Connecticut's 2020 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 sixteenth update to the PSD manual ("2020 PSD manual").

The C&LM savings calculations in the 2020 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

[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 New England region three years in advance and then holding an annual auction to purchase power resources to satisfy the region's future needs.

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 2020 PSD manual provides the basis of any demand reduction value calculations submitted by Eversource and United Illuminating in the FCM.

1.3 Organization

C&LM measures in the 2020 PSD manual are grouped by primary sector and reflect how programs and measures are organized within C&LM. Commercial and industrial ("C&I") measures are also categorized as either "Lost Opportunity" or "Retrofit." The main sections of the 2020 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; and
- Appendices.

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

- ~~1.~~ **Description of Measure.** Describes the scope and basics of the measure;
- ~~2.~~ **Savings Methodology.** Lists the methods, reasoning, and tools used to perform calculations;
- ~~3.~~ **Inputs.** Captures required project or measure data used in the calculations;
- ~~4.~~ **Nomenclature.** Captures variables, constants, and other terminology used in the measure;
- ~~5.~~ **Retrofit Gross Energy Savings – Electric.** Describes the calculations used to determine electric gross energy savings;
- ~~6.~~ **Retrofit Gross Energy Savings – Fossil Fuel.** Describes the calculations used to determine fossil fuel gross energy savings;
- ~~7.~~ **Retrofit Gross Seasonal Peak Demand Savings – Electric (winter and summer).** Describes the calculations used to determine gross peak electric demand savings;
- ~~8.~~ **Retrofit Gross Peak Day Savings – Natural Gas.** Describes the calculations used to determine gross peak gas demand savings;
- ~~9.~~ **Lost Opportunity Gross Energy Savings – Electric.** Describes the calculations used to determine gross lost opportunity electric savings;

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- ~~10.~~ **Lost Opportunity Gross Energy Savings – Fossil Fuel.** Describes the calculations used to determine gross lost opportunity fossil fuel savings;
- ~~11.~~ **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;
- ~~12.~~ **Lost Opportunity Gross Peak Day Savings – Natural Gas.** Describes the calculations used to determine gross peak natural gas lost opportunity savings;
- ~~13.~~ **Non-Energy Impacts.** Describes any impacts not directly associated with energy savings;
- ~~14.~~ **Changes from Last Version.** If there are any changes from the previous version, they are described in this section;
- ~~15.~~ **References.** Sources used to construct the measure are listed here; and
- ~~16.~~ **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 Conservation Management Board, now called 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 Energy Efficiency Fund programs.

Energy Efficiency Fund programs are administrated by the Companies. These programs are designed to realize the Energy Efficiency Fund's three primary objectives:

1. **Advance the Efficient Use of Energy**: Energy Efficiency Fund programs are critical in reducing overall energy consumption and reducing load during periods of high demand. They help mitigate potential electricity shortages and reduce stress on transmission and distribution lines in the state.
2. **Reduce Air Pollution and Negative Environmental Impacts**: Energy Efficiency Fund programs produce environmental benefits by slowing the electricity demand growth rate, thereby avoiding emissions that would otherwise be produced by increased power generation activities. The 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.

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[2] Conn. Gen. Stat. § 16-245m.

Energy Efficiency 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," such as methane, are also emitted during the process. Greenhouse gases have been linked to global warming and climate change. Energy Efficiency Fund programs have helped to reduce carbon dioxide emissions by reducing electrical demand, and consequently the need for additional generation, through energy efficiency and conservation. These programs also produce environmental benefits by reducing the consumption of natural gas and fuel oil. With assistance from the EEB, the Companies have developed Energy Efficiency 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:** Energy Efficiency Fund programs generate considerable benefits for Connecticut customers. These programs are tailored to meet the particular needs of all customers, thereby benefiting all state residents and businesses. Energy efficiency measures assist residential customers in reducing their energy costs. Other groups that benefit from energy efficiency programs include educational institutions, non-profit organizations, municipalities, and businesses. By reducing operating costs and enhancing productivity, Connecticut businesses remain competitive in the dynamic global economy.

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Information regarding Energy Efficiency 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

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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 C&LM programs. The results of these evaluations are incorporated into the 2020 PSD manual through changes to savings algorithms and/or realization rates which are used to adjust savings.

The savings results presented in the 2020 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 C&LM measures to the corresponding time of day when those savings are realized.

Types of Savings

Energy efficiency measures are generally limited to two types:

- **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.

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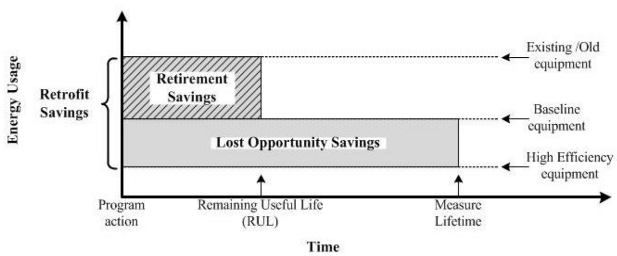
Many energy efficiency measures consist of both Retirement Savings and Lost Opportunity Savings. This is illustrated by Chart 1-A.

Chart 1-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 an Energy Efficiency 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.

Peak Savings

The values for electric demand savings (both winter and summer) in the 2020 PSD manual are given based on the following definition:

- ~~1.~~ 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;
- ~~2.~~ The “Summer Season” is defined as non-holiday weekdays during the months of June, July, and August; and
- ~~3.~~ The “Winter Season” is defined as non-holiday weekdays during December and January.

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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. Where appropriate, these are defined in the 2020 PSD manual. Non-energy impacts (“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 2020 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 (calculated) Savings. 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 (calculated) Energy Savings 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 2020 PSD manual rates have been updated based on recently completed studies.

Common Energy Conversions

Energy conversions used in the 2020 PSD manual that convert energy to a specific fuel type are summarized in Table 1-A.

Table 1-A: 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
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

1.6 Savings Calculations

See the individual measure “Changes from Last Version” sections for details.

1.7 Glossary

The Glossary provides definitions of the energy efficiency terms used in the 2020 PSD manual. Note that some of these terms may have alternative or multiple definitions some of which may be outside the context of the 2020 PSD manual. Only definitions pertaining to the 2020 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 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 compliance efficiency.*

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

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

Benefit-Cost Ratio ("BCR"): The efficiency programs determine cost-effectiveness using 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 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.

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

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

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

Coefficient of Performance ("COP"): The efficiency rating of heating or cooling equipment. The COP is, at specific standard conditions, based on the specific type of equipment. Typically used for heat pumps in heating mode and 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 2020 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 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:

- ~~1.0~~ **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.

- ~~2.0~~ **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.

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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 benefit-cost ratio is greater than or equal to 1.0.

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

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

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

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

Energy Efficiency: Reducing energy usage without a notable reduction in functional performance.

Energy Efficiency Ratio ("EER"): 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.

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

Evaluation Studies: 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.

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

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

Gross Savings: 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.

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

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

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

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

Impact Factor: A number (usually expressed as a percent) used to adjust the gross savings in order to reflect the savings observed by an impact study.

Installation Rate: 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.

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

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

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

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

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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.

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

Market Effect: A 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.

MMBtu: Millions of British Thermal Units.

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

Measure Cost: For new construction or measures that are installed at their natural time of replacement (replace upon burn-out), measure cost is defined as the incremental cost of upgrading to high-efficiency 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 2020 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 benefit-cost ratio is greater than or equal to 1.0.

Net Savings: The final value of savings that is attributable to a program or measure. Net Savings differs from “Gross Savings” because it includes adjustments from impact factors, such as free-ridership or spillover. Net Savings is sometimes referred to as “Verified Savings” or “Final Savings.”

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

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.

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

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

- ~~[1]~~ **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.

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- ~~[2]~~ **On-Peak Hours** are hours 1:00-5:00 p.m., Monday through Friday on non-holidays during the months of June, July, and August and from 5:00-7:00 p.m., Monday through Friday on non-holidays during the months of December and January.

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

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

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

Retrofit: The replacement of a piece of equipment or device before the end of its useful or planned life, for the purpose of achieving energy savings. Retrofit measures are sometimes referred to as "early retirement" when the removal of the old equipment is aggressively pursued. Residential measures utilize a two-part lifetime savings calculation. In certain situations, such as early retirement, savings may be claimed in two parts: (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."*

R-Value: A measure of thermal resistance of a material or system, equal to the reciprocal of the U-Value, used to calculate heat gain or loss. The R-Value is expressed as degree Fahrenheit square feet hours per Btu ($ft^2 \cdot °F \cdot h/Btu$).

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

Sector: A system for grouping customers with similar characteristics. For the purpose of the 2020 PSD manual, the sectors are C&I, Small Business ("SMB"), Residential, Non-Limited Income ("NLI"), and Limited Income ("LI").

Spillover: 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 DLC- or EnergyStar-approved lighting equipment ~~current energy code baseline~~.

Commented [SK1]: Recommended to add: "exceeds current energy code with DLC- or EnergyStar-approved lighting equipment"

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 (**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 2015 IECC standards and additional efficiency code requirements; choose the appropriate table. If projects are initiated after the new code adoption, then 2015 IECC is the default used to evaluate the energy savings. Current 2015 IECC Code requires lighting controls for buildings over 5,000 square feet. Therefore, occupancy sensor savings are only calculated if buildings > 5,000 square feet have occupancy sensors in addition to the code-required scheduled lighting control.

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- **Exterior Lighting:** The default baseline for exterior lighting is ASHRAE 90.1-2013. 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 2-F for the applicable lighting zone. Trade-offs are allowed only among exterior lighting applications listed in Table 2-F. The lighting zone for the building exterior is determined from Table 2-G.

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Inputs

Table 2-A: Inputs

Symbol	Description	Units
Allowable LPD	Allowable LPD from ~~2015~~ 2018 IECC	Watts/ft^2
	Total Fixture Connected kW	kW
	Facility Illuminated Area	ft^2

Commented [SK2]: Varies by site; baselines by building area method in table 2-D per IECC 2018 for 2021 PSD Update.
Specify that the space-by-space method may also be used (IECC 2018 C405.3.2(2)) for 2021 PSD Update.

$$S = S_{lpd} \pm S_{os} \pm S_{hw} \pm S_c$$

Nomenclature

Table 2-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	Note [3]
$DeltaW_{hw}$	Delta Watts of Hardwired Fluorescent Fixtures in Residential Areas as Calculated per Section 4.1.2 of the 2019 PSD			
F	Fraction of Lighting Energy that Must be Removed by the Facility's Cooling System			
G	Estimated Lighting Energy Heat		0.73	Note [4]
H	Facility Lighting Hours of Use	hrs		'Site Specific; Use Appendix Five only when site-specific assumptions do not exist.~~Site Specific or Appendix Five~~
HVAC	Heating, Ventilation, and Air Conditioning			
kW	Electric Demand	kW		
LPD	Lighting Power Density	Watts/ft^2		
~~N~~	~~Number of Different Fixture Types with Occupancy Sensors~~			
N	Fixture Number			
~~O_n~~	~~Quantity of Fixtures of Type n that have Occupancy Sensors~~			
S_c	Energy Savings from Reduced Cooling Load	kWh		
S_{hw}	Energy Savings from Installation of Hard-wired Fluorescent Fixtures in Residential Areas	kWh		
S_{lpd}	Energy Savings due to Lower Lighting Power Density	kWh		
~~S_{os}~~	~~Energy Savings from Use of Occupancy Sensors, if applicable~~	~~kWh~~		
S_{ext}	Exterior Energy Savings	kWh		
W	Fixture Input Wattage	Watts		
W_n	Input Watts for Fixture Type n	Watts		
W_allowance	Baseline W for exterior fixture lighting power	Watts		

Lost Opportunity Gross Energy Savings, Electric

Interior lighting:

S_int = S_lpd + S_hw + S_c

Commented [SK3]: Include "W_allowance - baseline W for exterior fixture lighting power" in the table for consistency.

Commented [SK4]: Recommended to create a separate measure for Lighting controls (occupancy sensors).
As discussed at 7/15 meeting: Lighting controls such as occupancy sensors may be installed independently of other lighting upgrades.
Other TRMs list Occupancy Sensors or Lighting Controls as an independent measure (e.g., MA and RI TRMs).
Recommend calling the new measure "Lighting controls" as opposed to "occupancy sensors" to allow for future addition of other types of controls, like advanced lighting controls (ALCS) - which could provide deeper savings. Could add photo sensors to this new measure and include approaches from MA TRM in the new measure. Creating a new measure for lighting controls would not encourage more replacements, although more savings could be achieved if a clear path for ALCS is developed. There are 3 options:
1. No change and keep occupancy sensors in Standard Lighting.
2. Create new "Lighting Controls" measure and move existing language from Standard Lighting to this new measure.
3. Option 2, and enhance this measure by adding photo sensors, approaches from MA TRM, and/or ALCS path.
TRC recommends option 2 for now, and that a separate study conduct secondary research to implement Option 3

Commented [SK5]: *No changes needed here but see recommended MF hours change in Appendix Five: MF hours default update = 6,388.*

Commented [SK6]: Update Comments field for *H - Facility Lighting Hours of Use* from 'Site Specific or Appendix Five' to 'Site Specific; Use Appendix Five only when site-specific assumptions do not exist.'

Commented [KR7]: Recommended to create a separate measure for Lighting controls (occupancy sensors). See comment above.

Commented [KR8]: Recommended to create a separate measure for Lighting controls (occupancy sensors). See comment above.

Commented [SK9]: Recommended to create a separate measure for Lighting controls (occupancy sensors). See comment above.

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

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 2015 IECC are provided in the tables below. Refer to 2015 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 2015 IECC 405.4.2(2).

- Actual LPD, in kW/ft^2, is calculated by dividing the total Fixture Wattage by the Lighted Area, ft^2, where Fixture Wattage is the sum of the power consumed by each fixture.
- A = is calculated (measured) for each project, either from architectural drawings or by physical measurement.
- ~~Calculation of savings due to occupancy sensors (Note [5]).~~

~~*If the Actual LPD is less than or equal to the Allowable LPD, then SOS will be calculated as follows; otherwise: SOS = 0:*~~

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

Explanation of numerical constants:

- ~~0.3 is the generally accepted average energy reduction fraction due to the use of occupancy sensors. See Ref [1].~~
- 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 2020 PSD's Section 4.1.2 "Luminaire" for this calculation. Normally, the total number and type of fixtures in living areas is not known at the time of construction, so the LPD method cannot be used to calculate these savings. Where hard-wired fixtures are installed as part of new construction, they are usually shown on the building plans. Their savings are calculated per fixture according to the residential methodology.

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

S_c = Savings resulting from reduced cooling:

S_c = (S_lpd + S_hw) x F / COP

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Commented [SK10]: Algorithm update to: S_int = S_lpd + S_hw + S_c

Commented [KR11R10]: Remove occupancy sensor and create separate measure savings for occupancy sensor.

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Commented [SK12]: Create separate measure for Occupancy Sensor. See comment above.

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

- ~~1.~~ 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 2-C.
- ~~2.~~ COP = 4.5 (**Note: [3]**).

Commented [SK13]: S_c = (S_lpd + S_hw) x F / COP

Commented [SK14R13]: Remove occupancy sensor and create separate measure savings for occupancy sensor.

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Table 2-C: Fraction of Annual kWh Energy Savings that Must Be Removed by the Cooling System (See Ref [2])

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

Table 2-D: Lighting Power Densities Using the Building Area Method – IECC ~~2015~~ 2018 Standard Section C405.4.2(1) Ref [5]) and Section C406.3 Additional Efficiency Options (Ref [6])

Building Area Type (see Note [2])	Standard LPD (W/ft^2)	Additional Efficiency Option (W/ft^2)
Automotive Facility	0.80	0.71~~0.72~~
Convention Center	1.01	0.76~~0.91~~
Court House	1.01	0.90~~0.91~~
Dining: Bar Lounge/Leisure	1.01	0.90~~0.91~~
Dining: Cafeteria/Fast Food	0.9	0.79~~0.81~~
Dining: Family	0.95	0.78~~0.86~~
Dormitory	0.57	0.61~~0.51~~
Exercise Center	0.84	0.65~~0.76~~
Fire Station	0.67	0.53~~0.60~~
Gymnasium	0.94	0.58~~0.85~~
Health Care Clinic	0.9	0.82~~0.81~~
Hospital	1.05	1.05~~0.95~~
Hotel/Motel	0.87	0.75~~0.78~~
Library	1.19	0.78~~1.07~~
Manufacturing Facility	1.17	0.90~~1.05~~
Motel	0.87	deleted~~0.78~~
Motion Picture Theatre	0.76	0.83~~0.68~~
Multi-Family	0.51	0.68~~0.46~~
Museum	1.02	1.06~~0.92~~
Office	0.82	0.79~~0.74~~
Parking Garage	0.21	0.15~~0.19~~
Penitentiary	0.81	0.75~~0.73~~
Performing Arts Theatre	1.39	1.18~~1.25~~
Police/Fire Station	0.87	0.80~~0.78~~
Post Office	0.87	0.67~~0.78~~
Religious Building	1.0	0.94~~0.9~~
Retail	1.26	1.06~~1.13~~
School/University	0.87	0.81~~0.78~~
Sports Arena	0.91	0.87~~0.82~~
Town Hall	0.89	0.80~~0.8~~
Transportation	0.70	0.61~~0.63~~
Warehouse	0.66	0.48~~0.59~~
Workshop	1.19	0.90~~1.07~~

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a. In cases where both a general building area type and a more specific building area type are listed, the more specific building area type shall apply.
b. First LPD value applies if no less than 30% 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.
c. 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.

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Exterior Lighting

Calculation of savings due to lower lighting power:

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

Watts as tabulated per 2-E, 2-F, and 2-G, based on IECC 2018 (for PSD 2021 update)~~allowance is determined from Table 2-F~~:

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Commented [SK15]: As tabulated per 2-E, 2-F, and 2-G, based on IECC 2018 (for PSD 2021 update)

H = Hours of Use

Table 2-E: Exterior Lighting Zones (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 2-F: Exterior Lighting Power Allowances – ~~2015~~ 2018 IECC Standard Section C405.5.2(2) (Ref [7])

Category	Space	Units	Power Allowance Zone 1	Power Allowance Zone 2	Power Allowance Zone 3	Power Allowance Zone 4
Base Site Allowance		W	350~~500~~	400~~600~~	500~~750~~	900~~1300~~
Uncovered Parking Areas	Parking Areas and Drives	W/ft²	0.03~~0.04~~	0.04~~0.06~~	0.06~~0.10~~	0.08~~0.13~~
Building Grounds	Walkways less than 10 Feet Wide	W/Linear Foot	0.50~~0.70~~	0.50~~0.70~~	0.60~~0.80~~	0.70~~1.00~~
Building Grounds	Walkways 10 feet Wide or Greater; plaza areas; special feature areas~~Walkways 10 feet Wide or Greater~~	W/ft²	0.10~~0.14~~	0.10~~0.14~~	0.11~~0.16~~	0.14~~0.20~~
Building Grounds	Plaza Areas	W/ft²	removed~~0.14~~	removed~~0.14~~	removed~~0.16~~	removed~~0.20~~
Building Grounds	Special Feature Areas	W/ft²	removed~~0.14~~	removed~~0.14~~	removed~~0.16~~	removed~~0.20~~
Building Grounds	Stairways	W/ft²	0.60~~0.75~~	0.70~~1.00~~	0.70~~1.00~~	0.70~~1.00~~
Building Grounds	Pedestrian Tunnels	W/ft²	0.12~~0.15~~	0.12~~0.15~~	0.14~~0.20~~	0.21~~0.30~~
Building Grounds	Landscaping	W/ft²	0.03~~0.04~~	0.04~~0.05~~	0.04~~0.05~~	0.04~~0.05~~
Building Entrances and Exits	Pedestrian and vehicular entrances and exits~~Main Entries~~	W/Linear Foot (door width)	14.00~~20.0~~	14.00~~20.0~~	21.00~~30.0~~	21.00~~30.0~~
Building Entrances and Exits	Loading Docks~~Other Doors~~	W/Linear Foot (door width)	0.35~~20.0~~	0.35~~20.0~~	0.35~~20.0~~	0.35~~20.0~~
Building Entrances and Exits	Entry Canopies	W/ft²	0.02~~0.25~~	0.25~~0.25~~	0.40~~0.40~~	0.40~~0.40~~
Sales Canopies	Canopies (free standing and attached)	W/ft²	0.04~~0.60~~	0.04~~0.60~~	0.60~~0.80~~	0.70~~1.00~~
Outdoor Sales	Open Areas (including vehicle sales lots)	W/ft²	0.02~~0.25~~	0.02~~0.25~~	0.35~~0.50~~	0.05~~0.70~~
Outdoor Sales	Street Frontage for Vehicle Sales Lots in Addition to "Open Area" Allowance	W/Linear Foot	- ~~-~~	7.00~~10.0~~	7.00~~10.0~~	21.00~~30.0~~

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Table 2-G – Exterior Lighting Power Allowances – ~~2015~~ 2018 IECC Standard Section C405.5.2(2) (continued) (Ref [7])

	Category	Units	Zone 1	Zone 2	Zone 3	Zone 4
			Power Allowance			
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 and Night Depositories	W per Location	135 W per location plus 45 W per additional ATM per location~~270 W plus 90 W per add ATM~~	135 W per location plus 45 W per additional ATM per location~~270 W plus 90 W per add ATM~~	135 W per location plus 45 W per additional ATM per location~~270 W plus 90 W per add ATM~~	135 W per location plus 45 W per additional ATM per location~~270 W plus 90 W per add ATM~~
	Entrances and Gatehouse Inspection Stations at Guarded Facilities	W/ft2 of Covered and Uncovered Area	0.5~~0.75~~	0.50~~0.75~~	0.50~~0.75~~	0.50~~0.75~~
	Loading Areas for Law Enforcement, Fire, Ambulance, and Other Emergency Vehicles	W/ft2of Covered and Uncovered Area	0.35~~0.50~~	0.35~~0.50~~	0.35~~0.50~~	0.35~~0.50~~
	Drive-Up Windows/Doors	W/Drive-Through	200~~400~~	200~~400~~	200~~400~~	200~~400~~
	Parking Near 24 Hour Retail Entrances	W/Main Entry	400~~800~~	400~~800~~	400~~800~~	400~~800~~

Lost Opportunity Gross Energy Savings, Fossil Fuel

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

- ~~1.~~ Annual Oil Savings = -0.000162279~~7129~~ MMBtu per annual kWh saved; and
- ~~2.~~ Annual Natural Gas Savings = -0.000162279~~75~~ MMBTU per kWh. See **Ref** [34].

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

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

kW(summer) = ((CF_L x (Allowable LPD - Actual LPD) x A) + (CF_hw x ΣDeltaW_hw)/1000) x (1 + G / COP)

kW(winter) = ((CF_L x (Allowable LPD - Actual LPD) x A) + (CF_hw x ΣDeltaW_hw)/1000)

Commented [SK16]: MA TRM was referenced previously; recommend update based on the latest MA TRM with updated study.

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Commented [SK17]: MA TRM was referenced previously; recommend update based on the latest MA TRM with updated study

Commented [SK18]: MA TRM recently updated. PSD reference should cite direct study used in the MA TRM.

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

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$$KW(summer) = \left(CF_L \times (AllowableLPD - ActualLPD) \times A) + CF_{OS} \times \frac{\sum_{n=1}^{N} O_n W_n}{1000} + CF_{hw} \times \frac{\sum DeltaW_{hw}}{1000} \right) \times \left(1 + \frac{G}{COP}\right)$$

$$KW(winter) = \left(CF_L \times (AllowableLPD - ActualLPD) \times A) + CF_{OS} \times \frac{\sum_{n=1}^{N} O_n W_n}{1000} + CF_{hw} \times \frac{\sum DeltaW_{hw}}{1000} \right)$$

- ~~1.~~ CF_L ~~and CF_{os} are~~is the lighting (CF_L) ~~and occupancy sensor (CF_{OS})~~ coincidence factors (summer/winter) taken from Appendix One.
- ~~2.~~ Allowable LPD, in kW/ft^2 = the value of Watts per ft^2 from the 2015 IECC for the facility type divided by 1,000.
- ~~3.~~ Actual LPD, in kW/ft^2 = Total Fixture Wattage (kW) divided by the Lighted Area, ft^2.
- ~~4.~~ A = is calculated for each project, either from architectural drawings or by physical measurement.
- ~~5.~~ CF_{hw} is the residential lighting coincidence factor (summer/winter) from Appendix One.
- ~~6.~~ $DeltaW_{hw}$ = Delta watts of hardwired fluorescent fixtures in residential areas as calculated per Section 4.1.2 of the 2020 PSD.
- ~~7.~~ G = 0.73.
- ~~8.~~ COP = 4.5. Note [3].

Exterior Lighting Demand Savings

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

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

Changes from Last Version

- Removed 2012 IECC references.

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~~1]	The source of the equation for Sc and the derivation of the values for F is from "*Calculating Lighting and HVAC Interactions*," ASHRAE Journal, pp. 11-93 as used by KCPL.

Commented [SK19]: kW(summer) = ((CF_L x (Allowable LPD - Actual LPD) x A) + (CF_hw x ΣDeltaW_hw)/1000) x (1 + G / COP)

Commented [SK20R19]: Remove occupancy sensor and create separate measure savings for occupancy sensor.

Commented [SK21]: kW(winter) = ((CF_L x (Allowable LPD - Actual LPD) x A) + (CF_hw x ΣDeltaW_hw)/1000)

Commented [KR22R21]: Remove occupancy sensor and create separate measure savings for occupancy sensor.

Commented [KR23]: Remove occupancy sensor and create separate measure savings for occupancy sensor.

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Commented [KR24]: Remove occupancy sensor and create separate measure savings for occupancy sensor.

[2~~3~~]	DNV KEMA (2014) Retrofit Lighting Controls Measures Summary of Findings FINAL REPORT. Pg 5-26, table 12~~Massachusetts Technical Reference Manual, 2015 Program Year, p. 215.~~
[3~~4~~]	2015 IECC, Table C405.5.2 (1) Exterior Lighting Zones.
[4~~5~~]	2015 IECC, Table C405.4.2 (1) Interior Lighting Power Allowances: Building Area Method.
[5~~6~~]	2015 IECC, Section C406.3 Reduced Interior Lighting Power.
[6~~7~~]	2015 IECC, Table C405.5.2 (2) Individual Lighting Power Allowances for Building Exteriors.

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.~~
[1~~2~~]	In cases where both general building area type and a specific building area type are listed; the specific building area type shall apply.
[2~~3~~]	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.
~~[4]~~	~~2015 IECC requires certain space types to have occupancy sensors. Savings for these occupancy sensors required by code therefore cannot be claimed. Refer to 2015 IECC C405.2.2.2 for details.~~

Commented [KR25]: Update reference: DNV KEMA (2014) Retrofit Lighting Controls Measures Summary of Findings FINAL REPORT. Pg 5-26, table 12

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Commented [KR26]: Remove occupancy sensor and create separate measure savings for occupancy sensor.

Commented [KR27]: Remove occupancy sensor and create separate measure savings for occupancy sensor.

2.1.2 Upstream Lighting

Description of Measure

This section describes the savings methodology for ENERGY STAR or DLC-certified lighting products ~~for LED lighting technologies~~ incentivized through an upstream model.

Commented [SK28]: Specify" ENERGY STAR or DLC-certified lighting products"

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 Design Lights Consortium ("DLC") (**Ref [3]**).

Inputs

Table 2-H: Inputs

Symbol	Description	Units
N	No. of Units Sold at the Point of Sale	
	Product Type	
	Facility Type	

Nomenclature

Table 2-I: Nomenclature

Commented [SK29]: C1635 EO Impact results include ISR recommendations by lighting category. See Appendix.

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 2-K) **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
HVAC_int	HVAC Interactive Factor			

Commented [SK30]: Update A5-1 table based on evaluation results. See Appendix.

~~Table 2-J: Delta Watts Ref [1]~~

~~Product~~	~~Product Type~~	~~Δ Watts[1]~~
~~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~~
~~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 Controls~~	~~Linear LEDs w Controls~~	~~42.9~~
~~2x4 LED Fixture Premium w Controls~~	~~Linear LEDs w Controls~~	~~48.1~~
~~2x2 LED Fixture Standard w Controls~~	~~Linear LEDs w Controls~~	~~37.7~~
~~2x2 LED Fixture Premium w Controls~~	~~Linear LEDs w Controls~~	~~42.9~~
~~1x4 LED Fixture Standard w Controls~~	~~Linear LEDs w Controls~~	~~20.8~~
~~1x4 LED Fixture Premium w Controls~~	~~Linear LEDs w Controls~~	~~26.0~~
~~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~~
~~Exterior LED 20-99W~~	~~Exterior LEDs~~	~~101.5~~
~~Exterior LED 100-199W~~	~~Exterior LEDs~~	~~176.5~~
~~Exterior LED >= 200W~~	~~Exterior LEDs~~	~~231.5~~
~~1x4 LED Troffer Retrofit Kit - Premium~~	~~Linear LEDs~~	~~37.3~~
~~1x4 LED Troffer Retrofit Kit - Standard~~	~~Linear LEDs~~	~~29.5~~
~~2x2 LED Troffer Retrofit Kit - Premium~~	~~Linear LEDs~~	~~19.6~~
~~2x2 LED Troffer Retrofit Kit - Standard~~	~~Linear LEDs~~	~~18.1~~
~~2x4 LED Troffer Retrofit Kit - Premium~~	~~Linear LEDs~~	~~56.2~~
~~2x4 LED Troffer Retrofit Kit - Standard~~	~~Linear LEDs~~	~~53.5~~
~~LED Ambient/Strip/Wrap~~	~~Linear LEDs~~	~~21.8~~
~~Mogul High Bay~~	~~High Bay/Low Bay~~	~~283.6~~

Commented [SK31]: See Appendix

~~Product~~	~~Product Type~~	~~Δ Watts[1]~~
~~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 Type A~~	~~Linear LEDs~~	~~12.0~~
~~LED Tubes, 8ft Type A~~	~~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~~
~~High/Low Bay LED, 20-99W w/controls~~	~~High Bay/Low Bay w Controls~~	~~189.5~~
~~High/Low Bay LED, 100-199W w/controls~~	~~High Bay/Low Bay w Controls~~	~~260.1~~
~~High/Low Bay LED, >= 200W w/controls~~	~~High Bay/Low Bay w Controls~~	~~388.4~~

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

The tracking system savings do not account for interactive effects. Include the energy and demand interactive factors in the PSD from C1635 evaluation. Update energy and demand savings algorithms to include interactive factors in calculations.

Product Type	**Energy Interactive Factor**	**Summer Demand Interactive Factor**
Category 1 LED Linear	1.081*	1.199*
Category 3 LED Downlights	1.023	1.189*
Category 4 LED A-line/Deco	1	1.176*
Category 7 LED High/Low Bay	1.008	1.047*
Overall	1.024	1.152*

Lost Opportunity Gross Energy Savings, Electric

AKWH = N x ΔW x H x HVAC_int x ISR / 1000

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

Where:

- N = No. of units.
- ΔW = Delta Watts per unit.
- H = Hours of Use are based on facility type in Appendix Five.

Commented [SK31]: See Appendix

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Commented [SK32]: Update- if using MA evaluated results, could keep the delta W value and use CT-specific hours results from CT evaluation. However, will need to include a cooling interactive effect multiplier- recommend as shown in MA table under "hvac Interactive effect".

AKWH = N x ΔW x H x HVAC_int x ISR / 1000

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

SKW = N x ΔW x CF_s x ISR / 1000

$$\cancel{SKW = \frac{N \times \Delta W \times CF_s}{1000}}$$

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

Lost Opportunity Gross Savings, Example

Example: A MR16 LED bulb is sold to be installed in an 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 Office hours of use from Appendix Five of 3,748 are used. For the Demand savings, the Office Coincidence Factors from Appendix One of 70.2% (summer) and 53.9% (winter) are used.

$$AKWH = \frac{N \times \Delta W \times H}{1000\frac{W}{kW}} = \frac{1 \times 22.1\ W \times 3{,}748\ Hours}{1000\frac{W}{kW}} = 82.8\ kWh$$

$$LTKWH = AKWH \times Lifetime = 82.8 \times 4 = 331.3\ kWh$$

$$SKW = \frac{N \times \Delta W \times CF_s}{1000\frac{W}{kW}} = \frac{1 \times 22.1 \times 70.2\%}{1000\frac{W}{kW}} = 0.016\ kW$$

$$WKW = \frac{N \times \Delta W \times CF_w}{1000\frac{W}{kW}} = \frac{1 \times 22.1 \times 53.9\%}{1000\frac{W}{kW}} = 0.012\ kW$$

Changes from Last Version

- Included Mass Saves delta watts table.

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]	C1635 Impact Evaluation of PY 2016 & 2017 Energy Opportunities (EO) Program. Review Draft Report. Prepared for CT EEB, June 2020.

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Commented [SK33]: SKW = N x ΔW x CF_s x ISR / 1000

Commented [SK34R33]: If using MA evaluation results, should follow MA upstream savings methodology (in-service rate is rolled into the Watts_EE portion of the MA algorithm)

Commented [SK35]: WKW = N x ΔW x CF_w x ISR / 1000

Commented [SK36R35]: If using MA evaluation results, should follow MA upstream savings methodology (in-service rate is rolled into the Watts_EE portion of the MA algorithm)

Commented [KR37]: Update example to reflect new parameters

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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.

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2.2 HVAC & WATER HEATING

2.2.1 Chillers

Description of Measure

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

Savings Methodology

Energy savings are custom calculated for each chiller installation based on the specific equipment, operational staging, operating profile, and load profile. A temperature BIN model is utilized to calculate the energy and demand savings for the chiller projects. Customer-specific information is used to estimate a load profile for the chilled water plant. Based on the loading, the chiller's actual part load performance is used to calculate 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 2-K: Inputs

Symbol	Description	Units
	Facility Occupancy Hours per Week (On and Off-Peak)	Hr/week
	Chiller Plant Availability per Month	Y or N
	Peak Cooling Load @100°F (Occupied)	Tons
	Peak Cooling Load @100°F (Unoccupied)	Tons
	Economizer Set Point	°F
	Load at Economizer Set Point + (Occupied)	Tons
	Load at Economizer Set Point + (Unoccupied)	Tons
	Load at Economizer Set Point - (Occupied)	Tons
	Load at Economizer Set Point - (Unoccupied)	Tons
	Load at @ 0°F Outside Air Temp - (Occupied)	Tons
	Load at @ 0°F Outside Air Temp - (Unoccupied)	Tons
	Chiller(s) Capacity	Tons
	Condenser – Air or Water-Cooled	
	Compressor Type	
	ARI Part Load Efficiency @100% load, @75% load, @50% load, and @25% load	**Note [2]**
	Primary and Secondary Pumping – Brake Horsepower ("BHP")	BHP
	Secondary Chilled Water Pump Controls – Single Speed or Variable Frequency Drive	
	Condenser Water Pump – BHP	BHP
	Tower Fan – BHP	BHP
	Tower Fan Control – Single Speed, 2 Speed, Variable Frequency Drive	
	Percent Load on Lead Chiller before Lag Chiller Operation	%

Nomenclature

Table 2-L: Nomenclature

Symbol	Description	Units	Values	Comments
IPLV	Integrated Part Load Value			Note [2]
BL100	Baseline Efficiency @ 100% load			Note [3]
BL75	Baseline Efficiency @ 75% load			
BL50	Baseline Efficiency @ 50% load			
BL25	Baseline Efficiency @ 25% load			

Lost Opportunity Gross Energy Savings, Electric

Equipment:

Each chiller plant is characterized by:

- ~~[1]~~ Number of chillers.
- ~~[2]~~ Sizes, in tons (the chillers may be of different sizes).
- ~~[3]~~ Type, which may be:
  - ~~a.~~ Water-cooled centrifugal;
  - ~~b.~~ Water-cooled positive displacement (screw, scroll, and reciprocating); and
  - ~~c.~~ Air-cooled.
- ~~d.~~ Speed, constant, or variable.
- ~~e.~~ Auxiliary equipment:
  - ~~f.~~ Chilled water pumps;
  - ~~g.~~ Cooling tower pumps;
  - ~~h.~~ Cooling tower fans; and
  - ~~i.~~ Other.

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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:

- ~~o~~ Occupied hours the chiller is operated each week; and

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- Un-occupied hours the chiller is operated each week.

Load profile:

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

Savings calculation:

With the above information (chiller load and part load efficiencies) a calculation is made for each time period of the year based on the appropriate temperature BIN data. The calculation is performed once for the chillers meeting the baseline efficiencies, Table 2-M, 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

Commented [SK38]: Add sentence for multifamily: "Multifamily building chiller installations are variable flow chillers and shall apply the savings prescribed in Path B"

Table 2-M: Baseline Efficiencies for Electric[1] Chillers (Note 3)

Equipment Type	Size Category (tons)	Units	Path A[2]		Path B[3]	
			Full Load[5]	IPLV[5]	Full Load[5]	IPLV[5]
Air-Cooled	<150	EER	≥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.
Rated based on **Note [2]**.

Table 2-N: 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 2-O: 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

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 non-electric benefits (Non-Energy Impacts).

Changes from Last Version

- Corrected Table 2-O part-load efficiency for ≥ 600 for 1,005 load.

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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 Tables 2-M. The tables are based on ~~2015~~ 2018 IECC Table C403.2.3(7).

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Commented [SK39]: Update reference to 2018 IECC.

2.2.2 Unitary A/C and Heat Pumps

Description of Measure

High-efficiency Direct-Expansion ("DX") unitary or split cooling system or air-source heat pump (including cold-climate ASHP).~~Installation of a high-efficiency Direct-Expansion ("DX") unitary or split cooling system or air-source heat pump.~~

Commented [SK40]: "High-efficiency Direct-Expansion ("DX") unitary or split cooling system or air-source heat pump (including cold-climate ASHP)."

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 2015 IECC standard efficiency options.

Inputs

Table 2-P: Inputs

Symbol	Description	Units
	Facility Type Served by Equipment	
CAP_C	Installed Cooling Capacity	Btu/hr
CAP_H	Installed Heating Capacity	Btu/hr
EER_i	EER , ≥65,000 Btu/hr – Installed (ARI 340/360)	Btu/watt-hr
$SEER_i$	SEER, Units<65,000 Btu/hr – Installed (ARI 210/240)	Btu/watt-hr
$HSPF_i$	HSPF, Heat Pumps <65,000 Btu/hr – Installed (ARI 210/240)	Btu/watt-hr
COP_i	High Temperature COP, Heat Pumps ≥65,000 Btu/hr – Installed (ARI 340/360)	

Nomenclature

Table 2-Q: 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 For Multifamily	44% 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
$EFLH_C$	Equivalent Full Load Hours – Cooling	Hrs		Appendix Five
$EFLH_H$	Equivalent Full Load Hours – Heating	Hrs		Appendix Five

Lost Opportunity Gross Energy Savings, Electric

Cooling (A/C units and air-source heat pumps):

AKWHC = EFLHC * CAPC * (1/EERb - 1/EERi) * (1/1000)

if CAPC < 65,000 kBtu/hr:

AKWHC = EFLHC * CAPC * (1/SEERb - 1/SEERi) * (1/1000)

if CAPC > 65,000 kBtu/hr and IEER is known:

AKWHC = EFLHC * CAPC * (1/IEERb - 1/ISEERi) * (1/1000)

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

Reminder: SEER used in place of EER for units under 65,000 Btu/hr.

Heating (air source heat pumps only):

AKWHH = EFLHH * CAPH * (1/HSPFb - 1/HSPFi) * (1/1000)

If heating efficiency is in COP:

AKWHH = EFLHH * CAPH * (1/COPb - 1/COPi) * (1/1000) * (1/3.412)

CAPH = 0.9 * CAPC for non cold-climate ASHP units AND supplemental heating source is present

Commented [SK41]: - Current value (82%) is based on RLW, Final Report, 2005 Coincidence Factor Study.
- Recommended value is in line with MA TRM, which comes from KEMA (2011). C&I Unitary HVAC LoadShape Project – Final Report
- NY TRM has no source listed for the CF value.

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Commented [SK42]: No change to the actual algorithm. Recommend explicitly listing out which baseline efficiency terms to use based on different equipment capacities and available information. The IEER usage algorithm aligns with Mid-Atlantic and NY TRMs

AKWHC = EFLHC * CAPC * (1/EERb - 1/EERi) * (1/1000)

if CAPC < 65,000 kBtu/hr:
AKWHC = EFLHC * CAPC * (1/SEERb - 1/SEERi) * (1/1000)

if CAPC > 65,000 kBtu/hr and IEER is known:
AKWHC = EFLHC * CAPC * (1/IEERb - 1/ISEERi) * (1/1000)

Commented [SK43]: AKWHH = EFLHH * CAPH * (1/HSPFb - 1/HSPFi) * (1/1000)

If heating efficiency is in COP:
AKWHH = EFLHH * CAPH * (1/COPb - 1/COPi) * (1/1000) * (1/3.412)

CAPH = 0.9 * CAPC for non cold-climate ASHP units AND supplemental heating source is present
CAPH = 1.0 * CAPC for cold-climate ASHP units
where,
CAPC = Cooling Capacity of efficient ASHP unit (kBtu/h)

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CAPH = 1.0 * CAPC for cold-climate ASHP units

where,

CAPC = Cooling Capacity of efficient ASHP unit (kBtu/h)

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

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

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 2013 Standards: (1) the Baseline Efficiencies (Table 2-R) and (2) Additional Efficiencies (Table 2-S).

Table 2-R: Baseline Efficiencies – Unitary and Split System-AC ~~2015~~ 2018 IECC (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

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Table 2-S: Baseline Efficiencies –Unitary and Split System Heat Pumps—~~2015~~ 2018 IECC (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

Lost Opportunity Gross Energy Savings, Example

Commented [KR44]: Update Example to reflect new parameters

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 2-R = 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 = 0 if installed unit is a unitary AC or non-ccASHP

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WKW = $CAP_{H,5F}$ * (1 - 1/$COP_{H,5F}$) *(12/3.412) * CF_H if installed unit is ccASHP
where,
$CAP_{H,5F}$ = Heating capacity of installed ccASHP at 5F (kBtu/h)

$COP_{H,5F}$ = Coefficient of performance of installed ccASHP at 5F
12 = Conversion factor from kBtu/h to kW
3.412 = Conversion factor from COP to HSPF
CF_H = Winter coincidence factor (Heating) = 0.44 (KEMA 2011 Load shape study)

~~$WKW_H = 0$~~

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

Lost Opportunity Gross Peak Demand Savings, Example

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.~~45~~~~82~~. ~~F~~or Multi-family applications, if installed units serve common area and dwelling unit spaces, apply residential cooling Coincidence Factor = 0.59.*

EER_b from Table 2-R = 11 EER:

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

$WKW_H = 0$

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

Changes from Last Version

- ~~o~~ Removed references to 2012 IECC.

Notes

[1]	Table 2-R above is based on ~~2015~~ 2018 IECC (CT Code) Table C403.2.3(1).
[2]	Table 2-S above is based on ~~2015~~ 2018 IECC (CT Code) Table C403.2.3(2).

Commented [SK45]: WKW = 0 if installed unit is a unitary AC or non-ccASHP

WKW = $CAP_{H,5F}$ * (1 - 1/$COP_{H,5F}$) *(12/3.412) * CF_H if installed unit is ccASHP
where,
$CAP_{H,5F}$ = Heating capacity of installed ccASHP at 5F (kBtu/h)
$COP_{H,5F}$ = Coefficient of performance of installed ccASHP at 5F
12 = Conversion factor from kBtu/h to kW
3.412 = Conversion factor from COP to HSPF
CF_H = Winter coincidence factor (Heating) = 0.44 (KEMA 2011 Load shape study)

Commented [SK46]: This (WKW = 0) is a commonly adopted value because:
1. The peak savings in winter are a fraction of the peak savings in Summer
2. The non-cold-climate ASHP unit will have a backup heat source (fossil fuel furnace/electric heat) which will kick on during the coldest peak winter day, thereby minimizing the operation of the ASHP unit.

However, if the installed unit is a cold-climate ASHP unit, it is designed to meet the heat load even at the coldest temperature. In this case the winter peak demand savings will be non-zero and can be calculated by an algorithm similar to the one used to calculate summer demand savings. This algorithm is based on the performance of the ccASHP unit at low temperatures. The ccASHP unit should be NEEP rated and the HSPF at 5F is used in the winter peak demand savings calculations.

Commented [KR47]: Update example to refenct new parameters

Commented [SK48]: *For Multifamily: "From Appendix One, the seasonal coincidence factor for cooling = 0.82. For Multi-family applications, if installed units serve common area and dwelling unit spaces, apply residential cooling Coincidence Factor = 0.59."*

Commented [SK49]: '- Current value (82%) is based on RLW, Final Report, 2005 Coincidence Factor Study.
- Recommended value is in line with MA TRM, which comes from KEMA (2011). C&I Unitary HVAC LoadShape Project – Final Report

Commented [KR50]: Update example to reflect new parameters

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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.

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 2-T: Inputs

Symbol	Description	Units
	Facility type served by equipment and system type (water source, ground water, ground loop)	
CAP_C	Installed Cooling Capacity	Btu/h
CAP_H	Installed Heating Capacity	Btu/h
EER_i	EER–Installed (ISO 13256-1)	Btu/watt-hr
COP_i	COP-Installed (ISO 13256-1)	

Commented [SK51]: EER is used as a placeholder for efficiency ratings. Cooling side of equipment is rated in SEER (units < 65MBH) and IEER (units > 65MBH). Additional language to explain the application of SEER/IEER in the savings equation would clarify the intention of the efficiency variable as applied here.

Nomenclature

Table 2-U: 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 For Multifamily	44% 59%		Appendix One
CF_H	Seasonal Summer Heating Coincidence Factor For Multifamily	44% 100%		Appendix One
COP_b	High-Temperature COP, Heat Pumps 65,000 Btu/h-Baseline			Note [1]
COP_i	COP- Installed			Input
EER_b	EER - Baseline	Btu/watt-hr		Note [1]
EER_i	EER- Installed	Btu/watt-hr		Input
$EFLH_C$	Equivalent Full Load Hours - Cooling	Hrs		Appendix Five
$EFLH_H$	Equivalent Full Load Hours - Heating	Hrs		Appendix Five

Commented [SK52]: - Current value (82%) is based on RLW, Final Report, 2005 Coincidence Factor Study. We recommend do use 44%.

- Recommended value is in line with MA TRM, which comes from KEMA (2011). C&I Unitary HVAC LoadShape Project – Final Report

Commented [SK53]: Same comment as for CFc - based on CT PSD method of equating SCF and WCF values.

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 2-V: 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 (The water used by the heat pump is in contact with the ground)	< 135,000	18.0	3.1
Ground Loop Heat Pump (The 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 energy savings?

Cooling:

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

From Appendix Five, the cooling equivalent full load hours for an office are 797 hours. The EER_b is from Table 2-V = 13.4:

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

Heating:

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

From Appendix Five, the heating equivalent full load hours for an office are 1,248 hours.

The COP_b is from Table 2-V = 3.1:

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

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

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Cooling:

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

Heating:

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

WKWH = CAPH * (1/COPb - 1/COPi) *CFH * (1/3.412) * (1/1000)

WKW_H = 0 if supplemental heating system is present or if boiler-fed hot water loop supplies heating side of WSHP

Commented [SK54]: If supplemental heating systems such as fossil fuel equipment is present on site, they will kick on during peak winter days when the HP unit cannot operate efficiently at such low temperatures. In this case, winter peak demand savings are 0.

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

Commented [SK55]: WKWH = CAPH * (1/COPb - 1/COPi) *CFH * (1/3.412) * (1/1000)

WKW_H = 0 if supplemental heating system is present or if boiler-fed hot water loop supplies heating side of WSHP

Lost Opportunity Gross Peak Demand Savings, Example

Commented [KR56]: Update example to reflect new parameters

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 EERb is from Table 2-V = 13.4~~:~~. For Multi-family applications with HVAC impacts in common area and in-unit spaces, apply residential seasonal coincidence factor for cooling = 0.59. The EERb is from Table 2-V = 13.4:

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

Heating:

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

The seasonal coincidence factor is assumed to be the same as the summer factor = 0.82. The COPb from Table 2-V = 3.1. For Multi-family applications with HVAC impacts in common area and in-unit spaces, apply residential winter factor = 1.0. The COPb from Table 2-V = 3.1~~:~~:

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

Changes from Last Version

- Removed any references to 2012 IECC.

Notes

[1]	Table 2-V is based on the ~~2015~~ 2018 IECC's Table C403.2.3 (CT Code).

Commented [SK57]: Update Note for multifamily:

"From Appendix One, the seasonal coincidence factor for cooling = 0.82. For Multi-family applications with HVAC impacts in common area and in-unit spaces, apply residential seasonal coincidence factor for cooling = 0.59. The EERb is from Table 2-V = 13.4:"

Commented [SK58]: Update Note for MF CA and in-unit installations:

"The seasonal coincidence factor is assumed to be the same as the summer factor = 0.82. For Multi-family applications with HVAC impacts in common area and in-unit spaces, apply residential winter factor = 1.0. The COPb from Table 2-V = 3.1:"

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Commented [SK59]: No change in values. Update reference to IECC 2018 when CT adopts new code.

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2.2.4 Dual Enthalpy Controls

Commented [SK60]: Remove the dual enthalpy economizer measure from PSD. Recent evaluations found that dual enthalpy economizer measures exhibit little to no savings for facilities in Connecticut based on energy model simulation of sampled measures.

