# Connecticut's 2023 Program Savings Document

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# TABLE OF CONTENTS

# 1 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 since the first iteration of the PSD in 2003 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 Companies have incorporated the results of program impact evaluations. 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 twentieth update to the PSD manual (2023 PSD manual).

The C&LM savings calculations in the 2023 PSD manual represent typical energy-efficient measures and the prescriptive calculations used for those measures. In some cases, projects are more comprehensive and prescriptive measure calculations are not appropriate. To accurately calculate the savings related to these types of projects, more detailed spreadsheets or computer simulation models must be used. Third-party engineering consultants may be contracted to run simulations and create these spreadsheets; all simulations and spreadsheets are reviewed for reasonableness.

## 1.2 FORWARD CAPACITY MARKET

In June 2006, the Federal Energy Regulatory Commission (FERC) approved a settlement that established a redesigned wholesale electric capacity market in New England intended to encourage the maintenance of current power plants and construction of new generation facilities. The settlement established a Forward Capacity Market (FCM). ISO-New England, Inc. (ISO-NE), the operator of the region's bulk power system and wholesale electricity markets, was made responsible for projecting the energy needs of the New England region three years in advance and then holding an annual auction to purchase power resources to satisfy the region's future needs.

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

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

electrical demand compared to some baseline pattern of use. The 2023 PSD manual provides the basis of any demand reduction value calculations submitted by Eversource and United Illuminating in the FCM.

## 1.3 ORGANIZATION

Energy efficiency and demand management measures in the 2023 PSD manual are grouped by primary sector and reflect how programs and measures are organized within the programs. Commercial and industrial (C&I) measures are also categorized as either “Lost Opportunity” or “Retrofit.” The main sections of the 2023 PSD manual are as follows:

- Section 1: Introduction.
- Section 2: C&I.
- Section 3: Residential, including Limited-Income.
- Appendices.

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

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

- **Measure Life.** Describes the expected life of the measure in years. Life may vary by measure technology, installation event type (retrofit or lost opportunity) or other factor.
- **Peak Factors.** The summer and winter electric **coincidence factors** and winter natural gas **peak day factors** are ratios that specify the measure load during peak periods relative to average loads. The glossary explains the basis of each.
- **Load Shapes.** The load shape tables specify the percentage of annual energy used between 7 am and 11 pm on non-holiday weekdays and other times, for each of the summer and winter seasons.
- **Non-Energy Impacts.** Describes any impacts not directly associated with energy savings.
- **Realization Rates and Net Impact Factors.** These tables present the gross realization rates for energy and demand savings as well as free ridership and spillover factors and resulting net realization percentages (e.g., net-to-gross ratios).
- **Changes from Last Version.** If there are any changes from the previous version, they are described in this section.
- **References.** Sources used to construct the measure are listed here. ***Subsections that do not apply to a particular measure are not included.***

## 1.4 BACKGROUND

In 1999, the State Legislature created the Energy Efficiency Board (EEB), to guide and assist Connecticut's electric and natural gas distribution companies in the development and implementation of cost-effective energy conservation programs and market transformation initiatives.[2] The Connecticut Energy Efficiency Fund (Fund) created by this legislation provides the financial support for EEB-guided programs and initiatives. The Department of Energy and Environmental Protection (DEEP) is responsible for final approval of all Fund programs. Fund programs are administrated by the Companies and are designed to realize the Fund's three primary objectives:

1. **Advance the efficient use of energy.** Fund programs are critical in reducing overall energy consumption and reducing load during periods of high demand. They help mitigate potential electricity shortages and reduce stress on transmission and distribution lines in the state.

2. **Reduce air pollution and negative environmental impacts.** Fund programs produce environmental benefits by slowing the electricity demand growth rate, thereby avoiding emissions that would otherwise be produced by increased power generation activities. The US Environmental Protection Agency (EPA) regulates "criteria" air pollutants under the Clean Air Act's National Ambient Air Quality Standards (NAAQS). The EPA calls them criteria air pollutants because the agency regulates them by developing human health-based and/or environmentally based criteria (science-based guidelines) for setting permissible levels.

   Fund programs have significantly reduced two NAAQS criteria pollutants emitted in the process of generating electricity: sulfur dioxide and nitrogen dioxide. Carbon dioxide and other greenhouse gases (GHGs), such as methane, are also emitted during the process. GHGs are linked to global warming and climate change. Fund programs have helped to reduce carbon dioxide emissions by reducing electrical demand, and consequently the need for additional generation, through energy efficiency and conservation. These programs also produce environmental benefits by reducing the consumption of natural gas and fuel oil. With assistance from the EEB, the Companies have developed

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

Fund programs that support the state's environmental initiatives to reduce these air pollutants, as well as fine particulate and ozone emissions.

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

Information regarding Fund programs is available at the following websites:

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

## 1.5 PROGRAM SAVINGS

Consistent with Public Act 13-298, Public Act 11-80 § 33, and Connecticut General Statute § 16-245m(d)(4), the EEB Evaluation Road Map Process provides a mechanism to conduct independent third-party evaluation studies to assess program savings. Through this process, impact evaluations are conducted to evaluate savings for programs or measures that are delivered through Fund programs. The results of these evaluations are incorporated into the 2023 PSD manual through changes to savings algorithms and/or realization rates which are used to adjust savings.

The savings results presented in the 2023 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). Load shapes are used to assign the proper value of energy savings resulting from the implementation of energy efficiency and demand management measures to the corresponding time of day when those savings are realized.

## 1.6 TYPES OF SAVINGS

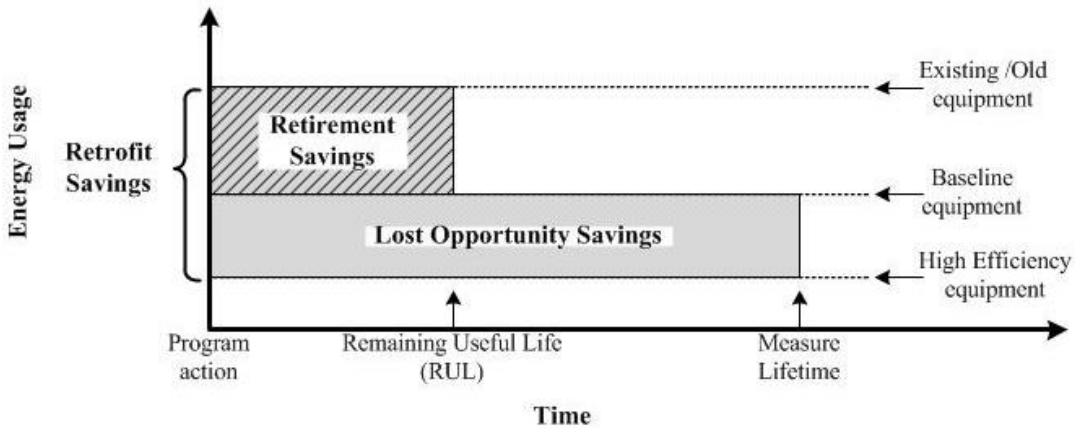
Energy efficiency measures are generally described as three types:

- **Lost Opportunity:** Where new measures are installed that are more efficient than a baseline or standard.
- **Retrofit:** Where less efficient measures are replaced before the end of their useful life with energy-efficient measures. Retrofit savings are calculated as the combination of Lost Opportunity Savings and Retirement Savings.

- **Early Retirement**: The portion of retrofit savings where the efficient measure replaced working equipment, but that after some period of time when the pre-existing equipment otherwise would have failed, the presumed replacement equipment would have had a different efficiency, generally higher than the working equipment.

Many energy efficiency measures consist of both Early Retirement Savings and Lost Opportunity Savings. This is illustrated in Figure 1-1 below.

**Figure 1-1 Retrofit, Retirement, and 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; **Early Retirement Savings** may be claimed between the existing unit to the standard baseline unit (driven by the level of efficiency most standard units achieve) for the retirement measure life. The residential retirement lifetime refers to how much longer the existing unit would have operated absent the influence of a Fund program. For example, a working heating system may be retired prior the end of its useful life as a result of program intervention.

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

If the retirement life is much greater than zero, the Retirement and Lost Opportunity Savings are combined to generate total **Retrofit Savings**. When the retirement life is approximately zero, savings are reduced to Lost Opportunity Savings only. Retirement Savings are acknowledged to exist; however, they are ignored because they are assumed to be short lived. **Remaining Useful Life (RUL):** This is how long the pre-existing but replaced piece of equipment would have remained in operation if the measure had not been installed. In the absence of site-specific information, a default value of 1/3 the equipment's effective useful life should be used.[3]

[3] DNV. 2021. "X1939 Phase 1 Best Practices Research Prepared for the CT Energy Efficiency Board and Evaluation Administration Team." https://energizect.com/sites/default/files/2022-02/X1939%20Phase%201%20Best%20Practices%20Research_ReviewDraft_2021_06_04_Clean.pdf.

**Measure Lifetime:** 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.

**Effective Useful Life (EUL):** The median number of years that the installed measure is in place and operable. In principle, this is the equipment technical life (e.g., median time to failure), discounted for measure persistence, the likelihood of the equipment being removed entirely from use due to business closure, remodeling, etc. EUL is not discounted for savings persistence, the possible gradual erosion of savings over time for a measure still in place.

## 1.7 IECC CODE CHANGE

Where applicable, the 2023 PSD manual's values have been revised to reference the 2021 International Energy Conservation Code (2021 IECC). If a project permit is issued before this code is adopted by the State (October 1, 2022), the previous code (2015 IECC) should be referenced.

Commercial New Buildings and Major Renovation projects in CT will receive the baseline that was in place when the projects were initiated. Project initiation is defined as the earliest of the following milestones that could occur, depending on the project and Energize CT Sponsor: 1) Memorandum of Understanding date; 2) Date of signed Design Agreement for studies; 3) Signed Project Intake Form, or 4) Date Data Collection Form received

## 1.8 PEAK SAVINGS

*Electric Measures*

The values for electric demand savings (both winter and summer) in the 2023 PSD manual are given based on the following definitions:

- A "Seasonal Peak" reduction is based on the average peak reduction for a measure during the ISO-NE definition for a Seasonal Peak Demand Resource; when the real-time system hourly load is equal to or greater than 90% of the most recent "50/50" system peak load forecast for the applicable Summer or Winter Season.[4]
- The "Summer Season" is defined as non-holiday weekdays during the months of June, July, and August.
- The "Winter Season" is defined as non-holiday weekdays during December and January.

Typically, seasonal peaks are weather driven and occur in the mid to late afternoon on Summer Season weekdays, or for the Winter Season, in the early evening.

[4] Many peak factors in this document reference the CT X1931-2 research study. This study used 2019 data to define the most recent seasonal peak hours in order to avoid grid-level impacts due to COVID. This study used a summer seasonal peak definition of 5:00 p.m. – 8:00 p.m., non-holiday weekdays during July and August. While the ISO-NE summer season runs from June through September, ISO-NE did not log June or September seasonal peak hours between 2013 and 2019. This study used a winter seasonal peak definition of 7:00 a.m. – 10:00 a.m. and 4:00 p.m. – 9:00 p.m., non-holiday weekdays during December and January. All winter seasonal peak hours have occurred during these two months since 2013.

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.

*Natural Gas Measures*

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 methodology for peak day savings estimating for natural gas efficiency measures is summarized below:

- **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 (Values varies per Utility).
- **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 National Renewable Energy Laboratory (NREL). 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.
- **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.
- **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.

## 1.9 NON-ENERGY IMPACTS

In addition to direct electric and natural gas benefits, some measures have other non-energy impacts (NEIs). Where appropriate, these are defined in the PSD manual. NEIs may be included in the Total Resource Cost Test and include resource impacts (e.g., water) and non-resource impacts (e.g., operations and maintenance (O&M), comfort, etc.). The Companies include the table in individual measure descriptions, when applicable, in the CTET test and Total Resource Cost Test, for Home Energy Solutions-Income Eligible only. The test is described in Section 5 of the 2022-2024 Conservation & Load Management Plan (2022-2024 Plan).

## 1.10 SAVINGS ADJUSTMENT FACTORS

The savings for the C&LM measures defined in the 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 key factors such as the hours of use, differences in efficiency, differences in power consumption, etc. Gross Savings is an estimate of expected customer savings; however, it does not include program attribution factors such as free ridership.

When calculating the total impact of energy-saving measures, there are also some other factors beyond the engineering parameters that need to be considered, such as installation rates, free-ridership, and spillover. The equation for Net Savings is as follows:

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

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

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

Realization rates can be applied to specific measures or across programs depending on their source. Since C&I programs typically offer a wide range of diverse measures, defining specific impact factors for C&I programs can be difficult, and therefore program-specific realization rates are usually limited to C&I programs. Each measure contains a list of program specific realization rates relevant to the measure. These 2023 PSD manual rates have been updated based on recently completed studies.

## 1.11 COMMON ENERGY CONVERSIONS

Energy conversions used in the PSD manual that convert energy to a specific fuel type are summarized in *Figure 1-2* below.

**Figure 1-2 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 |

## 1.12 SAVINGS CALCULATIONS

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

## 1.13 GLOSSARY

The Glossary provides definitions of the energy efficiency terms used in the PSD manual. Note that some of these terms may have alternative or multiple definitions some of which may be outside the context of the PSD manual. Only definitions pertaining to the 2023 PSD manual are included in the Glossary.

**Annual Fuel Utilization Efficiency (AFUE):** The thermal efficiency measure of combustion equipment, like furnaces and boilers. The AFUE differs from the true 'thermal efficiency' in that it is not a steady-state, peak measure of conversion efficiency, but instead attempts to represent the actual, season-long, average efficiency of that piece of equipment, including the operating transients. The method for determining the AFUE for equipment is based on the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE) standards.

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

**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.[5] *Contrast with Compliance Efficiency.*

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

**Benefit-Cost Ratio (BCR):** The energy efficiency programs determine cost effectiveness using the Utility Cost Test (i.e., Electric System and the Natural Gas System), the Connecticut Efficiency Test (CTET), or Total Resource Test. Energy efficiency efforts are cost effective if the BCR 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).

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

2. The **Connecticut Efficiency Test "CTET"** includes all benefits and costs included in the Utility Cost Test, with the addition of oil and propane-avoided costs, avoided greenhouse gas costs, as well as low-income NEIs, and program costs associated with acquiring oil and propane savings.

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

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

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

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

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

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

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

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

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

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

**Degree Days:** For any individual day, degree days indicate how far that day's average temperature departed from 65°F. Heating Degree Days measure heating energy demand and indicate how far the average daily temperature fell below 65°F. Similarly, CDDs, which measure cooling energy demand, indicate how far the average daily temperature was above 65°F.

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

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

**__Demand Resources__:** ISO-NE classifies demand reduction from energy efficiency and conservation measures into the following two categories:

- **__Active Resource__:** Demand reduction that is dispatched (i.e., demand response and emergency generation) that must respond to the electric system operator during shortage events. For example, resources entered into the ISO-NE Demand Response program are active resources because they are called upon for specific shortage events. *See additional discussion under 2.8.2 C&I Custom Measures.*
- **__Passive Resource__:** Demand reduction that is not dispatched (i.e., energy efficiency, plus a small amount of distributed generation) that reduces load during pre-defined hours and periods. Most C&LM measures are passive because they reduce load across a pre-defined operating period. For example, energy-efficient lighting will reduce load whenever lights are on throughout the year.

**__Diversity Factor__:** See Coincidence Factor.

**__Demand Reduction-Induced Price Effects (DRIPE)__:** The reduction in prices in the wholesale energy and capacity markets because of the reduction in energy and demand resulting from conservation efforts.

**__Early Retirement (ER)__:** A measure is classified as early retirement when the participant replaces working equipment before the end of its effective useful life (EUL). 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.

**__Effective Useful Life (EUL__)**: The median number of years that the installed measure is in place and operable. In principle, this is the equipment technical life (e.g., median time to failure), discounted for measure persistence, the likelihood of the equipment being removed entirely from use due to business closure, remodeling, etc. EUL is not discounted for savings persistence, the possible gradual erosion of savings over time for a measure still in place.

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

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

**__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.

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

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

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

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

**<u>Evaluation Studies</u>:** Studies that evaluate program impacts, free-ridership, and spillover, as well as processes, specific measures, and market assessments. The Companies' program administrators use results of these studies to modify the programs and savings estimates.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

**<u>Market Effect</u>:** A long-term change in the behavior of a market because of conservation and energy efficiency efforts. "Market effect savings" are the result of changes in market behaviors.

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

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

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

**<u>Measure Lifetimes</u>:** 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.

**<u>Measure Type</u>:** Refers to a category of similar measures. There are several different acceptable industry standards for defining end-use categories. For the purpose of the PSD manual, primary end-use categories include: cooling, heating, lighting, motors, process, refrigeration, water heating, and other.

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

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

**Net-to-Gross:** The ratio of Net Savings to the Gross Savings (for a measure or program). Net-to-gross is usually expressed as a percent. Net-to-gross ratios include elements of free-ridership and spillover.

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

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

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

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

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

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

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

**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. Two peak periods are used:

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

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

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

**<u>Preponderance of Evidence</u>**: The principle of preponderance of evidence is often invoked to determine event type. This simply means that when trying to determine if a measure is ER or ROF, evidence is gathered in support of both types. Whichever option is more compelling is the event type. Alternative methods could be to default to one or the other case absent overwhelming evidence (beyond a reasonable doubt), or to declare a certain event type under certain generalized conditions, regarding of the conditions of a specific measure. This principle is generally used for custom measures only, prescriptive or other high-volume measures should be managed through the use of market studies or other means.

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

**<u>Remaining Useful Life (RUL):</u>** This is how long the pre-existing but replaced piece of equipment would have remained in operation if the measure had not been installed. In the absence of site-specific information, a default value of 1/3 the equipment EUL should be used.

**<u>Retrofit</u>:** The replacement of a piece of equipment or device before the end of its useful or planned life, for the purpose of achieving energy savings. Retrofit measures are sometimes referred to as "early retirement" when the removal of the old equipment is aggressively pursued. Residential measures utilize a two-part lifetime savings calculation. In certain situations, such as early retirement, savings may be claimed in two parts: (1) where the retirement part is additional to the lost opportunity part until the end of the Remaining Useful Life (RUL), and (2) after which lost opportunity savings continue until the last year of the retrofit measure's Effective Useful Life (EUL). *Contrast "Lost Opportunity."*

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

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

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

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

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

**<u>U-Value</u>:** 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.

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

# 2 COMMERCIAL AND INDUSTRIAL

## 2.1 LIGHTING

### 2.1.1 STANDARD LIGHTING

| | |
|---|---|
| Market | Commercial |
| Baseline Type | Retrofit/Lost Opportunity |
| Category | Lighting |

***Description***

**Lost Opportunity**

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

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

**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. 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.

Reduction of lighting power reduces the cooling load and provides additional savings, which are also calculated in this measure. This measure includes baseline LPDs based on 2021 IECC standards and additional efficiency code requirements; choose the appropriate table.

**Allowable LPD:** Refer to 2021 IECC for the space-by-space method. When using the space-by-space method to calculate the LPD, an increase in a space's power allowances can be used, in accordance with 2021 IECC 405.3.2(2).

**Occupancy Sensors:** 2021 IECC requires occupancy controls for classrooms, conference rooms, copy rooms, breakrooms, offices, restrooms, storage rooms, locker rooms, corridors, warehouses, and spaces less than 300 square feet. Savings for these occupancy sensors required by code therefore cannot be claimed. Refer to 2021 IECC C405.2 for details.

**Exterior Lighting:** The default baseline for exterior lighting is ASHRAE 90.1-2019. According to the ASHRAE code, the total lighting power allowance for exterior building applications is the sum of the base site allowance plus the individual allowances for areas listed in Table 2-9 Exterior Lighting Power Allowances – 2021 IECC Standard Section C405.5.2(2) and Section C405.5.2(3)for the applicable lighting zone. Trade-offs are allowed only among exterior lighting applications listed in Table 2-9 Exterior Lighting Power Allowances – 2021 IECC Standard Section C405.5.2(2) and Section C405.5.2(3). The lighting zone for the building exterior is determined from Table 2-8 Exterior Lighting Zones.

**Retrofit**

Replacement of inefficient lighting with efficient lighting.

The energy and seasonal peak demand savings come from reduced fixture wattage, and reduced cooling load. The baseline is the wattage and existing operating hours of the fixtures being replaced. To account for the Energy Independence and Security Act of 2007 (EISA), 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 specified in EISA of 2007 updated terminology and are intended for general service applications. Lost Opportunity savings for general service lamps defined under the reinstated backstop are no longer allowed.

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

The following assumptions were used to develop this calculation methodology:

- A COP of 3.5 for retrofit lighting measures is estimated based on the 2015 Connecticut Code.
- The estimated lighting energy heat to space based on modeling is 0.73. 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 conducted an analysis. The analysis was based on a DOE-2 default analysis and information was provided to David Bebrin (Eversource) on Aug. 17, 2007.

## ***Annual Energy Savings Algorithm***

*Lost Opportunity Gross Energy Savings, Electric*

*Interior Lighting*

$$\Delta kWh = \Delta kWh_{LPD} + \Delta kWh_{HW} + \Delta kWh_{CLO}$$

*Where,*

$$\Delta kWh_{LPD} = \left((LPD_B \times LPD_{AF}) - LPD_I\right) \times \frac{kW}{1{,}000\ W} \times H \times A$$

$$LPD_I = \frac{W_{TOT}}{A}$$

$$\Delta kWh_{HW} = EF \times \frac{\Delta W \times H_R \times 365\ day}{1{,}000\ \frac{W}{kW}}$$

$$\Delta W = W_{BR} - W_{IR}$$

$$\Delta kWh_{CLO} = \frac{(\Delta kWh_{LPD} + \Delta kWh_{HW}) \times F}{COP_{LO}}$$

*Exterior Lighting*

$$\Delta kWh = (W_B - W_I) \times \frac{kW}{1{,}000\ W} \times H$$

*Retrofit Gross Energy Savings, Electric*

$$\Delta kWh = \Delta kWh_R + \Delta kWh_{CR}$$

*Where,*

$$\Delta kWh_{CR} = \frac{\Delta kWh_R \times F}{COP_R}$$

$$\Delta kWh_R = (kW_B - kW_I) \times H$$

*For EISA-qualifying bulbs, 75% of the actual wattage is used for $kW_B$.*

*Heating Penalty, Fossil Fuel*

$$\Delta MMBtu = \Delta kWh \times HVAC_H$$

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

*Lost Opportunity Gross Seasonal Peak Demand Savings, Electric*

$$\Delta kW_S = \left( \left( CF_S \times \left( (LPD_B \times LPD_{AF}) - LPD_I \right) \times A \right) + CF_{SR} \times \frac{\sum \Delta W}{1{,}000 \frac{W}{kW}} \right) \times \left( 1 + \frac{G}{COP_{LO}} \right)$$

$$\Delta kW_W = \left( CF_W \times \left( (LPD_B \times LPD_{AF}) - LPD_I \right) \times A \right) + CF_{WR} \times \frac{\sum \Delta W}{1{,}000 \frac{W}{kW}}$$

*Where,*

$$\Delta W = W_{BR} - W_{IR}$$

*Retrofit Gross Seasonal Peak Demand Savings, Electric*

$$\Delta kW_S = CF_S \times \left( \sum kW_B - \sum kW_I \right) \times \left( 1 + \frac{G}{COP_R} \right)$$

$$\Delta kW_W = CF_W \times \left( \sum kW_B - \sum kW_I \right)$$

*Exterior Lighting Demand Savings*

$$\Delta kW_S = (W_B - W_I) \times \frac{kW}{1{,}000\ W} \times CF_S$$

$$\Delta kW_W = (W_B - W_I) \times \frac{kW}{1{,}000\ W} \times CF_W$$

## ***Calculation Parameters***

**Table 2-1 Calculation Parameters**

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| $\Delta kWh$ | Annual electric savings | Calculated | kWh | |
| $\Delta kWh_{LPD}$ | Annual electric savings due to lower LPD | Calculated | kWh | |
| $\Delta kWh_{HW}$ | Annual electric savings from installation of hardwired fixtures in residential areas | Calculated | kWh | |
| $\Delta kWh_{CLO}$ | Annual electric savings from reduced cooling load | Calculated | kWh | |
| $\Delta kWh_{R}$ | Annual electric savings due to lighting retrofit | Calculated | kWh | |
| $\Delta kWh_{CR}$ | Annual electric savings from reduced cooling load for retrofit lighting measures | Calculated | kWh | |
| $\Delta MMBtu$ | Annual heating penalty | Calculated | MMBtu | |
| $\Delta kW_S$ | Seasonal summer peak demand savings | Calculated | kW | |
| $\Delta kW_W$ | Seasonal winter peak demand savings | Calculated | kW | |
| $LPD_I$ | Actual lighting power density after installation | Calculated | W/ft2 | |
| $\Delta W$ | The difference between the wattage of the lower efficiency baseline bulb and the wattage of the new bulb | Calculated (37.6 if unknown) | W | |
| H | Facility lighting hours of use | Site-specific<br><br>Table 2-2 if unknown | hr | |
| A | Facility illuminated area | Site-specific | ft2 | |
| $W_{TOT}$ | Total power consumed by each fixture in the lighted area | Site-specific | W | |
| $W_{BR}$ | Rated wattage of existing low-efficiency bulb | Site-specific | W | |
| $W_{IR}$ | Rated wattage of high efficiency bulb | Site-specific | W | |
| $W_I$ | Actual exterior lighting power after installation | Site-specific | W | |
| $kW_B$ | Total power usage of the lighting fixtures that are being replaced | Site-specific | kW | |
| $kW_I$ | Total power usage of the new lighting fixtures that are being installed | Site-specific | kW | |

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| EF | Average energy factor due to lighting interactive effect | 1.04 | N/A | [6] |
| $LPD_B$ (Building Area Method) | Lighting power density allowance using the building area method | Lookup in Table 2-5 | W/ft2 | [4] |
| $LPD_B$ (Space-By-Space Method) | Lighting power density allowance using the space-by-space method | Lookup in Table 2-6 | W/ft2 | [4] |
| $LPD_{AF}$ | LPD adjustment factor IECC 2021 (20% better) | 0.8 | N/A | [21] |
| $LPD_{AF}$ | LPD adjustment factor IECC 2015 (40% better) | 0.6 | N/A | [21] |
| $H_R$ | Daily hours of use by room type | Site specific Table 2-3 if unknown | hr | |
| F | Fraction of lighting energy that must be removed by the facility's cooling system for an HVAC system | Lookup in Table 2-4 | N/A | [2] |
| $COP_{LO}$ | Coefficient of performance for lost opportunity lighting measures | 4.5 | N/A | [5] |
| $COP_R$ | Coefficient of performance for retrofit lighting measures | 3.5 | N/A | [5] |
| $W_B$ | Exterior lighting power allowance | Lookup in Table 2-8 and Table 2-9 | W | [4] |
| $CF_S$ | Summer lighting coincidence factor | Lookup in Table 2-11 | N/A | |
| $CF_W$ | Winter lighting coincidence factor | Lookup in Table 2-11 | N/A | |
| $CF_{SR}$ | Average summer seasonal peak coincidence factor for hardwired fixtures | 0.13 | N/A | |
| $CF_{WR}$ | Average winter seasonal peak coincidence factor for hardwired fixtures | 0.20 | N/A | |
| G | Estimated lighting energy heat to space based on modeling | 0.73 | N/A | |
| $HVAC_H$ | HVAC interactivity multiplier, heating | -0.000162279 | MMBtu/kWh | [3] |

**Table 2-2 C&I Lighting Hours of Use**

| Facility Type | Hours | Facility Type | Hours | Facility Type | Hours |
|---|---|---|---|---|---|
| Auto related [8] | 2,807 | Hospital† [9] | 5,413 | Performing arts theatre [8] | 913 |
| Bakery [9] | 5,468 | Hospitals/health care† [8] | 5,564 | Police/fire station (24 Hr) [8] | 8,760 |
| Banks, financial center† [10] | 3,748 | Industrial: 1 shift [8] | 2,897 | Post office [8] | 3,748 |
| Church [8] | 913 | Industrial: 2 shift [8] | 5,793 | Pump station [10] | 1,949 |
| College: cafeteria [9] | 5,018 | Industrial: 3 shift [8] | 8,690 | Refrigerated warehouse [9] | 6,512 |
| College: classes/administrative† [9] | 4,839 | Laundromat [10] | 4,056 | Religious building [8] | 913 |
| College: dormitory [9] | 4,026 | Library [10] | 3,748 | Residential (excl. nursing homes) [10] | 3,066 |
| Commercial condominium [9] | 4,026 | Light manufacturer [8] | 5,793 | Restaurant [9] | 5,018 |
| Convenience store [9] | 5,468 | Lodging (hotel/motel) [8] | 3,112 | Retail [9] | 4,939 |
| Convention center [8] | 913 | Mall concourse† [8] | 4,939 | School/university† [8] | 2,967 |
| Court house† [9] | 4,181 | Manufacturing facility [8] | 5,793 | Schools (Jr./Sr. High)† [8] | 2,967 |
| Dining: bar lounge/leisure [9] | 5,018 | Medical office [9] | 3,673 | Schools (preschool/elementary)† [8] | 2,967 |
| Dining: cafeteria/fast food [9] | 5,018 | Motion picture theatre [10] | 1,954 | Schools (technical/vocational)† [8] | 2,967 |
| Dining: family [9] | 5,018 | Multifamily (common areas)[11] | 6,388 | Small services [8] | 3,748 |
| Entertainment [10] | 1,952 | Museum [10] | 3,748 | Sports arena [8] | 913 |
| Exercise center [10] | 5,836 | Nursing home [10] | 5,840 | Town hall [8] | 4,181 |
| Fast food restaurant [9] | 5,018 | Office (general office types) [8] | 4,098 | Transportation [10] | 6,456 |
| Fire station (unmanned) [9] | 4,336 | Office/retail [8] | 4,181 | Warehouse (not refrigerated) [8] | 5,667 |
| Food store [8] | 5,468 | Parking garage and lot [8] | 6,887 | Wastewater treatment plant [10] | 6,631 |
| Gymnasium [10] | 2,586 | Penitentiary [10] | 5,477 | Workshop [10] | 3,750 |

**Table 2-3 Multifamily Hours of Use per Day by Location**

| Location | Daily Hours of Use |
|---|---|
| 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 |

† Results are based on VAV systems with economizers.

**Table 2-4 Fraction of Lighting Energy that Must Be Removed by Facility's Cooling System [2]**

| Building Description | F |
|---|---|
| HVAC system includes an economizer | 0.35 |
| No economizer, building area < 2,000 ft$^2$ | 0.48 |
| No economizer, building area 2,000 – 20,000 ft$^2$ | $0.48 + \frac{0.195 \times (A_{ctrl} - 2{,}000)}{18{,}000}$ |
| No economizer, building area > 20,000 ft$^2$ | 0.675 |

**Table 2-5 Lighting Power Densities Using the Building Area Method – IECC 2021 Standard Section C405.3.2(1) and Section C406.3 Additional Efficiency Options [4]**

| Building Area Type | Standard LPD (W/ft$^2$) | Additional Efficiency Option (W/ft$^2$) | Building Area Type | Standard LPD (W/ft2) | Additional Efficiency Option (W/ft2) |
|---|---|---|---|---|---|
| Automotive facility | 0.75 | 0.68 | Multifamily | 0.45 | 0.41 |
| Convention center | 0.64 | 0.58 | Museum | 0.55 | 0.50 |
| Court house | 0.79 | 0.72 | Office | 0.64 | 0.58 |
| Dining: bar lounge/leisure | 0.80 | 0.72 | Parking garage | 0.18 | 0.17 |
| Dining: cafeteria/fast food | 0.76 | 0.69 | Penitentiary | 0.69 | 0.63 |
| Dining: family | 0.71 | 0.64 | Performing arts theatre | 0.84 | 0.76 |
| Dormitory | 0.53 | 0.48 | Police/fire station | 0.66 | 0.60 |
| Exercise center | 0.72 | 0.65 | Post office | 0.65 | 0.59 |
| Fire station | 0.56 | 0.51 | Religious building | 0.67 | 0.61 |
| Gymnasium | 0.76 | 0.69 | Retail | 0.84 | 0.76 |
| Health care clinic | 0.81 | 0.73 | School/university | 0.72 | 0.65 |
| Hospital | 0.96 | 0.87 | Sports arena | 0.76 | 0.69 |
| Hotel/motel | 0.56 | 0.51 | Town hall | 0.69 | 0.63 |
| Library | 0.83 | 0.75 | Transportation | 0.50 | 0.45 |
| Manufacturing facility | 0.82 | 0.74 | Warehouse | 0.45 | 0.41 |
| Motion picture theatre | 0.44 | 0.40 | Workshop | 0.91 | 0.82 |

**Note**: In cases where both a general building area type and a more specific building area type are listed, the more specific building area type shall apply:

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

b. No less than 70% of the floor area shall be in the daylight zone. Automatic daylighting controls shall be installed in daylight zones and shall meet the requirements of Section C405.2.2.3.Table 2-6 Lighting Power Densities Using the Space-By-Space Method – 2021 IECC Section C405.3.2(2)

**Table 2-7 Lighting Power Densities Using the Space-By Space Method – 2021 IECC section C405.3.2(2); Interior Lighting Power Allowances: Space-By-Space Method [4]**

| Common Space Types[a] | LPD (watts/ft²) |
|---|---|
| **Atrium** | |
| *Less than 40 feet in height* | 0.48 |
| *Greater than 40 feet in height* | 0.6 |
| **Audience seating area** | |
| *In an auditorium* | 0.61 |
| *In a gymnasium* | 0.23 |
| *In a motion picture theater* | 0.27 |
| *In a penitentiary* | 0.67 |
| *In a performing arts theater* | 1.16 |
| *In a religious building* | 0.72 |
| *In a sports arena* | 0.33 |
| *Otherwise* | 0.33 |
| **Automotive (see Vehicular maintenance area)** | |
| **Banking activity area** | 0.61 |
| **Breakroom (See Lounge/breakroom)** | |
| **Classroom/lecture hall/training room** | |
| *In a penitentiary* | 0.89 |
| *Otherwise* | 0.71 |
| **Computer room, data center** | 0.94 |
| **Conference/meeting/multipurpose room** | 0.97 |
| **Convention center—exhibit space** | 0.61 |
| **Copy/print room** | 0.31 |
| **Corridor** | |
| *In a facility for the visually impaired (and not used primarily by the staff)[b]* | 0.71 |
| *In a hospital* | 0.71 |
| *Otherwise* | 0.41 |
| **Courtroom** | 1.2 |
| **Dining area** | |
| *In bar/lounge or leisure dining* | 0.86 |

| Common Space Types | LPD (watts/ft²) |
|---|---|
| **Laundry/washing area** | 0.53 |
| **Library** | |
| *In a reading area* | 0.96 |
| *In the stacks* | 1.18 |
| **Loading dock, interior** | 0.88 |
| **Lobby** | |
| *For an elevator* | 0.65 |
| *In a facility for the visually impaired (and not used primarily by the staff)[b]* | 1.69 |
| *In a hotel* | 0.51 |
| *In a motion picture theater* | 0.23 |
| *In a performing arts theater* | 1.25 |
| *Otherwise* | 0.84 |
| **Locker room** | 0.52 |
| **Lounge/breakroom** | |
| *In a healthcare facility* | 0.42 |
| *Otherwise* | 0.59 |
| **Manufacturing facility** | |
| *In a detailed manufacturing area* | 0.8 |
| *In an equipment room* | 0.76 |
| *In an extra-high-bay area (greater than 50 feet floor-to-ceiling height)* | 1.42 |
| *In a high-bay area (25–50 feet floor-to-ceiling height)* | 1.24 |
| *In a low-bay area (less than 25 feet floor-to-ceiling height)* | 0.86 |
| **Museum** | |
| *In a general exhibition area* | 0.31 |
| *In a restoration room* | 1.1 |
| **Office** | |
| *Enclosed* | 0.74 |
| *Open plan* | 0.61 |
| **Parking area, interior** | 0.15 |

| Common Space Types[a] | LPD (watts/$ft^2$) |
|---|---|
| *In cafeteria or fast-food dining* | 0.4 |
| *In a facility for the visually impaired (and not used primarily by the staff)*[b] | 1.27 |
| *In family dining* | 0.6 |
| *In a penitentiary* | 0.42 |
| *Otherwise* | 0.43 |
| **Dormitory—living quarters**[c, d] | 0.5 |
| **Electrical/mechanical room** | 0.43 |
| **Emergency vehicle garage** | 0.52 |
| **Facility for the visually impaired**[b] | |
| *In a chapel (and not used primarily by the staff)* | 0.7 |
| *In a recreation room (and not used primarily by the staff)* | 1.77 |
| **Fire Station—sleeping quarters**[c] | 0.23 |
| **Food preparation area** | 1.09 |
| **Guest room**[, d] | 0.41 |
| **Gymnasium/fitness center** | |
| *In an exercise area* | 0.9 |
| *In a playing area* | 0.85 |
| **Healthcare facility** | |
| *In an exam/treatment room* | 1.4 |
| *In an imaging room* | 0.94 |
| *In a medical supply room* | 0.62 |
| *In a nursery* | 0.92 |
| *In a nurse's station* | 1.17 |
| *In an operating room* | 2.26 |
| *In a patient room*[c] | 0.68 |
| *In a physical therapy room* | 0.91 |
| *In a recovery room* | 1.25 |
| **Laboratory** | |
| *In or as a classroom* | 1.11 |
| *Otherwise* | 133 |

| Common Space Types | LPD (watts/$ft^2$) |
|---|---|
| **Pharmacy area** | 1.66 |
| **Performing arts theater—dressing room** | 0.41 |
| **Post office—sorting area** | 0.76 |
| **Religious buildings** | |
| *In a fellowship hall* | 0.54 |
| *In a worship/pulpit/choir area* | 0.85 |
| **Restroom** | |
| *In a facility for the visually impaired (and not used primarily by the staff*[b] | 1.26 |
| *Otherwise* | 0.63 |
| **Retail facilities** | |
| *In a dressing/fitting room* | 0.51 |
| *In a mall concourse* | 0.82 |
| **Sales area** | 1.05 |
| **Seating area, general** | 0.23 |
| **Stairwell** | 0.49 |
| **Sports arena—playing area** | |
| *For a Class I facility*[e] | 2.94 |
| *For a Class II facility*[f] | 2.01 |
| *For a Class III facility*[g] | 1.3 |
| *For a Class IV facility*[h] | 0.86 |
| **Storage room** | 0.38 |
| **Transportation facility** | |
| *At a terminal ticket counter* | 0.51 |
| *In a baggage/carousel area* | 0.39 |
| *In an airport concourse* | 0.25 |
| **Vehicular maintenance area** | 0.6 |
| **Warehouse—storage area** | |
| *For medium to bulky, palletized items* | 0.33 |
| *For smaller, hand-carried items* | 0.69 |
| **Workshop** | 1.26 |

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

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

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

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

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

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

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

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

**Table 2-8 Exterior Lighting Zones - 2021 IECC section C405.5.2 (1) [4]**

| Lighting Zone | Description |
|---|---|
| 1 | Developed areas of national parks, state parks, forest land, and rural areas |
| 2 | Areas consisting predominantly 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 2-9 Exterior Lighting Power Allowances – 2021 IECC Standard Section C405.5.2(2) and Section C405.5.2(3) [4]**

| | Category | Space | Units | Zone 1 | Zone 2 | Zone 3 | Zone 4 |
|---|---|---|---|---|---|---|---|
| **Base Site Allowance** | | | W | 350 | 400 | 500 | 900 |
| Tradable Surfaces | Uncovered Parking Areas | Parking areas and drives | W/ft$^2$ | 0.03 | 0.04 | 0.06 | 0.08 |
| | Building Grounds | Walkways and ramps less than 10 feet wide | W/Linear Foot | 0.50 | 0.50 | 0.60 | 0.70 |
| | Building Grounds | Walkways and ramps 10 feet wide or greater, plaza areas | W/ft$^2$ | 0.10 | 0.10 | 0.11 | 0.14 |
| | Building Grounds | Dining areas | W/ft$^2$ | 0.65 | 0.65 | 0.75 | 0.95 |
| | Building Grounds | Stairways | W/ft$^2$ | 0.60 | 0.70 | 0.70 | 0.70 |
| | Building Grounds | Pedestrian tunnels | W/ft$^2$ | 0.12 | 0.12 | 0.14 | 0.21 |
| | Building Grounds | Landscaping | W/ft$^2$ | 0.04 | 0.05 | 0.05 | 0.05 |
| | Building Entrances and Exits | Pedestrian and vehicular entrances and exits | W/Linear Foot of opening | 14 | 14 | 21 | 21 |
| | Building Entrances and Exits | Entry canopies | W/ft$^2$ | 0.20 | 0.25 | 0.40 | 0.40 |
| | Building Entrances and Exits | Loading docks | W/ft$^2$ | 0.35 | 0.35 | 0.35 | 0.35 |
| | Sales Canopies | Canopies (free-standing and attached) | W/ft$^2$ | 0.40 | 0.40 | 0.6 | 0.7 |
| | Outdoor Sales | Open areas (including vehicle sales lots) | W/ft$^2$ | 0.20 | 0.20 | 0.35 | 0.50 |
| | Outdoor Sales | Street frontage for vehicle sales lots in addition to "Open Area" allowance | W/Linear Foot | - | 7 | 7 | 21 |
| Non- | Building facades | | W/ft$^2$ of gross above-grade wall area | - | 0.075 | 0.113 | 0.15 |
| | Automated teller machines (ATMs) and night depositories | | W per location | 135 plus 45 per | 135 plus 45 per | 135 plus 45 per | 135 plus 45 per |

| Category | Space | Units | Zone 1 | Zone 2 | Zone 3 | Zone 4 |
|---|---|---|---|---|---|---|
| | | | additional ATM | additional ATM | additional ATM | additional ATM |
| | Uncovered entrances and gatehouse inspection stations at guarded facilities | W/ft² | 0.5 | 0.5 | 0.5 | 0.5 |
| | Uncovered loading areas for law enforcement, fire, ambulance, and other emergency vehicles | W/ft² | 0.35 | 0.35 | 0.35 | 0.35 |
| | Drive-up windows and doors | W/drive-through | 200 | 200 | 200 | 200 |
| | Parking near 24-hour retail entrances | W/main entry | 400 | 400 | 400 | 400 |

## ***Measure Life***

**Table 2-10 Measure Life**

| Equipment Type | Retrofit | Lost Opportunity | Ref |
|---|---|---|---|
| Fixture (LED) | 7 | 12.2 | [12] |
| Lamp replacement (LED) | 6.6 | N/A | [12] |
| LEDs (screw-in bulbs) | 1 | N/A | [7] |
| Remove unnecessary lighting fixture | 5 | N/A | [20] |

## ***Peak Factors***

**Table 2-11 Peak Factors**

| Facility Type | Summer Coincidence Factor | Winter Coincidence Factor | |
|---|---|---|---|
| Grocery | 90.4% | 85.6% | [8] |
| Manufacturing | 83% | 66.5% | [8] |
| Medical (hospital) | 82.5% | 69.6% | [8] |
| Multifamily common area | 17.0% | 100.0% | [13] |
| Large office | 70.2% | 53.9% | [8] |
| Small office | 76.8% | 44.1% | [8] |
| Other | 86.9% | 76.7% | [8] |
| Restaurant | 77.5% | 77.0% | [8] |
| Retail | 98.4% | 85.6% | [8] |
| University/college | 36.8% | 46.0% | [8] |
| Warehouse | 89.3% | 72.4% | [8] |
| School | 59.9% | 38.8% | [8] |
| Parking lot/street lighting | 1.5% | 87.3% | [8], [14] |

| Facility Type | Summer Coincidence Factor | Winter Coincidence Factor | |
|---|---|---|---|
| Automotive | 68.3% | 36.9% | [8] |
| Hotel/motel | 40.6% | 37.5% | [8] |
| Industrial | 83.0% | 66.5% | [8] |
| Religious building/convention center | 17.0% | 9.2% | [8] |

## ***Load Shapes***

**Table 2-12 Load Shapes**

| End Use | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % | Ref |
|---|---|---|---|---|---|
| Lighting (Large C&I) | 44.50% | 19.40% | 25.70% | 10.50% | [15] |
| Lighting (Small C&I) | 38.30% | 25.10% | 22.50% | 14.10% | [15] |

## ***Realization Rates and Net Impact Factors***

**Table 2-13 Realization Rates**

| | Gross Realization % | | | FR & SO | | Net Realization % | | | |
|---|---|---|---|---|---|---|---|---|---|
| Measure | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Free-ridership | Spillover | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Ref |
| Energy Conscious Blueprint – Lighting | 129.0% | 116.6% | 104.6% | 16.7% | 2.4% | 110.6% | 99.9% | 89.6% | [16], [17] |
| Energy Opportunities – Lighting | 97.9% | 115.3% | 98.9% | 11.0% | 5.0% | 92.0% | 108.4% | 93.0% | [8], [18] |
| Small Business Energy Advantage – Lighting | 109.0% | 108.0% | 119.0% | 3.8% | 2.5% | 107.6% | 106.6% | 117.5% | [17], [19] |

## ***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] "Calculating Lighting and HVAC Interactions," ASHRAE Journal 11-93.

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

[4] (ICC), International Code Council. "2021 International Energy Conservation Code (IECC): ICC Digital Codes." 2021 INTERNATIONAL ENERGY CONSERVATION CODE (IECC) | ICC DIGITAL CODES, https://codes.iccsafe.org/content/IECC2021P1/chapter-4-ce-commercial-energy-efficiency.

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

[6] Connecticut Residential Lighting Interactive Effect, NMR Group Inc., Dec. 2014, Table 1, p. 2.

[7] Engineering judgement based on expected existing incandescent or halogen lamp remaining life. Once the existing lamp has burned out, replacement with an EISA-compliant lamp is assumed to be the only option.

[8] DNV, 2020 C1635 Impact Evaluation of PY 2016 & 2017 Energy Opportunities (EO) Program, Aug. 27, 2020.

[9] DNV GL, MA C&I Project 86 Lighting Hours of Use Study, Apr. 12, 2019.

[10] RLW Analytics, "CT and MA Utilities 2004-05 Lighting Hours of Use for School Buildings Baseline Study," Final Report, Sep. 7, 2006.

[11] TRC. X1941: Multifamily Impact Evaluation, PSD Savings Review, Jul. 2020.

[12] DNV. June 2022. "C2014-A: Connecticut C&I Lighting Saturation and Remaining Potential Study ."

[13] 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%.

[14] United Illuminating analysis performed using historical seasonal peak hours (2010-2014).

[15] DNV. 2021. "X1931-2 Load Shape and Coincidence Factor Research – Final Report".

[16] Cadmus, C1634 Impact Evaluation of PY 2016 & 2017 Energy Conscious Blueprint Program, Oct. 18, 2020

[17] Tetra Tech, *2011 C&I Electric and Gas Free-ridership and Spillover Study*, Oct. 5, 2012.

[18] EMI Consulting. 2019. "C1644: EO Net-to-Gross Study." Connecticut Energy Efficiency Board.

[19] ERS, *C1639: Impact Evaluation of the Connecticut Small Business Energy Advantage Program*, Mar. 20, 2018.

[20] ERS. 2005. "Measure Life Study" prepared for The Massachusetts Joint Utilities.

[21] C1902B: ECB Baseline and Code Compliance Results


## ***Changes from Last Version***

- Updated exterior lighting power allowances to match 2021 IECC.
- Updated measure life for LED screw-in bulbs from 4 years to 1 year.
- Formatting updates.

### 2.1.2 UPSTREAM LIGHTING

| | |
|---|---|
| Market | Commercial |
| Baseline Type | Lost Opportunity |
| Category | Lighting |

***Description***

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

The individual bulb or fixture's delta watts are based on the Bright Opportunities Program, an upstream lighting initiative in Massachusetts [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 or DLC [2], [3].

Description of lighting control types:

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

***Annual Energy Savings Algorithm***

*Lighting Fixture Lost Opportunity Gross Energy Savings, Electric*

Interior Lighting

$$\Delta kWh = \frac{N \times \Delta W \times H \times HVAC_C}{1{,}000 \frac{W}{kW}}$$

*Heating Penalty, Fossil Fuel*

$$\Delta MMBtu = \Delta kWh \times HVAC_H$$

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

Exterior Lighting

$$\Delta kWh = \frac{N \times \Delta W \times H}{1{,}000 \frac{W}{kW}}$$

*Lighting Fixture Lost Opportunity Gross Seasonal Peak Demand Savings, Electric*

$$\Delta kW_{Summer} = \frac{N \times \Delta W \times CF_S \times DSF}{1{,}000 \frac{W}{kW}}$$

$$\Delta kW_{Winter} = \frac{N \times \Delta W \times CF_W}{1{,}000 \frac{W}{kW}}$$

*Lighting Controls Gross Energy Savings, Electric*

$$\Delta kWh_{LC} = \Delta kWh_F + \Delta kWh_C$$

Where,

$$\Delta kWh_F = \frac{W_F \times H_F \times (SF_I - SF_B)}{1{,}000 \frac{W}{kW}}$$

$$\Delta kWh_C = \frac{\Delta kWh_F \times RCF}{COP}$$

***Lifetime Energy Savings Algorithm***

$$\Delta kWh_{LT} = \Delta kWh \times LT$$

Where,

Interior Lighting

$$\Delta kWh = \frac{N \times \Delta W \times H \times HVAC_C}{1{,}000 \frac{W}{kW}}$$

Exterior Lighting

$$\Delta kWh = \frac{N \times \Delta W \times H}{1{,}000 \frac{W}{kW}}$$

***Calculation Parameters***

**Table 2-14 Calculation Parameters**

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| ΔkWh | Annual electric savings from light fixtures | Calculated | kWh | |
| $\Delta kWh_{LT}$ | Lifetime electric savings from light fixtures | Calculated | kWh | |
| $\Delta kW_S$ | Summer demand savings from light fixtures | Calculated | kW | |
| $\Delta kW_W$ | Winter demand savings from light fixtures | Calculated | kW | |
| $\Delta kWh_{LC}$ | Total annual electric savings from installing a lighting control system | Calculated | kWh | |
| $\Delta kWh_F$ | Annual electric savings associated with the reduced electric consumption of controlled lighting fixtures | Calculated | kWh | |
| $\Delta kWh_C$ | Annual electric savings associated with the reduced cooling required from the installation of a lighting control system | Calculated | kWh | |
| ΔMMBtu | Annual heating penalty | Calculated | MMBtu | |
| N | Number of units sold at the point of sale | Site-specific | N/A | |
| $W_F$ | Facility lighting load controlled by the lighting control system | Site-specific | W | |
| $H_F$ | Total operating hours of the controlled lighting circuit before the lighting controls are installed | Site-specific<br><br>Table 2-16 if unknown | hr | |
| COP | Coefficient of performance | Site-specific | N/A | |
| ΔW | The difference between the wattage of the lower efficiency baseline bulb or fixture and the wattage of the new bulb or fixture | Lookup in Table 2-15 | W | [1] |
| H | Annual hours of use | Lookup in<br><br>Table 2-16 | hr | |
| $HVAC_C$ | HVAC interactivity multiplier, cooling | 1.024 | N/A | [4] |
| $HVAC_H$ | HVAC interactivity multiplier, heating | -0.000329 | MMBtu/kWh | [5] |

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| $CF_S$ | Summer lighting coincidence factor | Lookup in Table 2-19 | N/A | |
| $CF_W$ | Winter lighting coincidence factor | Lookup in Table 2-19 | N/A | |
| DSF | Demand savings factor | 1.152 | N/A | [4] |
| LT | Equipment lifetime | Lookup in Table 2-18 | yr | |
| $SF_I$ | Average annual reduction in electric consumption achieved by a particular control measure type in the installed condition | Lookup in Table 2-17 | N/A | |
| $SF_B$ | Average annual reduction in electric consumption achieved by a particular control measure type in the baseline condition | 0 | N/A | |
| RCF (Interior) | Energy savings factor due to reduced cooling required as the result of controls – interior lighting | 0.35 | N/A | |
| RCF (Exterior) | Energy savings factor due to reduced cooling required as the result of controls – exterior lighting | 0 | N/A | |

**Table 2-15 Wattage Difference**

| Measure Description | ΔW |
|---|---|
| Exterior: Low Output (250-5,000 lumens) | 53.4 |
| Exterior: Mid Output (5,000-10,000 lumens) | 101.5 |
| Exterior: High Output (10,000-30,000 lumens) | 176.5 |
| Exterior: Very High Output (>30,000 lumens) | 231.5 |
| Exterior: Low Output w/Occ Sensor (250-5,000 lumens) | 61.4 |
| Exterior: Mid Output w/Occ Sensor (5,000-10,000 lumens) | 114.9 |
| Exterior: High Output w/Occ Sensor (10,000-30,000 lumens) | 208.9 |
| Exterior: Very High Output w/Occ Sensor (>30,000 lumens) | 303.9 |
| High/Low Bay: Mid Output (5,000-10,000 lumens) | 174 |
| High/Low Bay: High Output (10,000-30,000 lumens) | 229 |
| High/Low Bay: Very High Output (>30,000 lumens) | 334 |
| High/Low Bay: Mid Output w/Occ Sensor (5,000-10,000 lumens) - Premium | 192.1 |
| High/Low Bay: Mid Output w/Dual Sensor (5,000-10,000 lumens) - Premium | 202.7 |
| High/Low Bay: Mid Output w/LLLC/ NLC (5,000-10,000 lumens) - Premium | 211 |
| High/Low Bay: High Output w/Occ Sensor (10,000-30,000 lumens) - Premium | 264.5 |

| Measure Description | ΔW |
|---|---|
| High/Low Bay: High Output w/Dual Sensor (10,000-30,000 lumens) - Premium | 285.2 |
| High/Low Bay: High Output w/LLLC/ NLC (10,000-30,000 lumens) - Premium | 301.5 |
| High/Low Bay: Very High Output w/Occ Sensor (>30,000 lumens) - Premium | 392.3 |
| High/Low Bay: Very High Output w/Dual Sensor (>30,000 lumens) - Premium | 426.3 |
| High/Low Bay: Very High Output w/LLLC/ NLC (>30,000 lumens) - Premium | 453.1 |
| High/Low Bay: Mid Output w/Occ Sensor (5,000-10,000 lumens) - Standard | 191.5 |
| High/Low Bay: Mid Output w/Dual Sensor (5,000-10,000 lumens) - Standard | 201.8 |
| High/Low Bay: Mid Output w/LLLC/ NLC (5,000-10,000 lumens) - Standard | 209.8 |
| High/Low Bay: High Output w/Occ Sensor (10,000-30,000 lumens) - Standard | 264 |
| High/Low Bay: High Output w/Dual Sensor (10,000-30,000 lumens) - Standard | 284.4 |
| High/Low Bay: High Output w/LLLC/ NLC (10,000-30,000 lumens) - Standard | 300.4 |
| High/Low Bay: Very High Output w/Occ Sensor (>30,000 lumens) - Standard | 393 |
| High/Low Bay: Very High Output w/Dual Sensor (>30,000 lumens) - Standard | 427.5 |
| High/Low Bay: Very High Output w/LLLC/ NLC (>30,000 lumens) - Standard | 454.5 |
| Down Light Kits/Fixtures – Hard Wired, Screw-base or GU-24 base (250-3,500 lumens) | 38.4 |
| Down Light Kits/Fixtures – Hard Wired, Screw-base or GU-24 base (3,500-7,000 lumens) | 56.6 |
| Down Light Kits/Fixtures – Hard Wired, Screw-base or GU-24 (>7,000 lumens) | 116.4 |
| Mogul Exterior Low Output (250-5,000 lumens) | 141.9 |
| Mogul Exterior Mid Output (5,000-10,000 lumens) | 184.9 |
| Mogul Exterior High Output (10,000-30,000 lumens) | 283.3 |
| Mogul Exterior Very High Output ( > 30,000 lumens) | 283 |
| LED Strip/Wrap w/ Occ Sensor | 37.2 |
| LED Strip/Wrap w/ Dual Sensor | 49.6 |
| LED Strip/Wrap w/ LLLC/ NLC | 59.915 |
| T8 LED 2' Type C (UL Type C replacement) | 7.7 |
| T8 LED 3' Type C (UL Type C replacement) | 13.4 |
| T8 LED 4' Type C (UL Type C replacement) | 15.5 |
| T5 LED 4' Type C (UL Type C replacement) | 22.4 |
| T8 U BEND LED Type C (UL Type C replacement) | 26.2 |

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

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

**Table 2-16 C&I Lighting Hours of Use**

| Facility Type | Hours | Facility Type | Hours | Facility Type | Hours |
|---|---|---|---|---|---|
| Auto related [4] | 2,807 | Hospital† [5] | 5,413 | Performing arts theatre [4] | 913 |
| Bakery [5] | 5,468 | Hospitals/health care† [4] | 5,564 | Police/fire station (24 hr.) [4] | 8,760 |
| Banks, financial center† [7] | 3,748 | Industrial: 1 shift [4] | 2,897 | Post office [4] | 3,748 |
| Church [4] | 913 | Industrial: 2 shift [4] | 5,793 | Pump station [7] | 1,949 |
| College: cafeteria [5] | 5,018 | Industrial: 3 shift [4] | 8,690 | Refrigerated warehouse [5] | 6,512 |
| College: classes/administrative† [5] | 4,839 | Laundromat [7] | 4,056 | Religious building [4] | 913 |
| College: dormitory [5] | 4,026 | Library [7] | 3,748 | Residential (excl. nursing homes) [7] | 3,066 |
| Commercial condominium [5] | 4,026 | Light manufacturer [4] | 5,793 | Restaurant [5] | 5,018 |
| Convenience store [5] | 5,468 | Lodging (hotel/motel) [4] | 3,112 | Retail [5] | 4,939 |
| Convention center [4] | 913 | Mall concourse† [4] | 4,939 | School/university† [4] | 2,967 |
| Court house† [5] | 4,181 | Manufacturing facility [4] | 5,793 | Schools (Jr./Sr. High)† [4] | 2,967 |
| Dining: bar lounge/leisure [5] | 5,018 | Medical office [5] | 3,673 | Schools (preschool/elementary)† [4] | 2,967 |
| Dining: cafeteria/fast food [5] | 5,018 | Motion picture theatre [7] | 1,954 | Schools (technical/vocational)† [4] | 2,967 |
| Dining: family [5] | 5,018 | Multifamily (common areas)[8] | 6,388 | Small services [4] | 3,748 |
| Entertainment [7] | 1,952 | Museum [7] | 3,748 | Sports arena [4] | 913 |
| Exercise center [7] | 5,836 | Nursing home [7] | 5,840 | Town hall [4] | 4,181 |
| Fast food restaurant [5] | 5,018 | Office (general office types) [4] | 4,098 | Transportation [7] | 6,456 |
| Fire station (unmanned) [5] | 4,336 | Office/retail [4] | 4,181 | Warehouse (not refrigerated) [4] | 5,667 |
| Food store [4] | 5,468 | Parking garage and lot [4] | 6,887 | Wastewater treatment plant [7] | 6,631 |
| Gymnasium [7] | 2,586 | Penitentiary [7] | 5,477 | Workshop [7] | 3,750 |

**Table 2-17 Savings Factor by Lighting Control Type**

| Lighting Control Type | Savings Factor | Ref |
|---|---|---|
| Networked Lighting Controls (NLC) or Luminaire-Level Lighting Controls (LLLC) | 0.49 | [1] |
| Dual Occupancy and Daylight Dimming Controls | 0.38 | [2] |
| Any One Control Strategy Savings Factor | 0.24 | [2] |
| No Lighting Controls | 0 | |

*Note: Maximum of only one control strategy available for Exterior Lighting.*

† Results are based on VAV systems with economizers.

## ***Calculation Examples***

*Example 1: Lost Opportunity Gross Savings*

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

$$\Delta kWh = \frac{N \times \Delta W \times H \times HVAC_C}{1{,}000\,\frac{W}{kW}}$$

$$\Delta kWh = \frac{1 \times 22.1W \times 3{,}595\ hr \times 1.024}{1{,}000\,\frac{W}{kW}} = 81.35\ kWh$$

$$\Delta kWh_{LT} = \Delta kWh \times LT$$

$$\Delta kWh_{LT} = 81.35\ kWh \times 4 = 325.42\ kWh$$

$$\Delta kW_S = \frac{N \times \Delta W \times CF_S \times DSF}{1{,}000\,\frac{W}{kW}}$$

$$\Delta kW_S = \frac{1 \times 22.1W \times 0.768 \times 1.152}{1{,}000\,\frac{W}{kW}} = 0.020\ kW$$

$$\Delta kW_W = \frac{N \times \Delta W \times CF_W}{1{,}000\,\frac{W}{kW}}$$

$$\Delta kW_W = \frac{1 \times 22.1W \times 0.441}{1{,}000\,\frac{W}{kW}} = 0.010\ kW$$

## ***Measure Life***

**Table 2-18 Measure Life**

| Equipment Type | Retrofit | Lost Opportunity | Ref |
|---|---|---|---|
| Fixture (LED) | 7 | 12.2 | [9] |
| Lamp Replacement (LED) | 6.6 | N/A | [9] |
| LEDs (screw-in bulbs) | 1 | N/A | [13] |

## ***Peak Factors***

**Table 2-19 Electric Coincidence Factors**

| Facility Type | Lighting | | Ref |
|---|---|---|---|
| | Summer Coincidence Factor | Winter Coincidence Factor | |
| Grocery | 90.4% | 85.6% | [4] |
| Manufacturing | 83% | 66.5% | [4] |
| Medical (hospital) | 82.5% | 69.6% | [4] |
| Multifamily common area | 17.0% | 100.0% | [8] |
| Large office | 70.2% | 53.9% | [4] |
| Small office | 76.8% | 44.1% | [4] |
| Other | 86.9% | 76.7% | [4] |
| Restaurant | 77.5% | 77.0% | [4] |
| Retail | 98.4% | 85.6% | [4] |
| University/college | 36.8% | 46.0% | [4] |
| Warehouse | 89.3% | 72.4% | [4] |
| School | 59.9% | 38.8% | [4] |
| Parking lot/street lighting | 1.5% | 87.3% | [4], [10] |
| Automotive | 68.3% | 36.9% | [4] |
| Hotel/motel | 40.6% | 37.5% | [4] |
| Industrial | 83.0% | 66.5% | [4] |
| Religious building/convention center | 17.0% | 9.2% | [4] |

## ***Load Shapes***

**Table 2-20 Load Shapes**

| End Use | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % | Ref |
|---|---|---|---|---|---|
| Lighting (Large C&I) | 44.50% | 19.40% | 25.70% | 10.50% | [12] |
| Lighting (Small C&I) | 38.30% | 25.10% | 22.50% | 14.10% | [12] |

## ***Realization Rates and Net Impact Factors***

**Table 2-21 Realization Rates and Net Impact Factors**

| | Gross Realization % | | | | | | FR & SO | | Net Realization % | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Measure | kWh=(ISRXΔW RRX HOU RR) | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Install Rate (ISR) | ΔW RR | HOU RR | Free-ridership | Spillover | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW |
| LED Screw In | 98.1% | 127.9% | 110.1% | 59.4% | 163.2% | 101.3% | 51.7% | 0.0% | 47.4% | 61.8% | 53.2% |
| LED Stairwell Kit | 54.6% | 71.2% | 61.3% | 76.2% | 77.0% | 93.0% | 64.4% | 0.0% | 19.4% | 25.4% | 21.8% |
| LED Linear Lamp (TLED) | 121.3% | 152.1% | 130.9% | 97.1% | 105.0% | 119.0% | 61.5% | 0.0% | 46.7% | 58.6% | 50.4% |
| LED Linear Lamp (TLED) with Controls | 90.7% | 120.2% | 103.5% | 91.9% | 99.0% | 99.6% | 49.0% | 0.0% | 46.3% | 61.3% | 52.8% |
| LED Linear Fixture | 126.1% | 167.7% | 144.3% | 96.2% | 131.9% | 99.3% | 64.4% | 0.0% | 44.9% | 59.7% | 51.4% |
| LED Linear Fixture with Controls | 90.7% | 120.2% | 103.5% | 91.9% | 99.0% | 99.6% | 49.0% | 0.0% | 46.3% | 61.3% | 52.8% |
| High Bay / Low Bay | 107.2% | 97.4% | 83.8% | 99.6% | 74.1% | 145.3% | 41.3% | 0.0% | 62.9% | 57.2% | 49.2% |
| High Bay / Low Bay with Controls | 90.7% | 120.2% | 103.5% | 91.9% | 99.0% | 99.6% | 49.0% | 0.0% | 46.3% | 61.3% | 52.8% |
| LED Exterior | 138.0% | 183.5% | 157.9% | 92.3% | 150.6% | 99.4% | 74.0% | 35.9% | 35.9% | 47.7% | 41.0% |
| LED Exterior with Controls | 90.7% | 120.2% | 103.5% | 91.9% | 99.0% | 99.6% | 49.0% | 46.3% | 46.3% | 61.3% | 52.8% |

* Gross kWh RRs are the product of the ISR, delta watts RR, and HOU RR for each product group. Any differences are due to rounding.

## ***References***


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

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

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

[4] DNV GL. 2020. “C1635 Impact Evaluation of PY 2016 & 2017 Energy Opportunities (EO) Program”. Tables 6-11. Connecticut Energy Efficiency Board (EEB) and Evaluation Administrators.

[5] DNV GL. 2017. “Impact Evaluation of PY2015 Massachusetts Commercial and Industrial Upstream Lighting Initiative.” Massachusetts Program Administrators and Energy Efficiency Advisory Council.

[6] DNV GL. 2019. “MA C&I Project 86: Lighting Hours of Use Study.” Massachusetts Program Administrators and Energy Efficiency Advisory Council.

[7] RLW Analytics. 2006. “CT and MA Utilities 2004-05 Lighting Hours of Use for School Buildings Baseline Study.”

[8] TRC. 2020. “X1941: Multifamily Impact Evaluation.” Connecticut Energy Efficiency Board (EEB) Evaluation Committee.

