref [4]**, and **Ref [5]**.

4.4.4 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 (e.g., 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

Table A: Inputs

Symbol	Description	Units
A	Surface area above grade of conditioned space	ft^2
	System/fuel type (e.g., electric resistance, heat pump, air handler, central A/C, natural gas, oil, propane, etc.)	

Nomenclature

Table B: 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 Two*

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],** **Note [2]**
SKW	Summer demand savings	kW		
WKW	Winter demand savings	kW		

Lost Opportunity Gross Energy Savings, Electric

Table C: 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 heating (fan)	REM_F	0.018	kWh/ ft^2
Cooling	REM_C	0.008	kWh/ ft^2

For electric resistance 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 A/C:

$$AKWH_C = REM_C \times A$$

Lost Opportunity Gross Energy Savings, Fossil Fuel

Table D: Fossil Fuel Savings per ft², 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

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 A/C. The total floor area of conditioned space is 1,100 ft². 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 A/C system:

$$AKWH_C = REM_C \times A = 0.008 \times 1{,}100 = 9 kWh$$

Lost Opportunity Gross Seasonal Peak Demand Savings, Electric (winter and summer)

- $WKW_H = REM_{WKW} \times A$ (electric resistance and heat pump)
- $SKW_C = REM_{SKW} \times A$ (central A/C 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

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 A/C. The total floor area of conditioned space is 1,500 ft². 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, Oct. 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 multifamily homes.

[2] Winter demand savings (kW) only apply for electric resistance, heat pump and ground source heat pump heating systems.

4.4.5 INSTALL STORM WINDOW

Description of Measure

Installation of a storm window on the interior or exterior of the existing single-pane window.

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 C* and *D*. 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

Table A: Inputs

Symbol	Description	Units
	No. of storm windows installed	
D_H	Height of the window	Inches
D_W	Width of the window	Inches
	Primary existing heating fuel type	

Nomenclature

Table B: 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 C*	**Note [2]**
AEH	Annual electric heating usage	kWh/ft^2	*Table C*	**Note [2]**
AGU	Annual natural gas usage	ccf/ft^2	*Table D*	**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 D*	**Note [2]**
APG_H	Annual propane savings - heating	gallons		

APU	Annual propane usage	gal/ft^2	*Table D*	**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		
$..._b$	Baseline			
$..._{dp}$	Double pane			
$..._{HP}$	Heat pump heating			
$..._R$	Resistance heating			

Retrofit Gross Energy Savings, Electric

Table C: Annual Electric Energy Usage

Window Type	AEH (kWh/ft^2)	AEC (kWh/ft^2)
Single pane ("leaky")	35.50	6.86
Single pane ("tight")	32.96	6.76
Double pane (or single with storm)	28.69	6.34

Savings by heating fuel:

$$A = \frac{D_H \times D_W}{144 \, {}^{in^2}\!/_{ft^2}}$$

*Heating (electric resistive heating and heat pump, see **Note [1]**):*

$$AKWH_{H,R} = \left(AEH_b - AEH_{dp}\right) \times A$$

$$AKWH_{H,R} = (32.96 - 28.69) \times A$$

$$AKWH_{H,R} = 4.27 \times A$$

$$AKWH_{H,HP} = 2.135 \times A$$

Retrofit Gross Energy Savings, Fossil Fuel

Table D: Annual Natural Gas Energy Usage

Window Type	AGU (kWh/ft^2)	AOU (gal/ft^2)	APU (gal/ft^2)
Single pane ("leaky")	2.76	1.99	3.02
Single pane ("tight")	2.50	1.80	2.73
Double pane (or single with storm)	2.05	1.48	2.24

Savings by heating fuel:

$$A = \frac{D_H \times D_W}{144 \, {}^{in^2}\!/_{ft^2}}$$

Natural gas:

$$ACCF_H = (AGU_b - AGU_{dp}) \times A$$

$$ACCF_H = (2.50 - 2.05) \times A$$

$$ACCF_H = 0.45 \times A$$

Oil:

$$AOG_H = (AOU_b - AOU_{dp}) \times A$$

$$AOG_H = (1.80 - 1.48) \times A$$

$$AOG_H = 0.32 \times A$$

Propane:

$$APG_H = (APU_b - APU_{dp}) \times A$$

$$APG_H = (2.73 - 2.24) \times A$$

$$APG_H = 0.49 \times A$$

Retrofit Gross Energy Savings, Example

Example: *A new storm window is added to a single-pane 24" x 36" window heated by electric resistance.*

$$A = \frac{24\,in \times 36\,in}{144 \, {}^{in^2}\!/_{ft^2}} = 6\,sq\ ft$$

$$AKWH_H = 4.27 \times 6 = 25.62\ kWh$$

Retrofit Gross Seasonal Peak Demand Savings, Electric (winter and summer)

If home has electric resistance heat:

$$WKW = AKWH_{H,R} \times \frac{PFW}{1000\,\frac{W}{kW}} = 4.27_{\frac{kWh}{sqft}} \times A \times \frac{0.570\,\frac{W}{kWh}}{1000\,\frac{W}{kW}}$$

WKW = 0.00243 x A

*If home has a heat pump: (**Note [1]**):*

$$WKW = \frac{AKWH_{H,R}}{2} \times \frac{PFW}{1000\,\frac{W}{kW}} = \frac{0.00243 \times A}{2}$$

WKW = 0.00122 x A

$$SKW = 0$$

Retrofit Gross Peak Demand Savings, Example

***Example:** For the above example with electric resistance heat and Central A/C, demand savings are as follows:*

$$WKW = 0.0064\, {}^{kW}\!/_{sf} \times 6\, sq\, ft = 0.038\, kW$$

WKW = 0.00243 x 6 sq ft

= 0.01458 kW

$$SKW = 0\, kW$$

Changes from Last Version

- Updated the savings factors based on new RESFEN 6.0 computer software simulation
- Removed the ENERGY STAR windows energy usage from *Table D* per ERS recommendation.

References

[1] Lawrence Berkeley National Laboratory, RESFEN 6.0 computer software, August 23, 2021, Available online at: http://windows.lbl.gov/software.

[2] KEMA, *Evaluation of the Weatherization Residential Assistance Partnership and Helps Programs (WRAP/Helps)*, Sep. 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.

4.4.6 INSULATE ATTIC OPENINGS

Description of Measure

Baseline assumptions included no insulation. This is for uninsulated attic hatch, attic stairs, or whole house fan. Not applicable to Multifamily.

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 Infiltration Reduction Testing (*Measure 4.4.2: Blower Door Test*) 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

Table A: Inputs

Symbol	Description	Units
	Type of attic penetration being insulated	
	Was the infiltration reduction Included in blower door measurements?	
	Heating fuel/heating system type (e.g., electric resistance, heat pump, gas, etc.)	
	customer Utility	

Nomenclature

Table B: 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 4-FFFF*	
$ABTU_{Infiltration}$	Annual Btu savings - infiltration	Btu/yr	*Table 4-GGGG*	
$ACCF_H$	Annual natural gas savings - heating	ccf/yr	*Table 4-IIII*	
$AKWH_H$	Annual electric savings - heating	kWh/yr		
$AKWH_{Conductive}$	Annual electric savings - conductive	kWh/yr	*Table 4-HHHH*	
$AKWH_{Infiltration}$	Annual electric savings - infiltration	kWh/yr	*Table 4-HHHH*	

AOG_H	Annual oil savings - heating	Gal/yr	*Table 4-IIII*	
APG_H	Annual propane savings - heating	Gal/yr	*Table 4-IIII*	
Dh, Dw	Attic opening dimensions			
EF	Heating system efficiency (fossil fuel)	%	**Note [3]**	Estimated
F_{adj}	ASHRAE adjustment factor		0.61	**Ref [3]**
HDD UI, SCG, CNG	Heating degree days - UI, SCG & CNG	^{0}F-day	5,165	**Ref [2]**
HDD Eversource	Heating degree days – Eversource (Electric and Gas)	^{0}F-day	5,473	**Ref [2]**
PD_H	Peak day savings - heating	ccf	*Table 4-KKKK*	
PDF_H	Peak day factor – natural gas heating		0.00977	*Appendix One*
PF_W	Peak factor - winter	Watts/kWh	0.57	**Ref [1]**
R_e	Effective R-value - existing	ft²hrºF/Btu	*Table 4-FFFF*	
R_i	Effective R-value - installed	ft²hrºF/Btu	*Table 4-FFFF*	
WKW_H	Winter seasonal demand savings - heating	kW	*Table 4-JJJJ*	

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 C: Annual Btu Savings - Conductive

Insulation Measure	R_e	R_i	A	Eversource $ABTU_{Conductive}$	UI, SCG & CNG $ABTU_{Conductive}$
Attic hatch	1.69	21.7	5.60	244,825	231,047
Attic pull-down stairs	1.69	11.7	11.25	456,332	430,651
Whole house fan	1.32	11.3	4.00	214,439	202,372

Table D: Annual Btu Savings - Infiltration

Insulation Measure	Eversource $ABTU_{Infiltration}$	UI, SCG & CNG $ABTU_{Infiltration}$
Attic hatch	154,876	154,876
Attic pull-down stairs	533,461	533,461
Whole house fan	243,195	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 E: Annual Electric Savings

Insulation Measure	Eversource (Electric and Gas)				UI, SCG and CNG			
	$AKWH_{Cond}$ for Electric Resistance	$AKWH_{Infilt}$ for Electric Resistance	$AKWH_{Cond}$ for Heat pump	$AKWH_{Infilt}$ for Heat pump	$AKWH_{Cond}$ for Electric Resistance	$AKWH_{Infilt}$ for Electric Resistance	$AKWH_{Cond}$ for Heat pump	$AKWH_{Infil}$ for Heat pump
Attic hatch	71.8	45.4	35.9	22.7	67.8	45.4	33.9	22.7
Attic pull-down stairs	133.8	156.4	66.9	78.2	126.3	156.4	63.2	78.2
Whole house fan	62.9	71.3	31.5	35.7	59.4	71.3	29.7	35.7

Reminder: *Only include infiltration savings if not included in blower door measure.*

Retrofit Gross Energy Savings, Fossil Fuel

Using the savings from *Table C*, *Table D*, and an equipment efficiency of 75%, the fossil fuel savings are as follows:

Savings by fuel type:

$$A = \frac{D_H \times D_W}{144 \, {}^{in^2}\!/_{ft^2}}$$

Natural 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 F: Annual Fossil Fuel Savings

Insulation Measure	Eversource (Electric and Gas)						UI, SCG & CNG					
	$ACCF_H$		AOG_H		APG_H		$ACCF_H$		AOG_H		APG_H	
	Cond	Infil	Cond	Infil	Cond	Infil	Cond	Infil	Cond	Infil	Cond	Infil
Attic hatch	3.18	2.01	2.36	1.49	3.58	2.27	3.00	2.01	2.23	1.49	3.38	2.27
Attic pull-down stairs	5.92	6.92	4.39	5.13	6.67	7.79	5.59	6.92	4.15	5.13	6.29	7.79
Whole house fan	2.78	3.16	2.07	2.34	3.14	3.56	2.63	3.16	1.95	2.34	2.96	3.56

Reminder: *Only include infiltration savings if measure if not included in blower door.*

Retrofit Gross Seasonal Peak Demand Savings, Electric (winter and summer)

$$WKW = Annual\ Electric\ energy\ savings\ for\ heating\ x\ \frac{PFw}{1000}$$

Table G: Winter Demand Savings

	Eversource (Electric and Gas)				UI, SCG & CNG			
Insulation Measure	$WKW_{H\ Conductive}$ For Electric Resistance	WKW_H Infiltration For Electric Resistance	WKW_H Conductive For Heat Pump	WKW_H Infiltration For Heat Pump	WKW_H Conductive For Electric Resistance	WKW_H Infiltration For Electric Resistance	WKW_H Conductive For Heat Pump	WKW_H Infiltration For Heat Pump
Attic hatch	0.05	0.03	0.03	0.02	0.04	0.03	0.02	0.02
Attic pull-down stairs	0.08	0.09	0.04	0.05	0.08	0.09	0.04	0.05
Whole house fan	0.04	0.05	0.02	0.03	0.04	0.05	0.02	0.03

Retrofit Gross Peak Day Savings, Natural Gas

$$PD_H = ACCF_H \times PDF_H$$

Table H: Peak Day Savings

	Eversource (Electric and Gas)		UI, SCG & CNG	
Insulation Measure	$PD_{Conductive}$	$PD_{Infiltration}$	$PD_{Conductive}$	$PD_{Infiltration}$
Attic hatch	0.04	0.02	0.03	0.02
Attic pull-down stairs	0.06	0.07	0.06	0.07
Whole house fan	0.03	0.04	0.03	0.04

Changes from Last Version

- ABTU value for Attic Hatch changed.
- HDD updated to Utility specific values.
- F_{adj} value changed from 0.64 to 0.61

References

[1] KEMA, *Evaluation of the Weatherization Residential Assistance Partnership and Helps Programs (WRAP/Helps)*, Sep. 10, 2010, pp. 1-10, see Table ES-8.

[2] DNV, X1931-7 PSD HDD/CDD Update Study, July 29, 2021

[3] ASHRAE degree-day correction. *1989 ASHRAE Handbook – Fundamentals*, 28.2, see Fig 1. Updated value of 0.61 from **Ref [2].**

[4] Cadmus, *High Efficiency Heating Equipment Impact Evaluation Final Report*, 2015.

Notes

[1] *ASHRAE 1997 Handbook – Fundamentals*, p. 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; and
- $R_{existing}$ = 0.61 + 0.10 + 0.61 = 1.32 for fan.

Where:

- 3/8” particle board = R 0.47; and
- 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.

[3] Use site-specific heating system efficiency if available. If unknown, use a default of 80% for boilers, 78% for natural gas and propane furnaces, and 76% for oil furnaces.

4.4.7 INFILTRATION REDUCTION (PRESCRIPTIVE)

Description of Measure

Prescriptive infiltration reduction measures not validated by Blower Door testing, including: electric outlet covers, door sweeps, door kits, caulking and sealing, polyethylene tape, weather-strip doors/windows, and window repairs.

Savings Methodology

Savings from this measure shall only be claimed if a Blower Door Test (*Measure 4.4.2*) 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 a Door Sweep and a Door Kit for weatherization of a single door.*

Savings are calculated by multiplying the savings per unit by the number of units, and then 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

Table A: 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

Table B: Nomenclature

Symbol	Description	Units	Values	Comments
…gasket	Installation of air sealing gasket on an electric outlet	per gasket	*Tables C and D*	**Ref [1]**, p. 1-11, Table ES 9
…door kit	Installation of door sweep or door kit	per sweep	*Tables C and D*	**Ref [1]**, p. 1-11, Table ES 9

…sealing	Foot of caulking, sealing, or polyethylene tape	per foot	*Tables C and D*	**Ref [1]**, p. 1-11, Table ES 9
…wx	Window repaired, window weather-stripped, or door weather-stripped	per linear foot	*Tables C and D*	**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		Use site-specific heating system efficiency if available. If unknown, use default of 80% for boilers, 78% for natural gas and propane furnaces, and 76% for oil furnaces	
PDF_H	Peak day factor – natural gas heating		0.00977	*Appendix One*
PF_W	Winter peak factor	W/kWh	0.570	**Ref [1]**
WKW	Winter seasonal peak electric demand savings	kW		
AKWH	Annual electric energy savings	kWh		

Retrofit Gross Energy Savings, Electric

Table C: 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 = AKWH x 3412/EF

Table D: 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

- Format changes.

References

[1] KEMA, *Evaluation of the Weatherization Residential Assistance Partnership and Helps Programs (WRAP/Helps)*, Sep. 10, 2010.

[2] Cadmus Group, “High Efficiency Heating Equipment Impact Evaluation Final Report,” Mar. 2015, MA.

4.4.8 WALL, CEILING AND FLOOR INSULATION

Description of Measure

Installation of insulation in walls, ceiling or floors 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, ceiling and floor structure Factors 7/12 and -4 are used to adjust for typical wall structure and framing. The savings are calculated using a degree day analysis and the difference in the pre and post R-values.