Commented [SK61]: The last two ECB evaluations recommended removing this measure due to code requirements for a single point drybulb temperature economizer. The incremental savings for a dual enthalpy economizer are minimal. The NY TRM measure is based on a "no economizer" baseline and is not comparable to this measure. Recommend removing.

Description of Measure

Upgrade to a dual enthalpy economizer instead of an outside air dry bulb economizer. The system will continuously monitor the enthalpy of both the outside air and return air while controlling system dampers to adjust the outside quantity based on the two readings. When the measured enthalpy of the outdoor air is greater than the enthalpy of the return air, the enthalpy economizer will disengage.

Savings Methodology

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

Inputs

Table 2-W: Inputs

Symbol	Description	Units
CAP_i	Installed Cooling Capacity Controlled by Economizers	Tons

Nomenclature

Table 2-X: Nomenclature

Symbol	Description	Units	Values	Comments
ADET	Annual Differential Electrical Energy Savings per Ton	kWh/Ton	276	Note [2]
$AKWH_C$	Annual Electric Energy Savings, Cooling	kWh		
CAP_i	Installed Cooling Capacity Controlled by Economizers	Tons		Input
SKW	Summer Demand Savings	kW	0	Note [3]
WKW	Winter Demand Savings	kW	0	Note [3]

Lost Opportunity Gross Energy Savings, Electric

$$AKWH_C = ADET \times CAP_i$$

$$AKWH_C = 276 \times CAP_i$$

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

- SKW = 0 (See Note [3]).
- WKW = 0 (See Note [3]).

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Changes from Last Version

- No changes.

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Notes

[1]	Wood, Byk, & Associates, Consulting Engineers, 829 Meadowview Road, Kennett Square, PA 19348.
[2]	Results are from the modeling performed by Wood, Byk, and Associates in 2001. The model provided savings for several locations throughout the Northeast. Savings for this measure is based on Hartford, Conn.
[3]	Since economizers save when outdoor air temperature is relatively low (< 70°F) and the seasonal peak is expected to occur at high outside air temperature, the seasonal peak savings for this measure are assumed to be 0.

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2.2.5 Demand Control Ventilation

Commented [SK62]: Recommend offering this measure both as lost opportunity and retrofit options. Aligns with other jurisdictions.

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 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 2-Y: 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	°F
	Building Balance Point	°F

Changes from Last Version

- No changes.

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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.

Savings Methodology

Energy savings are calculated using the efficiency of the proposed boiler or furnace versus the baseline efficiency. ~~Baseline minimum efficiencies for boilers and furnaces are specified in the 2015 IECC's Tables 403.2.3 (4) and 403.2.3 (5), respectively (Note [2]).~~ If the boiler is used for domestic hot water, in addition to heating, the project should be handled as a custom measure (See 2.6.3 Lost Opportunity Custom in the 2020 PSD).

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 2-Z: Inputs

Symbol	Description	Units
	Facility Type	
ηp	Proposed Case Efficiency	
CAP	Boiler or Furnace Output Capacity	BTU/hr

Nomenclature

Table 2-AA: Nomenclature

Symbol	Description	Units	Values	Comments
ACCF	Gross Annual Energy Savings	ccf		
AF	Adjustment Factor		1.0 or 0.97	Use 1.0 for non-condensing units and 0.97 for condensing units
CAP	Installed Boiler or Furnace Output Capacity	BTU/hr		
EFLH	Equivalent Full Load Hours	Hours	Table 2-AA	
OF	Oversize Factor			Note [2]
PD	Gross Peak Day Natural Gas Savings			
ηb	Base Case Efficiency	Percent		For Furnaces Warm Air, Gas-fired <225 MBH = 85% AFUE Warm Air, Oil-fired <225 MBH = 83% AFUE Warm Air Ducted, Gas-fired <225 MBH = 85% AFUE IECC 2015 Table 403.2.3 (4) (IECC 2018 starting in 2020) ASHRAE 90.1-2013 Table 6.8.1-5 (ASHRAE 90.1-2016 starting in 2020)"~~2015 IECC~~ For Boilers use IECC 2018
ηp	Proposed Case Efficiency	Percent		

Lost Opportunity Gross Energy Savings, Fossil Fuel

Heating savings:

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

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

Table 2-BB: Equivalent Full Load Heating Hour Range (Note [1])

Occupancy Category	Equivalent Full-Load Heating Hours (Note 4)
Residential, Hospitals, Police, and Fire Stations	1,519

Commented [SK63]: Other TRMs do not consider the AF in the savings calculation. The PSD does not provide a source and/or explanation on how the AF is calculated. Recommend providing a source for AF.

Commented [KR64]: No source for oversize factor

(24/7 operation)	
Manufacturing	1,140
Retail Sales/Restaurants	1,170
Offices	1,306
Schools	1,176
Average Value for Upstream Program	1,100
Occupancy Category	Equivalent Full Load Heating Hours

Note: *The above EFLH should be used for boilers and furnaces and not Appendix Five values. Appendix Five's heating EFLH are for heat pumps only.*

Lost Opportunity Gross Peak Day Savings, Natural Gas

- Factors based.

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 reference to the 2020 PSD.

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.~~
[2~~3~~]	ASHRAE and ~~2015~~ 2018 IECC minimum efficiency requirements are based on input capacity.

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Commented [SK65]: This study is not available for review. Provide a reference link.

Commented [SK66]: Other TRMs do not consider the oversize factor in the savings calculation because the factor should be accounted for in the EFLH. Recommend remove if this factor if accounted for in EFLH based on recommended update.

Commented [SK67]: Update to 2018 IECC.

2.2.7 Natural Gas Radiant Heaters

Description of Measure

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

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 2-CC: Inputs

Symbol	Description
CAP	Installed Heating Capacity in BTU/hr
	Facility Type

Nomenclature

Table 2-DD: 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 2-DD, 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]

Commented [SK68]: Most instances will use existing furnace size, so adjusting for oversizing is not relevant unless proper sizing is required by the program. Adjusting oversize by 1.1 for multiple systems is reasonable but could be researched during evaluation to confirm its accurate.

Commented [SK69]: Savings are highly dependent on how the system is used, and the referenced source is 17 years old. The savings percentage is currently consistent with other TRMs but could be updated with further evaluation.

Lost Opportunity Gross Energy Savings, Fossil Fuel

Heating savings:

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

Table 2-EE: 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

- No changes.

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References

[1]	ASHRAE Technical Paper No. 4643, "*Evaluation of an Infrared Two-Stage Heating System in a Commercial Application,*" 2003, Conclusions, p. 138.
[2]	~~2015~~ 2018 IECC, Table C403.2.3(4), for warm air unit heaters, gas fired.

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Commented [SK70]: The value is the same, but the reference should be updated to 2018 IECC Table C403.3.2(4) Warm Air Furnace Minimum Efficiency Requirements. CT adopting IECC 2018.

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.~~
[2~~3~~]	The equivalent full load heating hour ("EFLH") range is shown in Table 2-EE. 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 2-EE.

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2.2.8 Natural Gas-Fired Domestic Hot Water Heaters

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Description of Measure

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

Savings Methodology

Energy savings are calculated using proposed water heater thermal efficiency and standby losses versus baseline efficiency and standby losses. The baseline for efficiency and standby losses were based on a natural gas storage water heater (> 75,000 Input Btu/hr) as specified in 2015 IECC (Ref [1]).

Based on facility type and square footage, Table 2-GG (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.

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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.

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Inputs

Table 2-FF: 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 2-GG: 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 2-HH~~GG~~	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 2-HH: Annual Base Case Gas Usage Rate by Occupancy Type (Ref [2])

Building Occupancy Category	Annual Base Case Gas Usage Rate, E_b (Ccf/ft^2)
Education	0.068
Food Sales	0.043
Food Service	0.382
Health Care	0.232
Inpatient Health Care	0.334
Outpatient Health Care	0.038
Lodging	0.258
Mercantile	0.103
Retail (other than mall)	0.024
Enclosed and Strip Malls	0.137
Office	0.047
Public Assembly	0.02
Public Order and Safety	0.209
Service	0.147
Warehouse and Storage	0.028
Other	0.023
Vacant	0.013
Multi-family Low-Rise	0.193
Multi-family High-Rise	0.176

Commented [SK71]: *For multifamily, add two lines to table:*

Multi-family Low-Rise = 0.193 (ccf/ft^2)
Multi-family High-Rise = 0.176 (ccf/ft^2)
Add additional Reference and Notes to direct to Multi-family calculations sources

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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:

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

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

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

Calculate annual natural gas savings using the following equation:

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

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:

- ~~1.~~ Capacity = 300 MBH;
- ~~2.~~ Storage capacity = 100 gallons;
- ~~3.~~ Thermal efficiency = 91%; and
- ~~4.~~ Rated standby loss = 1,044 Btu/hr.

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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:

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

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

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

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

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

Calculate annual natural gas savings using the following equation:

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

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

Lost Opportunity Gross Peak Day Savings, Natural Gas

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

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

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

Changes from Last Version

- Updated examples.

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References

[1]	~~2015~~ 2018 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.
[4]	RECS Table CE4.7 Annual household site end-use consumption by fuel in the Northeast—averages, 2015 https://www.eia.gov/consumption/residential/data/2015/c&e/pdf/ce4.7.pdf
[5]	RECS Table HC10.10 Average square footage of Northeast homes, 2015 https://www.eia.gov/consumption/residential/data/2015/hc/php/hc10.10.php

Notes

[1]	For instantaneous hot water heaters, the SLR = 0
[2]	Multi-family Low- and High-Rise Annual Base Case Gas Usage Rate, Eb (Ccf/ft2) 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 Multi-family Housing Unit (1,105ft2 for low-rise and 834ft2 for high-rise)

Commented [SK72]: *Add two references:*

[4] RECS Table CE4.7 Annual household site end-use consumption by fuel in the Northeast—averages, 2015 https://www.eia.gov/consumption/residential/data/2015/c&e/pdf/ce4.7.pdf
And
[5] RECS Table HC10.10 Average square footage of Northeast homes, 2015 https://www.eia.gov/consumption/residential/data/2015/hc/php/hc10.10.php

Commented [SK73]: Update to IECC 2018

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Commented [SK74]: *Add note for multifamily:*

[2] "Multi-family Low- and High-Rise Annual Base Case Gas Usage Rate, Eb (Ccf/ft2) 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 Multi-family Housing Unit (1,105ft² for low-rise and 834ft² for high-rise)"

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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 only (not to be used for apartments, motels, hotels, or another residential-type occupancy)~~.

Commented [SK75]: Remove exclusion of residential-type spaces.
The EA Team provided TRC a residential specific custom calculator to review which allows for use in residential-type occupancies (including apartments, motels, hotels). And VRFs can be used in these applications, including multifamily. No changes are recommended to the calculator.

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 2016 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 2-II: 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 (≥ 65000 BTUh)	Btu/hr
	Cooling Capacity (≥ 65000 BTUh)	Btu/hr
	EER	Btu/watt-hr
	IEER	Btu/watt-hr
	High Temperature COP	
	Low Temperature COP	

Nomenclature

Table 2-JJ: 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.

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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.

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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 2-KK~~LL~~, 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 2-KK: Baseline Efficiencies – Electronically Operated Variable-Refrigerant-Flow and Applied Heat Pumps (Note [2])

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

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

- Measure created.

Notes

[1]	Table 3-KK~~II~~ above is based on the ~~2016~~ 2018 ASHRAE Code, Table 6.8.1-10.

Commented [SK76]: The savings algorithms in the PSD are applicable to all VRF measures including cooling-only air conditioners, however, minimum efficiency values are only listed for VRF heat pumps with and without heat recovery. We recommend listing the minimum efficiency values for VRF air conditioners, as shown in psd2.2.9 Supporting Info.

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Commented [SK77]: Update to ASHRAE 2019.

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2.3 MOTORS AND TRANSFORMERS

Commented [SK78]: Savings were based on CEE tier level efficiency requirements; CEE initiative has been suspended. Recommend removing from PSD.

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.

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References

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

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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

Commented [SK79]: New methodology update: Please review recommendations made for the measure PSD2.4.1. Utilities reviewing recommendations. Did not redline measure for the 2021 PSD update.

The baseline is a constant speed fan [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 utilized to calculate the power for both the baseline equipment (constant speed) and the proposed equipment (variable speed) over the annual load profile. The difference between the base and proposed equipment determines the energy savings. Demand savings is the power (kW) savings at the highest load temperature BINs.

Inputs

Table 2-LL: Inputs

Symbol	Description
BHP	Brake Horsepower
EFFi	Installed Motor Efficiency
H	Annual Hours of Operation
	Fan Type

Nomenclature

Table 2-MM: Nomenclature

Symbol	Description	Units	Values	Comments
AF	Air Foil Fan			Fan Type
AKWH	Gross Annual Electric Energy Savings	kWh		
BHP	System Brake Horsepower	HP	Use equipment specific BHP if available, else BHP = Nominal HP x 65% LF	
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-NN	
$SF_{kW,S}$	Summer Seasonal Demand Savings Based on Typical Load Profile for Application	(kW/HP)	Table 2-NN	
$SF_{kW,W}$	Summer Seasonal Demand Savings Based on Typical Load Profile for Application	(kW/HP)	Table 2-NN	
SKW	Seasonal Summer Peak Savings	kW		
WKW	Seasonal Winter Peak Savings	kW		
HP	Nominal Horsepower			
LF	Load Factor		0.65	

Commented [SK80]: Add to the table:

HP - Nominal Horsepower

LF_ Load Factor = 0.65

Commented [SK81]: Use equipment specific BHP if available, else BHP = Nominal HP x 65% LF

Lost Opportunity Gross Energy Savings, Electric

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

Note: *Refer to Table 2-JJ for the appropriate SF_{kWh}.*

Table 2-NN: 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

Commented [SK82]: For Supply & Return Fans - Recommend change in methodology from Savings Factors to a Part Load Ratio for the baseline and proposed system. This allows for different VFD control strategies while not making overly complex savings factor tables. Fundamentally it is the same approach but displayed differently.

For Pumps - Consider creating a separate measure to reduce confusion with the supply and return fans.

Cooling Tower - Recommend research the addition of cooling tower fans. These fans are fundamentally different from the supply and return fans in both type and operation.

Commented [SK83R82]: For Part Load Ratio: Recommend research on ISO-NE specific PLR factors for the summer peak.

Commented [SK84]: Include additional fan control types as shown in the IL and MidAtlantic TRM.

Commented [SK85R84]: The IL and MidAtlantic TRM provides different values for VFDs depending upon their control strategy.

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.

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References

[1]	*ASHRAE 90.1-1989 User's Manual*.

Commented [SK86]: The ASHRAE 90.1-1989 Reference was not verified. The ASHRAE reference provided in the IL and MidAtlantic TRMs is newer but specific to VAV systems which is appropriate. Recommend additional research for this load profile to make it CT specific.

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Notes

[1]	The constants in Table 2-NN 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].

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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] [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 who 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.~~Producing more products in the same time period saves on the non-manufacturing consumption (mostly lighting); and~~

- ~~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).~~

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).

Commented [SK87]: 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 who 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.

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Inputs

Table 2-OO: 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 2-PP: 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

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

Estimated annual consumption with increase in productivity without PRIME:

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

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

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

<u>Estimated annual consumption with increase in productivity with PRIME</u>:

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

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

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

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

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

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

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

Lost Opportunity Gross Energy Savings, Example

<u>Example</u>: 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.

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

<u>Estimated annual consumption with increase in productivity without PRIME:</u>

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

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

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

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

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

<u>Estimated annual consumption with increase in productivity with PRIME:</u>

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

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.

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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.

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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.

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2.6.2 Commercial Kitchen Equipment

Description of Measure

Installation of ENERGY STAR-qualified commercial kitchen equipment.

Savings Methodology

Energy savings for this measure are calculated using the savings calculator for ENERGY STAR-qualified commercial kitchen equipment located on the ENERGY STAR website (**Ref [1]**) or the Food Technology Service Center ("FSTC") 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 2-QQ below.

Table 2-QQ: Savings Baseline

Equipment	Baseline
Oven	Conventional Unit per **Ref [1]** and **Ref [2]** Calculator
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]**
Refrigerator	**Ref [3]**
Steam Cooker	Conventional Unit per **Ref [2]** Calculator
WaterSense Pre-Rinse Spray Valve	See Water-Saving Measures 3.2.1

Nomenclature

Table 2-RR: 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 2-SS: Deemed Savings Ref [4]

Measure	CCF	CCF/Day	kWh	kW
Gas Combination Oven **Ref** [2]	912~~1,072~~	2.5~~2.9~~		
Gas Convection Oven **Ref** [2]	295~~347~~	0.8~~1.0~~		
Gas Conveyor Oven **Ref** [2]	731~~859~~	2~~2.4~~		
Gas Fryer - Standard Vat **Ref** [2]	595~~761~~	1.6~~2.1~~		
Gas Griddle with 3ft Countertop Width **Ref** [2]	313~~368~~	0.9~~1.0~~		
Gas Pre-Rinse Spray Valve **Ref** [2]	94~~111~~	0.3~~0.3~~		
Gas Rack Oven **Ref** [2]	1,748~~2,053~~	4.8~~5.6~~		
Gas Steamer **Ref** [2]	3,066~~3,603~~	8.4~~9.9~~		
Electric Combination Oven **Ref** [2]			15,095	1.723
Electric Convection Oven **Ref** [1]			1,937~~2,787~~	0.221~~0.318~~
Electric Fryer - Standard Vat **Ref** [2]			2,976	0.340
Electric Fryer - Large Vat **Ref** [2]			2,841	0.324
Electric Griddle 36” **Ref** [2]			3,965	0.453
Electric Griddle over 36” **Ref** [2]			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
Electric Hot Food Holding Cabinets Half Size **Ref** [2]			1,095	0.125
Electric Dishwasher High Temp – Door Type **Ref** [1]			11,863~~4,583~~	1.354~~0.523~~
Electric Dishwasher High Temp – Multi Tank Conveyor **Ref** [1]			27,408~~52,013~~	3.129~~5.938~~
Electric Dishwasher High Temp – Pot, Pan, Utensil **Ref** [1]			3,311~~1,032~~	0.378~~0.118~~
Electric Dishwasher High Temp – Single Tank Conveyor **Ref** [1]			9,212~~26,626~~	1.052~~3.039~~
Electric Dishwasher High Temp – Under Counter **Ref** [1]			3,171~~697~~	0.362~~0.080~~
Electric Dishwasher Low Temp – Door Type **Ref** [1]			16,153~~4,961~~	1.844~~0.566~~
Electric Dishwasher Low Temp – Multi Tank Conveyor **Ref** [1]			18,811~~18,998~~	2.147~~2.169~~
Electric Dishwasher Low Temp – Single Tank Conveyor **Ref** [1]			13,626~~12,384~~	1.555~~1.414~~
Electric Dishwasher Low Temp – Under Counter **Ref** [1]			2,540~~1,020~~	0.290~~0.116~~

Commented [SK88]: Savings sourced from ENERGY STAR calculator are not consistent with the version accessed June 12, 2020. See linked table in PSD 2.6.2 Supporting Info tab for new values.

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Measure	CCF	CCF/Day	kWh	kW
Gas Dishwasher High Temp – Door Type **Ref** [1]	285~~96~~	0.781~~0.3~~	4,840~~3,333~~	0.553~~0.380~~
Gas Dishwasher High Temp – Multi Tank Conveyor **Ref** [1]	656~~1,095~~	1.796~~3.0~~	11,230~~14,185~~	1.282~~1.619~~
Gas Dishwasher High Temp – Pot, Pan, Utensil **Ref** [1]	85~~86~~	0.234~~0.2~~	1,204~~1,204~~	0.137~~0.137~~
Gas Dishwasher High Temp – Single Tank Conveyor **Ref** [1]	173~~561~~	0.473~~1.5~~	4,948~~19,364~~	0.565~~2.211~~
Gas Dishwasher High Temp – Under Counter **Ref** [1]	44~~15~~	0.12~~0.0~~	2,089~~190~~	0.238~~0.022~~
Gas Dishwasher Low Temp – Door Type **Ref** [1]	654.75~~230~~	1.794~~0.6~~	~~13,851~~	~~1.581~~
Gas Dishwasher Low Temp – Multi Tank Conveyor **Ref** [1]	762.42~~880~~	2.089~~2.4~~	~~16,131~~	~~1.841~~
Gas Dishwasher Low Temp – Single Tank Conveyor **Ref** [1]	528.65~~574~~	1.448~~1.6~~	584~~11,685~~	0.067~~1.334~~
Gas Dishwasher Low Temp – Under Counter **Ref** [1]	102.82~~47~~	0.282~~0.1~~	~~2,178~~	~~0.249~~
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 0-400 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
Refrigerator, Solid Door, Self-Contained (<15 cubic ft) **Ref** [1]			170	0.03
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~~245~~	0.093~~0.03~~
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~~540~~	0.101~~0.06~~
Refrigerator, Glass Door, Self-Contained (50+ cubic ft) **Ref** [1]			1,212~~610~~	0.138~~0.07~~
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

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Measure	CCF	CCF/Day	kWh	kW
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
Commercial Electric Deck Ovens **Ref [4]**			7,519~~7,519~~	1.7~~0.858~~
On-Demand Commercial Electric Hand Wrap Machine **Ref [4]**			1,565	0.18
Energy Efficient Commercial Underfired Broiler **Ref [4]**	212	~~0.581~~	N/A	N/A
Energy Efficient Commercial Conveyor Broilers <20" Wide **Ref [4]**	1,113	3.049	7,144	0.816
Energy Efficient Commercial Conveyor Broilers 20-26" Wide **Ref [4]**	1,879	5.148	6,403	0.~~731~~88
Energy Efficient Commercial Conveyor Broilers >26" Wide **Ref [4]**	3,072	8.416	23,849	~~2.722~~3.29
Commercial Kitchen Demand Ventilation Controls **Ref [4]**	35	0.096	4,423 kWh/HP of Exh.	0.~~5505~~551 kW/HP of Exh
Commercial Kitchen Demand Ventilation Controls **Ref [4]**	35	0.096	4,423 kWh/HP of Exh	0.~~505~~551 kW/HP of Exh
Ultra-Low Temp Freezers **Ref [4]**			5,737	~~0.9970.655~~0

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

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

- Corrected deemed savings table to use values from the Memorandum: *2020 PSD Foodservice Equipment Update Recommendations Memo,* dated September 10, 2019, from Energy Solutions.

References

[1]	ENERGY STAR Commercial Kitchen Package for businesses and operators, 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, https://caenergywise.com/calculators/ Last Accessed July 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 Foodservice Equipment Update Recommendations Memo* from Energy Solutions.

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Commented [SK89]: This reference could not be found. No changes were recommended to the values from this source, but the source should be posted to a commonly accessible platform.

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.

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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. ~~Electric demand savings methodologies are categorized as follows:~~

~~a. Temperature dependent measures (e.g., HVAC measures that vary with ambient temperature);~~
~~b. Non-temperature dependent measures (e.g., process, lighting, time control); and~~
~~c. Whole building performance.~~

Temperature dependent measures:

Savings from individual temperature dependent measures are typically determined by either full-load hour analysis or BIN temperature analysis.

Full load hour analysis:

Summer and winter demand savings are calculated using an appropriately derived seasonal peak coincidence factor. Coincident factors for various measures (and/or end use) are provided in Appendix

Commented [KR90]: 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.

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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.

- ~~1.~~ 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.
- ~~2.~~ 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.

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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 the ISO, is equal to or greater than 90% of the most recent 50/50 system peak load forecast, as determined by the ISO, for the applicable summer or winter season.~~Demand savings for measures that are not temperature-dependent will be determined by either the coincidence factors from Appendix One or the average estimated week day ("WD") savings over the summer or winter seasonal peak period. A custom coincidence factor may also be used for measures or end uses that are not identified in Appendix One. However, the analysis determining the custom coincidence factor must be performed or approved by a qualified in-house engineer.~~

Commented [KR91]: Instead of specifying 12 pm to 6 pm for summer and 4 pm to 9 pm for winter, we recommend utilizing the approproate hours as defined in the CT PSD for the ISO seasonal peak: "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 the ISO, is equal to or greater than 90% of the most recent 50/50 system peal load forecast, as determined by the ISO, for the applicable summer or winter season."

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

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

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

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

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

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

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 ~~2015~~ 2018 IECC Table C407.5.1(1) must be used to evaluate the energy savings or as applicable codes and standards.

Commented [SK92]: Update the reference code to 2018 IECC.

Nomenclature

Table 2-TT: Nomenclature

Symbol	Description	Units	Values	Comments
WD	Weekdays	Days		

Changes from Last Version

- No changes.

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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 Multi-Family (1,241 Loads per year)) or project specific information for any facility type. Installed energy use will be based on the installed modified energy factor.

Note that the Federal Standard and ENERGY STAR-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 2-UU: 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 Multi-Family)	
MEF_i	Modified Energy Factor - Installed	ft^3/kWh/cycle
LDS	Average Number of Loads per Week	Loads/wk
WK	Average Number of Weeks per Year	wk/yr

Nomenclature

Table 2-VV: Nomenclature

Symbol	Description	Units	Values	Comments
AKWH	Annual Electric Energy Savings	kWh		
$AKWH_O$	Annual Electric Energy Savings – Other	kWh		
$AKWH_W$	Annual Electric Energy Savings – Water Heating	kWh		
$ABTU_O$	Annual Btu Savings - Other	Btu		
$ABTU_W$	Annual Btu Savings – Water Heating	Btu		
ACCF	Annual Natural Gas Savings - Total	ccf		
$ACCF_O$	Annual Natural Gas Savings - Other	ccf		
$ACCF_W$	Annual Natural Gas Savings – Water Heating	ccf		
APG	Annual Propane Savings - Total	Gallons		
APG_O	Annual Propane Savings - Other	Gallons		
APG_W	Annual Propane Savings – Water Heating	Gallons		
AOG_W	Annual Oil Savings – Water Heating	Lbs/h		
$DKWH_b$	Dryer kWh per Load - Baseline	kWh/ld	0.872/ 0.698	Note [1]
$DKWH_{es}$	Dryer kWh per Load – ENERGY STAR	kWh/ld	0.634	Note [1]
$DRBTU_b$	Dryer Btu - Baseline	Btu/ld	2,969/ 2,376	Note [1]
$DRBTU_{es}$	Dryer Btu – ENERGY STAR	Btu/ld	2,160	Note [1]
AGW	Annual Water Savings	Gallons/year		
Gal_b	Gallons of Water - Baseline	Gallons	26.35/ 17.1	Note [1]
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]
WKBTUb	Washer KBTU per Load - Baseline	kWh/ld	2,597	Note [1]

Commented [SK93]: Add WHKWHB – Water Heater kWh – Baseline and WHBTUb – Water Heater BTU – Baseline to the nomenclature table.

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Lost Opportunity Gross Energy Savings, Electric

Electric savings will be calculated in three pieces. Electric dryer and water heating savings are present only if the heat element fuel source is electric.

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

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

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

Lost Opportunity Gross Energy Savings, Fossil Fuel

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

Annual Savings = Water Heating Savings + Dryer Savings

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

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

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

Savings by Fuel Source

Water heating:

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

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

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

Dryer:

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

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

Lost Opportunity Gross Energy Savings, Example

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:

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

- 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.

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

Natural gas savings:

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

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

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

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

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

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

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

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

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

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

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

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

Assumed to be zero.

Lost Opportunity Gross Peak Day Savings, Natural Gas

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

Lost Opportunity Gross Peak Day Savings, Example

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

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

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

- No changes.

References

[1]	https://energy.gov/eere/femp/energy-and-cost-savings-calculators-energy-efficient-products Modified based on 2013 Federal Standard and ENERGY STAR requirements.

Commented [SK94]: Consider updating demand savings algorithm based on mid-Atlantic TRM.

Other TRMs have considered demand savings for this measure. CT PSD does not provide any explanations for the zero savings assumption.

The Mid-Atlantic TRM provides coincidence factors for residential clothes washer applications, which is used as a proxy for laundromats and multifamily buildings. This value is likely low for commercial applications like Laundromats as they operate various times of the day, so there will demand savings based on an updated coincidence factor. See PSD2.6.4 Supporting Info.

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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].

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2.7 ENVELOPE

Commented [KR95]: Remove from PSD

2.7.1 Cool Roof

Changes from Last Version

- This measure was discontinued in 2019 due to increase in code for baseline roof thermal emittance is now 0.75 since 2015 IECC. The savings calculations no longer are applicable.

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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~~, and use of occupancy sensors~~. The baseline is the wattage and existing operating hours of the fixtures being replaced. **Note [1]**.

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

Inputs

Table 3-A: Inputs

Symbol	Description	Units
kW_B	Existing Fixture Connected kW	
kW_A	Replacement Fixture Connected kW	
	Hours of Operation (if available)	

Nomenclature

Table 3-B: Inputs

Item	Description	Units	Values	Comments
AKWH	Annual Gross Electric Energy Savings	kWh		
CF_L	Lighting Coincidence Factor from Appendix One			Appendix One
~~CF_{os}~~	~~Occupancy Sensor 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]
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			
O_n	Quantity of Fixtures of Type n that have Occupancy Sensors			
S_r	Energy Savings due to Lighting Retrofit	kWh		
S_{os}	Energy Savings from Use of Occupancy Sensors, if applicable	kWh		
S_c	Energy Savings from Reduced Cooling Load	kWh		
SKW	Seasonal Summer Peak Summer Demand Savings	kW		
W_n	Input Watts for Fixture Type n	Watts		
WKW	Seasonal Winter Peak Summer Demand Savings	kW		

Retrofit Gross Energy Savings, Electric

AKWH = Sr + Sc

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

Calculation of savings due to fixture retrofit:

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

Commented [SK97R96]: Update reference: Source: C1635 Impact Evaluation of PY 2016 & 2017 Energy Opportunities (EO) Program. Review Draft Report. Prepared for CT EEB, June 2020.

Commented [SK96]: C1635 evaluation report provides updated summer and winter coincidence factors, see Appendix.

Commented [SK99R98]:

Commented [SK98]: Create separate measure for Occupancy Sensor

Commented [SK100]:

Commented [SK101R100]: Updated based on recommendations from C1635 EO Impact Evaluation, see Appendix.

Commented [SK102]: *For Multifamily: Hours = 6388; site specific or default hours from Appendix 5*

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Commented [SK103]: AKWH = Sr + Sc
= [(kWb- kWa)xH] + [Sr x F/COP]

Commented [SK104R103]: Remove occupancy sensor and create separate measure savings for occupancy sensor.

- 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 due to occupancy sensors:*~~

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

- ~~0.3 is the generally accepted average hour reduction due to the use of occupancy sensors (**Ref [1]**).~~
- ~~Additional savings maybe claimed if lighting fixtures have multiple controls (e.g. daylighting, personal tuning or institutional tuning) and/or integrated controls.~~

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:

Sc = Sr x F/COP

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

- F = Fraction of annual kWh energy savings that must be removed by the cooling system. If the HVAC system includes an economizer, then F = 0.35. Otherwise, use Table 3-C.
- COP = 3.5 (**Note [2]**).

Table 3-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~~07129~~ MMBtu per annual kWh saved; and
- Annual Natural Gas Savings = -0.0001622793~~3649~~ MMBtu per kWh. See (**Ref [3]**).

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Commented [SK105]: *Recommendation of moving this to its own measure, titled, "Lighting controls".*

Commented [SK106]:

Commented [SK107R106]: Create separate measure for Occupancy Sensor

Commented [SK108]: Update from 0.3 to 0.28 to align with TRC recommendation.

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Commented [SK109]: *Add language: If a lighting control is installed with a lighting retrofit, the new fixture wattage is used for W_n to calculate savings from the lighting control*

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

SKW = [CFL x (kWb - kWa) + (O x W /1000)] x (1 + G/COP)

WKW = [CFL x (kWb - kWa) + (O x W /1000)]

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

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

- CF_L ~~and CF_{os} are~~is the lighting (CF_L) ~~and occupancy sensor (CF_{OS})~~ coincidence factor~~s~~ (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

- No changes.

References

[1]	DNV KEMA (2014) Retrofit Lighting Controls Measures Summary of Findings FINAL REPORT. Pg 5-26, table 12~~D. Maniccia B. Von Neida, and A. Tweed. An analysis of the energy and cost savings potential of occupancy sensors for commercial lighting systems. Illuminating Engineering Society of North America 2000 Annual Conference: Proceedings. IESNA: New York, NY, pp. 433-459. Accessed online at: http://www.lrc.rpi.edu/resources/pdf/dorene1.pdf.~~
[2]	*"The source of the equation for S_c and the derivation of the values for F is from "Calculating Lighting and HVAC Interactions,"* ASHRAE Journal, 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~~Massachusetts Technical Reference Manual, 2012 Program Year, p. 170.~~

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Commented [SK110]: SKW = [CFL x (kWb - kWa) + (O x W /1000)] x (1 + G/COP)

WKW = [CFL x (kWb - kWa) + (O x W /1000)]

Commented [SK111R110]: Remove occupancy sensor and create separate measure savings for occupancy sensor.

Commented [SK112]: *If a new measure is created for occupancy sensors, this should move with it*

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Commented [SK113]: Reference update: DNV KEMA (2014) Retrofit Lighting Controls Measures Summary of Findings FINAL REPORT. Pg 5-26, table 12

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Commented [SK114]: Update: 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 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.

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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 3-D: Inputs

Symbol	Description	Units
EER	Energy Efficiency Ratio of Refrigeration Units	
~~H~~h	Lighting Annual Run Hours	Hours
N	Number of Lights	
L	Ballast Location Factor	
ΔkW	Reduction in Power for Each Light	kW

Nomenclature

Table 3-E: 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			
~~Hh~~h	Lighting Annual Run Hours			
ΔkW	Reduction in Power for Each Light	kW		

Commented [SK115]: CT PSD obtained ACOP values from 2009 ASHRAE handbook. NY TRM uses COP values from more recent evaluation report; however, the review team was unable to locate that study. CT values generally align with other TRMs, but we recommend further research for this parameter.

Retrofit Gross Energy Savings, Electric

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

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

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3.2 HVAC & WATER HEATING

3.2.1 Water-Saving Measures

Description of Measure

This measure replaces e~~xisting~~ xisting pre-rinse spray valves, shower heads, and faucet aerators. 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. ~~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.~~

Commented [SK116]: Existing pre-rinse spray valves, shower heads, and faucet aerators. 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.

Commented [SK117]: Use actual installed GPM. If actual installed GPM is not available, use minimum program requirements value.

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 3-F: Inputs

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

Nomenclature

Table 3-G: 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 3-H.

Table 3-H: 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 3-I:

Table 3-I: 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

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

Commented [SK118]: Recalculate savings based on the updated baseline and installed GPM values. Provide a default deemed savings value where project/site-specific information is not available.

Commented [SK119]: Recalculate savings based on the updated baseline and installed GPM values. Provide a default deemed savings value where project/site-specific information is not available.

Table 3-J: 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 3-K: 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.

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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. Table 3-9, p. 26.
[2]	Federal Energy Management Program ("FEMP") Energy Cost Calculator for Faucets and Showerheads. Available at: https://www.energy.gov/eere/femp/energy-cost-calculator-faucets-and-showerheads-0.

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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.

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3.2.2 Pipe Insulation

Description of Measure

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

Savings Methodology

Savings were determined using 3E Plus v4.1 software (**Ref [1]**) with 50°F ambient temperature and 180°F fluid temperature. If the difference between the actual average ambient temperature and fluid temperature varies significantly from this difference (130°F), the savings should be scaled using linear interpolation. The hourly heat loss ("HL") savings per linear foot for various pipe and insulation sizes/material are provided in Table 3-L. For parameter values not listed in the PSD, heat loss values will be calculated using 3E Plus.

Commented [SK120]: The table 3-L has HL values for one temperature differential (130°F) only. As such, linear interpolation cannot be applied. It is recommended to add a language in the PSD to say that "for parameter values not listed in the PSD, heat loss values will be calculated using 3E Plus. "

The measure does not include steam pipes. It is recommended to update the methodology to include steam pipes.

Table 3-L: Hourly Heat Loss Savings per Linear Foot of Pipe Insulation

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

	1.5	Mineral Fibers	114	128	132	136
	2.0	Mineral Fibers	144	158	164	167

Inputs

Table 3-M: Inputs

Symbol	Description	Units
	Nominal Pipe Size Diameter	Inches
	Insulation Material	
	Insulation Thickness	Inches
L	Length of Insulation	Linear Foot
	Heating Fuel Type (Oil, Natural Gas)	

Nomenclature

Table 3-N: Nomenclature

Symbol	Description	Units	Values	Comment
ACCF	Annual Natural Gas Savings	CCF		
EFLH	Equivalent Heating Full-Load Hours for the Facility Type	Hours	Appendix Five	Multifamily chillers should use CHWP & Cooling Towers EFLH in Appendix Five
HL	Heat Loss Savings per Linear Foot of Pipe	Btu/ft/hr	Table 3-L	
L	Length of Pipe Being Insulated	Linear ft		
AFUE	Use site-specific Annual Fuel Utilization Efficiency (AFUE) if available. In unknown use default ~~Annual Fuel Utilization Efficiency~~value, Estimated Boiler Efficiency		0.80	
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:

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

Commented [SK121]: *For multifamily: General recommendations include expansion of the measure to incorporate DHW and chiller pipe insulation savings. If expansion agreed - Add rows for MF DHW and Chiller efficiency defaults: DHW Efficiency (thermal efficiency) = 92% Chiller Efficiency (EER) = 11.4*

Commented [SK122]: *Add row: Hours, Description: Hours assumed for Multifamily DHW, units Hours, Value: 8,760*

Commented [SK123]: *Add Note in Comments: "Multifamily chillers should use CHWP & Cooling Towers EFLH in Appendix Five"*

Commented [SK124]: Use site specific AFUE if available. If unknown, use default 0.8.

Annual oil heating savings:

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

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 3-L, the corresponding HL savings is 73 Btu/ft/hr. The length of pipe being insulated L = 100 ft. Using Appendix Five (hours of use), heating EFLH for an office/retail space is 1,248.

Using the savings formula:

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

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

Retrofit Gross Peak Day Savings, Natural Gas

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

Changes from Last Version

- No changes.

References

[1]	NAIMA, 3E Plus software tool, Version 4.1, Rel. 2012.
[2]	R1705/R1609 Multifamily Baseline and Weatherization Study https://www.energizect.com/sites/default/files/R1705-1609%20MF%20Baseline%20Weatherization%20Study_Final%20Report_10.10.19.pdf

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Commented [SK125]: Include MF Efficiency source: R1705/R1609 Multifamily Baseline and Weatherization Study https://www.energizect.com/sites/default/files/R1705-1609%20MF%20Baseline%20Weatherization%20Study_Final%20Report_10.10.19.pdf

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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 2020 PSD manual (Measure 4.2.5~~9~~).

Commented [SK126]: IPSD measure ID of the duct sealing measure in the Residential Section is **4.2.5**

Changes from Last Version

- No changes.

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3.2.4 Duct Insulation

Description of Measure

Installation of R-6 insulation on ducting located in unconditioned spaces in commercial buildings.

Commented [SK127]: Savings estimates are based on R-6 insulation in proposed case

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 3-O and 3-P 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 3-O: 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 3-P: Heat Transfer Rates per Hour per ft^2 of Insulation

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

Inputs

Table 3-Q: Inputs

Symbol	Description
A	Insulation Area in Square Feet
	Heating Fuel/Heating System type (e.g., electric heat pump, natural gas furnace)

Nomenclature

Table 3-R: 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 3-P	
$BTUH_{cb}$	Cooling Heat Transfer Rate of Un-insulated Ducting	Btu/hr/ft^2	Table 3-P	
$BTUH_{ha}$	Heating Heat Transfer Rate of Insulated Ducting	Btu/hr/ft^2	Table 3-P	
$BTUH_{hb}$	Heating Heat Transfer Rate of Un-insulated Ducting	Btu/hr/ft^2	Table 3-P	
COP_H	Coefficient of Performance of Heating Equipment	Unit-less	Use site-specific heating system COP if available. If unknown, use default of: ~~1.~~ 1.0 for Electric Furnace ~~2.~~ 2.4 for~~for~~ Heat Pump ~~3.~~ 3.0 for Ground-Source Heat Pump	
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		

Commented [SK128]: Include ACCF -Annual Natural Gas Savings, CCF

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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:

3412 = converts Btu to kWh

~~4.~~3.5 = Use site-specific cooling system COP if available. If unknown, use default of 3.5 for central A/C or heat pump.~~estimated cooling equipment efficiency, COP~~

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Commented [SK129]: 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:

~~*0.80 = estimated heating equipment efficiency*~~

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 Conversion use 102,900 Btu/ccf

For Oil Conversion use 138,690 Btu/gallon

For propane conversion 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 is the savings?

Annual gross electric heating savings:

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

- From Table 3-P: $BTUH_{hb}$ =132.34;
- From Table 3-P: $BTUH_{ha}$ =12.04;
- From Appendix Five: EFLH heating =1248 hr;
- A = 100 ft^2; and
- From Nomenclature Table 3-R: COP_H for heat pump = 2.0.

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

Annual gross electric cooling savings:

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

- From Table 3-P: $BTUH_{cb}$ = 25.22;
- From Table 3-P: $BTUH_{ca}$ = 2.73;
- From Appendix Five: EFLH cooling = 797; and

Commented [SK130]: Include options for MMBtu conversion factors for Oil and Propane in addition to the natural gas conversion of 102,900 Btu/ccf.
Oil - 138,690 Btu/gallon
Propane - 91,330 Btu/gallon

Commented [SK131]: 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.

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- A = 100 ft^2.

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

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

Currently no demand savings are claimed for this measure.

Changes from Last Version

- No changes.

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References

[1]	NAIMA, 3E Plus software tool, Version 4.1, Rel. 2012.
[2]	Minimum Duct Insulation R-Value, Table 6.8.2-2, ASHRAE Standard 90.1 – 2013.

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3.2.5 Setback Thermostats

Commented [SK132]: Recommend remove measure from PSD.

Description of Measure

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

Savings Methodology

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

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

Inputs

Table 3-S: Inputs

Symbol	Description	Units
CAP	Output Capacity of Natural Gas Heating Equipment	MBh
Hrs	Occupied Hours per Week	Hrs
Tons	Installed Cooling Capacity	Tons
Nr	Nameplate Rating of Baseboard Electric Resistance Heat	kW (Note [2])

Nomenclature

Table 3-T: Nomenclature

Symbol	Description	Units	Values	Comments
ACCF	Annual Natural Gas Savings	ccf		
AKWH	Annual Gross Electric Energy Savings	kWh		
CAP	Output Capacity of Natural Gas Heating Equipment	MBh		Input
Hrs	Occupied Hours per Week	Hours		Input
MBh	Thousands of Btu per Hour			
Nr	Nameplate Rating of Baseboard Electric Resistance Heat	kW		Input
PDF	Peak Day Factor		0.0477	
PD	Peak Day Savings	ccf		
SF_{CCF}	ccf Savings Factor	ccf/MBh		Note [1]
$SF_{kWh,H}$	kWh Savings Factor – Electric Heat	kWh/kW		Note [1]
$SF_{kWh,C}$	kWh Savings Factor – Cooling	kWh/Ton		Note [1]
Tons	Installed Cooling Capacity	Tons		Input

Retrofit Gross Energy Savings, Electric

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

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

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

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

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

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

Retrofit Gross Energy Savings, Fossil Fuel

Heating (applicable only if the facility has existing natural gas heat):

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

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

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

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

Retrofit Gross Peak Day Savings, Natural Gas

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

Changes from Last Version

- No changes.

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References

[1]	Trane System Analyzer, Version 6.1.

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Notes

[1]	Ref [1] to model a number of different occupancy schedules. These results were used to develop a correlation between occupancy schedule and energy savings. These equations are used to adjust savings for different occupancy schedules.
[2]	If nameplate kW is not available for electric baseboard, use 200 watts per foot for baseboards < 3 feet and 250 watts per foot for all other baseboards. These values are based on research of typical existing equipment.
[3]	Steam Efficiency Improvement, Boiler Efficiency Institute, AL, 1987.
[4]	Steam Pressure Reduction: Opportunities and Issues, Energy Efficiency and Renewable Energy, US Department of Energy, Wash. DC, 2005.
[5]	Steam Tables, Spirax Sarco, 2013. Available at: http://www2.spiraxsarco.com/esc/Ss_Properties.aspx. Last accessed on Oct. 10, 2013.

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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]**).

Commented [SK133]: Modify to include the repair of steam traps in addition to the replacement of steam traps. This change would also bring the measure in alignment with the other TRMs.

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 3-U: Inputs

Symbol	Description
P	Steam Pressure (psig)
D	Orifice Diameter (in)
EFLH	Equivalent Full Load Hours (hrs)

Nomenclature

Table 3-V: 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 80%	
EFLH	Equivalent Full Load Hours	Hours	See below	Note [1] Note [2]
h_{fg}	Specific Enthalpy of Evaporation	Btu/lb_m	Varies based on pressure	
Lb_m	Steam Flow through Orifice	lb_m/hr		
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		

Commented [SK134]: Use site-specific boiler efficiency if available; if boiler efficiency is unknown, use default of 80%.

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%).

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

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

Step 2 – Using the following equation estimate annual savings based on the steam loss (Step 1), specific enthalpy of evaporation (Table 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 area.

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Commented [SK135]: *Add: EFLH = 5,376 for multifamily common area*

Changes from Last Version

- No changes.

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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 Tables, Spirax Sarco, 2013. Available at: http://www2.spiraxsarco.com/esc/Ss_Properties.aspx. Last accessed on Oct. 10, 2013.
[4]	*Steam Trap Evaluation Phase 2*, Massachusetts Program Administrators and Energy Efficiency Advisory Council, Mar. 8, 2017.

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Commented [SK136]: Reference link no longer active. There is a steam trap evaluation study that is slated to wrap up at the end of the 2020 summer season (MA Steam Traps and Boiler Efficiency Research MA20C05-G-STBE). The results of this study should be incorporated into the PSD as applicable.

Notes

[1]	Estimated.
[2]	Estimated.

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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.

Commented [SK137]: *Add: "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 2020 PSD's Residential Blower Door Measure (Measure 4.4.~~4~~2). The savings would be reviewed with customer billing data by the Companies' staff.

Commented [SS138]: The correct Measure ID for Residential Blower Door Measure is 4.4.2.

Inputs

Table 3-X: 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 3-Y: 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		

Commented [SK139]: Add the following to the nomenclature table:

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 3-Z: Retrofit Electric Savings per CFM Reduction (at 50 Pa)

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

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

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

For fossil fuel heating with air handler unit:

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

<u>For homes with central air cooling</u>:

$$AkWH_{C} = BD_{Cooling} \times (CFM_{\text{Pre}} - CFM_{Post})$$

Retrofit Gross Energy Savings, Fossil Fuel

Table 3-AA: Retrofit Fossil Fuel Savings per CFM Reduction (at 50 Pa)

Measure	Symbol	Energy Savings	Units
Fossil Fuel Heating			
Natural Gas Heating	BD_{NG}	0.11	ccf
Propane Heating	$BD_{propane}$	0.12	Gallons
Oil Heating	BD_{Oil}	0.07	Gallons

For homes with natural gas heating system:

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

For homes with oil heating system:

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

For homes with propane heating system:

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

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

Commented [SS140]: In accordance with Measure 4.4.2, the demand savings are based on a REM/Rate model that was run in 2008. Changes to the model or to the input variables would change the deemed values. Recommend update values with new REM/rate model every three years, analogous to typical codes and standards updates, to ensure that the values reflect changes to the model and input variables.

Table 3-BB: Demand Savings per CFM Reduction

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

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

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

Note: *The demand savings are from the Residential Measure 4.4.2~~4~~—Infiltration Reduction Testing (Blower Door Test).*

Retrofit Gross Peak Day Savings, Natural Gas

For homes with natural gas heating system:

$$PD_H = ACCF_H \times PDF_H$$

Changes from Last Version

- No changes.

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Notes

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

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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

Commented [SK141]: The current approach relies on a spreadsheet. This approach appears to yield negative savings if the hours are low. The IL TRM addressed this by modeling systems and providing savings per tons.

Commented [SK142R141]: Proposed Secondary Research

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

1. Full load cooling and heating hours from Appendix Five.
2. 13% of the fan hours are assumed to be in free cooling; based on local temperature BINs.
3. 25% of heating/cooling equivalent full-load hours are assumed to be in Stage 2 (based on local temperature BINs).
4. 75% of heating/cooling equivalent full-load hours are assumed to be in Stage 1 (50% output). To calculate the fan hours in stage one, the equivalent full load heating/cooling are multiplied by (75% from above) then divided by 50% capacity.

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Ref [1] is for information only.

Inputs

Table 3-CC: 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 3-DD: 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
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	%	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.~~80%~~	
SP1	Stage 1 Fan Speed	%	75%	
SP2	Stage 2 Fan Speed	%	90%	
SPV	Ventilation Only Fan Speed	%	40%	
	Fan Savings Exponent		2.7	Note [1]

Commented [SK143]: Proposed further secondary research

Commented [SK144]: Allow for custom input and default to current 80%, or update to LF of 65% recommended for HVAC Variable Frequency Drives.

Retrofit Gross Energy Savings, Electric

Commented [SK145]: The current approach relies on a spreadsheet. This approach appears to yeld negative savings if the hours are low. The IL TRM addressed this by modeling systems and providing savings per tons. Further secondary research proposed.

$$AKWH = AKWH_E - AKWH_R$$

$$AKWH_E = KW_E * H$$

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

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

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

Commented [SS146]: Unclear what this value represents – provide in nomenclature.