[9] DNV. 2021. “C2014 - Connecticut C&I Lighting Saturation and Remaining Potential Study Phase One Results and Recommendations.” Connecticut EEB Evaluation Administrators.
[10] The Cadmus Group, Inc. 2012. “Demand Impact Model User Manual.” Massachusetts Program Administrators.
[11] United Illuminating analysis performed using historical seasonal peak hours (2010-2014).
[12] “DNV (2021). X1931-2 Load Shape and Coincidence Factor Research – Final Report”.
[13] Engineering judgement based on expected existing incandescent or halogen lamp remaining life. Once the existing lamp has burned out, replacement with an EISA-compliant lamp is assumed to be the only option.

***Changes from Last Version***

- Add LED strip lighting.
- Updated fixture descriptions based on lumens rather than wattage.
- Formatting updates.

### 2.1.3 INTERIOR LIGHTING CONTROLS

| | |
|---|---|
| Market | Commercial |
| Baseline Type | Retrofit/Lost Opportunity |
| Category | Lighting |

***Description***

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

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

Installation of lighting controls reduces the cooling load and provides additional savings, which are also calculated in this measure.

- 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.
- It is assumed that the occupancy sensor coincidence factors (summer/winter) would apply to all control types [6].
- Savings factors for the combination of high-end trim with daylight dimming and high-end trim with occupancy sensors were calculated based on savings factors from the individual controls from The Journal of the Illuminating Engineering Society of North America's *Lighting Controls in Commercial Buildings*[2].

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

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

*Description of lighting control types:*

- **Occupancy sensor.** Reduces lighting operating hours by switching off lighting in unoccupied spaces.
- **Daylight dimming control.** Reduces lighting output to a set level or reduces lighting operating hours in response to natural daylighting using continuous, stepped, or on/off dimming capability.

- **High-end trim.** Reduces lighting output of individual lights or groups of lights to a set level continuously. Must have the ability to set a maximum light level.
- **Dual occupancy and daylight dimming controls.** Combines the capabilities of occupancy and daylight sensors, allowing lighting fixtures to respond to occupancy and daylight.
- **Networked lighting controls (NLC).** An intelligent network of individually addressable luminaires and control devices for remote access by the user. NLC have fixture networking capabilities, individual addressability, occupancy sensing, daylight harvesting, high-end trim, flexible zoning, continuous dimming, scheduling, and cybersecurity.
- **Luminaire-level lighting controls (LLLC) – Networked and Cx.** Network-capable fixtures which integrates high-end trim, occupancy and daylight sensors into the LED fixture. Networked and commissioned.
- **Integrated Fixture with room-based controls.** LLLC that is not networked.

***Annual Energy Savings Algorithm***

*Retrofit Gross Energy Savings, Electric*

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

Where,

$$\Delta kWh_{ctrl} = \frac{W_{ctrl} \times H_{Pre} \times (SF_{EE} - SF_{base})}{1{,}000\ W/kW}$$

$$\Delta kWh_{cool} = \frac{\Delta kWh_{ctrl} \times F}{COP}$$

*Lost Opportunity Gross Energy Savings, Electric*

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

Where,

$$\Delta kWh_{ctrl} = \frac{A_{ctrl} \times LPD_{ctrl} \times H_{Pre} \times (SF_{EE} - SF_{base})}{1{,}000\ W/kW}$$

$$\Delta kWh_{cool} = \frac{\Delta kWh_{ctrl} \times F}{COP}$$

*Annual Gross Energy Savings, MMBtu [3]*

$$\Delta MMBtu = \Delta kWh \times -0.000162279\ MMBtu/kWh$$

*Retrofit Gross Seasonal Peak Demand Savings, Electric*

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

$$\Delta kW_{winter} = \frac{W_{ctrl} \times (SF_{EE} - SF_{base}) \times CF_{OS}}{1{,}000\ W/kW}$$

*Lost Opportunity Gross Seasonal Peak Demand Savings, Electric*

$$\Delta kW_{summer} = \frac{A_{ctrl} \times LPD_{ctrl} \times (SF_{EE} - SF_{base}) \times CF_{OS} \times (1 + G/COP)}{1{,}000\ W/kW}$$

$$\Delta kW_{winter} = \frac{A_{ctrl} \times LPD_{ctrl} \times (SF_{EE} - SF_{base}) \times CF_{OS}}{1{,}000\ W/kW}$$

***Calculation Parameters***

**Table 2-22 Calculation Parameters**

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| ΔkWh | Annual energy savings, electric | Calculated | kWh | |
| $\Delta KW_{summer}$ | Summer demand savings | Calculated | kW | |
| $\Delta KW_{winter}$ | Winter demand savings | Calculated | kW | |
| $\Delta kWh_{cool}$ | Annual energy savings from reduced cooling load | Calculated | kWh | |
| $\Delta kWh_{ctrl}$ | Annual energy savings from use of interior lighting controls | Calculated | kWh | |
| $A_{ctrl}$ | Controlled lighted building area | Input | ft$^2$ | |
| $CF_{os}$ | Occupancy sensor coincidence factor (summer/winter) | Table 2-27 | N/A | [6] |
| COP (lost opportunity) | Coefficient of performance (lost opportunity) | 4.5 | N/A | See footnote* |
| COP (retrofit) | Coefficient of performance (retrofit) | 3.5 | N/A | See footnote* |
| F | Fraction of energy savings due to reduced cooling required by reducing lighting operating hours and/or fixture illumination through lighting controls | Table 2-24 | % | [3] |
| G | Estimated lighting energy heat to space based on modeling | 0.73 | N/A | [4] |
| $H_{pre}$ | Total operating hours of the controlled lighting circuit **before** the lighting controls are installed | Site-specific, if unknown lookup in Table 2-25 | Hours/year | |

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| $LPD_{ctrl}$ | Calculated by dividing the total controlled fixture wattage by the corresponding lighted area, $ft^2$ | Site-specific | $Watts/ft^2$ | |
| $W_{ctrl}$ | Facility lighting load that is controlled by the lighting control system | Site-specific | Watts | |
| $SF_{EE}$ | Lighting controls savings factor – installed | Table 2-23 | | |
| $SF_{base}$ | Lighting controls savings factor – baseline | Table 2-23 | | |

*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.

**Table 2-23 Energy Savings Factor by Lighting Control Type**

| Lighting Control Type | Savings Factor (SF) | Ref |
|---|---|---|
| Networked lighting controls (NLC) | 0.49 | [18] |
| Luminaire-level lighting controls (LLLC) – Networked & Cx | 0.49 | [18] |
| Integrated fixture with room-based controls | 0.38* | [18] |
| Dual occupancy and daylight sensors | 0.38 | [18] |
| Combination of high-end trim and daylight dimming | 0.35 | [18] |
| Combination of high-end trim and occupancy sensors | 0.33 | [18] |
| Daylight dimming | 0.28 | [18] |
| Occupancy sensors | 0.24 | [18] |
| No lighting controls | 0.0 | |

* 38% is highest savings factor associated with a non-networked fixture with integrated controls Per discussion with the EA team, this was agreed to be a reasonable assumption for a fixture with three integrated controls that is not networked or verified/commissioned.

**Table 2-24 Fraction of Energy Savings due to Reduced Cooling from the HVAC System [3]**

| Building Description | F |
|---|---|
| HVAC system includes an economizer | 0.35 |
| No economizer, building area < 2,000 $ft^2$ | 0.48 |
| No economizer, building area 2,000 – 20,000 $ft^2$ | $0.48 + \frac{0.195 \times (A_{ctrl} - 2{,}000)}{18{,}000}$ |
| No economizer, building area > 20,000 $ft^2$ | 0.675 |

**Table 2-25 C&I Lighting Hours of Use**

| Facility Type | Hours | Facility Type | Hours | Facility Type | Hours |
|---|---|---|---|---|---|
| Auto related [1] | 2,807 | Hospital† [2] | 5,413 | Performing arts theatre [1] | 913 |
| Bakery [2] | 5,468 | Hospitals/health care† [1] | 5,564 | Police/fire station (24 Hr) [1] | 8,760 |
| Banks, financial center† [3] | 3,748 | Industrial: 1 shift [1] | 2,897 | Post office [1] | 3,748 |
| Church [1] | 913 | Industrial: 2 shift [1] | 5,793 | Pump station [3] | 1,949 |
| College: cafeteria [2] | 5,018 | Industrial: 3 shift [1] | 8,690 | Refrigerated warehouse [2] | 6,512 |
| College: classes/administrative† [2] | 4,839 | Laundromat [3] | 4,056 | Religious building [1] | 913 |
| College: dormitory [2] | 4,026 | Library [3] | 3,748 | Residential (excl. nursing homes) [3] | 3,066 |
| Commercial condominium [2] | 4,026 | Light manufacturer [1] | 5,793 | Restaurant [2] | 5,018 |
| Convenience store [2] | 5,468 | Lodging (hotel/motel) [1] | 3,112 | Retail [2] | 4,939 |
| Convention center [1] | 913 | Mall concourse† [1] | 4,939 | School/university† [1] | 2,967 |
| Court house† [2] | 4,181 | Manufacturing facility [1] | 5,793 | Schools (Jr./Sr. High)† [1] | 2,967 |
| Dining: bar lounge/leisure [2] | 5,018 | Medical office [2] | 3,673 | Schools (preschool/elementary)† [1] | 2,967 |
| Dining: cafeteria/fast food [2] | 5,018 | Motion picture theatre [3] | 1,954 | Schools (technical/vocational)† [1] | 2,967 |
| Dining: family [2] | 5,018 | Multifamily (common areas)[4] | 6,388 | Small services [1] | 3,748 |
| Entertainment [3] | 1,952 | Museum [3] | 3,748 | Sports arena [1] | 913 |
| Exercise center [3] | 5,836 | Nursing home [3] | 5,840 | Town hall [1] | 4,181 |
| Fast food restaurant [2] | 5,018 | Office (general office types) [1] | 4,098 | Transportation [3] | 6,456 |
| Fire station (unmanned) [2] | 4,336 | Office/retail [1] | 4,181 | Warehouse (not refrigerated) [1] | 5,667 |
| Food store [1] | 5,468 | Parking garage and lot [1] | 6,887 | Wastewater treatment plant [3] | 6,631 |
| Gymnasium [3] | 2,586 | Penitentiary [3] | 5,477 | Workshop [3] | 3,750 |

***Measure Life***

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

**Table 2-26 Measure Life**

| Equipment Type | Retrofit Measure Life | Lost Opportunity Measure Life | Ref |
|---|---|---|---|
| Fixture (LED)<br>applies to: LED luminaire, troffers, high/low bay, exterior/outdoor | 7 | 12.2 | [19] |

† Results are based on VAV systems with economizers.

***Peak Factors***

**Table 2-27 Peak Factors**

| Facility Type [10]* | Occupancy Sensor Summer CF | Occupancy Sensor Winter CF |
|---|---|---|
| Grocery | 14.7% | 13.3% |
| Manufacturing | 19.8% | 17.2% |
| Medical (hospital) | 23.9% | 22.1% |
| Multifamily common area [12] | 18.0% | 12.0% |
| Large office | 27.4% | 29.6% |
| Small office | 27.4% | 29.6% |
| Other | 2.4% | 6.6% |
| Restaurant | 14.7% | 13.3% |
| Retail | 14.7% | 13.3% |
| University/college | 28.3% | 23.1% |
| Warehouse | 24.6% | 18.3% |
| School | 20.9% | 15.9% |
| Automotive (Other) | 2.4% | 6.6% |
| Hotel/motel (MF Common) | 18.0% | 12.0% |
| Industrial (Manufacturing) | 19.8% | 17.2% |
| Religious building/convention center (Other) | 2.4% | 6.6% |

*reference applies to all values unless otherwise noted.

***Load Shapes***

**Table 2-28 Load Shapes**

| Measure | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % | Ref |
|---|---|---|---|---|---|
| Lighting (large C&I) | 44.50% | 19.40% | 25.70% | 10.50% | [6] |
| Lighting (small C&I) | 38.30% | 25.10% | 22.50% | 14.10% | [6] |

***Non-Energy Impacts***

There are no other resource impacts identified for this measure.

***Realization Rates and Net Impact Factors***

**Table 2-29 Realization Rates and Net Impact Factors**

| | Gross Realization % | | | FR and SO | | Net Realization % | | | |
|---|---|---|---|---|---|---|---|---|---|
| Measure | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Free-ridership | Spill-Over | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Ref |
| Lighting **Energy Conscious Blueprint** | 129.0% | 116.6% | 104.6% | 16.7% | 2.4% | 110.6% | 99.9% | 89.6% | [15], [14] |
| Lighting **Energy Opportunities** | 97.9% | 115.3% | 98.9% | 11.0% | 5.0% | 92.0% | 108.4% | 93.0% | [9], [16] |
| Lighting **Small Business Energy Advantage** | 109.0% | 108.0% | 119.0% | 3.8% | 2.5% | 107.6% | 106.6% | 117.5% | [17], [14] |

***References***


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

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

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

[4] DNV GL. 2017. "Impact Evaluation of PY2015 Massachusetts Commercial and Industrial Upstream Lighting Initiative." Massachusetts Program Administrators and Energy Efficiency Advisory Council.

[5] DNV. 2021. "C2014: Connecticut C&I Lighting Saturation and Remaining Potential Study." Connecticut Energy Efficiency Board (EEB) and Evaluation Administrators.

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[10] RLW. 2007. "Coincidence Factor Study Residential and C&I Lighting Measures." p. XII, Table i-17, i-18. New England State Program Working Group (SPWG).

[11] The Cadmus Group, Inc. 2012 . "Demand Impact Model User Manual." Massachusetts Program Administrators.

[12] The Cadmus Group, Inc. 2012. "Small Business Direct Install Program: Pre/Post Occupancy Sensor Study." Massachusetts Program Administrators.

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[14] Tetra Tech. 2012. “2011 C&I Electric and Gas Free-ridership and Spillover Study.” Table 3-5. Connecticut Energy Efficiency Fund.

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[17] ERS. 2018. “C1639: Impact Evaluation of the Connecticut Small Business Energy Advantage Program.” Table 1-4. Connecticut Energy Efficiency Board.

[18] DNV. 2022. “X1931-4 ALC PSD Phase 2 Memo.” Connecticut Energy Efficiency Board (EEB) and Evaluation Administrators.

[19] DNV. 2021. “Connecticut C2014 C&I Lighting Saturation and Remaining Potential – Phase One Results and Recommendations – Memo.”


***Changes from Last Version***

- Formatting updates.
- Added Integrated fixture with room-based controls.
- Updated description for NLC and LLLC measures.

### 2.1.4 REFRIGERATOR LED

| | |
|---|---|
| Market | Commercial |
| Baseline Type | Retrofit |
| Category | Lighting |

***Description***

The replacement of older fluorescent lighting in commercial display refrigerators, coolers, and freezers with LED lighting.

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.

For open-case refrigerators, only lighting savings are claimed, no interactive refrigeration savings are achieved.

***Annual Energy Savings Algorithm***

*Annual Retrofit Gross Energy Savings, Electric*

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

Where,

$$\Delta kW = kW_{existing} - kW_{installed}$$

If refrigeration EERs are available, calculate ACOP as follows, otherwise lookup in Table 2-31

$$ACOP = \frac{Average\ EER}{3.413}$$

$$Average\ EER = \frac{Full\ Load\ EER}{0.85}$$

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

$$\Delta kW = N\ x\ \Delta kW_{unit}\ x\ \left(1 + \frac{CF\ x\ L}{COP}\right)$$

Where,

$$\Delta kW_{unit} = kW_{existing} - kW_{installed}$$

If refrigeration EERs are available, calculate COP as follows, otherwise lookup in Table 2-31

$$COP = \frac{EER}{3.413}$$

## ***Calculation Parameters***

**Table 2-30 Calculation Parameters**

| Symbol | Description | Units | Values | Ref |
|---|---|---|---|---|
| $\Delta kWh$ | Annual gross electric energy savings | kWh | Calculated | |
| $\Delta kW$ | Annual demand savings | kW | Calculated | |
| $\Delta kW_{unit}$ | Reduction in power for each light | kW | Calculated | |
| $kW_{existing}$ | Power of existing light | kW | Site-specific | |
| $kW_{installed}$ | Power of installed light | kW | Site-specific | |
| ACOP | Average coefficient of performance | N/A | Calculated or lookup in Table 2-31 | [5] |
| COP | Coefficient of performance | N/A | Calculated or lookup in Table 2-31 | [5] |
| EER | Energy Efficiency Ratio | N/A | Site-specific | See footnote* |
| CF | Seasonal peak demand coincident factor for refrigeration | % | 100% | [3] |
| L | Ballast location factor | N/A | Table 2-32 | |
| N | Number of lights | N/A | Site-specific | |
| h | Lighting annual run hours | Hours | Site-specific | |

*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.

**Table 2-31 Cooler and Freezer ACOP and COP Values**

| Equipment Type | ACOP [5] | COP |
|---|---|---|
| Coolers | 3.35 | 2.29 |
| Freezers | 1.88 | 1.72 |

**Table 2-32 Ballast Location Factor**

| Ballast Location Type | Ballast Location Factor (L) |
|---|---|
| Refrigerated | 1 |
| Non-refrigerated | 0 |
| Unknown | 0.5 |

## *Measure Life*

**Table 2-33 Measure Life**

| Equipment Type | Retrofit | Ref |
|---|---|---|
| Fixture (LED) | 7 | [4] |

## *Peak Factors*

**Table 2-34 Peak Factors**

| Measure | Summer Coincidence Factor | Winter Coincidence Factor | Ref |
|---|---|---|---|
| Refrigerator LED | 100% | 100% | [3] |

## *Load Shapes*

**Table 2-35 Load Shapes**

| Measure | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % | Ref |
|---|---|---|---|---|---|
| Lighting | 42.10% | 32.50% | 13.90% | 11.50% | [3] |

## *Realization Rates and Net Impact Factors*

**Table 2-36 Realization Rates and Net Impact Factors**

| | Gross Realization % | | | FR and SO | | Net Realization % | | | |
|---|---|---|---|---|---|---|---|---|---|
| Measure | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Free-ridership | Spill-over | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Ref |
| Lighting* Energy Opportunities | 97.9% | 115.3% | 98.9% | 11.0% | 5.0% | 92.0% | 108.4% | 93.0% | [6], [7] |
| Lighting* Small Business Energy Advantage | 109.0% | 108.0% | 119.0% | 3.8% | 2.5% | 107.6% | 106.6% | 117.5% | [1], [2] |

## *References*

[1] The Cadmus Group, Inc. 2020 . “C1634 Impact Evaluation of PY 2016 & 2017 Energy Conscious Blueprint Program.” Connecticut Energy Efficiency Board (EEB) and Evaluation Administrators.

[2] Tetra Tech. 2012. “2011 C&I Electric and Gas Free-ridership and Spillover Study.” Table 3-5. Connecticut Energy Efficiency Fund.

[3] DNV. 2021. “X1931-2 Load Shape and Coincidence Factor Research.” Connecticut Energy Efficiency Board (EEB) and Evaluation Administrators.

[4] DNV. 2021. “Connecticut C2014 C&I Lighting Saturation and Remaining Potential – Phase One Results and Recommendations.” Connecticut Energy Efficiency Board (EEB) and Evaluation Administrators.

[5] DNV. 2022. “X1931-5 PSD Commercial Refrigeration Efficiency Update Study.” Connecticut Energy Efficiency Board.

[6] EMI Consulting. 2019. “C1644: EO Net-to-Gross Study.” Connecticut Energy Efficiency Board.

[7] DNV GL. 2020. “C1635 Impact Evaluation of PY 2016 & 2017 Energy Opportunities (EO) Program”. Tables 6-11. Connecticut Energy Efficiency Board (EEB) and Evaluation Administrators.

***Changes from Last Version***

- Formatting updates.
- Updated ACOP values.

## 2.2 HVAC AND WATER HEATING

### 2.2.1 CHILLERS

| | |
|---|---|
| Market | Commercial |
| Baseline Type | Lost Opportunity |
| Category | HVAC & Water Heating |

***Description***

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

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

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. 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. 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).

*Equipment:*

Each chiller plant is characterized by:

- Number of chillers.
- Sizes, in tons (the chillers may be different sizes).
- Type, which may be:
    1. Water-cooled centrifugal
    2. Water-cooled positive displacement (screw, scroll, and reciprocating)
    3. Air cooled
- Speed, constant, or variable.
- Auxiliary equipment:

1. Chilled water pumps;
2. Cooling tower pumps;
3. Cooling tower fans;
4. Other.

*Operational staging:*

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

*Operating profile:*

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

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

*Load profile:*

A customer's representative (typically a design engineer) provides loads at various conditions. The customer's load profile is estimated by determining the load at the peak outdoor conditions and the load at the minimum conditions. For systems with an airside 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 for the site based on engineering best practices; in this case it is also necessary to determine the value of any process loads.

*Savings calculations:*

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

## ***Annual Energy Savings Algorithm***

*Lost Opportunity Gross Energy Savings, Electric*

$$\Delta kWh = kWh_B - kWh_I$$

Where $kWh_B$ and $kWh_I$ are each calculated via BIN analysis as follows:

$$kWh = \sum kWh_{Bin}$$

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

$$kWh_{Bin} = EFF_{Bin} \times L_{T,Bin}$$

Where $L_{T,Bin}$ is the sum of the chiller load values at outdoor temperature bin for both occupied and unoccupied periods,

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

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

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

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

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

$$L_{T,Bin} = L_{0°F} + \frac{L_{100°F} - L_{Econ,OAT+}}{100 - T_{Econ,OAT}} \times (T_{T,Bin} - T_{Econ})$$

*Lost Opportunity Gross Seasonal Peak Demand Savings, Electric*

Summer seasonal peak demand savings are determined by summing the energy saved in bins where outdoor temperature is greater than 80°F and then averaging across total bin hours in the range:

$$\Delta kW_{Summer} = \frac{\sum_{Bin=80°F}^{Bin=Max} kWh_{B,Bin} - \sum_{Bin=80°F}^{Bin=Max} kWh_{I,Bin}}{\sum_{Bin=80°F}^{Bin=Max} H_{Bin}}$$

Winter seasonal peak demand savings are determined by summing energy saved in bins where outdoor temperature is less than 30°F and then averaging across total bin hours in the range:

$$\Delta kW_{Winter} = \frac{\sum_{Bin=Min}^{Bin=30°F} kWh_{B,Bin} - \sum_{Bin=Min}^{Bin=30°F} kWh_{I,Bin}}{\sum_{Bin=Min}^{Bin=30°F} H_{Bin}}$$

## ***Calculation Parameters***

**Table 2-37 Calculation Parameters**

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| ΔkWh | Annual electric savings | Calculated | kWh | |
| $\Delta kW_{Summer}$ | Electric peak day savings – summer | Calculated | kW | |
| $\Delta kW_{Winter}$ | Electric peak day savings – winter | Calculated | kW | |
| kWh | Total annual electric consumption | Calculated | kWh | |
| $kWh_{Bin}$ | Annual electric consumption in temperature bin | Calculated | kWh | |
| $L_{T,Bin}$ | Sum of chiller load values at temperature bin | Calculated | Tons | |
| $L_{Econ,OAT+}$ | Load at economizer set point + | Calculated | Tons | |

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| $L_{Econ,OAT+}$ | Load at economizer set point - | Calculated | Tons | |
| $L_{100°F}$ | Peak cooling load at 100°F | Calculated | Tons | |
| $L_{0°F}$ | Load at 0°F | Calculated | Tons | |
| $T_{T,Bin}$ | Temperature of bin | Per bin analysis | °F | |
| $T_{Econ}$ | Economizer set point | Site-specific | °F | |
| $H_{Bin}$ | Annual hours in temperature bin, determined from equipment use and TMY3 data | Site-specific | Hours | |
| $EFF_{Bin}$ | Chiller efficiency; interpolated for the specific load percent using the AHRI spec sheet for the efficient case, or using tables for baseline case[6] | Site-specific or lookup in Table 2-38, Table 2-39 | kW/ton | |
| $..._B$ | Baseline | | | |
| $..._I$ | Installed | | | |
| $..._{Occ}$ | Occupied | | | |
| $..._{Unocc}$ | Unoccupied | | | |

Table 2-38 and Table 2-39 presents baseline part-load efficiencies for electric chillers, developed using typical chiller part load curves and the baseline efficiencies in Table 2-40, is based on 2021 IECC Table C403.3.2(3). Path A is intended for applications where significant operating time is expected at full load. Path B is intended for applications where significant operating time is expected at part load.

**Table 2-38 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 | 12.538 | 15.149 | 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 |

6 When efficiency is expressed as EER, convert to kW/ton using the following formula:

$$\frac{kW}{ton} = \frac{12}{EER}$$

| Equipment Type | Size Category (tons) | Units | Part-Load Efficiencies | | | |
|---|---|---|---|---|---|---|
| | | | 100% Load | 75% Load | 50% Load | 25% Load |
| | ≥ 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 | 0.536 | 0.494 | 0.565 |
| | ≥600 | kW/ton | 0.560 | 0.515 | 0.475 | 0.547 |

**Table 2-39 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 | 0.486 | 0.335 | 0.349 |
| | ≥ 600 | kW/ton | 0.585 | 0.474 | 0.327 | 0.338 |

**Table 2-40 Baseline Efficiencies for Electric Chillers**

| Equipment Type | Size Category (tons) | Units | Path A[2] | | Path B[3] | |
|---|---|---|---|---|---|---|
| | | | Full Load[4] | IPLV[4] | Full Load[4] | IPLV[4] |
| Air cooled | <150 | EER | ≥ 10.100 | ≥ 13.700 | ≥ 9.700 | ≥ 15.800 |
| | ≥150 | EER | ≥ 10.100 | ≥ 14.000 | ≥ 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 |

| Equipment Type | Size Category (tons) | Units | Path A[2] | | Path B[3] | |
|---|---|---|---|---|---|---|
| | | | Full Load[4] | IPLV[4] | Full Load[4] | IPLV[4] |
| Water cooled centrifugal | <150 | kW/ton | ≤ 0.610 | ≤ 0.550 | ≤ 0.695 | ≤ 0.440 |
| | ≥ 150 & < 300 | kW/ton | ≤ 0.610 | ≤ 0.550 | ≤ 0.635 | ≤ 0.400 |
| | ≥ 300 & < 400 | kW/ton | ≤ 0.560 | ≤ 0.520 | ≤ 0.595 | ≤ 0.390 |
| | ≥ 400 | kW/ton | ≤ 0.560 | ≤ 0.500 | ≤ 0.585 | ≤ 0.380 |

[1] For water cooled ≤ 300 tons, positive displacement is the baseline. For > 300 tons, centrifugal is the baseline.

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

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

[4] Rated based on AHRI 550/590, EER for air cooled or kW/ton for water cooled.

## ***Measure Life***

The measure life for electric chiller is 23 years [3].

**Measure Life**

| Equipment Type | Remaining Useful Life | Retrofit | Lost Opportunity | Ref |
|---|---|---|---|---|
| Electric Chiller | 5 | N/A | 23 | [3] |

## ***Peak Factors***

**Table 2-41 Peak Factors**

| Measure | Summer Coincidence Factor | Winter Coincidence Factor | Ref |
|---|---|---|---|
| Chillers | 70% | 3% | [4] |

## ***Load Shapes***

**Table 2-42 Load Shapes**

| End Use | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % | Ref |
|---|---|---|---|---|---|
| Cooling - Chillers | 18.45% | 17.26% | 32.23% | 32.06% | [4] |

## *Realization Rates*

**Table 2-43 Realization Rates**

| | Gross Realization % | | | FR & SO | | Net Realization % | | | |
|---|---|---|---|---|---|---|---|---|---|
| End Use | Energy (kWh) | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Free-ridership | Spill-over | Energy (kWh) | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Ref |
| Cooling **Energy Opportunities** | 102.1% | 125.0% | 146.4% | 12.0% | 5.0% | 95.0% | 116.3% | 136.2% | [5], [6] |
| Cooling **Small Business Energy Advantage** | 72.0% | 73.0% | 85.0% | 15.3% | 0.2% | 61.1% | 62.0% | 72.2% | [7], [8] |

## *References*


[1] AHRI 550/590.

[2] 2021 IECC Table C403.3.2(3).

[3] GDS Associates Inc., *Measure Life Report, Residential and Commercial Industrial Lighting and HVAC Measures*, Jun. 2007, see Table 2.

[4] DNV. 2021. “X1931-2 Load shape and Coincidence Factor Research – Final Report.”

[5] DNV-GL, C1635 Impact Evaluation of PY 2016 & 2017 Energy Opportunities (EO) Program.

[6] EMI Consulting. 2019. “C1644: EO Net-to-Gross Study.” Connecticut Energy Efficiency Board.

[7] ERS, C1639: Impact Evaluation of the Connecticut Small Business Energy Advantage Program, Mar. 20, 2018.

[8] Tetra Tech, *2011 C&I Electric and Gas Free-ridership and Spillover Study*, Oct. 5, 2012.


## *Changes from Last Version*

- Formatting updates.

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

| | |
|---|---|
| Market | Commercial |
| Baseline Type | Lost Opportunity |
| Category | HVAC & Water Heating |

### ***Description***

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

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

Savings are estimated using full-load hours analysis, comparing the difference in efficiency between a baseline (code compliant or Industry standard practice) and installed efficiency. This measure includes baseline efficiency values based on 2021 IECC standard efficiency options.

Reminders: SEER used in place of EER for units < 65,000 Btu/hr. IEER should be used instead of EER when available. COP multiplied by 3.412 can be used in place of HSPF for units ≥ 65,000 Btu/hr. There are two paths for complying with the ASHRAE 90.1 2019 Standards: (1) the Baseline Efficiencies (Table 2-45) and (2) Additional Efficiencies (Table 2-46). Cooling-only units have no winter demand savings since they do not operate during the winter.

### ***Energy Savings Algorithm***

*Lost opportunity gross energy savings, electric:*

Cooling (A/C units and air source heat pumps < 65,000 Btu/hr):

$$\Delta kWh_C = CAP_C \times \left(\frac{1}{SEER_b} - \frac{1}{SEER_i}\right) \times \frac{kW}{1000W} \times EFLH_C$$

Cooling (A/C units and air source heat pumps ≥ 65,000 Btu/hr with IEER available):

$$\Delta kWh_C = CAP_C \times \left(\frac{1}{IEER_b} - \frac{1}{IEER_i}\right) \times \frac{kW}{1000W} \times EFLH_C$$

Cooling (A/C units and air source heat pumps ≥ 65,000 Btu/hr with EER available):

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

Heating (air source heat pumps < 65,000 Btu/hr):

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

Heating (air source heat pumps ≥ 65,000 Btu/hr):

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

*Lost opportunity gross seasonal peak demand savings, electric (winter and summer):*

$$\Delta kW_{Summer} = \frac{\Delta kWh_C}{EFLH_C} \times CF_{Summer}$$

Where,

$$\Delta kW_{Summer} = \frac{\Delta kWH_H}{EFLH_H} \times CF_{Winter}$$

## ***Calculation Parameters***

**Table 2-43 Calculation Parameters**

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| $\Delta kWh_C$ | Annual gross electric energy savings – cooling | Calculated | kWh | |
| $\Delta kWh_H$ | Annual gross electric energy savings – heating | Calculated | kWh | |
| $\Delta kW_{Summer}$ | Summer peak demand savings | Calculated | kW | |
| $\Delta kW_{Winter}$ | Winter peak demand savings | Calculated | kW | |
| $CAP_C$ | Installed cooling capacity | Site-specific | Btu/hr | |
| $CAP_H$ | Installed heating capacity | Site-specific | Btu/hr | |
| $EER_i$ | Installed EER (for units ≥ 65,000 Btu/hr) | Site-specific | Btu/watt-hr | |
| $SEER_i$ | Installed SEER (for units < 65,000 Btu/hr) (if unit is rated by SEER2, convert using Table 2-46) | Site-specific | Btu/watt-hr | |
| $HSPF_i$ | Installed heat pump HSPF (if unit is rated by HSPF2, convert using Table 2-47) | Site-specific | Btu/watt-hr | |
| $COP_i$ | Installed COP (for units < 65,000 Btu/hr) | Site-specific | N/A | |
| $EFLH_H$ | Effective full-load hours, heating | Site-specific or lookup in | Hours | |
| $EFLH_C$ | Effective full-load hours, cooling | Site-specific or lookup in | Hours | |
| $CF_{Summer}$ | Seasonal summer cooling coincidence factor | Table 2-49 | N/A | [4] |
| $CF_{Winter}$ | Seasonal winter heating coincidence factor | Table 2-49 | N/A | [4] |

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| $COP_b$ | Baseline COP (for units ≥ 65,000 Btu/hr) | Table 2-45 | N/A | [1] |
| $HSPF_b$ | Baseline HSPF (use COP for units ≥ 65,000 Btu/hr) | Table 2-45 | N/A | [1] |
| $EER_b$ | Baseline EER (for units ≥ 65,000 Btu/hr with no IEER available) | Table 2-44 (A/C),Table 2-45 (HP) | Btu/watt-hr | [1] |
| $SEER_b$ | Baseline SEER (for units < 65,000 Btu/hr) | Table 2-44 (A/C),Table 2-45 (HP) | Btu/watt-hr | [1] |
| $IEER_b$ | Baseline IEER (for units ≥ 65,000 Btu/hr) | Table 2-44 (A/C),Table 2-45 (HP) | Btu/watt-hr | |

**Table 2-44 Baseline Efficiencies – Unitary and Split System-A/C 2021**

| Size (Btu/h) | Units with Electric Resistance or No Heating Section | Units with Heating Section Other Than Electric Resistance |
|---|---|---|
| Whole Building New Construction Baseline [5] | | |
| < 65,000 | 14.0 SEER (split system)[5] | 14.0 SEER (split system)[5] |
| | 15.0 SEER (single package)[5] | 15.0 SEER (single package)[5] |
| ≥ 65,000 and < 135,000 | 12.0 EER[5] | 12.0 EER[5] |
| | 14.8 IEER[1] | 14.6 IEER[1] |
| ≥ 135,000 and < 240,000 | 11.0 EER[1] | 10.8 EER[1] |
| | 14.2 IEER[1] | 14.0 IEER[1] |
| ≥ 240,000 and < 760,000 | 10.0 EER[1] | 9.8 EER[1] |
| | 13.2 IEER[1] | 13.0 IEER[1] |
| ≥ 760,000 | 9.7 EER[1] | 9.5 EER[1] |
| | 12.5 IEER[1] | 12.3 IEER[1] |
| Existing Building Lost Opportunity Baseline [1] | | |
| < 65,000 | 14.0 SEER/13.4SEER2(split system)[1] | 14.0 SEER/13.4SEER2 (split system)[1] |
| | 14.0 SEER/13.4SEER2 (single package)[1] | 14.0 SEER/13.4SEER2 (single package)[1] |
| ≥ 65,000 and < 135,000 | 11.2 EER[1] | 11.0 EER [1] |
| | 14.8 IEER[1] | 14.6 IEER[1] |
| ≥ 135,000 and < 240,000 | 11.0 EER[1] | 10.8 EER[1] |
| | 14.2 IEER[1] | 14.0 IEER[1] |
| ≥ 240,000 and < 760,000 | 10.0 EER[1] | 9.8 EER[1] |
| | 13.2 IEER[1] | 13.0 IEER[1] |
| ≥ 760,000 | 9.7 EER[1] | 9.5 EER[1] |
| | 12.5 IEER[1] | 12.3 IEER[1] |

**Table 2-45 Baseline Efficiencies –Unitary and Split System Heat Pumps—2021 IECC [2] [5]**

| Size (Btu/h) | Cooling Mode | | .0 |
|---|---|---|---|
| | Units with Electric Resistance or No Heating Section | Units with Heating Section Other Than Electric Resistance | |
| Whole Building New Construction Baseline [5] | | | |
| < 65,000, split systems | 17.3 SEER | 17.3 SEER | 10.2 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 | 3.4 COP |
| ≥ 135,000 and < 240,000 | 10.6 EER | 10.4 EER | 3.3 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 |
| Existing Building Lost Opportunity Baseline [1] | | | |
| < 65,000, split systems | 14.3SEER2 / 14 SEER | 14.3 SEER2 / 14 SEER | 7.5 HSPF2/8.2 HSPF |
| < 65,000, single package | 13.4 SEER2 / 14 SEER | 13.4 SEER2 / 14 SEER | 6.7 HSPF2 / 8.0 HSPF |
| ≥ 65,000 and < 135,000 | 11.0 EER / 14.1 IEER | 10.8 EER / 13.9 IEER | 3.4 COP |
| ≥ 135,000 and < 240,000 | 10.6 EER / 13.5 IEER | 10.4 EER / 13.3 IEER | 3.3 COP |
| ≥ 240,000 and < 375,000 | 9.5 EER / 12.5 IEER | 9.3 EER / 12.3 IEER | 3.2 COP |

**Table 2-46 SEER2 to SEER Conversion for Unitary and Split System Air Conditioners and Heat Pumps**

| SEER2 | SEER |
|---|---|
| 13.4 | 14 |
| 14.3 | 15 |
| 15.2 | 16 |
| 16 | 17 |
| 17 | 18 |
| 18 | 19 |
| 19 | 20 |
| 20 | 21 |
| 21 | 22 |
| 22 | 23 |
| 23 | 24 |

**Table 2-47 HSPF2 to HSPF Conversion for Unitary and Split System Heat Pumps**

| HSPF2 | HSPF |
|---|---|
| 6.7 | 8.0 |
| 7.1 | 8.5 |
| 7.5 | 8.8 |
| 7.8 | 9.2 |
| 8 | 9.5 |
| 8.4 | 10 |
| 8.5 | 10.2 |
| 8.9 | 10.8 |
| 9.1 | 11 |
| 9.3 | 11.3 |
| 9.7 | 11.9 |
| 10 | 12.4 |
| 10.4 | 12.9 |

## ***Calculation Examples***

*Lost opportunity gross energy savings:* A 120,000 Btu/hr rooftop A/C unit is installed on an office building. The new unit has a rated EER of 12.5. What is the measure's annual lost opportunity savings?

*Cooling (A/C units and air source heat pumps):* The cooling equivalent full load hours for an office are 797 hours. $EER_b$ from Table 2-45 is 11 EER.

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

*Lost opportunity gross peak seasonal demand savings:* A 120,000 Btu/hr rooftop A/C unit is installed on an office building. The new unit has a rated EER of 12.5. What is the unit's seasonal peak savings? Note: From Table 2-49, the seasonal coincidence factor for cooling = 0.44. $EER_b$ from Table 2-45 = 11 EER.

$$\Delta kW_{Summer} = 120{,}000 \times \left(\frac{1}{11} - \frac{1}{12.5}\right) \times \frac{kW}{1000W} \times 0.44 = 0.575kW$$

Where,

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

## *Measure Life*

**Table 2-48 Measure Life**

| Equipment Type | Measure Life | Ref |
|---|---|---|
| Remaining Useful Life | 5 | |
| Lost Opportunity | 15 | [3] |

## *Peak Factors*

**Table 2-49 Peak Factors**

| Measure | Summer Coincidence Factor | Winter Coincidence Factor | Ref |
|---|---|---|---|
| Unitary A/C and heat pumps | 42% | 0.01% | [4] |

## *Load Shapes*

**Table 2-50 Load Shapes**

| Measure Type | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % | Ref |
|---|---|---|---|---|---|
| Cooling - Chillers | 18.45% | 17.26% | 32.23% | 32.06% | [4] |
| Cooling - RTUs | 18.19% | 10.22% | 43.16% | 28.43% | [4] |
| Heating | 55.00% | 27.00% | 12.00% | 6.00% | [4] |

## *Realization Rates and Net Impact Factors*

**Table 2-51 Realization Rates and Net Impact Factors**

| | Gross Realization % | | | FR and SO | | Net Realization % | | | |
|---|---|---|---|---|---|---|---|---|---|
| Measure | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Free-ridership | Spill-over | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Ref |
| Cooling Energy Conscious Blueprint | 86.20% | 151.10% | 89.70% | 29.50% | 12.40% | 71.46% | 125.26% | 74.36% | [8], [7] |
| Cooling Energy Opportunities | 102.10% | 125.00% | 146.40% | 12.00% | 5.00% | 94.95% | 116.25% | 136.15% | [10], [9] |
| Cooling | 72.00% | 73.00% | 85.00% | 15.30% | 0.20% | 61.13% | 61.98% | 72.17% | [6], [7] |

| | Gross Realization % | | | FR and SO | | Net Realization % | | | |
|---|---|---|---|---|---|---|---|---|---|
| Small Business Energy Advantage | | | | | | | | | |
| Cooling Midstream Program | 86.20% | 151.10% | 89.70% | 32.00% | | 58.62% | 102.75% | 61.00% | [8], [7],[11] |
| Heating Energy Conscious Blueprint | 97.80% | 93.00% | 94.40% | 23.70% | 28.00% | 102.01% | 97.00% | 98.46% | [8], [7] |
| Heating Energy Opportunities | 102.10% | 125.00% | 146.40% | 14.00% | 7.00% | 94.95% | 116.25% | 136.15% | [10], [9] |
| Heating Small Business Energy Advantage | 72.00% | 73.00% | 85.00% | 0.00% | 0.00% | 72.00% | 73.00% | 85.00% | [6], [7] |
| Heating Midstream Program | 97.80% | 93.00% | 94.40% | 32.00% | | 66.50% | 63.24% | 64.19% | [8], [7],[11] |

Note: Whole Building New Construction Baseline applies to non EUI based offering (currently referred as path 3 and 4).

## ***References***


[1] 2021 IECC (CT Code), see Table C403.3.2(1).

[2] 2021 IECC (CT Code), see Table C403.3.2(4).

[3] GDS Associates Inc. 2007. "Measure Life Report, Residential and Commercial Industrial Lighting and HVAC Measures." Table 2. New England State Program Working Group (SPWG).

[4] DNV. 2021. "X1931-2 Load Shape and Coincidence Factor Research." Connecticut Energy Efficiency Board (EEB) and Evaluation Administrators.

[5] NMR. 2022. "C1902-B: Energy Conscious Blueprint Baseline and Code Compliance Results." Connecticut Energy Efficiency Board.

[6] ERS. 2018. "C1639: Impact Evaluation of the Connecticut Small Business Energy Advantage Program." Connecticut Energy Efficiency Board (EEB) and Evaluation Administrators.

[7] Tetra Tech. 2012. "2011 C&I Electric and Gas Free-ridership and Spillover Study." Table 3-5. Connecticut Energy Efficiency Fund.

[8] Cadmus. 2020. C1634 Impact Evaluation of PY 2016 & 2017 Energy Conscious Blueprint Program.

[9] EMI Consulting. 2019. "C1644 EO Net-to-Gross Study." Connecticut Energy Efficiency Board.

[10] DNV-GL. 2020. "C1635 Impact Evaluation of PY 2016 & 2017 Energy Opportunities (EO) Program". Tables 6-11. Connecticut Energy Efficiency Board (EEB) and Evaluation Administrators.

[11] NMR, DNV, Brightline Group. 2022. "C1902a: Connecticut Midstream C&I HVAC & Water Heating and Foodservice Net-to-Gross Review."


## ***Changes from Last Version***

- Formatting updates.

- Updated savings algorithms to include IEER method.
- Updated  DX < 65,000 SEER value.
- Updated DX ≥ 65,000 and < 135,000 EER value.
- Updated Split System < 65,000 EER value.
- Updated Split System Heat Pump < 65,000 Overall HSPF value.
- Updated Split System Heat Pump < 65,000 Overall SEER value.
- Updated  coincidence factors and seasonal peak savings algorithms.
- Updated net realization rates.

### 2.2.3 WATER AND GROUND SOURCE HEAT PUMP

| | |
|---|---|
| Market | Commercial |
| Baseline Type | Lost Opportunity |
| Category | HVAC & Water Heating |

***Description***

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

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

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

***Annual Energy Savings Algorithm***

*Lost Opportunity Gross Energy Savings, Electric*

Cooling:

$$\Delta kWh_C = CAP_C \, x \left(\frac{1}{EER_b} - \frac{1}{EER_1}\right) x \, \frac{kW}{1000\ W} \, x \, EFLH_C$$

Heating:

$$\Delta kWh_H = CAP_H \, x \left(\frac{1}{COP_b} - \frac{1}{COP_1}\right) x \, \frac{1}{3.412} \, x \, \frac{kW}{1000\ W} \, x \, EFLH_H$$

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

Cooling:

$$\Delta kW_{Summer} = CF_C \, x \, CAP_C \, x \left(\frac{1}{EER_b} - \frac{1}{EER_1}\right) x \, \frac{kW}{1000\ W}$$

Heating:

$$\Delta kW_{Winter} = CF_H \, x \, CAP_H x \left(\frac{1}{COP_b} - \frac{1}{COP_1}\right) x \frac{1}{3.412} \, x \, \frac{kW}{1000\ W}$$

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

*Early Retirement or Retrofit Gross Energy Savings, Electric*

Cooling:

$$\Delta kWh_C = CAP_C \, x \left(\frac{1}{EER_e} - \frac{1}{EER_i}\right) x \frac{kW}{1000\ W} \, x \, EFLH_C$$

Heating:

$$\Delta kWh_H = CAP_H x \left(\frac{1}{COP_e} - \frac{1}{COP_i}\right) x \frac{1}{3.412} \, x \frac{kW}{1000\ W} \, x \, EFLH_H$$

*Early Retirement or Retrofit Gross Peak Demand Savings, Electric*

Cooling:

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

Heating:

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

## Calculation Parameters

**Table 2-52 Calculation Parameters**

| Symbol | Description | Units | Values | Ref |
|---|---|---|---|---|
| $\Delta kWh_C$ | Annual electric energy savings - cooling | kWh | Calculated | |
| $\Delta kWh_H$ | Annual electric energy savings - heating | kWh | Calculated | |
| $\Delta kW_{Summer}$ | Seasonal summer peak savings - cooling | kW | Calculated | |
| $\Delta kW_{Winter}$ | Seasonal winter peak savings - heating | kW | Calculated | |
| $CAP_C$ | Installed cooling capacity | Btu/hr | Site-specific | |

| Symbol | Description | Units | Values | Ref |
|---|---|---|---|---|
| $CAP_H$ | Installed heating capacity | Btu/hr | Site-specific | |
| $CF_C$ (MF) | Seasonal summer cooling coincidence factor (Multifamily) | % | 59% | [2] |
| $CF_H$ (MF) | Seasonal summer heating coincidence factor (Multifamily) | % | 100% | [2] |
| $CF_C$ | Seasonal summer cooling coincidence factor | % | 82% | [3] |
| $CF_H$ | Seasonal summer heating coincidence factor | % | 82% | [3] |
| $COP_b$ | Baseline COP | | Table 2-53 | [1] |
| $COP_i$ | COP – installed | | Site-specific | Input |
| $COP_e$ | COP – existing | | Site-specific | Input |
| $EER_b$ | EER – baseline | Btu/watt-hr | Table 2-53 | [1] |
| $EER_i$ | EER – installed | Btu/watt-hr | Site-specific | Input |
| $EER_e$ | EER – existing | Btu/watt-hr | Site-specific | Input |
| $EFLH_C$ | Equivalent full load hours - cooling | Hrs | Table 2-54 | |
| $EFLH_H$ | Equivalent full load hours - heating | Hrs | Table 2-54 | |

**Table 2-53 Baseline Efficiencies [1]**

| Type | Cooling Capacity Btu/hr | Rating Condition | | $EER_b$ | $COP_b$ |
|---|---|---|---|---|---|
| | | Cooling Mode | Heating Mode | | |
| Water to Air: Water Loop Heat Pump (closed loop within a building, served by boiler and cooling tower) | < 17,000 | 86°F | 68°F | 12.2 | 4.3 |
| Water to Air: Water Loop Heat Pump (closed loop within a building, served by boiler and cooling tower) | ≥ 17,000 and < 135,000 | 86°F | 68°F | 13.0 | 4.3 |
| Water to Air: Ground Water Heat Pump (water used by the heat pump is in contact with the ground) | < 135,000 | 59°F | 50°F | 18.0 | 3.7 |
| Water to Water: Ground Water Heat Pump (water used by the heat pump is in contact with the ground) | < 135,000 | 59°F | 50°F | 16.3 | 3.1 |
| Brine to Air: Ground Loop Heat Pump (water used by the heat pump is isolated from contact with the ground) | < 135,000 | 77°F | 32°F | 14.1 | 3.2 |

| Type | Cooling Capacity Btu/hr | Rating Condition | | $EER_b$ | $COP_b$ |
|---|---|---|---|---|---|
| | | Cooling Mode | Heating Mode | | |
| Brine to Water: Ground Loop Heat Pump (water used by the heat pump is isolated from contact with the ground) | < 135,000 | 77°F | 32°F | 12.1 | 2.5 |

**Table 2-54 Heating and Cooling Full Load Hours [3]**

| Facility Type | Cooling FLHrs | Heating FLHrs |
|---|---|---|
| Auto Related | 427 | 3,122 |
| Bakery | 565 | 1,065 |
| Church | 266 | 938 |
| College: Cafeteria | 591 | 1,178 |
| Convenience Store | 771 | 831 |
| Dining: Bar Lounge/Leisure | 558 | 1,118 |
| Dining: Cafeteria/Fast Food | 591 | 1,178 |
| Dining: Family | 558 | 1,118 |
| Entertainment | 726 | 1,042 |
| Exercise Center | 726 | 1,042 |
| Fast Food Restaurant | 591 | 1,178 |
| Food Store | 386 | 840 |
| Gymnasium | 726 | 1,042 |
| Industrial: 1 Shift | 565 | 1,065 |
| Industrial: 2 Shift | 767 | 727 |
| Industrial: 3 Shift | 972 | 384 |
| Laundromat | 771 | 831 |
| Library | 726 | 1,042 |
| Light Manufacturer | 565 | 1,065 |
| Lodging (Hotel/Motel) | 897 | 628 |
| Manufacturing Facility | 565 | 1,065 |
| Medical Office | 827 | 598 |
| Motion Picture Theatre | 726 | 1,042 |

| Facility Type | Cooling FLHrs | Heating FLHrs |
|---|---|---|
| Museum | 726 | 1,042 |
| Office (General Office Types) | 827 | 598 |
| Office/Retail | 827 | 598 |
| Parking Garage and Lot | 427 | 3,122 |
| Performing Arts Theatre | 726 | 1,042 |
| Post Office | 827 | 598 |
| Pump Station | 972 | 384 |
| Refrigerated Warehouse | 297 | 734 |
| Religious Building | 266 | 938 |
| Restaurant | 558 | 1,118 |
| Retail | 771 | 831 |
| Schools (Preschool/Elementary) | 307 | 1,086 |
| Small Services | 827 | 598 |
| Sports Arena | 726 | 1,042 |
| Town Hall | 726 | 1,042 |
| Transportation | 427 | 3,122 |
| Warehouse (Not Refrigerated) | 297 | 734 |
| Wastewater Treatment Plant | 972 | 384 |
| Workshop | 565 | 1,065 |

## ***Calculation Examples***

*Lost Opportunity Gross Energy Savings, Example*

Example: A ground loop water-to-air heat pump is installed in an office building. The heating capacity is 99,000 Btu/hr with a COP of 3.5. The cooling capacity is 125,000 Btu/h with an EER of 15. What are the annual Lost Opportunity Savings?

Cooling:

$$\Delta kWh_C = CAP_C\, x \left(\frac{1}{EER_b} - \frac{1}{EER_1}\right) x\, \frac{kW}{1000\ W}\, x\, EFLH_C$$

From Table 2-54, the cooling equivalent full load hours for an office are 797 hours. The EERb from Table 2-53 is 14.1:

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

Heating:

$$\Delta kWh_H = CAP_H\, x \left(\frac{1}{COP_b} - \frac{1}{COP_1}\right) x\, \frac{1}{3.412}\, x \frac{kW}{1000\ W}\, x\, EFLH_H$$

From Table 2-54, the heating equivalent full load hours for an office are 1,248 hours. The COPb from Table 2-53 is 3.2:

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

*Lost Opportunity Gross Peak Demand Savings, Example*

Example: A ground loop water-to-air-source heat pump is installed in an office building. The heating capacity is 99,000 Btu/hr with a COP of 3.5. The cooling capacity is 125,000 Btu/h with an EER of 15. What are the Lost Opportunity (seasonal demand) Savings?

Cooling:

$$\mathrm{S}kW_C = CF_C\, x\, CAP_C\, x \left(\frac{1}{EER_b} - \frac{1}{EER_1}\right) x\, \frac{kW}{1000\ W}$$

From Table 2-55, the seasonal coincidence factor for cooling = 0.82. The EERb from Table 2-53 is 14.1:

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

Heating:

$$WkW_H = CF_H\, x\, CAP_H x \left(\frac{1}{COP_b} - \frac{1}{COP_1}\right) x \frac{1}{3.412}\, x\, \frac{kW}{1000\ W}$$

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

The seasonal coincidence factor is assumed to be the same as the summer factor = 0.82. The COPb from Table 2-53 is 3.2:

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

***Measure Life***

The measure life for Water Source Heat Pump is 15 years [10].

The measure life for Ground Source Heat Pump is 25 years [10].

***Peak Factors***

**Table 2-55 Peak Factors**

| Measure | Summer Coincidence Factor | Winter Coincidence Factor | Ref |
|---|---|---|---|
| Water and ground source heat pumps (Com) | 82% | 82% | |

***Load Shapes***

**Table 2-56 Load Shapes**

| Measure | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % | Ref |
|---|---|---|---|---|---|
| Heating | 55.00% | 27.00% | 12.00% | 6.00% | |

***Realization Rates and Net Impact Factors***

**Table 2-57 Realization Rates**

| | Gross Realization % | | | FR & SO | | Net Realization % [11] | | | |
|---|---|---|---|---|---|---|---|---|---|
| Measure | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Free-ridership | Spill-over | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Ref |
| Cooling **Energy Conscious Blueprint** | 86.20% | 151.10% | 89.70% | 29.50% | 12.40% | 71.46% | 125.26% | 74.36% | [7],[6] |
| Cooling **Energy Opportunities** | 102.10% | 125.00% | 146.40% | 12.00% | 5.00% | 94.95% | 116.25% | 136.15% | [9],[8] |
| Cooling **Small Business Energy Advantage** | 72.00% | 73.00% | 85.00% | 15.30% | 0.20% | 61.13% | 61.98% | 72.17% | [5],[6] |

| | Gross Realization % | | | FR & SO | | Net Realization % [11] | | | |
|---|---|---|---|---|---|---|---|---|---|
| Heating<br>**Energy Conscious Blueprint** | 97.80% | 93.00% | 94.40% | 23.70% | 28.00% | 102.01% | 97.00% | 98.46% | [7],[6] |
| Heating<br>**Energy Opportunities** | 102.10% | 125.00% | 146.40% | 14.00% | 7.00% | 94.95% | 116.25% | 136.15% | [9],[8] |
| Heating<br>**Small Business Energy Advantage** | 72.00% | 73.00% | 85.00% | 0.00% | 0.00% | 72.00% | 73.00% | 85.00% | [5],[6] |

## ***References***


[1] 2021 IECC's Table C403.3.2(14).Revised IECC references from to remove reference to CT building code.

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

[3] DNV. 2021. "X1931-2: Load Shape and Coincidence Factor Research." Connecticut Energy Efficiency Board (EEB) and Evaluation Administrators.

[4] DNV. 2021. "X1931-6: PSD HOU/FLH Documentation and Update Study." Connecticut Energy Efficiency Board (EEB) and Evaluation Administrators.

[5] ERS. 2018. "C1639: Impact Evaluation of the Connecticut Small Business Energy Advantage Program." Connecticut Energy Efficiency Board (EEB) and Evaluation Administrators.

[6] Tetra Tech. 2012. "2011 C&I Electric and Gas Free-ridership and Spillover Study." Table 3-5. Connecticut Energy Efficiency Fund.

[7] Cadmus. 2020. C1634 Impact Evaluation of PY 2016 & 2017 Energy Conscious Blueprint Program.

[8] EMI Consulting. 2019. "C1644 EO Net-to-Gross Study." Connecticut Energy Efficiency Board.

[9] DNV GL. 2020. "C1635 Impact Evaluation of PY 2016 & 2017 Energy Opportunities (EO) Program". Tables 6-11. Connecticut Energy Efficiency Board (EEB) and Evaluation Administrators.

[10] GDS Associates Inc., *Measure Life Report, Residential and Commercial Industrial Lighting and HVAC Measures*, Jun. 2007.

[11] DNV. MA20C15-B-GSHP Ground Source Heat Pump eTRM Measure Review. March 5, 2021 https://ma-eeac.org/wp-content/uploads/MA20C15-B-GSHP_GroundSourceHeatPump_final.pdf.


## ***Changes from Last Version***

- Updated baseline efficiencies.
- Formatting updates.

## 2.2.4 DEMAND CONTROL VENTILATION

| | |
|---|---|
| Market | Commercial |
| Baseline Type | Lost Opportunity |
| Category | HVAC & Water Heating |

### Description

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. Spaces for which demand controlled ventilation is required by code are not eligible for savings.

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 2.2.5 Natural Gas Fired Boilers and Furnaces) 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.

**Note:** Refer to ASHRAE suggestions related to the spread of viruses in "ASHRAE Position Document on Infectious Aerosols" published April 14, 2020 available online at:
https://www.ashrae.org/File%20Library/About/Position%20Documents/PD_InfectiousAerosols_2020.pdf

### Annual Energy Savings Algorithm

To be calculated via BIN analysis.

### Calculation Parameters

**Table 2-58 Calculation Parameters**

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| | Operation schedule of HVAC Unit, including days and time | Site-specific | | |
| | Area type served by HVAC unit | Site-specific | | |
| EER | Cooling efficiency | Site-specific | Btu/watt-hr | |
| | Heating efficiency | Site-specific | % | |

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| | Total system air flow | Site-specific | CFM | |
| | Design outside air percentage | Site-specific | % | |
| | Average expected reduction in air flow | Site-specific | % | |
| | Return air temperature | Site-specific | ºF | |
| | Building balance point | Site-specific | ºF | |

## ***Measure Life***

**Table 2-59 Measure Life**

| Equipment Type | Measure Life | Ref |
|---|---|---|
| Demand control ventilation - multi zone | 10 | [1] |
| Demand control ventilation - single zone | 10 | [1] |

## ***Peak Factors***

**Table 2-60 Peak Factors**

| Measure | Summer Coincidence Factor | Winter Coincidence Factor | Natural Gas Peak Day Factor | Ref |
|---|---|---|---|---|
| Demand control ventilation | Custom | Custom | 0.0152 | [2] |

## ***Load Shapes***

Electric load shapes N/A.

## ***Realization Rates and Net Impact Factors***

**Table 2-61 Realization Rates**

| | Gross Realization % | | | | FR & SO | | Net Realization % | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Measure | CCF | Peak Day CCF | Summer Seasonal Peak kW | Delivered Fuels MMBtu | Free-ridership | Spill-over | CCF | Peak Day CCF | Summer Seasonal Peak kW | Delivered Fuels MMBtu |
| HVAC | 90.7% | 100.0% | | | 23.8% | 9.5% | 77.73% | 85.7% | 0.0% | 0.0% |

## ***References***


[1] ERS (2005). *Measure Life Study prepared for The Massachusetts Joint Utilities*.

[2] DNV (2021). *X1931-2 Load Shape and Coincidence Factor Research* – Final Report.


## ***Changes from Last Version***

- Formatting updates.

## 2.2.5 NATURAL GAS FIRED BOILERS AND FURNACES

| | |
|---|---|
| Market | Commercial |
| Baseline Type | Lost Opportunity |
| Category | HVAC & Water Heating |

***Description***

This measure encourages the installation of high efficiency, natural gas-fired, hydronic heating boilers and furnaces. This measure also includes condensing gas unit heaters.

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

Energy savings are calculated using the efficiency of the proposed boiler or furnace versus the baseline efficiency. Baseline minimum efficiencies for boilers and furnaces are based on Industry Standard Practice (ISP) baseline [1]. If the boiler is used for domestic hot water, in addition to heating, the project should be handled as a custom measure (see 2.8.1 Lost Opportunity Custom).

The peak day factors developed for this prescriptive approach are based on the results from a sampling of existing custom projects in which local BIN weather data was used to calculate savings of both high efficiency conventional and condensing boilers. The data from the temperature BIN analysis was used to compute savings for the coldest 24-hour period of the year. 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.

The following assumptions were used to develop this calculation methodology:

- 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.
- 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.

- ASHRAE 90.1-2019 and 2021 IECC minimum efficiency requirements are based on input capacity.
- Adopted efficiency units consistent with IECC 2021 Code instead of combustion efficiency because AHRI database indicates that Ec is not readily available for some equipment.

## ***Annual Energy Savings Algorithm***

*Lost Opportunity Gross Energy Savings, Natural Gas*

Standard boiler or furnace:

$$\Delta CCF = \frac{CAP}{OF} \times \frac{EFLH}{C_{NG}} \times \left(\frac{1}{\eta_b} - \frac{1}{\eta_p}\right)$$

Condensing gas unit heaters:

$$\Delta CCF = \frac{CAP \times \eta_p}{OF} \times \frac{EFLH}{C_{NG}} \times \left(\frac{1}{\eta_b} - \frac{1}{\eta_p}\right)$$

*Lost Opportunity Gross Peak Day Savings, Natural Gas*

$$\Delta CCF_{PD} = PDF \times \Delta CCF$$

## ***Calculation Parameters***

**Table 2-62 Calculation Parameters**

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| ΔCCF | Annual natural gas savings | Calculated | CCF | |
| $\Delta CCF_{PD}$ | Natural gas peak day savings | Calculated | CCF | |
| CAP | Installed equipment output capacity | Site-specific | Btu/hr | |
| $\eta_p$ | Proposed equipment efficiency | Site-specific | N/A | |
| $\eta_b$ | Baseline equipment efficiency | Lookup in Table 2-63 | N/A | [1] |
| OF (single) | Oversize factor for single boiler, furnace, or heater installations | 1.15 | N/A | |
| OF (multiple) | Oversize factor for multiple boiler, furnace, or heater installations | 1.3 | N/A | |
| EFLH | Equivalent full load hours | Lookup in *Adopted efficiency units consistent with IECC 2021 Code instead of combustion efficiency because AHRI database indicates that Ec is not readily | hr | |

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| | | available for some equipment<br>Table 2-64 | | |
| PDF | Natural gas peak day factor | Lookup in Table 2-66 | N/A | |
| $C_{NG}$ | Natural gas conversion constant | 102,900 | Btu/CCF | |

**Table 2-63 Baseline Efficiency**

| Equipment Type | | Size | Efficiency | Units* |
|---|---|---|---|---|
| Boiler | Small | < 300,000 Btu/hr | 0.92 | AFUE |
| Boiler | Medium | 300,000 to 2,500,000 Btu/hr | 0.90 | $E_t$ |
| Boiler | Large | > 2,500,000 Btu/hr | 0.90 | $E_c$ |
| Boiler | Steam | < 300,000 Btu/hr | 0.82 | AFUE |
| Boiler | Steam | > 300,000 Btu/hr | 0.82 | $E_t$ |
| Boiler | Cast Iron Sectional Hot Water | < 300,000 Btu/hr | 0.82 | AFUE |
| Boiler | Cast Iron Sectional Hot Water | 300,000 to 2,500,000 Btu/hr | 0.82 | $E_t$ |
| Boiler | Cast Iron Sectional Hot Water | > 2,500,000 Btu/hr | 0.82 | $E_c$ |
| Furnace | Unknown, existing venting or new construction, | 120,000 Btu/hr or greater | 0.85 | $E_t$ |
| | | | 0.87 | AFUE |
| Furnace | Existing condensing stack | 120,000 Btu/hr or greater | 0.90 | $E_t$ |
| | | | 0.96 | AFUE |
| Furnace | Existing non-condensing stack | 120,000 Btu/hr or greater | 0.80 or code | $E_t$ |
| | | | 0.80 | AFUE |
| Furnace | Furnaces | Less than 120,000 Btu/hr | 0.85 | AFUE |

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

**Table 2-64 C&I Heating EFLH [8]**

| Facility Type | Heating FLHrs | Facility Type | Heating FLHrs |
|---|---|---|---|
| Auto Related | 3,122 | Dining: Cafeteria/Fast Food | 1,178 |
| Bakery | 1,065 | Dining: Family | 1,118 |
| Church | 938 | Entertainment | 1,042 |
| College: Cafeteria | 1,178 | Exercise Center | 1,042 |
| Convenience Store | 831 | Fast Food Restaurant | 1,178 |
| Dining: Bar Lounge/Leisure | 1,118 | Food Store | 840 |

| Facility Type | Heating FLHrs |
|---|---|
| Gymnasium | 1,042 |
| Industrial: 1 Shift | 1,065 |
| Industrial: 2 Shift | 727 |
| Industrial: 3 Shift | 384 |
| Laundromat | 831 |
| Library | 1,042 |
| Light Manufacturer | 1,065 |
| Lodging (Hotel/Motel) | 628 |
| Manufacturing Facility | 1,065 |
| Medical Office | 598 |
| Motion Picture Theatre | 1,042 |
| Museum | 1,042 |
| Office (General Office Types) | 598 |
| Office/Retail | 598 |
| Parking Garage and Lot | 3,122 |

| Facility Type | Heating FLHrs |
|---|---|
| Performing Arts Theatre | 1,042 |
| Post Office | 598 |
| Pump Station | 384 |
| Refrigerated Warehouse | 734 |
| Religious Building | 938 |
| Restaurant | 1,118 |
| Retail | 831 |
| Schools (Preschool/Elementary) | 1,086 |
| Small Services | 598 |
| Sports Arena | 1,042 |
| Town Hall | 1,042 |
| Transportation | 3,122 |
| Warehouse (Not Refrigerated) | 734 |
| Wastewater Treatment Plant | 384 |
| Workshop | 1,065 |

## ***Measure Life***

**Table 2-65 Measure Life**

| Equipment Type | Measure Life | Ref |
|---|---|---|
| Gas Fired Boiler (Condensing) | 20 years | [2] |
| Gas Fired Boiler (Non-condensing) | 20 years | [3] |
| Gas Furnaces | 20 years | [3] |

## ***Peak Factors***

**Table 2-66 Peak Factors**

| Equipment Type | Natural Gas Peak Day Factor |
|---|---|
| Conventional (Non-condensing) Boiler | 0.0152 |
| Condensing Boiler | 0.0133 |
| Furnace | 0.0152 |

## ***Load Shapes***

Electric load shapes N/A for this fuel savings measure

## ***Realization Rates and Net Impact Factors***

**Table 2-67 Realization Rates and Net Impact Factors**

| | Gross Realization | | FR and SO | | Net Realization | | |
|---|---|---|---|---|---|---|---|
| Measure | Energy (CCF) | Peak Day (CCF) | Free-ridership | Spillover | Energy (CCF) | Peak Day (CCF) | Ref |
| Energy Opportunities – Heating/DHW | 76.50% | 100.00% | 16.00% | 2.00% | 65.79% | 86.00% | [5], [6] |
| Small Business Energy Advantage | 78.00% | 100.00% | 0.00% | 0.00% | 78.00% | 100.00% | [7] |
| Midstream Program | 76.50% | 100.00% | 32.00% | 0.00% | 52.02% | 68.00% | [9] |

## ***References***


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

[2] PA Consulting Group Inc. *Focus on Energy Evaluation. Business Programs: Measure Life Study,* Aug. 25, 2009.