Note: *The savings presented here do not apply to walls between conditioned spaces and fully enclosed unconditioned spaces, such as porches or hallways. Floors over unconditioned spaces where the walls of the unconditioned space are not insulated (Note [4]). Floor insulation only has heating savings associated with it. Do not apply to ceilings between conditioned spaces and fully enclosed unconditioned spaces, such as basement ceilings. It is assumed that attics are properly ventilated to the outside.*

Inputs

Table A: Inputs

Symbol	Description	Units
R_{pre}	Existing insulation R-value	ft²hrºF/Btu
R_{post}	Insulation R-value after upgrade	ft²hrºF/Btu
A	Total area of wall insulation	ft^2
GF	Ground factor; Percent of unconditioned space walls above-grade (rounded to nearest %)	%

Nomenclature

Table B: 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	**Note [3]**
CF	Summer seasonal peak coincidence factor		0.59	*Appendix One*
EER_B	Energy Efficiency Ratio, baseline	Btu/Watt-hr	11	
EF	Heating system efficiency	%	75	Estimated
F_{adj}	ASHRAE adjustment factor		0.61	**Ref [1]**
HDD UI, CNG, SCG	Heating degree days forUI, CNG & SCG	^{0}F-day	5,165	**Ref [2]**
HDD EVERSOURCE	Heating degree days for Eversource	^{0}F-day	5,473	**Ref [2]**
PDF_H	Peak day factor - heating		0.00977	*Appendix One*
PD_H	Peak day savings - heating			
$R_{existing}$	Effective R-value before upgrade	ft^2hrºF/Btu		
R_{new}	Effective R-value after upgrade	ft^2hrºF/Btu		
R_{pre}	Existing insulation R-value	ft^2hrºF/Btu		
R_{post}	Insulation R-value after upgrade	ft^2hrºF/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	20.5ºF	**Ref [3] a and b**
…CAC	Central A/C			
…RAC	Room A/Cs (cooling only)			**Note [1]**

Retrofit Gross Energy Savings, Electric

Effective R-value for Wall and Floor Insulation:

$$R_{existing} = \left(\frac{7}{12} \times R_{pre}\right) + 4$$

$$R_{new} = \left(\frac{7}{12} \times R_{post}\right) + 4$$

Effective R-value for Ceiling Insulation:

Table C: 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	$R_{new} = R_{post} - 2$

Heating savings:

$$ABTU_H = \left(\frac{1}{R_{existing}} - \frac{1}{R_{new}}\right) \times HDD \times 24 \times F_{Adj} \times A \times GF$$

Note: GF is not applicable when calculating ceiling insulation savings. GF = 1.0

For electric resistance heating:

$$AKWH_{H,R} = \frac{ABTU_H}{3{,}412}$$

For a 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

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 A/C. 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: (Using HDD UI, SCG, CNG value for this example):

$$\mathrm{ABTU_H} = \left(\frac{1}{\mathrm{R_{existing}}} - \frac{1}{\mathrm{R_{new}}}\right) \times \mathrm{HDD} \times 24 \times \mathrm{F_{Adj}} \times \mathrm{A} \times \mathrm{GF}$$

$$ABTU_H = \left(\frac{1}{7.5} - \frac{1}{11.6}\right) \times 5165 \times 24 \times 0.61 \times 100 \times 1$$

$$ABTU_H = 356{,}349.37\ Btu$$

Heating savings for electric resistance system:

$$AKWH_{H,R} = \frac{ABTU_H}{3{,}412}$$

$$AKWH_{H,R} = \frac{ABTU_H}{3{,}412}$$

$$AKWH_{H,R} = \frac{ABTU_H}{3{,}412} = \ 104.44kWh$$

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:

$$WKW = \frac{AKWH_H(Electric\_\mathrm{Re}\,sis\,\tan ce)}{1{,}000} \times WPF$$

$$WKW = \frac{AKWH_H(Electric\_\mathrm{Re}\,sis\,\tan ce)}{1{,}000} \times 0.57$$

For homes with a 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

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 A/C. What are the demand savings?*

$$WKW = \frac{AKWH_H(Electric\_Re\,sis\tan ce)}{1{,}000} \times 0.57$$

From the previous example, AKWHH = 108.42 kWh, therefore:

$$WKW = \frac{104.4}{1000} \times 0.57 = 0.060\ kW$$

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

- Merged three insulation measures into one: 4.4.8 – Wall Insulation; 4.4.9 – Ceiling Insulation; and 4.4.10 – Floor Insulation.
- Updated HDD to Utility specific values.
- F_{adj} value changed from 0.64 to 0.61.
- All the examples are updated based on revised HDD and F_{adj} values.

References

[1] ASHRAE degree-day correction. *1989 ASHRAE Handbook – Fundamentals*, 28.2, see Fig 1. Updated value of 0.61 from **Ref [2]**

[2] DNV, X1931-7 PSD HDD/CDD Update Study, July 29, 2021

[3] Residential Central A/C Regional Evaluation, ADM Associates, Inc., Nov. 2009, a) Table B-4 (Hartford) and p. B-9 and b) Figures 4-1&2 (Hartford) and pp. 4-15.

[4] KEMA, *Evaluation of the Weatherization Residential Assistance Partnership and Helps Programs (WRAP/Helps)*, Sep. 10, 2010, pp. 1-10, see Table ES-8.

[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, pp. iv and 22.

[7] ADM Associates, Inc., "*Residential Central A/C Regional Evaluation*," Sacramento, CA, 2009, p. 4-4.

Notes

[1] Room A/C cooling savings are derived from factors found in **Ref [5]**, **Ref [6]**, and **Ref [7]**.

[2] Calculated the $R_{effective}$ of un-insulated wall assembly based on see *Table D* below.

Table D: Effective of Un-Insulated Wall Assembly

	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 REM/Rate software.

[4] 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).

4.5 WATER HEATING

4.5.1 SHOWERHEADS

Description of Measure

Installation of low-flow showerheads input with 2.0 gpm maximum flow rate (**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

Table A: 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

Table B: Nomenclature

Symbol	Description	Units	Values	Comments
AKWH	Annual electric savings for homes with electric water heater	kWh/yr	Calculated	
ACCF	Annual natural 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	7.8	**Ref [1,2]**
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		0.78 for SF 0.67 for MF	**Ref [3]**
gpm	Gallons per minute flow rate	Gal/min	Federal Std: 2.5 Water Sense: 2.0	**Ref [1]**
# people	Multifamily, no. of people		1.9	**[5]**
n_a	Average total No. of showerheads per household		1.63 MF = 1.3	**Ref [4]**, pp. 185-186, Table 66, **Note [3], MF [6]**
n_e	Average No. of shower events per day per household		1.52	**Ref [4]**, p. 144, Table 41, **Note [3]**
n_i	Number of low-flow showerheads installed		As found	**Note [3]**
S_W	Annual water savings per showerhead	Gal/yr	1,327.4	
SH_W	Specific heat of water	BTU/lb-ºF	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 One*
PD_{WH}	Peak day savings, water heating		Calculated	

Retrofit Gross Energy Savings, Electric

$$S_W = n_e \times d_e \times \frac{365\ days}{year} \times \left(gpm_{fed.std.} - gpm_{WaterSense.}\right) \times \frac{1}{n_a}$$

$$S_W = 1.52 \text{ events} \times \frac{7.8 \text{ min.}}{\text{event}} \times \frac{365\ days}{year} \times \left(2.5\frac{gal.}{min.} - 2.0\frac{gal.}{min.}\right) \times \frac{1}{1.63}$$

$$= 1327.4\frac{gal.}{showerhead \cdot yr.}$$

$$MMBtu\ Savings = \frac{\sqrt{n_i} \times (T_{shower} - T_{supply})}{10^6 Btu/_{MMBtu}} \times d_w \times SH_W \times \frac{S_W}{10^6 Btu/_{MMBtu}}$$ (See **Note [2]**)

$$MMBtu\ Savings = \frac{\sqrt{n_i} \times (105\ F - 55\ F)}{10^6\ Btu/_{MMBtu}} \times 8.31\ ^{lb.}/_{gal.} \times 1327.4\ ^{Gal}/_{showerhead \cdot yr}$$

$$MMBtu\ Savings = 0.552\ ^{MMBtu}/_{showerhead} \times \sqrt{n_i}$$

$$AKWH = \frac{MMBtu_{Savings}}{0.003412\ ^{MMBtu}/_{kWh} \times RE_e} = \frac{0.552 \times \sqrt{n_i}}{0.003412 \times 0.98}$$

$$AKWH = 165.1\ ^{kWh}/_{showerhead} \times \sqrt{n_i}$$

Retrofit Gross Energy Savings, Fossil Fuel

For natural gas:

$$ACCF = \frac{MMBTU\ Savings}{0.1029\ ^{MMBtu}/_{CCF} \times RE_g} = \frac{0.552 \times \sqrt{n}}{0.1029 \times 0.78}$$

$$ACCF = 6.88 \times \sqrt{n}$$

For oil:

$$AOG = \frac{MMBTU\ Savings}{0.138690\ ^{MMBtu}/_{Gal-oil} \times RE_g} = \frac{0.552 \times \sqrt{n}}{0.138690 \times 0.78}$$

$$AOG = 5.10\ ^{gal}/_{showerhead} \times \sqrt{n_i}$$

For propane:

$$AOP = \frac{MMBTU\ Savings}{0.09133\ {}^{MMBtu}/_{Gal-propane} \times RE_g} = \frac{0.552 \times \sqrt{n}}{0.09133 \times 0.78}$$

$$AOP = 7.75\ {}^{gal}/_{showerhead} \times \sqrt{n_i}$$

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:

$$AKWH = 165.1\,{}^{kWh}/_{showerhead} \times \sqrt{n_i} = 165.1 \times \sqrt{2} = 233.5\,{}^{kWh}/_{yr}$$

Annual water savings:

$$AWG = 1327.4\,{}^{Gal}/_{showerhead} \times \sqrt{n_i} = 1327.4 \times \sqrt{2} = 1877.2\,{}^{Gal}/_{year}$$

Example 2: *Two showerheads are replaced in bathrooms of a home which uses natural gas hot water heating. What are the savings per household per year?*

Annual natural gas savings:

$$ACCF = 6.88\,{}^{CCF}/_{showerhead} \times \sqrt{n_i} = 6.88 \times \sqrt{2} = 9.73\,{}^{CCF}/_{yr}$$

Annual water savings:

$$AKWH = 1327.4\,{}^{Gal}/_{showerhead} \times \sqrt{n_i} = 1327.4 \times \sqrt{2} = 1877.2\,{}^{Gal}/_{year}$$

Retrofit Gross Peak Day Savings, Natural Gas

$$PD_{WH} = ACCF \times PDF_{WH}$$

Non-Energy Benefits

Annual water savings in gallons:

$$AWG = 1327.4\,{}^{Gal}/_{showerhead \cdot yr} \times \sqrt{n_i} = 1327.4 \times \sqrt{2} = 1877.2\,{}^{Gal}/_{year}$$

Changes from Last Version

- Measure description updates.
- Parameter updates in *Table B: Nomenclature*.

References

[1] EPA WaterSense Specification for Showerheads, Version 1.0, effective Feb. 9, 2010, last accessed on Jul. 21, 2010.

[2] KEMA. *Evaluation of the Weatherization Residential Assistance Partnership (WRAP) and Helps Programs*, Final Report, Sep. 10, 2010.

[3] *Illinois Statewide Technical Reference Manual for Energy Efficiency*, Version 2.0, Created by Illinois Energy Efficiency Stakeholder Advisory Group, Jun. 7, 2013, p. 491.

[4] Aquacraft Water Engineering & Management. *California Single Family Water Use Efficiency Study*, Jun. 1, 2011.

[5] NMR Group, Inc., "*R1706 Residential Appliance Saturation Survey & R1616/R1708 Residential Lighting Impact Saturation Studies*," Oct. 1, 2019.

[6] Energy & Resource Solutions. "*R1705 R1609 Multifamily Baseline and Weatherization Opportunity Study*," Oct. 10, 2019.

Notes

[1] **Ref [4]** (Table 35, p. 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 multifamily property, $n_{a,}$, n_i, and n_e are given per dwelling or unit, then multiply the savings results by the number of units or dwellings the measure is applied to.

4.5.2 FAUCET AERATORS

Description of Measure

Installation of aerator specific or EPA specified faucets with flow rate of 1.5 GPM as default (**Ref [1]**) to replace Federal Standard (2.2 gpm) or higher flow 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

Table A: 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

Table B: Nomenclature

Symbol	Description	Units	Values	Comments
AKWH	Annual electric savings for homes with electric water heater	kWh/yr	Calculated	
ACCF	Annual natural gas savings	ccf/yr	Calculated	
AKWH	Annual electric savings for homes with electric water heater	kWh/yr	Calculated	
ACCF	Annual natural gas savings	ccf/yr	Calculated	
AOG	Annual oil savings	Gal/yr	Calculated	
APG	Annual propane savings	Gal/yr	Calculated	

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_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	Federal Std. 2.2 Water Sense: 1.5	**Ref [1]**
No. of people	Multifamily, no. of people		1.9	**Ref [6]**
n_a	Estimated average total no. of faucets (all types) per household		2.01 MF = 1.4	**Note [3], Note [4], Ref [4], Ref [7]**
n_e	Median number of faucet events per day per household		13.8 MF = 10.1	**Note [4], Ref [4]**
n_i	No. of aerators installed		As found	**Note [4]**
S_W	Annual water savings per faucet	Gal/yr	860.03	
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 One*
PD_{WH}	Peak day savings, water heating			
d_e	Average duration per event	minutes	0.6167	**Ref [4]**

Retrofit Gross Energy Savings, Electric

$$S_W = n_e \times d_e \times 365\ {}^{days}/_{yr} \times r_g \times DF \times \frac{gpm_{federal\ standard} - gpm_{Water\ Sense}}{n_a}$$

$$S_W = 13.8 \times 0.6167 \times 365\ {}^{days}/_{yr} \times 0.795 \times \frac{2.2\ gpm - 1.5\ gpm}{2.01}$$

$$S_w = 860.03\ {}^{Gal}/_{faucet\ yr}$$

$$MMBtu\ Savings = \sqrt{n} \times (T_{Faucet} - T_{Supply}) \times d_W \times SH_W \times S_W / 10^6\ {}^{Btu}/_{MMBtu}$$ (See **Note [2]**)

$$MMBtu\ Savings = \sqrt{n} \times (80°F - 55°F) \times 8.31\ {}^{lb}/_{Gal} \times 1\ {}^{Btu}/_{lb°F} \times \frac{860.03\ {}^{Gal}/_{faucet\ yr}}{10^6}\ {}^{Btu}/_{MMbtu}$$

$$MMBtu\ Savings = 0.179\ {}^{MMBtu}/_{faucet} \times \sqrt{n}$$

$$AKWH = \frac{MMBtu\ Savings}{0.003412\ {}^{MMBtu}/_{kWh} \times RE_e} = \frac{0.179 \times \sqrt{n}}{0.003412\ {}^{MMBtu}/_{kWh} \times .98}$$

$$AKWH = 53.53\ {}^{kWh}/_{faucet} \times \sqrt{n}$$

Retrofit Gross Energy Savings, Fossil Fuel

Natural gas:

$$ACCF = \frac{MMBtu\ Savings}{0.102900\ {}^{MMBtu}/_{Ccf} \times RE_g} = \frac{0.179 \times \sqrt{n}}{0.102900\ {}^{MMBtu}/_{Ccf} \times .78}$$

$$ACCF = 2.23 \times \sqrt{n}$$

Oil:

$$AOG = \frac{MMBtu\ Savings}{0.138690\ {}^{MMBtu}/_{Gal\ oil} \times RE_g} = \frac{0.179 \times \sqrt{n}}{0.138690\ {}^{MMBtu}/_{Gal\ oil} \times .78}$$

$$AOG = 1.65 \times \sqrt{n}$$

Propane:

$$AOP = \frac{MMBtu\ Savings}{0.09133\ {}^{MMBtu}/_{Gal\ propane} \times RE_g} = \frac{0.179 \times \sqrt{n}}{0.09133\ {}^{MMBtu}/_{Gal\ propane} \times .78}$$

$$AOP = 2.51\ \times \sqrt{n}$$

Retrofit Gross Energy Savings, Example

Example One: *Two aerators are replaced in bathrooms of home which uses electric hot water heating. What are the total savings?*

$$AKWH = 53.53\ {}^{kWh}/_{faucet} \times \sqrt{2}\ = 75.70\ {}^{kWh}/_{yr}$$

$$Annual\ Gal\ Water\ Savings = S_W\ \times \sqrt{n}\ = 860.03\ {}^{Gal}/_{yr}\ \times \sqrt{2}\ = 1216.26\ {}^{Gal}/_{yr}$$

Example Two: *Two aerators are replaced in bathrooms of a home which uses natural gas hot water heating. What are the savings?*

$$ACCF = 2.23 \times \sqrt{2} = 3.15\ {}^{Ccf}/_{yr}$$

$$Annual\ Gal\ Water\ Savings = S_W\ \times \sqrt{n}\ = 860.03\ {}^{Gal}/_{yr}\ \times \sqrt{2}\ = 1216.26\ {}^{Gal}/_{yr}$$

Retrofit Gross Peak Day Savings, Natural Gas

$$PD_{WH} = ACCF \times PDF_{WH}$$

Non-Energy Benefits

$$Annual\ Gal\ Water\ Savings = S_W\ \times \sqrt{n}\ = 860.03\ {}^{Gal}/_{yr}\ \times \sqrt{n}$$

Changes from Last Version

- Format changes.
- Algorithm updates.
- Reference updates.

References

[1] US EPA WaterSense High-Efficiency Lavatory Faucet Specification, Effective Oct. 1, 2007, last accessed Jul. 21, 2010.

[2] KEMA, *Evaluation of the Weatherization Residential Assistance Partnership (WRAP) and Helps Programs*, Final Report, Sep. 10, 2010.

[3] *Illinois Statewide Technical Reference Manual for Energy Efficiency,* Version 2.0, Created by Illinois Energy Efficiency Stakeholder Advisory Group, Jun. 7, 2013, p. 491.