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

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

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

- No changes.

References

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

Notes

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

Commented [SK147]: The current approach relies on a spreadsheet which is not available to review. This approach appears to yeld negative savings if the hours are low. The IL TRM addressed this by modeling systems and providing savings per tons. Further secondary research proposed.

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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 2020 PSD’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 3-EE: 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	^{o}F-day
CDD	Modified Cooling degree Days	^{o}F-day

Changes from Last Version

- No changes.

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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.

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

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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.

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Non-Temperature-Dependent Measures

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 Appendix One. 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:

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

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

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

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

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

Computer Simulation Modeling

For certain unique or complex projects including those with interactive effects performance shall be determined using a computer simulation model. Approved software and modeling requirements are specified by the 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 3-FF: Nomenclature

Symbol	Description	Units	Values
WD	Weekdays	Days	

Changes from Last Version

- No changes.

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3.4 REFRIGERATION

3.4.1 Cooler Night Covers

Commented [MM148]: No recommended changes to this measure

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 3-GG: Inputs

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

Nomenclature

Table 3-HH: 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 3-II: 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.

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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.

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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 3-JJ: Inputs

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

Nomenclature

Table 3-KK: 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			

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.

Commented [SK149]: Appendix 4 does not currently list evaporator fan controls but only refrigeration controls. List EUL of 10 years for evaporator fan control.

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Commented [SK150]: CT PSD obtained ACOP values from 2009 ASHRAE handbook and consultant interviews which the review team was unable to verify. NY TRM uses COP values from a more recent evaluation report, however, the review team was unable to locate that study. CT values generally align with other TRMs but we recommend further research for this parameter.

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

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

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

Commented [SK151]: Currently assumes average kW reduction. It is reasonable to expect that fans operate more during peak periods to handle peak cooling loads reducing the peak savings.

Changes from Last Version

- Formatting and corrected spelling error in Notes.

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References

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

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Notes

[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.

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3.4.3 Evaporator Fans Motor Replacement

Description of Measure

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

Savings Methodology

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

Inputs

Table 3-LL: Inputs

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

Nomenclature

Table 3-MM: 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
~~COP~~	~~Coefficient of Performance (used to calculate interactive effects)~~		~~Freezers: 1.72~~ ~~Coolers: 2.29~~	
DP	Power Reduction Factor		PSC motors: 0.40 Shaded pole motors: 0.65	Note [1]
EER	Energy Efficiency Ratio			
h	Hours of Operation	Hours	With existing controls: 5,500 Without controls: 8,500	Note [2]
N	Number of Fans			
Pf	Power Factor of Existing Fans		0.65	Estimated
PSC	Permanent Split Capacitor Motor			
V	Volts of Existing Fans			

Retrofit Gross Energy Savings, Electric

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

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

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

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

Commented [SK152]: CT PSD obtained ACOP values from 2009 ASHRAE handbook and consultant interviews which the review team was unable to verify. NY TRM uses COP values from a more recent evaluation report, however, the review team was unable to locate that study. CT values generally align with other TRMs but we recommend further research for this parameter.

Commented [SK153]: Remove as it is not used in the analysis

Commented [SK154]: Fan power (W) should substitute for V x A x pf

Commented [MM155R154]: Aligns with other TRMs

Commented [MM156R154]: Add clarification on calculating fan power

Commented [SK157]: Fan power (W) should substitute for V x A x pf

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:

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

Changes from Last Version

- Formatting and corrected spelling in Notes.

References

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

Notes

[1]	Power reduction factors of existing fans are based on correspondence with a National Resource Management (NRM) representative on 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 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.

Commented [SK158]: AKW = AKWH / 8760 x CF

Commented [SK159R158]: CF is currently not included in the peak savings calculation. Recommend updating algorithm.

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Commented [SK160]: Add reference: Becker, B.R, and Fricke B.A., High Efficiency Evaporator Fan Motors for Commercial Refrigeration Applications, Purdue Labs, 2016.

https://docs.lib.purdue.edu/cgi/viewcontent.cgi?article=2588&context=iracc

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3.4.4 Door Heater Controls

Description of Measure

Installation of an on/off or micropulse 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. ~~The control system shuts off the door heaters when the facility's humidity is too low to allow condensation to occur.~~

Savings Methodology

The savings from this measure result from a reduction in the operating hours of the door heaters. The off hours are stipulated values and are overall averages based on vendor experience (See Note [1]). They are applicable to all store types and sizes.

Inputs

Table 3-NN: Inputs

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

Nomenclature

Table 3-OO: Nomenclature

Symbol	Description	Units	Values	Comments
A	Amperage of Door Heater			
AKW	Annual Summer and Winter Electric Demand Savings	kW		
AKWH	Annual Gross Electric Energy Savings	kWh		
CF	Seasonal Peak Demand Coincident Factor for Refrigeration (same for Summer and Winter)		Appendix One	
h	Heater Off Hours After Measure Installation	Hours	On/Off 2786 Micropulse 4196~~Coolers: 6,500 Freezers: 4,070~~	Note [1]
kW	Kilowatts			

Commented [SK161]: Recommend add On/Off and Micropulse to add flexibility to the measure as occurs with other TRMs.

Commented [SK162]: Add to nomenclature. This will be used in the modified algorithm:

WHFe - Interactive Effects - Coolers: ACOP 2.69 = WTFe 1.49

WHFe - Interactive Effects - Freezers: ACOP 2.03 = WHFe 1.37

WHFd - Interactive Effects - Coolers: ACOP 2.69 = WTFe 1.49

WHFd - Interactive Effects - Freezers: ACOP 2.03 = WHFe 1.37

Commented [SK163R162]: CT PSD obtained ACOP values from 2009 ASHRAE handbook and consultant interviews which the review team was unable to verify. NY TRM uses COP values from a more recent evaluation report, however, the review team was unable to locate that study. CT values generally align with other TRMs but we recommend further research for this parameter.

Commented [SK164]: On/Off SSP 0.315 (41w/130w), WSP 0.3 (39w/130w)
Micropulse SSP 0.462 (60w/130w), WSP 0.431 (56w/130w)

Commented [SK165]: On/Off 2786
Micropulse 4196

MidAtlantic TRM provides different reduced hours for control types. The referenced source for the values was reviewed and inputs adjusted for CT specific conditions. This change removes the cooler/freezer reduced hours and switches to control type. Further research could be completed to provide adjustments for control type and cooler/freezer.

N	Number of Heaters			
Pf	Power Factor		1	Note [2]
V	Volts of Door Heater			

Retrofit Gross Energy Savings, Electric

AkWh ={ [N x V x A x Pf x h] / 1000} x [1 + (1 / ACOP)]

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

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

AkW = AKWH / 8760 hrs/yr x CF

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

Changes from Last Version

- No changes.

Notes

[1]	Heater off hours after measure installation for freezers and refrigerators are based on Updeate to: https://cadmusgroup.com/wp-content/uploads/2016/02/NEEP-CRL_Report_FINAL_clean.pdf?submissionGuid=cb214243-bab8-479a-a4c4-c8e5c64ae7b2~~correspondence with a National Resource Management (“NRM”) representative, Jul. 14, 2017. For the purposes of electric demand savings calculations, CF for refrigeration is assumed to be the same for both winter and summer.~~
[2]	Assumes single-phase power.

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Commented [SK166]: Modify algorithm:

AkWh ={ [N x V x A x Pf x h] / 1000} x [1 + (1 / ACOP)]

Commented [SK167R166]: Modify to include the interactive effects when updating to the MidAtlantic TRM approach.

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Commented [SK168]: AkW = AKWH / 8760 hrs/yr x CF

Commented [SK169R168]: [1] Adding CF value to equation
[2] May require modification to include interactive effects if demand values are different from energy.

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Commented [SK170]: Updeate to: https://cadmusgroup.com/wp-content/uploads/2016/02/NEEP-CRL_Report_FINAL_clean.pdf?submissionGuid=cb214243-bab8-479a-a4c4-c8e5c64ae7b2

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 3-PP: 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 3-QQ: Nomenclature

Symbol	Description	Units	Values	Comments
A	Amperage of Vending Machine	amps		
AKWH	Annual Gross Electric Energy Savings	kWh		
ESF	Energy Savings Factor			Tables 3-SS and 3-TT
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 3-RR
WKW	Winter Demand Savings	kW	0	

Retrofit Gross Energy Savings, Electric

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

Where:

- $WATTS_{base}$ = connected kW of the controlled equipment; see Table 3-RR 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 3-RR below for Occupancy-Based Controls by equipment type, and Table 3-WW below for Time Schedule-Based Controls by equipment type.

Table 3-RR: 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

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Table 3-SS: Occupancy-Based Controls

Equipment Type	Energy Savings Factor (ESF)
Refrigerated Beverage Vending Machines	46~~4~~% (Ref [1])
Non-Refrigerated Snack Vending Machines	25~~52~~% (Ref [1])
Glass Front Refrigerated Coolers	35~~44~~% (Ref [2])

Table 3-TT: 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)

- ~~a.~~ SKW = 0; and
- ~~b.~~ 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.

- ~~o~~ AKWH = $WATTS_{base}$ /1000 x HOURS x ESF x N.
- ~~o~~ From Table 3-RR, Watts base = 400 W; From Table 3-SS, ESF = 0.44.
- ~~o~~ AKWH = 400/ 1000 x 8760 x 0.44 x 2 = 3,084 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:

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

$$\text{Watts}_{base} = V \times A \times PF = 120 \times 4.2 \times 0.85 = 428\ W$$

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

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

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

Commented [SK171]: Savings based on 2017 study. Recommend update to align with current manufacturer literature. https://www.energymisers.com/#:~:text=VM2iQ,Learn%20More.

The original studies referenced in the CT PSD are no longer available from energymiser. The current values listed by energymiser are found here. https://www.energymisers.com/

Commented [SK172]: Savings based on 2017 study. Recommend update to align with current manufacturer literature. https://www.energymisers.com/#:~:text=VM2iQ,Learn%20More.

The original studies referenced in the CT PSD are no longer available from energymiser. The current values listed by energymiser are found here. https://www.energymisers.com/

Commented [SK173]: The original studies referenced in the CT PSD are no longer available from energymiser. The current values listed by energymiser are found here. https://www.energymisers.com/

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

Changes from Last Version

- No changes.

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References

[1]	http://www.energymisers.com/calculator.php~~USA Technologies, Energy Savings Calculator Vending Machine USA TECH [Microsoft Excel], Jul. 2017.~~
[2]	Cooling Miser has the same ESF and Watts as Vending Misers. Based on correspondence and email from Bunny Proof, USA Technologies, Aug. 2017.

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Commented [SK174]: Energy Misers calculator: http://www.energymisers.com/calculator.php

Energy Misers Savings Factors: https://www.energymisers.com/#:~:text=VM2iQ,Learn%20More

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.

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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 3-UU: Inputs

Symbol	Description
L	Length of Display Case

Nomenclature

Table 3-VV: 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
CF	CF ssp – 1 CF wsp - 1	
COPref - Cooler	ACOP 2.69	

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Commented [SK175]: Remove parameter

Commented [MM176]: Remove parameter

COPref - Freezer	ACOP 2.03	
COPhvac - Other	ACOP 4.5	
Eff - AFUE of Gas Furnace	AFUE 0.80	
EFLHcooling	Varies by facility type. Table - Appendix 5	

~~Parameter~~	~~Recommended value~~
~~SFskw - Summer Demand Savings Factor~~	~~N/A~~
~~SFskw - Door Heater~~	~~N/A~~
~~SFskw - Gap~~	~~N/A~~
~~SFskw - Door Heater + Gap~~	~~N/A~~
~~SFskw - No Door Heater + No Gap~~	~~N/A~~
~~SFwkw - Winter Demand Savings Factor~~	~~N/A~~
~~SFwkw - Door Heater~~	~~N/A~~
~~SFwkw - Gap~~	~~N/A~~
~~SFwkw - Door Heater + Gap~~	~~N/A~~
~~SFwkw - No Door Heater + No Gap~~	~~N/A~~
~~SFaccf - Heating Savings Factor (ccf/Foot)~~	~~N/A~~
~~SFaccf - Door Heater~~	~~N/A~~
~~SFaccf - Gap~~	~~N/A~~
~~SFaccf - Door Heater + Gap~~	~~N/A~~
~~SFaccf - No Door Heater + No Gap~~	~~N/A~~
~~SFpd - Peak Day Savings Factor (ccf/Foot)~~	~~N/A~~
~~SFpd - Door Heater~~	~~N/A~~
~~SFpd - Gap~~	~~N/A~~
~~SFpd - Door Heater + Gap~~	~~N/A~~
~~SFpd - No Door Heater + No Gap~~	~~N/A~~
~~CF~~	~~CF ssp - 1~~ ~~CF wsp - 1~~

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~~COPref - Cooler~~	~~ACOP 2.69~~
~~COPref - Freezer~~	~~ACOP 2.03~~
~~COPhvac - Other~~	~~ACOP 4.5~~
~~Eff - AFUE of Gas Furnace~~	~~AFUE 0.80~~
~~EFLHcooling~~	~~Varies by facility type. Table - Appendix 5~~
~~EFLHheating~~	~~Varies by facility type. Table - Appendix 5~~

Retrofit Gross Energy Savings, Electric

Table 3-WW: Electric Savings Factors

Door Type	~~SF_{SKW}~~	~~SF_{WKW}~~	SF_{AKWH}
Door Heater	~~0~~	~~0.029~~	~~202.7~~Cooler: 182.5 Freezer: 375.3
Gap	~~0~~	~~0.029~~	Cooler: 182.5 Freezer: 375.3~~202.7~~
Door Heater + Gap	~~N/A~~	~~N/A~~	Cooler: -121.1 Freezer: 44.9
No Door Heater + No Gap	~~N/A~~	~~N/A~~	Cooler: 486.1 Freezer: 705.6

AKWH =

L x SFakwh x [1 - (EFLHcooling/8760) x (COPref / COPhvac)]

- ~~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 SFakwh/8760 x CF~~L x SF_{SKW}~~; and
- WKW = L x SFakwh/8760 x CF~~L x SF_{WKW}~~.

Retrofit Gross Energy Savings, Fossil Fuel

Table 3-XX: Natural Gas Savings Factors

Door Type	SF_{ACCF}	SF_{PD}
Door Heater	23.8	0.145
Gap	12.7	0.077

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

$ACCF_H$ = L x [(SFakwh x 3412) / 100,000] x (EFLHheating / 8760) x (1 / EFF)] x 1.029 (CCF to therms)~~L x SF_{ACCF}~~

AOG_H = ACCFh x 0.742~~L x SF_{ACCF} x 0.742~~

APG_H = ACCFh x1.1267~~L x SF_{ACCF} x 1.1267~~

Retrofit Gross Peak Day Savings, Natural Gas

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

Commented [SK177]: Door heater + Gap

Coolers - (-121.1)
Freezers - 44.9

Door heater + no gap

Coolers - 486.1
Freezers - 705.6

Commented [SK178]: Coolers - 182.5
Freezers - 375.3

Commented [SK179]: Aligning with NY TRM methodology using same source and correcting an error. 202.7 should have been 182.5.
Note: Standard doors have door heaters, high efficiency doors do not have door heaters.

Commented [SK180]: Coolers - 182.5
Freezers - 375.3

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Commented [SK181]: Update to:
AKWh = L x SFakwh x [1 - (EFLHcooling/8760) x (COPref / COPhvac)]

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Commented [SK182]: SkW = L x SFakwh/8760 x CF

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Commented [SK183]: SkW = L x SFakwh/8760 x CF

Commented [SK184]: Update: ACCFh = L x [(SFakwh x 3412) / 100,000] x (EFLHheating / 8760) x (1 / EFF)] x 1.029 (CCF to therms)

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Commented [SK185]: Update:

AOGh = ACCFh x 0.742

Commented [SK186]: Update to: APGh = ACCFh x1.1267

Changes from Last Version

- No changes.

References

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

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SECTION FOUR: RESIDENTIAL

4.1 LIGHTING

Commented [SK187]: Recommend removing Lost Opportunity Path.

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.

Inputs

Table 4-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 4-C for Available Options	

Nomenclature

Table 4-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 4-C for all known locations Retail: 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: 24 Watts (bulb) 26.3 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	Fossil Fuel Energy Savings			

Retrofit and direct install savings calculation:

$$AKWH = 1.04 \times \frac{Watt_\Delta \times h_d \times 365}{1000} = 1.04 \times \frac{(Watt_{pre} - Watt_{post}) \times h_d \times 365}{1000}$$

Fossil Fuel Energy Savings:

ABTU = AKWH x (-2,295)

Note: *1.04 is the average energy factor due to lighting interactive effect* ***Ref [1]****. Please refer to Table 4-C for the correct hours of use per day by location (h_d).*

For unknown wattage, light bulbs:

$$(Watt\Delta = Watt_{pre} - Watt_{post} = 24\ watt)$$

Commented [SK188]: 25 if unknown pre and post, for a light bulb
26.3 if unknown pre and post, luminaire

Commented [SK189R188]: Recommend removing Lost Opportunity Path.

Commented [SK190]: Recommended to add annual fossil fuel energy savings: ABTU = AKWH x (-2,295)

Commented [SK191R190]: Added to match with MA TRM interactive fossil fuel effect. May be updated to CT specific value with evaluation or study results.

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For unknown wattage, luminaires:

$$(Watt\Delta = Watt_{pre} - Watt_{post} = 26.3\,Watt)$$

Table 4-C: Hours of Use per Day by Location (h_d) Ref [2]†

Location	All Customers
	h_d
Bedroom	2.1
Bathroom	1.7
Kitchen	4.1
Living Room†	3.3
Dining Room	2.8
Exterior	5.6
Other	1.7
Unknown†	2.7

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:

$$\text{Watt}\Delta = Watt_{pre} - Watt_{post}$$

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

$$Watt\Delta = (45 - 10)$$

$$Watt\Delta = 35\, Watts$$

$$AKWH = 1.04 \times (35\, Watts) \times 3.3 \frac{hrs}{day} \times 365 \frac{days}{year} \div 1000\, W/kw$$

$$AKWH = 43.844 \frac{kwh}{yr}$$

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.

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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?

$$\text{Watt}\Delta = Watt_{pre} - Watt_{post} = 45 - 10$$

$$Watt_{\Delta} = 35.0\ Watts \cancel{Watt_{\Delta} = 35.0\ Watts}$$

$$SKW = 1.05 \times 35.0\ Watts \times 0.130 \div 1000\ {}^{W}/_{kW}$$

$$SKW = 0.005\ kW \cancel{SKW = 1.05 \times 35.0\ Watts \times 0.130 \div 1000\ {}^{W}/_{kW}}$$

$$\cancel{SKW = 0.005\ kW}$$

$$WKW = 35.0\ Watts \times 0.20 \div 1000\ {}^{W}/_{kW}$$

$$WKW = 0.007kW \cancel{WKW = 35.0\ Watts \times 0.20 \div 1000\ {}^{W}/_{kW}}$$

$$\cancel{WKW = 0.007kW}$$

Lost Opportunity Gross Energy Savings (for rebate and upstream), Electric

For bulb:

$$AKWH = 1.04 \times \frac{Watt_{\Delta} \times h_d \times 365}{1000} = 1.04 \times \frac{24.0 \times 2.7 \times 365}{1000}$$

$$AKWH = 24.598\ kWh$$

For luminaire:

$$AKWH = 1.04 \times \frac{Watt_{\Delta} \times h_d \times 365}{1000} = 1.04 \times \frac{26.3 \times 2.7 \times 365}{1000}$$

$$AKWH = 27.07\ kWh$$

Lost Opportunity Gross Energy Savings, Example

What are the electric energy savings when any LED bulb is purchased through a retailer?

$$\boldsymbol{AKWH} = 24.598kWh$$

Lost Opportunity Gross Peak Demand Savings, Example

For bulb:

$$\boldsymbol{SKW} = 1.05 \times \frac{Watt_{\Delta} \times CFs}{1000} = 1.05 \times \frac{24.0 \times 0.13}{1000} = 0.003\ kW$$

$$\boldsymbol{WKW} = \frac{Watt_{\Delta} \times CFw}{1000} = \frac{24.0 \times 0.20}{1000} = 0.005\ kW$$

For luminaire:

$$\boldsymbol{SKW} = 1.05 \times \frac{Watt_{\Delta} \times CFs}{1000} = 1.05 \times \frac{26.3 \times 0.13}{1000} = 0.004\ kW$$

$$\boldsymbol{WKW} = \frac{Watt_{\Delta} \times CFw}{1000} = \frac{26.3 \times 0.20}{1000} = 0.005\ kW$$

Non-Energy Benefits

Table 4-D: One-Time O&M Benefit per Bulb (Note [4]) and Lighting Interactive Effects (Note [10])

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

- Formatting updates.

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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. 30.
[3]	NMR Group Inc., *Northeast Residential Lighting Hour-of Use Study*, May 5, 2014, Table ES-7, p. VIII.

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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.

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4.2 HVAC

4.2.1 Energy-Efficient Central Air Conditioning

Description of Measure

Installation of an energy-efficient Central Air Conditioning ("CAC") 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.

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Retrofit measure:

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

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Savings are based on the CAC 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 Energy Efficiency Ratio ("EER").

Inputs

Table 4-E: 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 4-F: Nomenclature

Symbol	Description	Units	Values	Comments
$AKWH_C$	Annual Electric Energy Savings - Cooling	kWh		
ASF	Annual ~~Savings~~ 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 8 if existing EER is not known	Note [2]
EER_i	Installed EER of New Efficient Unit	Btu/Watt-hr		Input
EUL	Effective Useful Life	Years	18	Appendix Four
$LKWH_C$	Lifetime Electric Energy Savings - Cooling	kWh		
RUL	Remaining Useful Life	Years	~~3.67~~6~~5~~	Appendix Four
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	

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:

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

Retirement component:

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

Commented [SK192]: Add MAF: Multifamily Adjustment Factor, Units: none, Value: 0.4, Comments: Ref [2, 3]

Note we provided References 2 and 3 in comments further down

Commented [SK193]: Consider updating the term to "annual usage factor" as recommended by R8 evaluation report (page VI).

Commented [SK194]: Considering updating EER to 11.2 (SEER 13) to be consistent with other TRMs. This measure would result in summer season savings only, thus using SEER would make more sense instead of EER

Commented [SK195]: RUL is assumed 1/3 of the EUL when equipment specific information is not available.

Commented [SK196]: Update EERb in the savings algorithm

Commented [SK197]: Add multifamily equations: AKWH_C,Retire = MAF x ASF x CAP_c,I x (1-EER_e/EER_b)

For Multifamily: *AKWH_C,Retire = MAF x ASF x CAP_c,I x (1- EER_e/EER_b)*

The equation simplifies when the existing EER is not known:

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

Retrofit Gross Energy Savings, Example

Example: An existing working CAC is replaced by an energy-efficient unit. The new installed unit has a 3 ton cooling capacity, at 13.0 EER. What are the annual energy savings?

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

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

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

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

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

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

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

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

Retirement component:

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

The equation simplifies when the existing EER is not known:

$$SKW_{C,Retire} = 0.45\, {}^{kwh}/_{Ton} \times CAP_{C,i} \times \left(1 - \frac{8}{11.2}\right) = 0.123 \times CAP_{C,i}$$

Commented [KR198]: Update calculation to reflect new parameter

Commented [KR199]: Update example calculation to reflect new parameter

Commented [SK200]: update EER to 11.2 (SEER 13)

Commented [SK201]: *Note that this equation didn't convert correctly going from pdf to Word.*

Add multifamily-specific equation:
SKW =MAF x DSF x CAP_C,I x (1- EER_e/EER_b)

Commented [KR202]: Update calculation to reflect new parameter

For multifamily: SKW =MAF x DSF x CAP_C,I x (1- EER_e/EER_b)

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

Retrofit Gross Peak Demand Savings, Example

Commented [KR203]: Update calculation to reflect new parameter

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

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

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

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

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

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

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

Lost Opportunity Gross Energy Savings, Electric

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

Commented [SK204]: Add multifamily equation: AKWH_C,Lost Opp = MAF*ASF x Cap_c,I X (1- 11.2/EER_i)

$$AKWH_{C,Lost\ Opp} = 362\ {}^{kwh}/_{Ton} \times CAP_{C,i} \times \left(\frac{EER_i}{11.2} - 1\right)$$

For Multifamily: *AKWH_C,Lost Opp = MAF*ASF x Cap_c,I X (1- 11.2/EER_i)*

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Lost Opportunity Gross Energy Savings, Example

Commented [KR205]: Update calculation to reflect new parameter

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

To calculate annual savings, use the Lost Opportunity equation:

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

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

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

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

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

$$SKW_{C,Lost\ Opp} = 0.45\ {}^{kwh}/_{Ton} \times CAP_{C,i} \times \left(\frac{EER_i}{11.2} - 1\right)$$

For Multifamily: *SKW = MAF x DSF x CAP_C,I x (1- EER_b/EER_e)*

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

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

Using the equation for Lost Opportunity demand savings:

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

Input the size and efficiency of the new unit:

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

Changes from Last Version

- No changes.

References

[1]	*Central Air Conditioning Impact and Process Evaluation*, NMR Group, Inc., May 30, 2017.

Commented [SK206]: *Add multifamily-specific equation: SKW = MAF x DSF x CAP_C,I x (1- EER_b/EER_e)*

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Commented [KR207]: Update calculation to reflect new parameter

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Commented [SK208]: *Add references for MAF:*
[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.

[3] Energy & Resource Solutions. "R1705 R1609 Multifamily Baseline and Weatherization Opportunity Study," October 10, 2019.

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[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.*
[3]	*Energy & Resource Solutions. "R1705 R1609 Multifamily Baseline and Weatherization Opportunity Study," October 10, 2019.*

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Notes

[1]	**Ref [1]**, *NMR Central Air Conditioning Impact and Process Evaluation*, pp. I to III. "Because there were no instances of early replacement of CAC units in the monitoring sample, the baseline for estimating savings is the minimum standard for new installations, namely 11 EER."
[2]	EER for the existing unit is estimated based on average installed efficiency for an approximately 15-year-old unit. ASHRAE/IESNA Standard 90.1-1999, Table 6.2.1A has a minimum requirement of 10 SEER for 2011. **Note:** Units of that vintage were only rated on SEER. EER is approximately 80% of SEER (**Ref [1]**, p. ES-1 gives the ratio 11 EER/14 SEER). 8 EER is used as the estimated existing efficiency.

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4.2.2 Heat Pump

Description of Measure

We recommend modifying the language to "Installation of an energy-efficient ducted air source heat pump (ASHP) or cold-climate air source heat pump (ccASHP) 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 air conditioning.~~Installation of an energy-efficient air source heat pump and replacement of a working, less-efficient electric heating system, including heat pumps and electric resistance heating.~~

Commented [SK209]: Proposed measure description should include cold-climate ASHPs.

Commented [SK210]: We recommend modifying the language to "Installation of an energy-efficient ducted air source heat pump 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 air conditioning.

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).

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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 1.5).
- 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.

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~~The savings methodology presented here is for heating only; cooling savings from an efficient heat pump are the same as the cooling savings for an efficient central air conditioner, as presented in Measure 4.2.1: Energy-Efficient Central Air Conditioning of the 2020 PSD.~~

Commented [NP211]: Our recommendations for this measure involve including the cooling algorithms in the same writeup. We should delete this sentence and add the cooling algorithms below.

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

Inputs

Table 4-G: Inputs

Symbol	Description	Units
$CAP_{H,i}$	Installed Heating Capacity	Btu/hr
$HSPF_e$	Heating Season Performance Factor of Existing Unit (AHRI-Verified)	Btu/Watt-hr

$HSPF_i$	Heating Season Performance Factor, Installed Unit (AHRI-Verified)	Btu/Watt-hr
	Existing Heating System Type	

Nomenclature

Table 4-H: Nomenclature

Symbol	Description	Units	Values	Comments
AKWH	Annual Electric Energy Savings - Heating	kWh		
AKWC	Annual Electric Savings - Cooline	kWh		
$CAP_{H,i}$	Installed Heating Capacity	Btu/hr		Input
$EFLH_H$	Heating Equivalent Full-Load Hours	Hours	~~1349~~862	Note [3]
EFLHc	Cooling Equivalent Full-Load Hours	Hours	470	Note [3]
$HSPF_b$	Heating Season Performance Factor, Baseline, Representing Baseline New Model	Btu/Watt-hr	8.2	Note [1]
$HSPF_e$	Heating Season Performance Factor, Existing (AHRI-Verified)	Btu/Watt-hr	'Use site-specific preexisting equipment HSPF value if known. If installment year of preexisting system is known use: - 6.8 HSPF if preexisting ASHP system was installed before 2006	Note [2]

Commented [NP212]: Add cooling parameters :
1. Baseline EER (for Lost Opportunity)
2.Existing EER (for retrofit)
3. Cooling Capacity (Cap C, i)
4.EFLH_C

Commented [SK213]: Recommended EUL of 15 (Lost opportunity), 5 (Remaining useful life).

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Commented [SK214]: Current value is based on outdated research (1979 - 2008). 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

			- 7.7 HSPF if preexisting ASHP system was installed between 2006 -2014 - 8.2 HSPF if preexisting ASHP system was 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~~Use 6.8 if HSPF existing is not known; 3.41 for electric resistance heat~~	
$HSPF_i$	Heating Season Performance Factor, Installed (AHRI-Verified)	Btu/Watt-hr		Input
SKW	Summer Demand Savings	kW		
WKW	Winter Demand Savings	kW		
EERb	Baseline EER for Lost Opportunity			
EERe	Baseline EER for Retrofit			
CapC,i	Installed Cooling Capacity	Btu/hr		

Commented [SK215]: 'Use site-specific preexisting equipment HSPF value if known.

If installment year of preexisting system is known use:
- 6.8 HSPF if preexisting ASHP system was installed before 2006
- 7.7 HSPF if preexisting ASHP system was installed between 2006 -2014
- 8.2 HSPF if preexisting ASHP system was 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

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:

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

Early Retirement component:

AKWHH,Retire = EFLHH * CAPH,i * (1/HSPFe - 1/HSPFi) * (1/1000)

AKWHC = EFLHC * CAP_c,I * (1/EERe – 1/EERi) * (1/1000)

CAPH,i = 0.9 * CAPC,i for non cold-climate ASHP units AND supplemental heating source is present

CAPH,i = 1.0 * CAPC,i for cold-climate ASHP units

where,

CAPC,i = Cooling Capacity of efficient ASHP unit (kBtu/h)

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

The equation simplifies when the existing HSPF is not known:

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

Cooling: If the unit also provides cooling, calculate savings as presented in Central A/C Measure 4.2.

Retrofit Gross Energy Savings, Example

Example: A new air source heat pump with both heating and cooling capacity of 36,000 Btu/hr, $HSPF_i$ of 9.00, SEER of 15.50, and EER of 13.0 is installed in a home to replace an old working heat pump with heating capacity of 36,000 Btu/hr, and $HSPF_e$ of 6.8.

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

AKWHH,LostOpp = EFLHH * CAPH,i * (1/HSPFb - 1/HSPFi) * (1/1000)

AKWHC = EFLHC * CAP_c,I * (1/EERe – 1/EERi) * (1/1000)

CAPH,i = 0.9 * CAPC,i for non cold-climate ASHP units AND supplemental heating source is present

Commented [SK216]: For fossil fuel savings, if added to the PSD:
AMMBTUH = CAPH,i * EFLHH * (1/1000) * (1/AFUE)
where,
AMMBTUH = Annual MMBTU savings
AFUE = Annual fuel utilization efficiency of replaced fossil fuel heating system (%)
* Fossil fuel savings are based on pilot assumptions of the program where HP units will replace fossil fuel heat sources

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Commented [SK217]: AKWHH,Retire = EFLHH * CAPH,i * (1/HSPFe - 1/HSPFi) * (1/1000)

CAPH,i = 0.9 * CAPC,i for non cold-climate ASHP units AND supplemental heating source is present
CAPH,i = 1.0 * CAPC,i for cold-climate ASHP units
where,
CAPC,i = Cooling Capacity of efficient ASHP unit (kBtu/h)

Commented [KR218]: Update calculation based on new algorithm

Commented [KR219]: Update example based on new algorithm

Commented [NP220]: Cooling Savings algorithms
AKWHC = EFLHC * CAP_c,I * (1/EERb – 1/EERi) * (1/1000)

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CAPH,i = 1.0 * CAPC,i for cold-climate ASHP units

where,

CAPC,i = Cooling Capacity of efficient ASHP unit (kBtu/h)

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

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

Commented [KR221]: Update calculation based on new algorithm

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

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

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

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

~~Because the heat pump also provides cooling, calculate cooling savings as presented in the Central A/C Measure 4.2.1.~~

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

- Heating: ~~WKW= 0; Note [4]; and~~

WKW = 0 if installed unit is a non-ccASHP

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WKW = CAPH,5F,i * (1 - 1/COPH,5F,i) *(12/3.412) * CFH if installed unit is ccASHP

where,

CAPH,5F,i = Heating capacity of installed ccASHP at 5F (kBtu/h)

COPH,5F,i = Coefficient of performance of installed ccASHP at 5F

12 = Conversion factor from kBtu/h to kW

3.412 = Conversion factor from COP to HSPF

~~o~~ CFH = Winter coincidence factor (Heating) = 0.5 in CT PSD

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- Cooling: If the unit also provides cooling, calculate demand savings as presented in Central A/C

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SKWC = CAPC,i * (1/EERe - 1/EERi) * CFC

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where,

CAPC,i = installed cooing capacity (kBtu/hr)

EERe = Energy efficiency ratio of preexisting electric cooling system

CFC = Summer coincidence factor (Cooling) = 0.59 (CT-PSD)

~~measure (4.2.1).~~

Lost Opportunity Gross Energy Savings, Electric

AKWHH,LostOpp = EFLHH * CAPH,i * (1/HSPFb - 1/HSPFi) * (1/1000)

AKWHC = EFLHC * CAP_c,I * (1/EERe – 1/EERi) * (1/1000)

CAPH,i = 0.9 * CAPC,i for non cold-climate ASHP units AND supplemental heating source is present

CAPH,i = 1.0 * CAPC,i for cold-climate ASHP units

where,

CAPC,i = Cooling Capacity of efficient ASHP unit (kBtu/h)

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

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

~~Cooling: If the unit also provides cooling, calculate savings as presented in Central A/C Measure 4.2.1.~~

Lost Opportunity Gross Energy Savings, Example

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

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

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

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

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

- Heating: ~~WKW= 0; Note [4].~~

WKW = 0 if installed unit is a non-ccASHP

WKW = CAPH,5F,i * (1 - 1/COPH,5F,i) *(12/3.412) * CFH if installed unit is ccASHP

where,

Commented [NP222]: No longer the case. As per our recommendation, the cooling demand and energy savings should be in the same writeup.

SKWC = CAPC,i * (1/EERe - 1/EERi) * CFC
where,
CAPC,i = installed cooing capacity (kBtu/hr)
EERe = Energy efficiency ratio of preexisting electric cooling system
CFC = Summer coincidence factor (Cooling) = 0.59 (CT-PSD)

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Commented [KR223]: Update example based on new algorithm

Commented [SK224]: This (WKW = 0) is a commonly adopted value because:
1. The peak savings in winter are a fraction of the peak savings in Summer
2. The non-cold-climate ASHP unit will have a backup heat source (fossil fuel furnace/electric heat) which will kick on during the coldest peak winter day, thereby minimizing the operation of the ASHP unit.

However, if the installed unit is a cold-climate ASHP unit, it is designed to meet the heat load even at the coldest temperature. In this case the winter peak demand savings will be non-zero and can be calculated by an algorithm similar to the one used to calculate summer demand savings. This algorithm is based on the performance of the ccASHP unit at low temperatures. The ccASHP unit should be NEEP rated and the HSPF at 5F is used in the winter peak demand savings calculations.

Commented [SK225]: WKW = 0 if installed unit is a non-ccASHP

WKW = CAPH,5F,i * (1 - 1/COPH,5F,i) *(12/3.412) * CFH if installed unit is ccASHP (cold climate air source heat pump)
where,
CAPH,5F,i = Heating capacity of installed ccASHP at 5F (kBtu/h)
COPH,5F,i = Coefficient of performance of installed ccASHP at 5F

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CAPH,5F,i = Heating capacity of installed ccASHP at 5F (kBtu/h)

COPH,5F,i = Coefficient of performance of installed ccASHP at 5F

12 = Conversion factor from kBtu/h to kW

3.412 = Conversion factor from COP to HSPF

CFH = Winter coincidence factor (Heating) = 0.5 in CT PSD

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- **Cooling:** If the unit also provides cooling, calculate demand savings as:

SKWC = CAPC,i * (1/EERe - 1/EERi) * CFC

where,

CAPC,i = installed cooing capacity (kBtu/hr)

EERe = Energy efficiency ratio of preexisting electric cooling system

CFC = Summer coincidence factor (Cooling) = 0.59 (CT-PSD)

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- ~~presented in Measure 4.2.1: Energy-Efficient Central Air Conditioning.~~

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Changes from Last Version

- Corrected “Retrofit Gross Energy Savings, Example.”

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References

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[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 Fig. 1: Correction Factor versus Degree-Days.
[3]	*1989 ASHRAE Fundamentals*, 24.6 Table 1: Climatic Conditions for the United States: Connecticut: Hartford, Brainard Field.
[4]	McQuiston, Faye C.; Jerald D. Parker; Jeffrey D. Spitler. *Heating, Ventilating, and Air Conditioning: Analysis and Design*, Fifth Edition, Chapter 7: Space Heating Load, p. 192. ISBN 0-471-35098-2.

Notes

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[1]	~~The federal minimum efficiency standard for heat pumps is~~IECC 2018 Code Compliant Heat Pump HSPF 8.2~~, as of Jan. 1, 2015~~.
[2]	In 1992, the US government established the federal minimum heating efficiency standard for new heat pumps at 6.8 HSPF.

Commented [SK226]: IECC 2018 Code compliant HP - 8.2 HSPF

[3]	Opinion Dynamics, New York Statewide Residential Gas High-Efficiency Heating Equipment Programs – Evaluation of 2009-2011 Programs, August 2014~~Equivalent Full Load Hours estimated as follows:~~ $\cancel{EFLH_H} = \cancel{\left(\frac{24\times HDD\times AF}{T_{OC}-T_{IC}}\right)}\left(\frac{24\times HDD\times AF}{T_{OC}-T_{IC}}\right) = \cancel{\left(\frac{24\times 5885\times 0.64}{70-3}\right)}\left(\frac{24\times 5885\times 0.64}{70-3}\right) = \cancel{1349\ hr/yr}$
Where:	• **24** = conversion between degree-days to degree-hours. • **HDD = 5885** = 30-year average annual degree days, data from **Ref [1]** for CT, Jan. 1979 to Dec. 2008. • **AF = 0.64** = ASHRAE degree day correction factor to account for occupant behavior from **Ref [2]**. • **T_{OC} = 3° F** = outdoor heating design temperature for Hartford, Brainard Field at 99% level from **Ref [3]**. • **T_{OC} = 70° F** = indoor heating design temperature, **Ref [4]**. • **WKW = 0**; Demand savings are not claimed for this measure since backup resistance heat on the heat pump would most likely be used during winter seasonal peak periods.

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4.2.3 Geothermal Heat Pump

Commented [SK227]: Recommended measure: Lost Opportunity/Retrofit

Description of Measure

Installation and commissioning of a high-efficiency closed loop DX geothermal heat pump system.

Savings Methodology

Commented [SK228]: Update to: Engineering algorithm which will calculate savings based on difference in name plate efficiency between baseline/preexisting and efficient equipment for the nameplate capacity.

Engineering algorithm which will calculate savings based on difference in name plate efficiency between baseline/preexisting and efficient equipment for the nameplate capacity.~~Savings are determined using the results of "HVAC Systems in an ENERGY STAR Home: Owning & Operating Costs (Update 2008)" (Ref [1]) as a basis for the calculation. The report analyzed the annual consumption of geothermal heat pumps. To calculate savings for this measure, the results from the study are adjusted based on size (in tons) and efficiencies (COP and EER).~~

Baseline For Lost Opportunity:

Code Compliant Geothermal system

Baseline For retrofit:

Site Specific electric cooling (CAC/HP)

Site specific electric heating system (electric resistance/HP) or fossil fuel heating system (Boiler/furnace)

~~**Note:** *The savings baseline is an ENERGY STAR Tier 1 geothermal system.*~~

Commented [SK229]: Update to:

For Lost Opportunity:
Code Compliant Geothermal system

For retrofit:
Site Specific electric cooling (CAC/HP)
Site specific electric heating system (electric resistance/HP) or fossil fuel heating system (Boiler/furnace)

Inputs

Table 4-I: Inputs

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

Nomenclature

Table 4-J: Nomenclature

Symbol	Description	Units	Values	Comments
~~AH_{CDH}~~	~~Annual Heating Energy Usage per Ton~~	~~kWh/ton/yr~~	~~1,569~~	~~Ref [1]~~
~~AH_b~~	~~Annual Heating Energy Usage, Baseline~~	~~kWh/yr~~		
~~AH_i~~	~~Annual Heating Energy Usage, Installed~~	~~kWh/yr~~		
~~AC_{CDH}~~	~~Annual Cooling Energy Usage per Ton~~	~~kWh/ton/yr~~	~~326~~	~~Ref [1]~~
~~AC_b~~	~~Annual Cooling Energy Usage, Baseline~~	~~kWh/yr~~		
~~AC_i~~	~~Annual Cooling Energy Usage, Installed~~	~~kWh/yr~~		
CAP_i	Installed Cooling Capacity in Tons	Tons		Input
CF_C	Coincidence Factor, Residential Cooling		0.59	Appendix One
CF_H	Coincidence Factor, Residential Heating		0.50	Appendix One
EFLHH	Heating Equivalent Full-Load Hours	Hours	862	
EFLHc	Cooling Equivalent Full-Load Hours	Hours	470	
COP_b	COP - Baseline		Table 4-K	ENERGY STAR Tier 1
~~COP_{CDH}~~	~~EER Used to Model Consumption in the CDH Study~~		~~3.9~~	~~Ref [1]~~
COP_i	COP - Installed			Input
~~EER_{CDH}~~	~~EER Used to Model Consumption in the CDH Study~~	~~Btu/Watt-hr~~	~~17.2~~	~~Ref [1]~~
EER_b	EER - Baseline	Btu/Watt-hr	Table 4-K	ENERGY STAR Tier 1
EER_i	EER - Installed	Btu/Watt-hr		Input
SKW_C	Summer Seasonal Demand Savings	kW		
~~SKW_{CDH}~~	~~Summer kW per Ton~~	~~kW/ton~~	~~0.71~~	~~Ref [1]~~
WKW_H	Winter Seasonal Demand Savings	kW		

Lost Opportunity Gross Energy Savings, Electric

~~The annual consumption per ton and efficiencies per cooling capacity (tons) are as follows (Ref [1]):~~

- ~~AH_{CDH} = 1,569 kWh/Ton at 3.9 COP;~~
- ~~AC_{CDH} = 326 kWh/ton at 17.2 EER; and~~
- ~~SKW_{CDH} = 0.71 kW/ton.~~

Commented [SK230]: We recommend using:

EFLH$_H$ - Effective Full Load Hours – Heating = 862 hours

EFLH$_C$ - Effective Full Load Hours – Cooling = 470 hours

Commented [SK231]: No longer required. This value comes from the GSHP savings model in the CDH study. The recommended method for savings calculations will not require this input.

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Commented [SK232]: No longer required. This value comes from the GSHP savings model in the CDH study. The recommended method for savings calculations will not require this input.

Commented [SK233]: No longer required. This value comes from the GSHP savings model in the CDH study. The recommended method for savings calculations will not require this input.

Commented [SK234]: No longer required. This value comes from the GSHP savings model in the CDH study. The recommended method for savings calculations will not require this input.

Commented [SK235]: No longer required. This value comes from the GSHP savings model in the CDH study. The recommended method for savings calculations will not require this input.

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Commented [SK238]: No longer required. This value comes from the GSHP savings model in the CDH study. The recommended method for savings calculations will not require this input.

Commented [SK239]: No longer required. This value comes from the GSHP savings model in the CDH study. The recommended method for savings calculations will not require this input.

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Commented [SK240]: For Retrofit, if added to the PSD:

AKWH$_H$ - Annual Heating Energy Savings

Commented [SK241]: For Retrofit, if added to the PSD:

AMMBTUH - Annual Heating Fossil Fuel Savings

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Table 4-K: Baseline Efficiencies (ENERGY STAR Tier 1) Reference [2]

System Type	EER	COP_b
Closed Loop Water to Air	~~14.1~~18.0	~~3.3~~4.7
Closed Loop Water to Water	~~15.1~~16.3	~~3.0~~3.1
DGX	15.0	3.5

$$AKWH_C = (AC_b - AC_i)$$

$AKWH_C = CAP_{C,i} * EFLH_C * (1/EER_b)-(1/EER_i)$

where,

$CAP_{C,i}$ = installed cooling capacity (kBtu/hr)

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

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

$$AKWH_H = (AH_b - AH_i)$$

$AKWH_H = CAP_{H,i} * EFLH_H * (1/COP_b)-(1/COP_i) * (1/3.412)$

where,

$CAP_{H,i}$ = installed heating capacity (kBtu/hr). Can be assumed equal to installed cooling capacity if unknown

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

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

$$AKWH = AKWH_C + AKWH_H$$

If retrofit added:

AKWHH = EFLHH * CAPH,i * (1/HSPFe - 1/HSPFi)

where,

CAPH,i = installed heating capacity (kBtu/hr).

HSPFe = Heating seasonal performance factor of preexisting heating system

if replacing electric resistance heating:

HSPFe = 3.412 Btu/W-hr

If replacing fossil fuel equiment:

(1/HSPFe) = 0

Commented [SK242]: Update COPb based on IECC 2018.

Closed Loop (Water - Air) = 4.7
Closed Loop (Water - Water) = 3.1
DGX = 3.5

Commented [SK243]: Update to reflect 2018IECC:

Closed Loop (Water - Air) = 18.0
Closed Loop (Water - Water) = 16.3
DGX = 15.0

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Commented [SK244]: Update to:

$AKWH_C = CAP_{C,i} * EFLH_C * (1/EER_b)-(1/EER_i)$
where,
$CAP_{C,i}$ = installed cooling capacity (kBtu/hr)

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Commented [SK245]: $AKWH_H = CAP_{H,i} * EFLH_H * (1/COP_b)-(1/COP_i) * (1/3.412)$
where,
$CAP_{H,i}$ = installed heating capacity (kBtu/hr). Can be assumed equal to installed cooling capacity if unknown

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AKWHC = CAPC,i * EFLHC * (1/EERe)-(1/EERi)

where,

CAPC,i = installed cooling capacity (kBtu/hr)

EERe = Energy efficiency ratio of preexisting electric cooling system

~~*Lost Opportunity Gross Energy Savings, Example*~~

~~Example: A 3 ton closed loop geothermal heat pump is installed with an EER of 20.2 and COP of 4.2. What are the energy savings?~~

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

$$AKWH_C = 3 \times 326 \times \left(\frac{17.2}{14.1} - \frac{17.2}{20.2} \right) = 360kWh$$

$$AKWH_H = 3 \times 1{,}569 \times \left(\frac{3.9}{3.3} - \frac{3.9}{4.2} \right) = 1{,}192kWh$$

$$AKWH = 360 + 1{,}192 = 1{,}552kWh$$

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

SKWC = CAPC,i * (1/EERb - 1/EERi) * CFC

where,

CAPC,i = installed cooing capacity (kBtu/hr)

WKWH = CAPH,i * (1/3.412) * (1/COPb - 1/COPi) * CFH

If Retrofit added:

SKWC = CAPC,i * (1/EERe - 1/EERi) * CFC

where,

CAPC,i = installed cooing capacity (kBtu/hr)

EERe = Energy efficiency ratio of preexisting electric cooling system

WKWH = CAPH,i * (1/3.412) * (1/COPe - 1/COPi) * CFH

where,

CAPH,i = installed heating capacity (kBtu/hr).

COPe = Coefficient of performance of preexisting heating system

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Commented [SK246]: Demand savings for retrofit:

SKW_C - Summer Seasonal Demand Savings

SKW_C = $CAP_{C,i}$ * (1/EER_e - 1/EER_i) * CF_C
where,
$CAP_{C,i}$ = installed cooing capacity (kBtu/hr)
EER_e = Energy efficiency ratio of preexisting electric cooling system

WKW_H - Winter Seasonal Demand Savings

WKW_H = $CAP_{H,i}$ * (1/3.412) * (1/COP_e - 1/COP_i) * CF_H
where,
$CAP_{H,i}$ = installed heating capacity (kBtu/hr).
COP_e = Coefficient of performance of preexisting heating system

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

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

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

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

Commented [SK247]: Updated methodology:

SKW$_C$ = CAP$_{C,i}$ * (1/EER$_b$ - 1/EER$_i$) * CF$_C$
where,
CAP$_{C,i}$ = installed cooing capacity (kBtu/hr)

Commented [SK248]: Updated methodology:

WKW$_H$ = CAP$_{H,i}$ * (1/3.412) * (1/COP$_b$ - 1/COP$_i$) * CF$_H$

Changes from Last Version

- Updated Ref [2].