[3] 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.

[4] DNV. 2021. "X1931-2 Load Shape and Coincidence Factor Research – Final Report."

[5] DNV-GL, C1635 Impact Evaluation of PY 2016 & 2017 Energy Opportunities (EO) Program

[6] EMI Consulting. 2019. "C1644: EO Net-to-Gross Study." Connecticut Energy Efficiency Board.

[7] ERS, C1639: Impact Evaluation of the Connecticut Small Business Energy Advantage Program, Mar. 20, 2018.

[8] DNV. 2021. "X1931-6: PSD HOU/FLH Documentation and Update Study."

[9] NMR, DNV, Brightline Group. 2022. "C1902a: Connecticut Midstream C&I HVAC & Water Heating and Foodservice Net-to-Gross Review."


## ***Changes from Last Version***

- Added condensing gas unit heaters saving formula.
- Updated net realization rates.
- Formatting updates.
- Added equivalent AFUE to furnaces 120,000 Btu/hr or greater

## 2.2.6 NATURAL GAS RADIANT HEATERS

| | |
|---|---|
| Market | Commercial |
| Baseline Type | Lost Opportunity |
| Category | HVAC & Water Heating |

### ***Description***

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

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

Energy savings are estimated to be 25% of the consumption of a conventional natural gas-fired unit heater with the same heating load [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. 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.

The following assumptions were used to develop this calculation methodology:

- Peak day factors and full load hours  were updated in the 2021 X1931-6 PSD HOU/FLH Documentation and Update Study. [8]
- 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.
- EFLHs in each occupancy category was developed based on simulation of DOE-2 commercial building prototypes in eQUEST using Hartford weather data.

### ***Annual Energy Savings Algorithm***

*Lost Opportunity Gross Energy Savings, Natural Gas*

$$\Delta CCF = \frac{CAP}{OF} \times EFLH \times \frac{SFR}{C_{NG} \times \eta_b}$$

Lost Opportunity Gross Peak Day Savings, Natural Gas

$$\Delta CCF_{PD} = PDF \times \Delta CCF$$

## ***Calculation Parameters***

**Table 2-68 Calculation Parameters**

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| ΔCCF | Annual natural gas savings | Calculated | CCF | |
| $\Delta CCF_{PD}$ | Natural gas peak day savings | Calculated | CCF | |
| CAP | Output heating capacity of installed heater | Site-specific | Btu/hr | |
| OF (single) | Oversize factor for single heater installation | 1.0 | N/A | |
| OF (multiple) | Oversize factor for multiple heater installation | 1.1 | N/A | |
| PDF | Natural gas peak day factor | 0.00544 | N/A | |
| EFLH | Equivalent full load hours | Lookup in Table 2-69 | hr | |
| SFR | Savings fraction | 0.25 | N/A | [1] |
| $\eta_b$ | Baseline efficiency | 0.80 | N/A | [2] |
| $C_{NG}$ | Natural gas conversion constant | 102,900 | Btu/CCF | |

**Table 2-69 C&I Heating EFLH* [8]**

| Facility Type | Heating FLHrs |
|---|---|
| Auto Related | 3,122 |
| Bakery | 1,065 |
| Church | 938 |
| College: Cafeteria | 1,178 |
| Convenience Store | 831 |
| Dining: Bar Lounge/Leisure | 1,118 |
| Dining: Cafeteria/Fast Food | 1,178 |
| Dining: Family | 1,118 |
| Entertainment | 1,042 |
| Exercise Center | 1,042 |

| Facility Type | Heating FLHrs |
|---|---|
| Fast Food Restaurant | 1,178 |
| Food Store | 840 |
| Gymnasium | 1,042 |
| Industrial: 1 Shift | 1,065 |
| Industrial: 2 Shift | 727 |
| Industrial: 3 Shift | 384 |
| Laundromat | 831 |
| Library | 1,042 |
| Light Manufacturer | 1,065 |
| Lodging (Hotel/Motel) | 628 |
| Manufacturing Facility | 1,065 |
| Medical Office | 598 |

| Facility Type | Heating FLHrs |
|---|---|
| Motion Picture Theatre | 1,042 |
| Museum | 1,042 |
| Office (General Office Types) | 598 |
| Office/Retail | 598 |
| Parking Garage and Lot | 3,122 |
| Performing Arts Theatre | 1,042 |
| Post Office | 598 |
| Pump Station | 384 |
| Refrigerated Warehouse | 734 |
| Religious Building | 938 |

| Facility Type | Heating FLHrs |
|---|---|
| Restaurant | 1,118 |
| Retail | 831 |
| Schools (Preschool/Elementary) | 1,086 |
| Small Services | 598 |

| Facility Type | Heating FLHrs |
|---|---|
| Sports Arena | 1,042 |
| Town Hall | 1,042 |
| Transportation | 3,122 |
| Warehouse (Not Refrigerated) | 734 |

| Facility Type | Heating FLHrs |
|---|---|
| Wastewater Treatment Plant | 384 |
| Workshop | 1,065 |

## ***Measure Life***

The measure life for gas fired radiant heater is 15 years. [3]

## ***Peak Factors***

**Table 2-70 Peak Factors**

| Measure | Summer Coincidence Factor | Winter Coincidence Factor | Ref |
|---|---|---|---|
| Natural gas radiant heaters | 0% | 0% | [4] |

## ***Load Shapes***

Electric load shapes N/A for this fuel savings measure.

## ***Realization Rates and Net Impact Factors***

**Table 2-71 Realization Rates and Net Impact Factors**

| | Gross Realization % | | FR & SO | | Net Realization % | | |
|---|---|---|---|---|---|---|---|
| End Use | Energy (CCF) | Peak Day (CCF) | Free-ridership | Spillover | Energy (CCF) | Peak Day (CCF) | Ref |
| Energy Opportunities – Heating/DHW | 76.50% | 100.00% | 16.00% | 2.00% | 65.79% | 86.00% | [5], [6] |
| Small Business Energy Advantage | 78.00% | 100.00% | 0.00% | 0.00% | 78.00% | 100.00% | [7] |
| Midstream Program | 76.50% | 100.00% | 32.00% | 0.00% | 52.02% | 68.00% | [9] |

## ***References***


[1] ASHRAE Technical Paper No. 4643, "*Evaluation of an Infrared Two-Stage Heating System in a Commercial Application,*" 2003, Conclusions, p. 138.

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

[3] ERS. *Measure Life Study prepared for The Massachusetts Joint Utilities*, 2005.
[4] DNV. 2021. "X1931-2 Load Shape and Coincidence Factor Research – Final Report".
[5] DNV-GL. 2020. "C1635 Impact Evaluation of PY 2016 & 2017 Energy Opportunities (EO) Program"
[6] EMI Consulting.2019. "C1644: EO Net-to-Gross Study." Connecticut Energy Efficiency Board.
[7] ERS, C1639: Impact Evaluation of the Connecticut Small Business Energy Advantage Program, Mar. 20, 2018.
[8] DNV. 2021. "X1931-6: PSD HOU/FLH Documentation and Update Study."
[9] NMR, DNV, Brightline Group. 2022. "C1902a: Connecticut Midstream C&I HVAC & Water Heating and Foodservice Net-to-Gross Review."

## ***Changes from Last Version***

- Updated net realization rates.
- Formatting updates.

## 2.2.7 NATURAL GAS FIRED COMMERCIAL HOT WATER HEATERS

| | |
|---|---|
| Market | Commercial |
| Baseline Type | Lost Opportunity |
| Category | HVAC & Water Heating |

### ***Description***

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

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

Energy savings are calculated using proposed water heater thermal efficiency and standby losses versus baseline efficiency and standby losses. The baseline for efficiency and standby losses were based on a natural gas storage water heater (> 75,000 Input Btu/hr) as specified in 2021 IECC [1].

Based on facility type and square footage, Table 2-73 Annual Baseline Natural Gas Usage Rate by Occupancy Type 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:*

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

*Demand assumptions:*

- Lowest cold water temperature is 44°F [2].
- Annual average cold water temperature is 54°F [2].
- Hot water set point is 130°F.

## ***Annual Energy Savings Algorithm***

*Lost Opportunity Gross Energy Savings, Natural Gas*

$$\Delta CCF = CCF_{W,b} - \frac{GPY_W \times \Delta T \times C_{\text{Gal°F}} + SLR_i \times H}{C_{NG} \times \eta_p}$$

*Where,*

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

$$CAP_{H,b} = CAP_{H,i} \times \frac{\eta_p}{\eta_b}$$

$$SLR_b = CAP_{H,i} \times \frac{1{,}000 \frac{Btu/hr}{MBH}}{800} + 110 \times \sqrt{CAP_{W,i}}$$

$$H = \frac{\left(8760 \frac{hr}{yr} \times CAP_{H,b} \times 1{,}000 \frac{Btu/hr}{MBH}\right) - \left(CCF_{W,b} \times C_{NG}\right)}{\left(CAP_{H,b} \times 1{,}000 \frac{Btu/hr}{MBH}\right) - \frac{SLR_b}{\eta_b}}$$

$$GPY_W = \frac{\left(CCF_{W,b} \times C_{NG} \times \eta_b\right) - \left(SLR_b \times H\right)}{\Delta T \times C_{\text{Gal°F}}}$$

*Lost Opportunity Gross Peak Day Savings, Natural Gas*

$$\Delta CCF_{PD} = \Delta CCF \times PDF$$

*Where,*

$$SF = \frac{1\ day \times (130°\text{F} - 46°\text{F})}{365\ days \times (130°\text{F} - 57°\text{F})} = 0.0032$$

## ***Calculation Parameters***

**Table 2-72 Calculation Parameters**

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| ΔCCF | Annual natural gas savings | Calculated | CCF | |
| $\Delta CCF_{PD}$ | Natural gas peak day savings | Calculated | CCF | |
| $CCF_{W,b}$ | Annual baseline commercial HW natural gas usage | Calculated | CCF | |
| $CAP_{H,b}$ | Heat input capacity of baseline water heater | Calculated | MBH | |
| $SLR_b$ | Baseline water heater standby loss rate | Calculated<br>Calculated | Btu/hr | [1] |
| H | Annual standby hours | Calculated | hr | |
| $GPY_W$ | Annual building hot water usage | Calculated | Gal | |

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| A | Building floor area | Site-specific | $ft^2$ | |
| $CAP_{H,i}$ | Heat input capacity of installed water heater | Site-specific | MBH | |
| $\eta_p$ | Thermal efficiency of installed water heater | Site-specific | N/A | |
| $CAP_{W,i}$ | Water storage capacity of installed water heater | Site-specific | Gal | |
| $SLR_i$ | Installed water heater standby loss rate | Site-specific | Btu/hr | |
| $E_b$ | Annual baseline natural gas energy usage rate | Lookup in Table 2-73 | $CCF/ft^2$ | [3] |
| $\eta_b$ | Thermal efficiency of baseline water heater | 0.95 for new construction& Major renovation,<br>0.80 for equipment replacement | N/A | [9], [1] |
| ΔT | Differential temperature rise | 75 | °F | |
| PDF | Natural gas peak day factor | 0.0032 | N/A | |
| $C_{NG}$ | Natural gas conversion constant | 102,900 | Btu/CCF | |
| $C_{Gal°F}$ | Energy needed to increase one gallon of water by 1°F | 8.33 | Btu/Gal°F | |

**Table 2-73 Annual Baseline Natural Gas Usage Rate by Occupancy Type [3]**

| Building Occupancy Category | Annual Baseline Natural Gas Usage Rate ($CCF/ft^2$) | Building Occupancy Category | Annual Baseline Natural Gas Usage Rate (CCF/ft2) |
|---|---|---|---|
| Education | 0.068 | Office | 0.047 |
| Food sales | 0.043 | Public assembly | 0.02 |
| Food service | 0.382 | Public order and safety | 0.209 |
| Health care | 0.232 | Retail (other than mall) | 0.024 |
| Inpatient health care | 0.334 | Retail (enclosed and strip malls) | 0.137 |
| Outpatient health care | 0.038 | Service | 0.147 |
| Lodging | 0.258 | Warehouse and storage | 0.028 |
| Mercantile | 0.103 | Vacant | 0.013 |
| Multifamily low-rise* | 0.193 | Other | 0.023 |
| Multifamily high-rise* | 0.176 | | |

* Multifamily 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 Multifamily Housing Unit (1,105 ft2 for low-rise and 834 ft2 for high-rise).

## ***Calculation Examples***

*Example 1: Lost Opportunity Gross Energy Savings*

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

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

*What is the annual energy savings?*

*Calculate annual baseline DHW natural gas usage*

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

$$CCF_{W,b} = 50{,}000\ ft^2 \times 0.334 \frac{CCF}{ft^2} = 16{,}700\ CCF$$

*Calculate baseline heater input capacity in Btu/hr*

$$CAP_{H,b} = CAP_{H,i} \times \frac{\eta_p}{\eta_b}$$

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

*Calculate baseline standby losses*

$$SLR_b = CAP_{H,i} \times \frac{1{,}000 \frac{Btu/hr}{MBH}}{800} + 110 \times \sqrt{CAP_{W,i}}$$

$$SLR_b = 300\ MBH \times \frac{1{,}000 \frac{Btu/hr}{MBH}}{800} + 110 \times \sqrt{100\ Gal} = 1{,}475\ \frac{Btu}{hr}$$

*Calculate number of standby hours/year*

$$H = \frac{\left(8760 \frac{hr}{yr} \times CAP_{H,b} \times 1{,}000 \frac{Btu/hr}{MBH}\right) - \left(CCF_{W,b} \times C_{NG}\right)}{\left(CAP_{H,b} \times 1{,}000 \frac{Btu/hr}{MBH}\right) - \frac{SLR_b}{\eta_b}}$$

$$H = \frac{\left(8760\frac{hr}{yr} \times 341\ MBH \times 1{,}000\frac{Btu/hr}{MBH}\right) - \left(16{,}700\ CCF \times 102{,}900\frac{Btu}{CCF}\right)}{\left(341\ MBH \times 1{,}000\frac{Btu/hr}{MBH}\right) - \frac{1{,}475\frac{Btu}{hr}}{0.80}} = 3{,}741\ hr$$

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

$$GPY_W = \frac{\left(CCF_{W,b} \times C_{NG} \times \eta_b\right) - \left(SLR_b \times H\right)}{\Delta T \times C_{\mathrm{Gal°F}}}$$

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

*Calculate annual natural gas savings*

$$\Delta CCF = CCF_{W,b} - \frac{GPY_W \times \Delta T \times C_{\mathrm{Gal°F}} + SLR_i \times H}{C_{NG} \times \eta_p}$$

$$\Delta CCF = 16{,}700\ CCF - \frac{2{,}191{,}638\ Gal \times 75°\mathrm{F} \times 8.33\frac{Btu}{Gal°\mathrm{F}} + 1{,}044\frac{Btu}{hr} \times 3{,}741\ hr}{102{,}900\frac{Btu}{CCF} \times 0.91} = 2{,}036\ CCF$$

*Lost Opportunity Gross Peak Day Savings, Natural Gas*

$$\Delta CCF_{PD} = \Delta CCF \times SF$$

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

## ***Measure Life***

The measure life for natural gas fired water heater is 20 years [4].

## ***Peak Factors***

**Table 2-74 Peak Factors**

| End Use | Natural Gas Peak Day Factor | Ref |
|---|---|---|
| Water heating | 0.0032 | |

## ***Load Shapes***

Electric load shapes N/A for this fuel savings measure.

## *Realization Rates and Net Impact Factors*

**Table 2-75 Realization Rates and Net Impact Factors**

| | Gross Realization % | | FR & SO | | Net Realization % | | |
|---|---|---|---|---|---|---|---|
| End Use | Energy (CCF) | Peak Day (CCF) | Free-ridership | Spillover | Energy (CCF) | Peak Day (CCF) | Ref |
| Energy Opportunities – Heating/DHW | 76.50% | 100.00% | 16.00% | 2.00% | 65.79% | 86.00% | [5], [7] |
| Small Business Energy Advantage | 78.00% | 100.00% | 0.00% | 0.00% | 78.00% | 100.00% | [8] |
| Midstream Program | 76.50% | 100.00% | 32.00% | 0.00% | 52.02% | 68.00% | [10] |

Note

New Construction& Major renovation Baseline applies to non EUI based offering ( currently referred as path 3&4)

## *References*


[1] 2021 IECC, Table C404.2.

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

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

[4] Hewitt, D. Pratt, J. & Smith, G. (2005). Tankless Gas Water Heaters: Oregon Market Status, prepared for the Energy Trust of Oregon.

[5] DNV. 2021. “X1931-2 Load Shape and Coincidence Factor Research – Final Report”.

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

[7] EMI Consulting. 2019. “C1644: EO Net-to-Gross Study.” Connecticut Energy Efficiency Board.

[8] ERS. C1639: Impact Evaluation of the Connecticut Small Business Energy Advantage Program, Mar. 20, 2018.

[9] NMR Group Inc. 2022. “C1902-B: Energy Conscious Blueprint Baseline and Code Compliance Results.”

[10] NMR, DNV, Brightline Group. 2022. “C1902a: Connecticut Midstream C&I HVAC & Water Heating and Foodservice Net-to-Gross Review.”


## *Changes from Last Version*

- Updated thermal efficiency of baseline water heater.
- Added midstream program to realization rate table with updated NTG.
- Formatting updates.

## 2.2.8 VARIABLE REFRIGERANT FLOW (VRF) HVAC SYSTEM

| | |
|---|---|
| Market | Commercial |
| Baseline Type | Lost Opportunity |
| Category | HVAC & Water Heating |

### ***Description***

Installation of a large high efficiency air-sourced Variable Refrigerant Flow (VRF) multi-split HVAC system for commercial and residential applications. Heat recovery is not included in this measure.

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

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

### ***Annual Energy Savings Algorithm***

*Lost Opportunity Gross Energy Savings, Electric*

A custom calculation is made for each time period of the year based on the appropriate temperature BIN data and the information in Table 2-78 Baseline Efficiencies Electronically Operated Variable-Refrigerant-Flow and Applied Heat Pumps. The calculation is performed once for the VRF meeting the baseline efficiencies, 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 2-76 VRF Characterizations**

| Equipment Parameter | Characterizations |
|---|---|
| Indoor unit type | Ducted, non-ducted, mixed |
| VRF classifications | No VRF heat recovery, VRF heat recovery, cooling only |
| Heating and cooling capacity | Btuh |
| Cooling efficiency | EER, IEER |
| Heating efficiency | High temp COP, low temp 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.

## ***Calculation Parameters***

**Table 2-77 Calculation Parameters**

| Symbol | Description | Units | Values | Ref |
|---|---|---|---|---|
| $EER_I$ | Installed Energy Efficiency Ratio | Btu/watt-hr | Table 2-78 | |
| $IEER_I$ | Installed Integrated Energy Efficiency Ratio | Btu/watt-hr | Table 2-78 | |
| $COP_I$ | Installed Coefficient of performance | N/A | Table 2-78 | |
| | Heating capacity | Btu/hr | Site-specific | |
| | Cooling capacity | Btu/hr | Site-specific | |
| | Facility occupancy hours per week (on- and off-peak) | Hours | Site-specific | |
| | Indoor unit type (ducted, non-ducted, or mixed) | N/A | Site-specific | |
| | VRF classification (heat recovery, no heat recovery, or cooling only) | N/A | Site-specific | |
| $EER_B$ | Baseline Energy Efficiency Ratio | Btu/watt-hr | Site-specific | |
| $IEER_B$ | Baseline Integrated Energy Efficiency Ratio | Btu/watt-hr | Site-specific | |
| $COP_B$ | Baseline Coefficient of performance | N/A | Site-specific | |

**Table 2-78 Baseline Efficiencies Electronically Operated Variable-Refrigerant-Flow and Applied Heat Pumps [7]**

<table>
<tr><th rowspan="3">Size (Cooling)</th><th colspan="3">Cooling Mode</th><th colspan="2">Heating Mode</th></tr>
<tr><th colspan="2">VRF Multi-split System</th><th>VRF Multi-split System with Heat Recovery</th><th>Heating Mode @ 47°F db/43°F wb</th><th>Heating Mode @ 17°F db/15°F wb</th></tr>
<tr><th>Cooling Only</th><th colspan="4">Heating & Cooling</th></tr>
<tr><td rowspan="2">≥ 65,000 Btu/h and < 135,000 tBu/h</td><td>11.2 EER</td><td>11.0 EER</td><td>10.8 EER</td><td rowspan="2">3.3 COP</td><td rowspan="2">2.25 COP</td></tr>
<tr><td>15.5 IEER</td><td>14.6 IEER</td><td>14.4 IEER</td></tr>
<tr><td rowspan="2">≥ 135,000 Btu/h and < 240,000 Btu/h</td><td>11.0 EER</td><td>10.6 EER</td><td>12.1 EER for new construction [7], 10.4 EER for equipment replacement [6]</td><td rowspan="2">3.7 for new construction 3.2 COP for equipment replacement</td><td rowspan="2">2.9 COP for new construction [7], 2.05 COP for equipment replacement [6]</td></tr>
<tr><td>14.9 IEER</td><td>13.9 IEER</td><td>13.7 IEER</td></tr>
<tr><td rowspan="2">≥ 240,000</td><td>10.0 EER</td><td>9.5 EER</td><td>10.3 EER for new construction [7], 9.3 EER for equipment replacement [6]</td><td rowspan="2">3.2 COP</td><td rowspan="2">2.2 COP for new construction [7], 2.05 COP for equipment replacement [6]</td></tr>
<tr><td>13.9 IEER</td><td>12.7 IEER</td><td>12.5 IEER</td></tr>
</table>

## ***Measure Life***

The measure life for variable refrigerant flow is 15 years.

## ***Peak Factors***

**Table 2-79 Peak Factors**

| Measure | Summer Coincidence Factor | Winter Coincidence Factor | Ref |
|---|---|---|---|
| Variable refrigerant flow (VRF) HVAC system | Custom | Custom | |

## ***Load Shapes***

**Table 2-80 Load Shapes**

| Measure | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % | Ref |
|---|---|---|---|---|---|
| Cooling - Chillers | 18.45% | 17.26% | 32.23% | 32.06% | |
| Cooling - RTUs | 18.19% | 10.22% | 43.16% | 28.43% | |

## ***Realization Rates and Net Impact Factors***

**Table 2-81 Realization Rates - Electric**

| | Gross Realization % | | | FR & SO | | Net Realization % | | |
|---|---|---|---|---|---|---|---|---|
| End-use | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Free ridership | Spillover | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW |
| Cooling Energy Conscious Blueprint | 86.2% [1] | 151.1% [1] | 89.7% [1] | 29.5% [2] | 12.4% [2] | 58.60% | 102.70% | 61.00% |
| Heating Energy Conscious Blueprint | 97.8% [1] | 93.0% [1] | 94.4% [1] | 23.7% [2] | 28.0% [2] | 66.50% | 63.20% | 64.20% |
| Cooling Energy Opportunities | 102.1% [3] | 125.0% [3] | 146.4% [3] | 12.0% [4] | 5.0% [4] | 69.40% | 85.00% | 99.60% |
| Heating Energy Opportunities | 102.1% [3] | 125.0% [3] | 146.4% [3] | 14.0% [4] | 7.0% [4] | 69.40% | 85.00% | 99.60% |
| Cooling Small Business Energy Advantage | 72.0% [5] | 73.0% [5] | 85.0% [5] | 15.3% [2] | 0.2% [2] | 49.00% | 49.60% | 57.80% |
| Heating Small Business Energy Advantage | 72.0% [5] | 73.0% [5] | 85.0% [5] | 0.0% [2] | 0.0% [2] | 49.00% | 49.60% | 57.80% |
| Cooling Midstream Program | 86.20% [1] | 151.10% [1] | 89.70% [1] | 32.00% [8] | | 58.62% | 102.75% | 61.00% |
| Heating Midstream Program | 97.80% [1] | 93.00% [1] | 94.40% [1] | 32.00% [8] [1] | | 66.50% | 63.24% | 64.19% |

**Note:** New Construction Baseline applies to non EUI based offering ( currently referred as path 3&4)

## ***References***


[1] The Cadmus Group, Inc. 2020 . "C1634 Impact Evaluation of PY 2016 & 2017 Energy Conscious Blueprint. Program." Connecticut Energy Efficiency Board (EEB) and Evaluation Administrators.

[2] Tetra Tech. 2012. "2011 C&I Electric and Gas Free-ridership and Spillover Study." Table 3-5. Connecticut Energy Efficiency Fund.

[3] DNV-GL, C1635 Impact Evaluation of PY 2016 & 2017 Energy Opportunities (EO) Program.

[4] EMI Consulting. 2019. "C1644: EO Net-to-Gross Study." Connecticut Energy Efficiency Board.

[5] ERS. Mar. 20, 2018. "C1639: Impact Evaluation of the Connecticut Small Business Energy Advantage Program."

[6] 2019 ASHRAE Code, Table 6.8.1-10. 6.8.1-10.

[7] NMR Group Inc. 2022. :"C1902-B: Energy Conscious Blueprint Baseline and Code Compliance Results."

[8] NMR, DNV, Brightline Group. 2022. "C1902a: Connecticut Midstream C&I HVAC & Water Heating and Foodservice Net-to-Gross Review."

***Changes from Last Version***

- Formatting updates.
- Updated net realization.
- Updated  high and low temp COP values for VRF Multi-split System with Heat Recovery ≥ 135,000 Btu/h and < 240,000 Btu/h.
- Updated cooling EER value for VRF Multi-split System with Heat Recovery ≥ 135,000 Btu/h and < 240,000 Btu/h.
- Updated low temp COP value for VRF Multi-split System with Heat Recovery ≥ 240,000 Btu/h.
- Updated cooling EER value for VRF Multi-split System with Heat Recovery ≥ 240,000 Btu/h.

## 2.2.9 COMMERCIAL HEAT PUMP WATER HEATERS (CHPWH)

| | |
|---|---|
| Market | Commercial |
| Baseline Type | Lost Opportunity |
| Category | HVAC & Water Heating |

***Description***

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

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

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

***Annual Energy Savings Algorithm***

*Lost Opportunity Gross Energy Savings*

$$\Delta kWh = \Delta kWh_b - \Delta kWh_i$$

Where,

$$\Delta kWh_b = A \times EE_b$$

$$\Delta kWh_i = \frac{\Delta kWh_b}{COP_i}$$

$$EE_b = E_b \times \eta_b \times \frac{102{,}900}{3.413}$$

*Annual Seasonal Peak Demand Savings (Summer and Winter)*

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

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

*Annual hot water usage of CHPWH:*

$$AWG = (\Delta kWh_b \times 3{,}413) \div (75 \times 8.33)$$

## *Calculation Parameters*

**Table 2-82 Calculation Parameters**

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| ΔkWh | Annual energy savings | Calculated | kWh/yr | |
| $\Delta kW_{Summer}$ | Summer Demand Savings | 0 | kW | |
| $\Delta kW_{Winter}$ | Winter Demand Savings | 0 | kW | |
| $kWh_b$ | Annual electric energy usage of base case CHPWH | Calculated | kWh/yr | [1] |
| $kWh_i$ | Annual electric usage installed CHPWH | Calculated | kWh/yr | [1] |
| AWG | Annual Hot Water Usage | Calculated | Gal/Yr | |
| $EE_b$ | Annual base case electric energy usage rate (per $ft^2$) | Calculated | $kWh/ft^2/yr$ | |
| Eb | Annual base case gas energy usage rate (per $ft^2$) | Table 2-83 | $ccf/ft^2/yr$ | [2] |
| A | Building floor area served by water heater | Site-specific | $ft^2$ | |
| $COP_i$ | Rated COP (Coefficient of Performance) of installed water heater | Site-specific | N/A | |
| $\eta_b$ | Thermal efficiency of gas furnace | 80 | % | [3] |
| 102,900 | Conversion factor from CCF of natural gas to Btu | 102,900 | Btu/CCF | |

**Table 2-83 Annual Base Case Gas Usage Rate (Eb) by Occupancy Type**

| Building Occupancy Category | Annual Base Case Gas Usage Rate, Eb (ccf/ft2) | Building Occupancy Category | Annual Base Case Gas Usage Rate, Eb (ccf/ft2) |
|---|---|---|---|
| Education | 0.068 | Office | 0.047 |
| Enclosed and strip malls | 0.137 | Other | 0.023 |
| Food sales | 0.043 | Outpatient health care | 0.038 |
| Food service | 0.382 | Public assembly | 0.02 |
| Health care | 0.232 | Public order and safety | 0.209 |
| Inpatient health care | 0.334 | Retail (other than mall) | 0.024 |
| Lodging | 0.258 | Service | 0.147 |
| Mercantile | 0.103 | Vacant | 0.013 |
| Multifamily low-rise | 0.193 | Warehouse and storage | 0.028 |
| Multifamily high-rise | 0.176 | | |

## ***Calculation Examples***

*Lost Opportunity Gross Energy Savings, Electric*

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

Eb is derived from:

Table 2-83 based on building type (food sales, in this example).

$$EE_b = 0.043 \times 80\% \times \frac{102{,}900}{3.413}$$

$$EE_b = 1.037 kWh/ft^2/yr$$

$$kWh_b = 5{,}000 \times 1.037 kW/ft^2/yr$$

$$kWh_b = 5{,}186 kW/yr$$

$$kWh_i = \frac{5{,}186}{4.2}$$

$$kWh_i = 1{,}235 kWh/yr$$

$$\Delta kWh = 5{,}186 - 1{,}235$$

$$\Delta kWh = 3{,}951 kWh$$

## ***Measure Life***

The measure life for a heat pump water heater (lost opportunity) is 10 years.

## ***Peak Factors***

**Table 2-84 Peak Factors**

| Measure | Summer Coincidence Factor | Winter Coincidence Factor | Ref |
|---|---|---|---|
| Water and ground source heat pumps (Com) | 82% | 82% | [5] |

## ***Load Shapes***

**Table 2-85 Load Shapes**

| Measure/Facility/Equipment Type | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % | Ref |
|---|---|---|---|---|---|
| Other | 37.00% | 29.00% | 19.00% | 15.00% | [5] |

## *Realization Rates*

**Table 2-86 Realization Rates**

| | Gross Realization % | | | FR and SO | | Net Realization % | | | |
|---|---|---|---|---|---|---|---|---|---|
| Measure | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Free-ridership | Spill-over | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Ref |
| Other measures | 100.0% | 100.0% | 100.0% | 0.0% | 0.0% | 100.0% | 100.0% | 100.0% | [6], [7] |

## *References*


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

[2] US Energy Information Administration (201). Table E8. *Natural gas consumption and conditional energy intensities (cubic feet) by end use*, Rel. May 2016.

[3] 2021 IECC, Table C404.2. codes.iccsafe.org/content/IECC2021P1/chapter-4-ce-commercial-energy-efficiency

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

[5] DNV. 2021. "X1931-2 Load Shape and Coincidence Factor Research – Final Report."

[6] Cadmus. 2020. "C1634 Impact Evaluation of PY 2016 & 2017 Energy Conscious Blueprint Program."

[7] Tetra Tech. 2012. "2011 C&I Electric and Gas Free-ridership and Spillover Study."


## *Changes from Last Version*

- Formatting updates.

## 2.2.10 EC MOTOR CIRCULATING PUMP

| | |
|---|---|
| Market | Commercial |
| Baseline Type | Retrofit |
| Category | HVAC & Water Heating |

### ***Description***

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

Savings is based on Cadmus Study conducted for single-phase circulator pumps up to 3 horsepower (HP) used in commercial and industrial buildings within Massachusetts and Connecticut [1].[7]

Savings is calculated using the annual savings equation provided in the Cadmus Study and using the average circulator pump "ACP" size [1].

### ***Annual Energy Savings Algorithm***

*Retrofit Gross Annual Savings, Electric*

Hydronic heating:

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

Domestic Hot Water:

$$\Delta kWh = 2{,}780 \times ACP + 233$$

[7] The annual energy savings regression equations do not incorporate the more recent heating hot water pump hours in CT study X1931-6. [9] If the baseline and efficient pump powers are known, savings should be calculated as follows. If the site-specific hours are unknown, use the X1931-6 = estimated hours for the facility type as the baseline, and assume that ECM annual hours are equal to 139% of the baseline hours. [1]

$$\Delta kWh = Hours_{Baseline} \times kW_{Baseline} - Hours_{ECM} \times kW_{ECM}$$

*Gross Seasonal Peak Demand Savings, Electric*

Hydronic Heating:

$$\Delta kW_{Summer} = 0\ kW$$

$$\Delta kW_{Winter} = \frac{\Delta kWh}{HOU_{Heating}} \times CF_{Winter}$$

Domestic Hot Water:

$$\Delta kW_{winter} = \frac{\Delta kWh}{HOU_{DHW}} \times CF_{Winter}$$

$$\Delta kW_{summer} = \frac{\Delta kWh}{HOU_{DHW}} \times CF_{Summer}$$

## Calculation Parameters

**Table 2-87 Calculation Parameters**

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| ΔkWh | Annual electric energy savings | Calculated | kWh/yr | [1] |
| $\Delta kW_{Summer}$ | Seasonal summer peak savings | Calculated | kW | |
| $\Delta kW_{Winter}$ | Seasonal winter peak savings | Calculated | kW | |
| $CF_{Winter}$ | Seasonal winter peak coincidence factor | Table 2-91 | N/A | |
| $CF_{Summer}$ | Seasonal summer peak coincidence factor | Table 2-91 | N/A | |
| $HOU_{Heating}$ | Average run time for commercial application Hydronic Heating | Site-specific or lookup in Table 2-88 | Hr/Yr | [9] |
| $HOU_{DHW}$ | Average run time for commercial application Domestic Hot Water | Site-specific, use 6,248 if unknown | Hr/Yr | [8] |
| ACP | Average Circulator Pump size | Site-specific, lookup in Table 2-88 if unknown | HP | [8] |

**Table 2-88 Average Annual Runtime by Building Type for Hydronic Heating Application [9]**

| Facility Type | Heating Pump Hours | Facility Type | Heating Pump Hours |
|---|---|---|---|
| Banks, Financial Center | 5,629 | Commercial Condo | 8,760 |
| College: Classes/Administrative | 6,471 | Convention Center | 8,760 |
| College: Dormitory | 3,833 | Court House | 5,629 |

| Facility Type | Heating Pump Hours |
|---|---|
| Fire Station (Unmanned) | 3,833 |
| Hospital | 8,760 |
| Hospitals/Health Care | 8,760 |
| Mall Concourse | 4,932 |
| Multi-Family (Common Areas) | 3,833 |
| Nursing Home | 8,760 |
| Penitentiary | 8,760 |

| Facility Type | Heating Pump Hours |
|---|---|
| Police/Fire Station (24 Hr.) | 5,308 |
| Residential (Except Nursing Homes) | 3,833 |
| School/University | 6,471 |
| Schools (Jr./Sr. High) | 4,828 |
| Schools (Technical/Vocational) | 5,620 |

**Table 2-89 Average Circulator Pump Size**

| Pump Size | Average Hydronic Heating Size | Average Hot Water Size |
|---|---|---|
| ≤ 1 HP | 0.187 | 0.186 |
| ≥ 1 HP | 1 | 1 |

## ***Calculation Examples***

*Retrofit Gross Annual Savings, Electric*

Hydronic heating ≤ 1 HP:

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

Domestic Hot Water ≤ 1 HP:

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

Hydronic Heating ≥ 1 HP:

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

Domestic Hot Water ≥ 1 HP:

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

*Gross Seasonal Peak Demand Savings, Electric*

Hydronic Heating ≤ 1 HP:

$$\Delta kW_{Summer} = 0\ kW$$

$$\Delta kW_{Winter} = \frac{\Delta kWh}{HOU} = \frac{331.51}{2{,}745} = 0.121\ kW$$

Domestic Hot Water ≤ 1 HP:

$$\Delta kW_{PD} = \frac{\Delta kWh}{HOU} = \frac{725.86}{6{,}248} = 0.120\ kW$$

Hydronic Heating ≥ 1 HP:

$$\Delta kW_{Summer} = 0\ kW$$

$$\Delta kW_{Winter} = \frac{\Delta kWh}{HOU} = \frac{1{,}325}{2{,}745} = 0.483\ kW$$

Domestic Hot Water ≥ 1 HP:

$$\Delta kW = \frac{\Delta kWh}{HOU} = \frac{3{,}013}{6{,}248} = 0.482\ kW$$

***Measure Life***

**Table 2-90 Measure Life**

| Equipment Type | Measure Life | Ref |
|---|---|---|
| Zoned circulator pump system | 15 | [2] |

***Peak Factors***

**Table 2-91 Peak Factors**

| Measure | Summer Coincidence Factor | Winter Coincidence Factor | Ref |
|---|---|---|---|
| ECM Circulating Pump – Hydronic Heating | 0% | 100% | |
| ECM Circulating Pump – Domestic Hot Water | 100% | 100% | |

***Load Shapes***

**Table 2-92 Load Shapes**

| Measure Type | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % | Ref |
|---|---|---|---|---|---|
| Heating | 55.00% | 27.00% | 12.00% | 6.00% | [3] |
| Other | 37.00% | 29.00% | 19.00% | 15.00% | [5] |

## *Realization Rates*

**Table 2-93 Realization Rates**

| | Gross Realization % | | | FR & SO | | Net Realization % | | | |
|---|---|---|---|---|---|---|---|---|---|
| Measure | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Free-ridership | Spill-over | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Ref |
| Heating Energy Conscious Blueprint | 97.8% | 93.0% | 94.4% | 23.7% | 28.0% | 102.01% | 97.00% | 98.46% | [8], [7] |
| Heating Energy Opportunities | 102.1% | 125.0% | 146.4% | 14.0% | 7.0% | 94.95% | 116.25% | 136.15% | [4], [5] |
| Heating Small Business Energy Advantage | 72.0% | 73.0% | 85.0% | 0.0% | 0.0% | 72.00% | 73.00% | 85.00% | [6], [7] |
| Other Energy Conscious Blueprint | 98.5% | 106.3% | 97.4% | 18.2% | 7.1% | 87.57% | 94.50% | 86.59% | [7], [8] |
| Other Energy Opportunities | 67.6% | 162.1% | 114.7% | 0.0% | 0.0% | 67.60% | 162.10% | 114.70% | [4], [5] |
| Other Small Business Energy Advantage | 72.0% | 73.0% | 85.0% | 0.5% | 0.2% | 71.78% | 72.78% | 84.75% | [6], [7] |

## *References*


[1] The Cadmus Group. 2017. "Circulator Pump Technical Memo."

[2] DNV. 2021. "X1931-2 Load Shape and Coincidence Factor Research." Connecticut Energy Efficiency Board (EEB) and Evaluation Administrators.

[3] ERS. 2015. "Measure Life Study". Massachusetts Joint Utilities.

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

[5] EMI Consulting. 2019. "C1644: EO Net-to-Gross Study." Connecticut Energy Efficiency Board.

[6] ERS. 2018. "C1639: Impact Evaluation of the Connecticut Small Business Energy Advantage Program."

[7] Tetra Tech. 2012. "2011 C&I Electric and Gas Free-ridership and Spillover Study."

[8] Cadmus. 2020. "C1634 Impact Evaluation of PY 2016 & 2017 Energy Conscious Blueprint Program."

[9] DNV. 2021. "X1931-6: PSD HOU/FLH Documentation and Update Study."


## *Changes from Last Version*

- Adding full load hours by building type, for buildings modeled as a built-up system with hydronic heating.
- Formatting updates.

## 2.2.11 WATER SAVING MEASURES

| | |
|---|---|
| Market | Commercial |
| Baseline Type | Retrofit |
| Category | HVAC & Water Heating |

### ***Description***

This measure replaces existing pre-rinse spray valves, shower heads, and faucet aerators with units that have an average flow rate of 1.6 gpm (or less), 2.0 gpm, and 1.5 gpm, respectively. If existing information not available, use default existing conditions based on the DOE's online savings calculator [2].

Spray valve savings are based on the results of a replacement program in California [1]. Showerhead and faucet aerator savings are based on the Federal Energy Management Program (FEMP) Energy Cost Calculator for Faucets and Showerheads [2].

Savings for showerheads and faucet aerators are based on the default usage assumed in the DOE's online savings calculator [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 [2], and actual usage values should be used, when known, in lieu of default savings values.

The savings values presented below are per-unit.

### ***Annual Energy Savings Algorithm***

*Gross Annual Energy Savings, Electric*

$$\Delta kWh = lookup\ in\ \text{Table 2-95}$$

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

$$\Delta kW = 0$$

*Gross Annual Energy Savings, Natural Gas*

$$\Delta CCF = lookup\ in\ \text{Table 2-96}$$

*Gross Peak Day Savings, Natural Gas*

$$\Delta CCF_{PD} = PDF \times \Delta CCF$$

## ***Calculation Parameters***

**Table 2-94 Calculation Parameters**

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| ΔkWh | Annual gross electric energy savings – water heating | Table 2-95 | kWh | [1] |
| ΔCCF | Annual natural gas consumption – water heating | Table 2-96 | CCF | [1] |
| $CCF_{PD,w}$ | Peak day savings – water heating | Table 2-97 | CCF | N/A |
| PDF | Peak day factor – water heating | Table 2-99 | CCF | N/A |

**Table 2-95 Energy Savings – Electric Water Heater (Spray Valves and Aerators)[8]**

| Spray Valves | |
|---|---|
| **Facility Type** | **$\Delta kWh_W$ per Spray Valve** |
| Grocery | 126 kWh |
| Non-grocery | 957 kWh |
| **Showerheads/Faucet Aerators** | |
| **Type** | **$\Delta kWh_W$ per Unit** |
| Showerhead | 507 kWh |
| Aerator | 309 kWh |

**Table 2-96 Energy Savings – Natural Gas Water Heater (Spray Valves and Aerators)**

| Spray Valves | |
|---|---|
| **Facility Type** | **$\Delta CCF_W$ per Spray Valve** |
| Grocery | 5.3 ccf (5.5 Therms) |
| Non-grocery | 40.8 ccf (42 Therms) |
| **Showerheads/Faucet Aerators** | |
| **Type** | **$\Delta CCF_W$ per Unit** |
| Showerhead | 27.2 ccf (28 Therms) |
| Aerator | 16.5 ccf (17 Therms) |

[8] Electric water heater savings are based on electric resistance heaters. Heat pump water heater savings may be assumed to be equal to one-half of electric resistance savings, based on a typical COP ratio (assuming 1.0 COP for electric resistance and 2.0 COP for heat pump water heating).

**Table 2-97 Retrofit Gross Peak Day Savings (Spray Valves and Aerators)**

| Spray Valves | |
|---|---|
| **Facility Type** | **$\Delta CCF_W$ per Spray Valve** |
| Grocery | 0.0172 ccf |
| Non-grocery | 0.1310 ccf |
| **Showerheads/Faucet Aerators** | |
| **Type** | **$\Delta CCF_W$ per Unit** |
| Showerhead | 0.0811 ccf |
| Aerator | 0.0530 ccf |

## ***Measure Life***

**Table 2-98 Measure Life**

| Equipment Type | Measure Life | Ref |
|---|---|---|
| Faucet aerator | 10 | [3] |
| Low-flow showerhead | 10 | [3] |
| Pre-rinse spray valve | 5 | [4] |

## ***Peak Factors***

**Table 2-99 Peak Day Factor**

| Measure | Peak Day Factor | Ref |
|---|---|---|
| Water-saving measures | 0.00321 | |

## ***Load Shapes***

**Table 2-100 Load Shapes**

| Measure | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % | Ref |
|---|---|---|---|---|---|
| Water-saving measures | 0% | 0% | 0% | 0% | [5] |

## ***Non-Energy Impacts***

Water savings are estimated to be:

**Table 2-101 Water Savings**

| Spray Valves | |
|---|---|
| **Facility Type** | **Gallons per Year** |
| Grocery | 1,496 |
| Non-grocery | 8,603 |
| **Showerheads/Faucet Aerators** | |
| **Type** | **Gallons per Year** |
| Showerhead | 3,900 |
| Aerator | 5,460 |

***Realization Rates***

**Table 2-102 Realization Rates - Electric**

| | Gross Realization | | | FR and SO | | Net Realization | | |
|---|---|---|---|---|---|---|---|---|
| Measure | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Free-ridership | Spill-over | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW |
| Other<br>Energy Conscious Blueprint | 98.5%<br>[10] | 106.3%<br>[10] | 97.4%<br>[10] | 18.2%<br>[9] | 7.1%<br>[9] | 87.57% | 94.50% | 86.59% |
| Other<br>Energy Opportunities | 67.6%<br>[6] | 162.1%<br>[6] | 114.7%<br>[6] | 0.0%<br>[5] | 0.0%<br>[5] | 67.60% | 162.10% | 114.70% |
| Other<br>Small Business Energy Advantage | 72.0%<br>[8] | 73.0%<br>[8] | 85.0%<br>[8] | 0.5%<br>[9] | 0.2%<br>[9] | 71.78% | 72.78% | 84.75% |

**Table 2-103 Realization Rates – Natural Gas**

| | Gross Realization % | | FR & SO | | Net Realization % | |
|---|---|---|---|---|---|---|
| Measure | CCF | Peak Day CCF | Free-ridership | Spill-over | CCF | Peak Day CCF |
| Water Heating<br>Energy Conscious Blueprint | 88.7%<br>[10] | 100.0%<br>[11] | 23.8%<br>[9] | 9.5%<br>[9] | 76.02% | 85.70% |
| Heating/DHW<br>Energy Opportunities | 76.5%<br>[6] | 100.0% | 16.0%<br>[6] | 2.0%<br>[6] | 65.79% | 86.00% |

| | Gross Realization % | | FR & SO | | Net Realization % | |
|---|---|---|---|---|---|---|
| Overall Program Small Business Energy Advantage | 78.0% [8] | 100.0% | 0.0% | 0.0% | 78.00% | 100.00% |

## *References*


[1] California eTRM found at: ETRM (caetrm.com).

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

[3] GDS Associates, Inc. 2009. *Natural Gas Energy Efficiency Potential in Massachusetts*. Prepared for GasNetworks. See Table B-2a.

[4] Veritec Consulting. 2005. "Region of Waterloo Pre-Rinse Spray Valve Pilot Study Final Report" Executive Summary.

[5] DNV. 2021. "X1931-2 Load Shape and Coincidence Factor Research." Connecticut Energy Efficiency Board (EEB) and Evaluation Administrators.

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

[7] EMI Consulting. 2019. "C1644: EO Net-to-Gross Study." Connecticut Energy Efficiency Board.

[8] ERS. 2018. "C1639: Impact Evaluation of the Connecticut Small Business Energy Advantage Program."

[9] Tetra Tech. 2012. "2011 C&I Electric and Gas Free-ridership and Spillover Study."

[10] Cadmus. 2020. "C1634 Impact Evaluation of PY 2016 & 2017 Energy Conscious Blueprint Program."

[11] EMI, C20 Impact Evaluation of the Energy Conscious Blueprint, Program Years 2012 – 2013, Nov. 6. 2015.


## *Changes from Last Version*

- Formatting updates.

## 2.2.12 PIPE INSULATION

| | |
|---|---|
| Market | Commercial |
| Baseline Type | Retrofit |
| Category | Water Heating |

### *Description*

Installation of insulation on bare hydronic supply heating pipes and hot water pipes.

Savings were determined using 3E Plus v4.1 software with 50°F ambient temperature and 180°F fluid temperature [1]. 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 2-105. For parameter values not listed in the 2023 PSD manual, heat loss values will be calculated using 3E Plus.

### *Annual Energy Savings Algorithm*

*Annual Gross Energy Savings, Natural Gas*

$$\Delta CCF = \frac{HL \times EFLH}{102{,}900 \times Eff} \times L$$

*Annual Gross Energy Savings, Oil*

$$\Delta Gal_{oil} = \frac{HL \times EFLH}{138{,}690 \times Eff} \times L$$

*Gross Peak Day Savings, Natural Gas*

$$\Delta CCF_{PD} = \frac{\Delta CCF}{EFLH} \times 24$$

### *Calculation Parameters*

**Table 2-104 Calculation Parameters**

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| $\Delta$CCF | Annual natural gas energy savings | Calculated | CCF | |
| $\Delta Gal_{oil}$ | Annual oil savings | Calculated | Gal | |

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| $\Delta CCF_{PD}$ | Peak day savings, natural gas | Calculated | CCF | |
| L | Length of pipe insulation | Site-specific | Feet | |
| Eff | Efficiency of heating system | Site-specific, if unknown assume 0.8 | | |
| EFLH | Equivalent heating full load hours for the facility type | Site-specific, if unknown assume 536 | Hours | |
| HL | Heat loss savings per linear foot of pipe | Table 2-105 | Btu/ft/hr | |

**Table 2-105 Hourly Heat Loss Savings per Linear Foot of Pipe Insulation (Copper Pipe)**

| Nominal Pipe Size | 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 |
| 0.5 | Polyethylene foam tube | 40 | 47 | 50 | 52 |
| 0.75 | Polyethylene foam tube | 50 | 57 | 61 | 63 |
| 1.0 | Polyethylene foam tube | 62 | 73 | 77 | 79 |
| 1.25 | Polyethylene foam tube | 76 | 88 | 96 | 98 |
| 1.5 | Polyethylene foam tube | 86 | 103 | 109 | 113 |
| 2.0 | Polyethylene foam tube | 110 | 127 | 135 | 139 |
| 3.0 | Polyethylene foam tube | 156 | 184 | 195 | 201 |
| 0.5 | Mineral fibers | 46 | 52 | 54 | 55 |
| 0.75 | Mineral fibers | 57 | 63 | 66 | 68 |
| 1.0 | Mineral fibers | 71 | 79 | 82 | 84 |
| 1.25 | Mineral fibers | 86 | 96 | 102 | 103 |
| 1.5 | Mineral fibers | 97 | 111 | 115 | 119 |
| 2.0 | Mineral fibers | 123 | 137 | 142 | 145 |
| 3.0 | Mineral fibers | 173 | 196 | 205 | 209 |

**Table 2-106 C&I CHWP & Cooling Towers***

| Facility Type | Hours | Facility Type | Hours | Facility Type | Hours |
|---|---|---|---|---|---|
| Auto related | 1,442 | Hospital† | 7,682 | Performing arts theatre | 1,289 |
| Bakery | 1,037 | Hospitals/health care† | 7,682 | Police/fire station (24 Hr) | 2,774 |

| Facility Type | Hours | Facility Type | Hours | Facility Type | Hours |
|---|---|---|---|---|---|
| Banks, financial center† | 2,732 | Industrial: 1 shift | 1,037 | Post office | 1,077 |
| Church | 785 | Industrial: 2 shift | 1,037 | Pump station | 2,097 |
| College: cafeteria | 1,311 | Industrial: 3 shift | 1,037 | Refrigerated warehouse | 810 |
| College: classes/administrative† | 2,357 | Laundromat | 1,170 | Religious building | 785 |
| College: dormitory | 3,833 | Library | 1,289 | Residential (excl. nursing homes) | 3,833 |
| Commercial condo | 4,470 | Light manufacturer | 1,037 | Restaurant | 1,183 |
| Convenience store | 1,170 | Lodging (hotel/motel) | 769 | Retail | 1,170 |
| Convention center | 4,470 | Mall concourse† | 3,013 | School/university† | 2,357 |
| Court house † | 2,732 | Manufacturing facility | 1,037 | Schools (Jr./Sr. High)† | 2,097 |
| Dining: bar lounge/leisure | 1,183 | Medical office | 1,077 | Schools (preschool/elementary) | 865 |
| Dining: cafeteria/fast food | 1,311 | Motion picture theatre | 1,289 | Schools (technical/vocational)† | 2,170 |
| Dining: family | 1,183 | Multifamily (common areas) | 3,833 | Small services | 1,077 |
| Entertainment | 1,289 | Museum | 1,289 | Sports arena | 1,289 |
| Exercise center | 1,289 | Nursing home | 4,470 | Town hall | 1,289 |
| Fast food restaurant | 1,311 | Office (general office types) | 1,077 | Transportation | 1,442 |
| Fire station (unmanned) | 3,833 | Office/retail | 1,077 | Warehouse (not refrigerated) | 810 |
| Food store | 1,021 | Parking garage and lot | 1,442 | Wastewater treatment plant | 2,097 |
| Gymnasium | 1,289 | Penitentiary | 4,470 | Workshop | 1,037 |

* Developed based on simulation of DOE-2 commercial building prototypes in eQUEST using Hartford weather data *

† Results are based on VAV systems with economizers.

## ***Calculation Examples***

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 2-105, the corresponding HL savings is 73 Btu/ft/hr. The length of pipe being insulated L = 100 ft. Using

Table 2-106 (hours of use), the heating EFLH for an office/retail space is 1,248.

Using the savings formula:

$$\Delta CCF = \frac{HL \times EFLH}{102{,}900 \times Eff} \times L$$

$$\Delta CCF = \frac{73 \times 1{,}248}{102{,}900 \times 0.80} \times 100 = 110.7\ ccf$$

## *Measure Life*

The measure life for C&I pipe insulation is 10 years.

## *Peak Factors*

**Table 2-107 Natural Gas Peak Day Factors**

| Equipment Type | Peak Day Factor |
|---|---|
| Heating | 0.00977 |

## *Realization Rates*

**Table 2-108 Realization Rates**

| | Gross Realization | | FR and SO | | Net Realization | |
|---|---|---|---|---|---|---|
| End-use | Energy (CCF) [2] | Peak Day (CCF) | Free ridership [3] | Spillover [3] | Energy (CCF) | Peak Day (CCF) |
| Energy Opportunities Heating/DHW | 76.5% | 100.0% | 16.0% | 2.0% | 65.79% | 86.00% |

## *References*


[1] NAIMA, 3E Plus software tool, Version 4.1, Released 2021.Last accessed Aug. 19, 2021.

[2] DNV-GL, C1635 Impact Evaluation of PY 2016 & 2017 Energy Opportunities (EO) Program.

[3] 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).


## *Changes from Last Version*

- Formatting updates.

## 2.2.13 DUCT SEALING

| | |
|---|---|
| **Market** | Commercial |
| **Baseline Type** | Retrofit |
| **Category** | HVAC & Water Heating |

### ***Description***

Seal ducting located in unconditioned or semi-conditioned (buffer) 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.

Duct sealing to improve efficiency of air distribution from HVAC systems. Savings are verified by measuring outside duct leakage at 25 Pascal (Pa) using standard duct blaster testing procedures and blower door; other advanced sealing techniques can be used. It is recommended to use mastic rather than foil tape to seal the leaky duct.

Duct improvements (sealing) should be verified with duct blaster test at 25 Pa using an approved test method. Notice that a blower door is required as part of this test to maintain 25 Pa in the house in order to isolate duct leakage to the outside. Alternative test methods (i.e., subtraction method, flow hood method, delta Q, etc.) will generally yield inconsistent results and therefore are not permitted. Duct infiltration reduction was simulated using home energy rating software (HERS) [1]. For all duct sealing, savings may be subject to a final analysis which may include a billing analysis, calibration, engineering models, or other applicable methods.

**Reminder:** Heating savings may not be claimed if ducts are not used for heating distribution. For instance, a home with electric baseboard resistance heating or a fossil fuel boiler which has ducts used only for the Central A/C may only claim cooling savings. Demand Savings are based on design load calculation in HERS software; there is no need to use coincidence factors.

**Notes:**

- Fan energy savings are only to be captured for forced-air systems with a furnace or air handling unit (fan).
- Fossil fuel savings include estimated expected system efficiency of 75% including combustion and distribution.

### ***Energy Savings Algorithm***

*Annual Retrofit Gross Energy Savings, Electric*

$$\Delta kWh = \Delta kWh_H + \Delta kWh_C$$

Heating savings for electric (forced air), heat pump, or geothermal heating systems:

$$\Delta \mathrm{kWh_H} = HERS_{Heating} \times (CFM_{Pre} - CFM_{Post})$$

Heating savings for fossil fuel heating with air handler unit:

$$\Delta kWh_H = HERS_{AH} \times (CFM_{Pre} - CFM_{Post})$$

Cooling savings for buildings with Central A/C:

$$\Delta kWh_C = HERS_{Cooling} \times (CFM_{Pre} \times CFM_{Post})$$

Cooling savings for buildings without Central A/C:

$$\Delta kWh = 0$$

*Annual Retrofit Gross Energy Savings, Fossil Fuel*

For natural gas heating system:

$$\Delta CCF_H = HERS_{NG} \times (CFM_{Pre} - CFM_{Post})$$

For oil heating system:

$$\Delta Gal_{OilH} = HERS_{Oil} \times (CFM_{Pre} - CFM_{Post})$$

For propane heating system:

$$\Delta Gal_{PropaneH} = HERS_{Propane} \times (CFM_{Pre} - CFM_{Post})$$

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

$$\Delta kW_{Winter} = HERS_{\Delta kWHeating} \times (CFM_{Pre} - CFM_{Post})$$

$$\Delta kW_{Summer} = HERS_{\Delta kWSummer} \times (CFM_{Pre} - CFM_{Post})$$

*Retrofit Gross Seasonal Peak Demand Savings, Natural Gas*

$$\Delta kWh_{PDH} = \Delta CCF_H \times PDF_H$$

## ***Calculation Parameters***

**Table 2-109 Calculation Parameters**

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| ΔCCF | Annual natural gas savings | Calculated | CCF/yr | |
| $\Delta kWh_H$ | Annual electric energy savings, heating | Calculated | kWh/yr | |
| $\Delta kWh_C$ | Annual electric energy savings, cooling | Calculated | kWh/yr | |
| $\Delta Gal_{Oil}$ | Annual oil savings | Calculated | Gal/yr | |

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| $\Delta kW_{Summer}$ | Summer demand savings | Calculated | kW | |
| $\Delta kW_{Winter}$ | Winter demand savings | Calculated | kW | |
| $\Delta kWh_{PDH}$ | Natural gas peak day savings - heating | Calculated | CCF | |
| $\Delta Gal_{Propane}$ | Annual propane savings | Calculated | Gal/yr | |
| $CFM_{Pre}$ | Air leakage rate before duct sealing at 25 Pa | Site-specific; if unknown, estimate using the area served by relevant HVAC systems: $CFM_{Pre} = 0.195 \frac{CFM}{ft^2} \times Area$ | CFM | |
| $CFM_{Post}$ | Air leakage rate after duct sealing at 25 Pa | Site-specific; if unknown, estimate using the area served by relevant HVAC systems: $CFM_{Post} = 0.04 \frac{CFM}{ft^2} \times Area$ | CFM | |
| $PDF_H$ | Natural gas peak day factor - heating | 0.00977 | | |
| HERS | Home Energy Rating Software | Lookup in Table 2-110 for electric systems, Table 2-111 for fossil fuel systems | per CFM | |

**Table 2-110 Electric Duct Sealing Savings, kWh per CFM Reduction at 25 Pa**

| | $HERS_{Heating}$ for Heating | | | $HERS_{AH}$ | $HERS_{Cooling}$ |
|---|---|---|---|---|---|
| | Electric Forced Air | Heat Pumps | Geothermal | Heating Fan | Central A/C Cooling |
| Savings per CFM reduction | 13.494 | 5.971 | 4.089 | 0.883 | 1.780 |

**Table 2-111 Fossil Fuel Duct Sealing Savings, kWh per CFM Reduction at 25 Pa**

| | Heating (MMBtu) | Gallons Oil – Gallons ($HERS_{Oil}$) | Natural Gas – Ccf ($HERS_{NG}$) | Gallons Propane – Gallons ($HERS_{Propane}$) |
|---|---|---|---|---|
| Savings per CFM reduction | 0.058 | 0.415 | 0.559 | 0.630 |

## ***Calculation Examples***

*Retrofit Gross Energy Savings:* Duct sealing at 25 Pa was performed in a 2,400 ft$^2$ 1960's building in Hartford, Conn. The home is primarily heated by a natural gas furnace and cooled by Central A/C. The outside duct leakage readings at 25 Pa showed $CFM_{Pre}$ of 850 and $CFM_{Post}$ of 775. What are the energy savings? **Note:** This building has fossil fuel, air handler (fan), and cooling savings.

*Using the equation for natural gas heating savings:*

$$\Delta CCF_H = 0.559 \times (850 - 775)$$

$$\Delta CCF_H = 41.925Ccf$$

*Using the equation for electric heating fan savings:*

$$\Delta kWH_H = 0.883 \times (850 - 775)$$

$$\Delta kWH_H = 66.225kWh$$

*Using the equation for Central A/C savings:*

$$\Delta kWh_H = 1.780 \times (850 \times 775)$$

$$\Delta kWh_H = 133.5kWh$$

*Retrofit Gross Peak Demand Savings:* Duct sealing at 25 Pa was performed in a 2,400 ft$^2$ 1960's building in Hartford, Conn. The building is primarily heated by a heat pump and cooled by Central A/C. The outside duct leakage readings at 25 Pa showed $CFM_{Pre}$ of 850 and $CFM_{Post}$ of 775. What are the peak demand savings?

*Using the equation for heat pump winter demand (HERS $\Delta kW_{Winter}$ = 0.0158 kW per CFM):*

$$\Delta kW_{WinterH} = 0.0132 \times (850 - 775)$$

$$\Delta kW_{WinterH} = 0.99kW$$

*Using the equation for summer demand savings (HERS $\Delta kW_{Summer}$ = 0.0015 kW per CFM):*

$$\Delta kW_{SummerC} = 0.0015 \times (850 - 775)$$

$$\Delta kW_{SummerC} = 0.1125kW$$

*If the building 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:*

$$\Delta kWh_{PDH} = 41.925 \times 0.00977\ Ccf$$

$$PD_H = 0.409\ Ccf$$

## Measure Life

Measure life for commercial duct sealing is 18 years. [3]

## Peak Factors

**Table 2-112 Peak Factors**

| Measure | Summer Coincidence Factor | Winter Coincidence Factor | Ref |
|---|---|---|---|
| Duct sealing | 100% | 100% | [2] |

## ***Load Shapes***

**Table 2-113 Load Shapes**

| Measure Type | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % | Ref |
|---|---|---|---|---|---|
| Cooling - Chillers | 18.45% | 17.26% | 32.23% | 32.06% | [2] |
| Cooling - RTUs | 18.19% | 10.22% | 43.16% | 28.43% | [2] |
| Heating | 55.00% | 27.00% | 12.00% | 6.00% | [2] |

## ***Realization Rates and Net Impact Factors***

**Table 2-114 Realization Rates and Net Impact Factors**

| | Gross Realization % | | | | FR & SO | | Net Realization % | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 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 |
| Residential duct sealing, electric & gas [4] | 92.5% | 92.5% | 92.5% | 92.5% | 0.0% | 0.0% | 92.50% | 92.50% | 92.50% | 92.50% |
| MF duct sealing [4] | 92.5% | 92.5% | 92.5% | 92.5% | 0.0% | 0.0% | 92.50% | 92.50% | 92.50% | 92.50% |

## ***References***


[1] MaGrann Associates. Aug. 3, 2021. “Analysis of Energy Savings for Building Envelope Infiltration Reductions and Duct Leakage to Outside Reductions.”

[2] DNV. 2021. “X1931-2 Load Shape and Coincidence Factor Research.”

[3] 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.

[4] NMR and Cadmus, Impact Evaluation: Home Energy Services—Income-Eligible and Home Energy Services Programs: Volume 2 (R16), Final Report, Dec. 31, 2014.


## ***Changes from Last Version***

- Parameter descriptions changed from REM to HERS, to align with the software requirement changing from REMRate to Ekotrope or other approved Home Energy Rating Software.
- Formatting updates.

## 2.2.14 DUCT INSULATION

| | |
|---|---|
| Market | Commercial |
| Baseline Type | Retrofit |
| Category | HVAC & Water Heating |

### ***Description***

Installation of R-6 insulation on ducting located in unconditioned or semi-conditioned (buffer) spaces in commercial buildings.

**The savings were determined using 3E Plus v4.1 software [1]. The savings are based on insulating existing bare ducting with R-6 insulation [1]. Savings presented in**

Table 2-116 and Table 2-117 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.

### ***Energy Savings Algorithm***

*Retrofit Gross Energy Savings, Electric*

Annual gross electric heating savings for electrically heated buildings:

$$\Delta kWh_H = \frac{(BTUH_{hb} - BTUH_{ha})\ x\ EFLH\ x\ A}{3412\ x\ COP_H}$$

Annual gross electric cooling savings for building equipped with Central A/C or heat pump:

$$\Delta kWh_C = \frac{(BTUH_{cb} - BTUH_{ca})\ x\ EFLH\ x\ A}{3412\ x\ \mathrm{COP_C}}$$

*Retrofit Gross Energy Savings, Fossil Fuel*

Annual gross natural gas savings, natural gas heated buildings:

$$\Delta CCF = \frac{(BTUH_{hb} - BTUH_{ha})\ x\ EFLH\ x\ A}{102{,}900\ x\ \mathrm{Eff}}$$

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

Currently no demand savings are claimed for this measure.