[4] Aquacraft Water Engineering & Management. *California Single Family Water Use Efficiency Study,* Jun. 1, 2011.

[5] Cadmus, *Impact Evaluation: Home Energy Services-Income-Eligible and Home Energy Services Programs*: Volume 2 (R16), Revised Jul. 2, 2014.

[6] NMR Group, Inc., "*R1706 Residential Appliance Saturation Survey & R1616/R1708 Residential Lighting Impact Saturation Studies*," Oct. 1, 2019.

[7] Energy & Resource Solutions, "*R1705 R1609 Multifamily Baseline and Weatherization Opportunity Stud*y," Oct. 10, 2019.

Notes

[1] **Ref [4]** (Table 35, p. 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, pp. 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, and 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 multifamily property, $n_{a,}$ $n_{i\ and}$ n_e are given per dwelling/unit, then multiply the savings results by the number of unit/welling the measure is applied to.

4.5.3 FOSSIL FUEL WATER HEATERS

Description of Measure

Installation of a high-efficiency natural gas or propane tankless and storage water heaters. This measure is only applicable to water heaters with a capacity of less than 75,000 Btu/h for multifamily dwelling units.

Savings Methodology

Energy and demand savings calculations for a tankless or storage water heater are shown below. Savings for a high-efficiency indirect water heater and an 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 (uniform energy factors) were used to calculate natural gas and propane savings from the gross energy savings.

Inputs

Table A: Inputs

Symbol	Description	Units
	Water heating fuel	
UEF_B	Energy Factor-installed	%

Nomenclature

Table B: 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	9,630,521	**Note [1]**
APG_W	Annual propane savings – water heating	Gal		
UEF_B	Uniform Energy Factor - baseline		0.60	**Note [2] and Note [3]**
GPY	Annual domestic hot water usage in gallons	Gal	15,415	**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	55	**Note [1]**
T_{dhw}	Domestic hot water heater set point	ºF	130	**Note [1]**

Lost Opportunity Gross Energy Savings, Fossil Fuel

$$ABTU_W = ADHW \times \left(\frac{1}{UEF_B} - \frac{1}{UEF_I}\right)$$

$$ABTU_W = 9{,}630{,}521\ Btu \times \left(\frac{1}{0.60} - \frac{1}{UEF}\right)$$

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

Example: *A natural gas water heater with an UEF = 82% (0.82) is installed. What is the annual natural gas savings?*

$$ABTU_W = 9{,}630{,}521\ Btu \times \left(\frac{1}{0.60} - \frac{1}{.82}\right) = 4{,}306{,}330.5\ btu$$

$$ACCF_w = \frac{4{,}306{,}330.5\ Btu}{102{,}900\,\frac{btu}{Ccf}} = 41.85\ Ccf$$

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

- Changed value of UEF_B in the equation.

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 Mar 7, 2015. Baseline is an average of the 50-gal. storage gas water heater and tankless water heater Energy Factors.

[3] The 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. Available online at: www.energysavers.gov.

[4] A multifamily multiplier was applied to the single-family gallons per year since hot water usage is related the number of occupants. The multiplier was found to be 0.73 = 1.9 occupants/2.6 occupants where occupant numbers were found from **Ref [2]**.

References

[1] Tool for Generating Realistic Residential Hot Water Event Schedules, Preprint, NREL, Aug. 2010.

[2] Multifamily: NMR Group, Inc. *"R1706 Residential Appliance Saturation Survey & R1616/R1708 Residential Lighting Impact Saturation Studies,"* Oct. 1, 2019.

4.5.4 HEAT PUMP WATER HEATERS

Description of Measure

Installation of a heat pump water heater (HPWH). For tanks > than 55 gallons, the baseline would be a blended mix of electric resistance and minimally compliant HPWH.

Retrofit: Electric resistance water heater for sizes < 55 gallons and a minimal code compliant HPWH for sizes > 55 gallons.

Savings Methodology

Energy and demand savings calculations for a HPWH are shown below. The savings are based on the R1614/R1613 HVAC and Water Heater Evaluation (**Ref [1]**). The savings in the study represent a combination of electric savings and fossil fuel savings.

Inputs

Table A: Inputs

Symbol	Description	Units
	Number of units installed	
	Size: 55 gallons or less, or greater than 55 gallons	Gallons

Nomenclature

Table B: Nomenclature

Symbol	Description	Units	Comments
$AEDHW_W$	Annual electric energy savings	kWh/yr	**Ref [1]**
$AFDHW_W$	Annual fossil fuel savings	MMBTU/yr	**Ref [1]**
AOG	Annual oil savings	Gals	
APG	Annual propane savings	Gals	
SKW	Summer electric demand savings	kW	**Ref [1]**
WKW	Winter electric demand savings	kW	**Ref [1]**

For an installed HPWH:

Table C: Gross Energy Savings

Existing DHW Type	AkWh Savings (55 gallons or less)	AkWh Savings (> 55 gallons)	AOG Savings	APG Savings
Electric resistance (Retrofit)	1,818 kWh	197kWh		
Unknown (Lost Opportunity)	961 kWh	565 kWh	15.5 Gals	23.54 Gals

Table D: Gross Seasonal Peak Demand Savings (Electric)

Existing DHW Type	SKW (55 gallons or less)	WKW (55 gallons or less)	SKW (> 55 gallons)	WKW (> 55 gallons)
Electric resistance (Retrofit)	0.296 kW	0.234 kW	0.113 kW	0.101 kW
Unknown (Lost Opportunity)	0.175 kW	0.134 kW	0.04 kW	0.035 kW

Retrofit Gross Energy Savings, Example

Example: *An electric resistance water heater is replaced by a 50 Gallon HPWH. What are the annual and peak day savings?*

$$AEDHW_W = 1818\ kWh$$

$$SKW = 0.296\ kW$$

$$WKW = 0.234\ kW$$

Lost Opportunity Gross Energy Savings, Example

Example: *A 50 Gallon HPWH was sold through an upstream distributor. What are the annual and peak day savings? Since the unit was sold upstream the Lost Opportunity Savings are combination of electric savings and fossil fuel savings.*

For electric savings:

$$AEDHW_W = 961\ kWh$$

$$SKW = 0.175\ kW$$

$$WKW = 0.134\ kW$$

For oil savings:

$$AFDHW_W = 15.5Gal$$

For propane savings:

$$AFDHW_W = 23.54Gal$$

Changes from Last Version

- Updated the savings for HPWHs greater than 55 gallons.

References

[1] *R1614/R1613 CT HVAC and Water Heater Process and Impact Evaluation*, West Hill Energy and Computing, EMI Consulting & Lexicon Energy Consulting, Jul. 19, 2018, pp. 8.6-8.8.

4.5.5 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 A* 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 **Ref [4]**.

Inputs

Table A: 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.
	DHW fuel type (e.g., electric resistance, natural gas oil, and propane)
	Heating fuel type (e.g., natural gas, oil, and propane)

Nomenclature

Table B: Nomenclature

Symbol	Description	Units	Values	Comments
$ACCF_H$	Annual natural gas savings per linear foot, heating	ccf/ft		Table 4-IIIII
$ACCF_W$	Annual natural gas savings per linear foot, DHW	ccf/ft		*Table E*
AKW_H	Annual kWh energy savings coefficient, heating	kWh/ft		*Table D*
AKW_W	Annual kWh energy savings coefficient, DHW	kWh/ft		*Table C*
$AKWH_H$	Annual energy savings, heating	kWh	Calculated	
$AKWH_W$	Annual energy savings, DHW	kWh	Calculated	

AOG_H	Annual oil savings, heating	Gal/ft		*Table F*
AOG_W	Annual oil savings, DHW	Gal/ft		*Table E*
APG_HG_H	Ann Annual propane savings, Heating dual propane savings, heating	Gal/ft		*Table F*, *Table 4-18*
APG_W	Annual propane savings, DHW	Gal/ft		*Table E*
PD_W	Peak day natural Gas savings, DHW	ccf		
PD_H	Peak day natural gas savings, Heating	ccf		
PDF_H	Peak day factor, heating		0.00977	*Appendix One*
PDF_W	Peak day factor, DHW		0.00321	*Appendix One*
PF_S	Summer seasonal peak factor, DHW	W/kWh	0.1147	**Ref [3]**
PF_W	Winter seasonal peak factor, DHW	W/kWh	0.1747	**Ref [3]**
PF_S	Summer seasonal peak factor, Heating	W/kWh	0	
PF_W	Winter seasonal peak factor, Heating	W/kWh	0.57	**Ref [3]**
SKW_H	Summer seasonal peak demand savings, heating	kW		
SKW_W	Summer seasonal Peak demand savings, DHW	kW		
WKW_H	Winter seasonal peak demand savings, heating	kW		
WKW_W	Winter seasonal peak demand savings, DHW	kW		

Retrofit Gross Energy Savings, Electric

Table C: Annual Electrical Savings per Linear Foot of Domestic Hot Water Pipe Insulation

Pipe Diameter (inches)	AKW_W (kWh/ft)
0.50	12.1
0.75	18.1

Annual electric DHW savings can be calculated using the formula below, and using the values for AKW_W from Table C:

$$AKWH_W = AKW_W \times L$$

Table D: 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
2.00	57.74

Annual electric heating savings can be calculated using the formula below, and using the value for AKWH from Table D:

$$AKWH_H = AKW_H \times L$$

Retrofit Gross Energy Savings, Fossil Fuel

Table E: 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	0.55	0.40	0.60
0.75	0.81	0.58	0.88

Annual natural gas DHW savings can be calculated using the formula below and using the ACCFw coefficient in Table E:

$$ACCF = ACCF_W \times L$$

Annual oil DHW savings can be calculated using the formula below and using the AOGw coefficient in Table E:

$$AOG = AOG_W \times L$$

Annual propane DHW savings can be calculated using the formula below and using the APGw coefficient in Table E:

$$APG = APG_W \times L$$

Table F: 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
2.00	1.91	1.42	2.16

Annual natural gas heating savings can be calculated using the formula below and using the ACCFH coefficient in Table F:

$$ACCF = ACCF_H \times L$$

Annual oil heating savings can be calculated using the formula below and using the AOGH coefficient in Table F:

$$AOG = AOG_H \times L$$

Annual propane DHW savings can be calculated using the formula below and using the APGH coefficient in Table F:

$$APG = APG_H \times L$$

Retrofit Gross Energy Savings, Example

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?*

$$AOG = AOG_H \times L$$

$$AOG = 0.40 \frac{Gal}{ft} \times 5ft = 2.0 \frac{Gal}{yr} \text{ of Oil}$$

Retrofit Gross Seasonal Peak Demand Savings, Electric (winter and summer)

For DHW, the summer seasonal peak demand savings is:

$$SKW_W = \left(\frac{AKWH \times PF_S}{1000} \right)$$

$$= \left(\frac{AKWH \times 0.1147}{1000} \right) kW$$

For DHW, the winter seasonal peak demand savings is:

$$WKW_w = \left(\frac{AKWH \ \times PFw}{1000} \right)$$

For heating, summer seasonal peak demand:

$$SKW_H = 0$$

For heating, winter seasonal peak demand:

$$WKW_H = \left(\frac{AKWH \times 0.57}{1000} \right) \text{kW}$$

Retrofit Gross Peak Day Savings, Natural Gas

For DHW:

$$PD_W = ACCF \times PDF_W$$

$$= ACCF \ \times 0.00321$$

For heating:

$$PD_H = ACCF \times PDF_H =$$

$$ACCF \ X \ 0.00977$$

Retrofit Gross Peak Demand Savings, Example

Example: *Five 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?*

$$AKWH = 12.9\frac{kWh}{ft} \times 5ft = 64.7\frac{kWh}{yr}$$

$$SKW = \frac{64.7\ \text{kWh} \times 0.1147\frac{\text{W}}{\text{kwh}}}{\frac{1000\text{W}}{\text{kw}}} = 0.0074\ kW$$

$$WKW = \frac{64.7\ \text{kWh} \times 0.1747\frac{\text{W}}{\text{kwh}}}{\frac{1000\text{W}}{\text{kw}}} = 0.0113\ kW$$

Changes from Last Version

- Updated the DHW pipe insulation savings based on hot water recovery efficiency also updated corresponding examples
- Updated DHW recovery efficiencies in **Note [14]**.
- Added savings factors for 2" pipe diameter for heating pipes.
- Updated *Table B*.

References

[1] NAIMA, 3E Plus software tool, Version 4.1, Released 2021.Last accessed Aug. 19, 2021.

[2] Nexant, *Home Energy Solutions Evaluation: Final Report,* submitted to Connecticut Energy Efficiency Board, Mar. 2011.

[3] KEMA, *Evaluation of the Weatherization Residential Assistance Partnership (WRAP) and Helps Programs*, Final Report, Sep. 10, 2010.

[4] Cadmus, *Draft Impact Evaluation: Home Energy Services—Income-Eligible and Home Energy Services Programs*: Volume 2 (R16), Jun. 2, 2014.

Notes

[1] 3E Plus Inputs for DHW.

[2] Polyolefin (Polyethylene) Foam Tube insulation, 3/8" Thk for 1/2" pipe, 1/2" Thk for 3/4" pipe.

[3] No Jacket installed, so assume emittance (emissivity) of "jacket" is 1.0 (maximum).

[4] Ambient Temp range 40-70° F, no wind speed (used 60°F typical).

[5] Process Temp (water heater temp) 90°F to reflect average temperatures (normal range of WH setting is 120-140°F; 120°F for energy savings, 140°F carries risk of scalding).

[6] Tubing is copper.

[7] For DHW, savings counted 8,760 hours/yr since average temperature is used. For Heating pipes, 2,880 hours per year was used for simulation.

[8] Heat in pipes will dissipate during the time hot water is not being used, thus reducing the average water temperature in the pipe.

[9] Only 0.5 and 0.75-inch pipe necessary, since most DHW supply pipes are either 1/2 or 3/4 in.

[10] 3E Plus software v4. (2012) from NAIMA used to calculate heat loss.

[11] Temp difference between ambient temperatures and pipe temperatures: 30°F correlates with 90°F pipe and 60°F ambient.

[12] Efficiency of water heaters same as that used for faucet aerators and showerheads, see **Note [14]**.

[13] Horizontal pipes.

[14] Water heater recovery efficiencies: Electric: 98%, Oil: 78%, Natural Gas and Propane: 78%. This is based on the 10CFR 430 - Federal energy conservation code and review of AHRI-listed gas heaters and is consistent with the recovery efficiency values used in the showerheads and aerators measures.

4.5.6 SOLAR WATER HEATER

Description of Measure

Installation of a 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 (available at: 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

Table A: Inputs

Symbol	Description
SPF	Solar Path Finder software used to estimate the savings, **Note [1]**

Lost Opportunity Gross Energy Savings, Electric

- Based on the Solar Path Finder (SPF) report.

Lost Opportunity Gross Energy Savings, Electric

- Based on the SPF report.

Lost Opportunity Gross Seasonal Peak Demand Savings, Electric (winter and summer)

- Based on the SPF report.

Lost Opportunity Gross Peak Day Savings, Natural Gas

- Based on the SPF report.

Non-Energy Benefits

- Increases a home's value.

Changes from Last Version

- No changes.

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, and tank capacity and type. This software is widely used in sizing and estimating the savings from solar water heaters.

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]** and **[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

- Format 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 multifamily 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. Available online at: 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 and 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. Available online at: 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 DOE's SEE Action Recommendations, including but not limited to the use of a randomized controlled trial and a panel data model (**Ref [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

Table A: Inputs

Symbol	Description	Comments
Usage Electric	Annual electric energy consumption	
Usage Gas	Annual electric energy consumption	

Nomenclature

Table B: Inputs

Symbol	Description	Units	Comments
AKWH-H	Annual electric energy savings, heating	kWh	
AKWH-C	Annual electric energy savings, cooling	kWh	
ACCF	Annual natural 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.

Table C: Savings and Persistence Assumptions for UIL's HERs Program

Assumptions					
	Year 1	Year 2	Year 3	Year 4	Year 5
Persistence	1	0.71	0.4	0.3	0.1
Percent Savings	**Electric**	**Natural Gas**			
	1.17%	0.60%	1st year		
	1.35%	1.35%	2nd year adjustment for extension customers		
	1.58%	0.81%	Maximum percent savings		

Changes from Last Version

- Formatting changes.

References

[1] DOE, SEE Action, "*Evaluation, Measurement, and Verification (EM&V) of Residential Behavior-Based Energy Efficiency Programs: Issues and Recommendations*," May 2012, p. xi.

[2] *Evaluation of the Year 2 CL&P Pilot Customer Behavior Program (R2)*, Aug. 2014.

[3] Freeman, Sullivan & Co. *Evaluation of PG&E HER Program*, 2013, p. 29.