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References

[1]	*HVAC Systems in an ENERGY STAR Home: Owning & Operating Costs* (Update 2008), CDH Energy Corp, 2008, Tables 3 and 4.
[2]	ENERGY STAR Tier 1 Geothermal Heat Pumps Key Product Criteria. https://www.energystar.gov/products/heating_cooling/heat_pumps_geothermal/key_product_criteria. Accessed Oct. 21, 2019.

4.2.4 Electronically Commutated Motor HVAC Fan

Commented [SK249]: ERS/TRC proposes making this measure still available for retrofit applications. That would be applicable to both single family and multifamily. This would require more secondary research to determine new savings values.

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 has been discontinued due to increased federal standards, savings no longer applicable.

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 4-L: Inputs

Symbol	Description	Units
	Number of Systems with ECMs Installed	
	Heating Fuel Type	

Nomenclature

Table 4-M: Nomenclature

Symbol	Description	Units	Values	Comments
$AKWH_H$	Annual Electric Energy Savings During Heating Season	kWh/yr	321	Ref [1]
AKWHc	Annual Electric Energy Savings During Cooling Season	kWh/yr	45	Ref [1]
PkW_C	kW Savings – Cooling Mode	kW	0.065	Ref [1], Note [2]
PkW_H	kW Savings – Heating Mode	kW	0.118	Ref [1]
SKW	Summer Demand Savings	kW		
WKW	Winter Demand Savings	kW		

Lost Opportunity Net Energy Savings, Electric

Commented [SK250]: *Change equations to Retrofit savings. The secondary research would replace these values*

$$AKWH_H = 321 \text{ kWh}$$

$$AKWH_C = 45 \text{ kWh}$$

Lost Opportunity Net Demand Savings, Electric

$$kW_W = 0.118 \text{ kW}$$

$$kW_S = 0.065 \text{ kW}$$

Changes from Last Version

- Measure discontinued.

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References

[1]	*CT HVAC and Water Heating Process and Impact Evaluation Report*, West Hill Energy and Computing, R164/1613 R, Jul. 19, 2018.
[2]	Summer kWh and kW values are based on the assumption from **Ref [1]** that 60% of homes in CT with furnaces have central A/C.

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Notes

[1]	kW savings are derived from AMI data used in **Ref [1]**.
[2]	Summer kWh and kW values are based on the assumption from **Ref [1]** that 60% of homes in CT with furnaces have central A/C.

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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.

Savings Methodology

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

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

Inputs

Table 4-N: 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.)	

Commented [SK251]: R151 - CT HES Air Sealing, Duct Sealing, and Insulation Practices [2015] - recommendation 3 suggested to use mastic rather than foil tape to seal the leaky duct. The CT PSD does not include this recommendation.

Commented [SK252]: Recommend including interactivity per R91 - Review of Impact Evaluation Best Practices [2016] - recommendation "Account for interactivity between HVAC and envelope measures" pg 73.
Per R1603 HES Impact Evaluation [2018] - duct sealing savings overlaps with the air sealing savings. According to this evaluation study, all participants who installed duct sealing also installed air sealing.

Nomenclature

Table 4-O: 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 Residential Energy Modeling Software	per CFM		Ref [1]

Retrofit Gross Energy Savings, Electric

Commented [SK253]: The deemed values are based on a REM/Rate model that was run in 2010. Changes to the model or to the input variables would change the deemed values. Recommend updating values with new REM/rate model every three years, analogous to typical codes and standards updates, to ensure that the deemed values reflect changes to the model and input variables.

Table 4-P: Electric Duct Blaster Savings, kWh per CFM Reduction at 25 Pa (Note [3])

	$REM_{Heating}$ for Heating			REM_{AH}	$REM_{Cooling}$
	Electric Forced Air	Heat Pumps	Geothermal	Heating Fan (Note [3])	Central A/C Cooling
Savings per CFM Reduction	7.693	3.847	2.564	1.100	1.059

For electric (forced air), heat pump, or geothermal heating systems:

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

For fossil fuel heating with air handler unit:

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

Home with central air conditioning ("CAC"):

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

Commented [SK254]: Update to AKWHc

Retrofit Gross Energy Savings, Fossil Fuel

Commented [SK255]: The deemed values are based on a REM/Rate model that was run in 2010. Changes to the model or to the input variables would change the deemed values. Recommend updating values with new REM/rate model every three years, analogous to typical codes and standards updates, to ensure that the deemed values reflect changes to the model and input variables.

Table 4-Q: Fossil Fuel Duct Blaster Savings per CFM Reduction at 25 Pa (Note [4])

	Heating (MMBtu)	Gallons Oil – Gallons (REM_{Oil})	Natural Gas – Ccf (REM_{NG})	Gallons Propane – Gallons ($REM_{Propane}$)
Savings per CFM Reduction	0.035	0.252	0.340	0.383

For homes with natural gas heating system:

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

For homes with oil heating system:

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

For homes with propane heating system:

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

Retrofit Gross Energy Savings, Example

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 CAC. 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:

$$ACCF_H = REM_{NG} \times (CFM_{Pre} - CFM_{Post})$$
$$ACCF_H = 0.340 \times (850 - 775)$$
$$ACCF_H = 25.5\,Ccf$$

Using the equation for electric heating fan savings:

$$AKWH_H = REM_{AH} \times (CFM_{Pre} - CFM_{Post})$$
$$AKWH_H = 1.100 \times (850 - 775)$$
$$AKWH_H = 82.5\,kWh$$

Using the equation for CAC savings:

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

$$AKWH_C = 1.059 \times (850 - 775)$$

$$AKWH_C = 79.4\ kWh$$

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

Commented [SK256]: The deemed values are based on a REM/Rate model that was run in 2010. Changes to the model or to the input variables would change the deemed values. Recommend updating values with new REM/rate model every three years, analogous to typical codes and standards updates, to ensure that the deemed values reflect changes to the model and input variables.

Table 4-R: 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	0.0158	0.0158	0.0053	0	0.0023

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

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

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

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 ft^2 1960's ranch style home in Hartford, Conn. The home is primarily heated by a heat pump and cooled by CAC. The outside duct leakage readings at 25 Pa showed CFM_{Pre} of 850 and CFM_{Post} of 775. What are the peak demand savings for this home?

Using the equation for heat pump winter demand:

(REM_{WKW} = 0.0158 kW per CFM)

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

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

$$WKW_H = 1.19\ kW$$

Using the equation for summer demand savings (REMSKW = 0.0023 kW per CFM):

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

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

$$SKW_C = 0.173\, kW$$

If the home in this example has a natural gas furnace, instead of a heat pump, what are the natural gas peak day savings?

Using the formula for Peak Day Natural Gas:

$$PD_H = ACCF_H \times PDF_H$$

$$PD_H = 25.5 \times 0.00977 = 0.249\, Ccf$$

$$PD_H = 0.249\, Ccf$$

Changes from Last Version

- Formatting changes.

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References

[1]	REM/Rate™ version 12.99 is a residential energy analysis, code compliance, and rating software developed by Architectural Energy Corporation. This software calculates heating, cooling, hot water, lighting, and appliance energy loads, consumption and costs for new and existing single and multi-family homes. Duct blaster energy savings analysis using REM was performed by C&LM Planning team, Eversource & United Illuminating, Aug. 2010.
[2]	Residential Central A/C Regional Evaluation, ADM Associates, Inc., Final Report, Nov. 2009.

Commented [SK257]: Update the REM/Rate model and the version of the model used.

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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.

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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~~Installation of energy-efficient Ductless Heat Pump ("DHP").~~

Commented [SK258]: *Recommend adding new Ductless HP measure in Commercial section for MF common areas. MF common area applicable changes made in comments below.*

Commented [SK259]: Update to:

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

Commented [SK260]: Energy Efficient DHP or ccDHP unit

Proposed measure description should include cold-climate DHPs.

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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 4-S: 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 4-T: 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
$EFLH_H$ $\cancel{EFLH_H}$	Equivalent Full Load Hours – Heating	hr	535~~442~~	**Ref [1]**, p. 6
$EFLH_C$ $\cancel{EFLH_C}$	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 preexisting equipment HSPF for less efficient DHP units - 3.412 for electric resistance~~3.413 – Retrofit~~	**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		~~0.447~~0.2322	Appendix One
WKW	Winter Demand Savings	kW		
WCF	Winter Coincidence Factor		0.16125~~74~~	Appendix One

Retrofit Gross Energy Savings, Electric

Commented [SK261]: *New MF Common area measure: $EFLH_H$ (MF); value = 273, source = Appendix Five*

Commented [SK262]: Heating hours from Navigant Consulting (2018), Quick Hit Study: Ductless Mini-Split Heat Pump Survey (RES 29), March 30, 2018

Commented [SK263]: *New MF Common area measure: $EFLH_c$ (MF): value = 1,306, source = Appendix Five*

Commented [SK264]: - Site-specific preexisting equipment HSPF for less efficient DHP units
- 3.412 for electric resistance

Commented [SK265]: *Add default Res MF units (this measure) and New MF Common area (new measure):*
Add row for Multifamily default,
MF $SEER_E$: value = 12.8, source = Ref[3]

General recommendation includes replacing SEER variable in KW savings equation with EER variable and adding rows for EER in table. If that is followed, add row for Multifamily default;
MF EER_E: value = 11.1, source = "Ref[3]"

Commented [SK266]: Update to 0.2322 based on 2016 CADMUS DMSHP evaluation (table 7). These values are recommended because:
1. They are based on metered data
2. Evaluation is much more recent than sources found in other TRMs
Since the CADMUS study defines CF only for on-peak hours, we had to convert it to Seasonal Peak value. We did this by obtaining a regression between NE on peak and seasonal peak values from 2011 KEMA Load shape study. See table 0-5 ISO, values corresponding to Seasonal peak for NE-south coastal. With this regression, we were able to multiply the on-peak CF value from CADMUS study by 1.29 to convert it to the Seasonal Peak CF value.
3. This is measure specific research

Commented [SK267]: This value is based on 2016 CADMUS DMSHP evaluation (table 7). These values are recommended because:
1. They are based on metered data
2. Evaluation is much more recent than sources found in other TRMs
Since the CADMUS study defines CF only for on-peak hours, we had to convert it to Seasonal Peak value. We did this by obtaining a regression between NE on peak and seasonal peak values from 2011 KEMA Load shape study. See table 0-5 ISO, values corresponding to Seasonal peak for NE-south coastal. With this regression, we were able to multiply the on-peak CF value from CADMUS study by 1.29 to convert it to the Seasonal Peak CF value.
3. This is measure specific research

Commented [SK268]: Fossil fuel savings:
$AMMBTU_H = CAP_H * EFLH_H * (1/1000) * (1/AFUE)$
where,
$AMMBTU_H$ = Annual MMBTU savings
AFUE = Annual fuel utilization efficiency of replaced fossil fuel heating system (%)
* Fossil fuel savings are based on pilot assumptions of the program where HP units will replace fossil fuel heat sources

Heating:

$$AKWH_H = CAP_H \times \left(\frac{1}{HSPF_E} - \frac{1}{HSPF_I}\right) \times EFLH_H \times \frac{1}{1000}$$

$$\cancel{AKWH_H = CAP_H \times \left(\frac{1}{HSPF_E} - \frac{1}{HSPF_I}\right) \times EFLH_H \times \frac{1}{1000}}$$

Cooling:

$$AKWH_C = CAP_C \times \left(\frac{1}{SEER_E} - \frac{1}{SEER_I}\right) \times EFLH_C \times \frac{1}{1000}$$

$$\cancel{AKWH_C = CAP_C \times \left(\frac{1}{SEER_E} - \frac{1}{SEER_I}\right) \times EFLH_C \times \frac{1}{1000}}$$

Commented [SK269]: $AKWH_H = EFLH_H * CAP_H * (1/HSPF_E - 1/HSPF_I) * (1/1000)$

$CAP_H = 0.9 * CAP_C$ for non cold-climate DHP units AND supplemental heating source is present
$CAP_H = 1.0 * CAP_C$ for cold-climate DHP units
where,
CAP_C = Cooling Capacity of efficient DHP unit (kBtu/h)

If replacing fossil fuel equiment:
$(1/HSPF_E) = 0$

Retrofit Gross Energy Savings, Example

__Example__: An energy-efficient DHP is installed in an existing home with electric resistance heat. 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__:

$$AKWH_H = CAP_H \times \left(\frac{1}{HSPF_E} - \frac{1}{HSPF_I}\right) \times EFLH_H \times \frac{1}{1000}$$

$$\cancel{AKWH_H = CAP_H \times \left(\frac{1}{HSPF_E} - \frac{1}{HSPF_I}\right) \times EFLH_H \times \frac{1}{1000}}$$

$$AKWH_H = 24{,}000 \times \left(\frac{1}{3.413} - \frac{1}{11}\right) \times 442 \times \frac{1}{1{,}000} = 2{,}143\ kWh$$

$$\cancel{AKWH_H = 24{,}000 \times \left(\frac{1}{3.413} - \frac{1}{11}\right) \times 442 \times \frac{1}{1{,}000} = 2{,}143\,kWh}$$

__Using the equation for annual electric cooling savings__:

$$AKWH_C = CAP_C \times \left(\frac{1}{SEER_E} - \frac{1}{SEER_I}\right) \times EFLH_C \times \frac{1}{1000}$$

$$\cancel{AKWH_C = CAP_C \times \left(\frac{1}{SEER_E} - \frac{1}{SEER_I}\right) \times EFLH_C \times \frac{1}{1000}}$$

$$AKWH_C = 28{,}000 \times \left(\frac{1}{10.1} - \frac{1}{22}\right) \times 218 \times \frac{1}{1000} = 327kWh$$

$$\cancel{AKWH_C = 28{,}000 \times \left(\frac{1}{10.1} - \frac{1}{22}\right) \times 218 \times \frac{1}{1000} = 327kWh}$$

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

__Winter demand savings__:

__WKW = 0 if installed unit is a non-ccDHP__

__WKW = $CAP_{H,5F,i}$ * (1 - 1/$COP_{H,5F,i}$) *(12/3.412) * WCF if installed unit is ccDHP__
__where,__
__$CAP_{H,5F,i}$ = Heating capacity of installed ccDHP at 5F (kBtu/h)__
__$COP_{H,5F,i}$ = Coefficient of performance of installed ccDHP at 5F__
__12 = Conversion factor from kBtu/h to kW__
__3.412 = Conversion factor from COP to HSPF__
__WCF = Winter coincidence factor (Heating)__

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$$\cancel{WKW = CAP_H \times \left(\frac{1}{HSPF_E} - \frac{1}{HSPF_I}\right) \times WCF \times \frac{1}{1000}}$$

$$\cancel{WKW = CAP_H \times \left(\frac{1}{HSPF_E} - \frac{1}{HSPF_I}\right) \times WCF \times \frac{1}{1000}}$$

Summer demand savings:

$$SKW = CAP_C \times \left(\frac{1}{SEER_E} - \frac{1}{SEER_I}\right) \times SCF \times \frac{1}{1000}$$

$$\cancel{SKW = CAP_C \times \left(\frac{1}{SEER_E} - \frac{1}{SEER_I}\right) \times SCF \times \frac{1}{1000}}$$

Commented [SK270]: WKW = 0 if installed unit is a non-ccDHP

WKW = $CAP_{H,5F,i}$ * (1 - 1/$COP_{H,5F,i}$) *(12/3.412) * WCF if installed unit is ccDHP
where,
$CAP_{H,5F,i}$ = Heating capacity of installed ccDHP at 5F (kBtu/h)
$COP_{H,5F,i}$ = Coefficient of performance of installed ccDHP at 5F
12 = Conversion factor from kBtu/h to kW
3.412 = Conversion factor from COP to HSPF
WCF = Winter coincidence factor (Heating)

Retrofit Gross Peak Demand Savings, Example

Commented [KR271]: Update example based on new algorithm

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, and the installed SEER is 22. What are the annual summer and winter demand savings?

Using the equation for summer demand savings:

$$SKW = CAP_C \times \left(\frac{1}{SEER_E} - \frac{1}{SEER_I}\right) \times SCF \times \frac{1}{1000}$$

$$\cancel{SKW = CAP_C \times \left(\frac{1}{SEER_E} - \frac{1}{SEER_I}\right) \times SCF \times \frac{1}{1000}}$$

$$SKW = 24{,}000 \times \left(\frac{1}{10.1} - \frac{1}{22}\right) \times .59 = .75\ kW$$

Using the equation for winter demand savings:

$$WKW = CAP_H \times \left(\frac{1}{HSPF_E} - \frac{1}{HSPF_I}\right) \times WCF \times \frac{1}{1000}$$

$$\cancel{WKW = CAP_H \times \left(\frac{1}{HSPF_E} - \frac{1}{HSPF_I}\right) \times WCF \times \frac{1}{1000}}$$

$$WKW = 28{,}000 \times \left(\frac{1}{3.413} - \frac{1}{11}\right) \times .74 \times \frac{1}{1000} = 3.59$$

Lost Opportunity Gross Energy Savings, Electric

Heating:

AKWHH = EFLHH * CAPH * (1/HSPFB - 1/HSPFi) * (1/1000)

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CAPH = 0.9 * CAPC for non cold-climate DHP units

CAPH = 1.0 * CAPC for cold-climate DHP units

where,

CAPC = Cooling Capacity of efficient DHP unit (kBtu/h)

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$$AKWH_H = CAP_H \times \left(\frac{1}{HSPF_B} - \frac{1}{HSPF_I}\right) \times EFLH_H \times \frac{1}{1000}$$

$$AKWH_H = CAP_H \times \left(\frac{1}{HSPF_B} - \frac{1}{HSPF_I}\right) \times EFLH_H \times \frac{1}{1000}$$

Cooling:

$$AKWH_C = CAP_C \times \left(\frac{1}{SEER_B} - \frac{1}{SEER_I}\right) \times EFLH_C \times \frac{1}{1000}$$

$$AKWH_C = CAP_C \times \left(\frac{1}{SEER_B} - \frac{1}{SEER_I}\right) \times EFLH_C \times \frac{1}{1000}$$

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

Winter demand savings:

WKW = 0 if installed unit is a non-ccDHP

WKW = $CAP_{H,5F,i}$ * (1 - 1/$COP_{H,5F,i}$) *(12/3.412) * WCF if installed unit is ccDHP
where,
$CAP_{H,5F,i}$ = Heating capacity of installed ccDHP at 5F (kBtu/h)
$COP_{H,5F,i}$ = Coefficient of performance of installed ccDHP at 5F
12 = Conversion factor from kBtu/h to kW
3.412 = Conversion factor from COP to HSPF
WCF = Winter coincidence factor (Heating)

$$WKW = CAP_H \times \left(\frac{1}{HSPF_B} - \frac{1}{HSPF_I}\right) \times WCF \times \frac{1}{1000} \quad WKW = CAP_H \times \left(\frac{1}{HSPF_B} - \frac{1}{HSPF_I}\right) \times WCF \times \frac{1}{1000}$$

Summer demand savings:

$$SKW = CAP_C \times \left(\frac{1}{SEER_B} - \frac{1}{SEER_I}\right) \times SCF \times \frac{1}{1000} \quad SKW = CAP_C \times \left(\frac{1}{SEER_B} - \frac{1}{SEER_I}\right) \times SCF \times \frac{1}{1000}$$

Changes from Last Version

- Fixed example and updated SCF.

References

[1]	*Ductless Mini-Split Heat Pump Study*, Final Report, Cadmus, Dec. 30, 2016, (Table ES-3 p. 5).

Commented [SK272]: AKWH_H = EFLH_H * CAP_H * (1/HSPF_B - 1/HSPF_I) * (1/1000)

CAP_H = 0.9 * CAP_C for non cold-climate DHP units
CAP_H = 1.0 * CAP_C for cold-climate DHP units
where,
CAP_C = Cooling Capacity of efficient DHP unit (kBtu/h)

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Commented [SK273]: WKW = 0 if installed unit is a non-ccDHP

WKW = $CAP_{H,5F,i}$ * (1 - 1/$COP_{H,5F,i}$) *(12/3.412) * WCF if installed unit is ccDHP
where,
$CAP_{H,5F,i}$ = Heating capacity of installed ccDHP at 5F (kBtu/h)
$COP_{H,5F,i}$ = Coefficient of performance of installed ccDHP at 5F
12 = Conversion factor from kBtu/h to kW
3.412 = Conversion factor from COP to HSPF
WCF = Winter coincidence factor (Heating)

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Commented [SK274]: *Add Reference:*
"[3] Energy & Resource Solutions, "R1705 R1609 MF Baseline and Weatherization Opportunity Study" October 10, 2019 (Table 4-22, p42)"
https://www.energizect.com/sites/default/files/R1705-1609%20MF%20Baseline%20Weatherization%20Study_Final%20Report_10.10.19.pdf

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[2]	*Energy & Resource Solutions, "R1705 R1609 MF Baseline and Weatherization Opportunity Study" October 10, 2019 (Table 4-22, p42)" https://www.energizect.com/sites/default/files/R1705-1609%20MF%20Baseline%20Weatherization%20Study_Final%20Report_10.10.19.pdf*

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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 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 at: http://www.doe2.com/.

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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.

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Retrofit measure:

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

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Inputs

Table 4-U: 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
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 4-V: 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
COP_B	Coefficient of Performance, Baseline	Watt/Watt		~~Ref [1]~~
COP_E	Coefficient of Performance, Existing	Watt/Watt		Input
EER_B	Energy Efficiency Ratio, Baseline	Btu/Watt-hr		~~Ref [1]~~
EER_E	Energy Efficiency Ratio, Existing	Btu/Watt-hr		Input
EER_I	Energy Efficiency Ratio, Installed	Btu/Watt-hr		Input
EFLHc	Cookline Equivalent Full-Load Hours	nours	626 hours for buildings built prior to 1979 669 hours for buildings built between 1979 and 2006 812 hours for buildings built after 2007	Note [1]
$EFLH_H$	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 291 hours for buildings built after 2007~~1349~~	~~Ref [3]~~Note [1]
~~HR~~	~~Percent heating when Heat Pump is Not in Electric Resistance Back Up~~		~~60%~~	~~Note[1]~~
PTHP	Packaged Heat Pump Terminal			
~~S_{kWh}~~	~~Average Cooling kWh Savings per Unit Size~~	~~kWh/Ton~~	~~362.0~~	~~Ref [2]~~

Commented [SK275]: Add SCF - Summer Coincidence Factor = 58.80% to the nomenclature table. This value is used to estimate seasonal peak demand savings.

Commented [SK276]: Add EFLHc – Cooling Equivalent Full-Load hours:

626 hours for buildings built prior to 1979
669 hours for buildings built between 1979 and 2006
812 hours for buildings built after 2007

Commented [SK277]: 922 hours for uninsulated, pre-war buildings
656 hours for buildings built prior to 1979
510 hours for buildings built between 1979 and 2006
291 hours for buildings built after 2007

Commented [SK278R277]: Aligns with NY TRM for Poughkeepsie weather station, which is closest to CT. Facility type selected is multifamily high-rise buildings since they are the most common residential facility where PTHPs are installed

Commented [SK279]: We recommend a change in savings algorithm (see below) which does not require this factor.

~~S_{kW}~~	~~Average Peak kW Savings per Unit Size~~	~~kW/Ton~~	~~0.45~~	~~Ref [2]~~
~~SA~~	~~Seasonal Efficiency Adjustment for Heating~~		~~80%~~	~~Note[2]~~
SKW	Summer Demand Savings	kW		
WKW	Winter Demand Savings	kW	0	Note[~~3~~2]
SCF	Summer Coincidence Factor		58.8%	Ref [3]

Commented [SK280]: We recommend a change in savings algorithm (see below) which does not require this factor.

Commented [SK281]: We recommend a change in savings algorithm (see below) which does not require this factor.

Coefficient of Performance COPb:

For Lost Opportunity:

COPB = 3.7 - (0.052 * CAPH/1000)

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For Retrofit:

COPB = 2.9 - (0.026 * CAPH/1000)

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where,

CAPH = Installed heating capacity (kBtu/hr) which can be assumed equal to installed cooling capacity (CAPC)

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Energy Efficiency Ratio, EERb

For Lost Opportunity:

EERB = 14 - (0.3 * CAPC/1000)

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For Retrofit:

EERB = 10.8 - (0.213 * CAPC/1000)

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where,

CAPC = Installed cooling capacity (kBtu/hr)

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Retrofit Gross Energy Savings, Electric

Heating:

a) For replacement of old PTHP, use the following equations:

AKWH = AKWHH + AKWHC

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where:

AKWHH = HR * EFLHH * CAPC * (1/COPE - 1/COPi) * (1/3412)

AKWHC = EFLHC * CAPC * (1/EERE - 1/EERi) * (1/1000)

$$\mathrm{AKWH_H} = \mathrm{HR} \times \mathrm{EFLH_H} \times CAP_C \times \left(\frac{1}{COP_E} - \frac{1}{COP_B}\right) \times \frac{1}{3412} \quad \text{Where, } \mathrm{COP_B} = 2.9 - \left(0.026 \times \mathrm{CAP_C} \times \frac{1}{1{,}000}\right)$$

~~b) For replacement of electric resistance system, use the following equations:~~

$$\mathrm{AKWH_H} = \mathrm{HR} \times \mathrm{EFLH_H} \times CAP_C \times \left(1 - \frac{1}{SA \times COP_B}\right) \times \frac{1}{3412} \quad \text{Where, } \mathrm{COP_B} = 2.9 - \left(0.026 \times \mathrm{CAP_C} \times \frac{1}{1{,}000}\right)$$

Cooling:

$$\mathrm{AKWH_C} = S_{kWh} \times CAP_C \times \left(\frac{EER_B}{EER_E} - 1\right) \times \frac{1}{12{,}000}$$

$$\mathrm{AKWHc} = 362.0 \times \mathrm{CAP_C} \times \left(\frac{\mathrm{EER_B}}{\mathrm{EER_E}} - 1\right) \times \frac{1}{12{,}000}$$

$$\text{Where, } \mathrm{EER_B} = 10.8 - \left(0.213 \times \mathrm{CAP_C} \times \frac{1}{1{,}000}\right)$$

Reminder: *For working unit, claim additional lost opportunity savings.*

Retrofit Gross Energy Savings, Example

Example: A new PTHP with cooling capacity of 12,000Btu/hr, EER_I=12.5, and COP_I =3.6 is installed in an existing home equipped with an old working PTHP with cooling capacity of 12,000 Btu/hr, EER_E =7.8, and COP_E= 2.5.

Heating:

$$\mathrm{AKWH_H} = \mathrm{HR} \times \mathrm{EFLH_H} \times CAP_C \times \left(\frac{1}{COP_E} - \frac{1}{COP_B}\right) \times \frac{1}{3412}$$

$$\text{Where, } \mathrm{COP_B} = 2.9 - \left(0.026 \times 12{,}000 \times \frac{1}{1{,}000}\right) = 2.59$$

$$AKWH_H = 0.6 \times 1349 \times 12{,}000 \times \left(\frac{1}{2.5} - \frac{1}{2.59}\right) \times \frac{1}{3{,}412} = 39.55\ kWh$$

Cooling:

$$AKWHc = 362.0 \times CAP_C \times \left(\frac{EER_B}{EER_E} - 1\right) \times \frac{1}{12{,}000}$$

$$\text{Where, } \mathrm{EER_B} = 10.8 - \left(0.213 \times \mathrm{CAP_C} \times \frac{1}{1{,}000}\right)$$

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Commented [SK282]: AKWH = AKWHH + AKWHC
where:
AKWHH = HR * EFLHH * CAPC * (1/COPE - 1/COPi) * (1/3412)
AKWHC = EFLHC * CAPC * (1/EERE - 1/EERi) * (1/1000)

Commented [SK283]: For Retrofit:
COPB = 2.9 - (0.026 * CAPH/1000)

where,
CAPH = Installed heating capacity (kBtu/hr) which can be assumed equal to installed cooling capacity (CAPC)

Commented [SK284]: For Retrofit:
COPB = 2.9 - (0.026 * CAPH/1000)

where,
CAPH = Installed heating capacity (kBtu/hr) which can be assumed equal to installed cooling capacity (CAPC)

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Commented [KR285]: Update calculationa based on new algorithm

$$\mathrm{EER_B} = 10.8 - \left(0.213 \times 12{,}000 \times \frac{1}{1{,}000}\right) = 8.24$$

$$\mathrm{AKWH}_C = 362.0 \times 12{,}000 \times \left(\frac{8.24}{7.8} - 1\right) \times \frac{1}{12{,}000} = 20.42kW$$

$$\cancel{\mathrm{AKWH_C} = 362.0 \times 12{,}000 \times \left(\frac{8.24}{7.8} - 1\right) \times \frac{1}{12{,}000} = 20.42kW}$$

Reminder: *For working unit, claim additional Lost Opportunity Savings.*

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

- WKW = 0; Note [3].
- SKWc

SKWC = CAPC * (1/EERE - 1/EERi) * (1/1000) * SCF

where,

~~SCF = Summer coincidence factor~~

$$SKW_C = S_{kW} \times CAP_C \times \left(\frac{EER_B}{EER_E} - 1\right) \times \frac{1}{12{,}000}$$

$$\cancel{SKW_C = 0.45 \times CAP_C \times \left(\frac{EER_B}{EER_E} - 1\right) \times \frac{1}{12{,}000}}\ SKW_C = 0.45 \times CAP_C \times \left(\frac{EER_B}{EER_E} - 1\right) \times \frac{1}{12{,}000}$$

$$\text{Where, } \mathrm{EER_B} = 10.8 - \left(0.213 \times \mathrm{CAP_C} \times \frac{1}{1{,}000}\right)$$

Retrofit Gross Peak Demand Savings, Example

Example: A new PTHP with cooling capacity of 1 Ton/hr, EER_I = 12.5, and COP_I = 3.6 is installed in an existing home equipped with an old working PTHP with cooling capacity of 1 Ton/hr, EER_E = 7.8, and COP_E = 2.5.

- WKW = 0.

$$SKW_C = 0.45 \times CAP_C \times \left(\frac{EER_B}{EER_E} - 1\right) \times \frac{1}{12{,}000}\ \cancel{SKW_C = 0.45 \times CAP_C \times \left(\frac{EER_B}{EER_E} - 1\right) \times \frac{1}{12{,}000}}$$

$$\text{Where, } \mathrm{EER_B} = 10.8 - \left(0.213 \times 12{,}000 \times \frac{1}{1{,}000}\right) = 8.24$$

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Commented [SK286]: SKWC = CAPC * (1/EERE - 1/EERi) * (1/1000) * SCF
where,
SCF = Summer coincidence factor

Commented [KR287]: Update example calculation based on new algorithm

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$$\mathrm{SKW}_C = 0.45 \times 12{,}000 \times \left(\frac{8.24}{7.8} - 1\right) \times \frac{1}{12{,}000} = 0.025kW$$

$$\cancel{\mathrm{SKW_C} = 0.45 \times 12{,}000 \times \left(\frac{8.24}{7.8} - 1\right) \times \frac{1}{12{,}000} = 0.025kW}$$

Lost Opportunity Gross Energy Savings, Electric

Heating:

AKWH = AKWHH + AKWHC

where:

AKWHH = HR * EFLHH * CAPC * (1/COPB - 1/COPi) * (1/3412)

AKWHC = EFLHC * CAPC * (1/EERB - 1/EERi) * (1/1000)

$$\mathrm{AKWH_H} = \mathrm{HR} \times \mathrm{EFLH_H} \times CAP_C \times \left(\frac{1}{COP_B} - \frac{1}{COP_I}\right) \times \frac{1}{3412}$$

$$\text{Where, } \mathrm{COP_B} = 3.2 - \left(0.026 \times CAP_C \times \frac{1}{1{,}000}\right)$$

Cooling:

$$\mathrm{AKWH}_C = 362.0 \times CAP_C \times \left(\frac{EER_I}{EER_B} - 1\right) \times \frac{1}{12{,}000}$$

$$\cancel{\mathrm{AKWH_C} = 362.0 \times CAP_C \times \left(\frac{EER_I}{EER_B} - 1\right) \times \frac{1}{12{,}000}}$$

$$\text{Where, } \mathrm{EER_B} = 12.3 - \left(0.213 \times \mathrm{CAP_C} \times \frac{1}{1{,}000}\right)$$

Lost Opportunity Gross Energy Savings, 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.

Heating:

$$\mathrm{AKWH_H} = \mathrm{HR} \times \mathrm{EFLH_H} \times CAP_C \times \left(\frac{1}{COP_B} - \frac{1}{COP_I}\right) \times \frac{1}{3412}$$

$$\text{Where, } \mathrm{COP_B} = 3.2 - \left(0.026 \times 12{,}000 \times \frac{1}{1{,}000}\right) = 2.88$$

$$AKWH_H = 0.6 \times 1349 \times 12{,}000 \times \left(\frac{1}{2.88} - \frac{1}{3.6}\right) \times \frac{1}{3412} = 197.7kWh$$

Cooling:

$$\mathrm{AKWH_C} = 357.6 \times CAP_C \times \left(\frac{EER_I}{EER_B} - 1\right) \times \frac{1}{12{,}000}$$

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Commented [SK288]: AKWH = AKWHH + AKWHC
where:
AKWHH = HR * EFLHH * CAPC * (1/COPB - 1/COPi) * (1/3412)
AKWHC = EFLHC * CAPC * (1/EERB - 1/EERi) * (1/1000)

Commented [SK289]: For Lost Opportunity:
COPB = 3.7 - (0.052 * CAPH/1000)

For Retrofit:
COPB = 2.9 - (0.026 * CAPH/1000)

where,
CAPH = Installed heating capacity (kBtu/hr) which can be assumed equal to installed cooling capacity (CAPC)

Commented [KR290]: Update example calculation based on new algorithm

$$\text{Where, } EER_B = 12.3 - \left(0.213 \times 12{,}000 \times \frac{1}{1{,}000}\right) = 9.74$$

$$AKWH_C = 362.0 \times 12{,}000 \times \left(\frac{12.5}{9.74} - 1\right) \times \frac{1}{12{,}000} = 102.6kWh$$

$$\cancel{AKWH_C = 362.0 \times 12{,}000 \times \left(\frac{12.5}{9.74} - 1\right) \times \frac{1}{12{,}000} = 102.6kWh}$$

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

- WKW = 0
- SKWc

SKWC = CAPC * (1/EERB - 1/EERi) * (1/1000) * SCF

where,

SCF = Summer coincidence factor

$$\cancel{SKW_C = 0.45 \times CAP_C \times \left(\frac{EER_I}{EER_B} - 1\right) \times \frac{1}{12{,}000}}\ SKW_C = 0.45 \times CAP_C \times \left(\frac{EER_I}{EER_B} - 1\right) \times \frac{1}{12{,}000}$$

$$\text{Where, } EER_B = 12.3 - \left(0.213 \times CAP_C \times \frac{1}{1{,}000}\right)$$

Lost Opportunity Gross Peak Demand Savings, Example

<u>Example</u>: A PTHP is installed in a new construction project; the cooling capacity 12,000 Btu/hr, EER_I =12.5, COP_I = 3.6, and WKW = 0.

$$SKW_C = 0.45 \times CAP_C \times \left(\frac{EER_I}{EER_B} - 1\right) \times \frac{1}{12{,}000}\ \cancel{SKW_C = 0.45 \times CAP_C \times \left(\frac{EER_I}{EER_B} - 1\right) \times \frac{1}{12{,}000}}$$

$$\text{Where, } EER_B = 12.3 - \left(0.213 \times CAP_C \times \frac{1}{1{,}000}\right)$$

$$EER_B = 12.3 - \left(0.213 \times 12{,}000 \times \frac{1}{1{,}000}\right) = 9.74$$

$$SKW_C = 0.45 \times 12{,}000 \times \left(\frac{12.5}{9.74} - 1\right) \times \frac{1}{12{,}000} = 0.128kW$$

$$\cancel{SKW_C = 0.45 \times 12{,}000 \times \left(\frac{12.5}{9.74} - 1\right) \times \frac{1}{12{,}000} = 0.128kW}$$

Changes from Last Version

- Formatting changes.

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Commented [SK291]: $SKW_C = CAP_C * (1/EER_B - 1/EER_I) * (1/1000) * SCF$
where,
SCF = Summer coincidence factor

Commented [KR292]: Update example calculation based on new algorithm

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References

[1]	~~"Technical Support Document: Energy Efficiency Program for Commercial and Industrial Equipment: Efficiency Standards for Commercial Heating, Air Conditioning and Water Heating Equipment," Table 1, Chapter 2, p. 4.~~IECC 2018
[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]~~	~~EFLH$_H$ = 1,349 hours; Based on Heating Degree Day ("HDD") data and ASHRAE adjustment factor.~~
[3]	C&I Unitary HVAC Load Shape Project Final Report, KEMA, 2011. Final values are presented in Metoyer, Jarred, "Report Revision Memo," KEMA, August 2011.

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Commented [SK293]: Update EER$_B$ to reference IECC 2018

Commented [SK294]: EUL 15

Commented [SK295R294]: Update EUL based on DEER2014

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Notes

[1]~~[1]~~	Aligns with NY TRM for Poughkeepsie weather station, which is closest to CT. Facility type selected is multifamily high-rise buildings since they are the most common residential facility where PTHPs are installed~~HR = 60%, is percent heating when the heat pump is not in electric resistance back up, based on Hartford, Conn. BIN analysis.~~
~~[2]~~	~~SA = 80%, is COP adjustment factor for temperatures below 47°F, based on Hartford, Conn. BIN analysis.~~
[2]~~[3]~~	Winter demand savings are not claimed for this measure since backup resistance heat on the heat pump would most likely be used during winter seasonal peak periods.

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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 4-W) with Quality Installation ranges from 18% to 36% for air conditioners and heat pumps and 11% to 18% for furnaces (**Ref [6]**). A new residential central air conditioner ("CAC") 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 4-W: QIV, Performed with New Residential Air Conditioning System Installation, ENERGY STAR Savings Potential

	Cooling	Heating
Refrigerant Charge	2-6%	
Airflow	2-5%	
Sizing	3-7%	
Duct Sealing	11-18%	11-18%
Total	18-36%	11-18%

Due to these variations, the QIV savings being estimated for this measure (Table 4-X) are based on the low-end of the range.

Commented [SK296]: Conservative savings estimates are considered based on the low end of the energy savings range provided by ENERGY STAR. The reference provided for these savings estimate could not be located and the values could not be verified.

A Massachusetts baseline study is being performed currently, with results expected to come out end of this summer. The energy and demand savings from this measure is being looked at. Therefore, we recommend updating savings based on the baseline study when results are available.

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Table 4-X: Estimated QIV Savings

	Cooling	Heating
Refrigerant Charge	2%	
Airflow	2%	
Sizing	3%	
Duct Sealing	11%	11%
Total	**18%**	**11%**

Inputs

Table 4-Y: Inputs

Symbol	Description
CAP_C	Nominal Cooling Capacity, Btu
Ton	Capacity of the Equipment Converted to Tons

Nomenclature

Table 4-Z: 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]**):*

$$AKWH_C = 64.37 \times \frac{CAP_C}{12{,}000 \, ^{BTU}/_{ton}}$$

Heating savings:

Using the results of 39.34 kWh duct sealing savings from the above equation and the relationship of savings from Table 4-P in the 2020 PSD manual for Measure 4.2.5: Duct Sealing, the CFM reduction can be calculated as follows:

From Measure 4.2.~~9~~5, cooling savings per CFM reduction is 1.059 kWh. Therefore, for 39.34 kWh savings, there is a 37.15 CFM reduction.

$$CFM_{Savings} = \frac{39.34}{1.059} = 37.15\ {}^{CFM}/_{ton} \quad \cancel{CFM_{Savings} = \frac{39.34}{1.059} = 37.15\ {}^{CFM}/_{ton}}$$

Using Measure 4.2.~~9's~~ 5's duct sealing savings and based on system type, the savings can be summarized in Table 4-AA below.

Table 4-AA: Savings Calculation

System Type	$AKWH_C$	$AKWH_H$
Central A/C	$64.37 \times \frac{CAP_C}{12,000}$	
Heat Pump	$64.37 \times \frac{CAP_C}{12,000}$	$142.9 \times \frac{CAP_C}{12,000}$
Geothermal Heat Pump	$64.37 \times \frac{CAP_C}{12,000}$	$92.25 \times \frac{CAP_C}{12,000}$
Furnace (Fan Electric Savings)		$40.86 \times \frac{CAP_C}{12,000}$

Retrofit Gross Energy Savings, Fossil Fuel

$$ACCF_H = 13.3 \times \frac{CAP_C}{12,000}$$

$$AOG_H = 9.3 \times \frac{CAP_C}{12,000}$$

$$APG_H = 14.2 \times \frac{CAP_C}{12,000}$$

Commented [SK297]: The deemed values are based on a REM/Rate model that was run in 2010. Changes to the model or to the input variables would change the deemed values. Recommend update values with new REM/rate model every three years, analogous to typical codes and standards updates, to ensure that the deemed values reflect changes to the model and input variables.

Commented [SK298]: The deemed values are based on a REM/Rate model that was run in 2010. Changes to the model or to the input variables would change the deemed values. Recommend update values with new REM/rate model every three years, analogous to typical codes and standards updates, to ensure that the deemed values reflect changes to the model and input variables.

Commented [SK299]: Update algorithm based on the updated annual savings factor for residential CAC. See Notes [1].

Retrofit Gross Energy Savings, Example

Example: A 1980's home has a combination natural gas furnace with a 36,000 Btu (3 tons) CAC system. QIV is performed on the systems. What are the energy savings?

Using the equation for cooling savings:

$$AKWH_C = 64.37 \times \frac{CAP_C}{12{,}000}$$

$$AKWH_C = 64.37 \times \frac{36{,}000}{12{,}000} = 193.1kWh$$

Using the equation for heating fan energy:

$$AKWH_H = 40.86 \times \frac{CAP_C}{12{,}000}$$

$$AKWH_H = 40.86 \times \frac{36{,}000}{12{,}000} = 122.58kWh$$

Using the equation for natural gas heating:

$$ACCF_H = 13.3 \times \frac{CAP_C}{12{,}000}$$

$$ACCF_H = 13.3 \times \frac{36{,}000}{12{,}000} = 39.9ccf$$

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

The new residential CAC uses 0.591 kW per ton (**Ref [1]**). Therefore:

Annual Summer kW Savings = Percent Savings x 0.591 x Tons

$$SKW = 0.106 \times \frac{CAP_C}{12{,}000}$$

Using the CFM savings from Section 5 and peak savings per CFM from the 2020 PSD Measure 4.2.9, the winter demand savings for heat pumps only are as follows:

$$WKW = 0.587 \times \frac{CAP_C}{12{,}000}$$

Commented [SK300]: The deemed values are based on a REM/Rate model that was run in 2008. Changes to the model or to the input variables would change the deemed values. Recommend update values with new REM/rate model every three years, analogous to typical codes and standards updates, to ensure that the deemed values reflect changes to the model and input variables.

Retrofit Gross Peak Day Savings, Natural Gas

$$PD_H = ACCF_H \times PDF_H$$

Retrofit Gross Peak Demand Savings, Example

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?

For cooling savings:

$$SKW = 0.106 \times \frac{CAP_C}{12{,}000}$$

$$SKW = 0.106 \times \frac{36{,}000}{12{,}000} = 0.32kW$$

For heat pump savings:

$$WKW = 0.587 \times \frac{CAP_C}{12{,}000}$$

$$WKW = 0.587 \times \frac{36{,}000}{12{,}000} = 1.76kW$$

Changes from Last Version

- Formatting changes.

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References

[1]	*Central Air Conditioning Impact and Process Evaluation*, NMR Group, Inc., May 30, 2017.~~*Residential Central A/C Regional Evaluation*, ADM Associates, Inc., Nov. 2009, pp. 4-9, p. ES-4.~~
[2]	ACCA. 2010. HVAC Quality Installation Specification – Standard 5. Air Conditioning Contractors of America, Arlington, VA.
[3]	ACCA. 2011. HVAC Quality Installation Verification Protocols – Standard 9. Air Conditioning Contractors of America, Arlington, VA.
[4]	ENERGY STAR Homes National Programs Requirement V3.0, www.energystar.gov.
[5]	ENERGY STAR Homes Inspection Checklist, www.energystar.gov.
[6]	ENERGY STAR Quality Installation, Revised Jun. 1, 2013, Available at http://www.energystar.gov/index.cfm?c=hvac_install.hvac_install_index.

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Commented [SK301]: Conservative savings estimates are considered based on the low end of the energy savings range provided by ENERGY STAR. The reference provided for these savings estimate could not be located and the values could not be verified.

A Massachusetts baseline study is being performed currently, with results expected to come out end of this summer. The energy and demand savings from this measure is being looked at. Therefore, we recommend updating savings based on the baseline study when results are available.

Notes

[1]	The average new residential CAC uses 357.6 kWh/Ton annually (**Ref [1]**). *Annual cooling kWh savings = Percent savings x 357.6 x Tons, where:* Annual cooling savings (Refrigerant Charge) = 2% x 357.6 x tons = 7.15 x tons Annual cooling savings (Airflow) = 2% x 357.6 x tons = 7.15 x tons Annual cooling savings (Sizing) = 3% x 357.6 x tons = 10.73 x tons Annual cooling savings (Duct Sealing) = 11% x 357.6 x tons = 39.34 x tons, where; Total cooling savings = 18% x 357.6 x tons =64.37 $AKWH_C$/ton $$Ton = \frac{CAP_C}{12{,}000\, {}^{BTU}\!/_{ton}}$$ $$AKWH_C = 64.37 \times \frac{CAP_C}{12{,}000\, {}^{BTU}\!/_{ton}}$$

Commented [SK302]: Updated value available based on the new evaluation report. See update Ref [1]. The new evaluation report suggests using 362 kWh/ton.

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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 air conditioner ("CAC").

Commented [SS303]: Recommend accounting for interactivity between envelope and other HVAC-related measures.

Recommend including interactivity per R91 - Review of Impact Evaluation Best Practices [2016] - recommendation "Account for interactivity between HVAC and envelope measures" pg 73.

Inputs

Table 4-BB: 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 4-CC: Nomenclature

Symbol	Description	Units	Values	Comments
A	Surface Area of Duct Being Insulated	ft^2		Input
ACCF	Annual Natural Gas Savings	ccf		
AKWH	Annual Electric Energy Savings	kWh		
AOG	Annual Oil Savings	Gal		
APG	Annual Propane Savings	Gal		
DI_H	Annual Heating Savings per Square Foot	various	Tables 4-DD~~EE~~ and 4-EE~~3~~	**Ref [2]**
DI_C	Annual Cooling Savings per Square Foot	various	Tables 4-DD and 4-EE~~Tables 4-EE and 3~~	**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 4-DD: Annual Savings per ft^2 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 CAC or a heat pump providing cooling:

$$AKWH_C = DI_C \times A$$

Retrofit Gross Energy Savings, Fossil Fuel

Table 4-EE: 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.*

Retrofit Gross Energy Savings, Example

Example: A Cape Cod style home has a natural gas furnace. It is also equipped with a CAC system for cooling. 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 CAC, 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 CAC:

$$SKW = \frac{SPF \times DI_C \times A}{1{,}000 \, {}^{W}\!/_{kW}}$$

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.

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References

[1]	*Evaluation of the Weatherization Residential Assistance Partnership (WRAP) and Helps Programs,* conducted by KEMA, Sep. 2010, Table ES-9, pp. 1-11.
[2]	North American Insulation Manufacturers Association ("NAIMA"), 3E Plus software tool, Version 4.1, Rel. 2012.

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Notes

[1] Table 4-FF: 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

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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.~~7~~3.

Commented [ERS304]: Change to 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 4-GG: 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 4-HH: 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~~11,197,132~~	From Water Heater (Measure 4.5.3~~7~~)
$AFUE_B$	Annual Fuel Utilization Efficiency, Baseline	%	85% Gas/Propane 84% Oil	**Ref (1)**
$AFUE_E$	Annual Fuel Utilization Efficiency, Existing	%	Actual Rated if unknown use 0.80	
$AFUE_I$	Annual Fuel Utilization Efficiency, Installed	%		Input
EUL	Effective Useful Life			Appendix Four
HF	Average Heating Factor Based on 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

Commented [SK305]: Value changed based on the most recent evaluation report. Review CT PSD 4.5.3 for calculation and justification. Calculation shown in PSD4.5.3 Supporting Info Tab.

Commented [SK306]: Value changed based on the most recent evaluation report. Review CT PSD 4.5.3 for calculation and justification. Calculation shown in PSD4.5.3 Supporting Info Tab.