## ***Calculation Parameters***

**Table 2-115 Calculation Parameters**

| Symbol | Description | Units | Values | Ref |
|---|---|---|---|---|
| $\Delta kWh_H$ | Annual gross electric heating savings | kWh | Calculated | |
| $\Delta kWh_C$ | Annual gross electric cooling savings | kWh | Calculated | |
| ΔCCF | Annual natural gas savings | CCF | Calculated | |
| $BTUH_{hb}$ | Heating heat transfer rate of un-insulated ducting | $Btu/hr/ft^2$ | Table 2-116 | |
| $BTUH_{ha}$ | Heating heat transfer rate of insulated ducting | $Btu/hr/ft^2$ | Table 2-116 | |
| $BTUH_{cb}$ | Cooling heat transfer rate of un-insulated ducting | $Btu/hr/ft^2$ | Table 2-116 | |
| $BTUH_{ca}$ | Cooling heat transfer rate of insulated ducting | $Btu/hr/ft^2$ | Table 2-116 | |
| A | Insulation area in square feet | $ft^2$ | Site-specific. | |
| $COP_H$ | Coefficient of performance of heating equipment | N/A | Site-specific, lookup in Table 2-117 if unknown | |
| $COP_C$ | Coefficient of performance of cooling equipment | N/A | Site-specific, assume 3.5 if unknown | |
| Eff | Heating equipment efficiency | N/A | Site-specific, lookup if Table 2-117 if unknown | |
| EFLH | Equivalent heating or cooling full-load hours for the facility type | Hours | Table 2-118 Heating and Cooling Full Load Hours | |

**Table 2-116 Heat Transfer Rates per Hour per $ft^2$ of Insulation**

| Duct Location | $BTUH_{hb}$ ($Btu/hr/ft^2$) | $BTUH_{cb}$ ($Btu/hr/ft^2$) | $BTUH_{ha}$ ($Btu/hr/ft^2$) | $BTUH_{ca}$ ($Btu/hr/ft^2$) |
|---|---|---|---|---|
| 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 |

**Table 2-117 Heating Equipment Efficiencies**

| Equipment | $COP_H$ | Eff |
|---|---|---|
| Furnace (electric) | 1.0 | - |
| Heat pump | 2.4 | - |
| Ground-source heat pump | 3.0 | - |
| Boiler (<300,000 Btu/hr) | - | 0.92 |
| Boiler (300,000 to 2,500,000 Btu/hr) | - | 0.90 |
| Boiler (>2,500,000 Btu/hr) | - | 0.90 |
| Steam boiler (all sized) | - | 0.82 |
| Cast iron sectional hot water boiler (all sized) | - | 0.82 |
| Furnace (non-electric, <120,000 Btu/hr) | - | 0.85 |
| Furnace (non-electric, ≥120,000 Btu/hr) | - | 0.85 |

**Table 2-118 Heating and Cooling Full Load Hours* [4]**

| Facility Type | Heating FLHrs |
|---|---|
| Auto Related | 3,122 |
| Bakery | 1,065 |
| Church | 938 |
| College: Cafeteria | 1,178 |
| Convenience Store | 831 |
| Dining: Bar Lounge/Leisure | 1,118 |
| Dining: Cafeteria/Fast Food | 1,178 |
| Dining: Family | 1,118 |
| Entertainment | 1,042 |
| Exercise Center | 1,042 |
| Fast Food Restaurant | 1,178 |
| Food Store | 840 |
| Gymnasium | 1,042 |
| Industrial: 1 Shift | 1,065 |
| Industrial: 2 Shift | 727 |
| Industrial: 3 Shift | 384 |
| Laundromat | 831 |
| Library | 1,042 |
| Light Manufacturer | 1,065 |
| Lodging (Hotel/Motel) | 628 |
| Manufacturing Facility | 1,065 |
| Medical Office | 598 |
| Motion Picture Theatre | 1,042 |
| Museum | 1,042 |
| Office (General Office Types) | 598 |
| Office/Retail | 598 |
| Parking Garage and Lot | 3,122 |
| Performing Arts Theatre | 1,042 |
| Post Office | 598 |
| Pump Station | 384 |
| Refrigerated Warehouse | 734 |
| Religious Building | 938 |
| Restaurant | 1,118 |
| Retail | 831 |
| Schools (Preschool/Elementary) | 1,086 |
| Small Services | 598 |
| Sports Arena | 1,042 |
| Town Hall | 1,042 |
| Transportation | 3,122 |
| Warehouse (Not Refrigerated) | 734 |
| Wastewater Treatment Plant | 384 |
| Workshop | 1,065 |

## ***Calculation Examples***

*Retrofit Gross Energy Savings, Example*

Example: R-6 insulation was installed on 100 ft2 of bare supply ducting located in the basement of a small retail store. This system utilizes a heat pump and provides both heating and cooling. What are the savings?

Annual gross electric heating savings:

$$\Delta kWh_H = \frac{(BTUH_{hb} - BTUH_{ha})\ x\ EFLH\ x\ A}{3412\ x\ 2}$$

- From Table 2-116: $BTUH_{hb}$ =132.34;
- From Table 2-116: $BTUH_{ha}$ =12.04;
- From Table 2-118: EFLH heating = 1,248 hr;
- A = 100 $ft^2$; and
- From Table 2-117: $COP_H$ for heat pump = 2.0.

$$\Delta kWh_H = \frac{(132.34 - 12.04)\ x\ 1248\ x\ 100}{3412\ x\ 2} = 2220.09\ kWh$$

Annual gross electric cooling savings:

$$\Delta kWh_C = \frac{(BTUH_{cb} - BTUH_{ca})\ x\ EFLH\ x\ A}{3412\ x\ 3.5}$$

- From Table 2-116: $BTUH_{cb}$ = 25.22;
- From Table 2-116: $BTUH_{ca}$ = 2.73;
- From Table 2-118: EFLH cooling = 797; and
- A = 100 $ft^2$

$$\Delta kWh_C = \frac{(25.22 - 2.73)\ x\ 797\ x\ 100}{3412\ x\ 3.5} = 150.10\ kWh$$

## *Measure Life*

The measure life for Commercial Duct Insulation is 20 years.

## *Peak Factors*

**Table 2-119 Peak Factors**

| Measure | Summer Peak Factor | Winter Peak Factor | Ref |
|---|---|---|---|
| Duct insulation | 0% | 0% | |

## *Load Shapes*

**Table 2-120 Load Shapes**

| Measure | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % | Ref |
|---|---|---|---|---|---|
| Heating | 55.00% | 27.00% | 12.00% | 6.00% | [3] |

## *Realization Rates*

**Table 2-121 Realization Rates**

| | Gross Realization % | | | | FR and SO | | Net Realization % | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 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 |
| Other Measures | 100.0% | 100.0% | 100.0% | 100.0% | 0.0% | 0.0% | 100.0% | 100.0% | 100.0% | 100.0% |

## *References*


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

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

[3] DNV (2021). X1931-2 Load Shape and Coincidence Factor Research – Final Report.

[4] DNV. 2021. "X1931-6: PSD HOU/FLH Documentation and Update Study."

[5] DNV. 2021. CT X1931-1 Connecticut (CT) Industry Standard Practices for Boilers and Furnaces.


## *Changes from Last Version*

- Updated boiler and furnace efficiency assumptions based on CT X1931-1 Connecticut (CT) Industry Standard Practices for Boilers and Furnaces.
- Updated net realization rates.

## 2.2.15 COMMERCIAL ADVANCED THERMOSTATS

| | |
|---|---|
| Market | Commercial |
| Baseline Type | Retrofit |
| Category | HVAC & Water Heating |

***Description***

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

The measure energy savings are calculated using deemed energy savings factors based on DNV's X1931-8 Commercial Advanced Thermostats Phase 1 results [1]. Gas heating and electric cooling energy intensities of 40.7 kBtu/square feet and 1.17 kWh/square feet, were estimated based on commercial buildings located in New England in a US EIA Commercial Buildings Energy Consumption Survey (Table E7, [2]). The estimated energy intensities were then multiplied with deemed savings factors to estimate per square foot heating and cooling savings. These savings factors per square foot are constants used in the define formulas in this measure, which are to be used when heating fuel and cooling system is known and the total conditioned (properly specified as heated and/or cooled) building space/zone floor area in square feet is known for each thermostat being installed. Spaces/zones that are only heated; or only cooled; or both heated and cooled must be evaluated separately on a per square foot area basis as such and cannot be combined for calculation purposes.

If heating and cooling equipment is known (Direct Install Programs) but site-specific building conditioned area per thermostat information is not available, look up deemed savings in Table 2-123, which represent savings per thermostat.

If heating and cooling equipment is unknown (Midstream Programs, E-Commerce, etc.), look up deemed savings values in Table 2-124 which represent savings per thermostat.

**Notes:**

- Energy savings factors of 4.5% and 2% are used for heating and cooling, respectively [1].
- Heating electric savings are derived based on conversion of natural gas heating savings to electric heating savings (therm to kWh) multiplied by the equipment efficiency.

1. For electric resistance heating, kWh_savings=((therm_savings×29.3×0.85))/1, where 29.3 is therm to kWh conversion factor, 0.85 is the natural gas furnace efficiency  and 1 is the electric resistance heating efficiency.
2. For heat pump heating, kWh_savings=((therm_savings×29.3×0.85))/3.2, where 29.3 is therm to kWh conversion factor, 0.85 is the natural gas furnace efficiency and 3.2 is the heat pump COP.

## ***Energy Savings Algorithm***

**Note:** *Savings are applicable to existing systems only.*

*Retrofit Gross Energy Savings, Electric*

Electric resistance heating savings:

$$\Delta kWh_H = 0.4561 \times A$$

Heat pump heating savings:

$$\Delta kWh_H = 0.1425 \times A$$

Cooling savings:

$$\Delta kWh_C = 0.0234 \times A$$

*Retrofit Gross Energy Savings, Natural Gas*

$$\Delta CCF = 0.0178 \times A$$

*Retrofit Gross Energy Savings, Oil*

$$\Delta OG = 0.0134 \times A$$

*Retrofit Gross Energy Savings, Propane*

$$\Delta PG = 0.0201 \times A$$

If heating and cooling equipment is known (Direct Install Programs) but site-specific building conditioned area per thermostat information is not available, look up deemed savings values in Table 2-123.

If heating and cooling equipment is unknown (Midstream Programs, E-Commerce, etc.), look up deemed savings values in Table 2-124.

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

Seasonal peak demand savings are assumed to be zero until additional information is available.

## *Calculation Parameters*

**Table 2-122 Calculation Parameters**

| Symbol | Description | Units | Values | Ref |
|---|---|---|---|---|
| $\Delta kWh_H$ | Annual gross electric energy savings – heating | kWh | Calculated | |
| $\Delta kWh_C$ | Annual gross electric energy savings - cooling | kWh | Calculated | |
| ΔCCF | Annual natural gas savings | CCF | Calculated | |
| ΔOG | Annual oil savings | Gallons | Calculated | |
| ΔPG | Annual propane savings | Gallons | Calculated | |
| A | Building conditioned area served by thermostat | $ft^2$ | Site-specific | |

Table 2-123 presents deemed savings values to be used if when the heating fuel and cooling system is known, but the actual conditioned building area is unknown (Direct Install programs). These values are estimated based on deemed building conditioned area of 2,500 square feet per thermostat.

**Table 2-123 Deemed Annual Savings, Unknown Area**

| $\Delta kWh_C$ | $\Delta kWh_H$ Electric resistance | $\Delta kWh_H$ Heat pump | ΔCCF | ΔOG | ΔPG |
|---|---|---|---|---|---|
| 58.6 | 1,140.3 | 356.4 | 44.5 | 33.5 | 50.1 |

Table 2-124 presents deemed savings values to be used when the heating fuel and cooling system is unknown (Midstream Programs, E-Commerce, etc.) Heating primary fuel type for midstream savings calculation was estimated to be 14% electric (37% of the 14% was estimated to be heat pump heating and 63% of the 14% was estimated to be electric resistance heating), 28% natural gas, 35% fuel oil, and 22% propane, heating equipment, number of buildings for New England (Table B38, [2]).

**Table 2-124 Deemed Annual Savings, Unknown Heating/Cooling System**

| ΔkWh | ΔCCF | ΔOG | ΔPG |
|---|---|---|---|
| 181.1 | 12.6 | 11.8 | 11.0 |

## *Measure Life*

The measure life for Commercial Advanced Thermostats is 9.1 years.

## *Peak Factors*

**Table 2-125 Peak Factors**

| Measure | Summer Coincidence Factor | Winter Coincidence Factor | Ref |
|---|---|---|---|
| C&I Advanced Thermostats | 0% | 0% | |

## *Load Shapes*

**Table 2-126 Load Shapes**

| Measure | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % | Ref |
|---|---|---|---|---|---|
| Commercial cooling - RTUs | 18.19% | 10.22% | 43.16% | 28.43% | [4] |
| Commercial heating | 55.00% | 27.00% | 12.00% | 6.00% | [4] |

## *Realization Rates*

**Table 2-127 Electric Realization Rates**

| | Gross Realization % | | | FR & SO | | Net Realization % | | | |
|---|---|---|---|---|---|---|---|---|---|
| Measure | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Free-ridership | Spill-over | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Ref |
| Small Business Energy Advantage – Other | 72.0% | 73.0% | 85.0% | 0.5% | 0.2% | 71.78% | 72.78% | 84.75% | [5], [6] |

**Table 2-128 Natural Gas Realization Rates**

| | Gross Realization % | | FR & SO | | Net Realization % | | |
|---|---|---|---|---|---|---|---|
| Measure | CCF | Peak Day CCF | Free-ridership | Spill-over | CCF | Peak Day CCF | Ref |
| Small Business Energy Advantage – Overall Program [5] | 78.0% | 100.0% | 0.0% | 0.0% | 78.00% | 100.00% | |

## *References*


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

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

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

[4] DNV (2021). X1931-2 Load Shape and Coincidence Factor Research – Final Report.

[5] ERS, *C1639: Impact Evaluation of the Connecticut Small Business Energy Advantage Program*, Mar. 20, 2018.

[6] Tetra Tech, *2011 C&I Electric and Gas Free-ridership and Spillover Study*, Oct. 5, 2012.

***Changes from Last Version***

- Formatting updates.
- Added summer and winter coincidence factors of 0% per the assumption that there are no peak seasonal demand savings.

## 2.2.16 STEAM TRAP REPLACEMENT

| | |
|---|---|
| Market | Commercial |
| Baseline Type | Retrofit |
| Category | HVAC & Water Heating |

### ***Description***

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 [1].

The savings estimates below are based on the Grashof Equation. More information on the Grashof Equation can be found in *Marks' Standard Handbook for Mechanical Engineers* which provides steam loss through orifices at various pressures [2]. 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.

### ***Annual Energy Savings Algorithm***

*Annual Gross Energy Savings, Natural Gas*

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

Where,

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

$$P_a = P_g + P_{atm}$$

*Gross Peak Day Savings, Natural Gas*

$$\Delta CCF_{PD} = \frac{\Delta CCF \;\times 24}{EFLH}$$

## ***Calculation Parameters***

**Table 2-129 Calculation Parameters**

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| $\Delta CCF$ | Annual natural gas savings | Calculated | CCF | |
| $\Delta CCF_{pd}$ | Peak day natural gas savings | Calculated | CCF | |
| $lb_m$ | Steam flow through orifice | Calculated | $lb_m$/hr | |
| $P_a$ | Absolute pressure (gauge pressure + atmospheric pressure) | Calculated | psi | |
| $P_g$ | Gauge pressure | Site-specific | psi | |
| D | Orifice diameter | Site-specific | Inches | |
| Eff | Boiler efficiency | Site-specific, if unknown lookup in Table 2-130 | % | [6] |
| EFLH | Equivalent full load hours | Site-specific, if unknown lookup in Table 2-131 | Hours | [5],[10] |
| $h_{fg}$ | Specific enthalpy of evaporation | Lookup in Table 2-132 | Btu/$lb_m$ | [3] |
| CR (no return) | Condensate return factor for system with no condensate return line | 100.0% | % | [4] |
| CR (return) | Condensate return factor for condensate return line system | 36.3% | % | [4] |
| $L_f$ (failed) | Steam loss adjustment factor for failed traps | 55% | % | [4] |
| $L_f$ (leaking) | Steam loss adjustment factor for leaking traps | 26% | % | [4] |
| $P_{atm}$ | Atmospheric pressure | 14.696 | psi | |
| 0.97 | Empirically derived factor in Grashof Equation | 0.97 | N/A | [2] |
| 60 | Empirically derived factor in Grashof Equation | 60 | $lb_m$/ $in^{0.6}lb^{0.97}hr$ | [2] |
| 0.7 | Discharge coefficient | 70% | % | [2] |

**Table 2-130 Boiler Efficiency Assumptions**

| Type | Efficiency |
|---|---|
| Linkage Control | 83.2% |
| Parallel Positioning | 84.2% |
| Parallel Positioning and O2 Trim | 85% |

**Table 2-131 Equivalent Full Load Hours Assumptions**

| Type | EFLH | Ref |
|---|---|---|
| Process Steam | 7,752 | [5] |
| Banks, Financial Center Heating | 372 | [10] |
| College: Classes/Administrative Heating | 949 | [10] |
| College: Dormitory Heating | 536 | [10] |
| Commercial Condo Heating | 836 | [10] |
| Convention Center Heating | 836 | [10] |
| Court House Heating | 372 | [10] |
| Fire Station (Unmanned) Heating | 536 | [10] |
| Hospital Heating | 513 | [10] |
| Hospitals/Health Care Heating | 513 | [10] |

| Type | EFLH | Ref |
|---|---|---|
| Mall Concourse Heating | 672 | [10] |
| Multi-Family (Common Areas) Heating | 536 | [10] |
| Nursing Home Heating | 836 | [10] |
| Penitentiary Heating | 836 | [10] |
| Police/Fire Station (24 Hr) Heating | 717 | [10] |
| Residential (Except Nursing Homes) Heating | 536 | [10] |
| School/University Heating | 949 | [10] |
| Schools (Jr./Sr. High) Heating | 1,075 | [10] |
| Schools (Technical/Vocational) Heating | 783 | [10] |

**Table 2-132 Enthalpy of Steam by Pressure**

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

## *Measure Life*

**Table 2-133 Measure Life**

| Equipment Type | Measure Life | Ref |
|---|---|---|
| Steam Trap Replacement - Retrofit | 6 | N/A{11] |

## *Peak Factors*

**Table 2-134 Peak Factors**

| Measure | Summer Coincidence Factor | Winter Coincidence Factor | Ref |
|---|---|---|---|
| Steam trap replacement | 0% | 0% | [7] |

## *Load Shapes*

Electric load shapes N/A for this fuel savings measure.

## *Realization Rates and Net Impact Factors*

**Table 2-135 Realization Rates**

| | Gross Realization % | | FR and SO | | Net Realization % | | |
|---|---|---|---|---|---|---|---|
| Measure | CCF | Peak Day CCF | Free-ridership | Spill-over | CCF | Peak Day CCF | Ref |
| O&M Overall Program | 94.0% | 108.0% | 0.0% | 0.0% | 63.9% | 73.4% | [8], [9] |

## *References*


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

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

[3] U.S. Department of Energy. 2015. n.d. “Steam System Modeler Tool (SSMT)”. Accessed June 20, 2022. https://www4.eere.energy.gov/manufacturing/tech_deployment/amo_steam_tool/propSaturated.

[4] DNV & ERS. 2017. ”Steam Trap Evaluation Phase 2”. Massachusetts Program Administrators and Energy Efficiency Advisory Council.

[5] TRC. 2020. “X1941 Multifamily Impact Evaluation, PSD Savings Review.” Connecticut Energy Efficiency Board (EEB) and Evaluation Administrators. CT X1941 MFFinalReport_072221.pdf (energizect.com).

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

[7] DNV. 2021. “X1931-2 Load Shape and Coincidence Factor Research.” Connecticut Energy Efficiency Board (EEB) and Evaluation Administrators.

[8] ERS. 2018. "C1641: Impact Evaluation of the Business and Energy Sustainability Program", p. 4, Table 1-3; p. 5, Table 1-4; p.10, Recommendation 1.

[9] Michaels Energy & Evergreen Economics. 2013 "Impact Evaluation of the Retro-commissioning, Operation and Maintenance, and Business Sustainability Challenge Programs". Connecticut Energy Efficiency Board (EEB).

[10] DNV. 2021. "X1931-6: PSD HOU/FLH Documentation and Update Study."

[11] Energy and Environmental Analysis, Inc. *Steam Traps Workpaper for PY2006-2008.* Prepared for Southern California Gas Company, Dec. 2006, p. 14, see Section 9.1

## ***Changes from Last Version***

- Formatting updates.
- Added missing measure life

## 2.2.17 BLOWER DOOR TEST (SMALL C&I)

| | |
|---|---|
| Market | Commercial |
| Baseline Type | Retrofit |
| Category | HVAC & Water Heating |

### ***Description***

This measure is for verifying infiltration reduction of older residential type construction, less than 5,000 ft2, 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.

The savings methodology is based on seven pilot projects conducted under Eversource's small business air sealing pilot program in Connecticut [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 2023 PSD manual's Measure 3.4.1 Infiltration Reduction Testing (Blower Door Test). The savings are reviewed with customer billing data by the Companies' staff.

### ***Annual Energy Savings Algorithm***

*Annual Gross Energy Savings , Electric*

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

$$\Delta kWh_{heating} = BD_{heating} \times (CFM_{pre} - CFM_{post})$$

For fossil fuel heating with air handler unit:

$$\Delta kWh_{heating} = BD_{AH} \times (CFM_{pre} - CFM_{post})$$

For buildings with central A/C air cooling:

$$\Delta kWh_{cooling} = BD_{cooling} \times (CFM_{pre} - CFM_{post})$$

*Annual Gross Energy Savings, Natural Gas*

$$\Delta CCF_{heating} = BD_{NG} \times (CFM_{pre} - CFM_{post})$$

*Annual Gross Energy Savings, Oil*

$$\Delta Gal_{oil} = BD_{oil} \times (CFM_{pre} - CFM_{post})$$

*Annual Gross Energy Savings, Propane*

$$\Delta Gal_{propane} = BD_{propane} \times (CFM_{pre} - CFM_{post})$$

*Gross Seasonal Peak Demand Savings, Electric*

$$\Delta kW_{Winter} = BD_{kW,winter} \times (CFM_{pre} - CFM_{post})$$

$$\Delta kW_{Summer} = BD_{kW,summer} \times (CFM_{pre} - CFM_{post})$$

*Gross Peak Day Savings, Natural Gas*

$$\Delta \mathrm{CCF}_{PD} = \Delta \mathrm{CCF}_{Heating} \times PDF$$

## ***Calculation Parameters***

**Table 2-136 Calculation Parameters**

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| $\Delta kWh_{cooling}$ | Annual gross electric energy savings, cooling | Calculated | kWh | |
| $\Delta kWh_{heating}$ | Annual gross electric energy savings, heating | Calculated | kWh | |
| $\Delta CCF_{heating}$ | Annual gross natural gas savings, heating | Calculated | CCF | |
| $\Delta Gal_{oil}$ | Annual gross oil energy savings | Calculated | Gal | |
| $\Delta Gal_{propane}$ | Annual gross propane energy savings | Calculated | Gal | |
| $kW_{cooling}$ | Seasonal summer peak demand savings, cooling | Calculated | kW | |
| $kW_{heating}$ | Seasonal winter peak demand savings, heating | 0 | kW | |
| $\Delta CCF_{PD}$ | Natural gas peak day savings, heating | Calculated | CCF | |
| PDF | Natural gas peak day factor, heating | 0.00977 | | [2] |
| $CFM_{pre}$ | Infiltration after air sealing measured with the house being negatively pressurized to 50 Pa relative to outdoor conditions | Site-specific | CFM | |

| Variable | Description | Value | Units | Ref |
| --- | --- | --- | --- | --- |
| $CFM_{post}$ | Infiltration before air sealing measured with the house being negatively pressurized to 50 Pa relative to outdoor conditions | Site-specific | CFM | |
| BD | Blower door savings factor per CFM | Table 2-137<br>Table 2-138<br>Table 2-139 | Fuel dependent: savings/CFM | |

**Table 2-137 Retrofit Electric Savings per CFM Reduction (at 50 Pa)**

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

**Table 2-138 Retrofit Fossil Fuel Savings per CFM Reduction (at 50 Pa)**

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

**Table 2-139 Demand Savings per CFM Reduction (at 50 Pa)**

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

## ***Measure Life***

The measure life for Blower Door Test is N/A.

## Peak Factors

**Table 2-140 Peak Factors**

| Measure | Summer Coincidence Factor | Winter Coincidence Factor | Ref |
|---|---|---|---|
| Blower door test (Small C&I) | 100% | 100% | [2] |

## Load Shapes

**Table 2-141 Load Shapes**

| Measure | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % | Ref |
|---|---|---|---|---|---|
| Other | 37.00% | 29.00% | 19.00% | 15.00% | [2] |

## Realization Rates and Net Impact Factors

**Table 2-142 Realization Rates and Net Impact Factors**

| Gross Realization % | | | FR and SO | | Net Realization % | |
|---|---|---|---|---|---|---|
| End-use | Energy (CCF) | Peak Day (CCF) | Free-ridership | Spillover | Energy (CCF) | Peak Day (CCF) |
| Overall program | 78.0% [3] | 100.0% | 0.0% | 0.0% | 78.0% | 100.0% |

## References


[1] MaGrann Associates. 2021. “Analysis of Energy Savings for Building Envelope Infiltration Reductions and Duct Leakage to Outside Reductions".

[2] DNV. 2021. “X1931-2 Load Shape and Coincidence Factor Research.” Connecticut Energy Efficiency Board (EEB) and Evaluation Administrators.

[3] ERS, C1639: Impact Evaluation of the Connecticut Small Business Energy Advantage Program, Mar. 20, 2018.


## Changes from Last Version

- Updated net realization rates.
- Formatting updates.

## 2.2.18 ADD SPEED CONTROL TO ROOFTOP UNIT FANS

| | |
|---|---|
| Market | Commercial |
| Baseline Type | Retrofit |
| Category | HVAC & Water Heating |

### ***Description***

This measure installs speed control on existing constant speed rooftop unit supply 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.

The savings are determined via spreadsheet. Exponent for fan saving that adjust ideal fan law value of 3.0 to account for fan, motor, and VFD efficiency.

Ref [1] is for information only.

### ***Annual Energy Savings Algorithm***

*Retrofit Gross Energy Savings, Electric*

$$\Delta \text{kWh} = \Delta kWh_E - \Delta kWh_R$$

$$\Delta kWh_E = kW_E \text{ x H}$$

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

$$\Delta kWh_R = \frac{kW_E \times SP1^{2.7} \times H_1}{\text{EF}_{\text{VFD}}} + \frac{kW_E \times SP2^{2.7} \times H_2}{\text{EF}_{\text{VFD}}} + \frac{kW_E \times SP1^{2.7} \times H_O}{\text{EF}_{\text{VFD}}} + \frac{kW_E \times SPV^{2.7} \times H_V}{\text{EF}_{\text{VFD}}}$$

Where,

- H = Full load cooling and heating hours from Table 2-144.
- $H_0$ = 13% of the fan hours are assumed to be in free cooling; based on local temperature BINs.
- $H_2$ = 25% of heating/cooling equivalent full-load hours are assumed to be in Stage 2 (based on local temperature BINs).
- $H_1$ = 75% of heating/cooling equivalent full-load hours are assumed to be in Stage 1 (50% output).
  To calculate the fan hours in stage one, the equivalent full load heating/cooling are multiplied by (75% from above) then multiplied by 50% capacity.

- $H_v = H - (H_0 + H_1 + H_2)$.

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

$$\Delta kW = kW_E - \left(\frac{KW_E \times SP2^{2.7}}{\mathrm{EF_{VFD}}}\right)$$

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

## Calculation Parameters

**Table 2-143 Calculation Parameters**

| Symbol | Description | Units | Values | Ref |
|---|---|---|---|---|
| ΔkW | Annual summer and winter seasonal peak demand savings | kW | Calculated | |
| ΔkWh | Annual gross electric energy savings | kWh | Calculated | |
| $\Delta kWh_E$ | Annual gross electric energy consumption-existing system | kWh | Calculated | |
| $\Delta kWh_R$ | Annual gross electric energy consumption-after retrofit | kWh | Calculated | |
| $EF_M$ | Motor efficiency | % | Site-specific | |
| H | Total fan run hours, total full load heating and cooling hours | Hours | Table 2-143 | |
| $H_1$ | Fan run hours at Stage 1 | Hours | Calculated | |
| $H_2$ | Fan run hours at Stage 2 | Hours | Calculated | |
| $H_V$ | Fan run hours in ventilation only mode | Hours | Calculated | |
| $H_O$ | Fan run hours in free cooling mode | Hours | Calculated | |
| HP | Fan motor nameplate horsepower | Horsepower | Site-specific | |
| $kW_E$ | Existing fan kW | kW | Site-specific | |
| LF | Fan motor load factor | % | Site-specific, assume 65% if unknown | [2] |
| SP1 | Stage 1 fan speed | % | 75% | |
| SP2 | Stage 2 fan speed | % | 90% | |
| SPV | Ventilation only fan speed | % | 40% | |
| $EF_{VFD}$ | VFD efficiency | | 0.97 | |

**Table 2-144 Heating and Cooling Full Load Hours* [3]**

| Facility Type | Heating FLHrs |
|---|---|
| Auto Related | 3,122 |
| Bakery | 1,065 |
| Church | 938 |
| College: Cafeteria | 1,178 |
| Convenience Store | 831 |
| Dining: Bar Lounge/Leisure | 1,118 |
| Dining: Cafeteria/Fast Food | 1,178 |
| Dining: Family | 1,118 |
| Entertainment | 1,042 |
| Exercise Center | 1,042 |
| Fast Food Restaurant | 1,178 |
| Food Store | 840 |
| Gymnasium | 1,042 |
| Industrial: 1 Shift | 1,065 |
| Industrial: 2 Shift | 727 |

| Facility Type | Heating FLHrs |
|---|---|
| Industrial: 3 Shift | 384 |
| Laundromat | 831 |
| Library | 1,042 |
| Light Manufacturer | 1,065 |
| Lodging (Hotel/Motel) | 628 |
| Manufacturing Facility | 1,065 |
| Medical Office | 598 |
| Motion Picture Theatre | 1,042 |
| Museum | 1,042 |
| Office (General Office Types) | 598 |
| Office/Retail | 598 |
| Parking Garage and Lot | 3,122 |
| Performing Arts Theatre | 1,042 |
| Post Office | 598 |
| Pump Station | 384 |

| Facility Type | Heating FLHrs |
|---|---|
| Refrigerated Warehouse | 734 |
| Religious Building | 938 |
| Restaurant | 1,118 |
| Retail | 831 |
| Schools (Preschool/Elementary) | 1,086 |
| Small Services | 598 |
| Sports Arena | 1,042 |
| Town Hall | 1,042 |
| Transportation | 3,122 |
| Warehouse (Not Refrigerated) | 734 |
| Wastewater Treatment Plant | 384 |
| Workshop | 1,065 |

## ***Measure Life***

**Table 2-145 Measure Life**

| Equipment Type | Retrofit | Lost Opportunity | Ref |
|---|---|---|---|
| 2-speed motor control in rooftop unit | 5 | 15 | [4]* |

* This measure is similar to those in the report, so a measure life from Table 2 was used.

## ***Peak Factors***

**Table 2-146 Peak Factors**

| Measure | Summer Coincidence Factor | Winter Coincidence Factor | Ref |
|---|---|---|---|
| Add speed control to rooftop unit fan | 100% | 100% | |

## *Load Shapes*

**Table 2-147 Load Shapes**

| Measure | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % | Ref |
|---|---|---|---|---|---|
| Motors | 31.74% | 36.49% | 15.77% | 15.99% | |

## *Realization Rates and Net Impact Factors*

**Table 2-148 Realization Rates**

| | Gross Realization % | | | | FR & SO | | Net Realization % | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 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 |
| Other Measures | 100.0% | 100.0% | 100.0% | 100.0% | 0.0% | 0.0% | 100.0% | 100.0% | 100.0% | 100.0% |

## *References*


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

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

[3] DNV. 2021. "PSD HOU/FLH Documentation and Update Study." Connecticut Energy Efficiency Board (EEB) and Evaluation Administrators.

[4] GDS Associates Inc., *Measure Life Report, Residential and Commercial Industrial Lighting and HVAC Measures*, Jun. 2007, see Table 2.


## *Changes from Last Version*

- Added variable definition for VFD efficiency.
- Updated retrofit measure life to 1/3 RUL of host RTU.

## 2.2.19 COMMERCIAL KITCHEN HOOD CONTROLS

| | |
|---|---|
| Market | Commercial |
| Baseline Type | Retrofit |
| Category | HVAC & Water Heating |

### ***Description***

This measure is for the installation of controls to reduce airflow in commercial kitchen exhaust 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 airflow 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.

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 C&I Natural Gas Fired Boilers and Furnaces, Measure 2.2.5 in this document, 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.

### ***Annual Energy Savings Algorithms***

Savings are calculated using a custom spreadsheet with site-specific input.

## ***Calculation Parameters***

**Table 2-149 Calculation Parameters**

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| Hr | Hours of operation | Site specific | hrs | |
| HPEF | Horsepower of exhaust fans | Site specific | HP | |
| HPMA | Horsepower of make-up air fans | Site specific | HP | |
| NEF | Number of exhaust fans | Site specific | n/a | |
| NMA | Number of make-up air fans | Site specific | n/a | |
| EER | Cooling system efficiency | Site specific | Btu/watt-hr | |
| HEFF | Heating system efficiency | Site specific | % | |
| VR | Kitchen ventilation rate | Site specific | $CFM/ft^2$ | |
| A | Kitchen area | Site specific | $ft^2$ | |
| OF | Ventilation oversize factor | Site specific | % | |
| PR | Power reduction | Site specific | % | |
| FR | Flow reduction | Site specific | % | |
| MEff | Motor efficiency | Site specific | % | |

## ***Measure Life***

The measure life for make-up air units for exhaust hoods is 15 years [1].

## ***Peak Factors***

**Table 2-150 Peak Factors**

| Measure | Summer Coincidence Factor | Winter Coincidence Factor | Ref |
|---|---|---|---|
| Commercial kitchen hood controls | Custom | Custom | |

## ***Load Shapes***

**Table 2-151 Load Shapes**

| Measure Type | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % | Ref |
|---|---|---|---|---|---|
| Motors | 31.74% | 36.49% | 15.77% | 15.99% | [2] |

## ***Realization Rates***

**Table 2-152 Realization Rates**

| | Gross Realization % | | | FR & SO | | Net Realization %[3] | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Measure** | **kWh** | **Winter Seasonal Peak kW** | **Summer Seasonal Peak kW** | **Free-ridership** | **Spill-over** | **kWh** | **Winter Seasonal Peak kW** | **Summer Seasonal Peak kW** | **Ref** |
| Motors **Energy Conscious Blueprint** | 98.5% | 106.3% | 97.4% | 18.2% | 7.1% | 87.6% | 94.5% | 86.6% | [4], [5] |
| Motors **Energy Opportunities** | 67.6% | 162.1% | 114.7% | 12.0% | 3.0% | 61.5% | 147.5% | 104.4% | [6], [7] |

## ***References***

[1] ERS. 2005. "Measure Life Study prepared for The Massachusetts Joint Utilities."

[2] DNV. 2021. "X1931-2 Load Shape and Coincidence Factor Research," Final Report.

[3] West Hill Energy and Computing (Aug. 8, 2019). "R1603 HES/HES-IE Impact Evaluation Final Realization Rates Memorandum."

[4] Cadmus. Oct. 18, 2020. "C1634 Impact Evaluation of PY 2016 & 2017 Energy Conscious Blueprint Program."

[5] Tetra Tech. Oct. 5, 2012. "2011 C&I Electric and Gas Free-ridership and Spillover Study," pp. 3-5. Table 3-6.

[6] EMI Consulting. 2019. "C1644: EO Net-to-Gross Study." Connecticut Energy Efficiency Board.

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

## ***Changes from Last Version***

- Updated coincidence factors.
- Formatting updates.

## 2.2.20 FUEL OPTIMIZATION

| | |
|---|---|
| Market | Commercial |
| Baseline Type | Retrofit |
| Category | HVAC and Water Heating |

### ***Description***

Addition of heat pump partially or fully displacing existing HVAC. Unit savings are deemed based on a model developed to estimate the savings associated with the displacement of existing heating (and cooling) systems by CBECS building type.

### ***Annual Energy Savings Algorithm***

*Annual Gross Energy Savings, Electric*

$$\Delta kWh = CAP \times SF$$

*Annual Gross Energy Savings, Fossil Fuel*

$$\Delta \text{MMBtu} = CAP \times SF$$

*Gross Seasonal Peak Demand Savings, Electric*

$$\Delta kW_{Winter} = CAP \times SF \times CF_{Winter}$$

$$\Delta kW_{Summer} = CAP \times SF \times CF_{Summer}$$

### ***Calculation Parameters***

**Table 2-153 Calculation Parameters**

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| ΔkWh | Annual gross energy savings, electric | Calculated | kWh | |
| ΔMMBtu | Annual gross energy savings, fossil fuel | Calculated | MMBtu | |
| $\Delta kW_{Winter}$ | Gross winter peak demand savings | Calculated | kW | |
| $\Delta kW_{Winter}$ | Gross summer peak demand savings | Calculated | kW | |
| CAP | Installed unit capacity | Site-specific | Tons | |
| SF | Savings factor | Lookup in Table 2-154 | kWh/Ton or MMBtu/Ton | |

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| $CF_{Winter}$ | Winter coincidence factor | Lookup in Table 2-155 | N/A | |
| $CF_{Summer}$ | Summer coincidence factor | Lookup in Table 2-155 | N/A | |

**Table 2-154 Savings Factors**

| Proposed Measure | Electric SF (kWh/yr/ton) | Demand SF (kW/yr/ton) | Gas SF (MMBtu/yr/ton) | Oil SF (MMBtu/yr/ton) | Propane SF (MMBtu/yr/ton) |
|---|---|---|---|---|---|
| ASHP <5.4 tons, fully displacing electric | 2,583 | 0.000 | N/A | N/A | N/A |
| ASHP <5.4 tons, fully displacing oil | -2,473 | -1.286 | N/A | 22.77 | N/A |
| ASHP <5.4 tons, fully displacing propane | -2,473 | -1.286 | N/A | N/A | 20.55 |
| ASHP <5.4 tons, fully displacing gas | -2,418 | -1.286 | 20.10 | N/A | N/A |
| ASHP >5.4 tons, fully displacing electric | 2,583 | 0.000 | N/A | N/A | N/A |
| ASHP >5.4 tons, fully displacing oil | -2,473 | -1.286 | N/A | 22.77 | N/A |
| ASHP >5.4 tons, fully displacing propane | -2,473 | -1.286 | N/A | N/A | 20.55 |
| ASHP >5.4 tons, fully displacing gas | -2,418 | -1.286 | 20.10 | N/A | N/A |
| VRFHP fully displacing electric | 3,546 | 0.000 | N/A | N/A | N/A |
| VRFHP fully displacing oil | -1,801 | -0.936 | N/A | 22.77 | N/A |

| Proposed Measure | Electric SF (kWh/yr/ton) | Demand SF (kW/yr/ton) | Gas SF (MMBtu/yr/ton) | Oil SF (MMBtu/yr/ton) | Propane SF (MMBtu/yr/ton) |
|---|---|---|---|---|---|
| VRFHP fully displacing propane | -1,801 | -0.936 | N/A | N/A | 20.55 |
| VRFHP fully displacing gas | -1,761 | -0.936 | 20.10 | N/A | N/A |
| GSHP fully displacing electric | 3,439 | 0.000 | N/A | N/A | N/A |
| GSHP fully displacing oil | -1,857 | -0.966 | N/A | 22.77 | N/A |
| GSHP fully displacing propane | -1,857 | -0.966 | N/A | N/A | 20.55 |
| GSHP fully displacing gas | -1,816 | -0.966 | 20.10 | N/A | N/A |
| ASHP <5.4 tons, partially displacing electric | 3,346 | 0 | N/A | N/A | N/A |
| ASHP <5.4 tons, partially displacing oil | -2,160 | -0.621 | N/A | 19.41 | N/A |
| ASHP <5.4 tons, partially displacing propane | -2,160 | -0.621 | N/A | N/A | 17.52 |
| ASHP <5.4 tons, partially displacing gas | -2,112 | -0.621 | 17.13 | N/A | N/A |
| ASHP >5.4 tons, partially displacing electric | 3,346 | 0 | N/A | N/A | N/A |
| ASHP >5.4 tons, partially displacing oil | -2,160 | -0.621 | N/A | 19.41 | N/A |
| ASHP >5.4 tons, partially displacing propane | -2,160 | -0.621 | N/A | N/A | 17.52 |
| ASHP >5.4 tons, partially displacing gas | -2,112 | -0.621 | 17.13 | N/A | N/A |

| Proposed Measure | Electric SF (kWh/yr/ton) | Demand SF (kW/yr/ton) | Gas SF (MMBtu/yr/ton) | Oil SF (MMBtu/yr/ton) | Propane SF (MMBtu/yr/ton) |
|---|---|---|---|---|---|
| VRFHP partially displacing electric | 4,595 | 0 | N/A | N/A | N/A |
| VRFHP partially displacing oil | -1,573 | -0.452 | N/A | 19.41 | N/A |
| VRFHP partially displacing propane | -1,573 | -0.452 | N/A | N/A | 17.52 |
| VRFHP partially displacing gas | -1,573 | -0.452 | 17.13 | N/A | N/A |
| Air to water HP Displacing Oil | -1,849 | -0.53 | N/A | 17.78 | N/A |
| Air to water HP Displacing Propane | -1849 | -0.53 | N/A | N/A | 17.78 |
| Air to water HP Displacing Gas | -1849 | -0.53 | 17.78 | N/A | N/A |

## ***Measure Life***

The measure life for fuel optimization is 15  years, with an exception to ground source heat pump (it is 25 years).

## ***Peak Factors***

**Table 2-155 Peak Factors**

| Measure | Summer Coincidence Factor | Winter Coincidence Factor | Ref |
|---|---|---|---|
| Unitary A/C and heat pumps | 42% | 0.01% | [4] |
| Water and ground source heat pumps | 82% | 82% | [4] |

## ***Load Shapes***

**Table 2-156 Load Shapes**

| Measure | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % | Ref |
|---|---|---|---|---|---|
| Partial Replacement Fuel Optimization | 43.1% | 56.9% | 0% | 0% | [3] |

## *Non-Energy Impacts*

There are no other resource impacts identified for this measure.

## *Realization Rates*

**Table 2-157 Realization Rates**

| | Gross Realization % | | | | FR & SO | | Net Realization % | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Measure | kWh | Winter Seasonal Peak kW | 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 |
| Fuel Optimization | 100% | 100% | 100% | 100% | 25% | 9% | 84% | 84% | 84% | 84% |

## *References*


[1] Guidehouse. 2021. “Energy Optimization Fuel Displacement Impact and Process Study” (MA20R24-B-EOEVAL).

[2] GDS Associates Inc. 2007. “Measure Life Report, Residential and Commercial Industrial Lighting and HVAC Measures.” Table 2. New England State Program Working Group (SPWG).

[3] DNV. 2021. “X1931-2 Load Shape and Coincidence Factor Research.” Connecticut Energy Efficiency Board (EEB) and Evaluation Administrators.


## *Changes from Last Version*

Added missing measures related to partial displacement and added air to water heat pump.

## 2.3 MOTORS AND TRANSFORMERS

### 2.3.1 HVAC VARIABLE FREQUENCY DRIVES

| | |
|---|---|
| Market | Commercial |
| Baseline Type | Retrofit |
| Category | Motors & Transformers |

***Description***

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.

The baseline is a constant speed fan [an Air Foil (AF), Backward Inclined (BI), and Forward Curved (FC)] with or without inlet guide vanes or a constant speed/flow centrifugal pump. ASHRAE default performance curves are used to calculate the power for both the baseline equipment (constant speed) and the proposed equipment (variable speed) over the annual load profile[1]. 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.

The constants in Table 2-159 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 ASHRAE 90.1-1989 [1].

***Annual Energy Savings Algorithm***

*Retrofit Gross Energy Savings, Electric*

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

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

$$\Delta kW_{Summer} = \frac{BHP}{EFF_i} \times SF_{kW,S}$$

$$\Delta kW_{Winter} = \frac{BHP}{EFF_i} \times SF_{kW,W}$$

## *Calculation Parameters*

**Table 2-158 Calculation Parameters**

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| $\Delta kWh$ | Gross annual electric energy savings | Calculated | kWh | |
| $\Delta kW_{Summer}$ | Summer seasonal peak demand savings | Calculated | kW | |
| $\Delta kW_{Winter}$ | Winter seasonal peak demand savings | Calculated | kW | |
| BHP | System brake horsepower | Site-specific, if unknown estimate as BHP = Nominal HP x 65% LF | HP | |
| $EFF_i$ | Motor efficiency – installed | Site-specific | % | |
| H | Annual hours of operation | Site specific or lookup in Table 2-160 | Hours | |
| $SF_{kWh}$ | Annual kilowatt-hour savings factor based on typical load profile for application | Lookup in Table 2-159 | kW/HP | |
| $SF_{kW,S}$ | Summer seasonal demand savings factor based on typical load profile for application | Lookup in Table 2-159 | kW/HP | |
| $SF_{kW,W}$ | Winter seasonal demand savings factor based on typical load profile for application | Lookup in Table 2-159 | kW/HP | |

**Table 2-159 HVAC Fan VFD Savings Factor**

| 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 |

**Table 2-160 Hours of Use* [6]**

| Facility Type | HVAC Fan Motor | CHWP & Cooling Towers | Heating Pumps | Facility Type | HVAC Fan Motor | CHWP & Cooling Towers | Heating Pumps |
|---|---|---|---|---|---|---|---|
| Auto related | 6,421 | 1,442 | 2,484 | Manufacturing facility | 4,618 | 1,037 | 1,787 |
| Bakery | 4,618 | 1,037 | 1,787 | Medical office [5] | 4,795 | 1,077 | 1,855 |
| Banks, financial center† | 5,519 | 2,732 | 5,629 | Motion picture theatre [7] | 5,737 | 1,289 | 2,220 |
| Church | 3,493 | 785 | 1,351 | Multifamily (common areas) | 3,833 | 3,833 | 3,833 |
| College: cafeteria | 5,835 | 1,311 | 2,258 | Museum [7] | 5,737 | 1,289 | 2,220 |
| College: classes/administrative† | 5,995 | 2,357 | 6,471 | Nursing home [7] | 8,760 | 4,470 | 8,760 |
| College: dormitory | 3,833 | 3,833 | 3,833 | Office (general office types) | 4,795 | 1,077 | 1,855 |
| Commercial condo [5] | 8,760 | 4,470 | 8,760 | Office/retail | 4,795 | 1,077 | 1,855 |
| Convenience store [5] | 5,207 | 1,170 | 2,015 | Parking garage and lot | 6,421 | 1,442 | 2,484 |
| Convention center | 8,760 | 4,470 | 8,760 | Penitentiary [7] | 8,760 | 4,470 | 8,760 |
| Court house† [5] | 5,519 | 2,732 | 5,629 | Performing arts theatre | 5,737 | 1,289 | 2,220 |
| Dining: bar lounge/leisure [5] | 5,264 | 1,183 | 2,037 | Police/fire station (24 Hr.) | 6,778 | 2,774 | 5,308 |
| Dining: cafeteria/fast food [5] | 5,835 | 1,311 | 2,258 | Post office | 4,795 | 1,077 | 1,855 |
| Dining: family [5] | 5,264 | 1,183 | 2,037 | Pump station [7] | 2,241 | 2,097 | 4,828 |
| Entertainment [7] | 5,737 | 1,289 | 2,220 | Refrigerated warehouse [5] | 3,604 | 810 | 1,394 |
| Exercise center [7] | 5,737 | 1,289 | 2,220 | Religious building | 3,493 | 785 | 1,351 |
| Fast food restaurant [5] | 5,835 | 1,311 | 2,258 | Residential (excl. nursing homes) [7] | 3,833 | 3,833 | 3,833 |
| Fire station (unmanned) [5] | 3,833 | 3,833 | 3,833 | Restaurant [5] | 5,264 | 1,183 | 2,037 |
| Food store | 4,545 | 1,021 | 1,758 | Retail [5] | 5,207 | 1,170 | 2,015 |
| Gymnasium [7] | 5,737 | 1,289 | 2,220 | School/university† | 5,995 | 2,357 | 6,471 |
| Hospital† | 8,683 | 7,682 | 8,760 | Schools (Jr./Sr. High)† | 2,241 | 2,097 | 4,828 |
| Hospitals/health care† | 8,683 | 7,682 | 8,760 | Schools (preschool/elementary)† | 3,851 | 865 | 1,490 |
| Industrial: 1 shift | 4,618 | 1,037 | 1,787 | Schools (technical/vocational)† | 5,098 | 2,170 | 5,620 |
| Industrial: 2 shift | 6,771 | 1,037 | 2,620 | Small services | 4,795 | 1,077 | 1,855 |
| Industrial: 3 shift | 8,760 | 1,037 | 3,466 | Sports arena | 5,737 | 1,289 | 2,220 |
| Laundromat [7] | 5,207 | 1,170 | 2,015 | Town hall | 5,737 | 1,289 | 2,220 |
| Library [7] | 5,737 | 1,289 | 2,220 | Transportation [7] | 6,421 | 1,442 | 2,484 |
| Light manufacturer | 4,618 | 1,037 | 1,787 | Warehouse (not refrigerated) | 3,604 | 810 | 1,394 |
| Lodging (hotel/motel) | 3,421 | 769 | 1,324 | Wastewater treatment plant [7] | 2,241 | 2,097 | 4,828 |
| Mall concourse† | 4,690 | 3,013 | 4,932 | Workshop [7] | 4,618 | 1,037 | 1,787 |

* Developed based on simulation of DOE-2 commercial building prototypes in eQUEST using Hartford weather data.

† Results are based on VAV systems with economizers.

## ***Measure Life***

| Equipment Type | Retrofit | Lost Opportunity | Ref |
|---|---|---|---|
| Variable frequency drive | Remaining life of underlying equipment (estimate as 1/3 of host equipment measure life if unknown) | 15 | [5] |

## ***Peak Factors***

**Table 2-161 Peak Factors**

| Measure | Summer Coincidence Factor | Winter Coincidence Factor | Ref |
|---|---|---|---|
| HVAC variable frequency drives - Fans | 15% | 11% | [7] |
| HVAC variable frequency drives - CHWP | 13% | 5% | [7] |
| HVAC variable frequency drives - HWP | 12% | 38% | [7] |

## ***Load Shapes***

**Table 2-162 Load Shapes**

| Measure | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % | Ref |
|---|---|---|---|---|---|
| Motors | 31.74% | 36.49% | 15.77% | 15.99% | [7] |

## ***Realization Rates***

**Table 2-163 Realization Rates**

| | Gross Realization % | | | FR & SO | | Net Realization % | | | |
|---|---|---|---|---|---|---|---|---|---|
| Measure | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Free-ridership | Spill-over | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | |
| Motors [3], [4] | 98.5% | 106.3%[3] | 97.4% | 18.2% | 7.1% | 87.6% | 94.5% | 86.6% | |

## ***References***


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

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

[3] Cadmus, C1634 Impact Evaluation of PY 2016 & 2017 Energy Conscious Blueprint Program, Oct. 18, 2020.

[4] Tetra Tech, 2011 C&I Electric and Gas Free-ridership and Spillover Study, Oct. 5, 2012. pp. 3-4, see Table 3-5.

[5] EMI, Evaluation of the Energy Opportunities Program: Program Year 2011, Apr. 1, 2014. p. ES-5, see Table 1-1.

[6] DNV. 2021. "PSD HOU/FLH Documentation and Update Study." Connecticut Energy Efficiency Board (EEB) and Evaluation Administrators.

[7] DNV. 2021. "X1931-2 Load Shape and Coincidence Factor Research." Connecticut Energy Efficiency Board (EEB) and Evaluation Administrators.


## ***Changes from Last Version***

- Formatting updates.

## 2.4 REFRIGERATION

### 2.4.1 COOLER NIGHT COVERS

| | |
|---|---|
| Market | Commercial |
| Baseline Type | Retrofit |
| Category | Refrigeration |

***Description***

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.

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 [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).

***Annual Energy Savings Algorithm***

*Retrofit Gross Energy Savings, Electric*

$$\Delta kWh = W \ \times H \times SF$$

*Retrofit Gross Seasonal Peak Demand Savings, Electric*

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

***Calculation Parameters***

**Table 2-164 Calculation Parameters**

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| ΔkWh | Annual gross electric energy savings | Calculated | kWh/yr | |
| H | Hours per year the cover are in use | Site-specific | N/A | |
| W | Width of the opening that the covers protect, ft. | Site-specific | N/A | |

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| SF | Savings factor based on the temperature of the case | Table 2-165 | kW/ft | |
| W | Width of the opening that the covers protect | ft | ft | |

**Table 2-165 Savings Factor Based on Case Temperature [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 |

## ***Peak Factors***

There are no peak factors for these measures because covers will not be in use during peak periods.

## ***Load Shapes***

**Table 2-166 Load Shapes**

| Measure Type | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % | Ref |
|---|---|---|---|---|---|
| Refrigeration | 29.95% | 36.58% | 15.95% | 17.51% | |

## ***Realization Rates and Net Impact Factors***

**Table 2-167 Realization Rates and Net Impact Factors**

| | Gross Realization % | | | FR & SO | | Net Realization % | | | |
|---|---|---|---|---|---|---|---|---|---|
| Measure | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Free-ridership | Spill-over | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Ref |
| Refrigeration **Energy Conscious Blueprint** | 98.5% | 106.3% | 97.4% | 3.6% | 25.9% | 120.5% | 130.0% | 119.1% | [2], [3] |

## *References*


[1] Southern California Edison Refrigeration Technology and Test Center Energy Efficiency Division. Aug. 8, 1997. "Effects of the Low Emissivity Shields on Performance and Power Use of a Refrigerated Display Case."

[2] Tetra Tech. 2012. "2011 C&I Electric and Gas Free-ridership and Spillover Study." Table 3-5. Connecticut Energy Efficiency Fund.

[3] The Cadmus Group, Inc. 2020 . "C1634 Impact Evaluation of PY 2016 & 2017 Energy Conscious Blueprint Program." Connecticut Energy Efficiency Board (EEB) and Evaluation Administrators.


## *Changes from Last Version*

- Formatting updates.

## 2.4.2 EVAPORATOR FAN CONTROLS

| | |
|---|---|
| Market | Commercial |
| Baseline Type | Retrofit |
| Category | Refrigeration |

### *Description*

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.

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.

**Notes:** 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 2.4.3 to ensure the ending point of one measure (fan power/hours) is the starting point for the other.

Fan off-hours after measure installation (h) is based on correspondence with Nick Gianakos, Nicholas Group, P.C., Jun. 27, 2010.

Refrigeration interactive factors are derived from [1] and correspondence with Nick Gianakos, Nicholas Group, P.C., Jun. 27, 2010.

### *Annual Energy Savings Algorithm*

*Annual Gross Energy Savings, Electric*

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

$$\Delta kWh = N \times V \times A \times Pf \times r \times (1 - DP) \times \frac{h}{1{,}000\, {}^{W}/_{kW}} \times \left(1 + \frac{1}{ACOP}\right)$$

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

$$\Delta kWh = N \times V \times A \times \sqrt{3} \times Pf \times r \times (1 - DP) \times \frac{h}{1{,}000\, {}^{W}/_{kW}} \times \left(1 + \frac{1}{ACOP}\right)$$

If existing EERs are available, calculate ACOP as follows, otherwise lookup in Table 2-169:

$$ACOP = \frac{Average\ EER}{3.413}$$

$$Average\ EER = \frac{Full\ load\ EER}{0.85}$$

*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:

$$\Delta kWs = \frac{\Delta kWh}{8760} xCFs$$

$$\Delta kWw = \frac{\Delta kWh}{8760} xCFw$$

## ***Calculation Parameters***

**Table 2-168 Calculation Parameters**

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| ΔkWh | Annual gross electric energy savings | Calculated | kWh | |
| ΔkWs | Summer seasonal peak kW | Calculated | kW | |
| ΔkWw | Winter seasonal peak kW | Calculated | kW | |
| N | Number of fans | Site-specific | N/A | |
| A | Amperage of existing fans | Site-specific | Amps | |
| EER | Energy Efficiency Ratio | Site-specific | Btuh/W | |
| V | Volts of existing fans | Site-specific | Volts | |
| ACOP | Average coefficient of performance | Calculated or lookup in Table 2-169 | N/A | [8] |
| DP | Power reduction factor | Table 2-170 | % | |
| PF | Power factor of existing fans | 0.65 | N/A | |
| r (on/off controllers) | Adjustment factor for on/off controllers | 1 | N/A | |
| r (two speed controllers) | Adjustment factor for two speed controllers | 0.86 | N/A | |
| h | Fan off hours after measure installation | 3,000 | N/A | |
| CFs | Summer Seasonal peak demand coincident factor for refrigeration | Table 2-171 | N/A | |

| Variable | Description | Value | Units | Ref |
| --- | --- | --- | --- | --- |
| CFw | Winter  Seasonal peak demand coincident factor for refrigeration | Table 2-171 | N/A | |

**Table 2-169 ACOP Values**

| Equipment | ACOP | Ref |
| --- | --- | --- |
| Cooler | 3.35 | [8] |
| Freezer | 1.88 | [8] |

**Table 2-170 Power Reduction Factors**

| Description | DP |
| --- | --- |
| Evaporator fan controls added concurrently with replacement of PSC fan motors | 0.40 |
| Evaporated fan controls added concurrently with replacement of shaded pole fan motors | 0.65 |
| Fan motors not replaced with addition of evaporator fan controls, or if volt/amp readings taken after fans replaced | 0 |

## ***Measure Life***

The measure life for evaporator fan controls is 10 years [2].

## ***Peak Factors***

**Table 2-171 Peak Factors**

| Measure | Summer Coincidence Factor | Winter Coincidence Factor | Ref |
| --- | --- | --- | --- |
| Evaporator fan controls | 97.4%* | 98.2%* | [3] |

* Values denoted with an asterisk are relative to average demand savings. Average demand savings is defined as total energy (kWh) savings divided by 8760. Data available during X1931-2 did not include sufficient detail to calculate maximum connected loads for each profile, which necessitated the use of seasonal peak coincidence factors relative to average demand.

## ***Load Shapes***

**Table 2-172 Load Shapes**

| Measure Type | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % | Ref |
| --- | --- | --- | --- | --- | --- |
| Refrigeration | 29.95% | 36.58% | 15.95% | 17.51% | [3] |

## *Realization Rates and Net Impact Factors*

**Table 2-173 Realization Rates and Net Impact Factors**

| | Gross Realization % | | | FR & SO | | Net Realization % | | | |
|---|---|---|---|---|---|---|---|---|---|
| Measure | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Free-ridership | Spill-over | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Ref |
| Refrigeration **Energy Opportunities** | 67.6% | 162.1% | 114.7% | 13.0% | 0.0% **Error! Reference source not found.** | 58.8% | 141.0% | 99.8% | [4], |
| Refrigeration **Small Business Energy Advantage** | 72.0% | 73.0% | 85.0% | 1.4% | 0.0% | 71.0% | 72.0% | 83.8% | [6], [7] |

## *References*


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

[2] Energy & Resource Solutions. Oct 10, 2005. "Measure Life Study." Prepared for the Massachusetts Joint Utilities. Table 101.

[3] DNV. 2021. "X1931-2 Load Shape and Coincidence Factor Research," Final Report.

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

[5] EMI. Consulting. 2019. "C1644: EO Net-to-Gross Study." Connecticut Energy Efficiency Board.

[6] ERS. Mar. 20, 2018. "C1639: Impact Evaluation of the Connecticut Small Business Energy Advantage Program."

[7] Tetra Tech. Oct. 5, 2012. "2011 C&I Electric and Gas Free-ridership and Spillover Study." pp. 3-4, see Table 3-5.

[8] DNV. May 12, 2022. "X1931-5 PSD Commercial Refrigeration Efficiency Update Study." Connecticut Energy Efficiency Board (EEB) and Evaluation Administrators.


## *Changes from Last Version*

- Update ACOP values.
- Formatting updates.

## 2.4.3 EVAPORATOR FANS MOTOR REPLACEMENT

| | |
|---|---|
| Market | Commercial |
| Baseline Type | Retrofit |
| Category | Refrigeration |

### ***Description***

Replacement of an existing integral electric motor i.e., Shaded Pole (SP), Permanent Split Capacitor (PSC) or Electronically Commutated (EC) motor connected to evaporator fans in walk-in coolers, freezers, and reach-in display coolers with high efficiency EC or Permanent Magnet Synchronous (PMS) motor.

The savings estimates are based on the wattage reduction from replacing an existing PSC or SP motor with an EC or PMS motor or EC to PMS motor. Interactive refrigeration savings are also achieved due to reduced heat loads resulting from fan power reduction. To determine the energy savings associated with the PMS Motor, field study results are used. [2], [11]

- Power reduction factors of existing fans are based on correspondence with a National Resource Management (NRM) representative on Mar. 3 and Jun. 6, 2011.
- Fan off hours after measure installation (h) is based on correspondence with Nick Gianakos, Nicholas Group, P.C., Jun. 27, 2010. If fan controls are being installed concurrently with this measure, then savings calculation for this measure should be coordinated with Measure 2.4.2 to ensure the ending point of one measure (fan power/hours) is the starting point for the other.
- ACOP values are derived from x1931-5 Commercial Refrigeration Efficiency Update Study. Annual Energy Savings Algorithm

*Retrofit Gross Energy Savings, Electric*

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

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

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

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

Where ACOP can be found in lookup ACOP in Table 2-178 , but if EER is readily available ACOP can be calculated using formulas below

$$ACOP = \frac{Average\ EER}{3.413}$$

$$Average\ EER = \frac{EER}{0.85}$$

*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:

$$\Delta kW = \frac{\Delta kWh}{8760\frac{hr}{yr}} \times CF$$

## ***Calculation Parameters***

**Table 2-174 Calculation Parameters**

| Symbol | Description | Values | Units | Ref |
|---|---|---|---|---|
| ΔkWh | Annual gross electric energy savings | Calculated | kWh | |
| ΔkW | Annual gross seasonal demand savings | Calculated | kW | |
| DP | Power reduction factor for converting existing motor to either EC or to PMS | Table 2-175 | N/A | [11] |
| N | Number of fans | Site-Specific | | |
| V | Volts of Existing fan | Site-Specific | Volts | |
| A | Amperage of existing fan | Site-Specific | Amp | |
| Pf | Power factor of existing fan | 0.65 | NA | Estimated |
| | | | | |
| EER | Energy Efficiency Ratio | Site-specific | Btuh/Watts | |
| ACOP | Average coefficient of performance (used for interactive effects) | Calculated or Table 2-178 | N/A | [5] |
| DP | Power reduction factor for converting existing motor to either EC or to PMS | Table 2-176 | N/A | [11] |
| CF | Seasonal peak demand coincident factor for refrigeration (same for summer and winter) | Table 2-179 | N/A | |
| h (existing controls) | Hours of operation, with existing controls | 5,500 | Hours | |
| h (no controls) | Hours of operation, without existing controls | 8,500 | Hours | |

**Table 2-177 DP Values**

| Existing Motor | Replacement Motor | DP |
|---|---|---|
| PSC | EC | 0.40 |
| SP | EC | 0.65 |
| SP | PMS | 0.79 |
| PSC | PMS | 0.49 |
| EC | PMS | 0.43 |

**Table 2-178 ACOP Values**

| Equipment | ACOP | Ref |
|---|---|---|
| Cooler | 3.35 | [5] |
| Freezer | 1.88 | [5] |

## ***Measure Life***

The measure life for commercial evaporative fan motor replacement is 15 years.

## ***Peak Factors***

**Table 2-179 Peak Factors**

| Measure | Summer Coincidence Factor | Winter Coincidence Factor | Ref |
|---|---|---|---|
| Evaporator fans motor replacement | 97.4%* | 98.2%* | [5] |

*Values denoted with an asterisk are relative to average demand savings. Average demand savings is defined as total energy (kWh) savings divided by 8760. Data available during X1931-2 did not include sufficient detail to calculate maximum connected loads for each profile, which necessitated the use of seasonal peak coincidence factors relative to average demand. Values which do not have an asterisk are relative to connected load or seasonal peak demand as outlined by the measure characterization in the 2022 PSD.

## ***Load Shapes***

**Table 2-180 Load Shapes**

| Measure Type | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % | Ref |
|---|---|---|---|---|---|
| Refrigeration | 29.95% | 36.58% | 15.95% | 17.51% | [6] |

## ***Realization Rates and Net Impact Factors***

**Table 2-181 Realization Rates and Net Impact Factors**

| | Gross Realization | | | FR & SO | | Net Realization | | | |
|---|---|---|---|---|---|---|---|---|---|
| Measure | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Free-Ridership | Spill-Over | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Ref |
| Refrigeration **Energy Opportunities** | 67.6% | 162.1% | 114.7% | 13.0% | 0.0% **Error! Reference source not found.** | 58.8% | 141.0% | 99.8% | [7], [10] |
| Refrigeration **Small Business Energy Advantage** | 72.0% | 73.0% | 85.0% | 1.4% | 0.0% | 71.0% | 72.0% | 83.8% | [8], [9] |

## ***References***


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

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

[3] Tetra Tech. Oct 5, 2012. "2011 C&I Electric and Gas Free-ridership and Spillover Study."