APPENDIX ONE: PEAK FACTORS

A1.1 COINCIDENCE FACTORS FOR ISO-NE SEASONAL PEAK DEMAND REDUCTIONS

Table A1-1: C&I Lighting and Occupancy Sensors

Facility Type	Lighting		Occupancy Sensors	
	Summer	Winter	Summer	Winter
Grocery	90.4% (d,1)	85.6% (d,2)	14.7% (d,3)	13.3% (d,4)
Manufacturing	83% (d,1)	66.5% (d,2)	19.8% (d,3)	17.2% (d,4)
Medical (hospital)	82.5% (d,1)	69.6% (d,2)	23.9% (d,3)	22.1% (d,4)
Multifamily common area	17.0% (k)	100.0% (k)	18.0% (m)	12.0% (m)
Large office	70.2% (d,1)	53.9% (d,2)	27.4% (d,3)	29.6% (d,4)
Small office	76.8% (d,1)	44.1% (d,2)	27.4% (d,3)	29.6% (d,4)
Other	86.9% (d,1)	76.7% (d,2)	2.4% (d,3)	6.6% (d,4)
Restaurant	77.5% (d,1)	77.0% (d,2)	14.7% (d,3)	13.3% (d,4)
Retail	98.4% (d,1)	85.6% (d,2)	14.7% (d,3)	13.3% (d,4)
University/college	36.8% (d,1)	46.0% (d,2)	28.3% (d,3)	23.1% (d,4)
Warehouse	89.3% (d,1)	72.4% (d,2)	24.6% (d,3)	18.3% (d,4)
School	59.9% (d,1)	38.8% (d,2)	20.9% (d,3)	15.9% (d,4)
Parking lot/street lighting	1.5% (g)	87.3% (d,2)	N/A	N/A
Automotive	68.3% (d,1)	36.9% (d,2)	N/A	N/A
Hotel/motel	40.6% (d,1)	37.5% (d,2)	N/A	N/A
Industrial	83.0% (d,1)	66.5% (d,2)	N/A	N/A
Religious building/convention center	17.0% (d,1)	9.2% (d,2)	N/A	N/A

Table A1-2: Other C&I Measures

Other C&I Measures [p,1]		
Measure	**Summer**	**Winter**
Chillers	70%	3%
Unitary A/C and heat pumps	42%	0.01%
Water and ground source heat pumps (Com)	82%	82%
Water and ground source heat pumps (MF)	80%	100%
Dual enthalpy controls	NA	NA
Demand control ventilation	Custom	Custom
Natural gas-fired boilers and furnaces	0%	0%
Natural gas radiant heaters	0%	0%
Natural gas-fired domestic hot water heaters	0%	0%
Variable refrigerant flow (VRF) HVAC system	Custom	Custom
Low voltage dry type distribution transformers	0%	0%
HVAC variable frequency drives - Fans	15%	11%
HVAC variable frequency drives - CHWP	13%	5%
HVAC variable frequency drives - HWP	12%	38%
Lean manufacturing	0%	0%
Commercial kitchen equipment	100%	100%
Lost opportunity custom	Custom	Custom
Commercial clothes washers	0%	0%
Refrigerator LED	100%	100%
Water-saving measures	0%	0%
Pipe insulation	0%	0%
Duct sealing	100%	100%
Duct insulation	0%	0%
Setback thermostats	0%	0%
Steam trap replacement	0%	0%
Blower door test (Small C&I)	100%	100%
Add speed control to rooftop unit fan	100%	100%
Commercial kitchen hood controls	Custom	Custom
Custom measures	Custom	Custom
Cooler night covers	0%	0%
Evaporator fan controls	97.4%*	98.2%*
Evaporator fans motor replacement	97.4%*	98.2%*
Door heater controls	97.4%*	98.2%*
Vending machine controls	0%	0%
Add doors to open refrigerated display cases	97.4%*	98.2%*

*Values denoted with an asterisk are relative to average demand savings. Average demand savings is defined as total energy (kWh) savings divided by 8760. Data available during X1931-2 did not include sufficient detail to calculate maximum connected loads for each profile, which necessitated the use of seasonal peak coincidence factors relative to average demand. Values which do not have an asterisk are relative to connected load or seasonal peak demand as outlined by the measure characterization in the 2022 PSD.

Table A1-3: Residential Measures

Residential [p,2]		
Measure	**Summer**	**Winter**
Lighting	13%	20%
Energy-efficient central air conditioning	57%	0%
Heat pump	57%	0%
Geothermal heat pump	74%	50%
Electronically commutated motor HVAC fan	7%	12%
Duct sealing	100%	100%
Heat pump – ductless	23%	16%
Package terminal heat pump	59%	0%
Quality installation verification	11%	59%
Duct insulation	153%	46%
Boilers	0%	0%
Furnaces	0%	0%
Boiler reset controls	0%	0%
ECM circulating pump	0%	100%
Wi-Fi thermostat	0%	0%
Clean, tune, and test	0%	0%
Residential appliances	*Table A1-4*	*Table A1-4*
Electronics	*Table A1-4*	*Table A1-4*
REM savings	100%	100%
Infiltration reduction testing (blower door test)	100%	100%
Window or sliding glass door replacement	74%	46%
Thermal enclosure	100%	100%
Install storm window	0%	46%
Insulate attic openings	0%	46%
Infiltration reduction (prescriptive)	0%	46%
Wall insulation	74%	46%

Table A1-4: Residential Appliance and Electronics

Residential Appliance and Electronics† [p,3]		
Measure Name	**Summer**	**Winter**
Air cleaner/purifier	100%	100%
Clothes washer, Tier I	117%	140%
Clothes washer, Tier II	117%	140%
Clothes dryer (ENERGY STAR)	113%	191%
Clothes dryer (hybrid)	113%	191%
Clothes dryer (heat pump)	113%	191%
Dehumidifier	202%	15%
Dishwasher	110%	144%
Refrigerator Tier I (10% greater than ENERGY STAR)	151%	100%
Refrigerator Tier II (15% greater than ENERGY STAR)	151%	100%
Room A/C	1298%	0%
Freezer, upright	123%	79%
Freezer, chest	123%	79%
Refrigerator recycling	159%	68%
Freezer recycling	123%	79%
Multifamily clothes washer (in unit)	196%	13%
Multifamily clothes dryer	232%	54%
Multifamily dishwasher	66%	192%
Multifamily refrigerator	129%	93%
Multifamily room A/C	1065%	0%
Blu-Ray player	127%	157%
Computer monitor (displays)	121%	121%
Cordless phones	100%	100%
Desktop computers	121%	121%
DVD player	127%	157%
Laptop computers	121%	121%
Televisions	127%	157%
Set-top boxes	127%	157%
Sound bars	127%	157%
Advanced power strips Tier I	0%	0%
Advanced power strips Tier II (IR)	0%	0%
Advanced power strips Tier II (IR-OS)	0%	0%

†Values denoted with an † are relative to average demand savings. Average demand savings is defined as total energy (kWh) savings divided by 8760. Data available during X1931-2 did not include sufficient detail to calculate maximum connected loads for each profile, which necessitated the use of seasonal peak coincidence factors relative to average demand. Values which do not have an asterisk are relative to connected load or seasonal peak demand as outlined by the measure characterization in the 2022 PSD manual.

Calculating Peak Day Savings for Natural 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 on the next page:

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 30-year average (58.5°F) divided by the 30-year average HDDs (Values varies per Utility).

$$Peak\ Day\ Savings(residential\ heating) = 0.00977 \times Annual\ Heating\ Savings$$

2) **Residential Natural 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 **Ref [I]**. For Hartford, the coldest inlet water temperature was 45.96°F and average is 56.72°F. Assumed hot water set point is 120°F. 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 simulations 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

- Updated C&I lighting coincidence factors.

References

[a] KEMA, *C&I Lighting Load Shape Project*: *Final Report*, Jul. 2011.

[b] ADM Associates, Inc., *Residential Central A/C Regional Evaluation: Final Report*, Nov. 2009, see Table 4-17, CT weighted average. Winter seasonal peak CF is assumed to be zero.

[c] RLW, *Final Report: 2005 Coincidence Factor Study*, Jan. 4, 2007, see Table 5.

[d, 1] DNV-GL, *C1635 Impact Evaluation of PY 2016 & 2017 Energy Opportunities (EO) Program*, Aug. 27, 2020, see Table 6-7.

[d, 2] DNV-GL, *C1635 Impact Evaluation of PY 2016 & 2017 Energy Opportunities (EO) Program*, Aug. 27, 2020, see Table 6-11.

[d, 3] RLW, *Coincidence Factor Study Residential and C&I Lighting Measures*, Spring 2007 at p. XII, see Table i-17.

[d, 4] RLW, *Coincidence Factor Study Residential and C&I Lighting Measures*, Spring 2007 at p. XII, see Table i-18.

[e] *Coincidence Factor Study, Residential Room Air Conditioners,* Prepared by RLW, Dec. 2007, Table 22, Hartford, CT seasonal CF. Winter seasonal peak CF is assumed to be zero.

[f] Coincidence factors set to 1.00 since gross kW savings is the average kW reduction, rather than the instantaneous kW reduction when operating. MA TRM for 2016 to 2018 program years, Oct. 2015; RI TRM for 2016 program year, Oct. 2015. Also see 2022 PSD manual, *Measure 4.3.1* for residential refrigerators.

[g] United Illuminating analysis performed using historical seasonal peak hours (2010-2014).

[h] MA TRM for 2013 to 2015 program years, Oct. 2012.

[i] NMR Group Inc., *Northeast Residential Lighting Hour-of Use Study*, May 5, 2014, at p. XVIII, see Table ES-7.

[j] CF Value adapted from Cadmus "Ductless Mini-Split Heat Pump Impact Evaluation" , Table 7. (2016). Available online at: http://www.ripuc.ri.gov/eventsactions/docket/4755-TRM-DMSHP%20Evaluation%20Report%2012-30-2016.pdf.

[k] Estimated using the demand allocation methodology described in Cadmus Demand Impact Model (2012). Prepared for the Massachusetts Program Administrators. Summer heating coincidence is assumed to be 0%.

[l] NREL Tool for Generating Realistic Residential Hot Water Event Schedules, Preprint, Aug. 2010.

[m] The Cadmus Group, Inc. (2012), *Final Report, Small Business Direct Install Program: Pre/Post Occupancy Sensor Study*.

[n] "KEMA (2011). C&I Unitary HVAC LoadShape Project – Final Report". https://neep.org/sites/default/files/resources/NEEP_HVAC_Load_Shape_Report_Final_August2.pdf.

[p,1] "DNV (2021). X1931-2 Loadshape and Coincidence Factor Research – Final Report".

APPENDIX TWO: LOAD SHAPES

A2.1 LOAD SHAPES BY END USE AND SECTOR

Table A2-1: Load Shapes by End Use and Sector [a]

Load Shape	Winter Peak Energy %	Winter Off-Peak Energy %	Summer Peak Energy %	Summer Off-Peak Energy %
End Use	**Residential**			
Cooling - Central AC	4.83%	4.33%	54.40%	36.45%
Cooling - Room AC	1.75%	2.10%	51.81%	44.34%
Cooling - Ductless HP	8.56%	10.20%	47.51%	33.73%
Heating	47.23%	52.77%	0.00%	0.00%
Lighting	42.10%	32.50%	13.90%	11.50%
Refrigeration - Fridge	30.34%	30.85%	19.57%	19.24%
Refrigeration - Freezer	28.73%	31.76%	19.11%	20.40%
Water Heating - Electric	43.26%	29.72%	16.19%	10.82%
Water Heating - HP	41.88%	31.05%	15.56%	11.50%
Residential General	30.30%	36.30%	15.50%	17.90%
End Use	**C&I**			
Cooling - Chillers	18.45%	17.26%	32.23%	32.06%
Cooling - RTUs	18.19%	10.22%	43.16%	28.43%
Heating (b, f, **Note [3]**)	55.00%	27.00%	12.00%	6.00%
Lighting (large C&I) (b, h)	44.50%	19.40%	25.70%	10.50%
Lighting (small C&I) (b, h)	38.30%	25.10%	22.50%	14.10%
Refrigeration	29.95%	36.58%	15.95%	17.51%
Other (b, g, **Note [5]**)	37.00%	29.00%	19.00%	15.00%
Motors	31.74%	36.49%	15.77%	15.99%
Process (b, e, **Note [7]**)	32.00%	36.00%	16.00%	16.00%

- Winter is defined as October – May.
- Summer is defined as June – September.
- Peak is defined as 7:00 a.m. to 11:00 p.m. weekdays (no holidays).

- Off-peak is defined 11:00 p.m. to 7:00 a.m. plus all weekend and holiday hours.

Changes from Last Version

- *Table A2-1* updated **[a]**.

References

[a] "DNV (2021). X1931-2 Load Shape and Coincidence Factor Research – Final Report".

APPENDIX THREE: REALIZATION RATES

A3.1 COMMERCIAL AND INDUSTRIAL ELECTRIC REALIZATION RATES

Table A3-1: C&I Electric Realization Rates

	Gross Realization %			FR & SO		Net Realization % (Note 1)		
End-use	kWh	Winter Seasonal Peak kW	Summer Seasonal Peak kW	Free-ridership	Spillover	kWh	Winter Seasonal Peak kW	Summer Seasonal Peak kW
Energy Conscious Blueprint (Note 5)								
Cooling (**Note 10**)	86.2% (v)	151.1% (v)	89.7% (v)	29.5% (d, 1)	12.4% (d,1)	71.5%	125.3%	74.4%
Custom	98.5% (v)	106.3% (v)	97.4% (v)	22.5% (d, 1)	16.9% (d, 1)	93.0%	100.3%	91.9%
Heating (**Note 2, Note 10**)	97.8% (v)	93.0% (v)	94.4% (v)	23.7% (d, 1)	28.0% (d, 1)	102.0%	97.0%	98.5%
Lighting (**Note 2**)	129.0% (v)	116.6% (v)	104.6% (v)	16.7% (d, 1)	2.4% (d, 1)	110.6%	99.9%	89.6%
Motors	98.5% (v)	106.3% (v)	97.4% (v)	18.2% (d, 1)	7.1% (d, 1)	87.6%	94.5%	86.6%
Other	98.5% (v)	106.3% (v)	97.4% (v)	18.2% (d, 1)	7.1% (d, 1)	87.6%	94.5%	86.6%
Process	80.3 (v)	113.0% (v)	114.1% (v)	17.6% (d, 1)	0.9% (d, 1)	66.9%	93.7%	95.0%
Refrigeration (**Note 2**)	98.5% (v)	106.3% (v)	97.4% (v)	3.6% (d, 1)	25.9% (d, 1)	120.5%	130.0%	119.1%
Energy Opportunities								
EMS controls (**Note 11**)	67.6% (w)	162.1% (w)	114.7% (w)	39.0% (q)	14.0% (q)	50.7%	121.6%	86.0%
Cooling (**Note 2, Note 10**)	102.1% (w)	125.0% (w)	146.4% (w)	12.0% (q)	5.0% (q)	95.0%	116.3%	136.2%
Custom (**Note 2**)	93.8% (w)	120.1% (w)	103.1% (w)	23.0% (q)	0.0% (q)	72.2%	92.5%	79.4%
Heating (**Note 2, Note 10**)	102.1% (w)	125.0% (w)	146.4% (w)	14.0% (q)	7.0% (q)	95.0%	116.3%	136.2%
Lighting (**Note 2**)	97.9% (w)	115.3% (w)	98.9% (w)	11.0% (q)	5.0% (q)	92.0%	108.4%	93.0%
Motors (**Note 2**)	67.6% (w)	162.1% (w)	114.7% (w)	12.0% (q)	3.0% (q)	61.5%	147.5%	104.4%
Other (**Note 2**)	67.6% (w)	162.1% (w)	114.7% (w)	0.0% (q)	0.0% (q)	67.6%	162.1%	114.7%
Process (**Note 2**)	67.6% (w)	162.1% (w)	114.7% (w)	12.0% (q)	35.0% (q)	83.1%	199.4%	141.1%
Refrigeration (**Note 2**)	67.6% (w)	162.1% (w)	114.7% (w)	13.0% (q)	0.0% (q)	58.8%	141.0%	99.8%

Table A3-1: C&I Electric Realization Rates (continued)

	Gross Realization %			FR & SO		Net Realization % (Note 1)		
End-use	kWh	Winter Seasonal Peak kW	Summer Seasonal Peak kW	Free-ridership	Spillover	kWh	Winter Seasonal Peak kW	Summer Seasonal Peak kW
Small Business Energy Advantage								
Cooling	72.0% (c,1)	73.0% (c,1)	85.0% (c,1)	15.3% (d,1)	0.2% (d,1)	61.1%	62.0%	72.2%
Heating	72.0% (c,1)	73.0% (c,1)	85.0% (c,1)	0.0% (d,1)	0.0% (d,1)	72.0%	73.0%	85.0%
Lighting (**Note 2**)	109.0% (c,1)	108.0% (c,1)	119.0% (c,1)	3.8% (d,1)	2.5% (d,1)	107.6%	106.6%	117.5%
Custom	72.0% (c,1)	73.0% (c,1)	85.0% (c,1)	0.3% (d,1)	0.0% (d,1)	71.8%	72.8%	84.7%
Other	72.0% (c,1)	73.0% (c,1)	85.0% (c,1)	0.5% (d,1)	0.2% (d,1)	71.8%	72.8%	84.7%
Comp. Air	72.0% (c,1)	73.0% (c,1)	85.0% (c,1)	0.3% (d,1)	0.0% (d,1)	71.8%	72.8%	84.7%
Refrigeration	72.0% (c,1)	73.0% (c,1)	85.0% (c,1)	1.4% (d,1)	0.0% (d,1)	71.0%	72.0%	83.8%
Business & Energy Sustainability								
PRIME	54.0% (o)	100.0%	100.0%	0.0%	0.0%	54.0%	100.0%	100.0%
O&M (**Note 2**)	79.0% (o)	258.0% (o)	191.0% (o)	0.0%	0.0%	79.0%	258.0%	191.0%
RCx (**Note 2**)	105.0% (o)	175.0% (o)	126.0% (o)	0.0%	0.0%	105.0%	175.0%	126.0%
Load Management								
Load response	100.0%	100.0%	100.0%	0.0%	0.0%	100.0%	100.0%	100.0%