Commented [ERS307]: Change to 4.5.3

Lost Opportunity Gross Energy Savings, Fossil Fuel

Savings by heating fuel:

$$ABTU_H = HF \times \left(\frac{1}{AFUE_B} - \frac{1}{AFUE_I x0.98}\right) = 85{,}200{,}000 \times \left(1/.85 - \frac{1}{AFUE_I x0.98}\right)$$

$$\cancel{ABTU_H = HF \times \left(\frac{1}{AFUE_B} - \frac{1}{AFUE_I x0.98}\right) = 85{,}200{,}000 \times \left(1/.85 - \frac{1}{AFUE_I x0.98}\right)}$$

$$ACCF_H = \frac{ABTU_H}{102{,}900\,{}^{Btu}\!/_{Ccf}}$$

$$AOG_H = \frac{ABTU_H}{138{,}690 \, {}^{Btu}/_{Gal}}$$

$$APG_H = \frac{ABTU_H}{91{,}330 \, {}^{Btu}/_{Gal}}$$

Water heating savings by water heating fuel:

Commented [SK308]: Update algorithm to reflect updated ADHW

$$ABTU_W = 9{,}630{,}521 \times \left(\frac{1}{AFUE_B} - \frac{1}{AFUE_I x0.98}\right) \cancel{ABTU_W = 11{,}197{,}132 \times \left(\frac{1}{AFUE_B} - \frac{1}{AFUE_I x0.98}\right)}$$

$$ACCF_W = \frac{ABTU_W}{102{,}900 \, {}^{Btu}/_{Ccf}}$$

$$ACCF_W = \frac{ABTU_W}{138{,}690 \, {}^{Btu}/_{Ccf}}$$

$$ACCF_W = \frac{ABTU_W}{91{,}330 \, {}^{Btu}/_{Ccf}}$$

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.

$$ABTU_H = 85{,}200{,}000 \times \left(\frac{1}{0.85} - \frac{1}{AFUE_I X0.98}\right) = 85{,}200{,}000 \times \left(\frac{1}{0.85} - \frac{1}{0.95x0.98}\right)$$

$$ABTU_H = 8{,}720{,}793.58 \ Btu$$

$$ACCF_H = \frac{8{,}720{,}793.58 \ Btu}{102{,}900 \, {}^{Btu}/_{Ccf}} ACCF_H = 84.8 \ Ccf$$

Water heating:

Commented [SK309]: Update calculations based on the new ADHW value.

$$ABTU_W = 11{,}197{,}132 \times \left(\frac{1}{AFUE_B} - \frac{1}{AFUE_I x0.98}\right) = 11{,}197{,}132 \times \left(\frac{1}{.85} - \frac{1}{.95x0.98}\right)$$

$$ABTU_W = 1{,}146{,}101.84 Btu$$

$$ACCF_W = \frac{1{,}146{,}101.84 Btu}{102{,}900 \, {}^{Btu}/_{Ccf}}$$

$$ACCF_W = 11.1 \ Ccf$$

Total:

$$ACCF = ACCF_H + ACCF_W$$

$$ACCF = 83.8\,{}^{Ccf}/_{yr} + 11.0\,{}^{Ccf}/_{yr}$$

$$ACCF = ACCF_H + ACCF_W$$

$$ACCF = 94.8\,{}^{Ccf}/_{yr} \quad \cancel{ACCF = 83.8\,{}^{Ccf}/_{yr} + 11.0\,{}^{Ccf}/_{yr}}$$

$$ACCF = 94.8\,{}^{Ccf}/_{yr}$$

Lost Opportunity Gross Seasonal Peak Demand Savings, Natural Gas

$$PD_H = ACCF_H \times PDF_H$$

$$PD_W = ACCF_W \times PDF_W \; \cancel{PD_W = ACCF_W \times PDF_W}$$

Lost Opportunity Gross Peak Demand Savings, Example

For the same example as above:

$$PD_H = 84.75 \times 0.00977$$

$$PD_H = 0.819\ Ccf \; \cancel{\begin{matrix} PD_H = 84.75 \times 0.00977 \\ PD_H = 0.819\ Ccf \end{matrix}}$$

$$PD_W = 11.0 \times 0.00321$$

$$PD_W = 0.035\ Ccf \; \cancel{\begin{matrix} PD_W = 11.0 \times 0.00321 \\ PD_W = 0.035\ Ccf \end{matrix}}$$

Total:

$$PD = PD_H + PD_W$$

$$PD = 0.819 + 0.035$$

$$PD = 0.854\ Ccf \; \cancel{\begin{matrix} PD = PD_H + PD_W \\ PD = 0.819 + 0.035 \\ PD = 0.854\ Ccf \end{matrix}}$$

Retrofit Gross Energy Savings, Fossil Fuel

Commented [SK310]: Update example calculation to reflect updated ADHW

Reminder: Retrofit savings are the sum of Retirement savings and Lost Opportunity savings. This section presents the Retirement portion of savings.

$$ABTU_H = 85{,}200{,}000 \times \left(\frac{1}{AFUE_E} - \frac{1}{.85}\right) \; \cancel{ABTU_H = 85{,}200{,}000 \times \left(\frac{1}{AFUE_E} - \frac{1}{.85}\right)}$$

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:

$$ABTU_W = ADHW \times \left(\frac{1}{AFUE_E} - \frac{1}{AFUE_B}\right) \cancel{ABTU_W = ADHW \times \left(\frac{1}{AFUE_E} - \frac{1}{AFUE_B}\right)}$$

$$ABTU_W = 9{,}630{,}521 \times \left(\frac{1}{AFUE_E} - \frac{1}{0.85}\right) \cancel{ABTU_W = 11{,}197{,}312 \times \left(\frac{1}{AFUE_E} - \frac{1}{0.85}\right)}$$

Water heating savings by water heating fuel:

$$ACCF_W = \frac{ABTU_W}{102{,}900\ {}^{Btu}/_{Ccf}}$$

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

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

Retrofit Gross Energy Savings, Example

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:

$$ABTU_W = 11{,}197{,}132 \times \left(\frac{1}{0.80} - \frac{1}{0.85}\right)$$

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Commented [SK311]: Update example calculation to reflect updated ADHW

$$ABTU_W = 823{,}318.53BTU$$

$$ACCF_W = \frac{823{,}318BTU}{102{,}900\,{}^{BTU}/_{CCF}}$$

$$ACCF_W = 8.00CCF$$

Total:

$$ACCF = ACCF_H + ACCF_W$$

$$ACCF = 60.88CCF + 8.00CCF$$

$$ACCF = 68.88CCF$$

Retrofit Gross Peak Demand Savings, Example

For same example as above:

$$PD_H = 60.88 \times 0.00977$$
$$PD_H = 0.595Ccf$$

$$PD_W = 8.0 \times 0.00321$$
$$PD_W = 0.025\ Ccf$$

$$PD = PD_H + PD_W$$

$$PD_H = 60.88 \times 0.00977$$

$$PD_H = 0.595Ccf$$

$$PD = 0.62\ Ccf$$

$$PD_W = 8.0 \times 0.00321$$

$$PD_W = 0.025\,Ccf$$

$$PD = PD_H + PD_W$$

$$PD = 0.62\,Ccf$$

Changes from Last Version

- Formatting changes.

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References

[1]	*CT HVAC and Water Heating Process and impact Evaluation Report*, West Hill Energy and Computing, R1614/R1613 Jul. 19, 2018.

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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 memo (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.

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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.

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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 4-II: Inputs

Symbol	Description	Units
	Heating Fuel (e.g., natural gas, oil, and propane)	
AFUEE	AFUE, Existing (if available)	%
AFUEI	AFUE, Installed	%

Nomenclature

Table 4-JJ: 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		ROB: 85% AFUE NG/Propane, 83% AFUE Oil, ER: 78% AFUE for NG/Propane/Oil~~85% for Natural Gas or Propane 82% for Oil~~	**Ref [1]**
$AFUE_E$	AFUE of Existing Furnace		Actual rated Natural Gas or Propane 78% if unknown Oil 76% if unknown	**Ref [2]**,Table 4
AOG_H	Annual Oil Savings – Heating	Gallons		
APG_H	Annual Propane Savings – Heating	Gallons		
EUL	Effective Useful Life			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			Appendix Four
EFLH_H	Multifamily EFLH	995	Hours	
CAP_H	Multifamily Input Heating Capacity	41,098	Btu/hr	

Commented [SK312]: Add nomenclature for multifamily:
-EFLH_H: Heating equivalent full load hours (995 hours), Reference [1]
CAP_H: Input Heating Capacity (41,098 Btu/hr), Reference [3], which we provide in references section

Lost Opportunity Gross Energy Savings, Fossil Fuel

$$ABTU_H = 77{,}500{,}000 \times \left(\frac{1}{.85} - \frac{1}{AFUE_I}\right)$$

For multifamily: *ABTU_H = EFLH_H*CAP_H * (1/.85 - 1/AFUE_I)*

Commented [SK313]: Add multifamily equation: ABTU_H = EFLH_H*CAP_H * (1/.85 - 1/AFUE_I)

Note, this is another measure where the equations didn't convert correctly going from pdf to Word

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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

Commented [KR314]: Update example calculation to reflect new efficiency

Example: A new natural gas furnace with an AFUE of 96% is installed. What are the annual fossil fuel savings? Constant values include:

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- $AFUE_I$ = 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

Commented [KR315]: Update example calculation to reflect new efficiency

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

Reminder: *Retrofit savings are the sum of Retirement savings and Lost Opportunity savings. This section presents the Retirement portion of savings.*

$$ABTU_H = 77{,}500{,}000 \times \left(\frac{1}{AFUE_E} - \frac{1}{AFUE_B}\right)$$

Commented [SK316]: *Add multifamily equation: ABTU_H = EFLH_H*CAP_H * (1/AFUE_E- 1/AFUE_B)*

$$ABTU_H = 77{,}500{,}000 \times \left(\frac{1}{AFUE_E} - \frac{1}{0.85} \right)$$

For Multifamily: ABTU_H = EFLH_H*CAP_H * (1/AFUE_E- 1/AFUE_B)

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Savings by heating fuel:

$$ACCF_H = \frac{ABTU_H}{102{,}900\, {}^{Btu}\!/\!{}_{Ccf}}$$

$$AOG_H = \frac{ABTU_H}{138{,}690\, {}^{Btu}\!/\!{}_{Gal}}$$

$$APG_H = \frac{ABTU_H}{91{,}330\, {}^{Btu}\!/\!{}_{Gal}}$$

Reminder: *For electric savings for energy-efficient fan motors, see Measure 4.2.6 (ECM).*

Retrofit Gross Energy Savings, Example

Commented [KR317]: Update example calculation to reflect new efficiency

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).

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$$ABTU_H = 77{,}500{,}000 \times \left(\frac{1}{0.78} - \frac{1}{0.85} \right)$$

$$ABTU_H = 8{,}182{,}504\ Btu$$

$$ACCF_H = \frac{8{,}182{,}504\ Btu}{102{,}900\, {}^{Btu}\!/\!{}_{Ccf}}$$

$$ACCF_H = 79.5\ Ccf$$

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

- Formatting changes.

References

[1]	*CT HVAC and Water Heating Process and impact Evaluation Report*, West Hill Energy and Computing, R1614/ R 1613 Jul. 19, 2018.
[2]	Cadmus Group, "*High Efficiency Heating Equipment Impact Evaluation Final Report*," Mar. 2015, MA.
[3]	Energy & Resource Solutions. "R1705 R1609 Multifamily Baseline and Weatherization Opportunity Study," October 10, 2019.

Commented [KR318]: Update example calculation to reflect new efficiency

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Commented [SK319]: *Add for CAP_H: [3] Energy & Resource Solutions. "R1705 R1609 Multifamily Baseline and Weatherization Opportunity Study," October 10, 2019.*

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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 Home Energy Services Impact Evaluation by the Cadmus Group for the Electric and Natural Gas Program Administrators of Massachusetts (**Ref [1]**).

Inputs

Table 4-KK: Inputs

Symbol	Description
	Number of Gas Fired Boilers

Nomenclature

Table 4-LL: 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.

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Retrofit Gross Peak Day Savings, Natural Gas

- 0.439 ccf per boiler control.

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Non-Energy Benefits

- Not applicable.

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References

[1]	The Cadmus Group, Inc. *Home Energy Services Impact Evaluation*. Prepared for the Electric and Natural Gas Program Administrators of Massachusetts, 2012.

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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 4-MM: Inputs

Symbol	Description
	Number of ECM Circulator Pumps
Hp motor	For MF: Existing motor horsepower Eff: Existing motor efficiency or federal code minimum efficiency (CFR Section 431.446)

Nomenclature

Table 4-NN: 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
	Multifamily kW Reduction Factor		0.25	
	Multifamily Load Factor		0.90	
	Multifamily Operating Hours		5,376	Appendix 5
	Conversion HP to kW		0.746	

Retrofit Gross Annual Savings, Electric

- 68 kWh per year.

Retrofit Gross Seasonal Peak Demand Savings, Electric

Commented [SK320]: Add for multifamily:
- hp_motor: Existing motor horsepower
Eff: Existing motor efficiency or federal code minimum efficiency (CFR Section 431.446)

Commented [SK321]: Add for multifamily:
- 0.25 : kW reduction factor from installation of ECM circulating pump (no unit)
- 0.9 : Load factor
- hrs: Operating hours (5,376) from Appendix Table A5.1
- 0.746 kW/hp: Conversion of horsepower to kW
-

Commented [SK322]: Add equation for multifamily:

$$\Delta kWh = \frac{hp_{motor}}{Eff} \times 0.746 \left(\frac{kW}{hp}\right) \times 0.25 \times hrs \times 0.9$$

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Cooling:

$$SKW_C = 0$$

Heating:

$$WKW_H = 0.024\ kW$$

For Multifamily: *WKW_H = (hp_motor/Eff) x 0.746 kW/hp x 0.25 x 0.9*

Commented [SK323]: Add equation for multifamily: WKW_H = (hp_motor/Eff) x 0.746 kW/hp x 0.25 x 0.9

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- Formatting changes.

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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.

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4.2.14 ~~WI-FI~~Smart Thermostat

Description of Measure

This measure is the replacement of an existing manual or programmable residential thermostat with an ~~Wi-Fi enabled thermostat~~Energy Star qualified smart thermostat.

Savings Methodology

A smart~~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 calculated using an algorithm described below.~~per unit.~~

Table 4-OO: Assumed Baselines

Baseline	Comments
Manual or programable	

Inputs

Table 4-PP: 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 4-QQ: 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	
$AKWH_{H\text{-}ER}$	Annual Gross Electric Energy Savings - Heating (electric resistance)	kWh/yr	
$AKWH_{H\text{-}HP}$	Annual Gross Electric Energy Savings - Heating (heat pump)	kWh/yr	
$AKWH_{H\text{-}GHP}$	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	

Commented [SK324]: Wi-Fi only thermostats are no longer supported by Energy Star. Only learning thermostats are available.

The NY TRM has two thermostat measures: Wi-Fi Thermostat and Learning Thermostat. It provides deemed savings for Wi-Fi thermostats based on a 2012 pilot study. The Learning Thermostat measure uses a site-specific savings algorithm, with the option of using evaluation-based default values for sites with unknown heating or cooling equipment. Conversations with the NY TRC indicate that the Smart Thermostat measure should be used for most connected thermostats on the market as only a limited number of wifi-only thermostats are available, and the Wi-Fi thermostat measure has been slated for updating for several years. The NY TRM methodology for Learning Thermostats is strong and understandable, and many default inputs for it are available for CT based on CT evaluations.

The MA TRM uses a secondary research memo to provide savings estimates, which found that generic wi-fi systems (not including learning onboard) are not well-researched. The research memo acknowledges that findings for learning thermostats are more well-supported but awaits an evaluation for defining results.

The Mid-Atlantic TRM has no measure for wi-fi or programmable thermostats and only provides a measure for smart thermostats.

Recommendation for this measure is to adopt the NY methodology for Learning Thermostats (with CT-specific inputs), update the savings fractions with a CT-specific program evaluation, and remove Wi-Fi only thermostats from the TRM.

Commented [SK325]: *Add for multifamily –*
- Capacity_c: By site, or default 1.3 tons
-Capacity_h_out: By site, or default 41,098 Btu/hr

References for these values provided in the References section

These values will be used with the new algorithm proposed by ERS

SKW	Summer Demand Savings - Cooling	kW	Note [4]
WKW	Winter Demand Savings	kW	Note [4]
Capacity_c	Cooling capacity	Ton/unit	By site, or default 2.8 tons, Ref [5] For MF, by site or default 1.3 tons [Ref, 6]
Capacity h in	Heating capacity, input	Btu/hr	By site, or 120000 Btu/hr [Ref, 2]
Capacity_h_out	Heating capacity, output	Btu/hr	By site, or 102000 Btu/hr, Ref [5] **For MF = By site, or default 41,098 Btu/hr Ref [6]**
Eff_cooling	Cooling system efficiency, SEER		By site, or 14.0 SEER, Ref [5]
HSPF	Heat Pump seasonal performance factor		By site, or 8.2 for heat pumps, or 3.4 HSPF for electric resistance systems, Ref [5]
EFLH_cooling	Cooling Equivalent Full-Load Hours	Hours	804, Ref [3]
EFLH_heating	Heating Equivalent Full-Load Hours	Hours	842, Ref [2]
ESF_cooling	Energy savings factor for cooling		Interim value of 0.1; Ref [1]
ESF_heating	Energy savings factor for heating		Interim value of 0.8, Ref [1]
F_CEC	Central electric cooling flag		1.0 for central cooling; 0 for no central cooling; 0.277 for unknown, Ref [4]
F_EH	Central electric heating flag		1.0 for electric heat; 0 for no electric heat;

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			0.06 for unknown, Ref [4]
F_GH	Central gas heating flag		1.0 for gas heat; 0 for no gas heat; 0.34 for unknown, Ref [4]
F_OH	Central oil heating flag		1.0 for oil heat; 0 for no oil heat; 0.42 for unknown, Ref [4]
F_PH	Central propane heating flag		1.0 for propane heat; 0 for no propane heat; 0.08 for unknown, Ref [4]

~~Capacity_c - cooling capacity, ton/unit~~	~~By site, or default 2.8 tons based on R8 Central AC Impact and Process Evaluation~~
~~Capacity_h_in - heating capacity, input Btu/hr~~	~~By site, or 120000 Btu/hr based on results from R1614-1613 Residential HVAC Impact Evaluation~~
~~Capacity_h_out - heating capacity, output Btu/hr~~	~~By site, or 102000 Btu/hr based on results from R1614-1613 Residential HVAC Impact Evaluation~~
~~Eff_cooling - Cooling system efficiency, SEER~~	~~By site, or 14.0 SEER based on 10 CFR 430.32 (c)(1)~~
~~HSPF - Heat pump seasonal performance factor~~	~~By site, or 8.2 HSPF based on 10 CFR 430.32 (c)(1) for heat pumps, or 3.4 HSPF for electric resistance systems~~
~~EFLH_cooling - cooling equivalent full load hours~~	~~804 hr/yr, based on annual savings and seasonal demand savings factor results from R8 Central AC Impact and Process Evaluation~~
~~EFLH_heating - heating equivalent full load hours~~	~~842 hr/yr, based on average of boiler and furnace heating EFLH from R1614-1613 Residential HVAC Impact Evaluation~~

~~ESF_cooling - energy savings factor for cooling~~	~~Interim value of 0.1 based on ENERGY STAR® Program Requirements Product Specification for Connected Thermostat Products, Eligibility Criteria Version 1.0, January 2017, pg. 10. Recommend CT-specific program evaluation to determine an updated ESF~~
~~ESF_heating - energy savings factor for heating~~	~~Interim value of 0.08 based on ENERGY STAR® Program Requirements Product Specification for Connected Thermostat Products, Eligibility Criteria Version 1.0, January 2017, pg. 10. Recommend CT-specific program evaluation to determine an updated ESF~~
~~F_CEC - central electric cooling flag~~	~~1.0 for central cooling; 0 for no central cooling; 0.277 for unknown based on 2015 RECS data for New England~~
~~F_EH - central electric heating flag~~	~~1.0 for electric heat; 0 for no electric heat; 0.06 for unknown based on 2015 RECS data for New England~~
~~F_GH - central gas heating flag~~	~~1.0 for gas heat; 0 for no gas heat; 0.34 for unknown based on 2015 RECS data for New England~~
~~F_OH - central oil heating flag~~	~~1.0 for oil heat; 0 for no oil heat; 0.42 for unknown based on 2015 RECS data for New England~~
~~F_PH - central propane heating flag~~	~~1.0 for propane heat; 0 for no propane heat; 0.08 for unknown based on 2015 RECS data for New England~~

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Commented [SK326]: Add this to the nomenclature table.

Gross Energy Savings, Electric

Commented [SK327]: Remove table - use this algorithm:

AKWH = (Capacity_c x (12 / Eff_cooling) x EFLH_cooling x ESF_cooling x F_CEC) + (Capacity_h_out x (1 / HSPF) x EFLH_heating x ESF_heating x F_EH)

AKWH = (Capacity_c x (12 / Eff_cooling) x EFLH_cooling x ESF_cooling x F_CEC) + (Capacity_h_out x (1 / HSPF) x EFLH_heating x ESF_heating x F_EH)

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~~Table 4-RR: 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 Table 4-SS 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

For gas, ACCF_H = (Capacity_h_in x 1/102900 x EFLH_heating x ESF_heating x F_GH)

For oil, AGO_H = (Capacity_h_in x 1/138690 x EFLH_heating x ESF_heating x F_OH)

For Propane, AGP_H = (Capacity_h_in x 1/91330 x EFLH_heating x ESF_heating x F_PH)

~~Table 4-SS: 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 heating system is known:

PD_H = 0.00977 x ACCF_H

$$PD_H = ACCF_H \times PDF_H \cancel{=30.2X0.00977=0.295\ CCF}$$

For Midstream when heating system is unknown:

$$PD_H = ACCF_H \times PDF_H = 12.2X0.00977 = 0.119\ CCF$$

Changes from Last Version

- Updated savings for midstream initiative.

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.~~

Commented [SK328]: Remove table - use the following algorithm:

For gas, ACCF_H = (Capacity_h_in x 1/102900 x EFLH_heating x ESF_heating x F_GH)

For oil, AGO_H = (Capacity_h_in x 1/138690 x EFLH_heating x ESF_heating x F_OH)

For Propane, AGP_H = (Capacity_h_in x 1/91330 x EFLH_heating x ESF_heating x F_PH)

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Commented [SK329]: PD_H = 0.00977 x ACCF_H

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Commented [SK330]: *Add for multifamily - Capacity_c and Capacity_h_in: Energy & Resource Solutions. "R1705 R1609 Multifamily Baseline and Weatherization Opportunity Study," October 10, 2019.*

Commented [SK331]: Add the following references:

1. ENERGY STAR® Program Requirements Product Specification for Connected Thermostat Products, Eligibility Criteria Version 1.0, January 2017, pg. 10
2. R1614-1613 Residential HVAC Impact Evaluation
3. R8 Central AC Impact and Process Evaluation
4. EIA Residential Energy Consumption Survey (RECS) 2015 Microdata for New England states

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Commented [SK332]: Remove reference. Deemed savings are no longer used.

	~~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.~~
[1]~~[3]~~	ENERGY STAR® Program Requirements Product Specification for Connected Thermostat Products, Eligibility Criteria Version 1.0, January 2017, pg. 10~~Navigant Consulting "*Wi-Fi Thermostat Impact Evaluation--Secondary Research Study Memo*," 2018.~~
[2]	R1614-1613 Residential HVAC Impact Evaluation
[3]	R8 Central AC Impact and Process Evaluation
[4]	EIA Residential Energy Consumption Survey (RECS) 2015 Microdata for New England states
[5]	10 CFR 430.32 (c)(1)
[6]	Energy & Resource Solutions. "R1705 R1609 Multifamily Baseline and Weatherization Opportunity Study," October 10, 2019.

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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]	CT 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 CT.

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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 4-TT: Gross Energy Savings, Fossil Fuels

Symbol	Description	Units
	Heating Fuel (e.g., natural gas, oil, and propane)	

Nomenclature

Table 4-UU: 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	%	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.~~80%~~	Note [3]
HF	Average Heating Factor Based on Home's Heat Load	Btu/ ft^2	38,750 for Furnaces	Note [2]

Commented [SK333]: Include additional A default for MF applications: MF = 876 ft2.

Commented [SK335]: 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.

Commented [SK334]: Include additional AFUE for MF applications:
MF Boiler = 92%
MF Furnace = 88%

Commented [SK337]: HF values recommended in the 2018 CT R1614/1613 evaluation study: 38,750 Btu/sf for furnaces and 42,600 Btu/sf for boilers.

			46,400 for Boilers 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]

Commented [SK336]: Include additional HF Default for MF applications:
MF = 20,300

Gross Energy Savings, Fossil Fuel

$$ABTU_H = A \times HF \times \left(\frac{1}{AFUE_E}\right) \times ESF \; \cancel{ABTU_H = A \times HF \times \left(\frac{1}{AFUE_E}\right) \times ESF}$$

$$ABTU_H = 2{,}000 \times 46{,}400 \times \left(\frac{1}{.80}\right) \times 0.02 = 2{,}320{,}000 Btu$$

$$\cancel{ABTU_H = 2{,}000 \times 46{,}400 \times \left(\frac{1}{.80}\right) \times 0.02 = 2{,}320{,}000 Btu}$$

<u>Savings by heating fuel</u>:

$$ACCF_H = \frac{2{,}320{,}000}{102{,}900} = 22.5 CCF \; \cancel{ACCF_H = \frac{2{,}320{,}000}{102{,}900} = 22.5 CCF}$$

$$AOG_H = \frac{2{,}320{,}000}{138{,}690} = 16.7 Gal \; \cancel{AOG_H = \frac{2{,}320{,}000}{138{,}690} = 16.7 Gal}$$

$$APG_H = \frac{2{,}320{,}000}{91{,}330} = 25.4 Gal \; \cancel{APG_H = \frac{2{,}320{,}000}{91{,}330} = 25.4 Gal}$$

Peak Day Savings, Natural Gas

$$PD_H = ACCF_H \times PDF_H$$

$$PD_H = 22.5 CCF \times 0.00977 = 0.219 CCF$$

Changes from Last Version

- Formatting changes.

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References

[1]	ESF 2% value was used compared to 5% used in the *New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs – Residential, Multi-Family, and Commercial/Industrial Measures*, Version 3, Issue Date – 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 multi-family value selected based on recent data from Ref [3]. This evaluation reported an average size of 876 sq. ft for multi-family 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 multi-family value calculated by scaling single family Heating Factor and associated square footage by cited Multi-family dwelling unit square footage from Ref [3]*
[3]	The value of 80% is based on verified data from **Ref [2]**, Table 4, *and Multi-family defaults are based on data from Ref[3], Table 4-27. Defaults*~~and~~ should be used except in situations where either actual nameplate ratings or actual efficiency test data are available.

Commented [SK338]: Add reference [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

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Commented [SK339]: The CT Evaluation [R1614/R1613] found that residential boilers were performing 2% lower than their rated efficiency, based on site visit metering. The PSD currently cites the New York TRM as the source for the Energy Savings Factor. The NY TRM cites an Energy Trust of Oregon paper; Building Tune-Up and Operations Program Evaluation which suggests a savings between 2-5% for boiler tune-ups.
Recommendation to list both the CT Evaluation and the Energy Trust of Oregon paper as citations for savings and to include the language "Both references support 2% savings for this measure" in the PSD. The inclusion of both citations will corroborate the derated efficiency findings in CT homes in addition to the potential efficiency increase as supported by the Energy Trust of Oregon paper.

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Commented [SK340]: Expand Note [1] to include MF explanation:
"Default single-family 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 multi-family value selected based on recent data from Ref [3]. This evaluation reported an average size of 876 sq. ft for multi-family units"

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Commented [SK341]: Expand Note [2] to include MF explanation:
"Default single-family 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 multi-family value calculated by scaling single family Heating Factor and associated square footage by cited Multi-family dwelling unit square footage from Ref [3]"

Commented [SK342]: Expand Note [3] to include MF explanation:
"The single-family value of 80% is based on verified data from Ref [2], Table 4, and Multi-family defaults are based on data from Ref[3], 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. Note that the input and equipment tabs within the spreadsheet have default values that can be overridden by the user when project specific details are available. The peak electric and 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 4-VV: Inputs

Symbol	Description	Units
	No. of Units Purchased	

Nomenclature

Table 4-WW: Nomenclature

Symbol	Description	Units	Values	Comments
$ACCF_O$	Annual Natural Gas Savings	ccf		
AKWH	Annual Gross Electric Energy Savings	kilowatt-hours, 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 4-XX: Savings

	AKWH	SKW	WKW	Oil (Gal)	Propane (Gal)	Natural Gas (ccf)	Water (Gal)	Comments
Air Cleaner/Purifier	~~227~~213.9	0.024~~.026~~	0.024~~026~~					Ref [1]
Clothes Washer Tier I	88.1~~66~~	0.009~~1~~	0.012~~1~~	0.00~~99~~	0.44~~09~~	0.29~~86~~	823~~908~~	Note [1], Note [3] Ref [7]
Clothes Washer Tier II	120.3~~17~~	0.012~~2~~	0.016~~2~~	0.72~~1.60~~	2.08~~0.16~~	1.65~~41~~	1,795~~603~~	Note [1], Note [3], Ref [7]
Clothes Dryer (ENERGY STAR)	194~~93~~	0.026~~12~~	0.026~~12~~					Ref [2]
Clothes Dryer (Hybrid)	412~~229~~	~~0.029~~0.05	~~0.029~~0.05					Ref [2]
Clothes Dryer (Heat Pump)	658~~472~~	~~0.059~~0.08	~~0.059~~0.08					Ref [2]
Dehumidifier	~~214~~229	~~0.066~~0.07	~~0.000~~0.07					Ref [4]
Dishwasher	11	0.00	0.00	0.16	0.16	0.01	87	Ref [5], Note [1] Ref[7]
Refrigerator Tier I (10% greater than ENERGY STAR)	~~64~~59	~~0.012~~0.007	~~0.007~~0.006					Ref [2]
Refrigerator Tier II (15% greater than ENERGY STAR)	~~96~~89	~~0.018~~0.0105	~~0.010~~0.008					Ref [2]
Room Air Conditioner	10.7~~77.5~~	~~0.029~~0.009	~~0.000~~0.0					Ref [5], Note [4]
Freezer, Upright Freezer, Chest	4~~45~~ 24	0.005~~0.008~~ 0.003	0.00~~45~~ 0.002					Note [2]
Refrigerator Recycling	794	0.09	0.09					Ref [6]
Freezer Recycling	846	0.096	0.096					Ref [6]

For Multifamily Ref [8]:

	AKWH
Clothes Washer	27
Clothes Dryer	30
Dishwasher	32
Power Strip Upgrade - entertainment	51

Commented [SK343]: For multifamily:

Add the following Technologies and associated Savings:
Multi-Family Clothes Washer In unit: 27 AKWH, 0.003 KW
Multi-Family Clothes Dyer, electric: 30 AKWH, 0.004 KW
Multi-Family Dishwasher: 32 AKWH, 0.003 kW
Multi-Family Power Strip - entertainment: 51 AKWH, 0 kW
Multi-Family Power Strip - IT: 26 AKWH, 0 kW
Multi-Family Refrigerator: 73 AKWH, 0.010 kW
Multi-Family Room Air Conditioner: 13 AKWH, 0.011 kW
Comments: Ref [8]

Commented [SK344]: The recommended savings values are based on the 2018 VT TRM and are in line with the R1973 Retail Non-Lighting evaluation study recommended values.

Commented [SK345]: Values originally referenced from the 2017 VT TRM are propsoed to be updated with 2018 VT TRM values. Upcoming MA Baseline study evaluation to update EUL of clothes dryer.

Commented [SK346]: The recommended savings values are based on the 2018 VT TRM. The R1973 Retail Non-Lighting evaluation study references an older source than the 2018 VT TRM.

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PowerStrip Upgrade - IT	26
Refrigerator	73
Room AC	13

Retrofit Gross Energy Savings

1. Calculate Lost Opportunity savings using Table 4-XX ($AKWH_{Lost\ Opp}$).
2. Modify the ENERGY STAR Appliance Spreadsheet calculations **Ref [4]** to take into account existing equipment by going to the spreadsheet labeled after the appliance and replacing all the conventional model specifications (highlighted in blue) with the existing equipment specifications.
3. 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 [7]**).

References

[1]	EPA Next Gen Product Analysis_10.9.14.xlsx. Last Accessed on Jul. 1, 2015.
[2]	*Efficiency Vermont Technical Reference Manual*, Last Accessed on Aug. 30, 2017.
[3]	ENERGY STAR Dehumidifiers website, last accessed Aug. 2, 2012. Available at: http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=DE E.
[4]	Savings Calculator for ENERGY STAR Appliances, Available at: https://www.energystar.gov/sites/default/files/asset/document/appliance_calculator.xlsx, Last Accessed Jun. 21, 2017.
[5]	Savings Calculator of ENERGY STAR Window A/C, Available at: https://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/CalculatorRoomAC.xls Accessed Jun. 8, 2018.
[6]	*New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs*. Version7, Issued Apr. 15, 2019, p. 44.

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Commented [SK347]: *Add reference [8] for MF appliances: 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

Commented [SK348]: Need to provide updated reference

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Commented [SK349]: Link not valid and could not find quoted reference. Provide updated reference.

Commented [SK350]: Link not valid and could not find quoted reference. Provide updated reference.

[7]	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.
[8]	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

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Notes

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[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 4-YY: Estimated Fuel Mix

Water Heater Fuel				Clothes Dryer Heating Fuel		
Electric	**Gas**	**Oil**	**Propane**	**Electric**	**Gas**	**Propane**
30%	27%	41%	2%	93%	5%	2%

[2]	CT Utility Data. Savings Calculated using Equations from **Ref [4]**.
[3]	Eversource analysis of **Ref [2]**.
[4]	Average of CT and Bridgeport kWh saving values from **Ref [5]**. SKW calculated using **Ref [5]** and Room A/C Coincidence Factor from Appendix One.

4.3.2 Electronics

Description of Measure

Purchase of a new ENERGY STAR-qualified electronics equipment. Electronics equipment includes:

- Blu-Ray Player;
- Computer Monitor (Displays);
- Cordless Phones;
- Desktop Computers;
- DVD Player;
- Home Theatre in a Box Systems;
- Laptop Computers;
- Room Air Cleaners;
- Set-top Boxes & Cable Boxes;
- Sound Bars;
- Televisions; and
- Advanced Power Strips.

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Savings Methodology

The savings estimates in the Table 4-BBB 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 4-ZZ: Inputs

Symbol	Description	Units
	No. of Units Purchased	

Nomenclature

Table 4-AAA: Nomenclature

Symbol	Description	Units	Values	Comments
AKWH	Annual Electric Energy Savings	kWh		Table 4-BBB~~III~~
SKW	Summer Demand Savings	kW	0	
WKW	Winter Demand Savings	kW	0	

Lost Opportunity Gross Energy Savings, Electric

The savings estimates in the following table are for ENERGY STAR-qualified electronics equipment versus conventional equipment.

Table 4-BBB: ENERGY STAR Electronics Annual Savings

Electronics Equipment	Energy Savings AKWH	Comments
Blu-Ray 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	48	**Ref** [5]

Commented [SK351]: Referenced calculators are not available to verify or update savings values. We recommend further secondary research to identify resources for deemed savings values and to determine which measures should be included in the PSD based on the program rules. The Energy Star deemed savings values are to be verified for all the listed appliances except Sound bars and power strips.
We also recommend updating advanced power strips savings based on RLPNC 17-3: Advanced Power Strip Metering Study, 2018 and Soundbar savings based on NY TRM.
Stakeholder interviews mentioned possibility of adding residential energy kits to programs.

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

Commented [SK352]: Include demand savings after further secondary research

- WKW = 0;
- SKW = 0; and
- No demand savings are claimed for this measure.

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References

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[1]	Savings Estimate for ENERGY STAR Qualified Consumer Electronics, ENERGY STAR Consumer Electronics Calculator, ENERGY STAR. Last accessed on: Jul. 19, 2017. Available at: https://www.energystar.gov/sites/default/files/asset/document/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.

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[4]	Last accessed on: Jul. 26, 2017. Available at: https://static1.squarespace.com/static/53c96e16e4b003bdba4f4fee/t/556d387fe4b0d8dc09b24c28/1433221247215/RPP+Methodology+for+Developing+UEC+Estimates_Final.pdf, (Sound bar Section).
[5]	*Advanced Power Strips College Dorm Room Savings Verification Study Final Report*. Prepared for Eversource. Connecticut. Jun. 23, 2016. p. 2.

4.4 ENVELOPE

4.4.1 REM Savings

Commented [SK355]: No proposed changes for this measure.

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 4-CCC: Inputs

Symbol	Description
REM	REM Simulation File Submitted by an 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 4-DDD). The difference between those values is the energy savings. This savings is referred to as “REM” savings.

Table 4-DDD: 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.

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Lost Opportunity Gross Peak Day Savings, Natural Gas

- Described above in Lost Opportunity Gross Energy Savings – Gas.

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Non-Energy Benefits

- Improves personal comfort and health. It also increases a home's durability and value.

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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.

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4.4.2 Infiltration Reduction Testing (Blower Door Test)

Description of Measure

Blower Door Test equipment is used to verify infiltration reduction.

Savings Methodology

Commented [SK356]: Account for interactivity between the envelope and other HVAC-related measures as recommended by R91 study.

REM/Rate (Ref [1]), a residential energy analysis, code compliance and rating software, was used to simulate energy use in a typical home before and after infiltration reduction (CFM air leakage at 50 Pascals ("Pa") pressure difference). The average energy savings in MMBtu and kWh were estimated from the results of the REM/Rate simulations, then converted to the appropriate fuels using unit conversions and assumed distribution losses. The demand savings were also based on the REM simulation.

This methodology is used to estimate infiltration savings only when savings are a result of sealing surfaces that provide direct separation between conditioned and non-conditioned 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.~~9~~5).*

Inputs

Table 4-EEE: 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 4-FFF: Nomenclature

Symbol	Description	Units	Value	Comments
$ACCF_H$	Annual Natural Gas Savings, Heating	ccf		
$AKWH_H$	Annual Electric Energy Savings, Heating	kWh		
$AKWH_C$	Annual Electric Energy Savings, Cooling	kWh		
AOG_H	Annual Oil Savings, Heating	Gal		
APG_H	Annual Propane Savings, Heating	Gal		
CFM_{Pre}	Infiltration Before Air Sealing Measured with the House Being Negatively Pressurized to 50 Pa Relative to Outdoor Conditions	CFM		Inputs
CFM_{Post}	Infiltration After Air Sealing Measured with the House Being Negatively Pressurized to 50 Pa Relative to Outdoor Conditions	CFM		Inputs
PD_H	Natural Gas Peak Day Savings, Heating	ccf		
PDF_H	Natural Gas Peak Day Factor, Heating		0.00977	Appendix One
REM	Savings Factor in Energy Units per CFM Reduction Based on REM/Rate Simulation			
SKW	Summer Demand Savings	kW		
WKW	Winter Demand Savings	kW		
BF	Blower Door CFM Reduction Factor		1	SF
			Calculated	MF

Retrofit Gross Energy Savings, Electric

Commented [SK357]: The deemed values are based on a REM/Rate model that was run in 2008. Changes to the model or to the input variables would change the deemed values. Recommend update values with new REM/rate model every three years, analogous to typical codes and standards updates, to ensure that the deemed values reflect changes to the model and input variables.

Table 4-GGG: Retrofit Electric Savings per CFM Reduction (at 50 Pa)

Measure	Symbol	Energy Savings	Units
Electric Resistance Heat	$REM_{Heating}$	2.638	kWh
Heat Pump Heating	$REM_{Heating}$	1.319	kWh
Geothermal Heating	$REM_{Heating}$	0.879	kWh
Air Handler Heating (fan)	REM_{AH}	0.06	kWh
Cooling (central A/C only)	$REM_{Cooling}$	0.0593	kWh
Cooling (room A/C: window, sleeve, or PTAC) (Note [1])	$REM_{Cooling}$	0.0168	kWh

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

$$AKWH_H = REM_{Heating} \times (CFM_{Pre} - CFM_{Post}) \cancel{AKWH_H = REM_{Heating} \times (CFM_{Pre} - CFM_{Post})} \text{ x BF}$$

For Fossil Fuel heating with air handler unit:

$$AKWH_H = REM_{AH} \times (CFM_{Pre} - CFM_{Post}) \cancel{AKWH_H = REM_{AH} \times (CFM_{Pre} - CFM_{Post})} \text{ x BF}$$

For homes with cooling:

$$AKWH_C = REM_{Cooling} \times (CFM_{Pre} - CFM_{Post}) \cancel{AKWH_C = REM_{Cooling} \times (CFM_{Pre} - CFM_{Post})} \text{ x BF}$$

Retrofit Gross Energy Savings, Fossil Fuel

Commented [SK358]: Update the deemed values by re-running the REM/Rate simulation model every three years.

Table 4-HHH: 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}	0.117	ccf
Propane	$REM_{Propane}$	0.131	Gal
Oil	REM_{Oil}	0.087	Gal

For homes with natural gas heating system:

$$ACCF_H = REM_{NG} \times (CFM_{Pre} - CFM_{Post}) \cancel{ACCF_H = REM_{NG} \times (CFM_{Pre} - CFM_{Post})} \text{ x BF}$$

For homes with oil heating system:

$$AOG_H = REM_{Oil} \times (CFM_{Pre} - CFM_{Post}) \cancel{AOG_H = REM_{Oil} \times (CFM_{Pre} - CFM_{Post})} \text{ x BF}$$

For homes with propane heating system:

$$APG_H = REM_{Propane} \times (CFM_{Pre} - CFM_{Post}) \cancel{APG_H = REM_{Propane} \times (CFM_{Pre} - CFM_{Post})} \text{ x BF}$$

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 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. What are the electric and fossil fuel savings for this home?

Oil heating savings may be calculated using the following equation:

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

$$AOG_H = 0.087 \times (1850 - 1575) \times 1 = 23.9 \,{}^{\text{Gal-Oil}}/_{\text{yr}} \cancel{AOG_H = 0.087 \times (1850 - 1575) \times 1 = 23.9 \,{}^{\text{Gal-Oil}}/_{\text{yr}}}$$

Cooling savings may also be claimed as follows:

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

$$AKWH_C = 0.0168 \times (1850 - 1575) \times 1 = 4.62 \,{}^{kWh}/_{yr}$$

$$\cancel{AKWH_C = 0.0168 \times (1850 - 1575) \times 1 = 4.62 \,{}^{kWh}/_{yr}}$$

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

Commented [SK359]: Update the deemed values by re-running the REM/Rate simulation model every three years.

Table 4-III: Demand Savings, kW per CFM Reduction

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}
0.00117	0.00039	0.00009	0.00002

$$WKW_H = REM_{WKW} \times (CFM_{Pre} - CFM_{Post}) \cancel{WKW_H = REM_{WKW} \times (CFM_{Pre} - CFM_{Post})} \times \text{BF}$$

$$SKW_C = REM_{SKW} \times (CFM_{Pre} - CFM_{Post}) \cancel{SKW_C = REM_{SKW} \times (CFM_{Pre} - CFM_{Post})} \times \text{BF}$$

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:

$$PD_H = ACCF_H \times PDF_H \cancel{PD_H = ACCF_H \times PDF_H}$$

Retrofit Gross Peak Demand Savings, Example

Example: For the above Retrofit example, what is the summer demand savings for this home?

$$SKW_C = REM_{SKW} \times (CFM_{Pre} - CFM_{Post}) \cancel{SKW_C = REM_{SKW} \times (CFM_{Pre} - CFM_{Post})} \times \text{BF}$$

$$SKW_C = 0.00002 \times (1850 - 1575) \times 1 = 0.0055 \text{ kW} \quad \cancel{SKW_C = 0.00002 \times (1850 - 1575) \times 1 = 0.0055 \text{ kW}}$$

Changes from Last Version

- Format changes.

References

[1]	REM/Rate™ is a residential energy analysis, code compliance and rating software developed by Architectural Energy Corporation. This software calculates heating, cooling, hot water, lighting, and appliance energy loads, consumption and costs for new and existing single and multi-family homes. Blower Door energy savings analysis using REM/Rate™ was performed by C&LM Planning team, Eversource, Aug. 2008.
[2]	Nexant Market Research, Inc., "*Market Assessment for ENERGY STAR Room Air Conditioners in Connecticut*," Cambridge, MA, 2007, pp. 17-18.
[3]	RLW Analytics, "*Final Report: Coincidence Factor Study: Residential Room Air Conditioners,*" Middletown, CT, 2008, pp. iv, 22.
[4]	ADM Associates, Inc., "*Residential Central A/C Regional Evaluation*," Sacramento, CA, 2009, pp. 4-4.
[5]	Technical Report: Multifamily Envelope Leakage Model. O. Faakye & D. Griffiths. 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]**.
	For Multifamily:

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Commented [SK360]: The referenced analysis was performed in 2008. The deemed energy savings in this measure are taken from this reference. Recommend re-run the REM/Rate simulation to ensure that the savings are reflective of changes to the model and input variables.

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Commented [SK361]: *Multifamily:*

Change to:
BF = 0.67 + DuctLocationTerm - 0.088xDoors - 0.0002xD + 0.0012xF

DuctLocationTerm = 0.27 for ducts in unconditioned space, and 0.05 for ducts in conditioned space or if no ducts

Doors = number of doors to the unit

D = Shared Surface Area (ft2) between conditioned spaces. [no change]

F = Envelope Perimeter (ft) is used to describe the sum of all the lengths of the edges of the unit, common and exterior surfaces. [no change]

TRC also recommends adding an example to reduce confusion for the user.
Calculated Blower Door CFM Reduction (BF), Example, assuming a middle unit, ducts in conditioned space, and one door.

BF = 0.67 + DuctLocationTerm - 0.088xDoors - 0.002xD + 0.0012xF
BF = 0.67 + 0.05 – 0.088×1 – 0.0002×2515 + 0.0012×276 = 0.68

This will then be multiplied by the savings to account for outdoor air infiltration:
REM x (CFMpre - CFMpost) x 0.68

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	Change to: BF = 0.67 + DuctLocationTerm - 0.088xDoors - 0.0002xD + 0.0012xF DuctLocationTerm = 0.27 for ducts in unconditioned space, and 0.05 for ducts in conditioned space or if no ducts Doors = number of doors to the unit D = Shared Surface Area (ft2) between conditioned spaces. [no change] F = Envelope Perimeter (ft) is used to describe the sum of all the lengths of the edges of the unit, common and exterior surfaces. [no change] TRC also recommends adding an example to reduce confusion for the user. Calculated Blower Door CFM Reduction (BF), Example, assuming a middle unit, ducts in conditioned space, and one door. BF = 0.67 + DuctLocationTerm - 0.088xDoors - 0.002xD + 0.0012xF BF = 0.67 + 0.05 – 0.088×1 – 0.0002×2515 + 0.0012×276 = 0.68 This will then be multiplied by the savings to account for outdoor air infiltration: REM x (CFMpre - CFMpost) x 0.68

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 4-LLL and 4-MMM, 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 4-JJJ: 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)	$Btu/ft^2 \times h \times {}^0F$

Nomenclature

Table 4-KKK: 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 4-LLL~~SSS~~	Note [2]
AEH	Annual Electric Heating Usage	$kWh/ft^2/yr$	Table 4-LLL~~SS~~	Note [2]
AGU	Annual Natural Gas Usage	$ccf/ ft^2/yr$	Table 4-MMM~~TT~~	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 4-MMM~~TTT~~	Note [2]
APG_H	Annual Propane Savings - Heating	gallons/yr		
APU	Annual Propane Usage	$gal/ft^2/yr$	Table 4-MMM~~TTT~~	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			
$\ldots_b$	Baseline			
$\ldots_{es}$	ENERGY STAR			Ref [6]
$\ldots_{HP}$	Heat Pump Heating Only			
$\ldots_R$	Electric Resistance Heating Only			
$\ldots_{RAC}$	Room Air Conditioners (Cooling Only)			Note [3]

Retrofit Gross Energy Savings, Electric

Table 4-LLL: Annual Electric Energy Usage (Note [2])

Window /Sliding Glass Door Type	AEH (kWh/ft^2)	AEC (kWh/ft^2)
Single Pane ("leaky")	28.61	2.65
Single Pane ("tight") (baseline)	22.02	2.57

Commented [SK362]: The deemed values were calculated using RESFEN 5 software in 2005. The primary change between RESFEN 5 and RESFEN 6 was that some of the underlying modeling assumptions were changed to be consistent with the Energy Star 2008 analysis done by LBNL. The RESFEN 6 should be run to ensure that the deemed values reflect the changes to the model.

Double Pane (or single with storm)	10.79	2.57
ENERGY STAR - Double Pane	5.57	1.49
ENERGY STAR – Triple Pane	3.64	1.35

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]**):*

$$AKWH_{H,R} = (AEH_b - AEH_{es}) \times A$$

$$AKWH_{H,HP} = \frac{(AEH_b - AEH_{es})}{2} \times A$$

Example, for going from a baseline to an ENERGY STAR window:

$$AKWH_{H,R} = (22.02 - 5.57) \times A$$

$$AKWH_{H,R} = 16.36 \times A$$

$$AKWH_{H,HP} = \frac{(22.02 - 5.57)}{2} \times A$$

$$AKWH_{H,HP} = 8.23 \times A$$

Cooling (CAC Only):

$$AKWH_{C,CAC} = (AEC_b - AEC_{es}) \times A$$

$$AKWH_{C,CAC} = (2.57 - 1.49) \times A$$

$$AKWH_{C,CAC} = 1.08 \times A$$

*Cooling (Room A/C Only): (**Note [3]**):*

$$AKWH_{C,RAC} = (28.3\%) \times AKWH_{C,CAC}$$

$$AKWH_{C,RAC} = 0.305 \times A$$

Retrofit Gross Energy Savings, Fossil Fuel

Table 4-MMM: 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")	1.39	1.03	1.57
Single Pane ("tight") (baseline)	1.08	0.80	1.21
Double Pane (or single with storm)	0.53	0.39	0.59
ENERGY STAR – Double Pane	0.28	0.20	0.31
ENERGY STAR – Triple Pane	0.18	0.13	0.20

Commented [SK363]: The deemed values were calculated using RESFEN 5 software in 2005. The primary change between RESFEN 5 and RESFEN 6 was that some of the underlying modeling assumptions were changed to be consistent with the Energy Star 2008 analysis done by LBNL. The RESFEN 6 should be run to ensure that the deemed values reflect the changes to the model.