[4] Cadmus. Oct. 18, 2020. "C1634 Impact Evaluation of PY 2016 & 2017 Energy Conscious Blueprint Program."

[5] DNV. May 12, 2022. "X1931-5 PSD Commercial Refrigeration Efficiency Update Study." Connecticut Energy Efficiency Board (EEB) and Evaluation Administrators.

[6] DNV. 2021. "X1931-2 Load Shape and Coincidence Factor Research." Connecticut Energy Efficiency Board (EEB) and Evaluation Administrators.

[7] EMI Consulting. 2019. "C1644: EO Net-to-Gross Study." Connecticut Energy Efficiency Board.

[8] ERS. 2018. "C1639: Impact Evaluation of the Connecticut Small Business Energy Advantage Program."

[9] Tetra Tech. 2012. "2011 C&I Electric and Gas Free-ridership and Spillover Study." pp. 3-4, see Table 3-5.

[10] DNV GL. 2020. "C1635 Impact Evaluation of PY 2016 & 2017 Energy Opportunities (EO) Program". Tables 6-11. Connecticut Energy Efficiency Board (EEB) and Evaluation Administrators.

[11] Becker, B.R, and Fricke B.A. 2019. "Permanent Magnet Synchronous Motors for Commercial Refrigeration: Final Report," Oak Ridge National Laboratory. https://info.ornl.gov/sites/publications/Files/Pub115680.pdf.


## ***Changes from Last Version***

- Updated measure to include Permanent Magnet Synchronous (PMS) motors.
- Updated ACOP values.
- Formatting updates.
- Updated the savings to use N, V, A, Pf parameters.

## 2.4.4 DOOR HEATER CONTROLS

| | |
|---|---|
| Market | Commercial |
| Baseline Type | Retrofit |
| Category | Refrigeration |

### ***Description***

Installation of an on/off or micro-pulse control system to an existing facility where door heaters operate continuously. This measure is applicable to walk-in coolers and freezers that have electric heaters on their doors whose purpose is to prevent condensation from forming.

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

The algorithms presented below assume single-phase power.

### ***Annual Energy Savings Algorithm***

Retrofit Gross Energy Savings, Electric

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

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

$$\Delta kW = \frac{\Delta kWh}{8760 \frac{Hrs}{yr}} \times CF$$

### ***Calculation Parameters***

**Table 2-182 Calculation Parameters**

| Symbol | Description | Values | Units | Ref |
|---|---|---|---|---|
| ΔkW | Annual summer and winter electric demand savings | Calculated | kW | |
| ΔkWh | Annual gross electric energy savings | Calculated | kWh | |

| Symbol | Description | Values | Units | Ref |
|---|---|---|---|---|
| ACOP | Average Coefficient of Performance (cooler or freezer) | Calculated or Table 2-183 | | [7] |
| A | Amperage of door heater | Site-specific | Amps | |
| V | Volts of door heater | Site-specific | Volts | |
| N | Number of heaters | Site-specific | N/A | |
| Pf | Power factor (assumed) | 1 | N/A | |
| CF | Seasonal peak demand coincident factor for refrigeration (same for summer and winter) | Table 2-184 | N/A | [6] |
| h | Heater off-hours after measure installation | 2,786 | Hours | [1] |
| h | Heater off-hours after measure installation for micro-pulse system | 4,196 | Hours | [1] |

**Table 2-183 Cooler and Freezer ACOP Values**

| Equipment | ACOP | Ref |
|---|---|---|
| Cooler | 3.35 | [7] |
| Freezer | 1.88 | [7] |

## ***Measure Life***

The measure life for commercial door heater controls is 10 years.

## ***Peak Factors***

**Table 2-184 Peak Factors**

| Measure | Summer Coincidence Factor | Winter Coincidence Factor | Ref |
|---|---|---|---|
| Door heater controls | 97.4%* | 98.2%* | [6] |

*Values denoted with an asterisk are relative to average demand savings. Average demand savings is defined as total energy (kWh) savings divided by 8760. Data available during X1931-2 did not include sufficient detail to calculate maximum connected loads for each profile, which necessitated the use of seasonal peak coincidence factors relative to average demand. Values which do not have an asterisk are relative to connected load or seasonal peak demand as outlined by the measure characterization in the 2022 PSD.

## ***Load Shapes***

**Table 2-185 Load Shapes**

| Measure Type | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % | Ref |
|---|---|---|---|---|---|
| Refrigeration | 29.95% | 36.58% | 15.95% | 17.51% | [6] |

## *Realization Rates and Net Impact Factors*

**Table 2-186 Realization Rates and Net Impact Factors**

| | Gross Realization | | | FR & SO | | Net Realization % | | | |
|---|---|---|---|---|---|---|---|---|---|
| Measure | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Free-Ridership | Spill-Over | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Ref |
| Refrigeration **Energy Opportunities** | 67.6% | 162.1% | 114.7% | 13.0% | 0.0% | 58.8% | 141.0% | 99.8% | [2], [3] |
| Refrigeration **Small Business Energy Advantage** | 72.0% | 73.0% | 85.0% | 1.4% | 0.0% | 71.0% | 72.0% | 83.8% | [4], [5] |

## *References*


[1] Cadmus. 2015. "Commercial Refrigeration Load Shape Project." Northeast Energy Efficiency Partnerships.

[2] EMI Consulting. 2019. "C1644: EO Net-to-Gross Study." Connecticut Energy Efficiency Board.

[3] DNV GL. 2020. "C1635 Impact Evaluation of PY 2016 & 2017 Energy Opportunities (EO) Program". Tables 6-11. Connecticut Energy Efficiency Board (EEB) and Evaluation Administrators.

[4] Tetra Tech. 2012. "2011 C&I Electric and Gas Free-ridership and Spillover Study."

[5] ERS. 2018. "C1639: Impact Evaluation of the Connecticut Small Business Energy Advantage Program."

[6] DNV. 2021. "X1931-2 Load Shape and Coincidence Factor Research." Connecticut Energy Efficiency Board (EEB) and Evaluation Administrators.

[7] DNV. 2022. "X1931-5 PSD Commercial Refrigeration Efficiency Update Study." Connecticut Energy Efficiency Board.


## *Changes from Last Version*

- Revised peak seasonal demand savings equation to include CF term.
- Update ACOP values.

## 2.4.5 VENDING MACHINE CONTROLS

| | |
|---|---|
| Market | Commercial |
| Baseline Type | Retrofit |
| Category | Refrigeration |

### ***Description***

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.

### ***Annual Energy Savings Algorithm***

*Retrofit Gross Energy Savings, Electric*

$$\Delta kWh = \frac{WATTS_{base}}{1000} \times HOURS \times ESF \times N$$

To calculate the connected kW ($WATTS_{base}$) when the values of amperage and voltage are known:

$$WATTS_{base} = V \times A \times PF$$

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

$$\Delta kW_S = 0$$

$$\Delta kW_W = 0$$

Note: The peak period is assumed to be coincident with periods of high traffic diminishing the demand reduction potential of occupancy-based or time schedule-based controls.

## ***Calculation Parameters***

**Table 2-187 Calculation Parameters**

| Symbol | Description | Values | Units | Ref |
|---|---|---|---|---|
| ΔkWh | Annual gross electric energy savings | Calculated | kWh | |
| $\Delta kW_W$ | Winter demand savings | 0 | kW | |
| $\Delta kW_S$ | Summer demand savings | 0 | kW | |
| N | Number of vending machines | Site-specific | N/A | |
| A | Amperage of vending machine | Site-specific | amps | |
| V | Volts of vending machine | Site-specific | volts | |
| $HOURS_{after}$ | Hours vending machine turned on after measure installation | Site-specific | Hours | |
| $WATTS_{base}$ | Connected kW of the controlled equipment | Lookup in Table 2-188 | W | |
| ESF | Energy savings factor, represents the percent reduction in annual kWh consumption of the equipment controlled | Lookup in Table 2-189 and Table 2-190 | N/A | |
| HOURS | Hours vending machine turned on before measure installation | 8,760 | hours | |
| PF | Power factor | 0.85 | N/A | |

**Table 2-188 Connected Wattage of Vending Machines**

| Equipment Type | $WATTS_{base}$ | Ref |
|---|---|---|
| Refrigerated beverage vending machines | 400 | [1] |
| Non-refrigerated snack vending machines | 85 | [1] |
| Glass front refrigerated coolers | 460 | [1] |
| Custom calculation | V x A x PF | |

**Table 2-189 Occupancy-Based Controls**

| Equipment Type | Energy Savings Factor (ESF) | Ref |
|---|---|---|
| Refrigerated beverage vending machines | 0.46 | [1] |
| Non-refrigerated snack vending machines | 0.46 | [1] |
| Glass front refrigerated coolers | 0.30 | [1] |

**Table 2-190 Time Schedule-Based Controls**

| Equipment Type | Energy Savings Factor (ESF) | Notes |
|---|---|---|
| All | $1 - \frac{HOURS_{after}}{HOURS} \times 0.45$ | 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 |

## ***Calculation Examples***

*Retrofit of Occupancy Controls on Refrigerated Beverage Vending Machine*

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

$$\Delta kWh = \frac{WATTS_{base}}{1000} \times HOURS \times ESF \times N$$

From Table 2-189, $WATTS_{base}$ = 400 W; From Table 2-190, ESF = 0.46.

$$\Delta kWh = \frac{400}{1000} \times 8{,}760 \times 0.46 \times 2 = 3{,}223.7\ kWh$$

*Retrofit of On/Off Timer on a Glass Refrigerated Cooler*

*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:*

$$\Delta kWh = \frac{WATTS_{base}}{1000} \times HOURS \times ESF \times N$$

$$WATTS_{base} = V \times A \times PF = 120 \times 4.2 \times 0.85 = 428\ W$$

$$ESF = 1 - \frac{HOURS_{after}}{HOURS} \times 0.45$$

$$HOURS_{after} = 8{,}760 - (365 \times 11) = 4{,}745\ hrs$$

$$ESF = \left(1 - \frac{4{,}745}{8{,}760}\right) \times 0.45 = 0.2065$$

$$\Delta kWh = \frac{428}{1000} \times 8{,}760 \times 0.2065 \times 1 = 774\ kWh$$

## *Measure Life*

**Table 2-191 Measure Life**

| Equipment Type | Measure Life | Ref |
|---|---|---|
| Vending machine occupancy sensor | 5 | [4] |

## *Peak Factors*

**Table 2-192 Peak Factors**

| Measure | Summer Coincidence Factor | Winter Coincidence Factor | Ref |
|---|---|---|---|
| Vending machine controls | 0% | 0% | |

## *Load Shapes*

**Table 2-193 Load Shapes**

| Measure | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % | Ref |
|---|---|---|---|---|---|
| Refrigeration | 29.95% | 36.58% | 15.95% | 17.51% | |

## *Realization Rates*

**Table 2-194 Realization Rates**

| | Gross Realization % | | | FR & SO | | Net Realization % | | |
|---|---|---|---|---|---|---|---|---|
| Measure | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Free-ridership | Spill-over | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW |
| Refrigeration [4], [3] Energy Conscious Blueprint | 98.5% | 106.3%[4] | 97.4% | 3.6% | 25.9% | 120.5% | 130.0% | 119.1% |

## *References*


[1] Energy Misers – Vending Miser, available online at: https://api-plus.anbetrack.com/etrm-gateway/etrm/api/v1/etrm/documents/5ee488706996f2eb697df798/view?authToken=70f5b5a642bfa0b18681729ba0fc47aec714e4bf090c5d97fdce94b3ab363181213da48fbd5fa5e3acf59f969a63f951842c5997af787459e6035e879d16034a5de99814755156.

[2] Tetra Tech, 2011 C&I Electric and Gas Free-ridership and Spillover Study, Oct. 5, 2012.

[3] Cadmus, C1634 Impact Evaluation of PY 2016 & 2017 Energy Conscious Blueprint Program, Oct. 18, 2020

[4] Energy & Resource Solutions. ERS Measure Life Study.: Prepared for the Massachusetts Joint Utilities, Oct. 10, 2005.

## ***Changes Since Last Version***

- Formatting updates.
- Updated the Energy savings factor.

## 2.4.6 ADD DOORS TO REFRIGERATED DISPLAY CASES

| | |
|---|---|
| Market | Commercial |
| Baseline Type | Retrofit |
| Category | Refrigeration |

### *Description*

Installation of glass doors on open refrigerated display cases. The savings from this measure are based on an ASHRAE research project that compared the energy consumption of a new open refrigerated display case to that of a new refrigerated display case with glass doors [1]. 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].

**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.

### *Annual Energy Savings Algorithm*

*Annual Gross Energy Savings, Electric*

$$\Delta kWh = L \times SF_{\Delta kWh}$$

*Annual Gross Energy Savings, Natural Gas*

$$\Delta CCF = L \times SF_{\Delta CCF}$$

*Annual Gross Energy Savings, Oil*

$$\Delta Gal_{Oil} = L \times SF_{\Delta CCF} \times 0.742$$

*Annual Gross Energy Savings, Propane*

$$\Delta Gal_{Propane} = L \times SF_{\Delta CCF} \times 1.1267$$

*Gross Seasonal Peak Demand Savings, Electric*

$$\Delta kW_{summer} = L \times SF_{summer}$$

$$\Delta kW_{winter} = L \times SF_{winter}$$

*Gross Peak Day Savings, Natural Gas*

$$\Delta CCF_{PD} = L \times SF_{PD}$$

## Calculation Parameters

**Table 2-195 Calculation Parameters**

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| $\Delta kWh$ | Annual gross electric energy savings | Calculated | kWh/yr | |
| $\Delta CCF$ | Annual gross natural gas energy savings | Calculated | CCF/yr | |
| $\Delta Gal_{Oil}$ | Annual savings for oil heat | Calculated | Gal/yr | |
| $\Delta Gal_{Propane}$ | Annual savings for propane heat | Calculated | Gal/yr | |
| $\Delta CCF_{PD}$ | Peak day natural gas savings | Calculated | ccf | |
| $\Delta kW_{summer}$ | Summer demand savings | Calculated | kW | |
| $\Delta kW_{winter}$ | Winter demand savings | Calculated | kW | |
| L | Length of display case | Site-specific | feet | |
| $SF_{\Delta kWh}$ | Electric energy savings factor | Table 2-196, Table 2-197 | kWh/Foot | |
| $SF_{\Delta CCF}$ | Heating savings factor | Table 2-196, Table 2-197 | ccf/Foot | |
| $SF_{PD}$ | Peak day savings factor | Table 2-196, Table 2-197 | ccf/Foot | |
| $SF_{summer}$ | Summer demand savings factor | Table 2-196, Table 2-197 | kW/Foot | |
| $SF_{winter}$ | Winter demand savings factor | Table 2-196, Table 2-197 | kW/Foot | |

**Table 2-196 Electric and Gas Savings Factors for Coolers**

| Door Type | $SF_{summer}$ | $SF_{winter}$ | $SF_{\Delta kWh}$ | $SF_{\Delta CCF}$ | $SF_{PD}$ |
|---|---|---|---|---|---|
| Door heater | 0.00838 | 0.02083 | 160.681 | 24.389 | 0.14849 |
| Gap | 0.00838 | 0.02083 | 160.681 | 9.157 | 0.05575 |
| No door heater + No gap | 0.02232 | 0.05549 | 427.984 | 24.389 | 0.14849 |

**Table 2-197 Electric and Gas Savings Factors for Freezers**

| Door Type | $SF_{summer}$ | $SF_{winter}$ | $SF_{\Delta kWh}$ | $SF_{\Delta CCF}$ | $SF_{PD}$ |
|---|---|---|---|---|---|
| Door heater | 0.02352 | 0.04284 | 341.440 | 26.716 | 0.16265 |
| Gap | 0.02352 | 0.04284 | 341.440 | 14.210 | 0.086510 |
| No door heater + No gap | 0.04421 | 0.08055 | 641.939 | 26.716 | 0.16265 |

## ***Measure Life***

The measure life for adding doors to open display case is 12 years [2].

## ***Peak Factors***

**Table 2-198 Peak Factors**

| Measure | Summer Coincidence Factor | Winter Coincidence Factor | Ref |
|---|---|---|---|
| Add doors to open refrigerated display cases | 97.4%* | 98.2%* | [3] |

* Values denoted with an asterisk are relative to average demand savings. Average demand savings is defined as total energy (kWh) savings divided by 8760. Data available during X1931-2 did not include sufficient detail to calculate maximum connected loads for each profile, which necessitated the use of seasonal peak coincidence factors relative to average demand. Values which do not have an asterisk are relative to connected load or seasonal peak demand as outlined by the measure characterization in the 2022 PSD.

## ***Load Shapes***

**Table 2-199 Load Shapes**

| Measure | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % | Ref |
|---|---|---|---|---|---|
| Refrigeration | 29.95% | 36.58% | 15.95% | 17.51% | [3] |

## ***Realization Rates and Net Impact Factors***

**Table 2-200 Realization Rates and Net Impact Factors**

| | Gross Realization % | | | FR & SO | | Net Realization % | | | |
|---|---|---|---|---|---|---|---|---|---|
| Measure | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Free-ridership | Spill-over | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Ref |
| Refrigeration **Energy Opportunities** | 67.6% | 162.1% | 114.7% | 13.0% | 0.0% | 58.8% | 141.0% | 99.8% | [4], [5] |
| Refrigeration **Small Business Energy Advantage** | 72.0% | 73.0% | 85.0% | 1.4% | 0.0% | 71.0% | 72.0% | 83.8% | [6], [7] |

## ***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.

[2] California Public Utilities Commission. 2008. 2008 Database for Energy-Efficient Resources, Version 2008.2.05. EUL/RUL (Effective/Remaining Useful Life) Values, MS Excel Spreadsheet. Row 76.

[3] DNV. 2021. “X1931-2 Load Shape and Coincidence Factor Research.” Connecticut Energy Efficiency Board (EEB) and Evaluation Administrators.

[4] DNV-GL. 2020. “C1635 Impact Evaluation of PY 2016 & 2017 Energy Opportunities (EO) Program”. Tables 6-11. Connecticut Energy Efficiency Board (EEB) and Evaluation Administrators.

[5] EMI Consulting. 2019. ““C1644: EO Net-to-Gross Study.” Connecticut Energy Efficiency Board.

[6] ERS. 2018. “C1639: Impact Evaluation of the Connecticut Small Business Energy Advantage Program.” Connecticut Energy Efficiency Board (EEB) and Evaluation Administrators.

[7] Tetra Tech. 2012. “2011 C&I Electric and Gas Free-ridership and Spillover Study.” Table 3-5. Connecticut Energy Efficiency Fund.

## ***Changes from Last Version***

- Updated savings factors.

## 2.4.7 LAB EQUIPMENT

| | |
|---|---|
| Market | Commercial |
| Baseline Type | Retrofit/Lost Opportunity |
| Category | Category |

***Description***

Installation of laboratory grade high performance refrigerators and freezers.

***Calculation Parameters***

**Table 2-201 Calculation Parameters**

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| ΔkWh | Annual gross electric energy savings | Table 2-202 | kWh | |
| ΔkW | Average hourly summer and winter demand savings | Table 2-202 | kW | |

**Table 2-202 Lab Grade High Performance Refrigerator and Freezer Deems Savings**

| Measure | ΔkWh | ΔkW | Ref |
|---|---|---|---|
| Laboratory Grade High Performance Refrigerators, 6≤V<25 cu. ft. | 1,403 | 0.16 | |
| Laboratory Grade High Performance Refrigerators, 25≤V<44 cu. ft. | 1,913 | 0.22 | |
| Laboratory Grade High Performance Refrigerators, ≥44 cu. ft. | 2,552 | 0.29 | |
| Laboratory Grade High Performance Freezers, 6≤V<22 cu. ft. | 1,608 | 0.18 | |
| Laboratory Grade High Performance Freezers, ≥22 cu. ft. | 2,596 | 0.30 | |
| Ultra-low temp freezers | 5,737 | 0.655 | [2] |

***Measure Life***

**Table 2-203 Measure Life**

| Equipment Type | Retrofit | Lost Opportunity | Ref |
|---|---|---|---|
| Laboratory Grade High Performance Refrigerators | N/A | 15 | |
| Laboratory Grade High Performance Freezers | N/A | 15 | |

## *Peak Factors*

**Table 2-204 Peak Factors**

| Measure | Summer Coincidence Factor | Winter Coincidence Factor | Ref |
|---|---|---|---|
| Laboratory Grade High Performance Refrigerators | 90% | 90% | |
| Laboratory Grade High Performance Freezers | 90% | 90% | |

## *Load Shapes*

**Table 2-205 Load Shapes**

| Measure | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % | Ref |
|---|---|---|---|---|---|
| Laboratory Grade High Performance Refrigerators | 22.6% | 27.3% | 23.3% | 26.8% | |
| Laboratory Grade High Performance Freezers | 22.6% | 27.3% | 23.3% | 26.8% | |

## *Realization Rates*

**Table 2-206 Realization Rates**

| | Gross Realization % | | | FR & SO | | Net Realization % | | | |
|---|---|---|---|---|---|---|---|---|---|
| Measure | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Free-ridership | Spill-over | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Ref |
| Laboratory Grade High Performance Refrigerators | 100.0% | 100.0% | 100.0% | 18.00% | 0.00% | 82.0% | 82.0% | 82.0% | [1] |
| Laboratory Grade High Performance Freezers | 100.0% | 100.0% | 100.0% | 18.00% | 0.00% | 82.0% | 82.0% | 82.0% | [1] |

## *References*


[1] NMR, DNV, Brightline Group. 2022. "C1902a: Connecticut Midstream C&I HVAC & Water Heating and Foodservice Net-to-Gross Review."

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


## *Changes from Last Version*

- New measure.

## 2.4.8 ELECTRONIC DEFROST CONTROL

| | |
|---|---|
| Market | Commercial |
| Baseline Type | Retrofit |
| Category | Refrigeration |

### ***Description***

A control mechanism to skip defrost cycles when defrost is unnecessary.

The high efficiency case is an evaporator fan defrost system with electric defrost controls. The baseline efficiency case is an evaporator fan electric defrost system that uses a time clock mechanism to initiate defrost.

### ***Annual Energy Savings Algorithm***

Annual Gross Energy Savings, Electric

$$\Delta kWh = \Delta kWh_{Defrost} + \Delta kWh_{Heat}$$

$$\Delta kWh_{Defrost} = kW_{Defrost} \times Hours \times DRF$$

$$\Delta kWh_{Heat} = \Delta kWh_{Defrost} \times 0.28 \times Eff_{RS}$$

Gross Seasonal Peak Demand Savings, Electric

$$\Delta kW_{Summer} = \frac{\Delta kWh}{8760} \times CF_{Summer}$$

$$\Delta kW_{Winter} = \frac{\Delta kWh}{8760} \times CF_{Winter}$$

### ***Calculation Parameters***

**Table 2-207 Calculation Parameters**

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| ΔkWh | Annual gross electric energy savings | Calculated | kWh | |
| $\Delta kW_{Summer}$ | Summer peak seasonal demand savings | Calculated | kW | |
| $\Delta kW_{Winter}$ | Winter peak seasonal demand savings | Calculated | kW | |

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| $\Delta kWh_{Defrost}$ | Energy savings resulting from an increase in operating efficiency due to the addition of electronic defrost controls | Calculated | kWh | |
| $\Delta kWh_{Heat}$ | Energy savings due to reduced heat from reduced number of defrosts | Calculated | kWh | |
| $kW_{Defrost}$ | Load of electric defrost | Site-specific | kW | |
| Hours | Number of hours defrost occurs over a year without the defrost controls | Site-specific | Hours | |
| DRF | Defrost reduction factor – percent reduction in defrosts required per year | 0.35 | N/A | [4] |
| 0.28 | Conversion of kW to tons | 0.28 | Ton/kW | [4] |
| $Eff_{RS}$ | Efficiency of typical refrigeration system | 1.6 | kW/ton | [4] |

## ***Measure Life***

The measure life for electronic defrost control is 10 years.

## ***Peak Factors***

Delete extra rows if one set of peak factors applies to full measure.

**Table 2-208 Peak Factors**

| Measure | Summer Coincidence Factor | Winter Peak Factor | Ref |
|---|---|---|---|
| Electronic Defrost Control | 0.9 | 0.9 | [4] |

## ***Load Shapes***

Load shapes have not been defined for this measure.

## ***Non-Energy Impacts***

There are no other resource impacts identified for this measure.

## ***Realization Rates***

**Table 2-209 Realization Rates [4]**

| Gross Realization | | | | FR & SO | | | Net Realization | | |
|---|---|---|---|---|---|---|---|---|---|
| Measure | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Free-ridership | Spill-over | ISR | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW |
| Electronic defrost control | 95% | 142% | 127% | 14% | 5% | 100% | 89.3% | 133.5% | 119.4% |

## ***References***

[4] 2022-2024 MA Plan TRM.

## ***Changes from Last Version***

- New measure.

## 2.4.9 NOVELTY COOLER SHUTOFF

| | |
|---|---|
| Market | Commercial |
| Baseline Type | Retrofit |
| Category | Refrigeration |

### ***Description***

Installation of controls to shut off a facility's novelty coolers for non-perishable goods based on preprogrammed store hours. Energy savings occur as coolers cycle off during facility unoccupied hours. The high efficiency case is the novelty coolers operating fewer than 8,760 hours per year since they are controlled to cycle each night based on pre-programmed facility unoccupied hours. The baseline efficiency case is the novelty coolers operating 8,760 hours per year.

Savings are assumed to occur during evening hours and are therefore not coincident with either summer of winter peak demand periods.

### ***Annual Energy Savings Algorithm***

*Annual Gross Energy Savings, Electric*

$$\Delta kWh = kW_{NC} \times DC_{AVG} \times Hours_{OFF}$$

*Gross Seasonal Peak Demand Savings, Electric*

$$\Delta kW = 0$$

### ***Calculation Parameters***

**Table 2-210 Calculation Parameters**

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| ΔkWh | Annual gross energy savings, electric | Calculated | kWh | |
| ΔkW | Gross seasonal peak demand savings, electric | 0 | kW | |
| $kW_{NC}$ | Power demand of novelty cooler calculated from nameplate data and estimated 0.85 power factor | Site-specific | kW | |
| $Hours_{OFF}$ | Potential hours off every night per year, estimated as one less than the number of hours the store is closed per day | Site-specific | Hours | |
| $DC_{AVG}$ | Weighted average annual duty cycle | 48.75% | % | [5] |

## *Measure Life*

The measure life for novelty cooler shutoff is 10 years.

## *Peak Factors*

**Table 2-211 Peak Factors**

| Measure | Summer Coincidence Factor | Winter Coincidence Factor | Ref |
|---|---|---|---|
| Novelty Cooler Shutoff | 90% | 90% | [5] |

## *Load Shapes*

Load shapes not yet defined for this measure.

## *Non-Energy Impacts*

There are no other resource impacts identified for this measure.

## *Realization Rates*

**Table 2-212 Realization Rates**

| | Gross Realization | | | FR&SO | | | Net Realization | | |
|---|---|---|---|---|---|---|---|---|---|
| Measure | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Free-ridership | Spill-over | ISR | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW |
| Other measures | 95% | 142% | 127% | 14% | 5% | 100% | 89.3% | 133.5% | 119.4% |

## *References*

[5] 2022-2024 MA Plan TRM.

## *Changes from Last Version*

- New measure.

## 2.5 COMPRESSED AIR SYSTEMS

### 2.5.1 VARIABLE SPEED DRIVE-CONTROLLED AIR COMPRESSORS

| | |
|---|---|
| Market | Commercial |
| Baseline Type | Lost Opportunity |
| Category | Compressed Air Systems |

***Description***

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

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

The baseline is a typical load/unload compressor. The high efficiency replacement is a compressor with VFD part load control[9].

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

In case sufficient site-specific information or/and metered data are available, custom savings calculation should be used to calculate more accurate savings.

***Annual Energy Savings Algorithm***

*Annual Gross Energy Savings, Electric*

$$\Delta kWh = HP \times H \times SF$$

---

9 Savings are based on an oil flooded, rotary screw compressor with VFD part load control, may underestimate savings for more efficient equipment such as compressors with permanent magnet motors.

*Gross Seasonal Peak Demand Savings, Electric*

$$\Delta kW_{summer} = HP \times SF \times CF_s$$

$$\Delta kW_{winter} = HP \times SF \times CF_w$$

***Calculation Parameters***

**Table 2-213 Calculation Parameters**

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| ΔkWh | Annual electric savings | Calculated | kWh/yr | [1] |
| $\Delta kW_{summer}$ | Summer demand savings | Calculated | kW | |
| $\Delta kW_{winter}$ | Winter demand savings | Calculated | kW | |
| HP | Air compressor nominal rated horsepower | Site-specific | HP | |
| H | Hours of operation | Site-specific, if unknown lookup in Table 2-214 | Hours | |
| SF | Savings factor | 0.189 | kW/HP | [1] |
| $CF_s$ | Summer coincidence factor | Table 2-216 | N/A | [10] |
| $CF_w$ | Winter coincidence factor | Table 2-216 | N/A | [10] |

**Table 2-214 Default Operations Hours of Compressed Air Systems**

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

***Measure Life***

**Table 2-215 Measure Life**

| Equipment Type | Retrofit | Lost Opportunity | Ref |
|---|---|---|---|
| Air Compressor | 13 | 15 | [3] |

***Peak Factors***

**Table 2-216 Peak Factors**

| Measure | Summer Coincidence Factor | Winter Coincidence Factor | Ref |
|---|---|---|---|
| VFD-controlled Air Compressors | 94.7% | 74.3% | [10] |

***Load Shapes***

**Table 2-217 Load Shapes**

| Measure/Facility/Equipment Type | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % | Ref |
|---|---|---|---|---|---|
| Process | 32.00% | 36.00% | 16.00% | 16.00% | [2] |

***Realization Rates and Net Impact Factors***

**Table 2-218 Realization Rates**

| | Gross Realization % | | | FR and SO | | Net Realization % | | | |
|---|---|---|---|---|---|---|---|---|---|
| Measure | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Free-ridership | Spill-over | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Ref |
| **Process** Energy Conscious Blueprint | 80.3% | 113.0% | 114.1% | 17.6% | 0.9% | 66.9% | 93.7% | 95.0% | [5], [7] |
| **Process** Energy Opportunities | 67.6% | 162.1% | 114.7% | 12.0% | 35.0% | 83.1% | 199.4% | 141.1% | [6], [9] |
| **Comp. Air** Small Business Energy Advantage | 72.0% | 73.0% | 85.0% | 0.3% | 0.0% | 71.8% | 72.8% | 84.7% | [8], [7] |
| **O&M** Business & Energy Sustainability | 79.0% | 258.0% | 191.0% | 0.0% | 0.0% | 79.0% | 258.0% | 191.0% | [10] |

***References***


[1] DNV KEMA. 2015. "Impact Evaluation of Prescriptive Chiller and Compressed Air Installations." pp. 8-11.

[2] DNV. 2021. "X1931-2 Load Shape and Coincidence Factor Research." Connecticut Energy Efficiency Board (EEB) and Evaluation Administrators.

[3] Energy & Resource Solutions. 2005. ERS Measure Life Study.: Prepared for the Massachusetts Joint Utilities.

[4] Cadmus. 2020 "C1634 Impact Evaluation of PY 2016 & 2017 Energy Conscious Blueprint Program."

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

[6] Tetra Tech. 2012. "2011 C&I Electric and Gas Free-ridership and Spillover Study."

[7] ERS. 2018. "C1639: Impact Evaluation of the Connecticut Small Business Energy Advantage Program."

[8] EMI Consulting. 2019. "C1644: EO Net-to-Gross Study." Connecticut Energy Efficiency Board.

[9] ERS. 2018. **"**C1641: Impact Evaluation of the Business and Energy Sustainability Program." p. 4, see Table 1-3; p. 5, see Table 1-4; and p.10, Recommendation 1.

[10] DNV. 2021. "CTX1931-3 Compressed Air Systems (CAS) Memo." CT Energy Efficiency Board.

***<u>Changes from Last Version</u>***

- Formatting updates.
- Added summer and winter peak factors.

## 2.5.2 HIGH EFFICIENCY REFRIGERATED AIR DRYERS

| | |
|---|---|
| Market | Commercial |
| Baseline Type | Lost Opportunity |
| Category | Compressed Air Systems |

### ***Description***

Installation of cycling or Variable Frequency Drives (VFDs)-controlled refrigerated air dryers instead of non-cycling refrigerated dryers. This measure is applicable to single compressor systems only.

Refrigerated compressed air dryers use a refrigeration system to reduce the compressed air temperature below its dewpoint (about 35°F) to condense and remove moisture from a compressed air stream. The baseline condition is a compressed air system equipped with a non-cycling air dryer that uses hot gas bypass controls to modulate refrigeration capacity. Hot gas bypass requires constant refrigeration system operation at near-full input power. In contrast, a high efficiency air dryer cycles on and off or uses a VFD to modulate refrigeration capacity instead, which allows load reduction.

The savings calculation is based on a study of prescriptive compressed air [1], which used the actual compressed air systems loading measurements and metered operation hours to estimate a savings factor. This measure is not applicable for conversion from another type of dryer such as desiccant dryer to a refrigerated dryer.

In case sufficient site-specific information or/and metered data are available, custom savings calculation should be used to calculate more accurate savings.

### ***Annual Energy Savings Algorithm***

*Annual Gross Energy Savings, Electric*

$$\Delta kWh = CFM_{dryer} \times H \ \times SF$$

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

$$\Delta kW_{Winter} = CFM_{dryer} \ \times SF \ \times CF_s$$

### ***Calculation Parameters***

**Table 2-219 Calculation Parameters**

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| ΔkWh | Annual electric energy savings | Calculated | kWh/yr | |
| $\Delta kW_{summer}$ | Summer demand savings | Calculated | kW | |

| Variable | Description | Value | Units | Ref |
| --- | --- | --- | --- | --- |
| $\Delta kW_{winter}$ | Winter demand savings | Calculated | kW | |
| $CFM_{Dryer}$ | Full flow rated capacity of the refrigerated air dryer, per Compressed Air Gas Institute Datasheet | Site-specific | CFM | |
| H | Annual hours of operation | Site-specific, if unknown Table 2-220 | Hrs/yr | |
| SF | Savings factor | 0.00554 | kW/CFM | [1] |
| $CF_s$ | Summer coincidence factor | 0.838 | N/A | [10] |
| $CF_w$ | Winter coincidence factor | 0.777 | N/A | [10] |

**Table 2-220 Default Operations Hours of Compressed Air Systems**

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

## ***Measure Life***

**Table 2-221 Measure Life**

| Equipment Type | Measure Life | Ref |
| --- | --- | --- |
| Retrofit | 13 | [3] |
| Lost Opportunity | 15 | [3] |

## ***Peak Factors***

**Table 2-222 Peak Factors**

| Measure | Summer Coincidence Factor | Winter Coincidence Factor | Ref |
| --- | --- | --- | --- |
| High Efficiency Air Dryers | 83.8% | 77.7% | [10] |

## *Load Shapes*

**Table 2-223 Load Shapes**

| Measure Type | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % | Ref |
|---|---|---|---|---|---|
| Refrigeration | 29.95% | 36.58% | 15.95% | 17.51% | |

## *Realization Rates and Net Impact Factors*

**Table 2-224 Realization Rates**

| | Gross Realization % | | | FR and SO | | Net Realization % | | | |
|---|---|---|---|---|---|---|---|---|---|
| Measure | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Free-ridership | Spill-over | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Ref |
| Refrigeration **Energy Conscious Blueprint** | 98.5% | 106.3% | 97.4% | 3.6% | 25.9% | 120.5% | 130.0% | 119.1% | [4], [6] |
| Refrigeration **Energy Opportunities** | 67.6% | 162.1% | 114.7% | 13.0% | 0.0% | 58.8% | 141.0% | 99.8% | [5], [8] |
| Comp. Air **Small Business Energy Advantage** | 72.0% | 73.0% | 85.0% | 0.3% | 0.0% | 71.8% | 72.8% | 84.7% | [7], [6] |
| Refrigeration **Small Business Energy Advantage** | 72.0% | 73.0% | 85.0% | 1.4% | 0.0% | 71.0% | 72.0% | 83.8% | [7], [6] |
| O & M **Business & Energy Sustainability** | 79.0% | 258.0% | 191.0% | 0.0% | 0.0% | 79.0% | 258.0% | 191.0% | [9] |

## *References*


[1] DNV KEMA (2015), Impact Evaluation of Prescriptive Chiller and Compressed Air Installations, pp. 8-11.

[2] DNV. 2021. "X1931-2 Load Shape and Coincidence Factor Research." Connecticut Energy Efficiency Board (EEB) and Evaluation Administrators.

[3] Energy & Resource Solutions. ERS *Measure Life Study.*: Prepared for the Massachusetts Joint Utilities, Oct. 10, 2005.

[4] Cadmus, C1634 Impact Evaluation of PY 2016 & 2017 Energy Conscious Blueprint Program, Oct. 18, 2020.

[5] DNV-GL, C1635 Impact Evaluation of PY 2016 & 2017 Energy Opportunities (EO) Program.

[6] Tetra Tech, 2011 C&I Electric and Gas Free-ridership and Spillover Study, Oct. 5, 2012.

[7] ERS, C1639: Impact Evaluation of the Connecticut Small Business Energy Advantage Program, Mar. 20, 2018.

[8] EMI Consulting. 2019. "C1644: EO Net-to-Gross Study." Connecticut Energy Efficiency Board.

[9] ERS. 2018. "C1641: Impact Evaluation of the Business and Energy Sustainability Program." p. 4, see Table 1-3; p. 5, see Table 1-4; and p.10, Recommendation 1.

[10] DNV. 2021. "CTX1931-3 Compressed Air Systems (CAS) Memo" CT Energy Efficiency Board.

***Changes from Last Version***

- Formatting updates.
- Added Summer and Winter Peak Factors.

## 2.5.3 EFFICIENT COMPRESSED AIR NOZZLES

| | |
|---|---|
| Market | Commercial |
| Baseline Type | Retrofit |
| Category | Compressed Air Systems |

***Description***

Replacement of standard air nozzle with high efficiency nozzle in compressed air systems.

Engineered air nozzles entrain compressed air with surrounding air as it leaves the nozzle. This increases air flow volume with less compressed air use. The engineered air nozzles reduce the velocity of the resulting airflow but increase the mass flow of the air which improve the cooling and drying effect. The energy savings associated with the engineered air nozzles are due to the reduced compressor work. Efficient nozzles typically have the added benefits of noise reduction and improved safety in systems with greater than 30 psig.

The baseline condition is standard air nozzle. The high efficiency air nozzle must meet the following specifications:

1. High efficiency air nozzle must replace standard air nozzle.
2. High efficiency air nozzle must meet SCFM rating at 80psig less than or equal to 1/8” 11 SCFM, 1/4" 29 SCFM, 5/16” 56 SCFM, 1/2" 140 SCFM.
3. Manufacturer’s specification sheet of the high efficiency air nozzle must be provided along with the make and model.

If sufficient site-specific information or/and metered data are available, custom savings calculation should be used to calculate more accurate savings.

***Annual Energy Savings Algorithm***

*Annual Gross Energy Savings, Electric*

$$\Delta kWH = (CFM_s \times CFM_{R\%}) \times EFF_{Comp} \times MEF \times \%USE \times H$$

*Gross Seasonal Peak Demand Savings, Electric*

$$\Delta kW_{Summer} = {}^{\Delta kWh}/_{H} \times CF_s$$

***Calculation Parameters***

**Table 2-225 Calculation Parameters**

| Variable | Description | Values | Units | Ref |
|---|---|---|---|---|
| ΔKWH | Annual electric energy savings | Calculated | kWh/yr | |
| kW | Electric peak demand savings | Calculated | kW | |
| $CFM_S$ | Air flow through standard nozzle | Site-specific, if unknown Table 2-226 | CFM | [1] |
| %USE | Percent of the system total annual pressurized hours during which the nozzle is in use | Site-specific, if unknown use 0.03 | N/A | |
| H | Annual hours of operation | Site-specific, if unknown use Table 2-229 | Hrs/yr | |
| $CFM_{R\%}$ | Percent in reduction of air loss per nozzle* | 0.5 | N/A | |
| $EFF_{Comp}$ | Efficiency of air compressor | Table 2-227, if type unknown use 0.19 kW/CFM | kW/CFM | [2] |
| MEF | Marginal efficiency factor per control type for air compressor | Table 2-228, if control type unknown use 0.3 %kW/ %load | Percent kW/ Percent Load | [3] |
| CF | Coincidence factor | 0.95 | N/A | |

* Conservative estimate based on several manufacturers' technical specification sheets.

**Table 2-226 Specific Flow Rates for Various Orifice Diameters [1]**

| Pressure (psig)* | Orifice Diameter (inches) | | | | | |
|---|---|---|---|---|---|---|
| | 1/64 | 1/32 | 1/16 | 1/8 | 1/4 | 3/8 |
| 70 | 0.29 | 1.16 | 4.66 | 18.62 | 74.4 | 167.8 |
| 80 | 0.32 | 1.26 | 5.24 | 20.76 | 83.1 | 187.2 |
| 90 | 0.36 | 1.46 | 5.72 | 23.1 | 92 | 206.6 |
| 100 | 0.40 | 1.55 | 6.31 | 25.22 | 100.9 | 227 |
| 125 | 0.48 | 1.94 | 7.66 | 30.65 | 122.2 | 275.5 |

* Assuming 100% orifice flow for the standard nozzle in the baseline condition. If the orifice flow is <100%, the savings equation must be multiplied by the partial flow percentage.

**Table 2-227 kW/CFM Efficiencies for Several Air Compressor Types ($EFF_{Comp}$) [2]**

| Air Compressor Type | $EFF_{Comp}$ (kW/CFM) |
|---|---|
| Single-acting reciprocating air compressor | 0.230 |
| Double-acting reciprocating air compressor | 0.155 |

| Air Compressor Type | $EFF_{Comp}$ (kW/CFM) |
|---|---|
| Lubricant-injected rotary screw compressor | 0.185 |
| Lubricant-free rotary screw compressor | 0.200 |
| Centrifugal compressor | 0.180 |
| **Average** | **0.190** |

**Table 2-228 Marginal Efficiency Factors per Control Type for Air Compressor Types (MEF) [3]**

| Control Type | Percent kW/Percent Load |
|---|---|
| Inlet valve modulated | 0.31 |
| Variable displacement | 0.69 |
| Variable speed drive | 0.85 |

**Table 2-229 Default Operations Hours of Compressed Air Systems**

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

***Measure Life***

**Table 2-230 Measure Life**

| Equipment Type | Measure Life | Ref |
|---|---|---|
| Efficient compressed air nozzles | 15 | [11] |

***Peak Factors***

**Table 2-231 Peak Factors**

| Measure | Summer Coincidence Factor | Winter Coincidence Factor | Ref |
|---|---|---|---|
| Efficient Compressed Air Nozzles | 95% | 95% | |

***Load Shapes***

**Table 2-232 Load Shapes**

| End Use | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % | Ref |
|---|---|---|---|---|---|
| Other | 37.00% | 29.00% | 19.00% | 15.00% | |

***Realization Rates and Net Impact Factors***

**Table 2-233 Realization Rates**

| | Gross Realization % | | | FR and SO | | Net Realization % | | | |
|---|---|---|---|---|---|---|---|---|---|
| Measure | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Free-ridership | Spill-over | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Ref |
| **Process** Energy Conscious Blueprint | 80.3% | 113.0% | 114.1% | 17.6%[7] | 0.9% | 66.9% | 93.7% | 95.0% | [5], [7] |
| **Process** Energy Opportunities | 67.6% | 162.1% | 114.7% | 12.0% | 35.0% | 83.1% | 199.4% | 141.1% | [6], [9] |
| **Comp. Air** Small Business Energy Advantage | 72.0% | 73.0% | 85.0% | 0.3% | 0.0% | 71.8% | 72.8% | 84.7% | [8], [7] |
| **O & M** Business & Energy Sustainability | 79.0% | 258.0% | 191.0% | 0.0% | 0.0% | 79.0% | 258.0% | 191.0% | [10] |

***References***


[1] US Department of Energy. Energy Tips – Compressed Air. August 2004. Available online: https://www.energy.gov/sites/prod/files/2014/05/f16/compressed_air3.pdf. Originally from Fundamentals of Compressed Air Systems Training offered by the Compressed Air Challenge®.

[2] Compressed Air Challenge "Fundamentals of Compressed Air Systems, "pp. 28-32.

[3] Compressed Air Challenge "Fundamentals of Compressed Air Systems," pp. 90-91.

[4] PA Consulting Group. 2009. "Business Programs: Measure Life Study." Wisconsin Public Service Commission.

[5] Cadmus. 2020. "C1634 Impact Evaluation of PY 2016 & 2017 Energy Conscious Blueprint Program."

[6] DNV-GL. 2020. "C1635 Impact Evaluation of PY 2016 & 2017 Energy Opportunities (EO) Program." CT Energy Efficiency Board (EEB) and Evaluation Administrators.

[7] Tetra Tech. 2012. "2011 C&I Electric and Gas Free-ridership and Spillover Study."

[8] ERS. 2018. "C1639: Impact Evaluation of the Connecticut Small Business Energy Advantage Program."

[9] EMI Consulting. 2019. "C1644: EO Net-to-Gross Study." Connecticut Energy Efficiency Board.

[10] ERS. 2018. "C1641: Impact Evaluation of the Business and Energy Sustainability Program." p. 4, see Table 1-3; p. 5, see Table 1-4; and p.10, Recommendation 1.

[11] DNV. 2021. "CTX1931-3 Compressed Air Systems (CAS) Memo" CT Energy Efficiency Board.

***Changes from Last Version***

- Formatting updates.
- Added EUL.

### 2.5.4 COMPRESSED AIR LEAK DETECTION

| | |
|---|---|
| Market | Commercial |
| Baseline Type | Retrofit |
| Category | Compressed Air Systems |

***Description***

This measure covers the detection of compressed air losses through ultrasonic leak detection, and the repair of compressed air leaks.

Air leaks are common in compressed air systems, often wasting 20%-30% of the compressor's output. Air leak loss rate depends on the supply pressure in an uncontrolled system, as well as leak size quantity and time. This measure is applicable for general plant compressed air systems in manufacturing environments (70 to 125 psig).

**Note:** An average value is derived from two coincidence factors that were developed through two separate studies. The first study is Aspen Systems Corporation, Prescriptive Variable Speed Drive Incentive Development Support for Industrial Air Compressors Executive Summary, Jun. 20, 2005. The second study is KEMA, New Jersey's Clean Energy Program Energy Impact Evaluation and Protocol Review, Jul. 10, 2009.

***Annual Energy Savings Algorithm***

*Annual Gross Energy Savings, Electric*

$$\Delta kWh = NL \times CFM_{Leak} \times EFF_{Comp} \times MEF \times H$$

*Gross Seasonal Peak Demand Savings, Electric*

$$\Delta kW_{Summer} = \Delta kWh \div H \times CF_S$$

$$\Delta kW_{Winter} = \Delta kWh \div H \times CF_W$$

***Calculation Parameters***

**Table 2-234 Calculation Parameters**

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| ΔkWh | Annual electric energy savings | Calculated | kWh/yr | |
| $\Delta kW_{Summer}$ | Summer peak demand savings | Calculated | kW | |
| $\Delta kW_{Winter}$ | Summer peak demand savings | Calculated | kW | |

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| NL | Number of detected leaks | Site-specific | N/A | |
| H | Annual hours the compressed air system is pressurized | Site-specific, if unknown use Table 2-235 | Hrs/yr | |
| $CFM_{Leak}$ | Flow rate loss per leak in cubic feet per minute (CFM) | Table 2-236 | CFM | [1] |
| $EFF_{Comp}$ | Efficiency of air compressor | Table 2-237, if unknown use 0.19 | kW/CFM | [2] |
| MEF | Marginal efficiency factor per control type for air compressor | Table 2-238, if unknown use 0.3 | kW/% load | [3] |
| CF | Coincidence factor | Table 2-239 | N/A | [9][1] |

**Table 2-235 Default Operations Hours of Compressed Air Systems**

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

Table 2-236* For well-rounded orifices, values should be multiplied by 0.97 and by 0.61 for sharp ones.

Table 2-237 shows leakage rates for ideal orifices. Most gaps are irregular and sometimes ragged, which decreases the flow rate relative to the equivalent area.

**Table 2-236 CFM per Leak Size for Compressed Air Leaks[1]**

| Pressure (psig) | Orifice Diameter (inches)* | | | | | |
|---|---|---|---|---|---|---|
| | 1/64 | 1/32 | 1/16 | 1/8 | 1/4 | 3/8 |
| 70 | 0.29 | 1.16 | 4.66 | 18.62 | 74.4 | 167.8 |
| 80 | 0.32 | 1.26 | 5.24 | 20.76 | 83.1 | 187.2 |
| 90 | 0.36 | 1.46 | 5.72 | 23.1 | 92 | 206.6 |
| 100 | 0.40 | 1.55 | 6.31 | 25.22 | 100.9 | 227 |
| 125 | 0.48 | 1.94 | 7.66 | 30.65 | 122.2 | 275.5 |

* For well-rounded orifices, values should be multiplied by 0.97 and by 0.61 for sharp ones.

**Table 2-237 kW/CFM Efficiencies for Several Air Compressor Types ($EFF_{Comp}$)[2]**

| Air Compressor Type | $Eff_{Comp}$ (kW/CFM) |
|---|---|
| Single-acting Reciprocating Air Compressor | 0.230 |
| Double-acting Reciprocating Air Compressor | 0.155 |
| Lubricant-injected Rotary Screw Compressor | 0.185 |
| Lubricant-free Rotary Screw Compressor | 0.200 |
| Centrifugal Compressor | 0.180 |
| **Average** | **0.190** |

**Table 2-238 Marginal Efficiency Factors per Control Type for Air Compressor Types (MEF)[3]**

| Control Type | Percent kW/Percent Load |
|---|---|
| Inlet valve modulated | 0.31 |
| Variable displacement | 0.69 |
| Variable speed drive | 0.85 |

## ***Measure Life***

The measure life for repaired compressed air leaks is 5 years [4].

## ***Peak Factors***

**Table 2-239 Peak Factors**

| Measure | Summer Coincidence Factor | Winter Coincidence Factor | Ref |
|---|---|---|---|
| Compressed Air Lead Detection | 94.7% | 74.3% | [9] |

## ***Load Shapes***

**Table 2-240 Load Shapes**

| Measure Type | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % | Ref |
|---|---|---|---|---|---|
| Other | 37.00% | 29.00% | 19.00% | 15.00% | [5] |

## ***Realization Rates and Net Impact Factors***

**Table 2-241 Realization Rates and Net Impact Factors**

| | Gross Realization % | | | FR and SO | | Net Realization % [6] | | | |
|---|---|---|---|---|---|---|---|---|---|
| Measure | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Free-ridership | Spill-over | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Ref |
| **Process** Energy Conscious Blueprint | 80.3% | 113.0% | 114.1% | 17.6%[7] | 0.9% | 66.9% | 93.7% | 95.0% | [10], [8] |
| **Process** Energy Opportunities | 67.6% | 162.1% | 114.7% | 12.0% | 35.0% | 83.1% | 199.4% | 141.1% | [11], [12] |
| **Comp. Air** Small Business Energy Advantage | 72.0% | 73.0% | 85.0% | 0.3% | 0.0% | 71.8% | 72.8% | 84.7% | [8], [7] |
| **O&M** Business & Energy Sustainability | 79.0% | 258.0% | 191.0% | 0.0% | 0.0% | 79.0% | 258.0% | 191.0% | [13] |

## ***References***


[1] US Department of Energy (August 2004). “Energy Tips – Compressed Air.” Available online: https://www.energy.gov/sites/prod/files/2014/05/f16/compressed_air3.pdf. Originally from Fundamentals of Compressed Air Systems Training offered by the Compressed Air Challenge®.

[2] Compressed Air Challenge, "Fundamentals of Compressed Air Systems," pp. 28-32.

[3] Compressed Air Challenge, "Fundamentals of Compressed Air Systems," pp. 90-91.

[4] Energy & Resource Solutions. 2005. “ERS Measure Life Study: Prepared for the Massachusetts Joint Utilities.”

[5] DNV. 2021. “X1931-2 Load Shape and Coincidence Factor Research,” Final Report.

[6] West Hill Energy and Computing. 2019. “R1603 HES/HES-IE Impact Evaluation Final Realization Rates Memorandum.”

[7] ERS. 2018. “C1639: Impact Evaluation of the Connecticut Small Business Energy Advantage Program,” p. 4, see Table 1-4.

[8] Tetra Tech. 2012. “2011 C&I Electric and Gas Free-ridership and Spillover Study,” pp. 3-4, see Table 3-5.

[9] DNV. 2021. “CTX1931-3 Compressed Air Systems (CAS) Memo.” CT Energy Efficiency Board (EEB).

[10] Cadmus. 2020. “C1634 Impact Evaluation of PY 2016 & 2017 Energy Conscious Blueprint Program.”

[11] DNV-GL. 2020. “C1635 Impact Evaluation of PY 2016 & 2017 Energy Opportunities (EO) Program.” CT Energy Efficiency Board (EEB) and Evaluation Administrators.

[12] EMI Consulting. 2019. “C1644: EO Net-to-Gross Study.” Connecticut Energy Efficiency Board.

[13] ERS. 2018. “C1641: Impact Evaluation of the Business and Energy Sustainability Program.” p. 4, see Table 1-3; p. 5, see Table 1-4; and p.10, Recommendation 1.

## ***Changes from Last Version***

- Formatting updates.
- Added summer and winter peak factors per CT X1931-3 CAS PSD Memo_Final_101921.

## 2.6 APPLIANCES

### 2.6.1 COMMERCIAL KITCHEN EQUIPMENT

| | |
|---|---|
| Market | Commercial |
| Baseline Type | Lost Opportunity |
| Category | Appliances |

***Description***

Installation of ENERGY STAR qualified commercial kitchen equipment. Energy savings for this measure are calculated using the savings calculator for ENERGY STAR-qualified Commercial Food Service (CFS) Equipment Calculator on the ENERGY STAR Training Centre website or the Food Technology Service Center (FTSC) for the California Energy Wise [1]. 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 AHAM volume is the interior volume of a refrigerator as calculated by AHAM Standard Household Refrigerators/Household Freezers (ANSI/AHAM HRF-1-2004).

Actual full load hours should be used (when known) in the ENERGY STAR savings calculator, in lieu of the default hours.

The baselines from which savings are calculated are provided in Table 2-242 below.

**Table 2-242 Savings Baseline**

| Equipment | Baseline |
|---|---|
| Dishwasher | Conventional unit per ENERGY STAR savings calculator [1]. |
| Freezer | Federal standard [3]. |
| Fryer | Conventional unit per ENERGY STAR savings calculator and California Energy Wise savings calculator [1], [2]. |
| Griddle | Conventional unit per California Energy Wise savings calculator [2]. |
| Hot food holding cabinet | Conventional unit per California Energy Wise savings calculator [2]. |
| Ice machine | Conventional unit per ENERGY STAR savings calculator [1]. |
| Oven | Conventional unit per ENERGY STAR savings calculator and California Energy Wise savings calculator [1], [2]. |
| Refrigerator | Federal standard [3]. |
| Steam cooker | Conventional unit per California Energy Wise savings calculator [2]. |

| Equipment | Baseline |
|---|---|
| WaterSense pre-rinse spray valve | See section 2.2.11 |

## ***Annual Energy Savings Algorithm***

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

$$\Delta kW = \frac{\Delta kWh}{8760\, {}^{hrs}/_{yr}}$$

*Lost Opportunity Gross Peak Demand Savings, Natural Gas*

$$\Delta CCF_{PD} = \frac{\Delta CCF}{365 days/yr}$$

## ***Calculation Parameters***

**Table 2-243 Calculation Parameters**

| Symbol | Description | Units | Values | Ref |
|---|---|---|---|---|
| ΔkWh | Annual gross electric energy savings | kWh | Table 2-244 | |
| ΔkW | Average hourly summer and winter demand savings | kW | Table 2-244 | |
| ΔCCF | Annual natural gas savings | CCF | Table 2-244 | |
| $\Delta CCF_{PD}$ | Peak day natural gas savings | CCF/day | Table 2-244 | |

**Table 2-244 Commercial Kitchen Equipment Deemed Savings**

| Measure | ΔCCF | $\Delta CCF_{PD}$ | ΔkWh | ΔkW | Ref |
|---|---|---|---|---|---|
| Commercial electric deck ovens | - | - | 7,519 | 0.858 | [4] |
| Electric combination oven | - | - | 15,095 | 1.723 | [2] |
| Electric convection oven (full size) | - | - | 2001 | 0.228 | [1] |
| Electric convection oven (half size) | - | - | 244 | 0.027 | [1] |
| Electric dishwasher high temp – door type | - | - | 11,863 | 1.354 | [1] |
| Electric dishwasher high temp – multi-tank conveyor | - | - | 27,408 | 3.129 | [1] |
| Electric dishwasher high temp – pot, pan, utensil | - | - | 3,311 | 0.378 | [1] |
| Electric dishwasher high temp – single tank conveyor | - | - | 9,212 | 1.052 | [1] |
| Electric dishwasher high temp – under counter | - | - | 3,171 | 0.362 | [1] |
| Electric dishwasher low temp – door type | - | - | 16,153 | 1.844 | [1] |

| Measure | ΔCCF | $\Delta CCF_{PD}$ | ΔkWh | ΔkW | Ref |
|---|---|---|---|---|---|
| Electric dishwasher low temp – multi-tank conveyor | - | - | 18,811 | 2.147 | [1] |
| Electric dishwasher low temp – single-tank conveyor | - | - | 13,626 | 1.555 | [1] |
| Electric dishwasher low temp – under counter | - | - | 2,540 | 0.29 | [1] |
| Electric fryer - standard vat | - | - | 2,976 | 0.34 | [2] |
| Electric fryer - large vat | - | - | 2,841 | 0.324 | [2] |
| Electric griddle – up to 36” | - | - | 3,965 | 0.453 | [4] |
| Electric griddle – over 36” | - | - | 7,930 | 0.905 | [4] |
| Electric hot food holding cabinets – full size | - | - | 2,737 | 0.312 | [2] |
| Electric hot food holding cabinets – ¾ size | - | - | 1,095 | 0.125 | [2] |
| Electric hot food holding cabinets – half size | - | - | 1,095 | 0.125 | [2] |
| Electric ice machine, remote cond./split unit, continuous 1,750 lb/day | - | - | 3,641 | 0.416 | [2] |
| Electric ice machine, self-contained 200 lb/day | - | - | 805 | 0.092 | [2] |
| Electric ice making, head 0-500 lb/day | - | - | 1,117 | 0.127 | [2] |
| Electric ice machine, remote cond./split unit, batch 1,250 lb/day | - | - | 2,601 | 0.296 | [2] |
| Electric steam cooker | - | - | 30,156 | 3.442 | [2] |
| Energy-efficient commercial conveyor broilers, < 20" wide | 1,113 | 3.049 | 7,144 | 0.816 | [4] |
| Energy-efficient commercial conveyor broilers, 20-26" wide | 1,879 | 5.148 | 6,403 | 0.731 | [4] |
| Energy-efficient commercial conveyor broilers, > 26" wide | 3,072 | 8.416 | 23,849 | 2.722 | [4] |
| Energy-efficient commercial underfired broiler | 212 | 0.581 | - | - | [4] |
| Freezer, glass door, self-contained (< 15 cubic ft) | - | - | 427 | 0.05 | [1] |
| Freezer, glass door, self-contained (15-29.9 cubic ft) | - | - | 681 | 0.08 | [1] |
| Freezer, glass door, self-contained (30-49.9 cubic ft) | - | - | 541 | 0.06 | [1] |
| Freezer, glass door, self-contained (50+ cubic ft) | - | - | 589 | 0.07 | [1] |
| Freezer, solid door, self-contained (< 15 cubic ft) | - | - | 256 | 0.03 | [1] |
| Freezer, solid door, self-contained (15-29.9 cubic ft) | - | - | 269 | 0.03 | [1] |
| Freezer, solid door, self-contained (30-49.9 cubic ft) | - | - | 1062 | 0.12 | [1] |
| Freezer, solid door, self-contained (50+ cubic ft) | - | - | 1486 | 0.17 | [1] |
| Gas combination oven | 912 | 2.5 | - | - | [2] |
| Gas convection oven | 295 | 0.8 | - | - | [2] |
| Gas conveyor oven | 731 | 2 | - | - | [1] |
| Gas dishwasher high temp – door type | 285 | 0.781 | 4,840 | 0.553 | [1] |
| Gas dishwasher high temp – multi-tank conveyor | 656 | 1.796 | 11,230 | 1.282 | [1] |

| Measure | ΔCCF | $\Delta CCF_{PD}$ | ΔkWh | ΔkW | Ref |
|---|---|---|---|---|---|
| Gas dishwasher high temp – pot, pan, utensil | 85 | 0.234 | 1,204 | 0.137 | [1] |
| Gas dishwasher high temp – single-tank conveyor | 173 | 0.473 | 4,948 | 0.565 | [1] |
| Gas dishwasher high temp – under counter | 44 | 0.12 | 2,089 | 0.238 | [1] |
| Gas dishwasher low temp – door type | 654.75 | 1.794 | - | - | [1] |
| Gas dishwasher low temp – multi-tank conveyor | 762.42 | 2.089 | - | - | [1] |
| Gas dishwasher low temp – single-tank conveyor | 528.65 | 1.448 | 584 | 0.067 | [1] |
| Gas dishwasher low temp – under counter | 102.82 | 0.282 | - | - | [1] |
| Gas fryer – large vat | 435 | 1.2 | - | - | [7] |
| Gas fryer - standard vat | 531 | 1.5 | - | - | [7] |
| Gas griddle with 3 ft countertop width | 313 | 0.9 | - | - | [2] |
| Gas pre-rinse spray valve | 94 | 0.3 | - | - | [2] |
| Gas rack oven | 1,748 | 4.8 | - | - | [2] |
| Gas steamer | 3,066 | 8.4 | - | - | [2] |
| Induction Cooktop | - | - | 15,960 | 1.82 | [6] |
| On-demand commercial electric hand wrap machine | - | - | 1,565 | 0.18 | [4] |
| Conveyor Toaster | | | 3463 | 0.531 | [4] |
| Refrigerated chef bases, 35-54” | - | - | 1,051 | 0.11 | [5] |
| Refrigerated chef bases, 55-73” | - | - | 1,637 | 0.18 | [5] |
| Refrigerated chef bases, 74-89” | - | - | 1,986 | 0.21 | [5] |
| Refrigerated chef bases, 90-120” | - | - | 2,673 | 0.29 | [5] |
| Refrigerator, solid door, self-contained (< 15 cubic ft) | - | - | 170 | 0.0194 | [1] |
| Refrigerator, solid door, self-contained (15-29.9 cubic ft) | - | - | 230 | 0.03 | [1] |
| Refrigerator, solid door, self-contained (30-49.9 cubic ft) | - | - | 818 | 0.093 | [1] |
| Refrigerator, solid door, self-contained (50+ cubic ft) | - | - | 376 | 0.04 | [1] |
| Refrigerator, glass door, self-contained (< 15 cubic ft) | - | - | 69 | 0.01 | [1] |
| Refrigerator, glass door, self-contained (15-29.9 cubic ft) | - | - | 113 | 0.01 | [1] |
| Refrigerator, glass door, self-contained (30-49.9 cubic ft) | - | - | 883 | 0.101 | [1] |
| Refrigerator, glass door, self-contained (50+ cubic ft) | - | - | 1,212 | 0.138 | [1] |

## ***Measure Life***

**Table 2-245 Measure Life**

| Equipment Type | Measure Life | Ref |
|---|---|---|
| Convection oven | 12 | [10] |
| Dishwasher - under counter | 10 | [11] |
| Dishwasher - stationary single tank door | 15 | [11] |
| Dishwasher – single-tank conveyor | 20 | [11] |
| Dishwasher – multi-tank conveyor | 20 | [11] |
| Freezer | 12 | [10] |
| Fryer | 12 | [10] |
| Griddle | 12 | [10] |
| Hot food holding cabinet | 12 | [10] |
| Ice machine | 10 | [12] |
| Refrigerator | 12 | [10] |
| Steam Cooker | 12 | [10] |
| Conveyor Toaster | 12 | [10] |

## ***Peak Factors***

**Table 2-246 Peak Factors**

| Measure | Summer Coincidence Factor | Winter Coincidence Factor | Ref |
|---|---|---|---|
| Commercial kitchen equipment | 100% | 100% | [13] |

## ***Load Shapes***

**Table 2-247 Load Shapes**

| End Use | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % | Ref |
|---|---|---|---|---|---|
| Refrigeration | 29.95% | 36.58% | 15.95% | 17.51% | [13] |
| Other | 37.00% | 29.00% | 19.00% | 15.00% | [13] |

## ***Realization Rates***

**Table 2-248 Electric Realization Rates**

| | Gross Realization % | | | | FR and SO | | Net Realization % | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Measure | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Installation Rate (ISR) | Free-ridership | Spill-over | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Ref |
| Food service equipment | 100.0% | 100.0% | 100.0% | 100.0% | 18.00% | 0.00% | 82.0% | 82.0% | 82.0% | [8], [9] |

**Table 2-249 Natural Gas Realization Rates**

| | Gross Realization % | | FR and SO | | Net Realization % | | |
|---|---|---|---|---|---|---|---|
| Measure | Energy (CCF) | Peak Day (CCF) | Free ridership | Spillover | Energy (CCF) | Peak Day (CCF) | Ref |
| Food service | 100.0% | 100.0% | 18.00% | 0.00% | 82.0% | 82.0% | [9] |

## ***References***


[1] ENERGY STAR Commercial Kitchen Package for businesses and operators, available online at: https://energy.gov/eere/femp/energy-and-cost-savings-calculators-energy-efficient-products, last accessed Jun. 16, 2022.

[2] California Energy Wise Commercial Kitchen Energy Savings Calculators, Available online at: https://caenergywise.com/calculators/, last accessed June 16,2022.