Table A3-2: C&I Upstream Electric Realization Rates

End-use	Gross Realization %			Installation Rate (ISR)			FR & SO		Net Realization %		
	kWh =(Delta Watt RR x ISR x HOU RR)	Winter Seasonal Peak kW	Summer Seasonal kW		Delta Watt RR	HOU RR	Free Ridership	Spillover	kWh	Winter Seasonal Peak kW	Summer Seasonal Peak kW
LED screw in (**Notes 13, 14**)	98.1%	127.9%	110.1%	59.4%	163.2%	101.3%	51.7%	0.0%	47.4%	61.8%	53.2%
LED stairwell kit (**Notes 13, 14**)	54.6%	71.2%	61.3%	76.2%	77.0%	93.0%	64.4%	0.0%	19.4%	25.4%	21.8%
LED linear lamp (TLED) (**Notes 13, 14**)	121.3%	152.1%	130.9%	97.1%	105.0%	119.0%	61.5%	0.0%	46.7%	58.6%	50.4%
LED linear lamp (TLED) with controls (**Notes 13, 14**)	90.7%	120.2%	103.5%	91.9%	99.0%	99.6%	49.0%	0.0%	46.3%	61.3%	52.8%
LED linear fixture (**Notes 13, 14**)	126.1%	167.7%	144.3%	96.2%	131.9%	99.3%	64.4%	0.0%	44.9%	59.7%	51.4%
LED linear fixture with controls (**Notes 13, 14**)	90.7%	120.2%	103.5%	91.9%	99.0%	99.6%	49.0%	0.0%	46.3%	61.3%	52.8%
High bay / Low bay (**Notes 13, 14**)	107.2%	97.4%	83.8%	99.6%	74.1%	145.3%	41.3%	0.0%	62.9%	57.2%	49.2%
High bay / Low bay with controls (**Notes 13, 14**)	90.7%	120.2%	103.5%	91.9%	99.0%	99.6%	49.0%	0.0%	46.3%	61.3%	52.8%
LED exterior (**Notes 13, 14**)	138.0%	183.5%	157.9%	92.3%	150.6%	99.4%	74.0%	0.0%	35.9%	47.7%	41.0%
LED exterior with controls (**Notes 13, 14**)	90.7%	120.2%	103.5%	91.9%	99.0%	99.6%	49.0%	0.0%	46.3%	61.3%	52.8%
Food service equipment	100.0%	100.0%	100.0%	100.0%	NA	NA	22.5%	8.5%	86.0%	86.0%	86.0%

A3.2 C&I NATURAL GAS REALIZATION RATES

Table A3-3: C&I Natural Gas Realization Rates

	Gross Realization %		FR & SO		Net Realization % (Note 1)	
End-use	**Energy (ccf)**	**Peak Day (ccf)**	**Free-ridership**	**Spillover**	**Energy (ccf)**	**Peak Day (ccf)**
Energy Conscious Blueprint						
Envelope	90.7% (v)	100.0% (a)	23.8% (d, 2)	9.5% (d, 2)	77.7%	85.7%
HVAC	97.0% (v)	100.0% (a)	23.8% (d, 2)	9.5% (d, 2)	83.1%	85.7%
Process	90.7% (v)	100.0% (a)	23.8% (d, 2)	9.5% (d, 2)	77.7%	85.7%
Water heating	88.7% (v)	100.0% (a)	23.8% (d, 2)	9.5% (d, 2)	76.0%	85.7%
Energy Opportunities						
EMS controls (**Note 11**)	78.2% (w)	100.0%	31.0% (q)	2.0% (q)	55.5%	71.0%
Custom	77.3% (w)	100.0%	37.0% (q)	2.0% (q)	50.2%	65.0%
Heating/DHW	76.5% (w)	100.0%	16.0% (q)	2.0% (q)	65.8%	86.0%
Other	78.2% (w)	100.0%	0.0% (q)	0.0% (q)	78.2%	100.0%
Process	78.2% (w)	100.0%	14.0% (q)	16.0% (q)	79.8%	102.0%
Small Business Energy Advantage						
Overall program	78.0% (c, 2)	100.0%	0.0%	0.0%	78.0%	100.0%
O&M						
Overall program (**Notes 2, 7**)	94.0% (o)	108.0% (e)	0.0%	0.0%	94.0%	108.0%
RCx						
Overall program	90.0% (o)	72.0% (e)	0.0%	0.0%	90.0%	72.0%
Upstream						
Food service	100.0%	100.0%	23.7% (s)	7.0% (s)	83.3%	83.3%

A3.3 RESIDENTIAL ELECTRIC AND NATURAL GAS REALIZATION RATES

Table A3-4: Residential Electric & Natural Gas Realization Rates

	Gross Realization %				FR & SO		Net Realization % (Note 1)			
Measure	kWh or (ccf)	Winter Seasonal Peak kW or (Peak Day ccf)	Summer Seasonal Peak kW	Delivered Fuels, MMBtu	Free-ridership	Spill-over	kWh or (ccf)	Winter Seasonal Peak kW or (Peak Day ccf)	Summer Seasonal Peak kW	Delivered Fuels, MMBtu
Home Energy Solutions (HES) and HES-Income Eligible, Core Services (Realization Rates are applicable to both programs except where noted below.)										
Other measures	100.0%	100.0%	100.0%	100.0%	0.0%	0.0%	100.0%	100.0%	100.0%	100.0%
HES lighting LEDs	47.0% (u)	47.0% (u)	47.0% (u)	N/A	10.0% (k)	0.0%	42.3%	42.3%	42.3%	N/A
HES-IE lighting LEDs (**Note 12**)	47.0% (u)	47.0% (u)	47.0% (u)	N/A	0.0%	0.0%	47.0%	47.0%	47.0%	N/A
Prescriptive air sealing	56.5% (k)	56.5% (k)	56.5% (k)	56.5% (k)	0.0%	0.0%	56.5%	56.5%	56.5%	56.5%
Blower door air sealing, electric/ delivered fuels (**Note 12**)	77.0% (u)	77.0% (u)	77.0% (u)	70.0% (u)	0.0%	0.0%	77.0%	77.0%	77.0%	70.0%
Blower door air sealing, gas	70.0% (u)	70.0% (u)	N/A	N/A	0.0%	0.0%	70.0%	70.0%	N/A	N/A
Duct sealing, electric & gas	92.5% (k)	92.5% (k)	92.5% (k)	92.5% (k)	0.0%	0.0%	92.5%	92.5%	92.5%	92.5%
Water-saving measures	100.0% (u)	100.0% (u)	100.0% (u)	100.0% (u)	20.0% (k)	0.0%	80.0%	80.0%	80.0%	80.0%
Water pipe wrap	100.0%	100.0%	100.0%	100.0%	28.0% (k)	0.0%	72.0%	72.0%	72.0%	72.0%
HES and HES-Income Eligible, Add-On Measures (Realization Rates are applicable to both programs except where noted below.)										
HES insulation, electric/delivered fuels (**Note 12**)	62.0% (u)	62.0% (u)	62.0% (u)	121.0% (u)	6.0% (m)	0.0%	58.3%	58.3%	58.3%	113.7%
HES-IE insulation, electric/delivered fuels (**Note 12**)	62.0% (u)	62.0% (u)	62.0% (u)	84.0% (u)	0.0% (m)	0.0%	62.0%	62.0%	62.0%	84.0%
HES insulation, gas (**Notes 2, 12**)	121.0% (u)	121.0% (u)	N/A	N/A	6.0% (m)	0.0%	113.7%	113.7%	N/A	N/A
HES-IE insulation, gas (**Notes 2, 12**)	84.0% (u)	84.0% (u)	N/A	N/A	0.0% (m)	0.0%	84.0%	84.0%	N/A	N/A
Central A/C & HP	100.0%	100.0%	100.0%	N/A	38.8% (h)	0.0%	61.2%	61.2%	61.2%	N/A
Ductless heat Pump	100.0%	100.0%	100.0%	N/A	0.0%	0.0%	100.0%	100.0%	100.0%	N/A

Table A3-4: Residential Electric & Natural Gas Realization Rates (continued)

	Gross Realization %				FR & SO		Net Realization % (Note 1)			
Measure	kWh or (ccf)	Winter Seasonal Peak kW or (Peak Day ccf)	Summer Seasonal Peak kW	Delivered Fuels, MMBtu	Free-ridership	Spill-over	kWh or (ccf)	Winter Seasonal Peak kW or (Peak Day ccf)	Summer Seasonal Peak kW	Delivered Fuels, MMBtu
HES and HES-Income Eligible, Add-On Measures (Realization Rates are applicable to both programs except where noted below.)										
Appliances (**Note 4**)	94.3% (k)	94.3% (k)	94.3% (k)	N/A	0.0%	0.0%	94.3%	94.3%	94.3%	N/A
Refrigerators	100.0% (u)	100.0% (u)	100.0% (u)	100.0% (u)	0.0%	0.0%	100.0%	100.0%	100.0%	N/A
Windows	100.0%	100.0%	100.0%	100.0%	0.0%	0.0%	100.0%	100.0%	100.0%	100.0%
Water heating	100.0%	100.0%	100.0%	100.0%	0.0%	0.0%	100.0%	100.0%	100.0%	100.0%
Heating system retirement (**Note 4**)	63.7% (k)	63.7% (k)	63.7% (k)	63.7% (k)	0.0%	0.0%	63.7%	63.7%	63.7%	63.7%
HES and HES-Income Eligible Multifamily (“MF”)										
MF lighting LEDs	100.0%	100.0%	100.0%	N/A	10.0% (k)	0.0%	90.0%	90.0%	90.0%	N/A
MF common area and exterior lighting	97% (z)	118% (z)	47% (z)	N/A	0.0%	0.0%	97%	118%	47%	N/A
MF dwelling unit lighting	67% (z)	81% (z)	70% (z)	N/A	0.0%	0.0%	67%	81%	70%	N/A
MF refrigerators	80% (z)	81% (z)	80% (z)	N/A	0.0%	0.0%	80%	81%	80%	N/A
MF prescriptive air sealing	56.5% (k)	56.5% (k)	56.5% (k)	56.5% (k)	0.0%	0.0%	56.5%	56.5%	56.5%	56.5%
MF blower door air sealing	98% (z) [172%]	86% (z)	100% (z)	92.5% (k)	0.0%	0.0%	98% [172%]	86%	100%	92.5%
MF duct sealing	92.5% (k)	92.5% (k)	92.5% (k)	92.5% (k)	0.0%	0.0%	92.5%	92.5%	92.5%	92.5%
MF insulation	100% (z)	100% (z)	68.8% (k)	68.8% (k)	6.0% (m)	0.0%	94%	94%	64.7%	64.7%
MF insulation, income-eligible	100% (z)	100% (z)	68.8% (k)	68.8% (k)	0.0% (m)	0.0%	100%	100%	68.8%	68.8%
MF ECM pumps	59% (z)	68% (z)	N/A	N/A	N/A	N/A	59%	68%	N/A	N/A
MF windows	83% (z)	79% (z)	N/A	N/A	N/A	N/A	83%	79%	N/A	N/A
MF HVAC heat pumps	100% (z)	60% (z)	100% (z)	N/A	N/A	N/A	100%	60%	100%	N/A
MF boilers	[80%) (z)	N/A	N/A	N/A	N/A	N/A	[80%]	N/A	N/A	N/A
MF water-saving measures	100.0%	100.0%	100.0%	100.0%	20.0% (k)	0.0%	80.0%	80.0%	80.0%	80.0%
MF water pipe wrap	100.0%	100.0%	100.0%	100.0%	28.0% (k)	0.0%	72.0%	72.0%	72.0%	72.0%
MF low-flow fixtures	88% [107%] (z)	14% (z)	N.A	N.A	N.A	N.A	88% [107%] (z)	14% (z)	N.A	N.A

Table A3-4: Residential Electric & Natural Gas Realization Rates (continued)

	Gross Realization %				FR & SO		Net Realization % (Note 1)			
Measure	kWh or (ccf)	Winter Seasonal Peak kW or (Peak Day ccf)	Summer Seasonal Peak kW	Delivered Fuels, MMBtu	Free-ridership	Spill-over	kWh or (ccf)	Winter Seasonal Peak kW or (Peak Day ccf)	Summer Seasonal Peak kW	Delivered Fuels, MMBtu
HVAC										
Heat pump hot water heater	100.0%	100.0%	100.0%	100.0%	24%	1.0% (l)	77.0%	77.0%	770%	77.0%
Central A/C & HP	100.0%	100.0%	100.0%	100.0%	38.8% (h)	0.0%	61.2%	61.2%	61.2%	61.2%
Ductless heat pump	100.0%	100.0%	100.0%	100.0%	40.6% (t)	17.2% (t)	76.6%	76.6%	76.6%	76.6%
Gas boiler, below 94% AFUE	100.0%	100.0%	100.0%	100.0%	48.0% (l)	4.0% (l)	56.0%	56.0%	56.0%	56.0%
Gas boiler, 94% AFUE and above	100.0%	100.0%	100.0%	100.0%	16.0% (l)	0.0% (l)	84.0%	84.0%	84.0%	84.0%
Gas furnace	100.0%	100.0%	100.0%	100.0%	42.0% (l)	4.0% (l)	62.0%	62.0%	62.0%	62.0%
Boiler circulator pumps	100.0%	100.0%	100.0%	100.0%	40.0% (l)	9.0% (l)	69.0%	69.0%	69.0%	69.0%
ECM furnace fans	100.0%	100.0%	100.0%	100.0%	42.0% (l)	4.0% (l)	62.0%	62.0%	62.0%	62.0%
Retail Products										
LED bulbs/ luminaires, non-Hard-to-Reach (“HTR”) (**Note 3**)	100.0%	100.0%	100.0%	97.5% (g)	70.0% (f)	0.0%	29.3%	29.3%	29.3%	LED bulbs/ luminaires, non-Hard-to-Reach (HTR) (**Note 3**)
LED bulbs/ luminaires, HTR (**Note 3**)	100.0%	100.0%	100.0%	97.5% (g)	50.0% (f)	0.0%	48.8%	48.8%	48.8%	LED bulbs/ luminaires, HTR (**Note 3**)
LED bulbs/ luminaires, combined non HTR-HTR (**Note 6**)	100.0%	100.0%	100.0%	97.5% (g)	66.0% (f)	0.0%	33.2%	33.2%	33.2%	LED bulbs/ luminaires, combined non HTR-HTR (**Note 6**)

Table A3-4: Residential Electric & Natural Gas Realization Rates (continued)

	Gross Realization %				FR & SO		Net Realization % (Note 1)		
Measure	kWh or (ccf)	Winter Seasonal Peak kW or (Peak Day ccf)	Summer Seasonal Peak kW	Installation Rate	Free-ridership	Spill-over	kWh or (ccf)	Winter Seasonal Peak kW or (Peak Day ccf)	Summer Seasonal Peak kW
Retail Products (continued)									
Freezers	100.0%	100.0%	100.0%	100.0%	30.0% (n)	0.0%	70.0%	70.0%	70.0%
Clothes washers	100.0%	100.0%	100.0%	100.0%	50.0% (n)	0.0%	50.0%	50.0%	50.0%
Dryers	100.0%	100.0%	100.0%	100.0%	38.0% (n)	0.0%	62.0%	62.0%	62.0%
Refrigerators	100.0%	100.0%	100.0%	100.0%	43.0% (n)	0.0%	57.0%	57.0%	57.0%
Dehumidifiers	100.0%	100.0%	100.0%	100.0%	80.0% (n)	0.0%	20.0%	20.0%	20.0%
Dishwashers	100.0%	100.0%	100.0%	100.0%	91.0% (n)	0.0%	9.0%	9.0%	9.0%
Room A/Cs	100.0%	100.0%	100.0%	100.0%	50.0% (n)	0.0%	50.0%	50.0%	50.0%
Sound bars	100.0%	100.0%	100.0%	100.0%	19.0% (n)	0.0%	81.0%	81.0%	81.0%
Room air cleaners	100.0%	100.0%	100.0%	100.0%	43.0% (n)	0.0%	57.0%	57.0%	57.0%
Set-top boxes	100.0%	100.0%	100.0%	100.0%	9.0% (n)	0.0%	91.0%	91.0%	91.0%
Computers	100.0%	100.0%	100.0%	100.0%	77.0% (n)	0.0%	23.0%	23.0%	23.0%
Blu Ray player	100.0%	100.0%	100.0%	100.0%	69.0% (n)	0.0%	31.0%	31.0%	31.0%
Power strips Tier 1	92% (x)	92% (x)	92% (x)	86% (y)	100.0%	100.0%	79.1%	79.1%	79.1%
Power strips Tier 2	92% (x)	92% (x)	92% (x)	78% (y)	100.0%	100.0%	71.8%	71.8%	71.8%
Residential New Construction									
Residential new construction, HERS-rated (**Notes 2, 9**)	100.0%	100.0%	100.0%	100.0%	69.0% (p)	125.0% (p)	156.0%	156.0%	156.0%
Residential new construction, whole building/MF (**Note 9**)	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Behavioral Programs									
Home Energy Reports	100.0%	100.0%	100.0%	100.0%	0.0%	0.0%	100.0%	100.0%	100.0%

Table A3-4: Residential Electric & Natural Gas Realization Rates (continued)

Gross Realization %					FR & SO		Net Realization % (Note 1)		
Measure	kWh or (ccf)	Winter Seasonal Peak kW or (Peak Day ccf)	Summer Seasonal Peak kW	Installation Rate	Free-ridership	Spill-over	kWh or (ccf)	Winter Seasonal Peak kW or (Peak Day ccf)	Summer Seasonal Peak kW
Appliance Turn-In									
Refrigerator recycling	100.0%	100.0%	100.0%	100.0%	31.0% (i)	0.0%	69.0%	69.0%	69.0%
Freezer recycling	100.0%	100.0%	100.0%	100.0%	41.0% (i)	0.0%	59.0%	59.0%	59.0%

Changes from Last Version

- Updated residential multifamily realization rates.
- Corrected FR and SO values for C&I Upstream Lighting.