Savings by heating fuel:

$$A = \frac{D_H \times D_W}{144\,{}^{in^2}\!/\!_{ft^2}}$$

Natural gas:

$$ACCF_H = (AGU_b - AGU_{es}) \times A$$
$$ACCF_H = (1.08 - 0.28) \times A$$
$$ACCF_H = 0.80 \times A$$

Oil:

$$AOG_H = (AOU_b - AOU_{es}) \times A$$
$$AOG_H = (0.80 - 0.20) \times A$$
$$AOG_H = 0.60 \times A$$

Propane:

$$APG_H = (APU_b - APU_{es}) \times A$$
$$APG_H = (1.21 - 0.31) \times A$$
$$APG_H = 0.90 \times A$$

Retrofit Gross Energy Savings, Example

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.

$$A = \frac{24in \times 36in}{144\,{}^{sqin}\!/\!_{sf}} = 6\,sq\;ft$$

$$AKWH_H = 16.36\,{}^{kWh}\!/\!_{sf} \times 6\,sqft = 98\,kWh$$

$$AKWH_C = 1.08 \, {}^{kWh}\!/\!_{sf} \times 6\, sqft = 6.5\, kWh$$

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

If home has electric resistance heat:

$$WKW = AKWH_{H,R} \times \frac{PFW}{1000 \, {}^{W}\!/\!_{kW}} = 16.36 \, {}^{kWh}\!/\!_{ft^2} \times A \times \frac{0.570 \, {}^{W}\!/\!_{kWh}}{1000 \, {}^{W}\!/\!_{kW}} = 0.0093 \, {}^{kW}\!/\!_{ft^2} \times A$$

*If home has a heat pump (**Note [1]**):*

$$WKW = AKWH_{H,HP} \times \frac{PFW}{1000} = \frac{0.0093}{2} \times A = 0.00465 \times A$$

*If home has central air conditioning (**Note [2]**):*

$$SKW_{C,CAC} = \left(0.0046 \, {}^{kW}\!/\!_{sf} - 0.0025 \, {}^{kW}\!/\!_{sf}\right) \times CF_S \times A$$
$$SKW_{C,CAC} = 0.0012 \, {}^{kW}\!/\!_{sf} \times A$$

*If home has one or more room air conditioners (**Note [3]**):*

$$SKW_{C,RAC} = (25.1\%) \times SKW_{C,CAC}$$
$$SKW_{C,RAC} = 0.00031 \, {}^{kW}\!/\!_{sf} \times A$$

Retrofit Gross Peak Day Savings, Natural Gas

$$PD_H = ACCF_H \times PDF_H$$

Retrofit Gross Peak Demand Savings, Example

Example: For the above example with electric resistance heat and central air conditioning, demand savings are as follows:

$$WKW = 0.0093 \, {}^{kW}\!/\!_{sf} \times 6\, ft^2 = 0.056\, kW$$

$$SKW_{CAC} = 0.0012 \, {}^{kW}\!/\!_{sf} \times 6\, ft^2 = 0.0072\, kW$$

Changes from Last Version

- Format changes.

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References

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Commented [SK364]: Re-run the model with RESFEN 6 and update this reference.

[1]	Lawrence Berkeley National Laboratory, RESFEN 5.0 computer software, May 12, 2005. http://windows.lbl.gov/software
[2]	KEMA, *Evaluation of the Weatherization Residential Assistance Partnership and Helps Programs (WRAP/Helps)*, 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

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[1]	Heat pump energy savings are one-half of electric resistance savings based on a 2.0 COP. Since heat pumps use backup resistance heat during winter peak, winter demand savings for heat pumps equals one-half those of resistance heat demand savings.
[2]	The usage values were developed for different fuel types and windows/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]**.

Commented [SK365]: The deemed values were calculated using RESFEN 5 software in 2005. The primary change between RESFEN 5 and RESFEN 6 was that some of the underlying modeling assumptions were changed to be consistent with the Energy Star 2008 analysis done by LBNL. The RESFEN 6 should be run to ensure that the deemed values reflect the changes to the model.

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.

Commented [SK366]: *Research recommendation (not immediate PSD update): TRC is recommending that another study conduct secondary research for this measure. The baseline insulation standards used in the modeling software reflect single-family buildings: (NMR Group Inc., Connecticut 2011 Baseline Study of Single- Family Residential New Construction, Oct. 1, 2012). For this measure to apply to multifamily buildings, the models must be updated with multifamily values reflecting the most recent insulation standards. Please see multifamily workbook for more detail*

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 4-NNN: 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, gas, oil, propane, etc.)	

Nomenclature

Table 4-OOO: 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		

Commented [SK367]: Recommended EUL of 25 years (No value for specifically Thermal Enclosure, but based on the measure description, this measure falls under Appendix Four: Building Envelope Insulation)

Lost Opportunity Gross Energy Savings, Electric

Commented [SK368]: Re-run the simulation with updated baseline home values and confirm that no variables have changed that impact the savings values and update the 'Energy Savings' in the Table 4-PPP & Table 4-QQQ.

Table 4-PPP: 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

Commented [SK369]: It is not specified when the REM/Rate simulation was performed. Re-run the simulation with updated baseline home values to ensure that the savings values are up to date. Update REMWKW values based on updated REM/Rate output.

Table 4-QQQ: Fossil Fuel Savings per ft² (Note [1])

Heating Fuel	Symbol	Energy Savings	Units
Fossil Fuel Savings		0.0039	MMBtu/ft²
Natural Gas	REM_G	0.0354	Ccf/ ft²
Oil	REM_O	0.0279	Gal/ ft²
Propane	REM_P	0.0392	Gal/ ft²

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)

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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 ft^2. What are the peak demand savings (electric and natural gas)?

Summer demand savings:

$$WKW_H = REM_{WKW} \times A = 0.0004 \times 1{,}100 = 0.43\ kW$$

$$SKW_C = REM_{SKW} \times A = 0.00004 \times 1{,}100 = 0.05\ kW$$

Natural gas peak day savings:

$$PD_H = ACCF_H \times PDF_H = 53 \times 0.00977 = 0.52\,Ccf$$

Non-Energy Benefits

Increased personal comfort.

Changes from Last Version

- Format 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.

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Commented [SK370]: Reference added in PSD4.4.4 supporting info for RESNET standards should be added

Commented [SK371R370]: Insulation Installation A

Standards	https://www
Scope	https://basc.
Compliance	https://basc.

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Commented [SK372]: Baseline home according to NMR Group Inc., R1602 Residential New Construction Program Baseline Study, December 5, 2017. Update baseline based on latest evaluation report.

Commented [SK373]: We recommend adding a note stating "The baseline home referenced in the measure was predominantly fossil fuel-based heating (only one GSHP in NRM's study sample), while the transformation of the market to electric heating (heat pumps) may necessitate the inclusion of an additional baseline home type."

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[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.~~Installation of a storm window to augment an existing single-pane window that is between the conditioned space and the outdoors.~~

Savings Methodology

The savings for this measure are calculated using the installed storm window area and usage factors develop using RESFEN (**Ref [1]**) to model different window types and heating fuels. The results of that analysis are shown in Tables 4-TTT and 4-UUU. 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 4-RRR: Inputs

Symbol	Description	Units
	No. Storm Windows Installed	
D_H	Height of the Window	Inches
D_W	Width of the Window	Inches
	Primary Existing Heating Fuel Type	

Commented [SK374]: We recommend the program look into redefining the high efficiency options based on further research on the low-E and window glazing types on both interior and exterior of the existing window.
MO TRM - savings depends on storm window location (interior or exterior) and glazing type (clear or Low-E).
MN TRM considers low-E storm windows on the interior or exterior of the existing window. CT PSD does not consider the cooling savings - this can be accounted if low-E windows are installed.

Commented [SK375]: Replace measure description with "Installation of a storm window on the interior or exterior of the existing single-pane window".

Nomenclature

Table 4-SSS: 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 4-TTT	Note [2]
AEH	Annual Electric Heating Usage	kWh/ft^2	Table 4-TTT	Note [2]
AGU	Annual Natural Gas Usage	ccf/ft^2	Table 4-UUU	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 4-UUU	Note [2]
APG_H	Annual Propane Savings - Heating	gallons		
APU	Annual Propane Usage	gal/ft^2	Table 4-UUU	Note [2]
D_H	Height of the Window	inch		
D_W	Width of the Window	inch		
PFW	Winter Peak Factor	W per kWh	0.570	Ref [2]
SKW	Summer Coincident Peak Demand Savings	kW		
WKW	Winter Coincident Peak Demand Savings	kW		
$\ldots_b$	Baseline			
$\ldots_{dp}$	Double Pane			
$\ldots_{HP}$	Heat Pump Heating			
$\ldots_R$	Resistance Heating			

Retrofit Gross Energy Savings, Electric

Table 4-TTT: Annual Electric Energy Usage

Window Type	AEH (kWh/ft^2)	AEC (kWh/ft^2)
Single Pane (“leaky”)	28.61	2.65
Single Pane (“tight”)	22.02	2.57
Double Pane (or single with storm)	10.79	2.57
ENERGY STAR	5.66	1.49

Commented [SK376]: Make editorial changes to differentiate between the "Windows" measure and "Storm Windows" measure savings. Currently the savings factor tables, and the window types mentioned are the same across both measures.

The referenced model simulation using RESFEN 5 was performed in 2005. Run the simulations in RESFEN 6 to ensure that the savings are reflective of changes to the most recent values for input variables, namely typical building sizes, HVAC systems, sizing and efficiencies, that affect the savings from this measure.

Savings by heating fuel:

$$A = \frac{D_H \times D_W}{144\, {in^2}/{ft^2}}$$

Heating (Electric Resistive Heating and Heat Pump, Note [1]):

$$AKWH_{H,R} = \left(AEH_b - AEH_{dp}\right) \times A$$
$$AKWH_{H,R} = (22.02 - 10.79) \times A$$
$$AKWH_{H,R} = 11.23 \times A$$
$$AKWH_{H,HP} = 5.62 \times A$$

Retrofit Gross Energy Savings, Fossil Fuel

Table 4-UUU: Annual Natural Gas Energy Usage

Window Type	AGU (kWh/ft^2)	AOU (gal/ft^2)	APU (gal/ft^2)
Single Pane ("leaky")	1.39	1.03	1.57
Single Pane ("tight")	1.08	0.80	1.21
Single Pane with Storm~~Double Pane (or single with storm)~~	0.53	0.39	0.59
~~ENERGY STAR – Double Pane~~	~~0.28~~	~~0.20~~	~~0.31~~
~~ENERGY STAR – Triple Pane~~	~~0.18~~	~~0.13~~	~~0.20~~

Commented [SK377]: "Remove the Energy Star windows energy usage from Table 4-UUU and update the 'Double Pane (or single with storm)' window type to 'Single Pane with Storm'.

Additionally, update the annual electric energy usage deemed values by running the model in RESFEN 6."

Savings by heating fuel:

$$A = \frac{D_H \times D_W}{144 \, {}^{in^2}\!/_{ft^2}}$$

Natural gas:

$$ACCF_H = (AGU_b - AGU_{dp}) \times A = (1.08 - 0.53) \times A$$
$$ACCF_H = 0.55 \times A$$

Oil:

$$AOG_H = (AOU_b - AOU_{dp}) \times A = (0.80 - 0.39) \times A$$
$$AOG_H = 0.41 \times A$$

Propane:

$$APG_H = (APU_b - APU_{dp}) \times A = (1.21 - 0.59) \times A$$
$$APG_H = 0.62 \times A$$

Retrofit Gross Energy Savings, Example

Example: A new storm window is added to a single-pane 24" x 36" window heated by electric resistance.

$$A = \frac{24in \times 36in}{144 \, {}^{in^2}\!/\!_{ft^2}} = 6\,sq\,ft$$

$$AKWH_H = 11.25 \, {}^{kWh}\!/\!_{ft^2} \times 6\,ft^2 = 68\,kWh$$

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

If home has electric resistance heat:

$$WKW = AKWH_{H,R} \times \frac{PFW}{1000 \, {}^{W}\!/\!_{kW}} = 11.23 \, {}^{kWh}\!/\!_{ft^2} \times A \times \frac{0.570 \, {}^{W}\!/\!_{kWh}}{1000 \, {}^{W}\!/\!_{kW}} = 0.0064 \, {}^{kW}\!/\!_{ft^2} \times A$$

*If home has a heat pump: (**Note [1]**):*

$$WKW = \frac{AKWH_{H,R}}{2} \times \frac{PFW}{1000 \, {}^{W}\!/\!_{kW}} = \frac{0.0064 \, {}^{kW}\!/\!_{ft^2}}{2} \times A = 0.0032 \, {}^{kW}\!/\!_{ft^2} \times A$$

$$SKW = 0$$

Retrofit Gross Peak Demand Savings, Example

Example: For the above example with electric resistance heat and central A/C, demand savings are as follows:

$$WKW = 0.0064 \, {}^{kW}\!/\!_{sf} \times 6\,sq\,ft = 0.038\,kW$$

$$SKW = 0\,kW$$

Changes from Last Version

- Fixed Table 4-TTT header.
- Added ENERGY STAR triple-pane windows to Table 4-TTT.

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References

[1]	Lawrence Berkeley National Laboratory, RESFEN 5.0 computer software, May 12, 2005. http://windows.lbl.gov/software.

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[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.

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4.4.6 Insulate Attic Openings

Description of Measure

Thermal barrier applied to uninsulated attic hatch, attic stairs, or whole house fan. This measure is not applicable to multifamily units.

Savings Methodology

The energy savings are estimated in two parts: conductive savings and infiltration reduction savings. The conductive savings are calculated using a degree day analysis. The infiltration reduction will be included in the blower door reduction (Measure 4.4.2~~4~~) whenever possible or be estimated based on the KEMA Evaluation (**Ref [1]**) in combination with ASHRAE 1997 Fundamentals Handbook (**Note [1]**).

Reminder: *Only include infiltration savings, if not included in blower door measure.*

Inputs

Table 4-VVV: 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.)	

Commented [SK378]: Baseline assumptions included no insulation. Description of measure should specify that this is for uninsulated attic hatch, attic stairs, or whole house fan. Result of MA Baseline study forthcoming for insulation.

Commented [SK379]: *After this sentence, add language, "This measure is not applicable to multifamily units."*

Commented [SK380]: As stated in the review of measure 4.4.2, the deemed values are based on a REM/Rate model that was run in 2008. Changes to the model or to the input variables, especially the efficiency of the heating or cooling systems for projects in 2020 compared to 2008, could change the deemed savings factor values. The REM/rate model should be run every 3 years to ensure that the deemed values reflect changes to the model.

Nomenclature

Table 4-WWW: 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-XXX~~EEEE~~	
$ABTU_{Infiltration}$	Annual Btu Savings - Infiltration	Btu/yr	Table 4-~~FFFF~~YYY	
$ACCF_H$	Annual Natural Gas Savings - Heating	ccf/yr	Table 4-AAAA~~HHHH~~	
$AKWH_H$	Annual Electric Savings - Heating	kWh/yr		
$AKWH_{Conductive}$	Annual Electric Savings - Conductive	kWh/yr	Table 4-~~GGGG~~ZZZ	
$AKWH_{Infiltration}$	Annual Electric Savings - Infiltration	kWh/yr	Table 4-~~GGGG~~ZZZ	
AOG_H	Annual Oil Savings - Heating	Gal/yr	Table 4-AAAA~~HHHH~~	
APG_H	Annual Propane Savings - Heating	Gal/yr	Table 4-AAAA~~HHHH~~	
EF	Heating System Efficiency (Fossil fuel)	%	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.~~75%~~	Estimated
F_{adj}	ASHRAE Adjustment Factor		0.64	**Ref [3]**
HDD	Heating Degree Days - CT Average	^{0}F-day	5,885	**Ref [2]**
PD_H	Peak Day Savings - Heating	ccf	Table 4-CCCC~~JJJJ~~	
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	ft^2hr^oF/Btu	Table 4-XXX~~EEEE~~	
R_i	Effective R-value - Installed	ft^2hr^oF/Btu	Table 4-XXX~~EEEE~~	
WKW_H	Winter Seasonal Demand Savings - Heating	kW	Table 4-IIII	

Retrofit Gross Energy Savings, Electric

$$ABTU = ABTU_{Conductive} + ABTU_{Infiltration}$$

Commented [SK381]: Add Dh and Dw, attic opening dimensions to the nomenclature.

Commented [SK382]: 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.

Conductive savings:

$$ABTU_{Conductive} = A \times \left(\frac{1}{R_e} - \frac{1}{R_i}\right) \times HDD \times 24\frac{hrs}{day} \times F_{adj}$$

Commented [SK383]: ERS recommends that the Companies revise the PSD's single statewide CDD and HDD values with two sets of values reflecting coastal and inland climates. This recommendation echoes that of the R91 Impact Evaluation Best Practices study from 2015. Our analysis shows that inland homes (Hartford weather station) will experience 12% higher HDDs and 9% higher CDDs than coastal homes (Bridgeport weather station). These differences are substantial when propagated among thousands of residential projects per year.

Table 4-XXX: Annual Btu Savings - Conductive

Insulation Measure	R_e	R_i	A	$ABTU_{Conductive}$
Attic Hatch	1.69	21.7	5.60	276,202~~065~~
Attic Pull Down Stairs	1.69	11.7	11.25	514,816
Whole House Fan	1.32	11.3	4.00	241,922

Commented [SK384]: Calculation error found in this value as shown in PSD4.4.6 supporting info tab.

Table 4-YYY: Annual Btu Savings - Infiltration

Insulation Measure	$ABTU_{Infiltration}$
Attic Hatch	154,876
Attic Pull Down Stairs	533,461
Whole House Fan	243,195

Reminder: *Only include infiltration savings if not included in blower door measure.*

Annual Electric Savings

$$AKWH_H = AKWH_{Conductive} + AKWH_{Infiltration}$$

$$kWh = \frac{Btu}{3{,}412\,Btu/kWh}$$

Table 4-ZZZ: Annual Electric Savings

Insulation Measure	$AKWH_{Conductive}$ For Electric Resistance	$AKWH_{Infiltration}$ For Electric Resistance	$AKWH_{Conductive}$ For Heat pump	$AKWH_{Infiltration}$ For Heat pump
Attic Hatch	81	45	40.5	22.5
Attic Pull Down Stairs	151	156	75.5	78
Whole House Fan	71	71	35.5	35.5

Reminder: *Only include infiltration savings if not included in blower door measure.*

Retrofit Gross Energy Savings, Fossil Fuel

Using the savings from Table 4-AAAA, Table 4-BBBB, 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 4-AAAA: Annual Fossil Fuel Savings

Insulation Measure	$ACCF_H$		AOG_H		APG_H	
	Cond	Infil	Cond	Infil	Cond	Infil
Attic Hatch	3.6	2.0	2.7	1.5	4.0	2.3
Attic Pull Down Stairs	6.7	6.9	4.9	5.1	7.5	7.8
Whole House Fan	3.1	3.2	2.3	2.3	3.5	3.6

Reminder: *Only include infiltration savings if measure if not included in blower door.*

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

WKW = Annual electric energy savings for heating x PFw/1000

Commented [SK385]: Provide algorithm for winter peak demand savings:

WKW = Annual electric energy savings for heating x PFw/1000

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Table 4-BBBB: Winter Demand Savings

Insulation Measure	$WKW_{H\ Conductive}$	$WKW_{H\ Infiltration}$	$WKW_{H\ Conductive}$ For Heat Pump	$WKW_{H\ Infiltration}$ For Heat Pump

	For Electric Resistance	For Electric Resistance		
Attic Hatch	0.05	0.03	0.02	0.01
Attic Pull Down Stairs	0.09	0.09	0.04	0.04
Whole House Fan	0.04	0.04	0.02	0.02

Retrofit Gross Peak Day Savings, Natural Gas

$$PD_H = ACCF_H \times PDF_H$$

Table 4-CCCC: Peak Day Savings

Insulation Measure	$PD_{Conductive}$	$PD_{Infiltration}$
Attic Hatch	0.03	0.02
Attic Pull Down Stairs	0.07	0.07
Whole House Fan	0.03	0.03

Changes from Last Version

- Format changes.

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References

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[1]	KEMA, *Evaluation of the Weatherization Residential Assistance Partnership and Helps Programs (WRAP/Helps)*, Sep. 10, 2010. Table ES-8, pp. 1-10.
[2]	Degree day data from the National Climatic Data Center, Divisional Data, CT state, Jan. 1979 to Dec. 2008, 30-day average. Available at: http://www7.ncdc.noaa.gov/CDO/CDODivisionalSelect.jsp.
[3]	ASHRAE degree-day correction. *1989 ASHRAE Handbook – Fundamentals*, 28.2, Fig 1.

Notes

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[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.

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[2]	Heat pump energy savings are one half of electric resistance savings based on a 2.0 COP. Since heat pumps use backup resistance heat during winter peak, winter demand savings for heat pumps equals resistance heat demand savings.

4.4.7 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

Commented [SK386]: Account for interactivity between the envelope and other HVAC-related measures.

Savings from this measure shall only be claimed if a Blower Door Test (Measure 4.4.2~~4~~) is not feasible. Savings estimates based on actual measured infiltration reduction (through blower door testing) are more precise.

Note: *Infiltration reduction measures must be located directly between conditioned space and unconditioned space to be eligible for energy savings. Savings may not be claimed for both 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 4-DDDD: 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 4-EEEE: Nomenclature

Symbol	Description	Units	Values	Comments
…gasket	Installation of Air Sealing Gasket on an Electric Outlet	per gasket	Tables 4-FFFF, 4-GGGG	**Ref [1]**, p. 1-11, Table ES 9
…door kit	Installation of Door Sweep or Door Kit	per sweep	Tables 4-FFFF, 4-GGGG	**Ref [1]**, p. 1-11, Table ES 9
…sealing	Foot of Caulking, Sealing, or Polyethylene Tape	per foot	Tables 4-FFFF, 4-GGGG	**Ref [1]**, p. 1-11, Table ES 9
…wx	Window Repaired, Window Weather-stripped, or Door Weather-stripped	per linear foot	Tables 4-FFFF, 4-GGGG	**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.~~0.75~~	
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		
AKHW	Annual Electric Energy Savings	kWh		

Commented [SK387]: Add AKWH - Annual electric energy savings in the table

Commented [SK388]: 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.

Retrofit Gross Energy Savings, Electric

Table 4-FFFF: Electric Savings for Infiltration Reduction Measures

Savings	Units	Annual Savings for Electric Resistance Heating (kWh)	Annual Savings for Heat Pump (kWh)
$AKWH_{gasket}$	kWh per gasket	9	4.5
$AKWH_{door\ kit}$	kWh per sweep	173	86.5
$AKWH_{sealing}$	kWh per linear ft	9.9	4.95
$AKWH_{wx}$	kWh per linear ft	11.5	5.75

Retrofit Gross Energy Savings, Fossil Fuel

$$Annual\ Btu\ Savings = \frac{AKWH \times 3412\ {}^{Btu}\!/_{kWh}}{75\%}$$

Table 4-GGGG: 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

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Commented [SK389]: Recommend adding this to references: Cadmus Group, "High Efficiency Heating Equipment Impact Evaluation Final Report," Mar. 2015, MA

[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

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4.4.8 Wall Insulation

Commented [SK390]: Consider combining wall, ceiling and floor insulation into one measure.

Description of Measure

Installation of insulation in walls that separates conditioned space and unconditioned space, including: unconditioned basements, attics, and crawl spaces.

Savings Methodology

Energy savings are calculated using parallel flow method based on a typical 2x4 wall. Factors 7/12 and -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.*

Inputs

Table 4-HHHH: Inputs

Symbol	Description	Units
R_{pre}	Existing Insulation R-value	$ft^2hrºF/Btu$
R_{post}	Insulation R-value After Upgrade	$ft^2hrºF/Btu$
A	Total Area of Wall Insulation	ft^2
GF	Ground Factor; Percent of Unconditioned Space Walls Above-Grade (rounded to nearest %)	%

Nomenclature

Table 4-IIII: 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		
ABTUH	Annual Heating Savings	Btu/yr		
$ACCF_H$	Annual Natural Gas Savings	ccf/yr		
AKWH	Annual Electric Energy Savings	kWh/yr		
$AKWH_{H,HP}$	Annual Electric Savings due to Heat Pump Heating	kWh/yr		
$AKWH_{H,R}$	Annual Electric Savings due to Electric Resistance Heating	kWh/yr		
AOG_H	Annual Savings for Oil Heat	Gal/yr/unit		
APG_H	Annual Savings for Propane Heat	Gal/yr/unit		
GF	**Above Grade:** Adjustment for a wall between conditioned and ambient space which is 100% above grade (0 % below grade). This includes cold (uninsulated or open) crawl spaces and cantilever floors		1.0	Note [3]
	Mixed Grade: Adjustment for a wall between conditioned and ambient space which is between 31% and 99% above grade (inclusive) on average		0.75	Note [3]
	Below Grade: Adjustment for a wall between conditioned and ambient space which is between 0% and 30% above grade (inclusive) on average (e.g., a typical below grade basement)		0.60	Notes [3]
CF	Summer Seasonal Peak Coincidence Factor		0.59	Appendix One
COP	COP of Heat Pump		2.4	
EER_B	Energy Efficiency Ratio, Baseline	Btu/Watt-hr	11	
EF	Heating System Efficiency	%	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. ~~75~~	Estimated
F_{adj}	ASHRAE Adjustment Factor		0.64	Ref [1]
HDD	Heating Degree Days, CT State Average	^{0}F-day	5,885	Ref [2]

Commented [SK391]: Add ABTUH = Annual heating savings in BTU/yr

Commented [SK392]: Include COP of heat pump in nomenclature

Commented [KR393]: No reference is provided for the assumed COP value of 2 for a heat pump. The federal minimum efficiency standard for heat pumps is HSPF 8.2, as of Jan. 1, 2015, which converts to a COP value of 2.4. The current PSD value of 2 COP is lower than the federal minimum. Consider updating the COP value to federal minimum efficiency standard or more appropriate COP value for systems in Connecticut based on additional research.

Commented [SK394]: 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.
The referenced MA study from 2015 was determined to be the most appropriate source for these baseline efficiency values and found that the study did consider system efficiencies and not just unit efficiencies. However, we agree that updated CT-specific values would be most appropriate to use if available.

PDF_H	Peak Day Factor - Heating		0.00977	Appendix One
PD_H	Peak Day Savings - Heating			
$R_{existing}$	Effective R-value Before Upgrade	ft²hrºF/Btu		Existing insulation R-value if known. Default, IECC 2003 code where existing value is unknown.
R_{new}	Effective R-value After Upgrade	ft²hrºF/Btu		
R_{pre}	Existing Insulation R-value	ft²hrºF/Btu		
R_{post}	Insulation R-value After Upgrade	ft²hrºF/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 Air Conditioner			
…RAC	Room Air Conditioners (Cooling Only)			Note [1]

Retrofit Gross Energy Savings, Electric

Effective R-value:

$$R_{existing} = \left(\frac{7}{12} \times R_{pre}\right) + 4 \quad \cancel{R_{existing} = \left(\frac{7}{12} \times R_{pre}\right) + 4}$$

$$R_{new} = \left(\frac{7}{12} \times R_{post}\right) + 4 \quad \cancel{R_{new} = \left(\frac{7}{12} \times R_{post}\right) + 4}$$

Heating savings:

$$ABTU_H = \left(\frac{1}{R_{existing}} - \frac{1}{R_{new}}\right) \times HDD \times 24 \times F_{Adj} \times A \times GF$$

For electric resistance heating:

$$AKWH_{H,R} = \frac{ABTU_H}{3{,}412}$$

Commented [SK395]: Existing insulation R-value if known. ERS recommends using IECC 2003 code where existing value is not known.

Commented [SK396]: "Peak temperature data can vary across cities in the state. Using bin data from Hartford alone may not be accurate.
ERS recommends that the Companies revise the PSD's single statewide CDD and HDD values with two sets of values reflecting coastal and inland climates. This recommendation echoes that of the R91 Impact Evaluation Best Practices study from 2015. Our analysis shows that inland homes (Hartford weather station) will experience 12% higher HDDs and 9% higher CDDs than coastal homes (Bridgeport weather station). These differences are substantial when propagated among thousands of residential projects per year."

Commented [SK397]: Account for interactivity between the envelope and other HVAC-related measures.

Commented [SK398]: The (7/12 x R + 4) factor is accounting for uninsulated wall assembly R -value.
R Effective Whole Wall Assembly of 4 is explained in Note [2] but 7/12 factor is not justified/ no reference is provided.
The reference added for R-values is not valid
This factor involves an assumption that 25% of the wall area is framing, without any reference. Also assumes 2x4 column framing with 4" insulation depth, whereas 2x6 column framing with 6" insulation depth is relatively common in newer construction.
A valid reference for R existing and R new equation should be provided.
Consider using a table of factors for framing type instead of assuming relative area of framing. We found an ASHRAE reference for framing factors in the Mid Atlantic TRM.
Further secondary research would be beneficial to identify a defensible method to calculate effective R value.

Commented [SK399]: Region specific HDD will be more accurate than state average. Additionally, there is an Upcoming MA Baseline Study Evaluation that is slated to wrap up at the end of the 2020 summer season. The results of this study should be incorporated into the PSD if possible.
Also, R91 - Review of Impact Evaluation Best Practices (pg 73) included that some areas in the state have notably lower HDDs than reflected by the statewide average or Hartford weather profiles and recommended to consider whether additional weather and location assumptions can improve savings estimates.

ERS recommends that the Companies revise the PSD's single statewide CDD and HDD values with two sets of values reflecting coastal and inland climates. This recommendation echoes that of the R91 Impact Evaluation Best Practices study from 2015. Our analysis shows that inland homes (Hartford weather station) will experience 12% higher HDDs and 9% higher CDDs than coastal homes (Bridgeport weather station). These differences are substantial when propagated among thousands of residential projects per year.

For a heat pump:

$$AKWH_{H,HP} = \frac{AKWH_{H,R}}{2}$$

Commented [SK400]: No reference is provided for the assumed COP value of 2 for a heat pump. The federal minimum efficiency standard for heat pumps is HSPF 8.2, as of Jan. 1, 2015, which converts to a COP value of 2.4. The current PSD value of 2 COP is lower than the federal minimum. Consider updating the COP value to federal minimum efficiency standard or more appropriate COP value for systems in Connecticut based on additional research.

Cooling savings (CAC 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 (RAC 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?

$$R_{existing} = \left(\frac{7}{12} \times R_{pre}\right) + 4 = \left(\frac{7}{12} \times 6\right) + 4 = 7.5 \; \cancel{R_{existing} = \left(\frac{7}{12} \times R_{pre}\right) + 4 = \left(\frac{7}{12} \times 6\right) + 4 = 7.5}$$

$$R_{new} = \left(\frac{7}{12} \times R_{post}\right) + 4 = \left(\frac{7}{12} \times 13\right) + 4 = 11.6 \; \cancel{R_{new} = \left(\frac{7}{12} \times R_{post}\right) + 4 = \left(\frac{7}{12} \times 13\right) + 4 = 11.6}$$

Using the equation for heating savings:

$$ABTU_H = \left(\frac{1}{R_{existing}} - \frac{1}{R_{new}}\right) \times HDD \times 24 \times F_{Adj} \times A \times GF$$

$$ABTU_H = \left(\frac{1}{7.5} - \frac{1}{11.6}\right) \times 5885 \times 24 \times 0.64 \times 100 \times 1$$

$$ABTU_H = 425{,}993\ Btu$$

Heating savings for electric resistance system:

$$AKWH_{H,R} = \frac{ABTU_H}{3{,}412}$$

$$AKWH_{H,R} = \frac{ABTU_H}{3{,}412}$$

$$AKWH_{H,R} = \frac{ABTU_H}{3{,}412} = 124.8\ kWh\ \cancel{AKWH_{H,R} = \frac{ABTU_H}{3{,}412} = 124.8\ kWh}$$

Using the equation for cooling savings:

$$AKWH_C, CAC = \left(\frac{1}{R_{existing}} - \frac{1}{R_{new}}\right) \times \Delta T_{bin} \times A \times \frac{1}{SEER_B \times 1000}$$

$$AKWH_{C,CAC} = \left(\frac{1}{7.5} \times \frac{1}{11.6}\right) \times 3{,}888 \times 100 \times \frac{1}{13 \times 1{,}000} = 1.4\ kWh$$

$$\cancel{AKWH_{C,CAC} = \left(\frac{1}{7.5} \times \frac{1}{11.6}\right) \times 3{,}888 \times 100 \times \frac{1}{13 \times 1{,}000} = 1.4\ kWh}$$

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

For homes with electric resistance heat:

$$WKW = \frac{AKWH_H(Electric\_Resistance)}{1{,}000} \times WPF$$

$$WKW = \frac{AKWH_H(Electric\_Resistance)}{1{,}000} \times 0.57$$

$$WKW = \frac{AKWH_H(Electric\_Resistance)}{1{,}000} \times WPF$$

$$WKW = \frac{AKWH_H(Electric\_Resistance)}{1{,}000} \times 0.57$$

For homes with a heat pump:

$$WKW = \frac{AKWH_H}{1{,}000} \times 0.57$$

For CAC 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 RAC 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?

$$WKW = \frac{AKWH_H(Electric\_Resistance)}{1{,}000} \times 0.57$$

$$\cancel{WKW = \frac{AKWH_H(Electric\_Resistance)}{1{,}000} \times 0.57}$$

From the previous example, AKWHH = 124.8 kWh, therefore:

$$WKW = \frac{124.8}{1{,}000} \times 0.57 = 0.071\ kW$$

$$\cancel{WKW = \frac{124.8}{1{,}000} \times 0.57 = 0.071\,kW}$$

Using the equation:

$$SKW_{CAC} = CF \times \left(\frac{1}{R_{existing}} - \frac{1}{R_{new}} \right) \times \Delta T_{Summer} \times A \times \frac{1}{EER_B \times 1{,}000}$$

$$SKW_{CAC} = 0.59 \times \left(\frac{1}{7.5} - \frac{1}{11.6} \right) \times 20.5 \times 100 \times \frac{1}{11 \times 1{,}000} = 0.0052\ kW$$

$$\cancel{SKW_{CAC} = 0.59 \times \left(\frac{1}{7.5} - \frac{1}{11.6} \right) \times 20.5 \times 100 \times \frac{1}{11 \times 1{,}000} = 0.0052\ kW}$$

Changes from Last Version

- Format changes.

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References

[1]	ASHRAE degree-day correction. *1989 ASHRAE Handbook – Fundamentals*, 28.2, Fig 1.
[2]	Degree Day data from the National Climatic Data Center, Divisional Data, CT state, Jan. 1979 to Dec 2008, 30-year average. Available at: http://www7.ncdc.noaa.gov/CDO/CDODivisionalSelect.jsp.
[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. Table ES-8, pp. 1-10.
[5]	Nexant Market Research, Inc., "*Market Assessment for ENERGY STAR Room Air Conditioners in Connecticut*," Cambridge, MA, 2007, pp. 17, 18.
[6]	RLW Analytics, "*Final Report: Coincidence Factor Study: Residential Room Air Conditioners*," Middletown, CT, 2008, pp. iv and 22.
[7]	ADM Associates, Inc., "*Residential Central A/C Regional Evaluation*," Sacramento, CA, 2009, p. 4-4.

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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 4-JJJJ below.

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Table 4-JJJJ: 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.

Commented [SK401]: This reference link needs to be updated.

4.4.9 Ceiling Insulation

Commented [SK402]: Consider combining wall, ceiling and floor insulation measures into one measure.

Description of Measure

Installation of batt or loose fill insulation located between conditioned area and ambient (attic or outside) space.

Savings Methodology

Commented [SK403]: Account for interactivity between the envelope and other HVAC-related measures as recommended by R91 study.

Energy savings are calculated using parallel flow method and typical ceiling structure. The savings are calculated using a degree day analysis and the difference in the pre and post R-values. The conductive savings are calculated using a degree day analysis. 0.5, 3, and 2 are factors used to adjust for typical wall structure/framing.

Note: *The savings presented here do not apply to ceilings between conditioned spaces and fully enclosed unconditioned spaces, such as basement ceilings. It is assumed that attics are properly ventilated to the outside.*

Inputs

Table 4-KKKK: Inputs

Symbol	Description	Units
R_{pre}	Existing Insulation R-Value	ft^{2}hrºF/Btu
R_{post}	Insulation R-value after Upgrade	ft^{2}hrºF/Btu
A	Total Gross Area of Ceiling Insulation	ft^2

Nomenclature

Table 4-LLLL: Nomenclature

Symbol	Description	Units	Values	Comments
A	Total Gross Area of Ceiling Insulation	ft^2		
ABTUH	Annual Heating Savings	Btu/hr		
AKWH	Annual Electric Energy Savings	kWh		
$ACCF_H$	Annual Natural Gas Savings	ccf/yr		
~~AKWH~~	~~Annual Electric Energy Savings~~	~~kWh/yr~~		
$AKWH_{H,HP}$	Annual Electric Savings due to Heat Pump Heating	kWh/yr		
$AKWH_{H,R}$	Annual Electric Savings due to Electric Resistance Heating	kWh/yr		
AOG_H	Annual Savings for Oil Heat	Gal/yr/unit		
APG_H	Annual Savings for Propane Heat	Gal/yr/unit		
CF	Summer Seasonal Peak Coincidence Factor		0.59	Appendix One
COP	COP of Heat Pump		2.4	
EER_B	Energy Efficiency Ratio, Baseline	Btu/Watt-hr	11	
EF	Heating System Efficiency (fossil fuel)	%	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.~~75%~~	Estimated
F_{adj}	ASHRAE Adjustment Factor		0.64	Ref [1]
HDD	Heating Degree Days, CT State Average	^0F-day	5,885	Ref [2]
PD_H	Peak Day Savings - Heating			
PDF_H	Peak Day Factor - Heating		0.00977	Appendix One
$R_{existing}$	Effective R-value before Upgrade	ft^2hr^oF/Btu	Calculated	Existing insulation R-value if known. Default, IECC 2003 code where existing value is unknown.

Commented [SK404]: ABTUH = Annual heating savings in BTU/yr to Nomenclature table

Commented [SK405]: Include COP of heat pump in nomenclature

Commented [SK406]: These values (EER and SEER) are based on the referenced 2017 NMR evaluation study. Since the ceiling insulation measure would impact the cooling system, but not the duct losses, using these values seems appropriate. We recommend that DHP baseline should be looked into and updated if different.

Commented [SK407]: 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.
The referenced MA study from 2015 was determined to be the most appropriate source for these baseline efficiency values and found that the study did consider system efficiencies and not just unit efficiencies. However, we agree that updated CT-specific values would be most appropriate to use if available.

Commented [SK408]: Existing insulation R-value if known. ERS recommends using IECC 2003 code where existing value is unknown.

R_{new}	Effective R-value after Upgrade	ft²hrºF/Btu	Calculated	
R_{pre}	Existing Insulation R-value	ft²hrºF/Btu	Input	
R_{post}	Insulation R-value after Upgrade	ft²hrºF/Btu	Input	
$SEER_B$	Seasonal Energy Efficiency Ratio, Baseline	Btu/Watt-hr	13	
SKW	Summer Peak Demand Savings	kW		
WKW	Winter Peak Demand Savings	kW		
WPF	Winter Peak Factor	W/ kWh	0.57	**Ref [4]**
ΔT_{BIN}	It is the sum of the temperature BIN hours (based on Hartford) times delta between outside summer air for each BIN and average indoor temperature. (T_i = 76.5ºF)		3,888	**Ref [3]**a
ΔT_{summer}	Temperature Difference (peak $T_{outside}$ = 97ºF, T_{inside} = 76.5ºF)	ºF	20.5ºF	**Ref [3] a** and **Ref 3 [b]**
$\ldots_{H,R}$	Electric Resistance Heating			
$\ldots_{H,HP}$	Heat Pump Heating			
$\ldots_{C,CAC}$	Central A/C Cooling			
$\ldots_{C,RAC}$	Room A/C Cooling			**Note [1]**

Commented [SK409]: Bin data can vary for costal and non-coastal cities in the state. Using bin data from Hartford alone may not be accurate.
Additionally, there is an upcoming MA Baseline Study Evaluation that is slated to wrap up at the end of the 2020 summer season. The results of this study should be incorproated into the PSD if possible.
ERS recommends that the Companies revise the PSD's single statewide CDD and HDD values with two sets of values reflecting coastal and inland climates. This recommendation echoes that of the R91 Impact Evaluation Best Practices study from 2015. Our analysis shows that inland homes (Hartford weather station) will experience 12% higher HDDs and 9% higher CDDs than coastal homes (Bridgeport weather station). These differences are substantial when propagated among thousands of residential projects per year.

Commented [SK410]: Peak temperature data can vary across cities in the state. Using bin data from Hartford alone may not be accurate.
ERS recommends that the Companies revise the PSD's single statewide CDD and HDD values with two sets of values reflecting coastal and inland climates. This recommendation echoes that of the R91 Impact Evaluation Best Practices study from 2015. Our analysis shows that inland homes (Hartford weather station) will experience 12% higher HDDs and 9% higher CDDs than coastal homes (Bridgeport weather station). These differences are substantial when propagated among thousands of residential projects per year.

Retrofit Gross Energy Savings, Electric

Table 4-MMMM: Effective R-values

If	Use
R_{pre} <10	$R_{existing} = (0.5 \times R_{pre}) + 3$
If R_{pre} >=10	$R_{existing} = R_{pre} - 2$
R_{post} <10	$R_{new} = (0.5 \times R_{post}) + 3$
R_{post} >=10	$R_{new} = R_{post} - 2$

$$ABTU_H = \left(\frac{1}{R_{existing}} - \frac{1}{R_{new}} \right) \times HDD \times 24 \times F_{Adj} \times A$$

For electric resistance heating savings:

$$AKWH_{H,R} = \frac{ABTU_H}{3{,}412 \, {}^{Btu}\!/_{kWh}}$$

For heat pump:

$$AKWH_{H,HP} = \frac{AKWH_{H,R}}{2}$$

Cooling savings (CAC only):

$$AKWH_{C,CAC} = \left(\frac{1}{R_{existing}} - \frac{1}{R_{new}} \right) \times \Delta T_{Bin} \times A \times \frac{1}{SEER_B \times 1{,}000}$$

*Cooling savings (RAC only), **Note [1]**:*

$$AKWH_{C,RAC} = (28.3\%) \times AKWH_{C,CAC}$$

Commented [SK411]: No basis was provided for estimating effective R-Value and could not verify algorithm. Further secondary research would be beneficial to identify a defensible method to calculate effective R value.

Commented [SK412]: Region specific HDD will be more accurate than state average. Additionally, there is an Upcoming MA Baseline Study Evaluation that is slated to wrap up at the end of the 2020 summer season. The results of this study should be incorporated into the PSD if possible.
Also, R91 - Review of Impact Evaluation Best Practices (pg 73) included that some areas in the state have notably lower HDDs than reflected by the statewide average or Hartford weather profiles and recommended to consider whether additional weather and location assumptions can improve savings estimates.

ERS recommends that the Companies revise the PSD's single statewide CDD and HDD values with two sets of values reflecting coastal and inland climates. This recommendation echoes that of the R91 Impact Evaluation Best Practices study from 2015. Our analysis shows that inland homes (Hartford weather station) will experience 12% higher HDDs and 9% higher CDDs than coastal homes (Bridgeport weather station). These differences are substantial when propagated among thousands of residential projects per year.

Commented [SK413]: No reference is provided for the assumed COP value of 2 for a heat pump. The federal minimum efficiency standard for heat pumps is HSPF 8.2, as of Jan. 1, 2015, which converts to a COP value of 2.4. The current PSD value of 2 COP is lower than the federal minimum. Consider updating the COP value to federal minimum efficiency standard or more appropriate COP value for systems in Connecticut based on additional research.

Retrofit Gross Energy Savings, Fossil Fuel

$$ACCF_H = \frac{ABTU_H}{75\% \times 102{,}900\, {}^{Btu}\!/_{Ccf}}$$

$$APG_H = \frac{ABTU_H}{75\% \times 91{,}330\, {}^{Btu}\!/_{Gal}}$$

$$AOG_H = \frac{ABTU_H}{75\% \times 138{,}690\, {}^{Btu}\!/_{Gal}}$$

Reminder: *System Efficiency is 75%.*

Retrofit Gross Energy Savings, Example

Example: Ceiling insulation in a house is upgraded from R-9 to a total of R-60. The total square feet insulation added is 1,000. The home is heated by electric resistance heating system and has a CAC. What are the annual electric energy savings?

Since Rpre <10:

$$R_{existing} = (0.5 \times R_{pre}) + 3$$

$$R_{existing} = (0.5 \times 9) + 3 = 7.5$$

Since Rpost >=10:

$$R_{new} = R_{post} - 2$$

$$R_{new} = 60 - 2 = 58$$

$$ABTU_H = \left(\frac{1}{R_{existing}} - \frac{1}{R_{new}}\right) \times HDD \times 24 \times F_{Adj} \times A$$

$$ABTU_H = \left(\frac{1}{7.5} - \frac{1}{58}\right) \times 5{,}885 \times 24 \times 0.64 \times 1000 = 10{,}493{,}969\ Btu$$

$$AKWH_{H,R} = \frac{ABTU_H}{3{,}412\, {}^{Btu}\!/_{kWh}}$$

$$AKWH_{H,R} = \frac{10{,}493{,}969\ Btu}{3{,}412\, {}^{Btu}\!/_{kWh}} = 3075\, kWh$$

$$AKWH_C, CAC = \left(\frac{1}{R_{existing}} - \frac{1}{R_{new}}\right) \times \Delta T_{bin} \times A \times \frac{1}{SEER_B \times 1000}$$

$$AKWH_{C,CAC} = \left(\frac{1}{7.5} - \frac{1}{58}\right) \times 3{,}888 \times 1{,}000 \times \frac{1}{13 \times 1{,}000} = 35kWh$$

$$\cancel{AKWH_{C,CAC} = \left(\frac{1}{7.5} - \frac{1}{58}\right) \times 3{,}888 \times 1{,}000 \times \frac{1}{13 \times 1{,}000} = 35kWh}$$

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

For homes with electric resistance heat:

$$WKW = \frac{AKWH_{H,R}}{1{,}000} \times WPF$$

$$WKW = \frac{AKWH_{H,R}}{1{,}000} \times 0.57$$

For homes with a heat pump:

$$WKW = \frac{AKWH_{H,HP}}{1{,}000} \times 0.57$$

For homes with CAC only or heat pump providing cooling:

$$SKW_{C,CAC} = CF \times \left(\frac{1}{R_{existing}} - \frac{1}{R_{new}}\right) \times \Delta T_{Summer} \times A \times \frac{1}{EER_B \times 1{,}000}$$

$$\cancel{SKW_{C,CAC} = CF \times \left(\frac{1}{R_{existing}} - \frac{1}{R_{new}}\right) \times \Delta T_{Summer} \times A \times \frac{1}{EER_B \times 1{,}000}}$$

$$SKW_{C,CAC} = CF \times \left(\frac{1}{R_{existing}} - \frac{1}{R_{new}}\right) \times 20.5 \times A \times \frac{1}{11 \times 1{,}000}$$

$$\cancel{SKW_{C,CAC} = CF \times \left(\frac{1}{R_{existing}} - \frac{1}{R_{new}}\right) \times 20.5 \times A \times \frac{1}{11 \times 1{,}000}}$$

*For homes with RAC only, (**Note [1]**):*

$$SKW_{C,RAC} = (25.1\%) \times SKW_{C,CAC} \; \cancel{SKW_{C,RAC} = (25.1\%) \times SKW_{C,CAC}}$$

Retrofit Gross Peak Day Savings, Natural Gas

$$PDF_H = 0.00977$$

$$PD_H = ACCF_H \times PDF_H \; \cancel{PD_H = ACCF_H \times PDF_H}$$

Retrofit Gross Peak Demand Savings, Example

<u>Example</u>: Ceiling insulation in a house is upgraded from R-9 to a total of R-60. The total square feet insulation added is 1,000. The home is heated by electric resistance heating system and has CAC. What are the demand savings?

<u>Using the equation for winter demand savings</u>:

$$WKW = \frac{AKWH_{H,R}}{1{,}000} \times 0.57$$

<u>From previous example, AKWHH = 308 kWh. Therefore</u>:

$$WKW = \frac{3075}{1{,}000} \times 0.57 = 1.75\,kW$$

<u>Using the equation for summer demand savings:</u>

$$SKW_{C,CAC} = CF \times \left(\frac{1}{R_{existing}} - \frac{1}{R_{new}} \right) \times \Delta T_{Summer} \times A \times \frac{1}{EER_B \times 1{,}000}$$

$$SKW_{C,CAC} = 0.59 \times \left(\frac{1}{7.5} - \frac{1}{58} \right) \times 20.5 \times 1000 \times \frac{1}{11 \times 1{,}000}$$

$$SKW_{C,CAC} = 0.127\,kW$$

Changes from Last Version

- Format changes.