[3] Federal Standard: Title 10 Part 431 - Energy Efficiency Program for Certain Commercial and Industrial Equipment; Section 431.66. https://www.law.cornell.edu/cfr/text/10/431.66.

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

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

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

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

[8] NMR, DNV, Brightline Group. 2022. "C1902a: Connecticut Midstream C&I HVAC & Water Heating and Foodservice Net-to-Gross Review."

[9] NMR, DNV-GL, and Tetra-Tech, *Massachusetts Sponsors' Commercial and Industrial Programs Free-ridership and Spillover Study*, Aug. 14, 2018 (Table 48, Table 52).

[10] 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.

[11] ENERGY STAR commercial kitchen equipment savings calculator, at: https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator_0.xlsx.

[12] US EPA. Feb. 2015. Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment. Available online at: http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xls

[13] DNV. 2021. "X1931-2 Load Shape and Coincidence Factor Research." Connecticut Energy Efficiency Board (EEB) and Evaluation Administrators.

[14] 2020 California electronic Technical Reference Manual (eTRM), Report published by Emerging Technology Program developed by SCU, https://www.caetrm.com/media/reference-documents/2020-06-12_h.e._toaster_report_final_draft.pdf

## ***Changes from Last Version***

- Added peak day savings for energy-efficient commercial conveyor broilers, >26" wide, based on the deemed annual natural gas savings.
- Updated net realization rates.
- Formatting updates.
- Added Conveyor Toaster savings

## 2.6.2 COMMERCIAL CLOTHES WASHER

| | |
|---|---|
| Market | Commercial |
| Baseline Type | Lost Opportunity |
| Category | Appliances |

### ***Description***

The installation of an ENERGY STAR certified commercial clothes washer.

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 from the 2016 October Federal Standard and ENERGY STAR requirements [1]. The usage per load by fuel source for baseline (Federal Standard) and ENERGY STAR certified units were calculated based on from the 2016 October Federal Standard and ENERGY STAR requirements [1]. Using the average loads per year the annual savings are calculated. Number of annual loads will either be based on the CEE default calculator default values (i.e., laundromats (2,190 loads per year) or multifamily (1,241 loads per year)) or project specific information for any facility type. Installed energy use will be based on the installed modified energy factor.

Note: The Federal Standard and ENERGY STAR certified requirements changed in 2013. There are now separate Federal Standard levels for front loading and top loading washers. The CEE savings calculator from the 2016 October Federal Standard and ENERGY STAR requirements [1] used for this measure was modified based on the new Federal Standard and ENERGY STAR certified requirements.

### ***Annual Energy Savings Algorithm***

*Lost Opportunity Gross Energy Savings, Electric*

Electric savings are calculated as the sum of washer, dryer, and water heating savings. Electric dryer and water heating savings are present only if the heat element fuel source is electric.

$$\Delta kWh = \Delta kWh_{washer} + \Delta kWh_{dryer} + \Delta kWh_{WH}$$

Where,

$$\Delta kWh_{washer} = N \times LDS \times Weeks \times \left( kWh_{b,washer} - kWh_{ES,washer} \times \frac{MEF_{ES}}{MEF_i} \right)$$

$$\Delta kWh_{dryer} = N \times LDS \times Weeks \times \left( kWh_{b,dryer} - kWh_{ES,dryer} \times \frac{MEF_{ES}}{MEF_i} \right)$$

$$\Delta kWh_{WH} = N \times LDS \times Weeks \times \left( kWh_{b,WH} - kWh_{ES,WH} \times \frac{MEF_{ES}}{MEF_i} \right)$$

*Lost Opportunity Gross Energy Savings, Natural Gas*

$$\Delta CCF = \frac{\Delta Btu}{102{,}900 \, {}^{Btu}/_{CCF}}$$

Where ΔBtu is calculated per the *Lost Opportunity Gross Energy Savings, Fossil Fuel Btu* section below.

*Lost Opportunity Gross Energy Savings, Oil*

$$\Delta Gal_{Oil} = \frac{\Delta Btu}{138{,}690 \, {}^{Btu}/_{Gal_{Oil}}}$$

Where ΔBtu is calculated per the *Lost Opportunity Gross Energy Savings, Fossil Fuel Btu* section below.

*Lost Opportunity Gross Energy Savings, Propane*

$$\Delta Gal_{Propane} = \frac{\Delta Btu}{91{,}330 \, {}^{Btu}/_{Gal_{Propane}}}$$

Where ΔBtu is calculated per the *Lost Opportunity Gross Energy Savings, Fossil Fuel Btu* section below.

*Lost Opportunity Gross Energy Savings, Fossil Fuel Btu*

Fossil fuel savings will be calculated as the sum of dryer and water heater savings. Fossil fuel dryer and water heating savings are only present if the heat element fuel source is a fossil fuel.

$$\Delta Btu = \Delta Btu_{dryer} + \Delta Btu_{WH}$$

Where,

$$\Delta Btu_{dryer} = N \times LDS \times Weeks \times \left( Btu_{b,dryer} - Btu_{ES,dryer} \times \frac{MEF_{ES}}{MEF_i} \right)$$

$$\Delta Btu_{WH} = N \times LDS \times Weeks \times \left( Btu_{b,WH} - Btu_{ES,WH} \times \frac{MEF_{ES}}{MEF_i} \right)$$

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

$$\Delta kW_{Winter} = \frac{\Delta kWh}{Hours} \times CF_{Winter}$$

$$\Delta kWh_{Summer} = \frac{\Delta kWh}{Hours} \times CF_{Summer}$$

*Lost Opportunity Gross Peak Day Savings, Natural Gas*

$$\Delta CCF_{PD} = \frac{\Delta CCF_{dryer}}{365 \; days/yr} + PDF_{WH} \times \Delta CCF_{WH}$$

***Calculations Parameters***

**Table 2-250 Calculation Parameters**

| Symbol | Description | Value (Laundromat) | Value (Multifamily) | Units | Ref |
|---|---|---|---|---|---|
| $\Delta kWh$ | Annual electric energy savings | Calculated | Calculated | kWh | |
| $\Delta kWh_{washer}$ | Annual electric energy savings, washer | Calculated | Calculated | kWh | |
| $\Delta kWh_{dryer}$ | Annual electric energy savings, dryer | Calculated | Calculated | kWh | |
| $\Delta kWh_{WH}$ | Annual electric energy savings, water heater | Calculated | Calculated | kWh | |
| $\Delta CCF$ | Annual natural gas savings | Calculated | Calculated | CCF | |
| $\Delta Gal_{Oil}$ | Annual oil savings | Calculated | Calculated | Gallons | |
| $\Delta Gal_{Propane}$ | Annual propane savings | Calculated | Calculated | Gallons | |
| $\Delta Btu$ | Annual fossil fuel energy savings | Calculated | Calculated | Btu | |
| $\Delta Btu_{dryer}$ | Annual fossil fuel energy savings, dryer | Calculated | Calculated | Btu | |
| $\Delta Btu_{WH}$ | Annual fossil fuel energy savings, water heater | Calculated | Calculated | Btu | |
| $\Delta kW_{Winter}$ | Winter peak seasonal demand savings | Calculated | Calculated | kW | |
| $\Delta kW_{Summer}$ | Summer peak seasonal demand savings | Calculated | Calculated | kW | |
| $\Delta CCF_{PD}$ | Annual peak day natural gas savings | Calculated | Calculated | CCF | |
| $kWh_{b,washer}$ | Baseline washer kWh per load | 0.116 | 0.093 | kWh/load | [1] |
| $kWh_{ES,washer}$ | ENERGY STAR washer kWh per load | 0.085 | 0.085 | kWh/load | [1] |
| $kWh_{b,dryer}$ | Baseline dryer kWh per load | 0.872 | 0.698 | kWh/load | [1] |
| $kWh_{ES,dryer}$ | ENERGY STAR dryer kWh per load | 0.634 | 0.634 | kWh/load | [1] |
| $kWh_{b,WH}$ | Baseline water heater kWh per load | 0.444 | 0.356 | kWh/load | [1] |
| $kWh_{ES,WH}$ | ENERGY STAR water heater kWh per load | 0.325 | 0.325 | kWh/load | [1] |
| $Btu_{b,dryer}$ | Baseline dryer Btu per load | 2,969 | 2,376 | Btu/load | [1] |
| $Btu_{ES,dryer}$ | ENERGY STAR dryer Btu per load | 2,160 | 2,160 | Btu/load | [1] |
| $Btu_{b,WH}$ | Baseline water heater Btu per load | 2,597 | 2,597 | Btu/load | [1] |
| $Btu_{ES,WH}$ | ENERGY STAR water heater Btu per load | 2,361 | 2,361 | Btu/load | [1] |
| $MEF_{ES}$ | Modified Energy Factor, ENERGY STAR | 2.2 | 2.2 | $Ft^3$/kWh/cycle | [1] |
| $MEF_i$ | Modified Energy Factor, installed | Site-specific | Site-specific | $Ft^3$/kWh/cycle | |
| N | Number of units | Site-specific | Site-specific | N/A | |
| LDS | Average number of loads per week | Site-specific, use 42 if unknown | Site-specific, use 24 if unknown | Loads/week | |

| Symbol | Description | Value (Laundromat) | Value (Multifamily) | Units | Ref |
|---|---|---|---|---|---|
| Weeks | Average number of weeks used per year | Site-specific, use 52 if unknown | Site-specific, use 52 if unknown | Weeks/year | |
| Hours | Assumed run hours of clothes washer | Site-specific, use 265.7 if unknown | Site-specific, use 265.7 if unknown | Hours | [2] |
| $CF_{Winter}$ | Winter coincidence factor | Table 2-252 | Table 2-252 | N/A | |
| $CF_{Summer}$ | Summer coincidence factor | Table 2-252 | Table 2-252 | N/A | |
| PDF | Natural gas peak day factor | Table 2-253 | Table 2-253 | N/A | |

## ***Calculation Examples***

*Example 1: Lost Opportunity Gross Energy Savings*

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:*

$$\Delta kWh = N \times LDS \times Weeks \times \left[ \left( kWh_{b,washer} - kWh_{ES,washer} \times \frac{MEF_{ES}}{MEF_i} \right) + \left( kWh_{b,dryer} - kWh_{ES,dryer} \times \frac{MEF_{ES}}{MEF_i} \right) + \left( kWh_{b,WH} - kWh_{ES,WH} \times \frac{MEF_{ES}}{MEF_i} \right) \right]$$

- Dryer and Water Heater Electric Usage = 0;
- N = 25;
- LDS x Weeks = 2,190 (default loads per year);
- WKWHb = 0.093 kWh/ld;
- WKWHes = 0.085 kWh/ld;
- MEFes = 2.2; and
- MEFi = 2.2.

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

*Annual Natural Gas Savings:*

$$\Delta BTU = \Delta BTU_{dryer} + \Delta BTU_{WH}$$

$$\Delta BTU_{WH} = N \times LDS \times Weeks \times \left(BTU_{b,WH} - BTU_{ES} \times \frac{MEF_{ES}}{MEF_i}\right)$$

$$\Delta BTU_{WH} = 25 \times 2{,}190 \times \left(2{,}597 - 2{,}361 \times \frac{2.2}{2.2}\right) = 12{,}921{,}000 Btu$$

$$\Delta CCF_{WH} = \frac{\Delta BTU_{WH}}{102{,}900\ Btu/ccf} = 125.6\ CCF$$

$$\Delta BTU_{dryer} = N \times LDS \times Weeks \times \left(BTU_{b,dryer} - BTU_{ES,dryer} \times \frac{MEF_{ES}}{MEF_i}\right)$$

$$\Delta BTU_{dryer} = 25 \times 2{,}190 \times \left(2{,}376 - 2{,}160 \times \frac{2.2}{2.2}\right) = 11{,}826{,}000 Btu$$

$$\Delta CCF_{dryer} = \frac{\Delta BTU_{dryer}}{102{,}900\ Btu/ccf} = 115\ CCF$$

$$\Delta CCF = \Delta CCF_{dryer} + \Delta CCF_{WH} = 125.6 + 115 = 240.6\ CCF$$

*Example 2: Lost Opportunity Gross Peak Day Savings, Natural Gas*

$$\Delta CCF_{PD} = \frac{\Delta CCF_{dryer}}{365\ days/yr} + PDF_{WH} \times \Delta CCF_{WH} = \frac{115}{365\ days/yr} + 0.00321 \times 125.6 = 0.72\ CCF$$

## Measure Life

**Table 2-251 Measure Life**

| Equipment Type | Measure Life | Ref |
|---|---|---|
| Clothes Washer | 7 | [3] |

## Peak Factors

**Table 2-252 Peak Factors (Electric)**

| Measure | Summer Coincidence Factor | Winter Coincidence Factor | Ref |
|---|---|---|---|
| Commercial clothes washers | 0% | 0% | [4] |

**Table 2-253 Peak Factors (Natural Gas)**

| End Use | Peak Day Factor | Ref |
|---|---|---|
| Water Heating | 0.00321 | |

## *Load Shapes*

**Table 2-254 Load Shapes**

| End Use | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % | Ref |
|---|---|---|---|---|---|
| Process | 32.00% | 36.00% | 16.00% | 16.00% | [4] |

## *Non-Energy Impacts*

ENERGY STAR certified washers use less water than the base unit. Water savings are calculated as follows:

$$\Delta Gal_{H2O} = N \times LDS \times Weeks \times \left(Gal_b - Gal_{ES} \times \frac{IWF_{es}}{IWF_i}\right)$$

**Table 2-255 Water Savings Calculation Parameters**

| Symbol | Description | Value (Laundromat) | Value (Multifamily) | Units | Ref |
|---|---|---|---|---|---|
| ΔGalH2O | Annual water savings | Calculated | Calculated | Gallons | |
| N | Number of units | Site-specific | Site-specific | N/A | |
| LDS | Average number of loads per week | Site-specific, use 42 if unknown | Site-specific, use 24 if unknown | Loads/week | |
| Weeks | Average number of weeks used per year | Site-specific, use 52 if unknown | Site-specific, use 52 if unknown | Weeks/year | |
| Galb | Baseline gallons of water per load | 26.35 | 17.1 | Gal/load | [1] |
| GalES | ENERGY STAR gallons of water per load | 13.95 | 13.95 | Gal/load | [1] |
| $IWF_{ES}$ | Modified Energy Factor, ENERGY STAR | 4.0 | 4.0 | $Ft^3$/kWh/cycle | [1] |
| $IWF_i$ | Modified Energy Factor, installed | Site-specific | Site-specific | $Ft^3$/kWh/cycle | |

## *Realization Rates*

| | Gross Realization % | | | FR & SO | | Net Realization % | | |
|---|---|---|---|---|---|---|---|---|
| Measure | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Free-ridership | Spill-over | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW |
| Process **Energy Conscious Blueprint** | 80.3% [5] | 113.0% [5] | 114.1% [5] | 17.6% [7] | 0.9% [7] | 66.9% | 93.7% | 95.0% |
| Process **Energy Opportunities** | 67.6% [6] | 162.1% [6] | 114.7% [6] | 12.0% [8] | 35.0% [8] | 83.1% | 199.4% | 141.1% |

## *References*


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

[2] Mid Atlantic Technical Reference Manual Version 10, May 2020.

[3] EPA ENERGY STAR calculator, accessed Apr. 25, 2017, based on Cadmus review of four retailer websites: Sears, Home Depot, Lowes, and Best Buy. https://dnr.mo.gov/sites/dnr/files/media/file/2021/01/2015-clothes-washer-analysis.xlsx.

[4] DNV. 2021. "X1931-2 Load Shape and Coincidence Factor Research." Connecticut Energy Efficiency Board (EEB) and Evaluation Administrators.

[5] Cadmus. 2020. "C1634: Impact Evaluation of PY 2016 & 2017 Energy Conscious Blueprint Program."

[6] DNV GL. 2020. "C1635: Impact Evaluation of PY 2016 & 2017 Energy Opportunities Program."

[7] Tetra Tech. 2012. "2011 C&I Electric and Gas Free-ridership and Spillover Study."

[8] EMI Consulting. 2019. "C1644: EO Net-to-Gross Study." Connecticut Energy Efficiency Board.


## *Changes from Last Version*

- Added missing kWh per load and Btu per load value to table based on ENERGY STAR calculator and existing parameters
- Updated water savings equation to use integrated water factor, using $IWF_{ES}$ per ENERGY STAR product criteria
- Formatting updates.

## 2.7 OTHER

### 2.7.1 LEAN MANUFACTURING

| | |
|---|---|
| Market | Commercial |
| Baseline Type | Lost Opportunity |
| Category | Category |

***Description***

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

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 derived from references [1], [2]. Savings are estimated based on facility’s existing actual annual electrical usage and estimating the production increase with and without PRIME.

Savings are based on two concepts:

- 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).

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

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

***Annual Energy Savings Algorithm [1], [2]***

*Annual Gross Energy Savings, Electric*

$$\Delta kWh = kWh_{Est,wop} - kWh_{Est,wp}$$

Where,

Estimated annual consumption with increase in productivity without PRIME:

$$kWh_{Est,wop} = kWh_{Ind,wop} + kWh_{Hrs,wop} + kWh_{Prod,wop}$$

$$kWh_{Ind,wop} = DF_{Ind} \times PPA \times kWh_{Hist}$$

$$kWh_{Hrs,wop} = DF_{Hrs} \times PPA \times kWh_{Hist} \times \frac{N_a}{N_e}$$

$$kWh_{Prod,wop=}DF_{Prod} \times PPA \times kWh_{Hist} \times \frac{N_a}{N_e}$$

Estimated annual consumption with increase in productivity with PRIME:

$$kWh_{E,wop} = kWh_{Ind,wp} + kWh_{Hrs,wp} + kWh_{Prod,wp}$$

$$kWh_{Ind,wop} = DF_{Ind} \times PPA \times kWh_{Hist}$$

$$kWh_{Hrs,wop} = DF_{Hrs} \times PPA \times kWh_{Hist}$$

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

$$kWh_{Prod,wp} = DF_{Prod} \times PPA \times \frac{N_a}{N_e} \times (1 - SF)$$

*Gross Seasonal Peak Demand Savings, Electric*

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

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

## ***Calculation Parameters***

**Table 2-256 Calculation Parameters**

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| ΔkWh | Annual gross kWh savings | Calculated | kWh | |
| $\Delta kW_{Summer}$ | Gross seasonal peak demand savings, summer | 0 | kWh | |
| $\Delta kW_{Winter}$ | Gross seasonal peak demand savings, winter | 0 | kWh | |
| $kWh_{Est}$ | Estimated annual electric usage with an increase in production | Calculated | kWh | |
| $kWh_{Ind}$ | Annual electric energy usage independent of production hours and production quantity | Calculated | kWh | |
| $kWh_{Hrs}$ | Annual electric energy usage dependent on hours of production | Calculated | kWh | |
| $kWh_{Prod}$ | Annual electric energy usage dependent on production quantity | Calculated | kWh | |

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| SF | Savings factor[10] | Calculated | N/A | [1] |
| $kWh_{Hist}$ | Facility's annual electric usage based on billing history | Site-specific | kWh | |
| PPA | Percent of facility's energy usage affected by PRIME | Site-specific | % | |
| $DF_{Ind}$ | Load dependence factor Type A, B, and Office<br>Percentage of facility loads independent of production hours and production throughput | .41 | | [2] |
| $DF_{Hrs}$ | Load dependence factor Type C<br>Percentage of facility loads dependent on hours of production | .41 | | [2] |
| $DF_{Prod}$ | Load dependence factor Type D<br>Percentage of facility loads dependent on production throughput | .18 | | [2] |
| $N_a$ | Production rate after PRIME | Site-specific | Units/hour | |
| $N_e$ | Existing production rate | Site-specific | Units/hour | |
| …wop | Without PRIME | | | |
| …wp | With PRIME | | | |

## ***Calculation Examples***

*Lost Opportunity Gross Energy Savings Example*

A manufacturing plant that has an annual electricity consumption of 1,000,000 kWh ($kWh_{Hist}$) 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 ($N_e$) to 330 ($N_a$) products per hour.

$$\Delta kWh = kWh_{Est,wop} - kWh_{Est,wp}$$

*Where,*

*Estimated annual consumption with increase in productivity without PRIME:*

$$kWh_{Est,wop} = kWh_{Ind,wop} + kWh_{Hrs,wop} + kWh_{Prod,wop}$$

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

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

10 This savings factor represents the percent savings as a function of percent production increase. The constants are the results of a regression analysis in reference [1].

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

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

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

$$kWh_{Est,wp} = kWh_{Ind,wp} + kWh_{Hrs,wp} + kWh_{Prod,wp}$$

$$kWh_{Ind,wp} = 0.41 \times\ 0.25 \times 1{,}000{,}000 = 102{,}500\ kWh$$

$$kWh_{Hrs,wp} = 0.41 \times 0.25 \times 1{,}000{,}000 = 102{,}500\ kWh$$

$$SF = 0.1168 \times \left[\frac{330 - 300}{300}\right]^3 - 0.3402 \times \left[\frac{330 - 300}{300}\right]^2 + 0.4732 \times \left[\frac{330 - 300}{300}\right] + 0.0011 = 0.045$$

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

$$kWh_{Est,wp} = 102{,}500 + 102{,}500 + 47{,}272.5 = 252{,}272.5\ kWh$$

$$\Delta kWh = 264{,}750 - 252{,}272.5 = 12{,}477.5\ kWh$$

## ***Measure Life***

The measure life for PRIME is 5 years [1].

## ***Peak Factors***

**Table 2-257 Peak Factors**

| Measure | Summer Coincidence Factor | Winter Coincidence Factor | Ref |
|---|---|---|---|
| Lean manufacturing | 0% | 0% | [1] |

## ***Load Shapes***

**Table 2-258 Load Shapes**

| Measure Type | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % | Ref |
|---|---|---|---|---|---|
| C&I Other | 37.00% | 29.00% | 19.00% | 15.00% | [3] |

## ***Realization Rates and Net Impact Factors***

**Table 2-259 Realization Rates**

| | Gross Realization % | | | FR & SO | | Net Realization % | | |
|---|---|---|---|---|---|---|---|---|
| Measure | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Free ridership | Spillover | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW |
| PRIME | 54.0% [2] | 100.0% | 100.0% | 0.0% | 0.0% | 54.0% | 100.0% | 100.0% |

## ***References***


[1] Energy & Resource Solutions. 2007. "Process Reengineering for Increased Manufacturing Efficiency (PRIME) Program Evaluation."

[2] Energy & Resource Solutions. 2018. "C1641: Impact Evaluation of the Business and Energy Sustainability Program." Tables 4-5.

[3] DNV. 2021. "X1931-2 Load Shape and Coincidence Factor Research – Final Report."


## ***Changes from Last Version***

- Formatting updates.

## 2.7.2 ACTIVE DEMAND RESPONSE

| | |
|---|---|
| Market | Commercial |
| Baseline Type | Retrofit |
| Category | Other |

***Description***

C&I Active Demand Reduction includes Interruptible Load Curtailment, Battery Storage Daily Dispatch, Battery Storage Targeted Dispatch, Thermal Storage Daily Dispatch, and Thermal Storage Targeted Dispatch.

- The peak demand savings will be the difference between the estimated peak demand of a customer baseline in the absence of a demand response program and the measured peak demand after implementation of a demand response program. Reporting for demand response measures should include ex-post reporting or ex-ante reporting. For ex-post reporting, measure savings should be quantified by using meter-based methods, such as day- or weather-matching customer baseline including a control group, regression-based methods on customer historical data, or similar methods. For ex-ante reporting, measure savings should be estimated by using a scalar weather normalization method, a time-temperature matrix, or similar methods.
- Program Offerings:
- The **Interruptible Load Curtailment offering** is technology agnostic (similar to a Custom measure) and provides an incentive for verifiable shedding of load in response to a signal or communication from the EDCs coinciding with system peak conditions. Large C&I customers with the ability to control lighting, comfort, and/or process loads can use this demand reduction performance offering to generate revenue by altering their operations a few times per year. The offering focuses on reducing demand during summer peak events, typically targeting fewer than twenty-five hours per summer.
- The **Battery Storage Daily Dispatch offering** provides pay-for-performance incentives to customers with battery storage that can reduce load on a daily basis. Customers are routinely dispatched to reduce regional peak loads on non-holidays June to September.
- The **Battery Storage Targeted Dispatch Summer offering** provides pay-for-performance incentives to customers with battery storage that can reduce load during peak events. Customers are dispatched up to eight times during the summer with the goal of reducing regional peak loads, specifically the annual system peak hour.
- The **Thermal Storage Daily Dispatch offering** provides pay-for-performance incentives to customers with thermal storage that can reduce load on a daily basis. Customers are routinely dispatched to reduce regional peak loads on non-holiday weekdays June to September up to 60 times per summer.
- The **Thermal Storage Targeted Dispatch offering** provides pay-for-performance incentives to customers with thermal storage that can reduce load during peak events. Customers are dispatched up to eight times during the summer with the goal of reducing regional peak loads with a focus on the annual system peak hour.

*Baseline*

Baseline conditions will be determined based on technology.

- For Interruptible Load Curtailment both targeted and daily dispatch, baseline conditions are based on an adjustment settlement baseline with symmetric, additive adjustment. The symmetrically adjusted settlement baseline is developed based on a pool of the most recent 10 non-holiday weekdays. The baseline shape consists of average load per interval across the eligible days. The baseline is adjusted based on the difference between baseline and facility load in the second hour prior to the event (the baseline adjustment period), and the adjustment can either increase or decrease the estimated load reduction (i.e., symmetric adjustment). This adjustment accounts for weather-related and other differences of load magnitude.
- For battery storage, both daily dispatch and targeted dispatch, demand reduction is calculated based on battery load. A baseline value is not directly calculated for storage, instead, the counterfactual is the actual facility load without the battery, which is derived based on the facility load with the battery and the battery load.
- For thermal storage, both daily dispatch and targeted dispatch, the average performance during non-event weekday afternoons is used to calculate the baseline load for events based on equipment-specific data. This analysis method is analogous to the settlement baselines for interruptible load curtailment.

### Annual Energy Savings Algorithm

C&I Active Demand Reduction measures generates site-specific demand savings. Savings estimates for these projects are calculated using engineering analysis with project-specific details.

### Calculation Parameters

Calculation parameters will be identified in the project-specific analysis.

### Measure Life

The measure life for Active Demand Reduction is one year, based on Program Administrators calling demand reduction events each year.

### Peak Factors

Calculation parameters will be identified in the project-specific analysis.

### Load Shapes

Calculation parameters will be identified in the project-specific analysis.

### Non-Energy Impacts

There are no other resource impacts identified for this measure.

## ***Realization Rates***

**Table 2-260 Realization Rates**

| | Gross Realization % | | | Install Rate (ISR) | FR and SO | | Net Realization % | | |
|---|---|---|---|---|---|---|---|---|---|
| Measure | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | | Free-ridership | Spillover | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW |
| Interruptible Load Curtailment1 | 86.6% | 86.6% | 86.6% | 100% | 0.0% | 0.0% | 86.6% | 86.6% | 86.6% |
| Battery Storage Daily Dispatch2 | 104% | 100% | 104% | 100% | 0.0% | 0.0% | 104% | 100% | 104% |
| Battery Storage Targeted Dispatch Summer1 | 101% | 100% | 101% | 100% | 0.0% | 0.0% | 101% | 100% | 101% |
| Thermal Storage Daily Dispatch | 100% | 100% | 100% | 100% | 0.0% | 0.0% | 100% | 100% | 100% |
| Thermal Storage Targeted Dispatch | 100% | 100% | 100% | 100% | 0.0% | 0.0% | 100% | 100% | 100% |

Active Demand Reduction offerings have not yet been evaluated with regard to net-to-gross ratios. Net-to-gross ratios are assumed to be 1.0 until the program is evaluated.

## ***References***

[6] ERS (2020). Cross-State C&I Active Demand Reduction Initiative Summer 2019 Evaluation Report 2019_ERS_Cross-State_CI_DR_Evaluation.

ERS (2020). Daily Dispatch Battery Project Evaluation Report. 2019_ERS_Daily_Dispatch_Battery

## ***Changes from Last Version***

- New measure.

# 2.8 CUSTOM

## 2.8.1 LOST OPPORTUNITY CUSTOM

| | |
|---|---|
| Market | Commercial |
| Baseline Type | Lost Opportunity |
| Category | Custom |

### ***Description***

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.

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. 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.

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.

**Note:** The demand savings methodologies below provide a gross, reasonable estimate based on available information. Final reported values are adjusted based on realization rates.

*Lost Opportunity Baseline*

Custom measures require description and specification of the baseline condition. For unique measures, those for which there is no broader market, the measure narrative should explain why the measure is unique and characterize the baseline condition. For non-unique measures, industry standard practice (ISP) is the baseline basis. When Connecticut has an established ISP for a measure, it defines baseline. When not, the applicant must document the basis of the ISP, preferably based on either a Connecticut "mini-ISP study" such as interviews with multiple vendors or market experts, and if not that ISP from another jurisdiction. Cost data is often informative in assessing baseline.

### ***Annual Energy Savings Algorithm***

*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 throughout the PSD, use the most applicable measure. Demand savings will be determined by multiplying the connected load kW savings by the appropriate coincidence factor.

*Temperature BIN analysis*

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

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

*Non-temperature dependent measures*

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

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

$$\Delta kW_{Summer} = \frac{Annual\ kWh\ savings\ Weekdays - June, July\ August}{Equipment\ Run\ Hours\ Weekdays - June, July\ August} \times \left(\frac{DR\ Seasonal\ Peak\ Hours}{6}\right)$$

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

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

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

*Whole building performance:*

Whole building performance (currently referred to as path1 and 2) shall be determined using a computer simulation model. Approved software and modeling requirements are specified by the Companies' program administrators. Baselines are determined using a combination of ASHRAE 90.1 Appendix G, and program's published energy modeling guidelines and exceptions.

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.

## ***Calculation Parameters***

Calculations parameters will be specific to each custom measures.

## ***Measure Life***

Measure life will be specific to each custom measure. For custom measures using technologies that are the same or similar to those addressed in other PSD measure chapters, refer to those chapters for load shapes. For other measures refer to Table 2-261 below

**Table 2-261 Selection of Measure Lives**

| Equipment Type | Lost Opportunity | Ref |
|---|---|---|
| **Lighting** | | |
| Automatic photocell dimming system | 10 | [5] |
| Bi-level switching (demand reduction) | 15 | [12] |
| Sweep controls/EMS based control | 15 | [5]* |
| **Building Envelope** | | |
| Cool roof | 15 | [6] |
| Insulation | 20 | [6] |
| Movable window insulation | 10 | [7] |
| New window | 20 | [6] |
| Roof spray cooling | 15 | [7] |
| Window film | 10 | [6] |

| Equipment Type | Lost Opportunity | Ref |
|---|---|---|
| **Domestic Hot Water** | | |
| Energy-efficient motor | 20 | [5] |
| Heat recovery | 15 | [7] |
| Point-of-use water heater | 20 | [6] |
| Solar water heater | 20 | [7] |
| **Heating, Ventilating and Air Condition (HVAC) Systems** | | |
| Additional pipe insulation | 15 | [9] |
| Additional vessel insulation | 10 | [7] |
| Air curtain | 15 | [7] |
| Air distribution system modifications & conversions | 20 | [7] |
| Cool thermal storage | 15 | [7] |
| Cooling tower alternates | 15 | [6] |
| Dehumidifier | 15 | [7] |
| Duct type air destratification system | 15 | [10] |
| Economizer - air/water | 10 | [5] |
| Electric spot radiant heat | 10 | [7] |
| Energy-efficient motor | 20 | [5] |
| Energy-efficient packaged terminal unit | 15 | [5] |
| Evaporative cooling (unitary) | 15 | [5]* |
| Gas engine chiller | 15 | **Error! Reference source not found.** |
| Low-leakage damper | 12 | [7] |
| Paddle type air destratification fan | 15 | [10] |
| Plate/heat pipe type heat recovery system | 14 | [6] |
| Rotary type heat recovery system | 14 | [6] |
| Water/steam distribution system modifications & conversions | 20 | [7] |
| **HVAC Controls** | | |
| EMS/linked HVAC controls | 15 | [5] |
| Enthalpy control economizer | 10 | [5] |
| New/additional EMS points | 15 | [5] |
| Upgrade to dual/comparative enthalpy economizer | 10 | [5]* |
| **Refrigeration** | | |

| Equipment Type | Lost Opportunity | Ref |
|---|---|---|
| Additional pipe insulation - refrigeration system | 11 | [6] |
| Additional vessel insulation - refrigeration system | 11 | [6] |
| Ambient sub-cooling | 15 | [6] |
| Auto cleaning system for condenser tubes | 10 | [7] |
| Demineralized water for ice | 10 | [7] |
| Heat recovery from refrigeration system | 13 | [7] |
| Hot gas bypass for defrost or regeneration | 10 | [7] |
| Low case HVAC returns | 10 | [7] |
| Low emissivity ceiling surfaces | 15 | [7] |
| Mechanical sub-cooling | 15 | [6] |
| Motorized insulated door | 8 | [6] |
| Oversized condenser | 15 | [6] |
| Polyethylene strip curtain | 4 | [6] |
| **Process Equipment** | | |
| Add regulator valves in compressed air system | 10 | [7] |
| Energy-efficient transformer | 20 | [5]* |
| Energy-efficient motor | 20 | [5] |
| Install air compressor no-loss condenser drain | 13 | [7] |
| Interlock air system solenoid valves with machine operation | 10 | [5]* |
| Interlock exhaust fans w/ machine operations | 10 | [5]* |
| Plastic injection molding machine | 15 | [7] |
| **Behavioral** | | |
| Strategic energy management | 4 | [12] |
| **Other** | | |
| Whole building performance | 17 | [7] |

## ***Peak Factors***

Peak factors will be specific to each custom measure.

## ***Load Shapes***

For custom measures using technologies that are the same or similar to those addressed in other PSD measure chapters, refer to those chapters for load shapes. For other measures refer to Table 2-262 below.

**Table 2-262 Load Shapes**

| Measure Type | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % | Ref |
|---|---|---|---|---|---|
| Other | 37.00% | 29.00% | 19.00% | 15.00% | [4] |
| Process | 32.00% | 36.00% | 16.00% | 16.00% | [4] |

## ***Realization Rates and Net Impact Factors***

For custom measures using technologies that are the same or similar to those addressed in other PSD measure chapters, refer to those chapters for realization rates and net impact factors. For other measures refer to Table 2-263 and Table 2-264 below.

**Table 2-263 Realization Rates and Net Impact Factors - Electric**

| | Gross Realization % | | | FR & SO | | Net Realization % | | |
|---|---|---|---|---|---|---|---|---|
| Measure | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Free-ridership | Spill-over | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW |
| Custom<br>**Energy Conscious Blueprint** | 98.5%<br>[1] | 106.3%<br>[1] | 97.4%<br>[1] | 22.5%<br>[2] | 16.9%<br>[2] | 93.0% | 100.3% | 91.9% |
| Other<br>**Energy Conscious Blueprint** | 98.5%<br>[1] | 106.3%<br>[1] | 97.4%<br>[1] | 18.2%<br>[2] | 7.1%<br>[2] | 87.6% | 94.5% | 86.6% |
| Process<br>**Energy Conscious Blueprint** | 80.3%<br>[1] | 113.0%<br>[1] | 114.1%<br>[1] | 17.6%<br>[2] | 0.9%<br>[2] | 66.9% | 93.7% | 95.0% |
| O&M<br>**Business & Energy Sustainability** | 79.0%<br>[3] | 258.0%<br>[3] | 191.0%<br>[3] | 0.0% | 0.0% | 79.0% | 258.0% | 191.0% |
| RCx<br>**Business & Energy Sustainability** | 105.0%<br>[3] | 175.0%<br>[3] | 126.0%<br>[3] | 0.0% | 0.0% | 105.0% | 175.0% | 126.0% |
| Load Response<br>**Load Management** | 100.0% | 100.0% | 100.0% | 0.0% | 0.0% | 100.0% | 100.0% | 100.0% |

**Table 2-264 Realization Rates and Net Impact Factors – Natural Gas**

| | Gross Realization % | | FR & SO | | Net Realization % | |
|---|---|---|---|---|---|---|
| Measure | CCF | Peak Day CCF | Free ridership | Spillover | CCF | Peak Day CCF |
| Process<br>**Energy Conscious Blueprint** | 90.7%<br>[1] | 100.0%<br>[1] | 23.8%<br>[2] | 9.5%<br>[2] | 77.7% | 85.7% |

| | Gross Realization % | | FR & SO | | Net Realization % | |
|---|---|---|---|---|---|---|
| O&M – Overall Program **Business & Energy Sustainability** | 94.0% [3] | 108.0% [4] | 0.0% | 0.0% | 94.0% | 108.0% |
| RCx – Overall Program **Business & Energy Sustainability** | 90.0% [3] | 72.0% [4] | 0.0% | 0.0% | 90.0% | 72.0% |

## ***References***


[1] Cadmus. 2020. "C1634: Energy Conscious Blueprint Impact Evaluation." Connecticut Energy Efficiency Board (EEB) and Evaluation Administrators.

[2] Tetra Tech. 2012. "2011 C&I Electric and Natural Gas Programs Free-Ridership and Spillover Study."

[3] ERS. 2018. "C1641: Impact Evaluation of the Business and Energy Sustainability Program." CT Energy Efficiency Board.

[4] Michaels Energy & Evergreen Economics. 2013. "Impact Evaluation of the Retro-commissioning, Operation and Maintenance, and Business Sustainability Challenge Programs." CT Energy Efficiency Board

[4] DNV. 2021. "X1931-2 Load Shape and Coincidence Factor Research – Final Report."

[5] GDS Associates Inc. 2007. "Measure Life Report, Residential and Commercial Industrial Lighting and HVAC Measures." Table 2. (*) Measure is similar to those in the report, so a measure life from Table 2 was used.

[6] 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. Found at: DEER Resources - CEDARS (sound-data.com).

[7] ERS. 2005. "Measure Life Study." Prepared for The Massachusetts Joint Utilities.

[8] Navigant. 2018. "ComEd Luminaire Level Lighting Control IPA Program Impact Evaluation Report."

[9] GDS Associates, Inc. 2009. "Natural Gas Energy Efficiency Potential in Massachusetts." Prepared for GasNetworks.

[10] Efficiency Maine TRM. March 5, 2007. Pg. 91. Similar measure.

[11] Gas chiller measure life was set by the CT DPUC (PURA) in their decision in Docket 05-07-14, in response to Public Act 05-01, "An Act Concerning Energy Independence". Dec. 28, 2005, p. 29, see Table 4.

[12] As part of the program, the Companies are providing 3 years of continual monitoring and check-ins with customers and expect savings to persist on average for at least one year beyond the 3 years of direct support. Measure life also supported by evaluated results of similar programs. See SBW Consulting, Inc. & The Cadmus Group, Industrial Strategic Energy Management (SEM) Impact Evaluation Report, Feb. 2017, and CEE, 2016 Strategic Energy Management Program Summary, Nov. 21, 2016.


## ***Changes from Last Version***

- Updated baseline description.
- Added measure parameters for measures not presented elsewhere in the PSD.
- Formatting updates.

## 2.8.2 RETROFIT CUSTOM MEASURES

| | |
|---|---|
| Market | Commercial |
| Baseline Type | Retrofit |
| Category | Custom Measures |

***Description***

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.

Retrofit savings are the combination of lost opportunity and early retirement. Use of ER requires a preponderance of evidence such as trend data, metered data, dated photos/videos of operation, bid quotations or similar demonstrating that the pre-existing equipment either:

- Is fully functional; or
- Needs only minor economically viable repairs (e.g., repair cost is < 20% of replacement cost) for continued operation; or
- Has run in failed or partially failed mode for more than two years; or
- Had failed but was replaceable with on-site in-stock inventory or back-up equipment similar in efficiency

In addition, evidence shall be presented that demonstrates that the replace equipment either:

- Was less than 2/3 through its standard EUL; or
- Was beyond 2/3 of its EUL (including beyond the EUL), with documented evidence of either commitment to long-term maintenance or a facility's inability to make the capital commitment necessary to replace it, even if major repairs are needed.

In the cases where the above evidence cannot be collected, implementers must use market studies to determine the average age of equipment in the market and the overall mix of ROF and ER measures that are implemented.

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 demand savings methodologies below provide a gross, reasonable estimate based on available information. Final reported values are adjusted based on realization rates. Electric demand savings methodologies are categorized as follows:

- Temperature dependent measures (i.e., HVAC measures that vary with ambient temperature).
- Non-temperature dependent measures (e.g., process, lighting, and time control).
- Computer simulation modeled measures (may include both 1 and 2).

## ***Annual Energy Savings Algorithm***

*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. 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.

*Non-Temperature-Dependent Measures*

Demand savings for measures that are not temperature-dependent will be determined by either the coincidence factors from 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. 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:

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

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

**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. The Companies' program administrators specify the approved software and modeling requirements. 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.

*Demand Response reporting*

The peak demand savings will be the difference between the estimated peak demand of a customer baseline in the absence of a demand response program and the measured peak demand after implementation of a demand response program. Reporting for demand response measures should include ex-post reporting or ex-ante reporting. For ex-post reporting, measure savings should be quantified by using meter-based methods, such as day- or weather-matching customer baseline including a control group, regression-based methods on customer historical data, or similar methods. For ex-ante reporting, measure savings should be estimated by using a scalar weather normalization method, a time-temperature matrix, or similar methods.

## ***Calculation Parameters***

Calculation parameters will be specific to each custom measures.

## ***Measure Life***

Measure life will be specific to each custom measure. For custom measures using technologies that are the same or similar to those addressed in other PSD measure chapters, refer to those chapters for load shapes. For other measures refer to the tables below.

**Table 2-265 Measure Lives – Lighting, Building Envelope, and DHW**

| Description | Remaining Useful Life | Retrofit | Lost Opportunity | Operations | Maintenance | RCx |
|---|---|---|---|---|---|---|
| **Lighting** | | | | | | |
| Automatic photocell dimming system | N/A | 9 | 10 | N/A | N/A | N/A |
| Bi-level switching (demand reduction) | N/A | 15 | 15 | N/A | N/A | N/A |
| Fluorescent lighting system power reduction control | N/A | 9 | N/A | N/A | N/A | N/A |
| Lamp and ballast conversions | N/A | 6.6 | N/A | N/A | N/A | N/A |
| Re-circuiting and new control | N/A | 10 | N/A | N/A | N/A | N/A |
| Remove unnecessary lighting fixture | N/A | 5 | N/A | N/A | N/A | N/A |
| Reprogramming of EMS control | N/A | N/A | N/A | 5 | N/A | 8 |
| Sweep controls/EMS based control | N/A | 10 | 15 | N/A | N/A | N/A |
| Timer switch | N/A | 10 | N/A | N/A | N/A | N/A |
| **Building Envelope** | | | | | | |
| Cool roof | N/A | N/A | 15 | N/A | N/A | N/A |
| Insulation | N/A | 20 | 20 | N/A | N/A | N/A |
| Movable window insulation | N/A | 10 | 10 | N/A | N/A | N/A |
| New window | N/A | N/A | 20 | N/A | N/A | N/A |
| Roof spray cooling | N/A | 15 | 15 | N/A | N/A | N/A |
| Window film | N/A | 10 | 10 | N/A | N/A | N/A |
| **Domestic Hot Water** | | | | | | |
| Energy-efficient motor | N/A | 15 | 20 | N/A | N/A | N/A |
| Heat recovery | N/A | 15 | 15 | N/A | N/A | N/A |
| Point-of-use water heater | N/A | 20 | 20 | N/A | N/A | N/A |
| Solar water heater | N/A | 20 | 20 | N/A | N/A | N/A |

**Table 2-266 Measure Lives - HVAC Systems**

| Description | Remaining Useful Life | Retrofit | Lost Opportunity | Operations | Maintenance | RCx |
|---|---|---|---|---|---|---|
| **Heating, Ventilating and Air Condition (HVAC) Systems** | | | | | | |
| 2-speed motor control in rooftop unit | N/A | 13 | 15 | N/A | N/A | N/A |
| Additional pipe insulation | N/A | 15 | 15 | N/A | N/A | N/A |
| Additional vessel insulation | N/A | 10 | 10 | N/A | N/A | N/A |
| Air curtain | N/A | 15 | 15 | N/A | N/A | N/A |

| Description | Remaining Useful Life | Retrofit | Lost Opportunity | Operations | Maintenance | RCx |
|---|---|---|---|---|---|---|
| **Heating, Ventilating and Air Condition (HVAC) Systems** | | | | | | |
| Air distribution system modifications & conversions | N/A | 20 | 20 | N/A | N/A | N/A |
| Cool thermal storage | N/A | 15 | 15 | N/A | N/A | N/A |
| Cooling tower alternates | N/A | 13 | 15 | N/A | N/A | N/A |
| Dehumidifier | N/A | 13 | 15 | N/A | N/A | N/A |
| Duct type air destratification system | N/A | 15 | 15 | N/A | N/A | N/A |
| Economizer - air/water | N/A | 7 | 10 | N/A | N/A | N/A |
| Electric spot radiant heat | N/A | 10 | 10 | N/A | N/A | N/A |
| Energy-efficient motor | N/A | 15 | 20 | N/A | N/A | N/A |
| Energy-efficient packaged terminal unit | N/A | N/A | 15 | N/A | N/A | N/A |
| Evaporative cooling (unitary) | N/A | N/A | 15 | N/A | N/A | N/A |
| Gas engine chiller | N/A | N/A | 15 | N/A | N/A | N/A |
| Low-leakage damper | N/A | 12 | 12 | N/A | 5 | N/A |
| Make-up air unit for exhaust hood | N/A | 15 | 15 | N/A | N/A | N/A |
| Outdoor air damper adjustment or modification | N/A | N/A | N/A | N/A | 5 | N/A |
| Paddle type air destratification fan | N/A | 15 | 15 | N/A | N/A | N/A |
| Plate/heat pipe type heat recovery system | N/A | 14 | 14 | N/A | N/A | N/A |
| Repair air side economizer | N/A | N/A | N/A | N/A | 5 | N/A |
| Repair steam/air leaks | N/A | N/A | N/A | N/A | 5 | N/A |
| Rotary type heat recovery system | N/A | 14 | 14 | N/A | N/A | N/A |
| VAV system components | N/A | 13 (m) | N/A | N/A | N/A | N/A |
| Water/steam distribution system modifications & conversions | N/A | 20 | 20 | N/A | N/A | N/A |
| Zoned circulator pump system | N/A | 15 | N/A | N/A | N/A | N/A |

**Table 2-267 Measure Lives - HVAC Controls**

| Description | Remaining Useful Life | Retrofit | Lost Opportunity | Operations | Maintenance | RCx |
|---|---|---|---|---|---|---|
| **HVAC Controls** | | | | | | |
| Adjust scheduling | N/A | N/A | N/A | 5 | N/A | 6 |
| Controls to eliminate simultaneous heating and cooling | N/A | 10 | N/A | 5 | N/A | 8 |

| Description | Remaining Useful Life | Retrofit | Lost Opportunity | Operations | Maintenance | RCx |
|---|---|---|---|---|---|---|
| **HVAC Controls** | | | | | | |
| EMS/linked HVAC controls | N/A | 10 | 15 | N/A | N/A | 8 |
| Enthalpy control economizer | N/A | 7 | 10 | N/A | N/A | N/A |
| Modify HVAC controls | N/A | 10 | N/A | N/A | N/A | 8 |
| New/additional EMS points | N/A | 10 | 15 | N/A | N/A | N/A |
| Programmable thermostat | N/A | 8 | N/A | N/A | N/A | N/A |
| Repair HVAC controls | N/A | N/A | N/A | N/A | 5 | N/A |
| Reprogramming of EMS controls | N/A | N/A | N/A | 5 | N/A | 8 |
| Reset set-points | N/A | N/A | N/A | 5 | N/A | 6 |
| Single zone controls NOT linked to other controls | N/A | 10 | N/A | N/A | N/A | N/A |
| Time clock | N/A | 11 | N/A | N/A | N/A | N/A |
| Upgrade to dual/comparative enthalpy economizer | N/A | 10 | 10 | N/A | N/A | N/A |

**Table 2-268 Measure Lives - Refrigeration**

| Description | Remaining Useful Life | Retrofit | Lost Opportunity | Operations | Maintenance | RCx |
|---|---|---|---|---|---|---|
| **Refrigeration** | | | | | | |
| Additional pipe insulation - refrigeration system | N/A | 11 | 11 | N/A | N/A | N/A |
| Additional vessel insulation - refrigeration system | N/A | 11 | 11 | N/A | N/A | N/A |
| Adjust scheduling | N/A | N/A | N/A | 5 | N/A | 8 |
| Ambient sub-cooling | N/A | 15 | 15 | N/A | N/A | N/A |
| Auto cleaning system for condenser tubes | N/A | 10 | 10 | N/A | N/A | N/A |
| Demineralized water for ice | N/A | 10 | 10 | N/A | N/A | N/A |
| Heat recovery from refrigeration system | N/A | 10 | 13 | N/A | N/A | N/A |
| Hot gas bypass for defrost or regeneration | N/A | 10 | 10 | N/A | N/A | N/A |
| Industrial refrigeration systems and components | N/A | 20 | 20 | 3 | N/A | N/A |
| Low case HVAC returns | N/A | 10 | 10 | N/A | N/A | N/A |
| Low emissivity ceiling surfaces | N/A | 15 | 15 | N/A | N/A | N/A |
| Mechanical sub-cooling | N/A | 15 | 15 | N/A | N/A | N/A |

| Description | Remaining Useful Life | Retrofit | Lost Opportunity | Operations | Maintenance | RCx |
|---|---|---|---|---|---|---|
| **Refrigeration** | | | | | | |
| Motorized insulated door | N/A | 8 | 8 | N/A | N/A | N/A |
| Oversized condenser | N/A | 15 | 15 | N/A | N/A | N/A |
| Polyethylene strip curtain | N/A | 4 | 4 | N/A | N/A | N/A |
| Refrigeration control | N/A | 10 | 10 | 5 | N/A | 10 |
| Reset set-points | N/A | N/A | N/A | 5 | N/A | 8 |

**Table 2-269 Measure Lives – Process Equipment, SEM, and Whole Building Performance**

| Description | Remaining Useful Life | Retrofit | Lost Opportunity | Operations | Maintenance | RCx |
|---|---|---|---|---|---|---|
| **Process Equipment** | | | | | | |
| Add regulator valves in compressed air system | N/A | 10 | 10 | N/A | N/A | 10 |
| Air compressor | N/A | 13 | 15 | N/A | N/A | N/A |
| Clothes washer | N/A | N/A | 7 | N/A | N/A | N/A |
| Compressed air distribution and storage system | N/A | 10 | N/A | N/A | N/A | N/A |
| Energy-efficient transformer | N/A | 15 | 20 | N/A | N/A | N/A |
| Energy-efficient motor | N/A | 15 | 20 | N/A | N/A | N/A |
| Injection molding machine jacket | N/A | 5 | N/A | N/A | N/A | N/A |
| Install air compressor no-loss condenser drain | N/A | 13 | 13 | N/A | 5 | 10 |
| Interlock air system solenoid valves with machine operation | N/A | 10 | 10 | N/A | N/A | 10 |
| Interlock exhaust fans w/ machine operations | N/A | 10 | 10 | N/A | N/A | 10 |
| Plastic injection molding machine | N/A | 13 | 15 | N/A | N/A | N/A |
| PRIME | N/A | N/A | 5 | N/A | N/A | N/A |
| Refrigerated air dryer | N/A | 13 | 15 | N/A | N/A | N/A |
| Repair steam/compressed air leaks | N/A | N/A | N/A | N/A | 5 | N/A |
| Replace steam traps | N/A | N/A | N/A | N/A | 6 | N/A |
| Variable frequency drive | N/A | 13 | 15 | N/A | N/A | N/A |
| Water treatment magnets | N/A | 10 | N/A | N/A | N/A | N/A |
| **Behavioral** | | | | | | |
| Strategic energy management | N/A | N/A | 4 | N/A | N/A | N/A |
| **Other** | | | | | | |

| Description | Remaining Useful Life | Retrofit | Lost Opportunity | Operations | Maintenance | RCx |
|---|---|---|---|---|---|---|
| **Process Equipment** | | | | | | |
| Whole building performance | N/A | N/A | 17 | N/A | N/A | N/A |

## ***Peak Factors***

Peak factors will be specific to each custom measure.

## ***Load Shapes***

See 2.8.1 Lost Opportunity Custom.

## ***Realization Rates and Net Impact Factors***

**Table 2-270 Realization Rates and Net Impact Factors - Electric**

| | Gross Realization % | | | FR & SO | | Net Realization % | | |
|---|---|---|---|---|---|---|---|---|
| Measure | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Free-ridership | Spill-over | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW |
| EMS Controls<br>**Energy Opportunities** | 67.6%% | 162.1% | 114.7% | 39.0% | 14.0% | 50.7% | 121.6% | 86.0% |
| Custom<br>**Energy Opportunities** | 93.8% | 120.1% | 103.1% | 23.0% | 0.0% | 72.2% | 92.5% | 79.4% |
| Other<br>**Energy Opportunities** | 67.6% | 162.1% | 114.7% | 0.0% | 0.0% | 67.6% | 162.1% | 114.7% |
| Process<br>**Energy Opportunities** | 67.6% | 162.1% | 114.7% | 12.0% | 35.0% | 83.1% | 199.4% | 141.1% |
| Custom<br>**Small Business Energy Advantage** | 72.0% | 73.0% | 85.0% | 0.3%) | 0.0% | 71.8% | 72.8% | 84.7% |
| Other<br>**Small Business Energy Advantage** | 72.0% | 73.0% | 85.0% | 0.5% | 0.2% | 71.8% | 72.8% | 84.7% |
| O&M<br>**Business & Energy Sustainability** | 79.0% | 258.0% | 191.0% | 0.0% | 0.0% | 79.0% | 258.0% | 191.0% |
| RCx<br>**Business & Energy Sustainability** | 105.0% | 175.0% | 126.0% | 0.0% | 0.0% | 105.0% | 175.0% | 126.0% |
| Load Response<br>**Load Management** | 100.0% | 100.0% | 100.0% | 0.0% | 0.0% | 100.0% | 100.0% | 100.0% |

**Table 2-271 Realization Rates and Net Impact Factors – Natural Gas**

| Measure | Gross Realization % | | FR & SO | | Net Realization % | |
|---|---|---|---|---|---|---|
| | CCF | Peak Day CCF | Free-ridership | Spillover | CCF | Peak Day CCF |
| EMS Controls **Energy Opportunities** | 78.2% | 100.0% | 31.0% | 2.0% | 55.5% | 71.0% |
| Custom **Energy Opportunities** | 77.3% | 100.0% | 37.0% | 2.0% | 50.2% | 65.0% |
| Other **Energy Opportunities** | 78.2% | 100.0% | 0.0% | 0.0% | 78.2% | 100.0% |
| Process **Energy Opportunities** | 78.2% | 100.0% | 14.0% | 16.0% | 79.8% | 102.0% |
| Overall Program **Small Business Energy Advantage** | 78.0% | 100.0% | 0.0% | 0.0% | 78.0% | 100.0% |
| O&M – Overall Program **Business & Energy Sustainability** | 94.0% | 108.0% | 0.0% | 0.0% | 94.0% | 108.0% |
| RCx – Overall Program **Business & Energy Sustainability** | 90.0% | 72.0% | 0.0% | 0.0% | 90.0% | 72.0% |

## ***References***


[1] GDS Associates Inc., Measure Life Report, Residential and Commercial Industrial Lighting and HVAC Measures, Jun. 2007.

[2] Energy & Resource Solutions. ERS *Measure Life Study.*: Prepared for the Massachusetts Joint Utilities, Oct. 10, 2005.

[3] 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.

[4] Gas chiller measure life was set by the CT DPUC in their decision in Docket 05-07-14, in response to Public Act 05-01, "An Act Concerning Energy Independence". Dec. 28, 2005, p. 29, see Table 4.

[5] Energy & Resource Solutions (ERS), Process Reengineering for Increased Manufacturing Efficiency Program Evaluation, Mar. 26, 2007, pp. 1-5.

[6] *Efficiency Maine TRM*, 3/5/07, p. 91. Similar measure.

[7] Energy and Environmental Analysis, Inc. *Steam Traps Workpaper for PY2006-2008.* Prepared for Southern California Gas Company, Dec. 2006, p. 14, see Section 9.1.

[8] Veritec Consulting, "*Region of Waterloo Pre-Rinse Spray Valve Pilot Study Final Report*," Jan. 2005, Executive Summary.

[9] Appliance Magazine. *U.S. Appliance Industry: Market Share, Life Expectancy & Replacement Market, and Saturation Levels,* Jan. 2010. p. 10.

[10] GDS Associates, Inc., *Natural Gas Energy Efficiency Potential in Massachusetts*, 2009, prepared for GasNetworks, see Table B-2a.

[11] 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.

[12] ERS. *Measure Life Study prepared for The Massachusetts Joint Utilities*, 2005.

[13] As part of the program, the Companies are providing 3 years of continual monitoring and check-ins with customers and expect savings to persist on average for at least one year beyond the 3 years of direct support. Measure life also supported by evaluated results of similar programs. See SBW Consulting, Inc. & The Cadmus Group, Industrial Strategic Energy Management (SEM) Impact Evaluation Report, Feb. 2017, and CEE, 2016 Strategic Energy Management Program Summary, Nov. 21, 2016.

[14] Navigant, ComEd Luminaire Level Lighting Control IPA Program Impact Evaluation Report, Jun. 5, 2018.

[15] Hewitt, D. Pratt, J. & Smith, G. (2005). *Tankless Gas Water Heaters: Oregon Market Status*, prepared for the Energy Trust of Oregon.

[16] GDS Associates, Inc., *Natural Gas Energy Efficiency Potential in Massachusetts,* 2009, prepared for GasNetworks.

[17] PA Consulting Group Inc. *Focus on Energy Evaluation. Business Programs: Measure Life Study,* Aug. 25, 2009.

[18] EPA ENERGY STAR calculator, accessed Apr. 25, 2017, based on Cadmus review of four retailer websites: Sears, Home Depot, Lowes, and Best Buy.

[19] DNV, (March, 2021) C2014 - Connecticut C&I Lighting Saturation and Remaining Potential Study Phase One Results and Recommendations

[20] DNV, CT X1931-8 Commercial Advanced Thermostat PSD New Measure Phase 1, Jul. 23, 2021.

## ***Changes from Last Version***

- Added demand response reporting guidelines.
- Updated early retirement savings definition.
- Formatting updates.

# 3 RESIDENTIAL

## 3.1 LIGHTING

### 3.1.1 LIGHTING

| | |
|---|---|
| Market | Residential |
| Baseline Type | Retrofit/Lost Opportunity |
| Category | Lighting |

***Description***

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.

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.

***Annual Energy Savings Algorithm***

*Retrofit and Direct Install Savings*

$$\Delta kWh = EF \times \frac{\Delta W \times H \times 365\ day}{1{,}000\,\frac{W}{kW}}$$

*Where,*

$$\Delta W = W_B - W_I$$

*Retrofit Gross Seasonal Peak Demand Savings, Electric*

$$\Delta kW_S = CAP \times \frac{\Delta W \times CF_S}{1{,}000\,\frac{W}{kW}}$$

$$\Delta kW_W = \frac{\Delta W \times CF_W}{1{,}000\,\frac{W}{kW}}$$

*Where,*

$$\Delta W = W_B - W_I$$

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

$$\Delta kWh = 38.54\ kWh$$

*Refer to Example 3 for deemed energy savings algorithm.*

*Lost Opportunity Gross Peak Demand Savings, Electric*

$$\Delta kW_S = 0.0051\ kW$$

$$\Delta kW_W = 0.0079\ kW$$

*Refer to Example 4 for deemed peak demand savings algorithms.*

## ***Calculation Parameters***

**Table 3-1 Calculation Parameters**

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| ΔkWh | Annual electric savings | Calculated | kWh | |
| ΔW (Direct Install) | The difference between the wattage of the lower efficiency baseline bulb and the wattage of the new bulb – Direct Install | Calculated<br>(37.6 if unknown) | W | |
| $\Delta kW_S$ | Summer demand savings | Calculated | kW | |
| $\Delta kW_W$ | Winter demand savings | Calculated | kW | |
| $W_B$ | Rated wattage of existing low-efficiency bulb | Site-specific | W | |
| $W_I$ | Rated wattage of high efficiency bulb | Site-specific | W | |
| H | Daily hours of use by room type for direct install | Lookup in Table 2-3 Multifamily Hours of Use per Day by Location | hr | [2] |
| EF | Average energy factor due to lighting interactive effect | 1.04 | N/A | [1] |
| CAP | Average capacity factor due to lighting interactive effect | 1.05 | N/A | [1] |
| $CF_S$ | Average summer seasonal peak coincidence factor for residential lighting | 0.13 | N/A | [7] |
| $CF_W$ | Average winter seasonal peak coincidence factor for residential lighting | 0.20 | N/A | [7] |

**Table 3-2 Hours of Use per Day by Location**

| Location | Daily Hours of Use | Ref |
|---|---|---|
| Bedroom | 2.1 | [2] |

| Location | Daily Hours of Use | Ref |
|---|---|---|
| Bathroom | 1.7 | [2] |
| Kitchen | 4.1 | [2] |
| Living Room | 3.3 | [2] |
| Dining Room | 2.8 | [2] |
| Exterior | 5.6 | [2] |
| Other | 1.7 | [2] |
| Unknown | 2.7 | [2] |

## ***Calculation Examples***

*Example 1: Retrofit Gross Energy Savings*

*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?*

$$\Delta W = W_B - W_I$$

$$\Delta W = 45W - 10W = 35W$$

$$\Delta kWh = EF \times \frac{\Delta W \times H \times 365\ day}{1{,}000\,\frac{W}{kW}}$$

$$\Delta kWh = 1.04 \times \frac{35W \times 3.3\,\frac{hr}{day} \times 365\ day}{1{,}000\,\frac{W}{kW}} = 43.844\ kWh$$

*Example 2: Retrofit Gross Peak Demand Savings*

*A 45-Watt bulb is replaced with a 10-Watt LED bulb in the living room of a home. What are the savings?*

$$\Delta W = W_B - W_I$$

$$\Delta W = 45W - 10W = 35W$$

$$\Delta kW_S = CAP \times \frac{\Delta W \times CF_S}{1{,}000\,\frac{W}{kW}}$$

$$\Delta kW_S = 1.05 \times \frac{35W \times 0.13}{1{,}000\,\frac{W}{kW}} = 0.005\ kW$$

$$\Delta kW_W = \frac{\Delta W \times CF_W}{1{,}000\,\frac{W}{kW}}$$

$$\Delta kW_W = \frac{35W \times 0.20}{1{,}000\,\frac{W}{kW}} = 0.007\ kW$$

## ***Measure Life***

**Table 3-3 Measure Life**

| Equipment Type | Retrofit Measure Life | Ref |
|---|---|---|
| General Service (A Lamps) | 1 Year | [12] |
| Specialty (Globe, Candelabra, etc.) | 1 year (all retail and direct install) | [4] [5] [12] |
| Reflectors and Recessed Downlights (PAR, BR, etc.) | 1 year (all retail and direct install) | [12] |
| Fixtures (Hard-wired Fixtures) | 7 years (all retail and direct install) | [12] |

## ***Peak Factors***

**Table 3-4 Peak Factors**

| Measure | Summer Coincidence Factor | Winter Coincidence Factor | Ref |
|---|---|---|---|
| Lighting | 13% | 20% | [7] |

## ***Load Shapes***

**Table 3-5 Load Shapes**

| End Use | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % | Ref |
|---|---|---|---|---|---|
| Lighting - Residential | 42.10% | 32.50% | 13.90% | 11.50% | [7] |

## ***Non-Energy Impacts***

Non-energy impacts for this measure include O&M cost benefits and lighting interactive effects. One-time O&M benefits are based on the avoided expense of replacement incandescent bulbs over the lifetime of the new bulb. [3] The lighting interactive effect penalty is to be applied to non-electric benefits when planning. [1]

**Table 3-6 O&M Benefit and Lighting Interactive Effects**

| Bulb Type | O&M Benefit ($/Bulb) | Lighting Interactive Effect Penalty (Btu/kWh) |
|---|---|---|
| LED Bulb | $3.00 | -1,902<br>(only applicable to fossil fuel-heated homes) |
| LED Luminaire | $4.00 | |

## ***Realization Rates***

**Table 3-7 Realization Rates**

| | Gross Realization % | | | | | FR and SO | | Net Realization % | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Measure | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Delivered Fuels MMBtu | Installation rate | Free-ridership | Spill-over | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Delivered Fuels MMBtu | Ref |
| HES Lighting LEDs | 47.0% | 47.0% | 47.0% | N/A | 98% | 36.0% | 7.0% | 32.7% | 32.7% | 32.7% | N/A | [7],[15] |
| HES-IE Lighting LEDs | 47.0% | 47.0% | 47.0% | N/A | 100% | 0.0% | 0.0% | 47.0% | 47.0% | 47.0% | N/A | [7] |
| MF Lighting LEDs | 100.0% | 100.0% | 100.0% | N/A | 100% | 10.0% | 0.0% | 90.0% | 90.0% | 90.0% | N/A | [8] |
| MF Common Area and Exterior Lighting | 97% | 118% | 47% | N/A | 100% | 0.0% | 0.0% | 97% | 118% | 47% | N/A | [9] |
| MF Dwelling Unit Lighting | 67% | 81% | 70% | N/A | 100% | 0.0% | 0.0% | 67% | 81% | 70% | N/A | [9] |
| Retail – LED Bulbs/Luminaires, Non-Hard-to-Reach (Non-HTR) | 100.0% | 100.0% | 100.0% | 97.5% | 100% | 70.0% | 0.0% | 29.3% | 29.3% | 29.3% | - | [10], [11] |
| Retail – LED Bulbs/Luminaires, Hard-to-Reach (HTR) | 100.0% | 100.0% | 100.0% | 97.5% | 100% | 50.0% | 0.0% | 48.8% | 48.8% | 48.8% | - | [10], [11] |

## ***References***


[1] Connecticut Residential Lighting Interactive Effect, NMR Group Inc., Dec. 2014, Table 1, p. 2.