References

[a] EMI, *C20 Impact Evaluation of the Energy Conscious Blueprint, Program Years 2012 – 2013*, Nov. 6. 2015.

[b] EMI, *Evaluation of the Energy Opportunities Program: Program Year 2011*, Apr. 1, 2014.

[b,1] p. ES-5, see Table 1-1.

[b,2] p. ES-6, see Table 1-2.

[b,3] p. ES-6, see Table 1-3.

[c] ERS, *C1639: Impact Evaluation of the Connecticut Small Business Energy Advantage Program*, Mar. 20, 2018.

[c,1] p. 4, see Table 1-4.

[c,2] p. 7, see Table 1-5, p. 9, see Recommendation 2.

[d] Tetra Tech, *2011 C&I Electric and Gas Free-ridership and Spillover Study*, Oct. 5, 2012.

[d,1] pp. 3-4, see Table 3-5.

[d,2] pp. 3-5, see Table 3-6.

[e] Michaels Energy & Evergreen Economics, *Impact Evaluation of the Retro-commissioning, Operation and Maintenance, and Business Sustainability Challenge Programs*, Report, Dec. 17, 2012.

[f] NMR Group, Inc., *R1615 LED Net-to-Gross Evaluation*, Aug. 7, 2017.

[g] *Connecticut LED Lighting Study Report (R154)*, Jan. 28, 2016 at 35, see Table 21.

[h] ADM Associates, Inc., *Residential Central A/C Regional Evaluation Free-Ridership Analysis*, Oct. 2009, p. 9.

[i] NMR, *Massachusetts Appliance Turn-in Program Impact Evaluation*, Jun. 15, 2011, p. 2, see Table ES-3.

[j] KEMA, *Process Evaluation of the 2012 Bright Opportunities Program Final Report*, Jun. 14, 2013, pp. 1-11, see Table 1-3.

[k] NMR and Cadmus, *Impact Evaluation: Home Energy Services—Income-Eligible and Home Energy Services Programs: Volume 2 (R16)*, Final Report, Dec. 31, 2014.

[l] Michael's Energy, *Efficiency Maine HPWH Free-ridership and Baseline Assessment Results Memo*, Jun. 26, 2020, available online at: https://www.efficiencymaine.com/docs/Heat-Pump-Water-Heater-Free-ridership-and-Baseline-Assessment.pdf.

[m] NMR Group, Inc., *HES/HES-IE Process Evaluation and Real Time Research*, Apr. 13, 2016.

[n] ENERGY STAR, *Unit Shipment and Market Penetration* Report Calendar Year 2019 Summary. Available at: https://www.energystar.gov/sites/default/files/asset/document/2019%20USD%20Summary%20Report.pdf.

[o] ERS, *C1641: Impact Evaluation of the Business and Energy Sustainability Program*, Sep. 5, 2018, [p. 4, see Table 1-3; p. 5, see Table 1-4; and p.10, Recommendation 1).

[p] NMR, *R1707: Net-to-Gross Study ("NTG") of Connecticut Residential New Construction*, Oct. 5, 2018, p. 3, see Table 1.

[q] EMI, Energy Efficiency Board, *C1644 EO Net-to-Gross Study*, Draft Report, Jul. 1, 2019 (Table ES-1-1 and Table ES-1-2, and Recommendation 1 on p. 49).

[r] DNV-GL, *Massachusetts Commercial and Industrial Upstream Lighting Program: "In Storage" Lamps Follow-Up Study*, Final Report, Mar. 27, 2015 (Table 9).

[s] NMR, DNV-GL, and Tetra-Tech, *Massachusetts Sponsors' Commercial and Industrial Programs Free-ridership and Spillover Study*, Aug. 14, 2018 (Table 48, Table 52).

[t] NMR Group, *Massachusetts Residential HVAC NTG and Market Effects Study* (TXC34), Jul. 27, 2018 (Table 8).

[u] West Hill Energy and Computing, *R1603 HES/HES-IE Impact Evaluation Final Realization Rates Memorandum*, Aug. 8, 2019.

[v] Cadmus, C1634 Impact Evaluation of PY 2016 & 2017 Energy Conscious Blueprint Program, Oct. 18, 2020

[w] DNV-GL, C1635 Impact Evaluation of PY 2016 & 2017 Energy Opportunities (EO) Program

[x] NMR Group, Inc. (2018). *RLPNC 17-3: Advanced Power Strip Metering Study*, Oct. 5, 2018

[y] NMR Group, Inc. (2018), *RLPNC 17-4 and 17-5: Products Impact Evaluation of In-Service and Short-Term Retention Rates Study*, Mar. 23, 2018.

[z] TRC . (2021). CT EEB X1941 Multifamily Impact Evaluation, Jul. 22, 2021 (Table 6).

<u>Notes</u>

[1] West Hill Energy and Computing, *R1603 HES/HES-IE Impact Evaluation Final Realization Rates Memorandum*, Aug. 8, 2019.

[2] United Illuminating, SCG, and CNG cap net realization rates at 100%.

[3] The installation rate is the average of the 4-year installation rates given in **Ref [g]**. The free-ridership values are linearly extrapolated from the 2018 to 2020 values given in **Ref [f]**.

[4] Weighted average of results from the HES evaluation **Ref [k]**.

[5] ECB Realization rates are based on the results in **Ref [a]**. For some categories, the results were weighted and averaged in order to accommodate the previously established end use categories.

[6] Weighted Realization Rate based on planned non-HTR-HTR bulb split.

[7] O&M realization rates are based on adopting recommendation No. 9 from the report, to use only the 2022 PSD manual's Grashof algorithm to calculate steam trap savings. See Section 3.2.6 for the steam trap replacement algorithm.

[9] Residential New Construction realization rates apply to HERS-rated projects only. The Companies use a realization rate of 100% for high-rise multifamily new construction projects based on whole-building performance characteristics.

[10] Due to the configuration of Eversource's tracking system, Eversource's EO and ECB HVAC measures apply blended realization rates based on weighted averages of heating and cooling savings.

[11] As detailed in Appendix E of the C1644 study, the controls projects EMI reviewed were all Energy Management System-related projects.

[12] Gross realization rates are the result of negotiation between the Companies and the Evaluation Administrator team to address the limitations of the R1603 billing analysis described in section 5.2.1 of the 2020 C&LM Plan Update. This includes (1) applying HES lighting realization rates to HES-IE; (2) applying natural gas realization rates to delivered fuels savings; and (3) adjusting insulation realization rates to reflect 2019 ex-ante savings claims and calculating statewide blended rates for HES insulation and HES-IE insulation.

[13] As detailed in the CT 2022 PSD Upstream Lighting RR Assumptions Memo (issued by DNV on Oct. 21, 2021)

[14] The CT 2022 PSD Upstream Lighting RR Assumptions Memo (issued by DNV on Oct. 21, 2021) provided recommended NTG ratios but not free-ridership and spillover values. For upstream lighting measures, spillover rates are assumed to be 0% and the values in the Free-ridership column are calculated as ‘1 minus the recommended NTG ratio.

APPENDIX FOUR: LIFETIMES

A4.1 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. In addition, the measure life for certain measures, such as LED lighting, takes into account the anticipated market adoption of more efficient baseline technologies.

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.

Table A4-1: Lifetimes of Measures

Description	Remaining Useful Life	Retrofit	Lost Opportunity	Operations	Maintenance	RCx
Lighting Systems, including:						
Automatic photocell dimming system	N/A	9 (a)	10 (a)	N/A	N/A	N/A
Bi-level switching (demand reduction)	N/A	15 (o)	15 (o)	N/A	N/A	N/A
Fixture (LED)	N/A	7 (u)	12.2 (u)	N/A	N/A	N/A
Fluorescent lighting system power reduction control	N/A	9 (a,*)	N/A	N/A	N/A	N/A
Lamp and ballast conversions	N/A	6.6 (u)	N/A	N/A	N/A	N/A
Lamp replacement (LED)	N/A	6.6 (u)	N/A	5 (l)	5 (l)	N/A
LEDs (screw-in bulbs)	N/A	4 (l)	N/A	N/A	N/A	N/A
Occupancy sensor	N/A	9 (a)	10 (a)	N/A	N/A	N/A
Re-circuiting and new control	N/A	10 (a,*)	N/A	N/A	N/A	N/A
Remove unnecessary lighting fixture	N/A	5 (m)	N/A	N/A	N/A	N/A
Reprogramming of EMS control	N/A	N/A	N/A	5 (b,2)	N/A	8 (m)
Sweep controls/EMS based control	N/A	10 (a,*)	15 (a,*)	N/A	N/A	N/A
Timer switch	N/A	10 (a,*)	N/A	N/A	N/A	N/A

Table A4-1: Lifetimes of Measures (continued)

Description	Remaining Useful Life	Retrofit	Lost Opportunity	Operations	Maintenance	RCx
Building Envelope						
Cool roof	N/A	N/A	15 (c/14)	N/A	N/A	N/A
Insulation	N/A	20 (c/19)	20 (c/19)	N/A	N/A	N/A
Movable window insulation	N/A	10 (m)	10 (m)	N/A	N/A	N/A
New window	N/A	N/A	20 (c/16)	N/A	N/A	N/A
Roof spray cooling	N/A	15 (m)	15 (m)	N/A	N/A	N/A
Window film	N/A	10 (c/18)	10 (c/18)	N/A	N/A	N/A
Domestic Hot Water						
Energy-efficient motor	N/A	15 (a)	20 (a)	N/A	N/A	N/A
Faucet aerator	N/A	10 (j)	N/A	N/A	N/A	N/A
Natural gas fired water heater	N/A	N/A	20 (p)	N/A	N/A	N/A
Heat pump water heater	N/A	10 (c/143*)	10 (c/143*)	N/A	N/A	N/A
Heat recovery	N/A	15 (m)	15 (m)	N/A	N/A	N/A
Low-flow showerhead	N/A	10 (j)	N/A	N/A	N/A	N/A
Point-of-use water heater	N/A	20 (c/95)	20 (c/95)	N/A	N/A	N/A
Pre-rinse spray valve	N/A	5 (h)	N/A	N/A	N/A	N/A
Solar water heater	N/A	20 (m)	20 (m)	N/A	N/A	N/A
Heating, Ventilating and Air Condition (HVAC) Systems						
2-speed motor control in rooftop unit	N/A	13 (a,*)	15 (a,*)	N/A	N/A	N/A
Additional pipe insulation	N/A	15 (q)	15 (q)	N/A	N/A	N/A
Additional vessel insulation	N/A	10 (m)	10 (m)	N/A	N/A	N/A
Air curtain	N/A	15 (m)	15 (m)	N/A	N/A	N/A
Air distribution system modifications & conversions	N/A	20 (m)	20 (m)	N/A	N/A	N/A
Cool thermal storage	N/A	15 (m)	15 (m)	N/A	N/A	N/A
Cooling tower alternates	N/A	13 (m)	15 (c/45*)	N/A	N/A	N/A
Dehumidifier	N/A	13 (m)	15 (m)	N/A	N/A	N/A
Duct insulation	N/A	20 (a,**)	N/A	N/A	N/A	N/A

Table A4-1: Lifetimes of Measures (continued)

Description	Remaining Useful Life	Retrofit	Lost Opportunity	Operations	Maintenance	RCx
Duct sealing	N/A	18 (c/31)	N/A	N/A	N/A	N/A
Duct type air destratification system	N/A	15 (f*)	15 (f*)	N/A	N/A	N/A
Economizer - air/water	N/A	7 (a)	10 (a)	N/A	N/A	N/A
Electric chiller	5	N/A	23 (a)	N/A	N/A	N/A
Electric spot radiant heat	N/A	10 (m)	10 (m)	N/A	N/A	N/A
Energy-efficient motor	N/A	15 (a)	20 (a)	N/A	N/A	N/A
Energy-efficient packaged terminal unit	N/A	N/A	15 (a)	N/A	N/A	N/A
Evaporative cooling (unitary)	N/A	N/A	15 (a,*)	N/A	N/A	N/A
Gas engine chiller	N/A	N/A	15 (d)	N/A	N/A	N/A
Gas fired boiler (condensing)	5	N/A	20 (r)	N/A	N/A	N/A
Gas fired boiler (non-condensing)	N/A	N/A	20 (c/24)	N/A	N/A	N/A
Gas fired radiant heater	N/A	N/A	15 (m)	N/A	N/A	N/A
Gas furnaces	N/A	N/A	20 (c/24*)	N/A	N/A	N/A
High-efficiency unitary equipment (A/C and heat pumps)	5	N/A	15 (a)	N/A	N/A	N/A
Low-leakage damper	N/A	12 (m)	12 (m)	N/A	5 (b,2)	N/A
Make-up air unit for exhaust hood	N/A	15 (m)	15 (m)	N/A	N/A	N/A
Outdoor air damper adjustment or modification	N/A	N/A	N/A	N/A	5 (b,2)	N/A
Paddle type air destratification fan	N/A	15 (f*)	15 (f*)	N/A	N/A	N/A
Plate/heat pipe type heat recovery system	N/A	14 (c/27)	14 (c/27)	N/A	N/A	N/A
Repair air side economizer	N/A	N/A	N/A	N/A	5 (b,2)	N/A
Repair steam/air leaks	N/A	N/A	N/A	N/A	5 (b,2)	N/A
Replace steam traps	N/A	N/A	N/A	N/A	6 (g)	N/A
Rotary type heat recovery system	N/A	14 (c/41)	14 (c/41)	N/A	N/A	N/A

Table A4-1: Lifetimes of Measures (continued)

Description	Remaining Useful Life	Retrofit	Lost Opportunity	Operations	Maintenance	RCx
Variable speed drive	N/A	13 (b,1)	15 (b,1)	N/A	N/A	N/A
Variable refrigerant flow	5	N/A	15	N/A	N/A	N/A
VAV system components	N/A	13 (m)	N/A	N/A	N/A	N/A
Water/steam distribution system modifications & conversions	N/A	20 (m)	20(m)	N/A	N/A	N/A
Zoned circulator pump system	N/A	15 (m)	N/A	N/A	N/A	N/A
HVAC Controls						
Adjust scheduling	N/A	N/A	N/A	5 (b,2)	N/A	6 (m)
Commercial Advanced Thermostats	N/A	9.1 (v)	N/A	N/A	N/A	N/A
Controls to eliminate simultaneous heating and cooling	N/A	10 (a)	N/A	5 (b,2)	N/A	8 (m)
Demand control ventilation - multi zone	N/A	10 (a)	10 (m)	N/A	N/A	N/A
Demand control ventilation - single zone	N/A	10 (a)	10 (m)	N/A	N/A	8 (m)
EMS/linked HVAC controls	N/A	10 (a)	15 (a)	N/A	N/A	8 (m)
Enthalpy control economizer	N/A	7 (a)	10 (a)	N/A	N/A	N/A
Modify HVAC controls	N/A	10 (a)	N/A	N/A	N/A	8 (m)
New/additional EMS points	N/A	10 (a)	15 (a)	N/A	N/A	N/A
Programmable thermostat	N/A	8 (a)	N/A	N/A	N/A	N/A
Repair HVAC controls	N/A	N/A	N/A	N/A	5 (b,2)	N/A
Reprogramming of EMS controls	N/A	N/A	N/A	5 (b,2)	N/A	8 (m)
Reset set-points	N/A	N/A	N/A	5 (b,2)	N/A	6 (m)
Single zone controls NOT linked to other controls	N/A	10 (a)	N/A	N/A	N/A	N/A
Time clock	N/A	11 (c/43)	N/A	N/A	N/A	N/A
Upgrade to dual/comparative enthalpy economizer	N/A	10 (a,*)	10 (a,*)	N/A	N/A	N/A