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References

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[1]	ASHRAE degree-day correction. *1989 ASHRAE Handbook – Fundamentals*, 28.2, Fig 1.
[2]	Degree Day data from the National Climatic Data Center, Divisional Data, CT state, Jan. 1979 to Dec. 2008, 30-year average.
[3]	*Residential Central A/C Regional Evaluation*, ADM Associates, Inc., Nov. 2009, a) Table B-4 (Hartford), p. B-9 and b) Figures 4-1 and 2 (Hartford), and pp. 4-15.
[4]	KEMA, *Evaluation of the Weatherization Residential Assistance Partnership and Helps Programs (WRAP/Helps)*, Sep. 10, 2010. Table ES-8, pp. 1-10.
[5]	Nexant Market Research, Inc., "Market Assessment for ENERGY STAR Room Air Conditioners in Connecticut," Cambridge, MA, 2007, pp. 17-18.
[6]	RLW Analytics, "*Final Report: Coincidence Factor Study: Residential Room Air Conditioners*," Middletown, CT, 2008, pp. iv and 22.

[7]	ADM Associates, Inc., "*Residential Central/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].

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4.4.10 Floor Insulation

Commented [SK414]: Three individual measures with similar savings algorithm for wall, ceiling, and floor insulation. Consider combining three measures into one.

Description of Measure

Installation of insulation in a floor that separates conditioned space and unconditioned space, including unconditioned basements, unconditioned garages, and crawl spaces.

Savings Methodology

Commented [SK415]: We recommend including interactivity per R91 - Review of Impact Evaluation Best Practices [2016] - recommendation "Account for interactivity between HVAC and envelope measures" pg 73.

Energy savings are calculated using parallel flow method and typical ceiling structure. The savings are calculated using a degree day analysis and the difference in the pre and post R-values with an adjustment to account for floors over tempered space.

Note: *This measure is only applicable to floors over unconditioned spaces where the walls of the unconditioned space are not insulated (**Note [1]**). This measure only has heating savings associated with it.*

Inputs

Table 4- NNNN: Inputs

Symbol	Description	Units
R_{pre}	Existing Insulation R-value	ft²hrºF/Btu
R_{post}	Insulation R-value after Upgrade	ft²hrºF/Btu
A	Total Gross Area of Floor ~~Ceiling~~ Insulation	ft²
GF	Ground Factor; Percent of Unconditioned Space Walls Above Grade (rounded to nearest %)	%

Commented [SK416]: Existing Insulation if known. Where unknown use IECC 2003 code.

Nomenclature

Table 4-OOOO: Nomenclature

Symbol	Description	Units	Values	Comments
A	Total Gross Area of Ceiling Insulation	ft^2		
ABTUH	Annual Heating Savings	Btu/hr		
AKWH	Annual Electric Energy Savings	kWh		
$ACCF_H$	Annual Natural Gas Savings	ccf/yr		
~~AKWH~~	~~Annual Electric Energy Savings~~	~~kWh/yr~~		
$AKWH_{H,HP}$	Annual Electric Savings due to Heat Pump Heating	kWh/yr		
$AKWH_{H,R}$	Annual Electric Savings due to Electric Resistance Heating	kWh/yr		
AOG_H	Annual Savings for Oil Heat	Gal/yr/unit		
APG_H	Annual Savings for Propane Heat	Gal/yr/unit		
COP	Heat Pump COP	2.4		
GF	**Above Grade**: Adjustment for a floor over unconditioned Space which is 100% above grade (0 % below grade). This includes cold (uninsulated or open) crawl spaces and cantilever floors		1.0	Note [2]
	Mixed Grade: Adjustment for a floor over unconditioned space which is between 31% and 99% above grade (inclusive) on average		0.75	Note [2]
	Below Grade: Adjustment for floors over unconditioned space which is between 0% and 30% above grade (inclusive) on average e.g. a typical below grade basement		0.60	Note [2]
EF	Heating System Efficiency (fossil fuel)	%	~~75~~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.~~%~~	Estimated
F_{adj}	ASHRAE Adjustment Factor		0.64	Ref [1]
HDD	Heating Degree Days, CT State Average	^{0}F-day	5,885	Ref [2]
PD_H	Peak Day Savings - Heating			
PDF_H	Peak Day Factor - Heating		0.00977	Appendix One
$R_{existing}$	Effective R-value before Upgrade	ft²hrºF/Btu	Calculated	Use existing Insulation if known.

Commented [SK417]: Add ABTU$_H$, Annual Heating Savings in BTU/yr, for consistency.

Commented [SK418]:

Commented [SK419R418]: Delete repeated line item.

Commented [SK420]: 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.
The referenced MA study from 2015 was determined to be the most appropriate source for these baseline efficiency values, and found that the study did consider system efficiencies and not just unit efficiencies. However, we agree that updated CT-specific values would be most appropriate to use if available.

				Where unknown use IECC 2003 code.
R_{new}	Effective R-value after Upgrade	ft²hrºF/Btu	Calculated	
R_{pre}	Existing Nominal Insulation R-value	ft²hrºF/Btu	Input	
R_{post}	Insulation Nominal R-value after Upgrade	ft²hrºF/Btu	Input	
WKW	Winter Peak Demand Savings	kW		
WPF	Winter Peak Factor	W/kWh	0.57	Ref [4]
$\ldots_{H,R}$	Electric Resistance Heating			
$\ldots_{H,HP}$	Heat Pump Heating			

Commented [SK421]: There is no reference [4] in the document.

Retrofit Gross Energy Savings, Electric

Commented [SK422]: Region specific HDD will be more accurate than state average. Additionally, there is an Upcoming MA Baseline Study Evaluation that is slated to wrap up at the end of the 2020 summer season. The results of this study should be incorporated into the PSD if possible. Also, R91 - Review of Impact Evaluation Best Practices (pg 73) included that some areas in the state have notably lower HDDs than reflected by the statewide average or Hartford weather profiles and recommended to consider whether additional weather and location assumptions can improve savings estimates.

ERS recommends that the Companies revise the PSD's single statewide CDD and HDD values with two sets of values reflecting coastal and inland climates. This recommendation echoes that of the R91 Impact Evaluation Best Practices study from 2015. Our analysis shows that inland homes (Hartford weather station) will experience 12% higher HDDs and 9% higher CDDs than coastal homes (Bridgeport weather station). These differences are substantial when propagated among thousands of residential projects per year.

$$ABTU_H = \left(\frac{1}{R_{existing}} - \frac{1}{R_{new}}\right) \times HDD \times 24 \times F_{Adj} \times A \times GF$$

$$\cancel{ABTU_H = \left(\frac{1}{R_{existing}} - \frac{1}{R_{new}}\right) \times HDD \times 24 \times F_{Adj} \times A \times GF}$$

Where:

$$R_{(existing)} = 0.55 \times R_{(pre)} + 3.9$$

$$R_{(new)} = 0.55 \times R_{(post)} + 3.9$$

$$R_{(existing)} = 0.55 \times R_{(pre)} + 3.9$$

$$R_{(new)} = 0.55 \times R_{(post)} + 3.9$$

Commented [SK423]: No basis was provided for estimating effective R-Value and could not verify algorithm. Further secondary research would be beneficial to identify a defensible method to calculate effective R value.

For electric resistance heating savings:

$$AKWH_{H,R} = \frac{ABTU_H}{3{,}412\ ^{Btu}/_{kWh}}$$

For heat pumps:

$$AKWH_{H,HP} = \frac{AKWH_{H,R}}{2}$$

Commented [SK424]: No reference provided for the assumed COP value of 2 for a heat pump. The federal minimum efficiency standard for heat pumps is HSPF 8.2, as of Jan. 1, 2015, which converts to a COP value of 2.4. The current PSD value of 2 COP is lower than the federal minimum. Consider updating the COP value to federal minimum efficiency standard or more appropriate COP value for systems in Connecticut.

Retrofit Gross Energy Savings, Fossil Fuel

$$ACCF_H = \frac{ABTU_H}{75\% \times 102{,}900\ ^{Btu}/_{Ccf}}$$

$$APG_H = \frac{ABTU_H}{75\% \times 91{,}330\ ^{Btu}/_{Gal}}$$

$$AOG_H = \frac{ABTU_H}{75\% \times 138{,}690\ ^{Btu}/_{Gal}}$$

<u>Reminder</u>: *System efficiency is 75%.*

Retrofit Gross Energy Savings, Example

<u>Example</u>: R-19 insulation is added to the floor over an unconditioned basement in a house. The basement walls are primarily mixed grade. The total square feet insulation added is 1,000 and the floor does not have any existing insulation. The home is heated by electric resistance heating system. What are the annual electric energy savings?

<u>Step 1: Calculate the effective R-values (Rexisting and Rnew)</u>:

<u>Determine R(existing)</u>:

$$R_{(existing)} = 0.55 \times R_{(pre)} + 3.9$$

$$R_{(existing)} = 0.55 \times R_{(pre)} + 3.9$$

$$R_{(existing)} = 0.55 \times 0 + 3.9 = 3.9$$

$$R_{(existing)} = 0.55 \times 0 + 3.9 = 3.9$$

<u>Determine R(new)</u>:

$$R_{(new)} = 0.55 \times R_{(post)} + 3.9$$

$$R_{(new)} = 0.55 \times R_{(post)} + 3.9$$

$$R_{(new)} = 0.55 \times 19 + 3.9 = 14.35$$

$$R_{(new)} = 0.55 \times 19 + 3.9 = 14.35$$

<u>Step 2: Determine the Ground Factor ("GF") and calculate savings</u>:

Since the basement below the floor is primarily mixed grade, the GF = 0.75.

$$ABTU_H = \left(\frac{1}{R_{existing}} - \frac{1}{R_{new}}\right) \times HDD \times 24 \times F_{Adj} \times A \times GF$$

$$\cancel{ABTU_H = \left(\frac{1}{R_{existing}} - \frac{1}{R_{new}}\right) \times HDD \times 24 \times F_{Adj} \times A \times GF}$$

$$ABTU_H = \left(\frac{1}{3.9} - \frac{1}{14.35}\right) \times 5{,}885 \times 24 \times 0.64 \times 1000 \times 0.75 = 12{,}658{,}980.43 Btu$$

$$\cancel{ABTU_H = \left(\frac{1}{3.9} - \frac{1}{14.35}\right) \times 5{,}885 \times 24 \times 0.64 \times 1000 \times 0.75 = 12{,}658{,}980.43 Btu}$$

$$AKWH_{H,R} = \frac{ABTU_H}{3{,}412\,{}^{Btu}\!/_{kWh}}$$

$$AKWH_{H,R} = \frac{12{,}658{,}980.43}{3{,}412} = 3{,}710.1\,kWh \quad \cancel{AKWH_{H,R} = \frac{12{,}658{,}980.43}{3{,}412} = 3{,}710.1\,kWh}$$

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

For homes with electric resistance heat:

$$WKW = \frac{AKWH_{H,R}}{1{,}000} \times WPF$$

$$WKW = \frac{AKWH_{H,R}}{1{,}000} \times 0.57$$

For homes with a heat pump:

$$WKW = \frac{AKWH_{H,HP}}{1{,}000} \times 0.57$$

Retrofit Gross Peak Day Savings, Natural Gas

$$PD_H = ACCF_H \times PDF_H \quad \cancel{PD_H = ACCF_H \times PDF_H}$$

Retrofit Gross Peak Demand Savings, Example

Example: R-19 insulation is added to the floor over an unconditioned basement in a house. The basement walls are primarily mixed grade. The total square feet insulation added is 1,000 and the floor does not have any existing insulation. The home is heated by electric resistance heating system. What are the demand savings?

Using the equation for winter demand savings:

$$WKW = \frac{AKWH_{H,R}}{1{,}000} \times 0.57$$

From previous example, AKWHH,R = 3957.5 kWh. Therefore:

$$WKW = \frac{3710.1}{1,000} \times 0.57 = 2.11kW$$ $$\cancel{WKW = \frac{3710.1}{1,000} \times 0.57 = 2.11kW}$$

Changes from Last Version

- Format changes.

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References

[1]	ASHRAE degree-day correction. *1989 ASHRAE Handbook – Fundamentals*, 28.2, Fig 1.
[2]	Degree day data from the National Climatic Data Center, Divisional Data, CT state, Jan. 1979 to Dec. 2008, 30-year average. Available at: http://www7.ncdc.noaa.gov/CDO/CDODivisionalSelect.jsp.
[3]	*Evaluation of WRAP and Helps Programs*, KEMA, 2010, Table ES-8, pp. 1-10.

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Commented [SK425]: Region specific HDD will be more accurate than state average.
Additionally, there is an Upcoming MA Baseline Study Evaluation that is slated to wrap up at the end of the 2020 summer season. The results of this study should be incorporated into the PSD if possible.
Also, R91 - Review of Impact Evaluation Best Practices (pg 73) included that some areas in the state have notably lower HDDs than reflected by the statewide average or Hartford weather profiles and recommended to consider whether additional weather and location assumptions can improve savings estimates.
ERS recommends that the Companies revise the PSD's single statewide CDD and HDD values with two sets of values reflecting coastal and inland climates. This recommendation echoes that of the R91 Impact Evaluation Best Practices study from 2015. Our analysis shows that inland homes (Hartford weather station) will experience 12% higher HDDs and 9% higher CDDs than coastal homes (Bridgeport weather station). These differences are substantial when propagated among thousands of residential projects per year.

Notes

[1]	This measure applies to all floors over unconditioned space including floors over unconditioned basements, floors over unconditioned garages, floors over crawl spaces, and cantilever floors. These energy savings estimates are based on an analysis assuming that the walls of the unconditioned space are not insulated. A custom energy savings analysis would have to be developed if the walls of that unconditioned space were insulated (even partially).
[2]	Grade Factors were developed using REM/Rate software.

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4.5 WATER HEATING

4.5.1 Showerheads

Description of Measure

Installation of low-flow showerheads meeting the EPA WaterSense® specification (2.0 gpm) (**Ref [1]**) to replace Federal Standard (2.5 gpm) or higher flow showerheads.

Savings Methodology

Savings shall be claimed based on the type of fuel used for water heating. Water savings is based on the difference between the Federal Standard (2.5 gpm) versus WaterSense (2.0 gpm).

No electric demand savings are claimed for this measure because there is insufficient peak coincident data.

Inputs

Table 4-PPPP: 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 4-QQQQ: 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	~~8.3~~7.8	Ref [41,2]
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 Fossil Fuel Water Heater		0.78 for SF 0.67 for MF	Ref [3]
gpm	Gallons per Minute Flow Rate	Gal/min	Federal Std: 2.5 Water Sense: 2.0	Ref [1]
# people	Multifamily # people		1.9	[5]
n_a	Average Total No. Showerheads per Household		2.3 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		1.97	Ref [4], p. 144, Table 41, Note [3]
n_i	Number of Low Flow Showerheads Installed		As found	Note [3]
r_g	Ratio to Adjust Usage for Cooler Climate		0.9344	Note [1], Ref [4]
S_W	Annual Water Savings per Showerhead	Gal/yr	Calculated	
SH_W	Specific Heat of Water	BTU/lb-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

$$S_W = n_e \times d_e \times 365\, {}^{days}\!/_{yr} \times r_g \times \left(gpm_{federalstd} - gpm_{WaterSense}\right)/n_a$$

$$S_W = 1.97\ events \times 8.3\ {}^{\min}\!/_{event} \times 365\, {}^{days}\!/_{yr} \times 0.9344 \times (2.5\ gpm - 2.0\ gpm)/2.3$$

$$S_W = 1{,}212.3\ {}^{Gal}\!/_{showerhead\text{-}yr}$$

Commented [SK426]: *Add # people (1.9 for multifamily), Ref [5]*

Commented [SK427]: The 2016 residential end water usage report (reference in the supporting document PSD4.5.1) found the average duration per shower to be 7.8 minutes. The mid-Atlantic TRM also uses 7.8, which is based on a 2013 evaluation study.

Commented [MM428]: Federal 2.5, EPA sense (from application or 2.0 as default)

Commented [MM429R428]: Other TRMs use < 2.0 GPM for energy efficient showerheads. NY TRM uses 2.0 as the baseline.

Commented [SK430]: PSD currently refers to a single-family water use study for California that was done in 2011. The study found 1.4 (not 2.3) showerheads per household for residential homes.

Commented [SK431]: *Add 1.3 for multifamily. Ref [6], which we provide in References section*

Commented [SK432]: Mid-Atlantic TRM uses 1.518 events per day, which comes from an assumption of 0.6 showers per day per person and 2.53 persons per household. The number of persons per household can be updated based on CT specific studies.

Commented [MM433]: Remove to align with nearby jurisdictions with similar climate where this value is not used.

Commented [SK434]: Update calculation based on revised parameters - Refer to PSD4.5.1 Supporting Info for calculations in detailed measure review workbook.

Commented [MM435]: 1239

Commented [MM436R435]: Savings updated based on parameter update. Refer to PSD4.5.1 Supporting Info for calculations.

Commented [SK437]: *Add 1,248.3 Gal/showerhead-yr for multifamily*

$$MMBtu\ \ Savings = \sqrt{n_i} \times \left(T_{shower} - T_{Supply}\right) \times d_W \times SH_W \times S_W / 10^6\ {}^{Btu}\!/\!_{MMBtu}$$ (See Note [2])

$$MMBtu\ Savings = \frac{\sqrt{n_i} \times \left(T_{shower} - T_{supply}\right)}{10^6\ {}^{Btu}\!/\!_{MMBtu}} \times d_W \times SH_W \times S_W / 10^6\ {}^{Btu}\!/\!_{MMBtu}$$

$$MMBtu\ Savings = \frac{\sqrt{n_i} \times \left(105^\circ F - 55^\circ F\right)}{10^6\ {}^{Btu}\!/\!_{MMBtu}} \times 8.31\ {}^{lb}\!/\!_{Gal} \times 1 \times 1{,}212.3\ {}^{Gal}\!/\!_{showerhead\text{-}yr}$$

$$MMBtu\ \ Savings = 0.504\ {}^{MMBtu}\!/\!_{showerhead} \times \sqrt{n_i}$$

$$AKWH = \frac{MMBtu\_Savings}{0.003412\ {}^{MMBtu}\!/\!_{kWh} \times RE_e} = \frac{0.504 \times \sqrt{n_i}}{0.003412 \times 0.98}$$

$$AKWH = 151\ {}^{kWh}\!/\!_{showerhead} \times \sqrt{n_i}$$

Retrofit Gross Energy Savings, Fossil Fuel

For natural gas:

$$ACCF = \frac{MMBTU\ Savings}{0.1029\ {}^{MMBtu}\!/\!_{CCF} \times RE_g} = \frac{0.504 \times \sqrt{n}}{0.1029 \times 0.78}$$

$$ACCF = 6.28 \times \sqrt{n}$$

For oil:

$$AOG = \frac{MMBTU\ Savings}{0.138690\ {}^{MMBtu}\!/\!_{Gal-oil} \times RE_g} = \frac{0.504 \times \sqrt{n}}{0.138690 \times 0.78}$$

$$AOG = 4.65\ {}^{gal}\!/\!_{showerhead} \times \sqrt{n_i}$$

For propane:

$$AOP = \frac{MMBTU\ Savings}{0.09133\ {}^{MMBtu}\!/\!_{Gal-propane} \times RE_g} = \frac{0.504 \times \sqrt{n}}{0.09133 \times 0.78}$$

$$AOP = 7.07\ {}^{gal}\!/\!_{showerhead} \times \sqrt{n_i}$$

Commented [MM438]: 0.51 x sqrt(ni)

Commented [MM439R438]: Algorithm will change with change in annual water savings value. Refer to PSD4.5.1 Supporting Info for calculations. Recommend removing the square root on the number of installed aerators to align with MidAtl TRM methodology.

Commented [SK440]: *Add for multifamily: MMBtu Savings = 0.519 MMBtu/showerhead x n*

Commented [MM441]: 154.29 x sqrt(ni)

Commented [MM442R441]: Algorithm will change with change in annual water savings value. Refer to PSD4.5.1 Supporting Info for calculations. Recommend removing the square root on the number of installed aerators to align with MidAtl TRM methodology.

Commented [SK443]: *Add for multifamily: AKWH = 155.2 kWh/showerhead x n*

Commented [SK444]: Savings updated based on parameter update. Refer to PSD4.5.1 Supporting Info for calculations.

Commented [KR445]: Update calculation based on revised parameters - Refer to PSD4.5.1 Supporting Info for calculations in detailed measure review workbook.

Commented [MM446]: 6.42 x sqrt(ni)

Commented [MM447R446]: Algorithm will change with change in annual water savings value. Refer to PSD4.5.1 Supporting Info for calculations. Recommend removing the square root on the number of installed aerators to align with MidAtl TRM methodology.

Commented [SK448]: *Add for multifamily: ACCF = 6.47 x n*

Commented [MM449]: 4.75 x sqrt(ni)

Commented [MM450R449]: Algorithm will change with change in annual water savings value. Refer to PSD4.5.1 Supporting Info for calculations. Recommend removing the square root on the number of installed aerators to align with MidAtl TRM methodology.

Commented [SK451]: *Add for multifamily: AOG = 4.80 gal/showerhead x n*

Commented [MM452]: 7.22 x sqrt(ni)

Commented [MM453R452]: Algorithm will change with change in annual water savings value. Refer to PSD4.5.1 Supporting Info for calculations. Recommend removing the square root on the number of installed aerators to align with MidAtl TRM methodology.

Commented [SK454]: *Add for multifamily: AOP = 7.29 gal/showerhead x n*

Retrofit Gross Energy Savings, Example

Commented [KR455]: Update calculation based on revised parameters

Example 1: Two showerheads are replaced in bathrooms of a home which uses electric hot water heating. What are the savings per household per year?

Annual electric savings:

$$AKWH = 151 \, {}^{kWh}/_{showerhead} \times \sqrt{n_i} = 151 \times \sqrt{2} = 213 \, {}^{kWh}/_{yr}$$

Annual water savings:

$$AWG = 1{,}212.3 \, {}^{Gal}/_{showerhead\text{-}yr} \times \sqrt{n_i} = 1714 \, {}^{Gallons}/_{yr}$$

Example 2: Two showerheads are replaced in bathrooms of a home which uses natural gas hot water heating. What are the savings per household per year?

Annual natural gas savings:

$$ACCF = 6.28 \, {}^{CCF}/_{showerhead} \times \sqrt{n_i} = 6.28 \times \sqrt{2} = 8.9 \, {}^{CCF}/_{yr}$$

Annual water savings:

$$AWG = 1{,}212.3 \, {}^{Gal}/_{showerhead\text{-}yr} \times \sqrt{n_i} = 1714 \, {}^{Gallons}/_{yr}$$

Retrofit Gross Peak Day Savings, Natural Gas

Commented [KR456]: Update calculation based on revised parameters

$$PD_{WH} = ACCF \times PDF_{WH}$$

Non-Energy Benefits

Annual water savings in gallons:

$$AWG = 1{,}212.3 \, {}^{Gal}/_{showerhead\text{-}yr} \times \sqrt{n_i}$$

Changes from Last Version

- Format changes.

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References

[1]	EPA WaterSense Specification for Showerheads, Version 1.0, effective Feb. 9, 2010. 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," October 1, 2019.
[6]	Energy & Resource Solutions. "R1705 R1609 Multifamily Baseline and Weatherization Opportunity Study," October 10, 2019.

Commented [SK457]: *Add:*
For # people: [5] NMR Group, Inc. "R1706 Residential Appliance Saturation Survey & R1616/R1708 Residential Lighting Impact Saturation Studies," October 1, 2019.
For n_a: [6] Energy & Resource Solutions. "R1705 R1609 Multifamily Baseline and Weatherization Opportunity Study," October 10, 2019.

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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.

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4.5.2 Faucet Aerators

Description of Measure

Installation of aerators meeting the EPA WaterSense specification of 1.5 (Ref [1]) to replace Federal Standard (2.2 gpm) or higher flow lavatory faucet aerators.

Commented [SK458]: Use aerator specific flow rate or default value of EPA specified 1.5 GPM

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 4-RRRR: 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)

Commented [SK459]: Use aerator specific flow rate or default value of EPA specified 1.5 GPM

Nomenclature

Table 4- SSSS: 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	
d_e	Average Duration per Event	minutes	0.6167	Ref [4]
d_W	Density of Water	lb/ Gal	8.31	
DF	Drain Factor		0.795	Ref [3]
RE_E	Recovery Efficiency of Electric Water Heater		0.98	Ref [3]
RE_{FG}	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]
# people	Multifamily # people		1.9	Ref [6]
n_a	Estimated Average Total No. of Faucets (all types) per Household		~~5.1~~2.01 MF = 1.4	Note [3], Note [4], Ref [4], Ref [7]
n_e	Median Number of Faucet Events per Day per Household		~~42.9~~13.8 MF = 10.1	Note [4], Ref [4]
n_i	No. of Aerators Installed		As found	Note [4]
~~r_e~~	~~Ratio to Adjust Usage for Cooler Climate~~		~~0.9344~~	~~Note [1],~~ ~~Ref [4]~~
S_W	Annual Water Savings per Faucet	Gal/yr	~~Calculated~~806.61	
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			

Commented [SK460]: *Add # people: 1.9 for multifamily, Ref [6], which we provide in References section*

Commented [SK461]: Updated to REF to align with showerhead nomenclature

Commented [SK462]: The PSD counts all faucets in a household. Since the measure is for lavatory faucets only, the PSD should count the lavatory faucets only. The CASE report, table 5.2 (see PSD4.5.2 Supporting Info) suggests 2.01 lavatory faucets per household.

Commented [SK463]: *Add: 1.4 for multifamily, Ref [7], which we provide in References section*

Commented [SK464]: The CASE study (See PSD4.5.2 Supporting Info) that the PSD currently refers to, found an average faucet events of 57.4 per day, with median events of 42.9. Out of the 57.4 events, lavatory faucets contribute 13.8 events only and the rest of the events are contributed by kitchen faucet. The PSD currently uses 42.9 as the total faucet events per day and divides this by the total number of faucets per household. The PSD's approach implies that the kitchen and lavatory faucets are equally used. This is wrong based on the CASE study. Lavatory faucets contribute only about 32% of the average daily events in a household. As such, it is recommended that the PSD use the number of faucet events contributed by lavatory faucets only (13.8) and divide it by the number of lavatory faucets (2.01).

Commented [SK465]: *Add 10.1 for multifamily. This is aligning with the new methodology proposed by ERS which references R1706 RASS.*
*Apply a multifamily multiplier by the ratio of number of occupants based on the Rass Study. 10.1 = 13.8 (ERS proposed n_e) * 1.9 (multifamily occupants)/2.6 (single family occupants)*

Commented [MM466]: Remove to align with nearby juristictions with similar climate where this value is not used.

Commented [SK467]: Remove to align with nearby juristictions with similar climate where this value is not used.

Commented [MM468]: Water savings will change with update in input parameters. Refer to PSD4.5.2 Supporting Info for calculations. Recommend removing the square root on the number of installed aerators to align with MidAtl TRM methodology.

Retrofit Gross Energy Savings, Electric

$$S_W = n_e \times d_e \times 365 \, {}^{days}/_{yr} \times r_g \times DF \times (gpm_{federal\ standard} - gpm_{Water\ Sense})/n_a$$

$$S_W = 42.9 \times 0.6167 \times 365 \, {}^{days}/_{yr} \times 0.9344 \times 0.795 \times (2.2\ gpm - 1.5\ gpm)/5.1$$

$$S_w = \cancel{985}806.61 \, {}^{Gal}/_{faucet\ yr}$$

$$MMBtu\ \ Savings = \sqrt{n} \times \left(T_{Faucet} - T_{Supply}\right) \times d_W \times SH_W \times S_W / 10^6 \, {}^{Btu}/_{MMBtu}$$ (See Note [2])

$$MMBtu\ Savings = \sqrt{n} \times (80°\mathrm{F} - 55°\mathrm{F}) \times 8.31 \, {}^{lb}/_{Gal} \times 1 \, {}^{Btu}/_{lb°F} \times 985 \, {}^{Gal}/_{faucet\ yr} / 10^6 \, {}^{Btu}/_{MMbtu}$$

$$MMBtu\ Savings = \cancel{0.205}0.167 \, {}^{MMBtu}/_{faucet} \times \sqrt{n}$$

$$AKWH = \frac{MMBtu\ Savings}{0.003412 \, {}^{MMBtu}/_{kWh} \times RE_e} = \frac{0.205 \times \sqrt{n}}{0.003412 \, {}^{MMBtu}/_{kWh} \times .98}$$

$$AKWH = \cancel{61.2}49.84 \, {}^{kWh}/_{faucet} \times \sqrt{n}$$

Retrofit Gross Energy Savings, Fossil Fuel

Natural gas:

$$ACCF = \frac{MMBtu\ Savings}{0.102900 \, {}^{MMBtu}/_{Ccf} \times RE_g} = \frac{0.205 \times \sqrt{n}}{0.102900 \, {}^{MMBtu}/_{Ccf} \times .78}$$

$$ACCF = \cancel{2.55}2.08 \times \sqrt{n}$$

Oil:

$$AOG = \frac{MMBtu\ Savings}{0.138690 \, {}^{MMBtu}/_{Gal\ oil} \times RE_g} = \frac{0.205 \times \sqrt{n}}{0.138690 \, {}^{MMBtu}/_{Gal\ oil} \times .78}$$

$$AOG = \cancel{1.89}1.54 \times \sqrt{n}$$

Commented [KR469]: Update calculation based on revised parameters Refer to PSD4.5.2 Supporting Info in the detailed review workbook for calculations.

Commented [SK470]: *Add for multifamily - S_w: 902 gallons/faucet-yr*

Commented [SK471]: *For multifamily: MMBtu = .187 Mmbtu/faucet x n*

Commented [SK472]: *For multifamily: AKWH = 55.93 kWh/faucet x n*

Commented [SK473]: Update savings based on revised parameters.

Commented [SK474]: *For multifamily: ACCF = 2.33 * n*

Commented [SK475]: *For multifamily: AOG = 1.73 *n*

Propane:

$$AOP = \frac{MMBtu\ Savings}{0.09133\ {}^{MMBtu}/_{Gal\ propane} \times RE_g} = \frac{0.205 \times \sqrt{n}}{0.09133\ {}^{MMBtu}/_{Gal\ propane} \times .78}$$

$$AOP = \cancel{2.88}2.35 \times \sqrt{n}$$

Commented [SK476]: *For multifamily: AOP = 2.63 * n*

Retrofit Gross Energy Savings, Example

Commented [KR477]: Update savings based on revised parameters.

Example One: Two aerators are replaced in bathrooms of home which uses electric hot water heating. What are the total savings?

$$AKWH = 61.2\ {}^{kWh}/_{faucet} \times \sqrt{2} = 87\ {}^{kWh}/_{yr}$$

$$Annual\ Gal\ Water\ Savings = S_W \times \sqrt{n} = 985\ {}^{Gal}/_{yr} \times \sqrt{2} = 1392\ {}^{Gal}/_{yr}$$

Example Two: Two aerators are replaced in bathrooms of a home which uses natural gas hot water heating. What are the savings?

$$ACCF = 2.65 \times 2 = 3.75\ {}^{Ccf}/_{yr}$$

$$Annual\ Gal\ Water\ Savings = S_W \times \sqrt{n} = 985\ {}^{Gal}/_{yr} \times \sqrt{2} = 1392\ {}^{Gal}/_{yr}$$

Retrofit Gross Peak Day Savings, Natural Gas

$$PD_{WH} = ACCF \times PDF_{WH}\ \cancel{PD_{WH} = ACCF \times PDF_{WH}}$$

Non-Energy Benefits

$$Annual\ Gal\ Water\ Savings = S_W \times \sqrt{n} = \cancel{985}806.61\ {}^{Gal}/_{yr} \times \sqrt{n}$$

Changes from Last Version

- Format changes.

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References

[1]	US EPA WaterSense High-Efficiency Lavatory Faucet Specification, Effective Oct. 1, 2007, 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.
[5]	NMR Group, Inc. "R1706 Residential Appliance Saturation Survey & R1616/R1708 Residential Lighting Impact Saturation Studies," October 1, 2019.
[6]	Energy & Resource Solutions. "R1705 R1609 Multifamily Baseline and Weatherization Opportunity Study," October 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 multi-family 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.

Commented [SK478]: *Add:*

For # people: [6] NMR Group, Inc. "R1706 Residential Appliance Saturation Survey & R1616/R1708 Residential Lighting Impact Saturation Studies," October 1, 2019.
For n_a: [7] Energy & Resource Solutions. "R1705 R1609 Multifamily Baseline and Weatherization Opportunity Study," October 10, 2019.

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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.

Commented [SK479]: Add: "This measure is only applicable to water heaters with a capacity of less than 75,000 Btu/h for multifamily dwelling units."

Savings Methodology

Commented [SK480]: The new Federal standard requires water heaters to be rated in terms of UEF for commercial water heaters: https://www.energy.gov/sites/prod/files/2016/08/f33/Water%20Heaters%20Test%20Procedure%20SNOPR.pdf

Even though residential water heaters are not required to follow the new Federal regulation, other TRMs are using the UEF as the efficiency metric for residential water heaters. Recommend update savings algorithm to use UEF as the efficiency metric to be consistent.

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 4-TTTT: Inputs

Symbol	Description	Units
	Water Heating Fuel	
~~EF~~UEF	Uniform Energy Factor-Installed	%

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Nomenclature

Table 4-UUUU: Nomenclature

Symbol	Description	Units	Values	Comments
$ABTU_W$	Annual BTU Savings – Water Heating	Btu		
$ACCF_W$	Annual Natural Gas Savings – Water Heating	ccf		
ADHW	Annual Domestic Hot Water Load	Btu	~~11,197,132~~9,630,521 MF = 7,004,370	Note [1] Ref [2]
APG_W	Annual Propane Savings – Water Heating	Gal		
~~EF_B~~UEF_B	Uniform Energy Factor - Baseline		0.71	Note [2] and Note [3]
~~EF_I~~UEF_I	Uniform Energy Factor - Installed			Note [3]
GPY	Annual Domestic Hot Water Usage in Gallons	Gal	~~19,839~~15,415 MF = 11,252	Note [1] Ref [2]
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	5~~7~~	Note [1]
T_{dhw}	Domestic Hot Water Heater Set Point	ºF	~~125~~130	Note [1]

Lost Opportunity Gross Energy Savings, Fossil Fuel

$$ADHW = GPY \times 8.3 \, {}^{lbs}\!/\!_{Gal} \times (T_{dhw} - T_{aiw})$$

$$ADHW = 19{,}839 \, {}^{Gal}\!/\!_{yr} \times 8.3 \, {}^{lbs}\!/\!_{Gal} \times (125°F - 57°F)$$

$$ADHW = 11{,}197{,}132 \; Btu$$

$$ABTU_W = ADHW \times \left(\frac{1}{EF_B} - \frac{1}{EF_I}\right)$$

$$ABTU_W = 11{,}197{,}132 Btu \times \left(\frac{1}{0.71} - \frac{1}{\ }\right)$$

Savings by water heating fuel:

$$ACCF_W = \frac{ABTU_W}{102{,}900 \, {}^{Btu}\!/\!_{Ccf}}$$

Commented [SK481]: Based on the recommendation made by R1614-1613 evaluation report, Table ES-7.

Commented [SK482]: *Add 7,004,370 for multifamily*

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Commented [SK483]: The R1706 evaluation report (page 5) reports baseline EF of 0.67. Recommend update the reference as well as to convert the EF to UEF.

Commented [SK484]: Update EF to UEF

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Commented [SK485]:

Commented [SK486]: The R1614-1613 evaluation report recommends annual domestic water usage of 15,415 gallons and temperature differential of 75°F.

Commented [SK487]: *Add 11,252 for multifamily Ref[2], Note[4]*

Commented [SK488]: The R1614-1613 evaluation report, Table ES-7 recommends temperature differential of 75°F. Value updated to reflect 75°F temperature differential.

Commented [SK489]: Update calculations based on new ADHW. See PSD4.5.3 Supporting Info in detailed review workbook.

Commented [MM490]: 9,630,521 x (1/0.6 -1/UEF_ee)

Commented [MM491R490]: Recommend savings algorithm update based on updated annual heating load.

Commented [SK492]: *Add for multifamily: ABTU_W =7,004,370 Btu x (1/0.6 - 1/UEF_ee)*

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

Lost Opportunity Gross Energy Savings, Example

Commented [KR493]: Update calculations based on new ADHW parameter.

Example: A natural gas water heater with an EF = 82% (0.82) is installed. What are the annual natural gas savings?

$$ABTU_W = 11{,}197{,}132\ Btu \times \left(\frac{1}{.71} - \frac{1}{.82}\right) = 2{,}115{,}569\ btu$$

$$ACCF_w = \frac{2{,}115569\ Btu}{102{,}900\ btu/Ccf} = 20.6\ Ccf$$

Lost Opportunity Gross Peak Day Savings, Natural Gas

$$PD_w = ACCF_w \times PDF_w$$

$$PD_w = ACCF_w \times 0.00321$$

Changes from Last Version

- Format changes.

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Notes

Commented [SK494]: *Add for multifamily:*

Note[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].

[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 at: www.energysavers.gov).

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References

Commented [SK495]: *Add for multifamily:*

Ref[2]: NMR Group, Inc. "R1706 Residential Appliance Saturation Survey & R1616/R1708 Residential Lighting Impact Saturation Studies," October 1, 2019.

[1]	Tool for Generating Realistic Residential Hot Water Event Schedules, Preprint, NREL, Aug. 2010.
[2]	NMR Group, Inc. "R1706 Residential Appliance Saturation Survey & R1616/R1708 Residential Lighting Impact Saturation Studies," October 1, 2019.

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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 should be minimally compliant HPWH.

Retrofit: Electric resistance water heater for sizes < 55 gallons and a minimal code compliant HPWH for sizes > 55 gallons.

Commented [SK496]: For tanks > than 55 gallons, the baseline should be minimally compliant HPWH.

Commented [MM497R496]: 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 4-VVVV: Inputs

Symbol	Description	Units
	Number of Units Installed	
	Size: 55 gallons or less, or greater than 55 gallons	Gallons

Nomenclature

Table 4-WWWW: 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 4-XXXX: 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	~~1,258~~197 kWh		
Unknown (Lost Opportunity)	961 kWh	565 kWh	15.5 Gals	23.54 Gals

Table 4 -YYYY: 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

Commented [SK498]: The baseline for >55 gallons should be a HPWH instead of an electric resistance water heater.

Update savings for >55 gallons HPWHs based on : https://api-plus.anbetrack.com/etrm-gateway/etrm/api/v1/etrm/documents/5ee488496996f24a6e7df6e9/view?authToken=0556e736ff4ffaa3f8f4cd05f80a5b1678689924692b100436dc12e99d785107f9247d43e311b41d4490f573193ead65c7b10b8c881c52f572300816683f3ad3848084b6719c21

Commented [SK499]: The baseline for >55 gallons should be a HPWH instead of an electric resistance water heater.

Update savings for >55 gallons HPWHs based on : https://api-plus.anbetrack.com/etrm-gateway/etrm/api/v1/etrm/documents/5ee488496996f24a6e7df6e9/view?authToken=0556e736ff4ffaa3f8f4cd05f80a5b1678689924692b100436dc12e99d785107f9247d43e311b41d4490f573193ead65c7b10b8c881c52f572300816683f3ad3848084b6719c21

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 water heaters greater than 55 gallons.

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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.

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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 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 4-ZZZZ: 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 4-AAAAA: Nomenclature

Symbol	Description	Units	Values	Comments
$ACCF_H$	Annual Natural Gas Savings per Linear Foot, Heating	ccf/ft		Table 4-18
$ACCF_W$	Annual Natural Gas Savings per Linear Foot, DHW	ccf/ft		Table 4-17
AKW_H	Annual kWh Energy Savings Coefficient, Heating	kWh/ft		Table 4-16
AKW_W	Annual kWh Energy Savings Coefficient, DHW	kWh/ft		Table 4-15
$AKWH_H$	Annual Energy Savings, Heating	kWh	Calculated	
$AKWH_W$	Annual Energy Savings, DHW	kWh	Calculated	
AOG_H	Annual Oil Savings, Heating	Gal/ft		Table 4-18
AOG_W	Annual Oil Savings, DHW	Gal/ft		Table 4-17
APG_H	Annual Propane Savings, Heating	Gal/ft		Table 4-18
APG_W	Annual Propane Savings, DHW	Gal/ft		Table 4-17
PD_W	Peak Day Savings, DHW			
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	W/kWh	0.1147	**Ref [3]**
PF_W	Winter Seasonal Peak Factor	W/kWh	0.1747	**Ref [3]**
SKW_H	Summer Seasonal Peak Demand Savings Heating	kW		
SKW_W	Summer Seasonal Peak Demand Savings, 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

Commented [SK500]: Update savings based on updated water heater efficiency values.

For DHW use recovery efficiency of 98% for electric, 78% for gas/propane and 75% for oil. This is based on 10CFR 430 - Federal Energy Conservation Code and review of AHRI rated water heaters.

For heating pipes, the PSD should report the efficiency values used to estimate savings. Boiler baseline AFUE from PSD4.2.10 (85% for gas/propane, 84% for oil, 98% for electric)

Table 4-BBBBB: Annual Electrical Savings per Linear Foot of Domestic Hot Water Pipe Insulation

Pipe Diameter (inches)	AKW_W (kWh/ft)
0.50	14.1
0.75	20.5

Annual electric DHW savings can be calculated using the formula below, and using the values for AKWW from Table 4-BBBBB:

$$AKWH_W = AKW_W \times L$$

Table 4-CCCCC: 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

Commented [SK501]: 2" pipes are listed as an input in the PSD. Include estimation for 2" diameter pipes.

Annual electric heating savings can be calculated using the formula below, and using the value for AKWH from Table 4-CCCCC:

$$AKWH_H = AKW_H \times L$$

Retrofit Gross Energy Savings, Fossil Fuel

Table 4-DDDDD: Annual Fossil Fuel Savings per Linear Foot of Domestic Hot Water Pipe Insulation

Pipe Diameter (inches)	$ACCF_W$ (Ccf/ft)	AOG_W (Gallons/ft)	APG_W (Gallons/ft)
0.50	0.75	0.63	0.82
0.75	1.10	0.91	1.20

Annual natural gas DHW savings can be calculated using the formula below and using the ACCFw coefficient in Table 4-DDDDD:

$$ACCF = ACCF_W \times L$$

Annual oil DHW savings can be calculated using the formula below and using the AOGw coefficient in Table 4-DDDDD:

$$AOG = AOG_W \times L$$

Annual propane DHW savings can be calculated using the formula below and using the APGw coefficient in Table 4-DDDDD:

$$APG = APG_W \times L$$

Table 4-EEEEE: 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

Commented [SK502]: 2" pipes are listed as an input in the PSD. Include estimation for 2" diameter pipes.

Annual natural gas heating savings can be calculated using the formula below and using the ACCFH coefficient in Table 4-EEEEE:

$$ACCF = ACCF_H \times L$$

Annual oil heating savings can be calculated using the formula below and using the AOGH coefficient in Table 4-EEEEE:

$$AOG = AOG_H \times L$$

Annual propane DHW savings can be calculated using the formula below and using the APGH coefficient in Table 4-EEEEE:

$$APG = APG_H \times L$$

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?

$$AOG = AOG_H \times L$$

$$AOG = 0.63 \, {}^{Gal}\!/_{ft} \times 5 \; ft = 3.15 \, {}^{Gal}\!/_{yr}$$

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

For DHW, the summer seasonal peak demand savings is:

$$SKW_W = \left(\frac{AKWH \times PF_S}{1000} \right)$$

For DHW, the winter seasonal peak demand savings is:

$$WKW_W = \left(\frac{AKWH \times PF_S}{1000} \right)$$

For heating, summer seasonal peak demand:

$$SKW_H = 0$$

$$WKW_H = \left(\frac{AKWH \times 0.57}{1000} \right)$$

Retrofit Gross Peak Day Savings, Natural Gas

For DHW:

$$PD_W = ACCF \times PDF_W$$

For heating:

$$PD_H = ACCF \times PDF_H$$

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?

$$AKWH = 5\,feet \times 14.1\,{}^{kWh}\!/_{ft \cdot yr} = 70.5\,{}^{kWh}\!/_{yr}$$

$$SKW = \frac{\left(70.5\,kWh \times 0.1147\,{}^{W}\!/_{kWh}\right)}{1000\,{}^{W}\!/_{kW}} = 0.0081\,kW$$

$$WKW = \frac{\left(70.5\,kWh \times 0.1747\,{}^{W}\!/_{kWh}\right)}{1000\,{}^{W}\!/_{kW}} = 0.012\,kW$$

Changes from Last Version

- Format changes.

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References

[1]	NAIMA, 3E Plus software tool, Version 4.1, Released 2012.
[2]	Nexant. *Home Energy Solutions Evaluation: Final Report,* submitted to Connecticut Energy Efficiency Board. 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.

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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]	Savings counted 8,760 hours/yr since average temperature is used.
[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 v4.01 (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 [13].
[13]	Horizontal pipes.
[14]	DHW use recovery efficiency of 98% for electric, 78% for gas/propane and 75% for oil. This is based on 10CFR 430 - Federal Energy Conservation Code and review of AHRI rated water heaters. For heating pipes use boiler baseline AFUE from PSD4.2.10 (85% for gas/propane, 84% for oil, 98% for electric)~~WH efficiencies: Electric: 90%, Oil: 49.5%, Natural Gas and Propane: 57.5%.~~

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Commented [SK503]: The PSD should provide information on temperature differential of heating pipes.

Commented [SK504]: For DHW use recovery efficiency of 98% for electric, 78% for gas/propane and 75% for oil. This is based on 10CFR 430 - Federal Energy Conservation Code and review of AHRI rated water heaters.

For heating pipes, the PSD should report the efficiency values used to estimate savings. We recommend using boiler baseline AFUE from PSD4.2.10 (85% for gas/propane, 84% for oil, 98% for electric)

4.5.6 Solar Water Heater

Commented [KR505]: No recommended changes to this measure

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 4-FFFFF: 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.

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Lost Opportunity Gross Energy Savings, Electric

- Based on the SPF report.

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

- Based on the SPF report.

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Lost Opportunity Gross Peak Day Savings, Natural Gas

- Based on the SPF report.

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Non-Energy Benefits

- Increases a home's value.

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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.

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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

Commented [SK506]: We recommend investigating other calculation techniques in addition to PRISM for this measure.

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

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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.

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Notes

[1]	REM/Rate™ is a residential energy analysis, code compliance, and rating software developed by Architectural Energy Corporation. This software calculates heating, cooling, hot water, lighting, and appliance energy loads, consumption, and costs for new and existing single and multi-family homes.
[2]	PRISM is an established statistical procedure for measuring energy conservation in residential housing. The PRISM software package was developed by the Center for Energy and Environmental Studies, Princeton University. The tool is used for estimating energy savings from billing data. Available at: http://www.marean.mycpanel.princeton.edu/Details.html **Error! Hyperlink reference not valid.**~~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 at: http://www.doe2.com/.

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Commented [SK507]: PRISM tool link in the references expired. Added latest link available in Princeton University website

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4.6.2 Behavioral Change

Commented [KR508]: No recommended changes to this measure

Description of Measure

This measure covers enrollment in a residential behavioral program or installation of a measure with a behavioral change component that is designed to encourage lower energy usage through behavioral messaging. These behavioral messages can be periodic normative reports or messages that present the customers with timely information on their energy usage and a call to action to reduce or save energy. Behavioral messages can be delivered through many avenues, including paper, email, and text messages.

Savings Methodology

Because the characteristics of behavioral programs make them amenable to robust, unbiased evaluation through randomized, controlled trials, and because Connecticut is expected to regularly evaluate its behavioral energy efficiency programs, use of evaluated savings estimates is recommended. Evaluations should be conducted, and savings calculated in accordance with the Department of Energy's SEE Action Recommendations, including but not limited to the use of a randomized controlled trial and a panel data model[1].

Savings are estimated by the difference between usage with the behavioral program and usage without the behavioral program. Usage without the behavioral program can be estimated by dividing adjusting actual usage by an adjustment factor based on the treatment effect to back out the effect of the program, or by application of a deemed savings value based on evaluation.

Inputs

Table 4-GGGGG: Inputs

Symbol	Description	Comments
Usage Electric	Annual Electric Energy Consumption	
Usage Gas	Annual Electric Energy Consumption	

Nomenclature

Table 4-HHHHH: 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 4-HHHHH: 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

- Format changes.

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References

[1]	Department of Energy, SEE Action, "
[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.

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New Measures – Air Compressor Measures

fAdd variable speed air compressor and compressed air dryer measures to future PSD updates.

Compressed air upgrades account for ~15% of all annual electric savings in the ECB program. Air compressor measures are not included as a standard measure in the CT PSD.

Reference: C1634 Energy Conscious Blueprint Impact Evaluation, Cadmus, Draft 7/7/2020

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APPENDIX ONE: PEAK FACTORS

A1.1 Coincidence Factors for ISO-NE Seasonal Peak Demand Reductions

Table A1-1: Commercial & Industrial Lighting and Occupancy Sensors

Update the EO lighting winter seasonal peak coincidence factor assumptions in Table A1-1 by building type in the PSD. Add additional building types not included in the PSD currently from table below.

Update the EO lighting summer seasonal peak coincidence factor assumptions in Table A1-1 by building type in the PSD. Add additional building types not included in the PSD currently from table below.