[2] NMR Group Inc., Connecticut LED Lighting Study Report (R154), Jan. 28, 2016, p. 45.

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

[4] NMR, R1963a Short-Term Residential Lighting Report, Draft, Jul 14, 2020.

[5] SCS Analytics, Preliminary Results from R1963B: Short Term Residential Lighting Analysis, Jul 13, 2020.

[6] "DNV (2021). X1931-2 Load Shape and Coincidence Factor Research – Final Report".

[7] West Hill Energy and Computing, R1603 HES/HES-IE Impact Evaluation Final Realization Rates Memorandum, Aug. 8, 2019.

[8] NMR and Cadmus, Impact Evaluation: Home Energy Services—Income-Eligible and Home Energy Services Programs: Volume 2 (R16), Final Report, Dec. 31, 2014.

[9] TRC. (2021). CT EEB X1941 Multifamily Impact Evaluation, Jul. 22, 2021 (Table 6).

[10] Connecticut LED Lighting Study Report (R154), Jan. 28, 2016 at 35, see Table 21.

[11] NMR Group, Inc., R1615 LED Net-to-Gross Evaluation, Aug. 7, 2017.

[12] NMR, R1707: Net-to-Gross Study ("NTG") of Connecticut Residential New Construction, Oct. 5, 2018, p. 3, see Table 1.

[13] *Engineering judgement based on expected existing incandescent or halogen lamp remaining life. Once the existing lamp has burned out, replacement with an EISA-compliant lamp is assumed to be the only option.*

[14] DNV. June 2022. "C2014-A: Connecticut C&I Lighting Saturation and Remaining Potential Study ."

[15] NMR. R1983 NTG Review Final Memo dated Sep. 12, 2022.


## ***Changes from Last Version***

- Formatting updates.
- EUL change for Type A lamps.
- Updated installation rate, free ridership and spillover values for HES lighting.

## 3.1.2 CONNECTED LED LIGHTING

| | |
|---|---|
| Market | Residential |
| Baseline Type | Retrofit |
| Category | Lighting |

### ***Description***

This measure details the savings associated with connected LED lighting that allows for remote user control through Wi-Fi and/or a smart device. Using the remote controls, users can remotely turn the light on and off, adjust its brightness, and set a schedule for the light. Connected lighting controls savings are based on a reduction of operating hours and dimming. The savings for this measure are the estimated incremental control savings compared to a non-connected efficient lamp.

The following assumptions are made to calculate savings for connected LED lighting.

- "Direct install" bulbs and luminaires are installed by vendors that have verified installation. Actual rated bulb wattage and location of the bulbs is used to calculate savings for direct install.
- "Retail" refers to bulbs and luminaires sold through retailers that do not have verified installation. For retail, the actual rated bulb wattage and a default (estimated) hours-of-use are used to calculate savings.
- There is a lighting interactive effect that applies to fossil fuel homes based on the results from Connecticut Residential Lighting Interactive Effects Memo. Penalty to be applied to non-electric benefits when planning. [1]

### ***Annual Energy Savings Algorithm***

*Retail and direct install savings calculation*:

$$\Delta \mathrm{kWh} = \mathrm{EE}_{IEF} \times \mathrm{SF} \times \frac{\mathrm{W_c} \times \mathrm{h_d} \times 365}{1000\,\frac{W}{kW}}$$

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

$$\Delta \mathrm{kW_S} = \mathrm{ED}_{IEF} \times \mathrm{SF} \times \frac{\mathrm{W_c} \times \mathrm{CF_S}}{1000\,\frac{W}{kW}}$$

$$\Delta \mathrm{kW_W} = \mathrm{SF} \times \frac{\mathrm{W_c} \times \mathrm{CF}_W}{1000\,\frac{W}{kW}}$$

## ***Calculation Parameters***

**Table 3-8 Calculation Parameters**

| Symbol | Description | Values | Units | Ref |
|---|---|---|---|---|
| ΔkWh | Annual electric energy savings | Calculated | kWh/yr | |
| $\Delta kWh_{lifetime}$ | Lifetime electric energy savings | Calculated | kWh | |
| ΔkWs | Summer demand savings | Calculated | kW | |
| $\Delta kW_w$ | Winter demand savings | Calculated | kW | |
| CFs | Average summer seasonal peak coincidence factor for residential(lighting) | 0.13 | N/A | [3] |
| $CF_w$ | Average winter seasonal peak coincidence factor for residential(lighting) | 0.20 | N/A | [3] |
| EUL | Measure life of the bulb | 12.2 | Years | [8] |
| SF | Percentage of annual lighting energy saved by connected lighting controls | 0.29 | N/A | [8] |
| $EE_{IEF}$ | Average energy factor due to lighting interactive effect | 1.04 | N/A | [1] |
| $ED_{IEF}$ | Average Electric Demand interactive effects factor | 1.05 | N/A | [1] |
| ΔBTU | Lighting interactive effect | -1,902 | Btu/kWh | [1] |
| $h_d$ | Daily hours of use, by room type for direct install. For Lost Opportunity or Retail, use “unknown” as the room type | Table 3-9 | Hours per day | [2] |
| $Watt_{controlled}$ | Rated wattage of installed or purchased connected high efficiency (LED) bulb | site specific | W | |

**Table 3-9 Hours of Use per Day by Location ($h_d$) [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 |

## ***Calculation Examples***

*Example 1: Gross Energy Savings*

A 10-Watt connected LED bulb installed in the living room of a home by direct install. What is the annual savings?

$$\Delta \text{kWh} = \text{EE}_{IEF} \times \text{SF} \times \frac{\text{Watt}_{controlled} \times \text{h}_\text{d} \times 365}{1000 \ \frac{W}{kW}}$$

$$\Delta \text{kWh} = 1.04 \times .29 \times \frac{10 \text{ Watts} \times 3.3 \text{ hrs/day} \times 365 \text{ days/year}}{1000 \frac{W}{kW}}$$

$$\Delta \text{kWh} = 3.6 \text{ kWh/year}$$

*Example 2: Gross Peak Demand Savings*

A 10-Watt connected LED bulb in the living room of a home. What are the savings?

$$\text{kW}_\text{s} = \text{ED}_{IEF} \times \text{SF} \times \frac{\text{Watt}_{controlled} \times \text{CF}_\text{S}}{1000 \frac{W}{kW}}$$

$$\text{kW}_\text{s} = 1.05 \times .29 \times \frac{10 \text{ Watts} \times 13\%}{1000 \ \frac{W}{kW}}$$

$$\text{kW}_\text{w} = 0.0004 \text{ kW}$$

$$\text{kW}_\text{w} = \text{SF} \times \frac{\text{Watt}_{controlled} \times \text{CF}_W}{1000 \ \frac{W}{kW}}$$

$$\text{kW}_\text{w} = .29 \times \frac{10 \text{ Watts} \times 20\%}{1000 \ \frac{W}{kW}}$$

$$\text{kW}_\text{w} = 0.0006 \text{ kW}$$

## ***Measure Life***

The measure life for Residential Connected LED lighting is 12.2 years [8].

## ***Peak Factors***

**Table 3-10 Peak Factors**

| Measure | Summer Coincidence Factor | Winter Coincidence Factor | Ref |
|---|---|---|---|
| Lighting | 13% | 20% | [7] |

## *Load Shapes*

**Table 3-11 Load Shapes**

| End Use | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % | Ref |
|---|---|---|---|---|---|
| Lighting - Residential | 42.10% | 32.50% | 13.90% | 11.50% | [7] |

## *Realization Rates*

**Table 3-12 Realization Rates**

| | Gross Realization % | | | | FR and SO | | Net Realization % | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Measure | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Delivered Fuels, MMBtu | Free-ridership | Spill-over | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Delivered Fuels, MMBtu |
| Lighting LEDs **Home Energy Solutions (HES)** | 47.0% [6] | 47.0% [6] | 47.0% [6] | N/A | 10.0% [5] | 0.0% | 42.3% | 42.3% | 42.3% | N/A |
| Lighting LEDs** **HES – Income Eligible (HES-IE)** | 47.0% [6] | 47.0% [6] | 47.0% [6] | N/A | 0.0% | 0.0% | 47.0% | 47.0% | 47.0% | N/A |
| Lighting LEDs **HES & HES– IE Multifamily** | 100.0% | 100.0% | 100.0% | N/A | 10.0% [5] | 0.0% | 90.0% | 90.0% | 90.0% | N/A |
| LED bulbs/ luminaires, non-Hard-to-Reach ("HTR")* **Retail Products** | 100.0% | 100.0% | 100.0% | 97.5% [2] | 70.0% [9] | 0.0% | 29.3% | 29.3% | 29.3% | 29.3% |
| LED bulbs/ luminaires, HTR* **Retail Products** | 100.0% | 100.0% | 100.0% | 97.5% [2] | 50.0% [9] | 0.0% | 48.8% | 48.8% | 48.8% | 48.8% |
| LED bulbs/ luminaires, combined non HTR-HTR † **Retail Products** | 100.0% | 100.0% | 100.0% | 97.5% [2] | 66.0% [9] | 0.0% | 33.2% | 33.2% | 33.2% | 33.2% |

* The installation rate is the average of the 4-year installation rates given in Ref [2]. The free-ridership values are linearly extrapolated from the 2018 to 2020 values given in Ref [9].

† Weighted Realization Rate based on planned non-HTR-HTR bulb split.

** 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 applying HES lighting Realization rates to HES IE.

## *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

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

[4] Navigant Consulting. Department of Energy Solid-State Lighting Program. Energy Savings Forecast of Solid-State Lighting in General Illumination Applications. December 2019.

[5] NMR and Cadmus, Impact Evaluation: Home Energy Services—Income-Eligible and Home Energy Services Programs: Volume 2 (R16), Final Report, Dec. 31, 2014.

[6] West Hill Energy and Computing, R1603 HES/HES-IE Impact Evaluation Final Realization Rates Memorandum, Aug. 8, 2019.

[7] “DNV (2021). X1931-2 Load Shape and Coincidence Factor Research – Final Report”.

[8] DNV. 2022 “CT X1931-4 ALC PSD Phase 2 Memo: Recommendations for ALC Measure Parameters.” Connecticut Energy Efficiency Board Evaluation Administrators

[9] NMR Group Inc. Aug 7, 2017. “R1615: LED Net-to Gross Evaluation.”

## ***Changes from Last Version***

- Formatting updates.
- Update measure life.

### 3.1.3 OCCUPANCY SENSORS

| | |
|---|---|
| Market | Residential |
| Baseline Type | Retrofit/Lost Opportunity |
| Category | Lighting |

***Description***

This measure details the savings associated with installing occupancy sensor(s) (hard-wired, fixture-, wall-, or ceiling-mounted) that switch lights off after a brief delay when they do not detect occupancy. Occupancy sensors reduce energy consumption by reducing the operating hours for lighting equipment in low occupancy areas, such as hallways, storage rooms, and bathrooms. The savings for this measure are the estimated control savings compared to lighting fixtures being controlled by manual wall switches (no occupancy sensors).

The following assumptions are made to calculate savings for occupancy sensors.

- "Direct install" bulbs and luminaires are installed by vendors that have verified installation. Actual rated bulb wattage and location of the bulbs is used to calculate savings for direct install.
- "Retail" refers to bulbs and luminaires sold through retailers that do not have verified installation. For retail, the actual rated bulb wattage and a default (estimated) hours-of-use are used to calculate savings.
- There is a lighting interactive effect that applies to fossil fuel homes.

**Note:** 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 [1]. Penalty to be applied to non-electric benefits when planning.

***Annual Energy Savings Algorithm***

*Annual Gross Energy Savings, Electric*

$$\Delta kWh = IE_F \times S_F \times \frac{Watt_{controlled} \times H_d \times 365\ days}{1000}$$

*Gross Seasonal Peak Demand Savings, Electric*

$$\Delta kW_{summer} = ED_{IEF} \times S_F \times \frac{Watt_{controlled} \times CF_{summer}}{1000}$$

$$\Delta kW_{winter} = S_F \times \frac{Watt_{controlled} \times CF_{winter}}{1000}$$

*Annual Gross Energy Savings, Fossil Fuel*

$$\Delta Btu = \Delta kWh \times -1{,}902$$

***Calculation Parameters***

**Table 3-13 Calculation Parameters**

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| ΔkWh | Annual electric energy savings | Calculated | kWh/yr | |
| $CF_{summer}$ | Average summer seasonal peak coincidence factor for residential (lighting) | 0.13 | N/A | [3], [6] |
| $CF_{winter}$ | Average winter seasonal peak coincidence factor for residential (lighting) | 0.20 | N/A | [3], [6] |
| $H_d$ | Daily hours of use, by room type for direct install. For Lost Opportunity or Retail, use "unknown" as the room type | Lookup in Table 3-15 | Hours per day | [2] |
| $kW_{summer}$ | Summer demand savings | Calculated | kW | |
| $kW_{winter}$ | Winter demand savings | Calculated | kW | |
| $\Delta kWh_{lifetime}$ | Lifetime electric savings | Calculated | kWh | [4] |
| $EE_{IEF}$ | Average Electric Energy interactive effects factor | 1.04 | N/A | [1] |
| $ED_{IEF}$ | Average Electric Demand interactive effects factor | 1.05 | N/A | [1] |
| $S_F$ | Percentage of annual lighting energy saved by occupancy sensors | 0.17 | N/A | [4] |
| $Watt_{controlled}$ | Rated wattage of installed or purchased connected high efficiency (LED) bulb | Site-specific. If unknown, see Table 3-14 | Watts | |
| $Watt_{default}$ | If Watt controlled is unknown, use default. | Lookup in Table 3-14 | Watts | [5] |
| ΔBtu | Lighting interactive effects | -1,902 | Btu/kWh | [1] |

*For unknown wattage:*

**Table 3-14 Default Wattage Assumption**

| Number of lamps in space with control | Average lamp wattage | Connected unit kW |
|---|---|---|
| 6.8 | 0.034 | 0.230 |

**Table 3-15 Hours of Use per Day by Location ($H_d$) [2]**

| Location | All Customers |
|---|---|
| | Hd |
| 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 |

***Calculation Examples***

*Retrofit Gross Energy Savings, Example*

*Example: A 10-Watt LED bulb with occupancy sensor is installed in the living room of a home by direct install. What is the annual savings?*

$$\Delta kWh = IE_F \times S_F \times \frac{Watt_{controlled} \times H_d \times 365^{days}}{1000}$$

$$\Delta kWh = (1.04 \times 0.17 = 0.1768) \times \left( \frac{10\ watts \times 3.3\ {}^{hrs}/_{day} \times 365\ {}^{days}/_{yr}}{1000} = 12.045 \right)$$

$$0.1768 \times 12.045 = 2.1$$

$$\Delta kWh = 2.1\ {}^{kWh}/_{yr}$$

*Gross Peak Demand Savings, Example*

Summer

$$\Delta kW_{summer} = ED_{IEF} \times S_F \times \frac{Watt_{controlled} \times CF_{summer}}{1000}$$

$$\Delta kW_{summer} = (1.05 \times 0.17 = 0.1785) \times \left( \frac{10\ watts \times 0.13}{1000} = .0013 \right)$$

$$0.1785 \times .0013 = .0002$$

$$\Delta kW_{summer} = 0.0002\ kW$$

Winter

$$\Delta kW_{winter} = S_F \times \frac{Watt_{controlled} \times CF_{winter}}{1000}$$

$$\Delta kW_{winter} = 0.17 \times \left(\frac{10\ watts \times 0.2}{1000} = 0.002\right)$$

$$0.17 \times .002$$

$$\Delta kW_{summer} = 0.0003\ kW$$

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

*Example: What is the annual electric energy savings when any LED bulb is purchased through a retailer?*

$$\Delta kWh = IE_F \times S_F \times \frac{Watt_{controlled} \times H_d \times 365^{days}}{1000}$$

$$\Delta kWh = (1.04 \times 0.17 = 0.1768) \times \left(\frac{34\ watts \times 2.7\ {}^{hrs}/_{day} \times 365\ {}^{days}/_{yr}}{1000} = 33.507\right)$$

$$0.1768 \times 33.507 = 5.9$$

$$\Delta kWh = 5.9\ {}^{kWh}/_{yr}$$

***Measure Life***

**Table 3-16 Measure Life**

| Equipment Type | Measure Life | Ref |
|---|---|---|
| Residential occupancy sensors | 12.2 | [4] |

***Peak Factors***

**Table 3-17 Peak Factors**

| Measure | Summer Coincidence Factor | Winter Coincidence Factor | Ref |
|---|---|---|---|
| Lighting | 13% | 20% | [6] |

***Load Shapes***

**Table 3-18 Load Shapes**

| End Use | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % | Ref |
|---|---|---|---|---|---|
| Lighting | 42.10% | 32.50% | 13.90% | 11.50% | [6] |

***Realization Rates***

**Table 3-19 Realization Rates**

| | Gross Realization % | | | | FR & SO | | Net Realization % | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Measure | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Delivered Fuels MMBtu | Free-ridership | Spill-over | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Delivered Fuels MMBtu |
| Other measures | 100.0% | 100.0% | 100.0% | 100.0% | 0.0% | 0.0% | 100.0% | 100.0% | 100.0% | 100.0% |

***References***


[1] NMR Group Inc. 2014. “Connecticut Residential Lighting Interactive Effect (R67).” Table 1.

[2] NMR Group Inc. 2016. “Connecticut LED Lighting Study Report (R154).” p. 45.

[3] NMR Group Inc. 2014. “Northeast Residential Lighting Hour-of Use Study.” Table ES-7, p. VIII.

[4] DNV. 2022 “CT X1931-4 ALC PSD Phase 2 Memo: Recommendations for ALC Measure Parameters.” Connecticut Energy Efficiency Board Evaluation Administrators.

[5] NMR Group Inc. 2016. “Connecticut LED Lighting Study Report (R154).” Connecticut Energy Efficiency Board (EEB).

[6] DNV. 2021. “X1931-2 Load Shape and Coincidence Factor Research.” Connecticut Energy Efficiency Board (EEB) and Evaluation Administrators.

[7] NMR Group, Inc. 2016. “Project R4 HES/HES-IE Process Evaluation and R31 Real-Time Research.” CT EEB, Eversource, and United Illuminating. R4HES-HESIE_Process_Eval2016_0413_Final (energizect.com).


***Changes from Last Version***

- Formatting updates.
- Measure life update.

## 3.2 HVAC

### 3.2.1 ENERGY-EFFICIENT CENTRAL AIR CONDITIONING

| | |
|---|---|
| Market | Residential |
| Baseline Type | Retrofit/Lost Opportunity |
| Category | HVAC |

***Description***

Installation of an energy-efficient Central Air Conditioning (Central A/C) system and replacement of a working inefficient A/C system. Savings are based on the NMR *Central Air Conditioning Impact and Process Evaluation* [1]. This regional study metered the usage of recently installed residential A/C units in New England. Using these measurements, the study provided factors and equations (see below) to calculate the savings using the installed capacity and the EER.

*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).
- Baseline efficiency based on NMR *Central Air Conditioning Impact and Process Evaluation*, the baseline for estimating savings is the minimum standard for new installations, 13 SEER [1].

*Retrofit measure:*

- Savings are the sum of Lost Opportunity savings and, 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 pre-existing unit and a baseline new model, continuing for the Remaining Useful Life (RUL) in Table 3-23 Measure Life.
- 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 [1], [2].
- Early retirement RUL is assumed 1/3 X EUL = 1/3 X 25 years = 8.33 years when equipment specific information is not available [2].

***Energy Savings Algorithm***

*Annual Lost Opportunity Gross Energy Savings, Electric*

$$\Delta kWh_{Lost\ Opp} = MAF \times AUF \times CAP_{C,i} \times \left(\frac{SEER_i}{SEER_b} - 1\right)$$

*Lifetime Retrofit Gross Energy Savings, Electric*

Reminder: Retrofit Savings are the sum of Retirement Savings and Lost Opportunity Savings.

$$\Delta kWh_{Lifetime} = \Delta kWh_{Retire} \times RUL + \Delta kWh_{Lost\ Opp} \times EUL$$

Where,

$$\Delta kWh_{Retire} = MAF \times AUF \times CAP_{C,i} \times \left(1 - \frac{SEERe}{SEER_b}\right)$$

$$\Delta kWh_{Lost\ Opp} = see\ above$$

The equation simplifies when the existing EER is not known:

Single family:

$$\Delta kWh_{Retire} = 362\, {}^{kWh}/_{Ton} \times CAP_{C,i} \times \left(1 - \frac{10}{13}\right) = 83.54 \times CAP_{C,i}$$

Multifamily:

$$\Delta kWh_{Retire} = 0.4 \times 362\, {}^{kWh}/_{Ton} \times CAP_{C,i} \times \left(1 - \frac{10}{13}\right) = 33.42 \times CAP_{C,i}$$

*Lost Opportunity Gross Seasonal Peak Demand Savings, Electric*

$$\Delta kW_{Lost\ Opp,Summer} = DSF \times CAP_{C,i} \times \left(\frac{SEER_i}{SEER_b} - 1\right)$$

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

*Retrofit Gross Seasonal Peak Demand Savings, Electric*

*Reminder: Retrofit Savings are the sum of Retirement Savings and Lost Opportunity Savings.*

$$\Delta kW_{Retro,Summer} = \Delta kW_{Lost\ Opp,Summer} + \Delta kW_{Retire,Summer}$$

Where,

$$\Delta kW_{Retire,Summer} = MAF \times SDF \times CAP_{C,i} \times \left(1 - \frac{SEER_e}{SEER_b}\right)$$

$$\Delta kW_{Lost\ Opp,Summer} = see\ above$$

## *Calculation Parameters*

**Table 3-20 Calculation Parameters**

| Symbol | Description | Units | Value | Ref |
|---|---|---|---|---|
| $\Delta kWh_{Lost\ Opp}$ | Annual lost opportunity electric energy savings | kWh | Calculated | |
| $\Delta kWh_{Retire}$ | Annual early retirement electric energy savings | kWh | Calculated | |
| $\Delta kWh_{Lifetime}$ | Lifetime retrofit electric energy savings | kWh | Calculated | |
| $\Delta kW_{Lost\ Opp,\ Summer}$ | Lost opportunity summer seasonal demand savings | kW | Calculated | |
| $\Delta kW_{Retro,\ Summer}$ | Lost opportunity summer seasonal demand savings | kW | Calculated | |
| $\Delta kW_{Retire,\ Summer}$ | Lost opportunity summer seasonal demand savings | kW | Calculated | |
| $CAP_{C,i}$ | Installed cooling capacity | Tons | Site-specific | |
| $SEER_i$ | Installed SEER of new efficient unit | Btu/Watt-hr | Site-specific | |
| $SEER_e$ | Existing SEER of removed unit | Btu/Watt-hr | Site-specific, if unknown use 10 | [1], [2] |
| $SEER_b$ | Baseline SEER, representing baseline new model | Btu/Watt-hr | Lookup in Table 3-21 | [1] |
| AUF | Annual usage factor | kWh/ton | 362 | [1] |
| MAF (SF) | Multifamily adjustment factor, single family | N/A | 1.0 | |
| MAF (MF) | Multifamily adjustment factor, multifamily | N/A | 0.4 | [3] |
| SDF | Seasonal demand factor | kW/ton | 0.45 | [1] |
| EUL | Effective useful life | Years | 25 | [5] |
| RUL | Remaining useful life | Years | 7 | [5] |

**Table 3-21 Baseline SEER Assumptions**

| Type | $SEER_b$ |
|---|---|
| Split and Packaged AC | 13.4 SEER2 / 14 SEER |
| Split Heat Pump | 14.3 SEER2 / 15 SEER |
| Single Package Heat Pump | 13.4 SEER2 / 14 SEER |

The baseline SEER assumptions in Table 3-21 are based on federal standard SEER2 ratings starting in January 2023. The SEER2 values are converted to SEER using Table 3-22.

**Table 3-22 SEER2 to SEER Conversion for Unitary and Split System Air Conditioners and Heat Pumps**

| SEER2 | SEER |
|---|---|
| 13.4 | 14 |
| 14.3 | 15 |
| 15.2 | 16 |
| 16 | 17 |
| 17 | 18 |
| 18 | 19 |
| 19 | 20 |
| 20 | 21 |
| 21 | 22 |
| 22 | 23 |

## ***Calculation Examples***

*Example 1: Retrofit Gross Energy Savings*

*A single-family home has an existing working Central A/C is replaced by an energy-efficient unit. The new installed unit has a 3-ton cooling capacity, at 17 SEER. What are the annual energy savings?*

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

$$\Delta kWh_{C,Lost\ Opp} = 362\ {}^{kwh}/_{Ton} \times CAP_{C,i} \times \left(\frac{SEER_i}{13} - 1\right)$$

$$\Delta kWh_{C,Lost\ Opp} = 362\ {}^{kwh}/_{Ton} \times CAP_{C,i} \times \left(\frac{SEER_i}{13} - 1\right)$$

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

$$\Delta kWh_{C,Lost\ Opp} = 362\frac{kwh}{Ton} \times 3\ tons \times \left(\frac{17}{13} - 1\right) = 334.15\ \ kWh$$

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):

$$\Delta kWh_{C,Retire} = 83.54 \times CAP_{C,i}$$

$$\Delta kWh_{C,Retire} = 83.54 \times 3 = 250.62\ kWh$$

*Example 2: Retrofit Gross Peak Demand Savings*

*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:

$$\Delta kW_{Lost\ Opp,Summer} = 0.45\ {}^{kwh}/_{Ton} \times CAP_{C,i} \times \left(\frac{SEER_i}{13} - 1\right)$$

$$\Delta kW_{Lost\ Opp,Summer} = 0.45\ {}^{kwh}/_{Ton} \times 3 \times \left(\frac{17}{13} - 1\right) = 0.415\ kW$$

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

$$\Delta kW_{Retire,Summer} = 0.104 \times CAP_{C,i}$$

$$\Delta kW_{Retire,Summer} = 0.104 \times 3 = 0.312 kW$$

*Example 3: Lost Opportunity Gross Energy Savings, Single-Family Unit*

*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, 17 SEER. What is the annual savings?*

To calculate annual savings, use the Lost Opportunity equation:

$$\Delta kWh_{Lost\ Opp} = 362\ {}^{kWh}/_{ton} \times CAP_{C,i} \times \left(\frac{SEER_i}{13} - 1\right)$$

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

$$\Delta kWh_{Lost\ Opp} = 362\ {}^{kWh}/_{ton} \times 3\ tons \times \left(\frac{17}{13} - 1\right) = 334.15\ kWh$$

*Example 4: Lost Opportunity Gross Peak Demand Savings, Single-Family Unit:*

*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, 17 SEER. What are the annual demand savings?*

Using the equation for Lost Opportunity demand savings:

$$\Delta kW_{Lost\ Opp,Summer} = 0.45\ {}^{kWh}/_{ton} \times CAP_{C,i} \times \left(\frac{EER_i}{13} - 1\right)$$

Input the size and efficiency of the new unit:

$$\Delta kW_{Lost\ Opp,Summer} = 0.45\ {}^{kWh}/_{ton} \times 3 \times \left(\frac{17}{13} - 1\right) = 0.415\ kW$$

## ***Measure Life***

**Table 3-23 Measure Life**

| Measure | Retirement RUL | Lost Opportunity EUL | Ref |
|---|---|---|---|
| Central A/C System | 8.33 | 25 | [5] |

## ***Peak Factors***

**Table 3-24 Coincidence Factors**

| Measure | Summer Coincidence Factor | Winter Coincidence Factor | Ref |
|---|---|---|---|
| Energy-efficient central air conditioning | 57% | 0% | [6] |

## ***Load Shapes***

**Table 3-25 Load Shapes**

| Measure | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % | Ref |
|---|---|---|---|---|---|
| Cooling - Central AC | 4.83% | 4.33% | 54.40% | 36.45% | [6] |

## ***Realization Rates and Net Impact Factors***

**Table 3-26 Realization Rates**

| | Gross Realization | | | FR & SO | | | Net Realization | | |
|---|---|---|---|---|---|---|---|---|---|
| Measure | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | ISR | Free-ridership | Spill-over | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW |
| Central A/C & HP | 100.0% | 100.0% | 100.0% | 100% | 38.8% | 0.0% | 61.2% | 61.2% | 61.2% |
| Central A/C & HP, HES-IE | 100.0% | 100.0% | 100.0% | 100% | 0.0% | 0.0% | 100% | 100% | 100% |
| Central A/C & HP, HES [4] | 100.0% | 100.0% | 100.0% | 100% | 38.0% | 7.0% | 69.0% | 69.0% | 69.0% |

## ***References***


[1] Central Air Conditioning Impact and Process Evaluation, NMR Group, Inc., Oct. 8, 2014.

[2] ASHRAE/IESNA Standard 90.1-1999.

[3] X1931 Connecticut's 2020 Program Savings Document, Eversource Energy, 16th Edition, Filed on Mar. 1, 2020

[4] ADM Associates, Inc., Residential Central A/C Regional Evaluation Free-Ridership Analysis, Oct. 2009, p. 9.

[5] Michaels Energy. 2022. "X2001A: Connecticut Measure Life/EUL Update Study-Residential Measures."

[6] DNV. 2021. "X1931-2 Load Shape and Coincidence Factor Research." Connecticut Energy Efficiency Board (EEB) and Evaluation Administrators.

[7] NMR. R1983 HES NTG Review Final Memo dated Sep. 12, 2022.

***Changes from Last Version***

- Formatting updates.
- Updated algorithms to use SEER instead of EER, revised calculation examples accordingly.
- Measure life update.
- Separated out HES and HES-IE measures.
- Updated installation rate, free ridership and spillover values for HES.

## 3.2.2 CENTRAL AIR SOURCE HEAT PUMP

| | |
|---|---|
| Market | Residential |
| Baseline Type | Retrofit/Lost Opportunity |
| Category | HVAC |

### ***Description***

Installation of an energy-efficient central ducted air source heat pump (ASHP) as replacement of a working, less-efficient electric heating system, including heat pumps and electric resistance heating or replacement of a fossil fuel-based heating system and Central A/C. The savings here do not apply to a Ductless Heat Pump; see Measure 3.2.4 for Ductless Heat Pumps methodology.

*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 EUL listed below.

*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.
- Retirement Savings are the difference in energy use between the older unit  and a baseline new model , continuing for the RUL listed below.

### ***Energy Savings Algorithm***

The savings methodology presented here is for heating only. Cooling savings from an efficient heat pump are the same as the cooling savings for an efficient central A/C.

If the unit also provides cooling, calculate savings as presented in *Measure 3.2.1: Energy-Efficient Central A/C*.

*Annual Lost Opportunity Gross Energy Savings, Electric*

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

*Lifetime 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:

$$\Delta kWh_{H,Total} = (\Delta kWh_{H,Retire} \times RUL) + (\Delta kWh_{H,Lost\ Opp} \times EUL)$$

Where,

$$\Delta kWh_{H,Retire} = EFLH_H \times CAP_{H,i} \times \left(\frac{1}{HSPF_e} - \frac{1}{HSPF_b}\right) \times \frac{1}{1000}$$

$$\Delta kWh_{H,Lost\ Opp} = see\ above$$

If replacing fossil fuel equipment:

$$\frac{1}{HSPF_e} = 0$$

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

$$\Delta kW_{Winter} = \frac{\Delta kWh_H}{EFLH_H} \times CF_{Winter}$$

## Calculation Parameters

**Table 3-27 Calculation Parameters**

| Symbol | Description | Units | Values | Ref |
|---|---|---|---|---|
| ΔkWh | Annual electric energy savings | kWh | Calculated | |
| $\Delta kW_{Summer}$ | Summer demand savings | kW | Calculated | |
| $\Delta kW_{Winter}$ | Winter demand savings | kW | Calculated | |
| $EFLH_H$ | Heating equivalent full-load hours (average detached single family FLHH for Poughkeepsie, NY which is the closest NY weather station to CT) | Hours | 862 | [1] |
| EUL | Effective useful life | Years | 20 | [6] |
| RUL | Remaining useful life | Years | 6 | [6] |
| $CAP_{H,i}$ | Installed heating capacity | Btu/hr | Site specific | |
| $HSPF_b$ | Heating season performance factor, baseline, representing baseline new model | Btu/Watt-hr | Lookup in Table 3-29 | [5] |
| $HSPF_e$ | Heating season performance factor, existing (AHRI-verified) | Btu/Watt-hr | Use site-specific pre-existing equipment HSPF value if known. | [5] |

| Symbol | Description | Units | Values | Ref |
|---|---|---|---|---|
| | | | If unknown use Table 3-28 | |
| $HSPF_i$ | Heating season performance factor, installed (AHRI-Verified) | Btu/Watt-hr | Site specific | |

**Table 3-28 Heating Season Performance Factor for Preexisting ASHP System (HSPFe) [5]**

| Preexisting system | $HSPF_e$ |
|---|---|
| If preexisting heating system is electric heat | 3.14 |
| Installed before 2006 | 6.8 |
| Installed between 2006-2014 | 7.7 |
| Installed after 2015 | 8.2 |
| If neither the HSPF nor installment year of preexisting system is known | 7.7 |

**Table 3-29 Heating Season Performance Factor Baseline ($HSPF_b$)**

| System Type | $HSPF_b$ |
|---|---|
| Split heat pump | 7.5 HSPF2 / 8.8 HSPF |
| Single package heat pump | 6.7 HSPF2 / 8.0 HSPF |

The values in Table 3-29 are based on federal standard for HSPF2 ratings beginning January 2023. HSPF2 is converted to HSPF using Table 3-30.

**Table 3-30 HSPF2 to HSPF Conversion for Unitary and Split System Heat Pumps**

| HSPF2 | HSPF |
|---|---|
| 6.7 | 8.0 |
| 7.1 | 8.5 |
| 7.5 | 8.8 |
| 7.8 | 9.2 |
| 8 | 9.5 |
| 8.4 | 10 |
| 8.5 | 10.2 |
| 8.9 | 10.8 |
| 9.1 | 11 |
| 9.3 | 11.3 |
| 9.7 | 11.9 |

| HSPF2 | HSPF |
|---|---|
| 10 | 12.4 |
| 10.4 | 12.9 |

## ***Calculation Examples***

*Lost Opportunity Gross Energy Savings, Example*

*Example: A rebate is provided for the installation of a new air source heat pump with an installed heating capacity of 36,000 Btu/hr and HSPF of 10. What are the annual electric heating and cooling savings?*

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

$$\Delta kWh_{H,LostOpp} = 862\ {}^{hrs}/_{yr} \times CAP_i \times \left(\frac{1}{8.2} - \frac{1}{HSPF_i}\right) \times \frac{1}{1000}$$

$$\Delta kWh_{H,LostOpp} = 862\ {}^{hrs}/_{yr} \times 36{,}000 \times \left(\frac{1}{8.2} - \frac{1}{10}\right) \times \frac{1}{1000} = 681.2\ kWh$$

*Retrofit Gross Energy Savings, Example*

*Example: A new air-source heat pump with a heating capacity of 36,000 Btu/hr, $HSPF_i$ of 10, SEER of 17, and EER of 13.0 is installed in a home to replace an old working heat pump with heating capacity of 36,000 Btu/hr, and $HSPF_e$ of 6.8.*

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

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

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

$$\Delta kWh_{H,LostOpp} = 862\ {}^{hrs}/_{yr} \times 36{,}000 \times \left(\frac{1}{8.2} - \frac{1}{10}\right) \times \frac{1}{1000} = 681.2\ kWh$$

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

$$\Delta kWh_{H,Retire} = EFLH_H \times CAP_{H,i} \times \left(\frac{1}{HSPF_e} - \frac{1}{HSPF_b}\right) \times \frac{1}{1000}$$

$$\Delta kWh_{H,Retire} = 862\ {}^{hrs}/_{yr} \times 36{,}000 \times \left(\frac{1}{6.8} - \frac{1}{8.2}\right) \times \frac{1}{1000} = 779.1\ kWh$$

Because the heat pump also provides cooling; calculate cooling savings as presented in the <u>*Measure 4.2.1: Energy-Efficient Central A/C*</u>.

## ***Measure Life***

**Table 3-31 Measure Life**

| Measure Life Type | Retirement RUL | Lost Opportunity EUL | Ref |
|---|---|---|---|
| Air-source heat pump | 6 | 20 | [6] |

## ***Peak Factors***

**Table 3-32 Peak Factors**

| Measure | Summer Coincidence Factor | Winter Coincidence Factor | Ref |
|---|---|---|---|
| Heat pump | 57% | 0% | [4] |

## ***Load Shapes***

**Table 3-33 Load Shapes**

| End Use | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % | Ref |
|---|---|---|---|---|---|
| Cooling - Central AC | 4.83% | 4.33% | 54.40% | 36.45% | [4] |
| Heating | 47.23% | 52.77% | 0.00% | 0.00% | [4] |

## ***Realization Rates***

**Table 3-34 Realization Rates**

| | Gross Realization % | | | | FR & SO | | Net Realization % | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 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 |
| Central A/C & HP **HES -IE** | 100.0% | 100.0% | 100.0% | N/A | 0.0% | 0.0% | 100% | 100% | 100% | N/A |
| Central A/C & HP **HES [7]** | 100.0% | 100.0% | 100.0% | N/A | 38.0% | 7.0% | 69% | 69% | 69% | N/A |
| MF HVAC heat pumps **HES / HES -IE MF** | 100% [3] | 60% [3] | 100% [3] | N/A | N/A | N/A | 100% | 60% | 100% | N/A |
| Central A/C & HP **HVAC** | 100.0% | 100.0% | 100.0% | 100.0% | 38.8% [2] | 0.0% | 61.2% | 61.2% | 61.2% | 61.2% |

## ***References***


[1] New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs, New York State Joint Utilities, Issue Date – Apr. 15, 2019.

[2] ADM Associates, Inc. 2009. "Residential Central A/C Regional Evaluation Free-Ridership Analysis." p. 9.

[3] TRC. 2021. "CT EEB X1941 Multifamily Impact Evaluation." Table 6.

[4] DNV. 2021. "X1931-2 Load Shape and Coincidence Factor Research." Connecticut Energy Efficiency Board (EEB) and Evaluation Administrators.

[5] 10 CFR Part 430 – Energy Conservation Program for Consumer Products. https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430/subpart-C/section-430.32.

[6] Michaels Energy. 2022. "X2001A: Connecticut Measure Life/EUL Update Study-Residential Measures." Connecticut Energy Efficiency Board.

[7] NMR. R1983 HES NTG Review Final Memo dated Sep. 12, 2022.


## ***Changes from Last Version***

- Formatting changes.
- Updated measure life.
- Separated out HES and HES-IE measures.
- Updated free ridership and spillover values for HES.

## 3.2.3 GROUND SOURCE HEAT PUMP

| | |
|---|---|
| Market | Residential |
| Baseline Type | Lost Opportunity |
| Category | HVAC |

### ***Description***

Installation and commissioning of a high efficiency closed loop ground source heat pump system.

Savings are determined using the engineering algorithm described below.

**Note:** The savings baseline for lost opportunity is a code-compliant geothermal system. For retrofit, the baseline is site-specific electric cooling (Central A/C and/or heat pump) and site-specific electric heating system (electric resistance/HP) or fossil fuel heating system (boiler/furnace).

### ***Energy Savings Algorithm***

*Lost Opportunity Gross Energy Savings, Electric*

Summer:

$$\Delta kWh_C = CAP_{C,i} \times EFLH_C \times \left(\frac{1}{EER_b} - \frac{1}{EER_i}\right) \times \frac{1}{1000}$$

Winter:

$$\Delta kWh_H = CAP_{H,i} \times EFLH_H \times \left(\frac{1}{COP_b} - \frac{1}{COP_i}\right) \times \frac{1}{3{,}412}$$

*Retrofit Gross Energy Savings, Electric*

Summer:

$$\Delta kWh_C = CAP_{C,i} \times EFLH_C \times \left(\frac{1}{EER_e} - \frac{1}{EER_i}\right) \times \frac{1}{1000}$$

Winter:

$$\Delta kWh_H = CAP_{H,i} \times EFLH_H \times \left(\frac{1}{COP_e} - \frac{1}{COP_i}\right) \times \frac{1}{3{,}412}$$

*Lost Opportunity Gross Seasonal Peak Demand Savings, Electric*

Summer kW:

$$\Delta kW_C = CAP_{C,i} \times \frac{1}{1000} \times \left(\frac{1}{EER_b} - \frac{1}{EER_i}\right) \times CF_C$$

Winter kW:

$$\Delta kW_H = CAP_{H,i} \times \frac{1}{3{,}412} \times \left(\frac{1}{COP_b} - \frac{1}{COP_i}\right) \times CF_H$$

*Retrofit Gross Seasonal Peak Demand Savings, Electric*

Summer kW:

$$\Delta kW_C = CAP_{C,i} \times \frac{1}{1000} \times \left(\frac{1}{EER_e} - \frac{1}{EER_i}\right) \times CF_C$$

Winter kW:

$$\Delta kW_H = CAP_{H,i} \times \frac{1}{3{,}412} \times \left(\frac{1}{COP_e} - \frac{1}{COP_i}\right) \times CF_H$$

## ***Calculation Parameters***

**Table 3-35 Calculation Parameters**

| Symbol | Description | Values | Units | Ref |
|---|---|---|---|---|
| $\Delta kW_C$ | Summer seasonal demand savings | Calculated | kW | |
| $\Delta kW_H$ | Winter seasonal demand savings | Calculated | kW | |
| $\Delta kWh_C$ | Annual cooling energy savings | Calculated | kWh | |
| $\Delta kWh_H$ | Annual heating energy savings | Calculated | kWh | |
| $CAP_{C,i}$ | Installed rated cooling capacity | Site specific | Btu/hr | |
| $CAP_{H,i}$ | Installed rated heating capacity (cooling capcity can be used if heating capacity is unknown) | Site specific | Btu/hr | |
| $EER_i$ | Installed EER | Site specific | Btu/Watt-hr | |
| $COP_i$ | Installed COP | Site specific | N/A | |
| $EER_e$ | Existing EER of electric cooling system | Site specific | Btu/Watt-hr | |
| $CF_C$ | Coincidence Factor, residential cooling | 0.69 | N/A | [4] |
| $CF_H$ | Coincidence Factor, residential heating | 0.50 | N/A | [4] |
| $EFLH_H$ | Effective full load hours, heating | 862 | Hours | [7][3] |
| $EFLH_C$ | Effective full load hours, cooling | 470 | Hours | [7] |

| Symbol | Description | Values | Units | Ref |
|---|---|---|---|---|
| $COP_b$ | Baseline COP | Table 3-36: Baseline Efficiencies | N/A | [2] |
| $COP_e$ | Coefficient of Performance of preexisting electric heating system. | Replacing electric resistance heating: $COP_e = 1$ Replacing fossil fuel equipment: $\frac{1}{COP_e} = 0$ | N/A | |
| $EER_b$ | Baseline EER | Table 3-36 | Btu/Watt-hr | [3] |

**Table 3-36: Baseline Efficiencies [2]**

| System Type | $EER_b$ | $COP_b$ |
|---|---|---|
| Closed loop water-to-air | 14.3 | 3.2 |
| Closed loop water-to-water | 15.1 | 2.5 |
| DGX | 15.0 | 3.5 |

## ***Calculation Examples***

*Lost Opportunity Gross Energy Savings, Example*

*Example: A 3-ton closed loop water-to-water geothermal heat pump is installed with an EER of 20.2 and COP of 4.2. What are the energy savings?*

Summer savings:

$$\Delta kWh_C = CAP_{C,i} \times EFLH_C \times \left(\frac{1}{EER_b} - \frac{1}{EER_i}\right) \times \frac{1}{1000}$$

$$\Delta kWh_C = 36{,}000 \times 470 \times \left(\frac{1}{15.1} - \frac{1}{20.2}\right) \times \frac{1}{1000} = 282.9\ kWh_C$$

Winter savings:

$$\Delta kWh_H = CAP_{H,i} \times EFLH_H \times \left(\frac{1}{COP_b} - \frac{1}{COP_i}\right) \times \frac{1}{3{,}412}$$

$$\Delta kWh_H = 36{,}000 \times 862 \times \left(\frac{1}{2.5} - \frac{1}{4.2}\right) \times \frac{1}{3{,}412} = 1472.5\ kWh_H$$

## *Measure Life*

The measure life for geothermal heat pump is 25 years [8].

## *Peak Factors*

**Table 3-37 Peak Factors**

| Measure | Summer Coincidence Factor | Winter Coincidence Factor | Ref |
|---|---|---|---|
| Ground source heat pump | 74% | 50% | [4] |
| Water and ground source heat pumps (MF) | 80% | 100% | [4] |

## *Load Shapes*

**Table 3-38 Load Shapes**

| End Use | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % | Ref |
|---|---|---|---|---|---|
| Cooling – Central AC | 4.83% | 4.33% | 54.40% | 36.45% | [4] |
| Heating | 47.23% | 52.77% | 0.00% | 0.00% | [4] |

## *Realization Rates*

**Table 3-39 Realization Rates**

| | Gross Realization % | | | | FR & SO | | Net Realization % | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Measure | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Delivered Fuels MMBtu | Free-ridership | Spill-over | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Delivered Fuels MMBtu |
| Ground Source Heat Pump | 100.0% | 100.0% | 100.0% | 100.0% | 38.8% [5] | 0.0% | 100.0% | 100.0% | 100.0% | 100.0% |
| Ground Source Heat Pump, HES [6] | 100.0% | 100.0% | 100.0% | 100.0% | 38.0% | 7.0% | 69% | 69% | 69% | 69% |

## *References*


[1] Aligns with other TRMs (NY and Mid-Atlantic) and based on more recent research by ERS.

[2] ENERGY STAR Tier 1 Geothermal Heat Pumps Key Product Criteria table 1. https://www.energystar.gov/sites/default/files/specs/private/Geothermal_Heat_Pumps_Program_Requirements%20v3.1.pdf. Accessed Jun. 2, 2021.

[3] 2021 International Energy Conservation Code (IECC).

[4] DNV. 2021. "X1931-2 Load Shape and Coincidence Factor Research." Connecticut Energy Efficiency Board (EEB) and Evaluation Administrators.

[5] ADM Associates, Inc. Oct 2009. "Residential A/C Regional Evaluation Free-Ridership Analysis."

[6] NMR. R1983 HES NTG Review Final Memo dated Sep. 12, 2022.

[7] NY TRM v9, EFLH values for Poughkeepsie.

[8] DNV. MA20C15-B-GSHP Ground Source Heat Pump eTRM Measure Review. March 5, 2021, https://ma-eeac.org/wp-content/uploads/MA20C15-B-GSHP_GroundSourceHeatPump_final.pdf.

## ***Changes from Last Version***

- Formatting updates.
- Updated free ridership and spillover values for HES.

### 3.2.4 MINI-SPLIT HEAT PUMP

| | |
|---|---|
| Market | Residential |
| Baseline Type | Retrofit, Lost Opportunity |
| Category | HVAC |

***Description***

Installation of an energy-efficient mini split air source heat pump as replacement of a working, less-efficient electric heating system, including mini split heat pumps and electric resistance heating or replacement of a fossil fuel-based heating system.

Savings methodology is based on *Ductless Mini-split Heat Pump Impact Evaluation*, Dec. 30, 2016, Cadmus [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] (see notes) 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 mini split heat pump installed in an existing home with electric resistance heating system is considered to have Retrofit Savings. A mini split heat pump installed in a home with fossil fuel heating system is considered to have Lost Opportunity Savings (or new construction).

**Notes:** The savings here are not to be applied to a heat pump with complete ducting. Only systems without ducts, or with short duct runs for mini splits sections installed above the ceiling, are addressed by this measure. The savings are independent of the number of zones (air handlers) installed.

The minimum heating efficiency standard set for DHPs in 2023 is 8.8 HSPF and cooling efficiency is 14.0 SEER.

PRISM is an established statistical procedure for measuring energy conservation in residential housing. The PRISM software package was developed by the Center for Energy and Environmental Studies, Princeton University. The tool is used for estimating energy savings from billing data. Available online at: http://www.princeton.edu/~marean/.

DOE-2 is a widely used and accepted building energy analysis program that can predict the energy use and cost for all types of buildings. DOE-2 uses a description of the building layout, constructions, operating schedules, conditioning systems (such as lighting and HVAC), and utility rates provided by the user, along with weather data, to perform an hourly simulation of the building and to estimate utility bills. Available online at: http://www.doe2.com/.

***Energy Savings Algorithm***

*Retrofit Gross Energy Savings, Electric*

Heating:

$$\Delta kWh_H = CAP_H \times \left(\frac{1}{HSPF_E} - \frac{1}{HSPF_I}\right) \times EFLH_H \times \frac{1}{1000}$$

Cooling:

$$\Delta kWh_C = CAP_C \times \left(\frac{1}{SEER_E} - \frac{1}{SEER_I}\right) \times EFLH_C \times \frac{1}{1000}$$

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

Winter demand savings:

$$\Delta kW_{Winter} = \frac{CAP_{H,5F}}{3.412} \times \left(1 - \frac{1}{COP_{H,5F}}\right) \times WCF$$

Summer demand savings:

$$\Delta kW_{Summer} = CAP_C \times \left(\frac{1}{SEER_E} - \frac{1}{SEER_I}\right) \times SCF \times \frac{1}{1000}$$

*Lost Opportunity Gross Energy Savings, Electric*

Heating:

$$\Delta kWh_H = CAP_H \times \left(\frac{1}{HSPF_B} - \frac{1}{HSPF_I}\right) \times EFLH_H \times \frac{1}{1000}$$

Cooling:

$$\Delta kWh_C = CAP_C \times \left(\frac{1}{SEER_B} - \frac{1}{SEER_I}\right) \times EFLH_C \times \frac{1}{1000}$$

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

Winter demand savings:

$$\Delta kW_{Winter} = CAP_H \times \left(\frac{1}{HSPF_B} - \frac{1}{HSPF_I}\right) \times WCF \times \frac{1}{1000}$$

Summer demand savings:

$$\Delta kW_{Summer} = CAP_C \times \left(\frac{1}{SEER_B} - \frac{1}{SEER_I}\right) \times SCF \times \frac{1}{1000}$$

## ***Calculation Parameters***

**Table 3-40 Calculation Parameters**

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| $\Delta kWh$ | Annual electric energy savings | Calculated | kWh | |
| $\Delta kW_{Winter}$ | Winter demand savings | Calculated | kW | |
| $\Delta kW_{Summer}$ | Summer demand savings | Calculated | kW | |
| $CAP_C$ | Nominal cooling capacity (input) | Site specific | Btu/hr | |
| $CAP_H$ | Nominal heating capacity (input) | Site specific | Btu/hr | |
| $HSPF_I$ | Heating Season Performance Factor, installed (input) | Site specific | Btu/Watt-hr | |
| $SEER_I$ | Seasonal Energy Efficiency Ratio, installed (input) | Site specific | Btu/Watt-hr | |
| $HSPF_E$ | Heating Season Performance Factor, existing (retrofit) | Site specific or assume 3.412 for electric resistance | Btu/Watt-hr | |
| $HSPF_B$ | Heating season performance factor, baseline (lost opportunity) | 8.8 | Btu/Watt-hr | [8] |
| $SEER_B$ | Seasonal Energy Efficiency Ratio, baseline (lost opportunity) | 14.0 | Btu/Watt-hr | [2] |
| $SEER_E$ | Seasonal Energy Efficiency Ratio, existing (retrofit) | 10.1 | Btu/Watt-hr | |
| $EFLH_H$ | Equivalent full load hours, heating | 535 | hr | [2] |
| $EFLH_C$ | Equivalent full load hours, cooling | 218 | hr | [1] |
| SCF | Summer coincidence factor | 0.232 | | [4] |
| WCF | Winter coincidence factor | 0.161 | | [4] |

## ***Calculation Examples***

### *Retrofit Gross Energy Savings Example*

An energy efficient DHP is installed in an existing home with electric resistance heat and existing cooling system with 10.1 SEER. The nominal heating capacity is 24,000 Btu, and the nominal cooling capacity is 28,000 Btu, installed HSPF is 11, and the installed SEER is 22. The system has two zones. What are the annual electric heating and cooling savings?

Using the equation for annual electric heating savings:

$$\Delta kWh_H = 24{,}000 \times \left(\frac{1}{3.413} - \frac{1}{11}\right) \times 535 \times \frac{1}{1{,}000} = 2{,}593.9\ kWh$$

Using the equation for annual electric cooling savings:

$$\Delta kWh_C = 28{,}000 \times \left(\frac{1}{10.1} - \frac{1}{22}\right) \times 218 \times \frac{1}{1000} = 327kWh$$

*Retrofit Gross Peak Demand Savings*

An energy efficient DHP is installed in an existing home with electric resistance heat. The rated heating capacity is 24,000 Btu, rated cooling capacity is 24,000 Btu, installed HSPF is 11, the installed SEER is 22. What are the annual summer and winter demand savings?

Using the equation for summer demand savings:

$$\Delta kW_{Summer} = 24{,}000 \times \left(\frac{1}{10.1} - \frac{1}{22}\right) \times .232 \times \frac{1}{1000} = 0.30\ kW$$

Using the equation for winter demand savings:

$$\Delta kW_{Winter} = 28{,}000 \times \left(\frac{1}{3.413} - \frac{1}{11}\right) \times .161 \times \frac{1}{1000} = 0.91kW$$

## Measure Life

**Table 3-41 Measure Life**

| Measure Life Type | Retirement RUL | Lost Opportunity EUL | Ref |
|---|---|---|---|
| Air-source heat pump | 5* | 17 | [5] |

* Recommended RUL if age is unknown

## Peak Factors

**Table 3-42 Peak Factors**

| Measure | Summer Coincidence Factor | Winter Coincidence Factor | Ref |
|---|---|---|---|
| Heat pump – ductless | 23% | 16% | [4] |

## Load Shapes

**Table 3-43 Load Shapes**

| Measure | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % | Ref |
|---|---|---|---|---|---|
| Cooling - Ductless HP | 8.56% | 10.20% | 47.51% | 33.73% | [4] |
| Heating | 47.23% | 52.77% | 0.00% | 0.00% | [4] |

## *Realization Rates*

**Table 3-44 Realization Rates**

| | Gross Realization % | | | | FR & SO | | Net Realization % | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Measure | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | ISR | Free-ridership | Spill-over | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Ref |
| Minisplit HP **HES -IE** | 100.0% | 100.0% | 100.0% | 100% | 0.0% | 0.0% | 100.0% | 100.0% | 100.0% | |
| Minisplit HP **HES** | 100.0% | 100.0% | 100.0% | 98% | 38.0% | 7.0% | 67.6% | 67.6% | 67.6% | [7] |
| Minisplit HP **HVAC** | 100.0% | 100.0% | 100.0% | 100% | 40.6% | 17.2% | 76.6% | 76.6% | 76.6% | [6] |

## *References*


[1] Cadmus. Dec. 30, 2016. "Ductless Mini-Split Heat Pump Impact Evaluation, Final Report." p. 5. Table ES-3. Available online at: http://www.ripuc.ri.gov/eventsactions/docket/4755-TRM-DMSHP%20Evaluation%20Report%2012-30-2016.pdf.

[2] Energy & Resource Solutions. Oct. 10, 2019. "R1705 R1609 MF Baseline and Weatherization Opportunity Study."p. 42, see Table 4-22. Available online at: https://www.energizect.com/sites/default/files/R1705-1609%20MF%20Baseline%20Weatherization%20Study_Final%20Report_10.10.19.pdf.

[3] CF value adapted from Cadmus *Ductless Mini-Split Heat Pump Impact Evaluation*, Table 7. (2016). Since the CADMUS study defines CF only for on-peak hours, it required conversion to Seasonal Peak value. This was done by obtaining a regression between NE on-peak and seasonal-peak values from a 2011 KEMA Load shape study. See Table 0-5 ISO, values corresponding to Seasonal peak for NE-south coastal. This regression suggested using a 1.29 factor to convert to Seasonal Peak CF.

[4] DNV. 2021. "X1931-2 Load Shape and Coincidence Factor Research – Final Report."

[5] Michaels Energy. 2022. "X2001A: Connecticut Measure Life/EUL Update Study-Residential Measures." Connecticut Energy Efficiency Board.

[6] NMR Group. 2018. "Massachusetts Residential HVAC NTG and Market Effects Study (TXC34)." Table 8.

[7] NMR. R1983 HES NTG Review Final Memo dated Sep. 12, 2022.

[8] Efficiency requirements for residential central AC and heat pumps to rise in 2023. .S. Energy Information Administration (EIA). (n.d.). https://www.eia.gov/todayinenergy/detail.php?id=40232.


## *Changes From Last Version*

- Formatting updates.
- Changed measure name from ductless to mini split.
- Updated 2023 minimum efficiency requirements.
- Updated measure life. Updated installation rate, free ridership and spillover values for HES.

## 3.2.5 PACKAGE TERMINAL HEAT PUMP

| | |
|---|---|
| Market | Residential |
| Baseline Type | Retrofit, Lost Opportunity |
| Category | HVAC |

### ***Description***

Installation of a new energy efficient package terminal heat pump.

The savings methodology for a package terminal heat pump (PTHP) is calculated from the baseline efficiencies in [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 Table 3-47.

*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 Table 3-47).
- 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 Table 3-47.

**Notes:** HR = 60%, is percent heating when the heat pump is not in electric resistance back up, based on Hartford, Conn. BIN analysis. Winter demand savings are not claimed for this measure since backup resistance heat on the heat pump would be used during winter seasonal peak periods.

### ***Energy Savings Algorithm***

*Lost Opportunity Annual Energy Savings, Electric*

*Heating:*

For replacement of a PTHP:

$$\Delta kWh_H = HR \times EFLH_H \times CAP_H \times \left(\frac{1}{COP_B} - \frac{1}{COP_I}\right) \times \frac{1}{3412}$$

Where,

$$COP_B = 2.9 - \left(0.026 \times CAP_H \times \frac{1}{1000}\right)$$

For replacement of electric resistance system:

$$\Delta kWh_H = HR \times EFLH_H \times CAP_C \times \left(1 - \frac{1}{COP_B}\right) \times \frac{1}{3412}$$

Where,

$$COP_B = 2.9 - \left(0.026 \times CAP_H \times \frac{1}{1000}\right)$$

*Cooling:*

$$\Delta kWh_C = EFLH_C \times CAP_C \times \left(\frac{1}{EER_B} - \frac{1}{EER_I}\right) \times \frac{1}{1000}$$

Where,

$$EER_B = 10.8 - \left(0.213 \times CAP_C \times \frac{1}{1000}\right)$$

*Lost Opportunity Gross Seasonal Peak Demand Savings, Electric*

*Winter:*

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

*Summer:*

$$\Delta kW_{Summer} = CAP_C \times \left(\frac{1}{EER_B} - \frac{1}{EER_I}\right) \times \frac{1}{1000} \times SCF$$

Where,

$$EER_B = 10.8 - \left(0.213 \times CAP_C \times \frac{1}{1,000}\right)$$

## Calculation Parameters

**Table 3-45 Calculation Parameters**

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| ΔkWh | Annual electric energy savings | Calculated | kWh | |
| $\Delta kW_{Summer}$ | Summer demand savings | Calculated | kW | |
| $\Delta kW_{Winter}$ | Winter demand savings (see notes) | 0 | kW | |
| $CAP_C$ | Cooling capacity (input) | Site specific | Btu/hr | |

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| $CAP_H$ | Heating capacity (input) | Site specific | Btu/hr | |
| $COP_B$ | Coefficient of performance, baseline | Site specific | Watt/Watt | [1] |
| $COP_E$ | Coefficient of performance, existing | Site specific | Watt/Watt | |
| $COP_I$ | Coefficient of performance, installed (input) | Site specific | Watt/Watt | |
| $EER_B$ | Energy Efficiency Ratio, baseline | Site specific | Btu/Watt-hr | [1] |
| $EER_E$ | Energy Efficiency Ratio, existing | Site specific | Btu/Watt-hr | |
| $EER_i$ | Energy Efficiency Ratio, installed (input) | Site specific | Btu/Watt-hr | |
| $EER_I$ | Energy Efficiency Ratio, installed (input) | Site specific | Btu/Watt-hr | |
| $EFLH_H$ | Heating equivalent full load hours | Table 3-46 | Hours | [3] |
| $EFLH_C$ | Cooling equivalent full load hours | Table 3-46 | Hours | [3] |
| HR | Percent heating when heat pump is not in electric resistance back up (see notes) | 60 | % | |
| SCF | Summer coincidence factor | 0.588 | N/A | [4] |
| 1 Ton | Capacity, nominal tonnage (Unit conversion) | 12,000 Btu/hr | Tons | |

**Table 3-46 Equivalent Full Load Hours**

| Building Type | $EFLH_H$ | $EFLH_C$ | Units |
|---|---|---|---|
| Uninsulated, pre-war | 922 | N/A | Hours |
| Built before 1979 | 656 | 626 | Hours |
| Built between 1979 and 2006 | 510 | 669 | Hours |
| Built after 2007 | 291 | 812 | Hours |

## ***Calculation Examples***

***New Construction Project:*** *A PTHP is installed in a new construction project; the cooling capacity is 12,000 Btu/hr,* $EER_I$ *= 12.5, and* $COP_I$ *= 3.6.*

*Annual Energy Savings, Lost Opportunity*

*Heating:*

$$\Delta kWh_H = HR \times EFLH_H \times CAP_H \times \left(\frac{1}{COP_B} - \frac{1}{COP_I}\right) \times \frac{1}{3412}$$

$$\Delta kWh_H = 0.6 \times 291 \times 12{,}000 \times \left(\frac{1}{2.588} - \frac{1}{3.6}\right) \times \frac{1}{3412} = 66.700\ kWh$$

*Cooling:*

$$\Delta kWh_c = EFLH_{Hc} \times CAP_C \times \left(\frac{1}{EER_B} - \frac{1}{EER_I}\right)$$

$$EER_B = 10.8 - \left(0.213 \times CAP_C \times \frac{1}{1{,}000}\right) = 10.8 - \left(0.213 \times 12{,}000 \times \frac{1}{1{,}000}\right) = 8.244$$

$$\Delta kWh_C = 812 \times 12{,}000 \times \left(\frac{1}{8.244} - \frac{1}{12.5}\right) \times \frac{1}{1000} = 402.43\ kWh$$

*Peak Demand Savings*

*Heating:*

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

*Cooling:*

$$\Delta kW_{Summer} = 12{,}000 \times \left(\frac{1}{8.244} - \frac{1}{12.5}\right) \times \frac{1}{1000} \times 0.588 = 0.291\ kW$$

## ***Measure Life***

**Table 3-47 Measure Life**

| Equipment Type | Retirement RUL | Lost Opportunity EUL | Ref |
|---|---|---|---|
| Package terminal heat pump | 5 | 18 | [6] |

## ***Peak Factors***

**Table 3-48 Peak Factors**

| Measure | Summer Coincidence Factor | Winter Coincidence Factor | Ref |
|---|---|---|---|
| Package terminal heat pump | 59% | 0% | [7] |

## ***Load Shapes***

**Table 3-49 Load Shapes**

| End Use | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % | Ref |
|---|---|---|---|---|---|
| Heating | 47.23% | 52.77% | 0.00% | 0.00% | [7] |
| Cooling - Ductless HP | 8.56% | 10.20% | 47.51% | 33.73% | [7] |

## *Realization Rates*

**Table 3-50 Realization Rates**

| | **Gross Realization %** | | | **FR & SO** | | **Net Realization %** | | | |
|---|---|---|---|---|---|---|---|---|---|
| Measure | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Free-ridership | Spill-over | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | **Ref** |
| Ductless HP **HES / HES -IE** | 100.0% | 100.0% | 100.0% | 0.0% | 0.0% | 100.0% | 100.0% | 100.0% | |
| Ductless HP **HVAC** | 100.0% | 100.0% | 100.0% | 40.6% | 17.2% | 76.6% | 76.6% | 76.6% | [6] |

## *References*


[1] $EER_B$ and $COP_B$ varies per equipment based on IECC2021, Table C403.3.2(4).

[2] ADM Associates Inc. “Residential Central A/C Regional Evaluation.” Tables 4-7 and 4-8, pp. 4-9.- Average Cooling kWh Savings per unit size = 357.6 kWh/ton, Average peak kW Savings per unit size = 0.591 kW/ton

[3] NY TRM v7 Appendix G Poughkeepsie, NY location values which are based on DOE-2.2 simulations of a set of prototypical residential buildings defined in the following database: *004-2005 Database for Energy Efficiency Resources (DEER) Update Study, Final Report*, Itron, Inc. Vancouver, WA. Dec. 2005.

[4] KEMA. August 2011. “C&I Unitary HVAC Load Shape Project: Final Report Revision Memo.”

[5] California Public Utilities Commission, *2014 Database for Energy-Efficient Resources*, Feb. 4, 2014, available online at: http://www.deeresources.com/files/DEER2013codeUpdate/download/DEER2014-EUL-table-update_2014-02-05.xlsx, last accessed Sep. 3, 2020.

[6] GDS Associates Inc. June 2007.”Measure Life Report, Residential and Commercial Industrial Lighting and HVAC Measures.” Appendix C. p. C-6.

[7] DNV. 2021. “X1931-2 Load Shape and Coincidence Factor Research.” Connecticut Energy Efficiency Board (EEB) and Evaluation Administrators.


## *Changes from Last Version*

- Formatting updates.

## 3.2.6 QUALITY INSTALLATION VERIFICATION

| | |
|---|---|
| Market | Residential |
| Baseline Type | Retrofit |
| Category | HVAC |

### ***Description***

Perform quality installation and verification (QIV) of a residential central air ducted system as described by ENERGY STAR.

ENERGY STAR Quality Installation Guidelines are based on standards 5 and 9 of the Air Conditioning Contractors of America's (ACCA) HVAC Quality Installation Specification and is recognized as an American National Standard [2], [3]. For new homes, the ENERGY STAR Inspection Checklist for National Programs Requirements V3.0 would be used [4], [5].