Table A4-1: Lifetimes of Measures (continued)

Description	Remaining Useful Life	Retrofit	Lost Opportunity	Operations	Maintenance	RCx
Refrigeration						
Additional pipe insulation - refrigeration system	N/A	11 (c/83)	11 (c/83)	N/A	N/A	N/A
Additional vessel insulation - refrigeration system	N/A	11 (c/83*)	11 (c/83*)	N/A	N/A	N/A
Adjust scheduling	N/A	N/A	N/A	5 (b,2)	N/A	8 (m)
Ambient sub-cooling	N/A	15 (c/85)	15 (c/85)	N/A	N/A	N/A
Auto cleaning system for condenser tubes	N/A	10 (m)	10 (m)	N/A	N/A	N/A
Case cover	N/A	5 (c/84)	5 (c/84)	N/A	N/A	N/A
Commercial refrigeration system and components	N/A	15 (c/85)	15 (c/85)	3 (l)	N/A	N/A
Demineralized water for ice	N/A	10 (m)	10 (m)	N/A	N/A	N/A
Electronically commutated motor	N/A	15 (c/85)	15 (c/85)	N/A	N/A	N/A
Heat recovery from refrigeration system	N/A	10 (c/80)	13(m)	N/A	N/A	N/A
Hot gas bypass for defrost or regeneration	N/A	10 (m)	10 (m)	N/A	N/A	N/A
Industrial refrigeration systems and components	N/A	20 (b,1)	20 (b,1)	3(l)	N/A	N/A
Low case HVAC returns	N/A	10 (m)	10 (m)	N/A	N/A	N/A
Low emissivity ceiling surfaces	N/A	15 (m)	15 (m)	N/A	N/A	N/A
Mechanical sub-cooling	N/A	15 (c/85)	15 (c/85)	N/A	N/A	N/A
Motorized insulated door	N/A	8 (c/75)	8 (c/75)	N/A	N/A	N/A
Open or enclosed display case	N/A	12 (c/76)	12 (c/76)	N/A	N/A	N/A
Adding doors on open display case	N/A	12 (c/76*)	N/A	N/A	N/A	N/A
Oversized condenser	N/A	15 (c/85)	15 (c/85)	N/A	N/A	N/A
Polyethylene strip curtain	N/A	4 (c/88)	4 (c/88)	N/A	N/A	N/A

Table A4-1: Lifetimes of Measures (continued)

Description	Remaining Useful Life	Retrofit	Lost Opportunity	Operations	Maintenance	RCx
Refrigeration control	N/A	10 (b,1)	10 (b,1)	5 (b,2)	N/A	10 (c/86)
Reset set-points	N/A	N/A	N/A	5 (b,2)	N/A	8(m)
Vending machine occupancy sensor	N/A	5 (b,1)	N/A	N/A	N/A	N/A
Process Equipment						
Add regulator valves in compressed air system	N/A	10 (m)	10 (m)	N/A	N/A	10 (c/86)
Air compressor	N/A	13 (b, 1)	15 (b, 1)	N/A	N/A	N/A
Clothes washer	N/A	N/A	7 (s)	N/A	N/A	N/A
Compressed air distribution and storage system	N/A	10 (m)	N/A	N/A	N/A	N/A
Energy-efficient transformer	N/A	15 (a,*)	20 (a,*)	N/A	N/A	N/A
Energy-efficient motor	N/A	15 (a)	20 (a)	N/A	N/A	N/A
Injection molding machine jacket	N/A	5 (m)	N/A	N/A	N/A	N/A
Install air compressor no-loss condenser drain	N/A	13 (m)	13 (m)	N/A	5 (b,2)	10 (c/86)
Interlock air system solenoid valves with machine operation	N/A	10 (a,*)	10 (a,*)	N/A	N/A	10 (c/86)
Interlock exhaust fans w/ machine operations	N/A	10 (a,*)	10 (a,*)	N/A	N/A	10 (c/86)
Plastic injection molding machine	N/A	13 (m)	15 (m)	N/A	N/A	N/A
PRIME	N/A	N/A	5 (e)	N/A	N/A	N/A
Refrigerated air dryer	N/A	13 (b,1)	15 (b, 1)	N/A	N/A	N/A
Repair steam/compressed air leaks	N/A	N/A	N/A	N/A	5 (b,2)	N/A
Replace steam traps	N/A	N/A	N/A	N/A	6 (g)	N/A
Variable frequency drive	N/A	13 (b,1)	15 (b,1)	N/A	N/A	N/A
Water treatment magnets	N/A	10 (m)	N/A	N/A	N/A	N/A

Table A4-1: Lifetimes of Measures (continued)

Description	Remaining Useful Life	Retrofit	Lost Opportunity	Operations	Maintenance	RCx
Commercial Kitchen Equipment						
Convection oven	N/A	N/A	12 (c/20)	N/A	N/A	N/A
Dishwasher - under counter	N/A	N/A	10 (k)	N/A	N/A	N/A
Dishwasher - stationary single tank door	N/A	N/A	15 (k)	N/A	N/A	N/A
Dishwasher – single-tank conveyor	N/A	N/A	20 (k)	N/A	N/A	N/A
Dishwasher – multi-tank conveyor	N/A	N/A	20 (k)	N/A	N/A	N/A
Freezer	N/A	N/A	12 (c/76)	N/A	N/A	N/A
Fryer	N/A	N/A	12 (c/20)	N/A	N/A	N/A
Griddle	N/A	N/A	12 (c/20)	N/A	N/A	N/A
Hot food holding cabinet	N/A	N/A	12 (c/23)	N/A	N/A	N/A
Ice machine	N/A	N/A	10 (t)	N/A	N/A	N/A
Refrigerator	N/A	N/A	12 (c/76)	N/A	N/A	N/A
Steam cooker	N/A	N/A	12 (c/20)	N/A	N/A	N/A
Behavioral						
Strategic energy management	N/A	N/A	4 (n)	N/A	N/A	N/A
Other						
Whole building performance	N/A	N/A	17 (m)	N/A	N/A	N/A

Changes from Last Version

- Updated measure lives of LED fixture, Lamp and ballast conversion, Lamp replacement (LED).
- Added new measure life – Commercial Advanced Thermostats.

References

[a] GDS Associates Inc., *Measure Life Report, Residential and Commercial Industrial Lighting and HVAC Measures*, Jun. 2007, see 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, Oct. 10, 2005.

[b,1] See Table 1-1.

[b,2] pp. 4-9.

[c] California Public Utilities Commission, *2008 Database for Energy-Efficient Resources*, Version 2008.2.05, Dec. 16, 2008, EUL/RUL (Effective/Remaining Useful Life) Values, MS Excel Spreadsheet.

[c/#] Row number.

[c/#*] Similar measure to row number; row number 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, p. 29, see Table 4.

[e] Energy & Resource Solutions (ERS), *Process Reengineering for Increased Manufacturing Efficiency Program Evaluation*, Mar. 26, 2007, pp. 1-5.

[f*] *Efficiency Maine TRM*, 3/5/07, p. 91. Similar measure.

[g] Energy and Environmental Analysis, Inc. *Steam Traps Workpaper for PY2006-2008.* Prepared for Southern California Gas Company, Dec. 2006, p. 14, see Section 9.1.

[h] Veritec Consulting, "*Region of Waterloo Pre-Rinse Spray Valve Pilot Study Final Report*", Jan. 2005, Executive Summary.

[i] Appliance Magazine. *U.S. Appliance Industry: Market Share, Life Expectancy & Replacement Market, and Saturation Levels,* Jan. 2010. p. 10.

[j] GDS Associates, Inc., *Natural Gas Energy Efficiency Potential in Massachusetts*, 2009, prepared for GasNetworks, see Table B-2a.

[k] ENERGY STAR commercial kitchen equipment savings calculator, at: https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator_0.xlsx.

[l] Adjusted measure life, estimated based on residential lighting market saturation trends, penetration, and hours of use from NMR, *Connecticut LED Lighting Study Report (R154)*, Jan. 2016.

[m] ERS. *Measure Life Study prepared for The Massachusetts Joint Utilities*, 2005.

[n] As part of the program, the Companies are providing 3 years of continual monitoring and check-ins with customers and expect savings to persist on average for at least one year beyond the 3 years of direct support. Measure life also supported by evaluated results of similar programs. See SBW Consulting, Inc. & The Cadmus Group, *Industrial Strategic Energy Management (SEM) Impact Evaluation Report*, Feb. 2017, and CEE, *2016 Strategic Energy Management Program Summary*, Nov. 21, 2016.

[o] Navigant, *ComEd Luminaire Level Lighting Control IPA Program Impact Evaluation Report*, Jun. 5, 2018

[p] Hewitt, D. Pratt, J. & Smith, G. (2005). *Tankless Gas Water Heaters: Oregon Market Status*, prepared for the Energy Trust of Oregon.

[q] GDS Associates, Inc., *Natural Gas Energy Efficiency Potential in Massachusetts,* 2009, prepared for GasNetworks.

[r] PA Consulting Group Inc. *Focus on Energy Evaluation. Business Programs: Measure Life Study,* Aug. 25, 2009.

[s] EPA ENERGY STAR calculator, accessed Apr. 25, 2017, based on Cadmus review of four retailer websites: Sears, Home Depot, Lowes, and Best Buy.

[t] US EPA. Feb. 2015. Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment. Available online at: http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx.

[u] DNV, (March, 2021) C2014 - Connecticut C&I Lighting Saturation and Remaining Potential Study Phase One Results and Recommendations

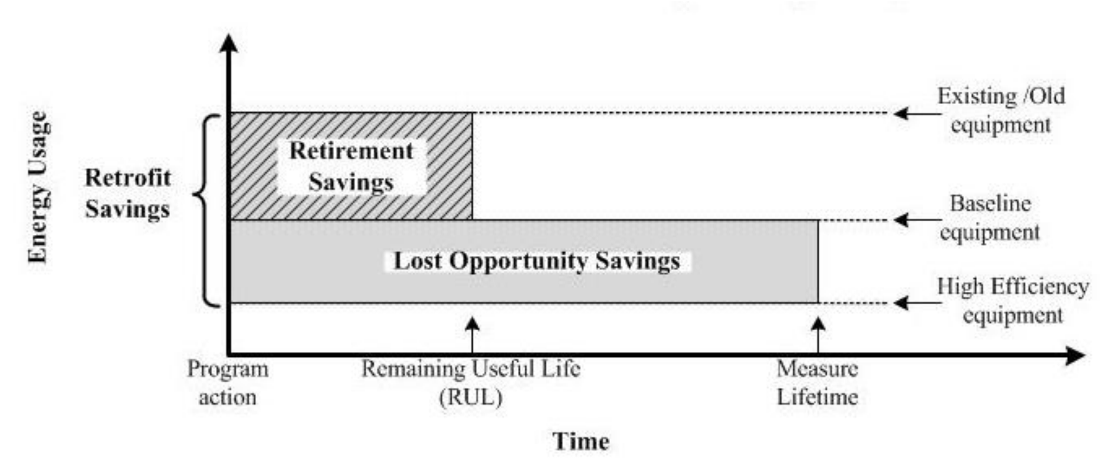
[v] DNV, CT X1931-8 Commercial Advanced Thermostat PSD New Measure Phase 1, Jul. 23, 2021.

A4.1 RESIDENTIAL LIFETIMES

Measure life for residential measures includes equipment life and measure persistence. Measure life for certain measures, such as LED lighting, takes into account anticipated market adoption of more efficient baseline technologies.

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. For early retirement, savings includes two parts: (1) the Retirement Savings piece that lasts until the end of the remaining useful life (RUL) of the existing equipment, after which (2) lost opportunity savings continue until the last year of the retrofit measure’s effective useful life (EUL). This is illustrated by Chart A4-1 on the next page.

Chart A4-1: Retrofit, Retirement, and Lost Opportunity Savings



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 result in Lost Opportunity Savings, while measures applied in existing homes and turn-in measures may result in both Retirement and Lost Opportunity Savings. Numbers in parentheses refer to lifetimes specially pertaining to a low-income home.

Table A4-2: Retirement and Lost Opportunity Lifetimes

Measure	Retirement RUL	Lost Opportunity EUL
Light Bulbs		
General service (A lamps)	N/A	2 years (all retail and direct install) (k)
Specialty (globe, candelabra, etc.)	N/A	2 years (all retail and direct install) (k)
Reflectors and recessed downlights (PAR, BR, etc.)	N/A	2 years (hard-to-reach retail and direct install) (k)
Fixtures (hard-wired fixtures)	N/A	2 years (all retail and direct install) (k)
Heating, Ventilation, and Air-Conditioning (HVAC) Systems		
Air-source heat pump	5 (b)	18 (c, 1)
Boiler (gas)	7 (b)	20 (a)
Boiler reset control	N/A	15 (e)
Central A/C system	3.67[4]	11 (s)
Clean tune and test	N/A	2 (j)
Duct insulation	N/A	20 (c, 1)
Duct sealing retrofit	N/A	20 (c, 1)
Ductless split heat pump	N/A	18 (s)
Electronically commutated motor (fan)	N/A	18 (c, 1)
ECM circulator pump	N/A	15 (f)
Furnace (natural gas)	7 (b)	20 (b)
Geothermal heat pump	N/A	18 (c, 1)
Package terminal heat pump	5 (b)	18 (c, 1)
QIV, air-source heat pump	N/A	18 (c, 1)
QIV, boiler (boiler reset)	N/A	20 (a)
QIV, Central A/C system	N/A	18(c, 1)
QIV, geothermal heat pump	N/A	18 (c, 1)
Wi-Fi thermostat	N/A	15 (g)

[4] Estimated as 1/3rd of Lost Opportunity EUL.

Appliances		
Room air cleaner	N/A	9 (m)
Clothes washers, clothes dryer	4(b)	11 (a)
Dehumidifier	4(b)	12 (c, 1)
Dishwasher	4(b)	10 (a)
Freezer	4 (8)(b)	11 (a)
Refrigerator	5 (10)(b)	12 (a)
Room A/C unit	3(b)	13 (p)
Refrigerator recycling	5(q)	N/A
Freezer recycling	4(q)	N/A
Electronics		
Advanced power strip	N/A	5 (i)
Television	N/A	6 (r)
Blu-Ray player	N/A	7 (n)
DVD player	N/A	7 (n)
Telephone	N/A	7 (n)
Computer monitor	N/A	7 (o)
Laptop/desktop computer	N/A	4 (o)
Sound bar	N/A	7 (m)
Envelope		
Air sealing and weatherization (non-blower door)	N/A	15 (c, 1)
Blower door	N/A	20 (c, 1)
Broken window repair	N/A	5 (b)
Insulating attic openings	N/A	25 (c, 1)
Insulation	N/A	25 (c, 1)
Storm window installation	N/A	20 (c, 1)
Window replacement	N/A	25 (c, 1)
Domestic Hot Water		
Flip and faucet aerator	N/A	10 (b)
Heat pump water heater	N/A	13.5 (s)
High-efficiency storage gas water heater	N/A	11 (b)
On-demand tankless gas water heater	N/A	20 (b)

Pipe insulation	N/A	15 (b)
Low-flow shower head	N/A	10 (c,2)
Water heater thermostat setting (existing unit)	N/A	4 (b)
Water heater wrap	N/A	7 (b)
Solar water heating	N/A	20 (h)
REM Savings (for ENERGY STAR Homes)		
Cooling	N/A	25 (c,1)
Domestic water heating	N/A	25 (c,1)
Heating	N/A	25 (c,1)
BOP (Builder Option Plan for ENERGY STAR Homes)		
Cooling	N/A	25 (c,1)
Domestic water heating	N/A	25 (c,1)
Heating	N/A	25 (c,1)
Behavioral Programs		
Home Energy Reports	N/A	2 (d)

Changes from Last Version

- Updated Residential LED lifetimes.
- Updated Central A/C and HPWH lifetimes.

References

[a] *Appliance Magazine*. *U.S. Appliance Industry: Market Share, Life Expectancy & Replacement Market, and Saturation Levels*, Jan. 2010. p. 10.

[b] California Public Utilities Commission, 2014 Database for Energy-Efficient Resources, Feb. 4, 2014, available online at: http://www.deeresources.com/files/DEER2013codeUpdate/download/DEER2014-EUL-table-update_2014-02-05.xlsx, last accessed Sep. 3, 2020.

[c] GDS Associates Inc., *Measure Life Report, Residential and Commercial Industrial Lighting and HVAC Measures*, Jun. 2007.

[c,1] Table 1.

[c,2] Appendix C, p. C-6.

[d] NMR, *1606 Eversource Behavior Program Persistence Evaluation*, Oct. 15, 2017.

[e] American Council for an Energy-Efficient Economy, *Emerging Technologies Report*, May 2006, p. 2.

[f] Rhode Island TRM, Nation Grid, 2012 edition, p. M-76.

[g] Environmental Protection Agency (2010), *Life Cycle Cost Estimate for Programmable Thermostats*, last accessed on Oct. 12, 2011.