Updated based on Reference [o]

~~Building Type Winter Seasonal Peak CF~~

Building Type	Summer Seasonal Peak	Winter Seasonal Peak
24x7 lighting	100.00%	100.00%
Automotive	68.30%	36.90%
Education	36.80%	46.00%
Grocery	90.40%	85.60%
Health Care	82.50%	69.60%
Hotel/Motel	40.60%	37.50%
Industrial	83.00%	66.50%
Large Office	70.20%	53.90%
Other	86.90%	76.70%
Parking Lot/Streetlights	67.20%	87.30%
Religious bldg/Convention center	17.00%	9.20%
Restaurant	77.50%	77.00%
Retail	98.40%	85.60%
Small Office	76.80%	44.10%
Warehouse	89.30%	72.40%

Facility Type	Lighting		Occupancy Sensors	
	Summer	Winter	Summer	Winter
24x7 lighting	100.0% (o)	100.0% (o)		

Automotive	68.3% (o)	36.9% (o)		
Health Care	82.50% (o)	69.60% (o)		
Hotel/Motel	40.60% (o)	37.50% (o)		
Industrial	83.00% (o)	66.50% (o)		
Religious bldg/Convention center	17.00% (o)	9.20% (o)		
Grocery	90.4% (~~d,1~~o)	~~77.0~~85.6% (~~d,2~~o)	14.7% (d,3)	13.3% (d,4)
Manufacturing	67.1% (d,1)	43.2% (d,2)	19.8% (d,3)	17.2% (d,4)
Medical (Hospital)	74.0% (d,1)	61.8% (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~~o)	53.9% (~~d,2~~o)	27.4% (d,3)	29.6% (d,4)
Small Office	76.80% (o)	44.10% (o)		
Other	~~47.6~~86.9% (~~d,1~~o)	~~42.8~~76.7% (~~d,2~~o)	2.4% (d,3)	6.6% (d,4)
Restaurant	77.5% (~~d,1~~o)	~~64.4~~77.0% (~~d,2~~o)	14.7% (d,3)	13.3% (d,4)
Retail	~~79.5~~98.4% (~~d,1~~o)	~~64.7~~85.6% (~~d,2~~o)	14.7% (d,3)	13.3% (d,4)
University/College (Education)	~~65.0~~36.8% (d,1)	~~52.8~~46.0% (d,2)	28.3% (d,3)	23.1% (d,4)
Warehouse	~~72.7~~89.3% (~~d,1~~o)	~~53.5~~73.4% (~~d,2~~o)	24.6% (d,3)	18.3% (d,4)
School (Education)	~~59.9~~36.8% (~~d,1~~o)	~~38.8~~46.0% (~~d,2~~o)	20.9% (d,3)	15.9% (d,4)
Parking Lot/Street Lighting	67.20% (o)~~1.5% (g)~~	87.30% (o)~~66.9% (g)~~	N/A	N/A

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Table A1-2: Other Commercial & Industrial Measures

Other Commercial and Industrial Measures		
Measure	Summer	Winter
Unitary A/C	82.0% (c)	0.0% (c)
Efficient Motors (cooling)	73.0% (c)	60.0% (c)
Efficient Motors (heating)	0.0% (c)	80.0% (c)
Refrigeration Controls	100% (f)	100% (f)
Air Compressors	77.0% (h)	54.0% (h)

Table A1-3: Residential Measures

Residential		
Measure	Summer	Winter
Lighting	13.0% (i)	20.0% (i)
Central A/C	59.0% (b)	0.0% (b)
Window A/C	30.3% (e)	0.0% (e)
Ductless Heat Pump	44.7% (n)	74.0% (j)
Heating	0.0% (k)	100.0% (k)
Refrigeration	100.0% (f)	100.0% (f)
Refrigeration/Freezer Recycling	100.0% (f)	100.0% (f)
Water Heating Measures	75.0% (k)	100.0% (k)

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:

~~o~~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 heating degree days (5,990).

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$$Peak\ Day\ Savings\,(residential\ heating) = 0.00977 \times Annual\ Heating\ Savings$$

~~o~~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:

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$$Peak\ Factor = \frac{(1\ day)\times(120\,°F - 45.96\,°F)}{(365\ days)\times(120\,°F - 56.72\,°F)} = 0.00321$$

$$Peak\ Day\ Savings\,(residential\ water) = 0.00321 \times Annual\ Water\ Heating\ Savings$$

~~o~~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.

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$$Peak\ Day\ Savings = \frac{Annual\ Savings}{365\ days\ per\ year}$$

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.

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Changes from Last Version

- Updated Residential ductless heat pump coincidence factors.
- Added refrigerator and freezer recycling coincidence factors.

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References

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[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, 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, Table 5.
[d]	RLW, Coincidence Factor Study Residential and Commercial Industrial Lighting Measures, Spring 2007.
[d, 1]	p. VIII, Table i-11.
[d, 2]	p. IX, Table i-12
[d, 3]	p. XII, Table i-17.
[d, 4]	p. XII, 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 PSD section 4.3.7 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, Table ES-7, page XVIII.
[j]	Navigant, RES1 Demand Impact Model Update, Aug. 2018.
[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]	Ductless heat pump summer coincidence factor estimated as an average of room A/C and central A/C summer coincidence.
[o]	C1635 Impact Evaluation of PY 2016 & 2017 Energy Opportunities (EO) Program, DNVGL, June 30, 2020.

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APPENDIX TWO: LOAD SHAPES

A2.1 Load Shapes by End Use and Sector

Table A2-1: Load Shapes by End Use and Sector

Load Shape	Winter Peak Energy %	Winter Off-Peak Energy %	Summer Peak Energy %	Summer Off-Peak Energy %
End Use	**Residential**			
Cooling (a)	0.0%	0.0%	74.4%	25.6%
Heating (a)	38.5%	58.7%	0.6%	2.2%
Lighting (a)	42.1%	32.5%	13.9%	11.5%
Refrigeration (a)	39.1%	28.0%	19.0%	13.9%
Water Heating (a)	37.2%	33.9%	14.6%	14.3%
Residential (General)(i)	30.3%	36.3%	15.5%	17.9%
End Use	**Commercial & Industrial**			
Cooling (Large C&I) (b, d, Note [1])	17.0%	12.0%	42.0%	29.0%
Cooling (Small C&I) (b, d, Note [2])	20.0%	12.0%	40.0%	28.0%
Heating (b, f, Note [3])	55.0%	27.0%	12.0%	6.0%
Lighting (Large C&I) (b, h)	44.5%	19.4%	25.7%	10.5%
Lighting (Small C&I) (b, h)	38.3%	25.1%	22.5%	14.1%
Refrigeration (b, c, Note [4])	30.0%	37.0%	15.0%	18.0%
Other (b, g, Note [5])	37.0%	29.0%	19.0%	15.0%
Motors (b, f, Note [6])	51.0%	16.0%	25.1%	7.9%
Process (b, e, Note [7])	32.0%	36.0%	16.0%	16.0%

- 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.

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Changes from Last Version

- Changed Reference numbers to letters, and other edits to Notes and References for clarity.

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References

a	DOE, Office of Energy Efficiency & Renewable Energy ("EERE") Commercial and Residential Hourly Load Profiles for Hartford, CT, updated Jul. 2013. Based on the NREL Building America House Simulation Protocols and EIA Residential Energy Consumption Survey.
b	Northeast Energy Efficiency Partnerships (NEEP) Load Shape Catalog, prepared for the NEEP Regional EM&V Forum by DNVGL. Last Updated Jul. 19, 2016.
c	Commercial Refrigeration Load Shape Project, prepared for the NEEP Regional EM&V Forum by Cadmus, Oct. 9, 2015.
d	C&I Unitary HVAC Load Shape Project Final Report, prepared for the NEEP Regional EM&V Forum by KEMA, Aug. 2, 2011.
e	New Hampshire Utilities Large C& Retrofit and New Equipment & Construction Program Impact Evaluation, DNV-GL, Sep. 25, 2015.
f	Variable Speed Drive Load Shape Project, prepared for the NEEP Regional EM&V Forum by Cadmus, Aug. 15, 2014.
g	New Hampshire Small Business Energy Solutions Program Impact and Process, prepared by KEMA, Jun. 27, 2012.
h	C&I Lighting Load Shape Project, prepared for the NEEP Regional EM&V Forum by KEMA, Jul. 19, 2011.
i	Percent of annual hours in each season.

Notes

[1]	Large C&I Efficient Unitary HVAC load shape (**Ref (b), (d)**).
[2]	Small C&I Efficient Unitary HVAC load shape, summer peak increased by 1.0% so periods sum to 100%. (Ref (b), (d)).
[3]	VFD Hot Water Pump load shapes used as source, as these were the best available option in the NEEP Load Shape data (larger sample size, closely related to heating) (**Ref (b), (f)**).
[4]	Load shape based on profile for electronically commutated motors installed on evaporator fans in coolers, as this measure had the largest savings and largest sample size of those studied (Ref (b), (c)).
[5]	NH Small Business Energy Solutions study, all equipment (**Ref (b), (g)**).
[6]	Averaged supply fans and return fans VSD load shapes (**Ref (b), (f)**).
[7]	NH-based study, Large C&I. Winter peak decreased by 1.0% so periods sum to 100% (**Ref (b), (e)**).

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APPENDIX THREE: REALIZATION RATES

A3.1 Commercial and Industrial Electric Realization Rates

Table A3-1: C&I Electric Realization Rates

Update kWh GRR in Table A3-1 for EO

End Use	2020 Program Savings Document (PSD) Assumption	Recommended Realization Rate
Cooling	101.00%	102.10%
Heating	101.00%	102.10%
Lighting	101.00%	97.90%
Custom	101.00%	93.80%
EMS	100.00%	67.60%
Motors	101.00%	67.60%
Other	101.00%	67.60%
Process	101.00%	67.60%
Refrigeration	101.00%	67.60%

~~.~~Update seasonal summer peak demand RR in Table A3-1 for EO

~~End Use Recommended Prospective Summer Seasonal Peak Demand Realization Rate~~

End Use	Recommended Prospective Summer Seasonal Peak Demand Realization Rate
Cooling	192.50%
Heating	192.50%
Lighting	98.90%
Custom	106.70%
EMS	123.90%
Motors	123.90%
Other	123.90%
Process	123.90%
Refrigeration	123.90%

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Update seasonal winter peak demand RR in Table A3-1 for EO

~~End Use Recommended Prospective Winter Seasonal Peak Demand Realization Rate~~

End Use	Recommended Prospective Winter Seasonal Peak Demand Realization Rate
Cooling	146.20%
Heating	146.20%
Lighting	115.30%
Custom	122.70%
EMS	179.80%
Motors	179.80%
Other	179.80%
Process	179.80%
Refrigeration	179.80%

	~~Gross Realization % FR & SO~~					~~Net Realization % (Note 1)~~		
	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)	87.1%(a)	108.0%(a)	66.0%(a)	29.5%(d,1)	12.4%(d,1)	72.2%	89.5%	54.7%
Custom	86.0%(a)	91.0%(a)	87.0%(a)	22.5%(d,1)	16.9%(d,1)	81.2%	85.9%	82.1%
Heating (Note 2, Note 10)	85.0%(a)	108.0%(a)	66.0%(a)	23.7%(d,1)	28.0%(d,1)	88.7%	112.6%	68.8%
Lighting (Note 2)	116.0%(a)	113.0%(a)	121.0%(a)	16.7%(d,1)	2.4%(d,1)	99.4%	96.8%	103.7%
Motors	86.0%(a)	91.0%(a)	87.0%(a)	18.2%(d,1)	7.1%(d,1)	76.5%	80.9%	77.3%
Other	86.0%(a)	45.0%(a)	45.0%(a)	18.2%(d,1)	7.1%(d,1)	76.5%	40.0%	40.0%
Process	69.3%(a)	81.9%(a)	78.7%(a)	17.6%(d,1)	0.9%(d,1)	57.7%	68.2%	65.6%

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Refrigeration (Note 2)	86.0%(a)	91.0%(a)	87.0%(a)	3.6%(d,1)	25.9%(d,1)	105.2%	111.3%	106.4%
Energy Opportunities								
EMS Controls (Note 11)	~~100.0~~67.6%(v)	~~100.0~~179.8%(v)	123.9%(v)~~100.0%~~	39.0%(q)	14.0%(q)	75.0%	75.0%	75.0%
Cooling (Note 2, Note 10)	102~~1~~.0%(~~b,1~~v)	~~160.0~~146.2%(v~~b,3~~)	~~116.0~~192.5%(~~b,2~~v)	12.0%(q)	5.0%(q)	93.9%	148.8%	107.9%
Custom (Note 2)	~~101.0~~93.8%(~~b,1~~v)	~~160.0~~122.7%(~~b,3~~v)	~~116.0~~106.7%(~~b,2~~v)	23.0%(q)	0.0%(q)	77.8%	123.2%	89.3%
Heating (Note 2, Note 10)	102~~1~~.0%(~~b,1~~v)	~~160.0~~146.2%(v~~b,3~~)	~~116.0~~192.5%(~~b,2~~v)	14.0%(q)	7.0%(q)	93.9%	148.8%	107.9%
Lighting (Note 2)	~~101.0~~97.9%(~~b,1~~v)	~~160.0~~115.3%(~~b,3~~v)	~~116.0~~98.9%(~~b,2~~v)	11.0%(q)	5.0%(q)	94.9%	150.4%	109.0%
Motors (Note 2)	67.6%(v)~~101.0%(b,1)~~	~~160.0~~179.8%(~~b,3~~v)	123.9%(v)~~116.0%(b,2)~~	12.0%(q)	3.0%(q)	91.9%	145.6%	105.6%
Other (Note 2)	67.6%(v)~~101.0%(b,1)~~	179.8%(v)~~160.0%(b,3)~~	123.9%(v)~~116.0%(b,2)~~	0.0%(q)	0.0%(q)	101.0%	160.0%	116.0%
Process (Note 2)	67.6%(v)~~101.0%(b,1)~~	179.8%(v)~~160.0%(b,3)~~	123.9%(v)~~116.0%(b,2)~~	12.0%(q)	35.0%(q)	124.2%	196.8%	142.7%
Refrigeration (Note 2)	67.6%(v)~~101.0%(b,1)~~	179.8%(v)~~160.0%(b,3~~)	123.9%(v)~~116.0%(b,2)~~	13.0%(q)	0.0%(q)	87.9%	139.2%	100.9%

Table A3-1: C&I Electric Realization Rates (Cont'd)

	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

Update kWh gross RR and Installation Rate in Table A3-2 for C&I Upstream Lighting - Include upstream lighting long term in-service rates in the PSD so that they are consistent with the results of C1635 evaluation

Product Type	Recommended Gross kWh RR	Long Term In-Service Rate
Category 1 LED Linear	113.5%	97.40%
Category 3 LED Downlights	126.7%	86.40%
Category 4 LED A-line/Deco	171.2%	74.90%
Category 7 LED High/Low Bay	74.7%	99.70%
Overall	98.9%	96.00%

Gross Realization %_				FR & SO	Net Realization % (Note 1)				
	Gross Realization %			Installation Rate	FR & SO		Net Realization % (Note 1)		
End-use	kWh	Winter Seasonal Peak kW	Summer Seasonal kW	Installation Rate	Free-ridership	Spillover	kWh	Winter Seasonal Peak kW	Summer Seasonal Peak kW

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Upstream									
Category 1 LED Linear	113.5%(v)			97.40%(v)					
Category 3 LED Downlights	126.7%(v)			86.40%(v)					
Category 4 LED A-line/Deco	171.2%(v)			74.90%(v)					
Category 7 LED High/Low Bay	74.7%(v)			99.70%(v)					
Overall	98.9%(v)			96.00%(v)					
LEDs (screw-based)	100.0%	100.0%	100.0%	84.6%(r)	40.0%(q)	23.0%(q)	70.2%	70.2%	70.2%
LEDs (linear) (Note 8)	100.0%	100.0%	100.0%	84.6%(r)	20.0%(q)	11.0%(q)	77.0%	77.0%	77.0%
LED Fixture (Note 8)	100.0%	100.0%	100.0%	100.0%	20.0%(q)	11.0%(q)	91.0%	91.0%	91.0%

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Food Service	100.0%	100.0%	100.0%	100.0%	22.5%(s)	8.5%(s)	86.0%	86.0%	86.0%

A3.2 C&I Natural Gas Realization Rates

Table A3-3: C&I Natural Gas Realization Rates

Update Natural Gas GRR in Table A3-3 for EO

End Use	Recommended Prospective Natural Gas Energy Realization Rate
HVAC/DHW	76.50%
Other	78.20%
Overall	77.30%

Gross Realization %			~~Net Realization % (Note 1)~~FR&SO			
End-use	Energy (ccf)	Peak Day (ccf)	Free-ridership	Spillover	Energy (ccf)	Peak Day (ccf)
Energy Conscious Blueprint						
Envelope	68.0%(a)	100.0%(a)	23.8%(d,2)	9.5%(d,2)	58.3%	85.7%
HVAC	96.0%(a)	100.0%(a)	23.8%(d,2)	9.5%(d,2)	82.3%	85.7%
Process	68.0%(a)	100.0%(a)	23.8%(d,2)	9.5%(d,2)	58.3%	85.7%
Water Heating	96.0%(a)	100.0%(a)	23.8%(d,2)	9.5%(d,2)	82.3%	85.7%
Energy Opportunities						
EMS Controls (Note 11)	84.0%(b,1)	100.0%	31.0%(q)	2.0%(q)	59.6%	71.0%
Custom	100.0%	100.0%	37.0%(q)	2.0%(q)	65.0%	65.0%
Heating/DHW	~~84.0~~76.5%(~~b, 1~~v)	100.0%	16.0%(q)	2.0%(q)	72.2%	86.0%
Other	~~100.0~~78.2% (v)	100.0%	0.0%(q)	0.0%(q)	100.0%	100.0%
Process	84.0%(b,1)	100.0%	14.0%(q)	16.0%(q)	85.7%	102.0%
Small Business Energy Advantage						
Overall Program	~~78.0~~77.3% (~~c,2~~v)	100.0%	0.0%	0.0%	78.0%	100.0%
O&M						
Overall Program (Note 7, Note 2)	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 (Note 2, Note 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 (Note 2, Note 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
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

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.)										
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 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	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 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	68.8%(k)	68.8%(k)	68.8%(k)	68.8%(k)	6.0%(m)	0.0%	64.7%	64.7%	64.7%	64.7%
MF Insulation, Income Eligible	68.8%(k)	68.8%(k)	68.8%(k)	68.8%(k)	0.0%(m)	0.0%	68.8%	68.8%	68.8%	68.8%
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%

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%	42.0%(l)	1.0%(l)	59.0%	59.0%	59.0%	59.0%
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%

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									
LED Bulbs/ Luminaires, Non-Hard-to-Reach (Note 3)	100.0%	100.0%	100.0%	97.5%(g)	67.0%(f)	0.0%	32.2%	32.2%	32.2%
LED Bulbs/ Luminaires, Hard-to-Reach (Note 3)	100.0%	100.0%	100.0%	97.5%(g)	47.0%(f)	0.0%	51.7%	51.7%	51.7%
LED Bulbs/ Luminaires, Combined Non HTR-HTR (Note 6)	100.0%	100.0%	100.0%	97.5%(g)	63.0%(f)	0.0%	36.1%	36.1%	36.1%
Freezers	100.0%	100.0%	100.0%	100.0%	37.0%(n)	0.0%	63.0%	63.0%	63.0%
Clothes Washers	100.0%	100.0%	100.0%	100.0%	48.0%(n)	0.0%	52.0%	52.0%	52.0%
Dryers	100.0%	100.0%	100.0%	100.0%	32.0%(n)	0.0%	68.0%	68.0%	68.0%
Refrigerators	100.0%	100.0%	100.0%	100.0%	46.0%(n)	0.0%	54.0%	54.0%	54.0%
Dehumidifiers	100.0%	100.0%	100.0%	100.0%	87.0%(n)	0.0%	13.0%	13.0%	13.0%
Dishwashers	100.0%	100.0%	100.0%	100.0%	90.0%(n)	0.0%	10.0%	10.0%	10.0%
Room A/Cs	100.0%	100.0%	100.0%	100.0%	42.0%(n)	0.0%	58.0%	58.0%	58.0%
Sound Bars	100.0%	100.0%	100.0%	100.0%	16.0%(n)	0.0%	84.0%	84.0%	84.0%
Room Air Cleaners	100.0%	100.0%	100.0%	100.0%	35.0%(n)	0.0%	65.0%	65.0%	65.0%
Set-top Boxes	100.0%	100.0%	100.0%	100.0%	11.0%(n)	0.0%	89.0%	89.0%	89.0%
Computers	100.0%	100.0%	100.0%	100.0%	65.0%(n)	0.0%	35.0%	35.0%	35.0%
Blu Ray Player	100.0%	100.0%	100.0%	100.0%	35.0%(n)	0.0%	65.0%	65.0%	65.0%

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)	Measure	kWh or (ccf)	Winter Seasonal Peak kW or (Peak Day ccf)	Measure	kWh or (ccf)	Winter Seasonal Peak kW or (Peak Day ccf)	Measure
Residential New Construction									
Residential New Construction, HERS-rated (Note 2, Note 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%
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 HES and HES-IE gross realization rates.
- Updated column headers.

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[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, Table 1-1.
[b,2]	p. ES-6, Table 1-2.
[b,3]	p. ES-6, Table 1-3.
[c]	ERS, *C1639: Impact Evaluation of the Connecticut Small Business Energy Advantage Program*, Mar. 20, 2018.
[c,1]	p. 4, Table 1-4.
[c,2]	p.7, Table 1-5, p.9, Recommendation 2.
[d]	Tetra Tech, *2011 C&I Electric and Gas Free-ridership and Spillover Study*, Oct. 5, 2012.

[d,1]	pp. 3-4, Table 3-5.
[d,2]	pp. 3-5, 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, p. 35, 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, Table ES-3.
[j]	KEMA, Process Evaluation of the 2012 Bright Opportunities Program Final Report, Jun. 14, 2013, pp. 1-11, 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]	West Hill Energy and Computing, CT HVAC and Water Heater Process and Impact Evaluation Report and CT Heat Pump Water Heater Impact Evaluation Report, R1614/R1613, May 16, 2018.
[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 2018 Summary. Available at: https://www.energystar.gov/index.cfm?c=partners.unit_shipment_data.
[o]	ERS, *C1641: Impact Evaluation of the Business and Energy Sustainability Program*, Sep. 5, 2018, (p. 4, Table 1-3; p. 5, 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, 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]	C1635 Impact Evaluation of PY 2016 & 2017 Energy Opportunities (EO) Program, DNVGL, June 30, 2020.

Notes

[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].
[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 #9 from the report, to use only the 2019 PSD manual's Grashof algorithm to calculate steam trap savings. See Section 3.2.6 for the steam trap replacement algorithm.
[8]	As recommended in the C1644 study, the NTG value for linear LEDs is 91%. To separate the contribution of free-ridership and spillover to this NTG value, we used a proportion equivalent to the levels of free-ridership and spillover found among screw-based LEDs in the C1644 study.
[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.

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.

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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	10 (a,*)	10 (a,*)	N/A	N/A	N/A
Fixture (LED)	N/A	13 (a)	15 (a)	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	13 (a)	N/A	N/A	N/A	N/A
Lamp Replacement (LED)	N/A	4 (l)	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)

Description	Remaining Useful Life	Retrofit	Lost Opportunity	Operations	Maintenance	RCx
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
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	15(c/93)	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	10 (m)	10 (m)	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
Duct Sealing	N/A	18 (c/31)	N/A	N/A	N/A	N/A

Description	Remaining Useful Life	Retrofit	Lost Opportunity	Operations	Maintenance	RCx
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	15 (m)	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
Variable Speed Drive	N/A	13 (b,1)	15 (b,1)	N/A	N/A	N/A
VAV System Components	N/A	13 (m)	N/A	N/A	N/A	N/A

Description	Remaining Useful Life	Retrofit	Lost Opportunity	Operations	Maintenance	RCx
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)
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
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

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Description	Remaining Useful Life	Retrofit	Lost Opportunity	Operations	Maintenance	RCx
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
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	11 (i)	N/A	N/A	N/A

Description	Remaining Useful Life	Retrofit	Lost Opportunity	Operations	Maintenance	RCx
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	10 (m)	10 (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
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

Description	Remaining Useful Life	Retrofit	Lost Opportunity	Operations	Maintenance	RCx
Ice Machine	N/A	N/A	12 (c/82)	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 LED lifetimes; and
- Added Strategic Energy Management lifetimes.

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References

[a]	GDS Associates Inc., *Measure Life Report, Residential and Commercial Industrial Lighting and HVAC Measures*, Jun. 2007, Table 2.
[a,*]	This measure is similar to those in the report, so a measure life from Table 2 was used.
[a,**]	This measure is similar to those in the report, so a measure life from Table 1 was used.
[b]	Energy & Resource Solutions. ERS *Measure Life Study.*: Prepared for the Massachusetts Joint Utilities, Oct. 10, 2005.
[b,1]	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, Table 4.
[e]	Energy & Resource Solutions (ERS), *Process Reengineering for Increased Manufacturing Efficiency Program Evaluation*, Mar. 26, 2007, pp. 1-5.

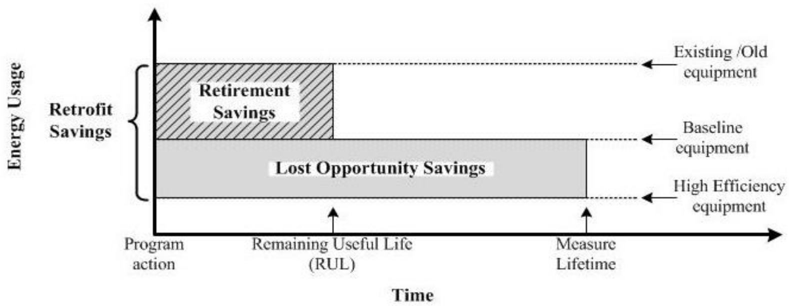
[f*]	Efficiency Maine TRM, 3/5/07, p. 91. Similar measure.
[g]	Energy and Environmental Analysis, Inc. *Steam Traps Workpaper for PY2006-2008.* Prepared for Southern California Gas Company, Dec. 2006, p. 14, Section 9.1.
[h]	Veritec Consulting, "*Region of Waterloo Pre-Rinse Spray Valve Pilot Study Final 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. (2009). *Natural Gas Energy Efficiency Potential in Massachusetts*. Prepared for GasNetworks; 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]	Estimated.
[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*, February 2017, and CEE, *2016 Strategic Energy Management Program Summary*, Nov. 21, 2016

A4.2 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.

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		
LED, Bulb	N/A	4 (k)
LED, Luminaire	N/A	5 (k)
Heating, Ventilation, and Air-Conditioning (HVAC) Systems		
Air-Source Heat Pump	5 (b)	18 (c,1)
Boiler (Gas)	5 (b)	20 (a)
Boiler Reset Control	N/A	15 (e)
Central Air Conditioning System	5 (b)	18 (c,1)
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 (c,1)
Electronically Commutated Motor (Fan)	N/A	18 (c,1)
ECM Circulator Pump	N/A	15 (f)
Furnace (Natural Gas)	5 (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)

Measure	Retirement RUL	Lost Opportunity EUL
QIV, Boiler (Boiler Reset)	N/A	20 (a)
QIV, Central Air Conditioning System	N/A	18(c,1)
QIV, Geothermal Heat Pump	N/A	18(c,1)
Wi-Fi Thermostat	N/A	15(g)
Appliances		
Room Air Cleaner	N/A	9(m)
Clothes Washers, Clothes Dryer	4(b)	11(a)
Dehumidifier	4(b)	12(c,1)
Dish Washer	4(b)	10(a)
Freezer	4 (8)(b)	11(a)
Refrigerator	5 (10)(b)	12(a)
Room A/C Unit	4(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	9 (n)
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	20 (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	5 (b)
Heat Pump Water Heater	N/A	13 (l)
High-Efficiency Storage Gas Water Heater	N/A	11 (b,5)
On Demand Tankless Gas Water Heater	N/A	20 (b,2)
Pipe Insulation	N/A	15 (b)

Measure	Retirement RUL	Lost Opportunity EUL
Low-Flow Shower Head	N/A	10 (c,2)
Water Heater Thermostat Setting (Existing Unit)	N/A	4 (b)
Water Heater Wrap	N/A	5 (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 Room A/C lifetime.
- Added refrigerator and freezer recycling lifetimes.

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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, 2008 Database for Energy-Efficient Resources, Dec. 16, 2008. Available at: http://www.deeresources.com/deer0911planning/downloads/EUL_Summary_10-1-08.xls, last accessed May 31, 2011, Version 2008.2.05.
[b,1]	Cell D135.
[b,2]	Cell D146.
[b,3]	Cell D141.
[b,4]	Cell D143.
[b,5]	Cell D145.
[c]	GDS Associates Inc. *Measure Life Report, Residential and Commercial Industrial Lighting and HVAC Measures*, 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, p. M-76.
[g]	Environmental Protection Agency (2010). *Life Cycle Cost Estimate for Programmable Thermostats*. Accessed on Oct. 12, 2011.
[h]	Solar Thermal Systems Analysis, Tim Merrigan, National Renewable Energy Laboratory. Available 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 saturation trends, penetration, and hours of use from NMR, *Connecticut LED Lighting Study Report (R154)*, Jan. 2016.
[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.xlsx. Last accessed on Jul. 19, 2017.
[p]	Conservative estimate, based on 13-year median age for room air conditioners 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, Multi-Family, and Commercial/Industrial Measures, Version 7,* Apr. 15, 2019.

APPENDIX FIVE: HOURS OF USE

A5.1 Commercial and Industrial Hours of Use and EFLH

Table A5-1: C&I Hours of Use

Update Upstream lighting annual hours of use assumptions by building type in Table A5-1 for Lighting

Building Type	Annual Hours of Use
24x7 lighting	8,760
Automotive	4,056
Education	2,967
Grocery	5,468*
Health Care	5,564
Hotel/Motel	3,064
Industrial	5,793
Large Office	4,098
Other	6,211
Parking Lot/Streetlights	6,887
Religious bldg/Convention center	913
Restaurant	5,018*
Retail	4,939*
Small Office	3,748
Warehouse	5,667

*Based on the MA TRM assumption since the data leveraging result assumes hours of operation which seem unreasonable for the average building of this type

~~Facility Type_Lighting Hours~~	~~Cooling FLHrs~~	~~Heat Pump FLHrs*~~	~~HVAC Fan Motor Hours~~	~~CHWP & Cooling Towers (Note [2])~~	~~Heating Pumps (Note [2])~~	
Facility Type	Lighting Hours	Cooling FLHrs	Heat Pump FLHrs*	HVAC Fan Motor Hours	CHWP & Cooling Towers (Note [2])	Heating Pumps (Note [2])
Auto Related	4,056	837	1,171	4,056	1,878	5,376
Bakery	2,854	681	1,471	2,854	1,445	5,376

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Commented [KR509]: 4,056 [2]

~~Facility Type~~ ~~Lighting Hours~~	~~Cooling FLHrs~~	~~Heat Pump FLHrs*~~	~~HVAC Fan Motor Hours~~	~~CHWP & Cooling Towers (Note [2])~~	~~Heating Pumps (Note [2])~~	
Banks, Financial Center	3,748	797	1,248	3,748	1,767	5,376
Church	1,955	564	1,694	1,955	1,121	5,376
College: Cafeteria	6,376	1,139	594	6,376	2,713	5,376
24x7 lighting	8,760 [2]					
College: Classes/Administrative (Education)	~~2,586~~2,967 [2]	646	1,537	2,586	1,348	5,376
College: Dormitory	3,066	709	1,418	3,066	1,521	5,376
Commercial Condo	4,055	837	1,172	4,055	1,877	5,376
Convenience Store	6,376	1,139	594	6,376	2,713	5,376
Convention Center	1,954	564	1,695	1,954	1,121	5,376
Court House	3,748	797	1,248	3,748	1,767	5,376
Dining: Bar Lounge/Leisure	4,182	854	1,140	4,182	1,923	5,376
Dining: Cafeteria/Fast Food	6,456	1,149	574	6,456	2,742	5,376
Dining: Family	4,182	854	1,140	4,182	1,923	5,376
Entertainment	1,952	564	1,695	1,952	1,120	5,376
Exercise Center	5,836	1,069	728	5,836	2,518	5,376
Fast Food Restaurant	6,376	1,139	594	6,376	2,713	5,376
Fire Station (Unmanned)	1,953	564	1,695	1,953	1,121	5,376
Food Store (Grocery)	~~4,055~~5,468*	837	1,172	4,055	1,877	5,376
Gymnasium	2,586	646	1,537	2,586	1,348	5,376
Hospital	7,674	1,308	270	7,674	3,180	5,376
Hospitals/Health Care	5,564 [2]~~7,666~~	1,307	272	7,666	3,177	5,376
Industrial: 1 Shift	2,857	681	1,470	2,857	1,446	5,376
Industrial: 2 Shift	4,730	925	1,003	4,730	2,120	5,376
Industrial: 3 Shift	6,631	1,172	530	6,631	2,805	5,376
Laundromat	4,056	837	1,171	4,056	1,878	5,376
Library	3,748	797	1,248	3,748	1,767	5,376
Light Manufacturer	2,857	681	1,470	2,857	1,446	5,376
Lodging (Hotel/Motel)	3,064	708	1,418	3,064	1,521	5,376
Mall Concourse	4,833	938	978	4,833	2,157	5,376
Manufacturing Facility	2,857	681	1,470	2,857	1,446	5,376
Medical Office	3,748	797	1,248	3,748	1,767	5,376
Motion Picture Theatre	1,954	564	1,695	1,954	1,121	5,376
Multi-Family (Common Areas)	7,665	1,306	273	7,665	3,177	5,376

Commented [KR510]: 5,793 [2]

Commented [SK511]: *Change to 6,388*
Add to References "Navigant Consulting (2018). Multi-Family Program Impact and Net-to-Gross Evaluation".

~~Facility Type_Lighting Hours~~	~~Cooling FLHrs~~	~~Heat Pump FLHrs*~~	~~HVAC Fan Motor Hours~~	~~CHWP & Cooling Towers (Note [2])~~	~~Heating Pumps (Note [2])~~	
Museum	3,748	797	1,248	3,748	1,767	5,376
Nursing Home	5,840	1,069	727	5,840	2,520	5,376
Large Office	4,098 [2]					
Office (General Office Types)	3,748[2]	797	1,248	3,748	1,767	5,376
Office/Retail	3,748[2]	797	1,248	3,748	1,767	5,376
Parking Garage and Lot/Streetlights	~~4,368~~6,887 [2]	878	1,094	4,368	1,990	5,376
Penitentiary	5,477	1,022	817	5,477	2,389	5,376
Performing Arts Theatre	2,586	646	1,537	2,586	1,348	5,376
Police/Fire Station (24 Hr)	7,665	1,306	273	7,665	3,177	5,376
Post Office	3,748	797	1,248	3,748	1,767	
Pump Station	1,949	563	1,696	1,949	1,119	5,376
Refrigerated Warehouse	2,602	648	1,533	2,602	1,354	5,376
Religious Building/Convention Center	~~1,955~~913 [2]	564	1,694	1,955	1,121	5,376
Residential (Except Nursing Homes)	3,066	709	1,418	3,066	1,521	5,376
Restaurant	~~4,182~~5,018 [2]*	854	1,140	4,182	1,923	5,376
Retail	4,~~057~~932 [2]	837	1,171	4,057	1,878	5,376
School/University (Ref [2~~1~~])	~~2,187~~2,967 [2]	594	1,637	2,187	1,205	5,376
Schools (Jr./Sr. High) (Ref [2~~1~~])	~~2,187~~2,967 [2]	594	1,637	2,187	1,205	5,376
Schools (Preschool/Elementary) (Ref [2~~1~~])	~~2,187~~2,967 [2]	594	1,637	2,187	1,205	5,376
Schools (Technical/Vocational) (Ref [2~~1~~])	~~2,187~~2,967 [2]	594	1,637	2,187	1,205	5,376
Small Services	3,750	798	1,247	3,750	1,768	5,376
Sports Arena	1,954	564	1,695	1,954	1,121	5,376
Town Hall	3,748	797	1,248	3,748	1,767	5,376
Transportation	6,456	1,149	574	6,456	2,742	5,376
Warehouse (Not Refrigerated)	5,667 [2]~~2,602~~	648	1,533	2,602	1,354	5,376
Waste Water Treatment Plant	6,631	1,172	530	6,631	2,805	5,376

~~Facility Type_Lighting Hours~~	~~Cooling FLHrs~~	~~Heat Pump FLHrs*~~	~~HVAC Fan Motor Hours~~	~~CHWP & Cooling Towers (Note [2])~~	~~Heating Pumps (Note [2])~~	
Workshop	3,750	798	1,247	3,750	1,768	5,376

*Based on the MA TRM assumption since the data leveraging result assumes hours of operation which seem unreasonable for the average building of this type.

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Changes from Last Version

- No changes.

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References

[1]	RLW Analytics. "*CT and MA Utilities 2004-05 Lighting Hours of Use for School Buildings Baseline Study*," Final Report, Sep. 7, 2006.
[2]	C1635 Impact Evaluation of PY 2016 & 2017 Energy Opportunities (EO) Program, DNVGL, June 30, 2020.

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Notes

[1]	The hours listed in Table A5-1 are default hours to be used when site-specific hours are not available. These hours have been developed over the years and are taken into account during program evaluations. Any errors, whether positive or negative, are trued up in the realization rates. Significant changes to Table A5-1 will only be accepted if the evaluation contractor provides "going forward" realization rates along with updated hours.
[2]	Since it is common to have redundant pumps, the hours provided above are estimated based on full operation of only the pumps(s) required to maintain system flow (lead pump(s)). Therefore, lag pump(s) have 0 hours of operation even if the pumps are typically alternated. For example, if a system had two 10 HP pumps but only one was required to operate at any given time to maintain system flow (lead/lag), then the EFLHs would be based on one 10 HP pump.

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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 2019-2021 Conservation & Load Management Plan ("2019-2021 Plan").

Table A6-1: Residential Non-Energy Impacts (Ref [2])

	HES	HES-IE	Rebate	MF
Comfort	0.25	0.17	0.31	0.14
Outside Noise	0.04	0.05	0.06	
Appliance Noise	0.05	0.06	0.15	
Maintenance	0.07	0.08	0.18	0.15
Home Value	0.12	0.07	0.24	0.09
Home Appearance	0.03	0.06	0.04	
Home Safety	0.05	0.07	0.05	0.21
Lighting Quality	0.08	0.14		
Complaints	0	0	0	0.08
Total	0.69	0.70	1.03	0.67

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: Commercial & Industrial Non-Energy Impacts (Ref [3])

NEI Category	NEI Dollar Impacts for Business and Energy Sustainability 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 Operations and Maintenance	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]	*Valuation of Non-Energy Benefits to Determine Cost-Effectiveness of Whole House Retrofit Programs: A Literature Review*. Jennifer Thorne Amann, May 2006.
[2]	NMR Group, Inc. Submitted to Energy Efficiency Board, Eversource, and United Illuminating. *Project R4 HES/HES-IE Process Evaluation and R31 Real-Time Research*. Apr. 13, 2016. Available at: http://www.energizect.com/sites/default/files/R4_HES-HESIE%20Process%20Evaluation%2C%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 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
AC	Air Conditioning	
AC	Annual Cooling Energy Usage	kWh/yr
ACCF	Annual Natural Gas Energy Savings	ccf/yr
ACOP	Average Coefficient of Performance	
ADET	Annual Differential Electrical Energy Savings per Ton	kWh/Ton/yr
ADHW	Annual Domestic Water Heating Load	Btu/yr
AEC	Annual Electric Cooling Usage per ft^2	kWh/ft^2/yr
AEH	Annual Electric Heating Usage per ft^2	kWh/ft^2/yr
AF/BI	Air Foil/Backward Inclined Fan	
AFUE	Annual Fuel Utilization Efficiency	
AGU	Annual Gas Usage per ft^2	ccf/ ft^2/yr
AH	Annual Heating Energy Usage	kWh/yr
AKW	Average Hourly Demand Savings for both Summer and Winter	
AKWH	Annual Gross Electric Energy Savings	kWh/yr
AOG	Annual Oil Savings	Gallon/yr
AOU	Annual Oil Usage per ft^2	gal/ft^2/yr
APG	Annual Propane Savings	Gallon/yr
APU	Annual Propane Usage per ft^2	gal/ft^2/yr
ASF	Annual Savings Factor	kWh/ton
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers	
AV	Adjusted Volume	ft^3
BB	Hartford kW Savings Factor from Pilot	kW/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

Symbol	Description (See Note [1])	Units
BTUH	Heat Transfer Rate of Ducting	Btu/hr/100 ft^2
C&I	Commercial and Industrial	
C&LM	Conservation and Load Management	
CAC	Central Air Conditioning	
CAP	Capacity of the Equipment	Btu/h or Ton
CC	Bridgeport kWh Savings Factor from Pilot	kWh/1,000 Btu
ccf, CCF	*100 Cubic Feet, Quantity of Natural Gas*	100 Cubic Feet
CDD	*Cooling Degree Days for CT*	603
CEEF	*Connecticut Energy Efficiency Fund*	
CF	*Seasonal Coincidence Factor*	
CFL	*Compact Florescent Light*	
CFM	*Cubic Feet per Minute, Air Flow Rate*	ft^3/min
CHWP	*Chilled Water Pump*	
CL&P	*Connecticut Light and Power*	
COP	*Coefficient of Performance*	
CWP	*Condenser Water Pump*	
d	*Duration*	minutes
D	*Density*	lb/Gal
D	*Dimension (height or width)*	inches
Days	*Annual Days of Use*	Days/yr
DD	*Bridgeport kW Savings Factor from Pilot*	kW/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*	

Symbol	Description (See Note [1])	Units
EFF	*Rated Motor Efficiency*	
EFLH	*Equivalent Full Load Hours*	hours
EKWH	*Estimated Annual Electric Usage with Increase in Production*	
EUL	*Effective Useful Life*	years
F	*Fraction of Lighting Heat Affecting Cooling*	
F	*Factor*	various
FC	*Forward Curved Fan*	
FCM	*Forward Capacity Market*	
FHLE	*Fryer Heavy Load Efficiency*	
FIR	*Fryer Idle Energy Rate*	Btu/hr
FLH	*Annual Full Load Hours*	Hr/yr
FPC	*Fryer Production Capacity*	Lbs/hr
FPE	*Fryer Preheat Energy*	Btu
FR	*Free-rider*	
ACCF	*Annual Gas Savings*	ccf/yr
G	*Estimated Lighting Energy Heat to Space Based on Modeling*	
GPH	*Average Peak Gallons per Hour*	Gal/hr
gpm	*Gallons Per Minute*	
GPY	*Gallons (of water) per Year*	Gal/yr
GSHP	*Ground Source Heat Pump*	
H, h	*Hours (annual or daily)*	hours
HAP	*Computer Energy Simulation Tool*	
HDD	*Heating Degree Days for CT*	°F
HF	*Heating Factor*	Btu/ft^2/yr
HL	*Heat Loss Savings per Linear Foot*	Btu/hr/ft
HP	*Horsepower (nameplate)*	
HPWH	*Heat Pump Water Heater*	
HR	*Ice Harvest Rate for Ice-Cube Machines*	
HR	*Annual Electric Energy Usage Dependent on Hours of Production*	kWh/yr
HR	*Percent Heating Not Using Backup Electric Resistance*	%
Hrs	*Operating Hours per Day*	Hr/day
HSPF	*Heating Seasonal Performance Factor*	
HVAC	*Heating, Ventilation, and Air Conditioning*	
HWP	*Hot Water Pump*	
IGV	*Inlet Guide Vane Fan Control*	
IND	*Annual Electric Energy Usage Independent of Production*	kWh/yr
IPLV	*Integrated Part Load Value*	EER or kW/ton
ISO-NE	*Independent System Operator New England*	
kW	*Electric Demand, kilowatts*	1,000 Watts

Symbol	Description (See Note [1])	Units
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

Symbol	Description (See Note [1])	Units
PF	*Peak Factor*	kW/kWh
Pf	*Power Factor*	
PkW	*kW Demand Savings*	kW
PSC	*Permanent Split Capacitor*	
PSD	*Program Savings Documentation*	
PTAC	*Package Terminal Air Conditioner*	
PTHP	*Package Terminal Heat Pump*	
r	*Climate Adjustment Ratio*	
R	*R Value is a Measure of Thermal Resistance*	ft^2 x h x ^{0}F / Btu
Ratio	*Ratio of Heating Capacity to Cooling Capacity*	
REM	*Residential Energy Modeling Software or Results*	
RNC	*Residential New Construction Sector*	
RP	*Retail Products Sector*	
RTU	*Roof Top Unit*	
RUL	*Remaining Useful Life*	Years
S	*Savings*	Varies
S	*C&I Lighting Annual kWh Savings*	kWh
SA	*Seasonal Efficiency Adjustment*	%
Savings Fraction	*Fraction of Base-Case Consumption Saved with Low-Intensity Radiant Heaters*	
SAWC	*Steamer Average Water Consumption Rate*	Gal/h
SEER	*Seasonal Energy Efficiency Ratio*	
SF	*Area*	Square Feet
SF	*Savings Factor*	
SHLE	*Steamer Heavy Load Efficiency*	%
SIR	*Steamer Idle Energy Rate*	Btu/h
size	*Capacity (Volume)*	ft^3, pints/day
SKF	*Summer Factor*	kW/ft^2
SKW	*Seasonal Summer Peak Summer Demand Savings*	kW
Sleeve	*Unit without Louvered Sides*	
SLR	*Standby Loss Rate*	Btu/hr
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*	

Symbol	Description (See Note [1])	Units
UDRH	*User Defined Reference Home*	
UI	*United Illuminating*	
V	*Volts of Existing Fans*	Volts
V	*Volume*	ft^3
VAV	*Variable Air Volume*	
VFD	*Variable Frequency Drives*	
W	*Width*	ft
Watt, W	*Wattage*	Watt
$Watt_{\Delta}$	*Delta Watts*	
WCS	*Electric Cooling Energy Savings from Wisconsin Study*	kWh
WF	*Water Factor*	Gal/ft^3
WH	*Water Heater, Water Heating*	
WHS	*Electric Heating Energy Savings from Wisconsin Study*	
WICDD	*Cooling Degree Days for WI*	
WIHDD	*Heating Degree Days for WI*	
Window	*Unit with Louvered Sides*	
WKW	*Seasonal Winter Peak Demand Savings*	kW
WP	*Water Heating Proportion of Clothes Washer Energy*	%
WPF	*Winter Peak Factor*	W/kWh
WSHP	*Water Source Heat Pump*	
YR	*Year*	
ΔkW	*Reduction in Power for Each Light*	kW
ΔT	*Delta (or Differential) Temperature*	°F
ηb	*Base Case Efficiency*	
ηp	*Proposed Case Efficiency*	

A7.2 Subscripts

Symbol	Description (See Note [1])	Units
…A	Actual/Installed Unit	
…a	After PRIME	
…b	Baseline Unit	
…BD	Blower Door Flow Rate Reading Performed at 50 Pa	Cubic Feet per Minute
…BIN	Temperature BIN Hours	
…C	Cooling	
. . . CAC	Central Air Conditioning	
…CDH	From CDH HVAC study	
…d	Number of Hours that Piece of Equipment is Expected to Operate per Day	h
…Δ	Delta	
…dp	Double Pane Window	
…door kit	Door Kit, Door Sweep	
…DS	Duct Sealing Flow Rate Reading Performed at 25 Pa	Cubic Feet per Minute
…E	Electric Energy	
…e	Existing (e.g., unit, production rate, etc.)	
…es	ENERGY STAR	
…ES 09	ENERGY STAR 2009 unit	
…fed std	Federal Standard Unit	
…G	Natural Gas	
…gasket	Air Sealing Gasket	
…h	Based on Billing History	
…H	Heating	
…HP	Heat Pump	
…HVAC	HVAC Motor	
…hw	Hardwired Light Fixtures	
…i	Incoming	
…i	Installed Unit	
…ic	Interactive Cooling	
…L	Lighting	
…LI	Low-Income Sector	
…LO	Lost Opportunity Measure	
…lpd	Lighting Power Density	

Symbol	Description (See Note [1])	Units
$\ldots_{lt}$	Life Time	
$\ldots_{M}$	Motors	
$\ldots_{N}$	Non-HVAC Applications	
$\ldots_{NLI}$	Non-Low-Income Sector	
$\ldots_{O}$	Oil	
$\ldots_{O}$	Others	
$\ldots_{os}$	Occupancy Sensors	
$\ldots_{P}$	Process	
$\ldots_{P}$	Propane	
$\ldots_{post}$	Final Reading	
$\ldots_{pre}$	Initial Reading	
$\ldots_{R}$	Electric Resistance	
$\ldots_{R}$	Refrigeration	
$\ldots_{ratio}$	Ratio between Low-Efficiency Value and High-Efficiency Value	
$\ldots_{retire}$	Retirement Portion	
$\ldots_{retro}$	Retrofit Portion	
$\ldots_{retrofit}$	Retrofit Portion	
$\ldots_{S}$	Summer	
$\ldots_{sealing}$	Caulking, Sealing, Polyethylene Tape	foot
$\ldots_{total}$	Total, Sum	
$\ldots_{W}$	Water Heating	
$\ldots_{wop}$	Without PRIME	
$\ldots_{wp}$	With PRIME	
$\ldots_{wt}$	Winter	
$\ldots_{wx}$	Weather-strip, Repair	
$\ldots_{y}$	Number of Hours that Piece of Equipment is Expected to Operate per Year	h

Changes from Last Version

- No changes.

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Notes

[1]	Many of these terms have more complete definitions in the Glossary section.