[h] Tim Merrigan, Solar Thermal Systems Analysis, National Renewable Energy Laboratory, available online at: https://www1.eere.energy.gov/solar/pdfs/solar_tim_merrigan.pdf.

[i] Plug Load –Smart Strips, 2015 Massachusetts TRM, p. 162.

[j] NYSERDA (New York State Energy Research and Development Authority), $mart Equipment Choices Database.

[k] Adjusted measure life, estimated based on lighting market share trends and sales and pricing data, from NMR, *R1963a Short-Term Residential Lighting Report, Draft*, Jul 14, 2020 and SCS Analytics, *Preliminary Results from R1963B: Short Term Residential Lighting Analysis*, Jul 13, 2020.

[l] *Heat Pump Water Heaters and American Homes: A Good Fit?*, Lawrence Berkeley National Laboratory, 2010, pp. 9-74.

[m] EPA Next Gen Product Analysis_10.9.14.xlsx, last accessed on Jul. 1, 2015.

[n] Savings Estimate for ENERGY STAR Qualified Consumer Electronics, ENERGY STAR Consumer Electronics Calculator, ENERGY STAR. Available at: https://www.energystar.gov/sites/default/files/asset/document/Consumer_Electronics_Calculator.xlsx, last accessed on Jul. 19, 2017.

[o] Savings Estimate for ENERGY STAR Qualified Office Equipment, ENERGY STAR Office Equipment Savings Calculator, ENERGY STAR. Available at: https://www.energystar.gov/sites/default/files/asset/document/Office%20Equipment%20Calculator.xlsxl, last accessed on Jul. 19, 2017.

[p] Conservative estimate, based on 13-year median age for Room A/Cs found in NMR, *R1706 Residential Appliance Saturation Survey & R1616/R1708 Residential Lighting Impact Saturation Studies*, DRAFT Report, Jun. 28, 2019.

[q] New York State Joint Utilities, *New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs – Residential, Multifamily, and Commercial/Industrial Measures, Version 7,* Apr. 15, 2019.

[r] ENERGY STAR Consumer Electronics Calculator, as recommended by ERS, *X1931 PSD Review, EUL*

Comparative Analysis, Jul 2020.

[s] Michael Energy, CT X2001 measure Life/EUL update measure group 1 results Jun. 28, 2021.

APPENDIX FIVE: HOURS OF USE

A5.1 COMMERCIAL AND INDUSTRIAL HOURS OF USE AND EFLH

Table A5-1: C&I Hours of Use

Facility Type	Lighting Hours		Cooling FLHrs (Note [1])	Heating FLHrs (Note [1])	HVAC Fan Motor Hours (Note [1])	CHWP & Cooling Towers (Note [1])	Heating Pumps (Note [1])
Auto related	2,807	**[1]**	427	3,122	6,421	1,442	2,484
Bakery	5,468	**[2]**	565	1,065	4,618	1,037	1,787
Banks, financial center **(Note [2])**	3,748	**[3]**	853	372	5,519	2,732	5,629
Church	913	**[1]**	266	938	3,493	785	1,351
College: cafeteria	5,018	**[2]**	591	1,178	5,835	1,311	2,258
College: classes/administrative **(Note [2])**	4,839	**[2]**	680	949	5,995	2,357	6,471
College: dormitory	4,026	**[2]**	729	536	3,833	3,833	3,833
Commercial condo	4,026	**[2]**	3,186	836	8,760	4,470	8,760
Convenience store	5,468	**[2]**	771	831	5,207	1,170	2,015
Convention center	913	**[1]**	3,186	836	8,760	4,470	8,760
Court house **(Note [2])**	4,181	**[2]**	853	372	5,519	2,732	5,629
Dining: bar lounge/leisure	5,018	**[2]**	558	1,118	5,264	1,183	2,037
Dining: cafeteria/fast food	5,018	**[2]**	591	1,178	5,835	1,311	2,258
Dining: family	5,018	**[2]**	558	1,118	5,264	1,183	2,037
Entertainment	1,952	**[3]**	726	1,042	5,737	1,289	2,220
Exercise center	5,836	**[3]**	726	1,042	5,737	1,289	2,220
Fast food restaurant	5,018	**[2]**	591	1,178	5,835	1,311	2,258
Fire station (unmanned)	4,336	**[2]**	729	536	3,833	3,833	3,833
Food store	5,468	**[1]**	386	840	4,545	1,021	1,758
Gymnasium	2,586	**[3]**	726	1,042	5,737	1,289	2,220
Hospital **(Note [2])**	5,413	**[2]**	1,204	513	8,683	7,682	8,760
Hospitals/health care **(Note [2])**	5,564	**[1]**	1,204	513	8,683	7,682	8,760
Industrial: 1 shift	2,897	**[1]**	565	1,065	4,618	1,037	1,787
Industrial: 2 shift	5,793	**[1]**	767	727	6,771	1,037	2,620

Industrial: 3 shift	8,690	**[1]**	972	384	8,760	1,037	3,466
Laundromat	4,056	**[3]**	771	831	5,207	1,170	2,015
Library	3,748	**[3]**	726	1,042	5,737	1,289	2,220
Light manufacturer	5,793	**[1]**	565	1,065	4,618	1,037	1,787
Lodging (hotel/motel)	3,112	**[1]**	897	628	3,421	769	1,324
Mall concourse **(Note [2])**	4,939	**[1]**	803	672	4,690	3,013	4,932
Manufacturing facility	5,793	**[1]**	565	1,065	4,618	1,037	1,787
Medical office	3,673	**[2]**	827	598	4,795	1,077	1,855
Motion picture theatre	1,954	**[3]**	726	1,042	5,737	1,289	2,220
Multifamily (common areas)	6,388	**[4]**	729	536	3,833	3,833	3,833
Museum	3,748	**[3]**	726	1,042	5,737	1,289	2,220
Nursing home	5,840	**[3]**	3,186	836	8,760	4,470	8,760
Office (general office types)	4,098	**[1]**	827	598	4,795	1,077	1,855
Office/retail	4,181	**[1]**	827	598	4,795	1,077	1,855
Parking garage and lot	6,887	**[1]**	427	3,122	6,421	1,442	2,484
Penitentiary	5,477	**[3]**	3,186	836	8,760	4,470	8,760
Performing arts theatre	913	**[1]**	726	1,042	5,737	1,289	2,220
Police/fire station (24 Hr)	8,760	**[1]**	2,007	717	6,778	2,774	5,308
Post office	3,748	**[1]**	827	598	4,795	1,077	1,855
Pump station	1,949	**[3]**	972	384	2,241	2,097	4,828
Refrigerated warehouse	6,512	**[2]**	297	734	3,604	810	1,394
Religious building	913	**[1]**	266	938	3,493	785	1,351
Residential (except nursing homes)	3,066	**[3]**	729	536	3,833	3,833	3,833
Restaurant	5,018	**[2]**	558	1,118	5,264	1,183	2,037
Retail	4,939	**[2]**	771	831	5,207	1,170	2,015
School/university **(Note [2])**	2,967	**[1]**	680	949	5,995	2,357	6,471
Schools (Jr./Sr. High) **(Note [2])**	2,967	**[1]**	485	1,075	2,241	2,097	4,828
Schools (preschool/elementary)	2,967	**[1]**	307	1,086	3,851	865	1,490
Schools (technical/vocational) **(Note [2])**	2,967	**[1]**	581	783	5,098	2,170	5,620
Small services	3,748	**[1]**	827	598	4,795	1,077	1,855
Sports arena	913	**[1]**	726	1,042	5,737	1,289	2,220

Town hall	4,181	**[1]**	726	1,042	5,737	1,289	2,220
Transportation	6,456	**[3]**	427	3,122	6,421	1,442	2,484
Warehouse (not refrigerated)	5,667	**[1]**	297	734	3,604	810	1,394
Wastewater treatment plant	6,631	**[3]**	972	384	2,241	2,097	4,828
Workshop	3,750	**[3]**	565	1,065	4,618	1,037	1,787

Note [1]: Developed based on simulation of DOE-2 commercial building prototypes in eQUEST using Hartford weather data.

Note [2]: Results are based on VAV systems with economizers.

Changes from Last Version

- Updated hours of use for all facility types and added new facility types based on **Ref [2]**.

References

[1] DNV, 2020 C1635 Impact Evaluation of PY 2016 & 2017 Energy Opportunities (EO) Program, Aug. 27, 2020.

[2] DNV GL, MA C&I Project 86 Lighting Hours of Use Study, Apr. 12, 2019.

[3] RLW Analytics, “CT and MA Utilities 2004-05 Lighting Hours of Use for School Buildings Baseline Study,” Final Report, Sep. 7, 2006.

[4] TRC. X1941: Multifamily Impact Evaluation, PSD Savings Review, Jul. 2020.

Notes

[1] Developed based on simulation of DOE-2 commercial building prototypes in eQUEST using Hartford weather data.

[2] Results are based on VAV systems with economizers.

APPENDIX SIX: NON-ENERGY IMPACTS

A6.1 NON-ENERGY IMPACTS

The Companies currently quantify and count several 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 their choice to adopt energy efficiency measures. NEIs have been estimated at 50-300% of annual household energy savings (**Ref [1]**). Many jurisdictions across the United States have quantified numerous NEIs and they include them in the Total Resource Cost Test.

The Companies include the NEIs in *Table A6-1* below in the Total Resource Cost Test, for HES-IE only. The test is described in Chapter 5 of the 2022-2024 Conservation & Load Management Plan (2022-2024 Plan).

Table A6-1: Residential NEIs (Ref [2])

	HES	HES-IE	Rebate	Multifamily
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**

The annual customer bill savings are multiplied by the factors in *Table A6-1* to estimate the NEIs. The NEI 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-IE program, the annual NEI is $0.70 cents for every dollar saved. The annual benefit is credited every year for the life (Appendix Four) of the measure.

The Companies do not include the NEIs in *Table A6-2* below in any of the benefit-cost tests—they are provided for informational purposes only.

Table A6-2: C&I NEIs (Ref [3])

NEI Category	NEI Dollar Impacts for BES Programs ($/source MMBtu Savings)		
	PRIME	O&M	RCx
Fuel oil, propane, and wood	N/A	N.D.	$0.15
Fresh potable water supplies	N/A	$0.06	$0.82
Labor requirements or labor associated costs	$153	$0.42	N/A
Equipment O&M	N.D.	N.D.	$0.53
Materials or other supply needs	N.D.	$1.47	($1.74)
Product spoilage	N/A	$0.44	N/A
TOTAL	**$153**	**$2.39**	**($0.23)**

N/A = Not applicable.
N.D. = No data from survey to quantify impacts.

Table A6-2 presents the average cost impacts from NEI categories for the BES suite of programs for all projects, not just those with NEIs. NEIs are converted to dollars per source MMBtu to apply to both natural gas and electricity savings. The following formula was used to convert values to source MMBtus:

1 kWh = 3.413 kBtu / ≈34% generation efficiency = 0.010 source MMBtus.

References

[1] Jennifer Thorne Amann, *Valuation of Non-Energy Benefits to Determine Cost-Effectiveness of Whole House Retrofit Programs: A Literature Review*, May 2006.

[2] NMR Group, Inc., submitted to EEB, Eversource, and United Illuminating. *Project R4 HES/HES-IE Process Evaluation and R31 Real-Time Research,* Apr. 13, 2016, available online at: https://www.energizect.com/sites/default/files/R4_HES-HESIE%20Process%20Evaluation,%20Final%20Report_4.13.16.pdf.

[3] ERS, Inc., *C1641: Impact Evaluation of the Business and Energy Sustainability Program*, draft report, Jul. 3, 2018. available online at: https://www.energizect.com/connecticut-energy-efficiency-board/evaluation-reports.

APPENDIX SEVEN: ABBREVIATIONS/ACRONYMS

A7.1 ABBREVIATIONS AND ACRONYMS

Table A7-1: Abbreviations and 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/1,000 Btu
ABTU	Annual Btu Savings	Btu/yr
A/C	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/1,000 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 A/C	
CAP	Capacity of the Equipment	Btu/h or Ton
CC	Bridgeport kWh Savings Factor from Pilot	kWh/1,000 Btu
ccf, CCF	100 Cubic Feet, Quantity of Natural Gas	100 Cubic Feet
CDD	Cooling Degree Days for CT	772
CEEF	Connecticut Energy Efficiency Fund	
CF	Seasonal Coincidence Factor	
CFL	Compact Florescent Light	
CFM	Cubic Feet per Minute, Air Flow Rate	ft^3/min
CHWP	Chilled Water Pump	
CL&P	Connecticut Light and Power	
COP	Coefficient of Performance	
CWP	Condenser Water Pump	
d	Duration	minutes
D	Density	lb/Gal
D	Dimension (height or width)	inches
Days	Annual Days of Use	Days/yr
DD	Bridgeport kW Savings Factor from Pilot	kW/1,000 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 UI ,CNG,SCG	Heating Degree Days for UI, SCG & CNG ,CT	°F
HDD EVERSOURCE	Heating Degree Days for EVERSOURCE ,CT	°F
HF	Heating Factor	Btu/ft^2/yr
HL	Heat Loss Savings per Linear Foot	Btu/hr/ft
HP	Horsepower (nameplate)	
HPWH	Heat Pump Water Heater	
HR	Ice Harvest Rate for Ice-Cube Machines	
HR	Annual Electric Energy Usage Dependent on Hours of Production	kWh/yr
HR	Percent Heating Not Using Backup Electric Resistance	%
Hrs	Operating Hours per Day	Hr/day
HSPF	Heating Seasonal Performance Factor	
HVAC	Heating, Ventilation, and Air Conditioning	
HWP	Hot Water Pump	
IGV	Inlet Guide Vane Fan Control	
IND	Annual Electric Energy Usage Independent of Production	kWh/yr
IPLV	Integrated Part Load Value	EER or kW/ton
ISO-NE	Independent System Operator New England	
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	1,000 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 1,000 Kilowatt	
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 Affected 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
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 Wisconsin	
WIHDD	Heating Degree Days for Wisconsin	
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	

A7.2 SUBSCRIPTS

Table A7-2: Subscripts

Symbol	Description (See Note [1])	Units
$..._A$	Actual/installed unit	
$..._a$	After PRIME	
$..._b$	Baseline unit	

$\ldots_{BD}$	Blower door flow rate reading performed at 50 Pa	Cubic feet per minute
$\ldots_{BIN}$	Temperature BIN hours	
$\ldots_{C}$	Cooling	
$\ldots_{CAC}$	Central A/C	
$\ldots_{CDH}$	From CDH HVAC study	
$\ldots_{d}$	Number of hours that piece of equipment is expected to operate per day	h
$\ldots_{\Delta}$	Delta	
$\ldots_{dp}$	Double pane window	
$\ldots_{door\ kit}$	Door kit, door sweep	
$\ldots_{DS}$	Duct sealing flow rate reading performed at 25 Pa	Cubic feet per minute
$\ldots_{E}$	Electric energy	
$\ldots_{e}$	Existing (e.g., unit, production rate, etc.)	
$\ldots_{es}$	ENERGY STAR	
$\ldots_{ES\ 09}$	ENERGY STAR 2009 unit	
$\ldots_{fed\ std}$	Federal standard unit	
$\ldots_{G}$	Natural gas	
$\ldots_{gasket}$	Air sealing gasket	
$\ldots_{h}$	Based on billing history	
$\ldots_{H}$	Heating	
$\ldots_{HP}$	Heat pump	
$\ldots_{HVAC}$	HVAC motor	
$\ldots_{hw}$	Hardwired light fixtures	
$\ldots_{i}$	Incoming	
$\ldots_{i}$	Installed unit	
$\ldots_{ic}$	Interactive cooling	
$\ldots_{L}$	Lighting	
$\ldots_{LI}$	Low-income sector	
$\ldots_{LO}$	Lost opportunity measure	
$\ldots_{lpd}$	Lighting Power Density	
$\ldots_{lt}$	Lifetime	
$\ldots_{M}$	Motors	
$\ldots_{N}$	Non-HVAC applications	
$\ldots_{NLI}$	Non-low-income sector	

$\ldots_O$	Oil	
$\ldots_O$	Others	
$\ldots_{os}$	Occupancy sensors	
$\ldots_P$	Process	
$\ldots_P$	Propane	
$\ldots_{post}$	Final reading	
$\ldots_{pre}$	Initial reading	
$\ldots_R$	Electric resistance	
$\ldots_R$	Refrigeration	
$\ldots_{ratio}$	Ratio between low-efficiency value and high-efficiency value	
$\ldots_{retire}$	Retirement portion	
$\ldots_{retro}$	Retrofit portion	
$\ldots_{retrofit}$	Retrofit portion	
$\ldots_S$	Summer	
$\ldots_{sealing}$	Caulking, sealing, polyethylene tape	foot
$\ldots_{total}$	Total, sum	
$\ldots_W$	Water heating	
$\ldots_{wop}$	Without PRIME	
$\ldots_{wp}$	With PRIME	
$\ldots_{wt}$	Winter	
$\ldots_{wx}$	Weatherstrip, repair	
$\ldots_y$	Number of hours that piece of equipment is expected to operate per year	h

Changes from Last Version

- No changes.

Notes

[1] These terms have more complete definitions in the Glossary section.