These industry best practices help ensure that HVAC equipment is:

1. Correctly sized to meet customer home's needs;
2. Connected to a well-sealed duct system;
3. Operating with sufficient airflow in the system; and
4. Installed with the proper amount of refrigerant.

Estimated savings potential with Quality Installation (Table 3-51) ranges from 18% to 36% for air conditioners and heat pumps and 11% to 18% for furnaces [6]. A new residential central A/C uses 357.6 kWh/ton annually [1]. The cooling and heating savings are a percentage of total cooling and heating energy consumption.

The cooling savings factor presented in Table 3-51 QIV, Performed with New Residential A/C System Installation was calculated as follows, assuming that the average new residential central A/C uses 357.6 kWh/ton annually.

$$Annual\ cooling\ kWh\ savings = \%\ savings \times 357.6\ \frac{kWh}{ton} \times ton$$

$$Annual\ cooling\ kWh\ savings\ (Refrigerant\ Charge) = 2\% \times 357.6\ \frac{kWh}{ton} \times ton = 7.15\ \frac{kWh}{ton} \times ton$$

$$Annual\ cooling\ kWh\ savings\ (Airflow) = 2\% \times 357.6\ \frac{kWh}{ton} \times ton = 7.15\ \frac{kWh}{ton} \times ton$$

$$Annual\ cooling\ kWh\ savings\ (Sizing) = 3\% \times 357.6\ \frac{kWh}{ton} \times ton = 10.73\ \frac{kWh}{ton} \times ton$$

$$Annual\ cooling\ kWh\ savings\ (Duct\ Sealing) = 15\% \times 357.6\ \frac{kWh}{ton} \times ton = 53.6\ \frac{kWh}{ton} \times ton$$

$$Annual\ cooling\ kWh\ savings\ (total\ cooling\ savings) = 22\% \times 357.6\ \frac{kWh}{ton} \times ton = 78.67\ \frac{kWh}{ton} \times ton$$

$$ton = \frac{CAP_C}{12{,}000\,\frac{Btu}{ton}}$$

$$\Delta kWh_C = 78.67\ \frac{kWh}{ton} \times \frac{CAP_C}{12{,}000\,\frac{Btu}{ton}}$$

Using the results of 53.6 kWh duct sealing and the relationship of savings factor of 1.78 from Table 3-82 in the 2023 PSD manual for 3.2.11_Duct Sealing. Cooling savings is 1.78 kWh per CFM reduction. Therefore, for 53.6 kWh savings, there is a 44.74 CFM reduction.

$$CFM_{Savings} = \frac{53.6}{1.78} = 30.112\ {}^{CFM}/_{ton}$$

Due to the variations presented in ENERGY STAR savings potential, the QIV savings being estimated for this measure are based on the low end of the range as shown in Table 3-51 below:

**Table 3-51 QIV, Performed with New Residential A/C System Installation**

| | Cooling | | Heating | |
|---|---|---|---|---|
| | ENERGY STAR Savings Potential [6] | Estimated Savings Used to Develop Savings Factor | ENERGY STAR Savings Potential [6] | Estimated Savings Used to Develop Savings Factor |
| Refrigerant Charge | 2-6% | 2% | - | - |
| Airflow | 2-5% | 2% | - | - |
| Sizing | 3-7% | 3% | - | - |
| Duct Sealing | 11-18% | 15% | 11-18% | 11% |
| Total | 18-36% | 22% | 11-18% | 11% |

## ***Energy Savings Algorithm***

*Retrofit Gross Energy Savings, Electric*

*Cooling savings*

$$\Delta kWh_C = SF_{kWh,C} \times \frac{CAP_C}{C_{ton}}$$

*Heating savings*

$$\Delta kWh_H = SF_{kWh,H} \times \frac{CAP_C}{C_{ton}}$$

*Retrofit Gross Energy Savings, Fossil Fuel*

*Heating savings*

$$\Delta CCF_H = SF_{CCF,H} \times \frac{CAP_C}{C_{ton}}$$

$$\Delta Gal_{Oil,H} = SF_{Gal,Oil,H} \times \frac{CAP_C}{C_{ton}}$$

$$\Delta Gal_{Propane,H} = SF_{Gal,Propane,H} \times \frac{CAP_C}{C_{ton}}$$

*Retrofit Gross Seasonal Peak Demand Savings, Electric*

$$\Delta kW_S = PF_S \times \frac{CAP_C}{C_{ton}}$$

*For heat pumps only*

$$\Delta kW_W = PF_W \times \frac{CAP_C}{C_{ton}}$$

*Retrofit Gross Peak Day Savings, Natural Gas*

$$\Delta CCF_{PD,H} = \Delta CCF_H \times PDF_H$$

## Calculation Parameters

**Table 3-52 Calculation Parameters**

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| $\Delta CCF_H$ | Annual natural gas savings - heating | Calculated | CCF | |
| $\Delta kWh_C$ | Annual electric savings - cooling | Calculated | kWh | |
| $\Delta kWh_H$ | Annual electric savings - heating | Calculated | kWh | |
| $\Delta Gal_{Oil,H}$ | Annual oil savings - heating | Calculated | Gal | |
| $\Delta Gal_{Propane,H}$ | Annual propane savings - heating | Calculated | Gal | |
| $\Delta CCF_{PD,H}$ | Natural gas peak day savings - heating | Calculated | CCF | |
| $\Delta kW_S$ | Summer demand savings - electric | Calculated | kW | |
| $\Delta kW_W$ | Winter demand savings - electric | Calculated | kW | |

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| $CAP_C$ | Cooling capacity | Site specific | Btu | |
| $SF_{kWh,C}$ | Electric savings factor – cooling | Lookup in Table 3-53 Electric Savings Factors | kWh/ton | |
| $SF_{kWh,H}$ | Electric savings factor – heating | Lookup in Table 3-53 Electric Savings Factors | kWh/ton | |
| $SF_{CCF,H}$ | Natural gas savings factor – heating | 25.01 | CCF/ton | |
| $SF_{Gal,Oil,H}$ | Oil savings factor – heating | 25.01 | Gal/ton | |
| $SF_{Gal,Propane,H}$ | Propane savings factor – heating | 28.19 | Gal/ton | |
| $PDF_H$ | Natural gas peak day factor – heating | 0.00977 | N/A | |
| $PF_S$ | Summer seasonal peak factor | 0.099 | kW/ton | [1] |
| $PF_W$ | Winter seasonal peak factor | 0.587 | kW/ton | |
| $C_{ton}$ | Ton conversion constant | 12,000 | Btu/ton | |
| $C_{NG}$ | Natural gas conversion constant | 102,900 | Btu/CCF | |
| $C_{Oil}$ | Oil conversion constant | 138,690 | Btu/Gal | |
| $C_{Propane}$ | Propane conversion constant | 91,330 | Btu/Gal | |

**Table 3-53 Electric Savings Factors**

| System Type | Cooling Factor (kWh/ton) | Heating Factor (kWh/ton) |
|---|---|---|
| Central A/C | 78.67 | - |
| Heat Pump | 78.67 | 267.15 |
| Geothermal Heat Pump | 78.67 | 182.95 |
| Furnace (Fan Electric Savings) | - | 39.50 |

## ***Calculation Examples***

*Example 1: Retrofit Gross Energy Savings*

*A 1980's home has a combination natural gas furnace with a 36,000 Btu (3 tons) Central A/C system. QIV is performed on the systems. What are the energy savings?*

*Using the equation for cooling savings:*

$$\Delta kWh_C = SF_{kWh,C} \times \frac{CAP_C}{C_{ton}}$$

$$\Delta kWh_C = 78.67 \frac{kWh}{ton} \times \frac{36{,}000\ Btu}{12{,}000 \frac{Btu}{ton}} = 236.0\ kWh$$

*Using the equation for heating fan energy:*

$$\Delta kWh_H = SF_{kWh,H} \times \frac{CAP_C}{C_{ton}}$$

$$\Delta kWh_H = 39.50 \frac{kWh}{ton} \times \frac{36{,}000\ Btu}{12{,}000 \frac{Btu}{ton}} = 118.52\ kWh$$

*Using the equation for natural gas heating:*

$$\Delta CCF_H = SF_{kWh,H} \times \frac{CAP_C}{C_{ton}}$$

$$\Delta CCF_H = 25.01 \frac{CCF}{ton} \times \frac{36{,}000\ Btu}{12{,}000 \frac{Btu}{ton}} = 75.03\ CCF$$

*Example 2: Retrofit Gross Peak Demand Savings*

*A 1980's home has a combination natural gas furnace with a 36,000 Btu (3 tons) Central A/C system. QIV is performed on the systems. What are the summer and winter demand savings?*

*For cooling savings:*

$$\Delta kW_S = PF_S \times \frac{CAP_C}{C_{ton}}$$

$$\Delta kW_S = 0.099 \frac{kW}{ton} \times \frac{36{,}000\ Btu}{12{,}000 \frac{Btu}{ton}} = 0.297\ kW$$

*For heat pump savings:*

$$\Delta kW_W = PF_W \times \frac{CAP_C}{C_{ton}}$$

$$\Delta kW_W = 0.587 \frac{kW}{ton} \times \frac{36{,}000\ Btu}{12{,}000 \frac{Btu}{ton}} = 1.76\ kW$$

## ***Measure Life***

**Table 3-54 Measure Life**

| Equipment Type | Measure Life | Ref |
|---|---|---|
| QIV, Central A/C System | N/A | |
| QIV, Air-Source Heat Pump | N/A | |
| QIV, Geothermal Heat Pump | N/A | |

## ***Peak Factors***

**Table 3-55 Peak Factors**

| Measure | Summer Peak Factor | Winter Peak Factor | Ref |
|---|---|---|---|
| Quality Installation Verification | 11% | 59% | [7] |

## ***Load Shapes***

**Table 3-56 Load Shapes**

| End Use | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % | Ref |
|---|---|---|---|---|---|
| Cooling – Central A/C | 4.83% | 4.33% | 54.40% | 36.45% | [7] |
| Heating | 47.23% | 52.77% | 0.00% | 0.00% | [7] |

## ***References***


[1] *Central Air Conditioning Impact and Process Evaluation,* NMR Group, Inc., May 30, 2014.

[2] ACCA. 2010. HVAC Quality Installation Specification – Standard 5. Air Conditioning Contractors of America, Arlington, VA.

[3] ACCA. 2011. HVAC Quality Installation Verification Protocols – Standard 9. Air Conditioning Contractors of America, Arlington, VA.

[4] ENERGY STAR Homes National Programs Requirement V3.0, Available online at: www.energystar.gov.

[5] ENERGY STAR Homes Inspection Checklist, Available online at: www.energystar.gov.

[6] ENERGY STAR Quality Installation, Revised Jun. 1, 2013, Available online at: http://www.energystar.gov/index.cfm?c=hvac_install.hvac_install_index.

[7] DNV. 2021. “X1931-2 Load Shape and Coincidence Factor Research – Final Report.”


## ***Changes from Last Version***

- Formatting updates.
- Updated error in cooling savings factor value calculation to 78.67 kWh/ton.

## 3.2.7 CLEAN, TUNE, AND TEST

| | |
|---|---|
| Market | Residential |
| Baseline Type | Lost Opportunity |
| Category | HVAC |

### ***Description***

Clean, test, and tune performed on boilers or furnaces by cleaning and adjusting burner, and cleaning heat exchanger.

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.

The savings methodology uses multiple inputs such as the square footage of the heated area served by boiler or furnace, existing heating fuel utilization efficiency, and the average heating factor based on home's heat load.

For homes served by a boiler or a furnace, the savings methodology recommends default values for the square footage of the heated area served by boiler or furnace, existing heating fuel utilization efficiency, and the average heating factor based on home's heat load inputs. These default values are based on recent data from Cadmus Group's High Efficiency Heating Equipment Impact Evaluation Final Report[2]. This evaluation reported increased heating loads for homes with boilers, and the previous default assumption of 38,700 Btu/ft$^2$ has correspondingly been increased by 20%.

For multifamily applications, the savings methodology recommends default values for the square footage of the heating area and the existing heating fuel utilization efficiency inputs based on recent data from Energy & Resource Solutions' R1705 R1609 Multifamily Baseline and Weatherization Opportunity Study[3]. The savings methodology recommends a default value for the average heating factor for multifamily applications, which was calculated by scaling single-family heating factor and the associated square footage by recommended multifamily dwelling unit square footage, which is based on the data from Energy & Resource Solutions' R1705 R1609 Multifamily Baseline and Weatherization Opportunity Study [3].

Note: Default values should be used for savings calculation except in situations where either actual nameplate ratings or actual efficiency test data are available

### ***Energy Savings Algorithm***

*Gross Energy Savings, Fossil Fuel:*

$$\Delta BTU_H = A \times HF \times \left(\frac{1}{Eff_E}\right) \times ESF$$

*Savings by heating fuel:*

$$\Delta CCF_H = \frac{\Delta BTU_H}{102{,}900}$$

$$\Delta Gal_{Oil} = \frac{\Delta BTU_H}{138{,}690}$$

$$\Delta Gal_{Propane} = \frac{\Delta BTU_H}{91{,}330}$$

*Peak Day Savings, Natural Gas:*

$$\Delta CCF_{PD} = \Delta CCF_H \times PDF_H$$

## *Calculation Parameters*

**Table 3-57 Calculation Parameters**

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| $\Delta BTU_H$ | Annual Btu savings - heating | Calculated | Btu/yr | |
| $\Delta CCF_H$ | Annual natural gas savings - heating | Calculated | CCF/yr | |
| $\Delta Gal_{Oil}$ | Annual oil savings | Calculated | Gal | |
| $\Delta Gal_{Propane}$ | Annual propane savings | Calculated | Gal | |
| $\Delta CCF_{PDH}$ | Natural gas peak day savings – heating | Calculated | CCF/yr | |
| A | Heated area served by boiler or furnace | 2000 – single family<br>876 -multifamily | $ft^2$ | [2], [3] |
| $Eff_E$ | Efficiency of existing boiler | Table 3-58 | % | [2], [3] |
| HF | Average heating factor based on home's heat load | 38,750 for furnaces<br>42,600 for boilers<br>MF = 20,300 | Btu/ $ft^2$ | [2], [3] |
| $PDF_H$ | Natural gas peak day factor – heating | 0.00977 | N/A | [4] |
| $PDF_W$ | Natural gas peak day factor – water heating | 0.00321 | N/A | [4] |
| ESF | Energy savings factor | 0.02 | N/A | [1] |

**Table 3-58 Baseline Efficiency**

| Equipment Type | | Size | Efficiency | Units | Ref |
|---|---|---|---|---|---|
| Boiler | Small | < 300,000 Btu/hr | 0.92 | AFUE | [2], [3] |
| Boiler | Medium | 300,000 to 2,500,000 Btu/hr | 0.90 | $E_c$ | [2], [3] |
| Boiler | Large | > 2,500,000 Btu/hr | 0.90 | $E_c$ | [2], [3] |

| Equipment Type | | Size | Efficiency | Units | Ref |
|---|---|---|---|---|---|
| Boiler | Steam | All sizes | 0.82 | $E_c$ | [2], [3] |
| Boiler | Cast Iron Sectional Hot Water | All sizes | 0.82 | $E_c$ | [2], [3] |
| Furnace | Unknown, existing venting or new construction, | 120,000 Btu/hr or greater | 0.85 | $E_t$ | [2], [3] |
| Furnace | Existing condensing stack | 120,000 Btu/hr or greater | 0.90 | $E_t$ | [2], [3] |
| Furnace | Existing non-condensing stack | 120,000 Btu/hr or greater | 0.80 or code | $E_t$ | [2], [3] |
| Furnace | Furnaces | Less than 120,000 Btu/hr | 0.85* | AFUE | [2], [3] |

## ***Calculation Examples***

*Gross Energy Savings, Fossil Fuel:*

$$\Delta BTU_H = 2{,}000 \times 24{,}600 \times \left(\frac{1}{0.80}\right) \times 0.02 = 2{,}130{,}000 Btu$$

*Savings by heating fuel:*

$$\Delta CCF_H = \frac{2{,}130{,}000}{102{,}900} = 20.69 CCF$$

$$\Delta Gal_{Oil} = \frac{2{,}130{,}000}{138{,}690} = 15.35 Gal$$

$$\Delta Gal_{Propane} = \frac{2{,}130{,}000}{91{,}330} = 23.32 Gal$$

*Peak Day Savings, Natural Gas:*

$$\Delta CCF_{PDH} = 20.69 ccf \times 0.00977 = 0.202 ccf$$

## ***Measure Life***

The measure life for a clean, tune, and test is 2 years.

## ***Peak Factors***

**Table 3-59 Peak Factors**

| Measure | Summer Coincidence Factor | Winter Coincidence Factor | Ref |
|---|---|---|---|
| Clean, tune, and test | 0% | 0% | [4] |

## ***Load Shapes***

**Table 3-60 Load Shapes**

| End Use | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % | Ref |
|---|---|---|---|---|---|
| Heating | 47.23% | 52.77% | 0.00% | 0.00% | |

## ***References***


[1] ESF 2% value was used compared to 5% used in the *New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs – Residential, Multifamily, and Commercial/Industrial Measures*, Version 3, Issue Date – Jun. 1, 2015, p. 98.

[2] Cadmus Group (Mar. 2015). *High Efficiency Heating Equipment Impact Evaluation Final Report*. Massachusetts.

[3] Energy & Resource Solutions (Oct. 2019). *R1705 R1609 Multifamily Baseline and Weatherization Opportunity Study*. Connecticut. https://www.energizect.com/sites/default/files/R1705-1609%20MF%20Baseline%20Weatherization%20Study_Final%20Report_10.10.19.pdf.

[4] DNV (2021). *X1931-2 Load Shape and Coincidence Factor Research* – Final Report.


## ***Changes from Last Version***

- Formatting updates.
- Baseline efficiency updates.

## 3.2.8 BOILERS

| | |
|---|---|
| Market | Residential |
| Baseline Type | Retrofit/Lost Opportunity |
| Category | HVAC |

### ***Description***

Installation of an energy efficient boiler.

The fossil fuel savings for this measure are calculated using the equation from West Hill Energy Computing's CT HVAC and Water Heater Process and Impact Evaluation Report [1]. Hot water savings are also estimated. Hot water savings are calculated based on the hot water load used in 3.3.3 Fossil Fuel Water Heaters.

Energy savings resulting from the removal of units in working condition or replacement on failure are calculated as follows:

*Lost Opportunity measure:*

Lost Opportunity savings are calculated using the proposed equipment AFUE to be installed and based on verified savings data from West Hill Energy Computing's CT HVAC and Water Heater Process and Impact Evaluation Report [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, continuing for the Remaining Useful Life (RUL).

### ***Energy Savings Algorithm***

*Annual Gross Energy Savings, Natural Gas*

$$\Delta CCF = \frac{\Delta Btu_H + \Delta Btu_W}{C_{NG}}$$

Where,

$\Delta Btu_H$ = annual heating Btu savings, see below

$\Delta Btu_W$ = annual water heating Btu savings, see below

*Annual Gross Energy Savings, Oil*

$$\Delta Gal_{Oil} = \frac{\Delta Btu_H + \Delta Btu_W}{C_{Oil}}$$

Where,

$\Delta Btu_H$ = annual heating Btu savings, see below

$\Delta Btu_W$ = annual water heating Btu savings, see below

*Annual Gross Energy Savings, Propane*

$$\Delta Gal_{Propane} = \frac{\Delta Btu_H + \Delta Btu_W}{C_{Propane}}$$

Where,

$\Delta Btu_H$ = annual heating Btu savings, see below

$\Delta Btu_W$ = annual water heating Btu savings, see below

*Lost Opportunity Btu Savings, Fossil Fuel*

Savings by heating fuel:

$$\Delta Btu_{\,H} = HF \times \left(\frac{1}{AFUE_B \times AF} - \frac{1}{AFUE_I \times AF}\right)$$

Water heating savings by water heating fuel if boiler also provides DHW:

$$\Delta Btu_{\,W} = ADHW \times \left(\frac{1}{AFUE_B \times AF} - \frac{1}{AFUE_I \times AF}\right)$$

If boiler does not provide DHW:

$$\Delta Btu_{\,W} = 0$$

*Retrofit Btu Savings, Fossil Fuel*

*Retrofit energy savings are calculated as the sum of lost opportunity savings and early retirement savings.*

Savings by heating fuel:

$$\Delta Btu_{\,H} = HF \times \left(\frac{1}{AFUE_E \times AF} - \frac{1}{AFUE_B \times AF}\right) + HF \times \left(\frac{1}{AFUE_B \times AF} - \frac{1}{AFUE_I \times AF}\right)$$

Water heating savings by water heating fuel if boiler also provides DHW:

$$\Delta Btu_W = ADHW \times \left(\frac{1}{AFUE_E \times AF} - \frac{1}{AFUE_B \times AF}\right) + ADHW \times \left(\frac{1}{AFUE_B \times AF} - \frac{1}{AFUE_I \times AF}\right)$$

If boiler does not provide DHW:

$$\Delta Btu_W = 0$$

*Early Retirement Btu Savings, Fossil Fuel*

Savings by heating fuel:

$$\Delta Btu_H = HF \times \left(\frac{1}{AFUE_E \times AF} - \frac{1}{AFUE_B \times AF}\right)$$

Water heating savings by water heating fuel if boiler also provides DHW:

$$\Delta Btu_W = ADHW \times \left(\frac{1}{AFUE_E \times AF} - \frac{1}{AFUE_B \times AF}\right)$$

If boiler does not provide DHW:

$$\Delta Btu_W = 0$$

*Retrofit/Lost Opportunity Gross Seasonal Peak Demand Savings, Natural Gas*

$$\Delta CCF_{PD} = \Delta CCF_{PD,H} + \Delta CCF_{PD,W}$$

Where,

$$\Delta CCF_{PD,H} = \Delta CCF_H \times PDF_H$$

$$\Delta CCF_{PD,W} = \Delta CCF_W \times PDF_W$$

## ***Calculation Parameters***

**Table 3-61 Calculation Parameters**

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| $\Delta Btu_H$ | Annual Btu savings - heating | Calculated | Btu | |
| $\Delta Btu_W$ | Annual Btu savings – water heating | Calculated | Btu | |
| ΔCCF | Annual natural gas savings | Calculated | CCF | |
| $\Delta CCF_H$ | Annual natural gas savings - heating | Calculated | CCF | |

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| $\Delta CCF_W$ | Annual natural gas savings – water heating | Calculated | CCF | |
| $\Delta Gal_{Oil}$ | Annual oil savings | Calculated | Gal | |
| $\Delta Gal_{Oil,H}$ | Annual oil savings – heating | Calculated | Gal | |
| $\Delta Gal_{Oil,W}$ | Annual oil savings – water heating | Calculated | Gal | |
| $\Delta Gal_{Propane}$ | Annual propane savings | Calculated | Gal | |
| $\Delta Gal_{Propane,H}$ | Annual propane savings – heating | Calculated | Gal | |
| $\Delta Gal_{Propane,W}$ | Annual propane savings – water heating | Calculated | Gal | |
| $\Delta CCF_{PD}$ | Natural gas peak day savings | Calculated | CCF | |
| $\Delta CCF_{PD,H}$ | Natural gas peak day savings - heating | Calculated | CCF | |
| $\Delta CCF_{PD,w}$ | Natural gas peak day savings - water heating | Calculated | CCF | |
| $AFUE_I$ | Annual fuel utilization efficiency – installed boiler | Site-specific | N/A | |
| $AFUE_E$ | Annual fuel utilization efficiency – existing boiler | Site-specific, if unknown assume 0.80 | N/A | |
| $AFUE_B$ | Annual fuel utilization efficiency – baseline boiler for midstream program | Table 3-62 AFUE of Baseline Boiler | N/A | [1] |
| $AFUE_B$ | Annual fuel utilization efficiency – baseline boiler for downstream program | Table 3-63 AFUE of Baseline Boiler for Downstream Program | N/A | |
| AF | Adjustment factor (condensing boilers) | 0.941 | N/A | [6] |
| AF | Adjustment factor (non-condensing boilers) | 0.967 | N/A | [6] |
| AF | Adjustment factor (midstream program or unknown) | 0.98 | N/A | [1] |
| HF | Average heating factor based on a home's heat load | 85,200,000 | Btu | [1] |
| ADHW | Annual domestic water heating load | 9,630,521 | Btu | [2] |
| $PDF_H$ | Natural gas peak day factor - heating | 0.00977 | N/A | |
| $PDF_W$ | Natural gas peak day factor – water heating | 0.00321 | N/A | [2] |
| $C_{NG}$ | Natural gas conversion constant | 102,900 | Btu/CCF | |

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| $C_{Oil}$ | Oil conversion constant | 138,690 | Btu/Gal | |
| $C_{Propane}$ | Propane conversion constant | 91,330 | Btu/Gal | |

**Table 3-62 AFUE of Baseline Boiler for Midstream Program**

| Fossil Fuel Type | $AFUE_B$ |
|---|---|
| Natural Gas | 0.85 |
| Oil | 0.84 |
| Propane | 0.85 |

**Table 3-63 AFUE of Baseline Boiler for Downstream Program**

| Fossil Fuel Type | $AFUE_B$ |
|---|---|
| Natural Gas (Non-Condensing) | 0.832 |
| Natural Gas (Condensing) | 0.944 |

## ***Calculation Examples***

*Example 1: Lost Opportunity Gross Energy Savings*

*A non-condensing boiler purchased through downstream channel is installed in a natural gas-heated home. The installed boiler has an $AFUE_I$ = 95% or 0.95.*

$$\Delta Btu_H = HF \times \left(\frac{1}{AFUE_B \times AF} - \frac{1}{AFUE_I \times AF}\right)$$

$$\Delta Btu_H = 85{,}200{,}000\ Btu \times \left(\frac{1}{0.832 \times 0.967} - \frac{1}{0.95 \times 0.967}\right) = 13{,}153{,}708\ Btu$$

$$\Delta CCF_H = \frac{\Delta Btu_H}{C_{NG}}$$

$$\Delta CCF_H = \frac{13{,}153{,}708\ Btu}{102{,}900\,\frac{Btu}{CCF}} = 127.8\ CCF$$

Water heating:

$$\Delta Btu_W = ADHW \times \left(\frac{1}{AFUE_B \times AF} - \frac{1}{AFUE_I \times AF}\right)$$

$$\Delta Btu_W = 9{,}630{,}521\ Btu \times \left(\frac{1}{0.832 \times 0.967} - \frac{1}{0.95 \times 0.967}\right) = 1{,}486{,}820\ Btu$$

$$\Delta CCF_W = \frac{\Delta Btu_W}{C_{NG}}$$

$$\Delta CCF_W = \frac{1{,}486{,}820\ Btu}{102{,}900\ \frac{Btu}{CCF}} = 14.5\ CCF$$

Total:

$$\Delta CCF = \Delta CCF_H + \Delta CCF_W$$

$$\Delta CCF = 127.8\ CCF + 14.5\ CCF = 142.3\ CCF$$

<u>*Example 2: Lost Opportunity Gross Peak Demand Savings*</u>

*For the same example as above:*

$$\Delta CCF_{PD,H} = \Delta CCF_H \times PDF_H$$

$$\Delta CCF_{PD,H} = 127.8\ CCF \times 0.00977 = 1.25\ CCF$$

$$\Delta CCF_{PD,W} = \Delta CCF_W \times PDF_W$$

$$\Delta CCF_{PD,W} = 14.5\ CCF \times 0.00321 = 0.047\ CCF$$

Total:

$$\Delta CCF_{PD} = \Delta CCF_{PD,H} + \Delta CCF_{PD,W}$$

$$\Delta CCF_{PD} = 1.25 CCF + 0.047\ CCF = 1.297\ CCF$$

<u>*Example 3: Retrofit Gross Energy Savings*</u>

*An existing non-condensing 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.*

- $AFUE_E$ = 80% or 0.80 (default value).
- $AFUE_B$ = 83.2% or 0.832 (baseline value).

*Reminder: Retrofit Savings do not depend on the efficiency of the new installed unit.*

$$\Delta Btu_{H} = HF \times \left(\frac{1}{AFUE_E \times AF} - \frac{1}{AFUE_B \times AF}\right)$$

$$\Delta Btu_{H} = 85{,}200{,}000\ Btu \times \left(\frac{1}{0.80 \times 0.967} - \frac{1}{0.832 \times 0.967}\right) = 4{,}235{,}940\ Btu$$

$$\Delta CCF_H = \frac{\Delta Btu_H}{C_{NG}}$$

$$\Delta CCF_H = \frac{4{,}235{,}940\ Btu}{102{,}900 \frac{Btu}{CCF}} = 41.2\ CCF$$

Water heating:

$$\Delta Btu_{W} = ADHW \times \left(\frac{1}{AFUE_E \times AF} - \frac{1}{AFUE_B \times AF}\right)$$

$$\Delta Btu_{W} = 9{,}630{,}521\ Btu \times \left(\frac{1}{0.80 \times 0.967} - \frac{1}{0.832 \times 0.967}\right) = 478{,}806\ Btu$$

$$\Delta CCF_W = \frac{\Delta Btu_W}{C_{NG}}$$

$$\Delta CCF_W = \frac{478{,}806\ Btu}{102{,}900\ \frac{Btu}{CCF}} = 4.65 CCF$$

Total:

$$\Delta CCF = \Delta CCF_H + \Delta CCF_W$$

$$\Delta CCF = 41.2\ CCF + 4.65\ CCF = 45.85\ CCF$$

*Example 4: Retrofit Gross Peak Demand Savings*

*For same example as above:*

$$\Delta CCF_{PD,H} = \Delta CCF_H \times \Delta PDF_H$$

$$\Delta CCF_{PD,H} = 41.2\ CCF \times 0.00977 = 0.403\ CCF$$

$$\Delta CCF_{PD,W} = \Delta CCF_W \times \Delta PDF_W$$

$$\Delta CCF_{PD,W} = 4.65\ CCF \times 0.00321 = 0.015\ CCF$$

$$\Delta CCF_{PD} = \Delta CCF_{PD,H} + \Delta CCF_{PD,W}$$

$$\Delta CCF_{PD} = 0.403\ CCF + 0.015\ CCF = 0.418\ CCF$$

## *Measure Life*

**Table 3-64 Measure Life**

| Equipment Type | Measure Life | Ref |
|---|---|---|
| Boiler (gas) – Lost Opportunity | 20 years | [3] |
| Boiler (gas) - Retrofit | 7 years | [3] |

## *Peak Factors*

**Table 3-65 Peak Factors**

| Measure | Summer Coincidence Factor | Winter Coincidence Factor | Ref |
|---|---|---|---|
| Boilers | 0% | 0% | [4] |

## *Realization Rates*

**Table 3-66 Realization Rates**

| | Gross Realization % | | | FR and SO | | Net Realization % | | |
|---|---|---|---|---|---|---|---|---|
| Measure | CCF | Peak Day CCF | Delivered Fuels MMBtu | Free-ridership | Spill-over | CCF | Peak Day CCF | Delivered Fuels MMBtu |
| MF boilers [5] | 80% | N/A | N/A | N/A | N/A | 80% | N/A | N/A |
| Gas boiler, below 94% AFUE | 100.0% | 100.0% | 100.0% | 48.0% | 4.0% | 56.0% | 56.0% | 56.0% |
| Gas boiler, 94% AFUE and above | 100.0% | 100.0% | 100.0% | 16.0% | 0.0% | 84.0% | 84.0% | 84.0% |

## *References*


[1] *CT HVAC and Water Heater Process and Impact Evaluation Report*, West Hill Energy and Computing, R1614/R1613, Jul. 19, 2018.

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

[3] California Public Utilities Commission, *2014 Database for Energy-Efficient Resources,* Feb. 4, 2014, available online at: http://www.deeresources.com/files/DEER2013codeUpdate/download/DEER2014-EUL-table-update_2014-02-05.xlsx, last accessed Sep. 3, 2020.

[4] “DNV (2021). X1931-2 Load Shape and Coincidence Factor Research – Final Report”.

[5] TRC . (2021). CT EEB X1941 Multifamily Impact Evaluation, Jul. 22, 2021 (Table 6).

[6] Cadmus. 2015. “High Efficiency Heating Equipment Impact Evaluation.” available at: https://ma-eeac.org/wp-content/uploads/High efficiency-Heating-Equipment-Impact-Evaluation-Final-Report.pdf.

## ***Changes from Last Version***

- Updated adjustment factors and baseline efficiencies for condensing and non-condensing boilers per MA EACC.
- Formatting updates.

## 3.2.9 FURNACES

| | |
|---|---|
| Market | Residential |
| Baseline Type | Retrofit/Lost Opportunity |
| Category | HVAC |

### ***Description***

Installation of a warm air or forced-air energy efficient furnace.

The fossil fuel savings for this measure are calculated using the results from the Furnace Results Memorandum [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) below.

*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); 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) below.

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 retrofit savings, see *Measure 3.2.13.*

### ***Energy Savings Algorithm***

*Savings by heating fuel*

$$\Delta CCF_H = \frac{\Delta Btu_H}{C_{NG}}$$

Where,

$\Delta Btu_H$ = annual heating Btu savings, see below

$$\Delta Gal_{Oil,H} = \frac{\Delta Btu_H}{C_{Oil}}$$

Where,

$\Delta Btu_H$ = annual heating Btu savings, see below

$$\Delta Gal_{Propane,H} = \frac{\Delta Btu_H}{C_{Propane}}$$

Where,

$\Delta Btu_H$ = annual heating Btu savings, see below

*Lost Opportunity Gross Energy Savings, Fossil Fuel*

$$\Delta Btu_H = HF \times \left(\frac{1}{AFUE_B \times AF} - \frac{1}{AFUE_I \times AF}\right)$$

Where,

HF (single-family) = 77,500,000 Btu

HF (multi-family) = $EFLH_M \times CAP_M$

*Retrofit Gross Energy Savings, Fossil Fuel*

*Retrofit energy savings are calculated as the sum of lost opportunity savings and early retirement savings.*

$$\Delta Btu_H = HF \times \left(\frac{1}{AFUE_E \times AF} - \frac{1}{AFUE_B \times AF}\right) + HF \times \left(\frac{1}{AFUE_B \times AF} - \frac{1}{AFUE_I \times AF}\right)$$

Where,

HF (single-family) = 77,500,000 Btu

HF (multi-family) = $EFLH_M \times CAP_M$

*Retirement Gross Energy Savings, Fossil Fuel*

$$\Delta Btu_H = HF \times \left(\frac{1}{AFUE_E \times AF} - \frac{1}{AFUE_B \times AF}\right)$$

Where,

HF (single-family) = 77,500,000 Btu

HF (multi-family) = $EFLH_M \times CAP_M$

*Retrofit/Lost Opportunity Gross Peak Day Savings, Natural Gas*

$$\Delta CCF_{PD,H} = \Delta CCF_H \times PDF_H$$

## *Calculation Parameters*

**Table 3-67 Calculation Parameters**

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| $\Delta Btu_H$ | Annual Btu savings - heating | Calculated | Btu | |
| $\Delta CCF_H$ | Annual natural gas savings - heating | Calculated | CCF | |
| $\Delta Gal_{Oil,H}$ | Annual oil savings - heating | Calculated | Gallons | |
| $\Delta Gal_{Propane,H}$ | Annual propane savings - heating | Calculated | Gallons | |
| $\Delta CCF_{PD,H}$ | Natural gas peak day savings - heating | Calculated | CCF | |
| $AFUE_I$ | Annual fuel utilization efficiency - installed furnace | Site-specific | N/A | |
| $AFUE_E$ | Annual fuel utilization efficiency - existing furnace | Site-specific (0.78 if unknown) | N/A | [2] |
| $AFUE_B$ | Annual fuel utilization efficiency – baseline furnace for midstream program | Table 3-68 | N/A | [1] |
| $AFUE_B$ | Annual fuel utilization efficiency – baseline furnace for upstream program | Table 3-69 AFUE of Baseline Furnace for Downstream Program | N/A | [6] |
| $PDF_H$ | Natural gas peak day factor - heating | 0.00977 | N/A | |
| HF | Average heating factor based on home's heat load | 77,500,000 | Btu | [1] |
| $EFLH_M$ | Equivalent full load heating hours for multifamily homes | 995 | hr | [1] |
| $CAP_M$ | Multifamily input heating capacity | 41,098 | Btu/hr | [3] |
| $C_{NG}$ | Natural gas conversion constant | 102,900 | Btu/CCF | |
| $C_{Oil}$ | Oil conversion constant | 138,690 | Btu/Gal | |
| $C_{Propane}$ | Propane conversion constant | 91,330 | Btu/Gal | |

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| AF | Adjustment factor (condensing furnace) | 1.002 | N/A | [6] |
| AF | Adjustment factor (non-condensing furnace) | 1.012 | N/A | [6] |
| AF | Adjustment factor (midstream program or unknown) | 1 | N/A | [6] |

**Table 3-68 AFUE of Baseline Furnace for Midstream program**

| Fossil Fuel Type | $AFUE_B$ |
|---|---|
| Natural Gas | 0.85 |
| Oil | 0.83 |
| Propane | 0.85 |

**Table 3-69 AFUE of Baseline Furnace for Downstream Program**

| Fossil Fuel Type (MA baseline) [6] | $AFUE_B$ |
|---|---|
| Natural Gas (Non-Condensing) baseline | 0.80 |
| Natural Gas (Condensing) baseline | 0.932 |

## ***Calculation Examples***

*Lost Opportunity Gross Energy Savings Example*

*A new natural gas furnace sold through midstream channel with an AFUE of 96% is installed. What are the annual fossil fuel savings? Constant values include:*

- $AFUE_I$ = 96% or 0.96.
- $AFUE_B$ = 85% or 0.85 (baseline value).

$$\Delta Btu_H = HF \times \left(\frac{1}{AFUE_B \times AF} - \frac{1}{AFUE_I \times AF}\right)$$

$$\Delta Btu_H = 77{,}500{,}000\ Btu \times \left(\frac{1}{0.85 \times 1} - \frac{1}{0.96 \times 1}\right) = 10{,}447{,}305\ Btu$$

$$\Delta CCF_H = \frac{\Delta Btu_H}{C_{NG}}$$

$$\Delta CCF_H = \frac{10{,}447{,}305\ Btu}{102{,}900\ \frac{Btu}{CCF}} = 101.5\ CCF$$

*Lost Opportunity Gross Peak Demand Savings Example*

*A new natural gas furnace sold through midstream channel with an AFUE of 96% is installed. What are the peak day natural gas savings?*

$$\Delta CCF_{PD,H} = \Delta CCF_H \times PDF_H$$

$$\Delta CCF_{PD,H} = 101.5\ CCF \times 0.00977 = \ 0.992\ CCF$$

*Retrofit Gross Energy Savings 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).
- $AFUE_B$ = 85% or 0.85 (baseline value).

$$\Delta Btu_{\ H} = HF \times \left(\frac{1}{AFUE_E \times AF} - \frac{1}{AFUE_B \times AF}\right)$$

$$\Delta Btu_{\ H} = 77{,}500{,}000\ Btu \times \left(\frac{1}{0.78 \times 1} - \frac{1}{0.85 \times 1}\right) = 8{,}182{,}504\ Btu$$

$$\Delta CCF_H = \frac{\Delta Btu_H}{C_{NG}}$$

$$\Delta CCF_H = \frac{8{,}182{,}504\ Btu}{102{,}900\ \frac{Btu}{CCF}} = 79.5\ CCF$$

*Example 4: Retrofit Gross Peak Demand Savings*

*An existing natural gas furnace was installed in 1985. What are the retirement peak day natural gas savings?*

$$\Delta CCF_{PD,H} = \Delta CCF_H \times PDF_H$$

$$\Delta CCF_{PD,H} = 79.5\ CCF \times 0.00977 = \ 0.78\ CCF$$

## ***Measure Life***

**Table 3-70 Measure Life**

| Equipment Type | Measure Life | Ref |
|---|---|---|
| Furnace – Lost Opportunity | 20 years | [4] |

| Equipment Type | Measure Life | Ref |
|---|---|---|
| Furnace - Retrofit | 7 years | [4] |

## *Peak Factors*

**Table 3-71 Peak Factors**

| Measure | Summer Coincidence Factor | Winter Coincidence Factor | Ref |
|---|---|---|---|
| Furnaces | 0% | 0% | [5] |

## *Load Shapes*

**Table 3-72 Load Shapes**

| End Use | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % | Ref |
|---|---|---|---|---|---|
| Heating | 47.23% | 52.77% | 0% | 0% | [5] |

## *Realization Rates*

**Table 3-73 Realization Rates**

| | Gross Realization % | | | FR and SO | | Net Realization % | | |
|---|---|---|---|---|---|---|---|---|
| Measure | CCF | Peak Day CCF | Delivered Fuels MMBtu | Free-ridership | Spill-over | CCF | Peak Day CCF | Delivered Fuels MMBtu |
| Gas furnace | 100.0% | 100.0% | 100.0% | 42.0% | 4.0% | 62.0% | 62.0% | 62.0% |

## *References*


[1] *CT HVAC and Water Heater Process and Impact Evaluation Report*, West Hill Energy and Computing, R1614/R1613, Jul. 19, 2018.

[2] Cadmus Group, "*High Efficiency Heating Equipment Impact Evaluation Final Report*," Mar. 2015, MA.

[3] R1705-R1609, Multifamily Baseline and Weatherization Opportunity Study, Oct. 10, 2019.

[4] California Public Utilities Commission, *2014 Database for Energy-Efficient Resources,* Feb. 4, 2014, available online at: http://www.deeresources.com/files/DEER2013codeUpdate/download/DEER2014-EUL-table-update_2014-02-05.xlsx, last accessed Sep. 3, 2020.

[5] "DNV (2021). X1931-2 Load Shape and Coincidence Factor Research – Final Report"

[6] MA boilers and furnace baseline.


## *Changes from Last Version*

- Updated adjustment factor values.

- Added AFUE of baseline furnace for downstream program.
- Formatting updates.

## 3.2.10 DUCT INSULATION

| | |
|---|---|
| Market | Residential |
| Baseline Type | Retrofit |
| Category | HVAC |

### ***Description***

Installation of insulation with an R-value greater than or equal to 6; on un-insulated heating or cooling ducts in unconditioned spaces (i.e., attic or unconditioned basement) in order to reduce heating and cooling losses.

Heating and cooling savings per square foot of insulated duct were modeled using "3E Plus Insulation" software under four different scenarios of duct location (i.e., supply basement, return basement, supply attic, and return attic), under typical conditions listed in Table 3-74 [1]. Cooling savings should be reported for homes equipped with Central A/C using the same duct being insulated.

**Table 3-74 Assumed Temperature and Operating Conditions**

| Duct Location | Season | Annual Hours | Ambient Temp (°F) | Supply Air Temp (°F) | Return Air Temp (°F) |
|---|---|---|---|---|---|
| Attic | Heating | 1,307 | 30 | 130 | 65 |
| | Cooling | 272 | 120 | 50 | 80 |
| Basement | Heating | 1,307 | 50 | 130 | 65 |
| | Cooling | 272 | 70 | 50 | 80 |

**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 Table 3-74, R-value about 6). In such a situation, the 3E Plus Insulation tool [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.

**Reminders:**

- Heating savings may not be claimed if ducts are not used for heating distribution; for instance, a home with electric baseboard resistance heating or a fossil fuel boiler which has ducts used only for the Central A/C.
- When installing duct insulation with other envelope measures and/or duct sealing measures, reduce annual heating and cooling savings by 16% [3].

### ***Energy Savings Algorithm***

*Retrofit Gross Energy Savings, Electric*

Heating savings, electric heat pumps:

$$\Delta kWh_H = DI_H \times$$

If Central A/C or a heat pump providing cooling:

$$\Delta kWh_C = DI_C \times A$$

*Retrofit Gross Energy Savings, Fossil Fuel*

For homes with a natural gas furnace:

$$\Delta CCF_H = \frac{DI_H \times A}{0.10290}$$

For homes with an oil furnace:

$$\Delta Gal_{Oil} = \frac{DI_H \times A}{0.13869}$$

For homes with a propane furnace:

$$\Delta Gal_{Propane} = \frac{DI_H \times A}{0.09133}$$

*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:

$$\Delta kW_{Winter} = \frac{CF_W \times DI_H \times A}{1000}$$

Summer seasonal peak demand (kW) will be claimed for homes equipped with Central A/C:

$$\Delta kW_{Summer} = \frac{CF_S \times DI_C \times A}{1000}$$

*Retrofit Gross Peak Day Savings, Natural Gas*

For homes with a natural gas furnace:

$$\Delta CCF_{PD} = \Delta CCF \times PDF$$

## *Calculation Parameters*

**Table 3-75 Calculation Parameters**

| Symbol | Description | Values | Units | Ref |
|---|---|---|---|---|
| ΔkWh | Annual electric energy savings | Calculated | kWh | |
| ΔCCF | Annual natural gas savings | Calculated | ccf | |

| | | | | |
|---|---|---|---|---|
| $\Delta Gal_{Oil}$ | Annual oil savings | Calculated | Gal | |
| $\Delta Gal_{Propane}$ | Annual propane savings | Calculated | Gal | |
| $\Delta kW_{Winter}$ | Summer demand savings | Calculated | kW | |
| $\Delta kW_{Summer}$ | Winter demand savings | Calculated | kW | |
| $\Delta CCF_{PD}$ | Natural gas peak day savings - heating | Calculated | CCF | |
| A | Surface area of duct being insulated | Site-specific | $ft^2$ | |
| $DI_H$ | Annual heating savings per square foot | Lookup in Table 3-76 and Table 3-77 | For electric savings: $kWh/ft^2$<br>For fossil fuel Savings: $MMBtu/ft^2$ | [2] |
| $DI_C$ | Annual cooling savings per square foot | Lookup in Table 3-76 and Table 3-77 | For electric savings: $kWh/ft^2$<br>For fossil fuel Savings: $MMBtu/ft^2$ | [2] |
| $PDF_H$ | Natural gas peak day factor - heating | 0.00977 | | |
| $PF_S$ | Summer peak factor | 0.017 | W/kWh | [1] |
| $PF_W$ | Winter peak factor | 0.570 | W/kWh | [1] |

**Table 3-76.Annual Savings per ft² for Homes with Heat Pump or Central A/C**

| Duct Location | Heating | | Cooling | |
|---|---|---|---|---|
| | $DI_H$ | Unit | $DI_C$ | Unit |
| Supply basement | 13.05 | $kWh/ ft^2$ | 0.7721 | $kWh/ ft^2$ |
| Return basement | 3.150 | $kWh/ ft^2$ | 0.2327 | $kWh/ ft^2$ |
| Supply attic | 14.46 | $kWh/ ft^2$ | 1.425 | $kWh/ ft^2$ |
| Return attic | 4.194 | $kWh/ ft^2$ | 0.8209 | $kWh/ ft^2$ |

**Table 3-77. Annual Savings per ft² for Homes with Fossil Fuel**

| Duct Location | Heating Savings per $ft^2$ | |
|---|---|---|
| | $DI_H$ | Unit |
| Supply basement | 0.1187 | $MMBtu/ft^2$ |
| Return basement | 0.02866 | $MMBtu/ft^2$ |
| Supply attic | 0.1316 | $MMBtu/ft^2$ |
| Return attic | 0.03816 | $MMBtu/ft^2$ |

## ***Calculation Examples***

*Retrofit Gross Energy Savings*

*Example: A Cape Cod style home has a natural gas furnace. It is also equipped with a Central A/C system for cooling. Approximately 50 ft² of insulation was installed on the supply duct in the unconditioned basement. What are the annual energy savings?*

$$\Delta CCF_H = \frac{DI_H \times A}{0.10290}$$

$$\Delta CCF_H = \frac{0.1187 \times 50\, ft^2}{0.10290} = 57.68\, CC$$

Since the house is equipped with Central A/C, there are cooling savings too:

$$\Delta kWh_C = DI_C \times A$$

$$\Delta kWh_C = 0.7721 \times 50\, ft^2 = 38.61\, kWh$$

*Retrofit Gross Peak Demand Savings*

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

Using the formula for peak day natural gas:

$$PD_H = \Delta ACF_H \times PDF_H$$

$$\mathrm{PD_H} = 57.68 \times 0.00977 = 0.564\ \mathrm{CCF}$$

Cooling demand savings may also be claimed:

$$\Delta kW = \frac{PF_S \times DI_C \times A}{1{,}000\, \frac{w}{kw}}$$

$$\Delta kW = \frac{0.017 \times 0.7721 \times 50\, ft^2}{1{,}000\, \frac{w}{kw}} = 0.000656\, kW$$

## ***Measure Life***

The measure life for duct insulation is 20 years.

## ***Peak Factors***

**Table 3-78 Peak Factors**

| Measure | Summer Coincidence Factor | Winter Coincidence Factor | Ref |
|---|---|---|---|
| Duct insulation | 153% | 46% | [4] |

## *Load Shapes*

**Table 3-79 Load Shapes**

| Measure | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % | Ref |
|---|---|---|---|---|---|
| Cooling - Central AC | 4.83% | 4.33% | 54.40% | 36.45% | [4] |

## *Realization Rates*

**Table 3-80 Realization Rates**

| | Gross Realization % | | | | FR & SO | | Net Realization % | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 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 |
| Other Measures | 100.0% | 100.0% | 100.0% | 100.0% | 0.0% | 0.0% | 100.0% | 100.0% | 100.0% | 100.0% |

## *References*


[1] Evaluation of the Weatherization Residential Assistance Partnership (WRAP) and Helps Programs, conducted by KEMA, Sep. 2010, pp. 1-11, see Table ES-9.

[2] North American Insulation Manufacturers Association ("NAIMA"), 3E Plus software tool, Version 4.1, Rel. 2012.

[3] *Methodology for Estimated Energy Savings from Cost-Effective Air Sealing and Insulating, United States Environmental Protection Agency,* , https://www.energystar.gov/campaign/seal_insulate/methodology, *last accessed Jun. 1, 2021.*

[4] DNV. 2021. "Load Shape and Coincidence Factor Research."


## *Changes from Last Version*

- Formatting changes.

## 3.2.11 DUCT SEALING

| | |
|---|---|
| Market | Residential |
| Baseline Type | Retrofit |
| Category | HVAC |

### ***Description***

Duct sealing to improve efficiency of air distribution from HVAC systems. Savings are verified by measuring outside duct leakage at 25 Pascal (Pa) using standard duct blaster testing procedures and blower door; other advanced sealing techniques can be used. It is recommended to use mastic rather than foil tape to seal the leaky duct.

Duct improvements (sealing) should be verified with duct blaster test at 25 Pa using an approved test method. Notice that a blower door is required as part of this test to maintain 25 Pa in the house in order to isolate duct leakage to the outside. Alternative test methods (i.e., subtraction method, flow hood method, delta Q, etc.) will generally yield inconsistent results and therefore are not permitted. Duct infiltration reduction was simulated using home energy rating software (HERS) [1]. For all duct sealing, savings may be subject to a final analysis which may include a billing analysis, calibration, engineering models, or other applicable methods.

**Reminder:** Heating savings may not be claimed if ducts are not used for heating distribution. For instance, a home with electric baseboard resistance heating or a fossil fuel boiler which has ducts used only for the Central A/C may only claim cooling savings. Demand Savings are based on design load calculation in HERS software; there is no need to use coincidence factors.

**Notes:**

- Fan energy savings are only to be captured for forced-air systems with a furnace or air handling unit (fan).
- Fossil fuel savings include estimated expected system efficiency of 75% including combustion and distribution.

### ***Energy Savings Algorithm***

*Annual Retrofit Gross Energy Savings, Electric*

$$\Delta kWh = \Delta kWh_H + \Delta kWh_C$$

Heating savings for electric (forced air), heat pump, or geothermal heating systems:

$$\Delta \mathrm{kWh_H} = HERS_{Heating} \times (CFM_{Pre} - CFM_{Post})$$

Heating savings for fossil fuel heating with air handler unit:

$$\Delta kWh_H = HERS_{AH} \times (CFM_{Pre} - CFM_{Post})$$

Cooling savings for home with Central A/C:

$$\Delta kWh_C = HERS_{Cooling} \times (CFM_{Pre} \times CFM_{Post})$$

Cooling savings for home with no Central A/C:

$$\Delta kWh = 0$$

*Annual Retrofit Gross Energy Savings, Fossil Fuel*

For homes with natural gas heating system:

$$\Delta CCF_H = HERS_{NG} \times (CFM_{Pre} - CFM_{Post})$$

For homes with oil heating system:

$$\Delta Gal_{OilH} = HERS_{Oil} \times (CFM_{Pre} - CFM_{Post})$$

For homes with propane heating system:

$$\Delta Gal_{PropaneH} = HERS_{Propane} \times (CFM_{Pre} - CFM_{Post})$$

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

$$\Delta kW_{Winter} = HERS_{\Delta kWHeating} \times (CFM_{Pre} - CFM_{Post})$$

$$\Delta kW_{Summer} = HERS_{\Delta kWSummer} \times (CFM_{Pre} - CFM_{Post})$$

*Retrofit Gross Seasonal Peak Demand Savings, Natural Gas*

$$\Delta kWh_{PDH} = \Delta CCF_H \times PDF_H$$

## Calculation Parameters

**Table 3-81 Calculation Parameters**

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| ΔCCF | Annual natural gas savings | Calculated | CCF/yr | |
| $\Delta kWh_H$ | Annual electric energy savings, heating | Calculated | kWh/yr | |
| $\Delta kWh_C$ | Annual electric energy savings, cooling | Calculated | kWh/yr | |
| $\Delta Gal_{Oil}$ | Annual oil savings | Calculated | Gal/yr | |
| $\Delta kW_{Summer}$ | Summer demand savings | Calculated | kW | |

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| $\Delta kW_{Winter}$ | Winter demand savings | Calculated | kW | |
| $\Delta kWh_{PDH}$ | Natural gas peak day savings - heating | Calculated | CCF | |
| $\Delta Gal_{Propane}$ | Annual propane savings | Calculated | Gal/yr | |
| $CFM_{Pre}$ | Air leakage rate before duct sealing at 25 Pa | Site-specific; if unknown, estimate using the area served by relevant HVAC systems: $CFM_{Pre} = 0.195 \frac{CFM}{ft^2} \times Area$ | CFM | |
| $CFM_{Post}$ | Air leakage rate after duct sealing at 25 Pa | Site-specific; if unknown, estimate using the area served by relevant HVAC systems: $CFM_{Post} = 0.04 \frac{CFM}{ft^2} \times Area$ | CFM | |
| $PDF_H$ | Natural gas peak day factor - heating | 0.00977 | | [3] |
| HERS | Home Energy Rating Software | Lookup in Table 3-82 for electric systems, Table 3-83 for fossil fuel systems | per CFM | [1] |

**Table 3-82 Electric Duct Sealing Savings, kWh per CFM Reduction at 25 Pa**

| | $HERS_{Heating}$ for Heating | | | $HERS_{AH}$ | $HERS_{Cooling}$ |
|---|---|---|---|---|---|
| | Electric Forced Air | Heat Pumps | Geothermal | Heating Fan | Central A/C Cooling |
| Savings per CFM reduction | 13.494 | 5.971 | 4.089 | 0.883 | 1.780 |

**Table 3-83 Fossil Fuel Duct Sealing Savings per CFM Reduction at 25 Pa**

| | Heating (MMBtu) | Gallons Oil – Gallons ($HERS_{Oil}$) | Natural Gas – Ccf ($HERS_{NG}$) | Gallons Propane – Gallons ($HERS_{Propane}$) |
|---|---|---|---|---|
| Savings per CFM reduction | 0.058 | 0.415 | 0.559 | 0.630 |

## ***Calculation Examples***

*Retrofit Gross Energy Savings:* Duct sealing at 25 Pa was performed in a 2,400 ft$^2$ 1960's ranch style home in Hartford, Conn. The home is primarily heated by a natural gas furnace and cooled by Central A/C. The outside duct leakage readings at 25 Pa showed $CFM_{Pre}$ of 850 and $CFM_{Post}$ of 775. What are the energy savings for this home? **Note:** This home has fossil fuel, air handler (fan), and cooling savings.

*<u>Using the equation for natural gas heating savings</u>:*

$$\Delta CCF_H = 0.559 \times (850 - 775)$$

$$\Delta CCF_H = 41.925Ccf$$

*<u>Using the equation for electric heating fan savings</u>:*

$$\Delta kWH_H = 0.883 \times (850 - 775)$$

$$\Delta kWH_H = 66.225kWh$$

*<u>Using the equation for Central A/C savings</u>:*

$$\Delta kWh_H = 1.780 \times (850 \times 775)$$

$$\Delta kWh_H = 133.5kWh$$

*<u>Retrofit Gross Peak Demand Savings</u>:* 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 Central A/C. The outside duct leakage readings at 25 Pa showed $CFM_{Pre}$ of 850 and $CFM_{Post}$ of 775. What are the peak demand savings for this home?

*<u>Using the equation for heat pump winter demand (HERS $\Delta kW_{Winter}$ = 0.0158 kW per CFM)</u>:*

$$\Delta kW_{WinterH} = 0.0132 \times (850 - 775)$$

$$\Delta kW_{WinterH} = 0.99kW$$

*<u>Using the equation for summer demand savings (HERS $\Delta kW_{Summer}$ = 0.0015 kW per CFM)</u>:*

$$\Delta kW_{SummerC} = 0.0015 \times (850 - 775)$$

$$\Delta kW_{SummerC} = 0.1125kW$$

*If the home in this example has a natural gas furnace, instead of a heat pump, what are the natural gas peak day savings?*

*<u>Using the formula for Peak Day Natural Gas</u>:*

$$\Delta kWh_{PDH} = 41.925 \times 0.00977\ Ccf$$

$$PD_H = 0.409\ Ccf$$

## ***<u>Measure Life</u>***

The measure life for duct sealing is 20 years.

## *Peak Factors*

**Table 3-84 Peak Factors**

| Measure | Summer Coincidence Factor | Winter Coincidence Factor | Ref |
|---|---|---|---|
| Duct sealing | 100% | 100% | [3] |

## *Load Shapes*

**Table 3-85 Load Shapes**

| Measure Type | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % | Ref |
|---|---|---|---|---|---|
| Cooling - Central AC | 4.83% | 4.33% | 54.40% | 36.45% | [3] |
| Heating | 47.23% | 52.77% | 0.00% | 0.00% | [3] |

## *Realization Rates and Net Impact Factors*

**Table 3-86 Realization Rates and Net Impact Factors**

| | Gross Realization % | | | | | FR & SO | | Net Realization % | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Measure | kWh or CCF | Winter Seasonal Peak kW or Peak Day CCF | Summer Seasonal Peak kW | Delivered Fuels MMBtu | Installation rate | Free-ridership | Spill-over | kWh or CCF | Winter Seasonal Peak kW or Peak Day CCF | Summer Seasonal Peak kW | Delivered Fuels MMBtu |
| Duct sealing, electric & gas (HES-IE) [4] | 92.5% | 92.5% | 92.5% | 92.5% | 100% | 0.0% | 0.0% | 92.5% | 92.5% | 92.5% | 92.5% |
| Duct sealing, electric & gas (HES) [4] | 92.5% | 92.5% | 92.5% | 92.5% | 100% | 14.0% | 7.0% | 86% | 86% | 86% | 86% |
| MF duct sealing [4] | 92.5% | 92.5% | 92.5% | 92.5% | 100% | 0.0% | 0.0% | 92.5% | 92.5% | 92.5% | 92.5% |

## *References*


[1] MaGrann Associates. Aug. 3, 2021. “Analysis of Energy Savings for Building Envelope Infiltration Reductions and Duct Leakage to Outside Reductions.”

[2] ADM Associates, Inc. Nov. 2009. “Residential Central A/C Regional Evaluation.”

[3] DNV. 2021. “X1931-2 Load Shape and Coincidence Factor Research.”

[4] NMR and Cadmus. 2014. “Impact Evaluation: Home Energy Services—Income-Eligible and Home Energy Services Programs: Volume 2 (R16).”

[5] NMR. R1983 NTG Review Final Memo dated Sep. 12, 2022.

## ***Changes from Last Version***

- Formatting updates.
- Updated installation rate, free ridership and spillover values for HES.

## 3.2.12 BOILER RESET CONTROLS

| | |
|---|---|
| Market | Residential |
| Baseline Type | Retrofit |
| Category | HVAC |

### ***Description***

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 is based on the Home Energy Services Impact Evaluation by Navigant for the Electric and Natural Gas Program Administrators of Massachusetts [1].

Since energy savings correlate directly to outside air temperatures, the demand savings for residential space heating measures is estimated based on as a percentage (0.977%) of annual savings. The 0.977% factor is based on Bradley Airport peak degree day 30-year average (58.5°F) divided by the 30-year average HDDs (Values varies per Utility).

### ***Energy Savings Algorithm***

*Retrofit Gross Annual Savings, Natural Gas*

$$\Delta CCF = 51 \times n$$

*Retrofit Gross Peak Day Savings, Natural Gas*

$$\Delta CCF_{PD} = 0.498 \times n$$

### ***Calculation Parameters***

**Table 3-87 Calculation Parameters**

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| ΔCCF | Annual natural gas savings - heating | 51 | CCF/yr | [1] |
| $PDF_H$ | Natural gas peak day factor | 0.00977 | Per boiler control | |
| $\Delta CCF_{PD}$ | Natural gas peak day savings - heating | 0.498 | CCF/yr | [1] |

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| n | Number of gas-fired boilers | Site-specific | N/A | N/A |

## *Measure Life*

The measure life for Boiler Reset Controls is 15 years [2].

## *Peak Factors*

**Table 3-88 Peak Factors**

| Measure | Natural Gas Peak Day Factor | Ref |
|---|---|---|
| Boiler Reset Controls | 0.00977 | |

## *Load Shapes*

Electric load shapes N/A for this fuel saving measure.

## *Realization Rates*

**Table 3-89 Realization Rates**

| | Gross Realization % | | | | FR and SO | | Net Realization % | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Measure | kWh or CCF | Winter Seasonal Peak Day CCF | Summer Seasonal Peak kW | Delivered Fuels MMBtu | Free-ridership | Spill-over | kWh or CCF | Winter Seasonal Peak Day CCF | Summer Seasonal Peak kW | Delivered Fuels MMBtu |
| Other measures | 100.0% | 100.0% | 100.0% | 100.0% | 0.0% | 0.0% | 100.0% | 100.0% | 100.0% | 100.0% |

## *References*


[1] Navigant. 2018. “Home Energy Services Impact Evaluation (Res 34). The Electric and Natural Gas Program Administrators of Massachusetts.

[2] American Council for an Energy-Efficient Economy, *Emerging Technologies Report*, May 2006, p. 2.


## *Changes from Last Version*

- Formatting updates.
- Update natural gas savings value.

## 3.2.13 ELECTRONICALLY COMMUTATED MOTOR HVAC FAN

| | |
|---|---|
| Market | Residential |
| Baseline Type | Retrofit |
| Category | HVAC |

***Description***

Installation of an electronically commutated motor (ECM) or brushless permanent magnet motor (BPM) when installed as part of a new high efficiency HVAC system or as a new ECM replacement on an existing HVAC system. This measure is only applicable to retrofit of existing fans.

Savings for this measure are calculated based on a typical home. These deemed savings are based on results from a 2014 Evaluation of Retrofit Variable-Speed Furnace Fan Motors published by the US Department of Energy [1]. Demand savings were derived from interval data adjusted to historical ISO-NE seasonal peak hours and Normalized NOAA weather. The average kW savings from Table 6 and Table 8 of *Evaluation of Retrofit Variable-Speed Furnace Fan Motors* were converted to Watts and multiplied with the Coincidence Factors in Table 3-91 [1].

***Energy Savings Algorithm***

*Annual Retrofit Net Energy Savings, Electric*

$$\Delta kWh = N \times (\Delta kWh_H + \Delta kWh_C)$$

Where,

$$\Delta kWh_H = 84\ kWh$$

$$\Delta kWh_C = 78\ kWh$$

*Annual Retrofit Net Demand Savings, Electric*

$$\Delta kW_{Winter} = 0.126kW$$

$$\Delta kW_{Summer} = 0.220kW$$

***Calculation Parameters***

**Table 3-90 Calculation Parameters**

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| ΔkWh | Annual electric energy savings | Calculated | kWh/yr | [1] |

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| $\Delta kWh_c$ | Annual electric energy savings during heating season | 84 | kWh/yr | [1] |
| $\Delta kWh_c$ | Annual electric energy savings during cooling season | 78 | kWh/yr | [1] |
| $\Delta kW_{summer}$ | Summer demand savings | 0.220 | kW | [1] |
| $\Delta kW_{winter}$ | Winter demand savings | 0.126 | kW | [1] |
| N | Number of systems with ECMs installed | Site-specific | N/A | [1] |

***Measure Life***

The measure life for an electronically commutated motor HVAC fan is 7 years.

Measure life limited to remaining life of host equipment in retrofit applications. The measure life for EC motor HVAC fans is calculated as 1/3 of the EUL for residential furnaces[3].

***Peak Factors***

**Table 3-91 Coincidence Factors**

| Measure | Summer Coincidence Factor | Winter Coincidence Factor | Ref |
|---|---|---|---|
| Electronically commutated motor HVAC fan | 7% | 12% | [2] |

***Load Shapes***

**Table 3-92 Load Shapes**

| Measure Type | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % | Ref |
|---|---|---|---|---|---|
| Cooling - Central AC | 4.83% | 4.33% | 54.40% | 36.45% | [2] |
| Cooling - Room AC | 1.75% | 2.10% | 51.81% | 44.34% | [2] |
| Heating | 47.23% | 52.77% | 0.00% | 0.00% | [2] |

***Realization Rates and Net Impact Factors***

**Table 3-93 Realization Rates and Net Impact Factors**

| | Gross Realization % | | | | FR & SO | | Net Realization % | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 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 |
| ECM furnace fans [4] | 100.0% | 100.0% | 100.0% | 100.0% | 42.0% | 4.0% | 62.0% | 62.0% | 62.0% | 62.0% |

***References***


[1] US Department of Energy. January 2014. "Evaluation of Retrofit Variable-Speed Furnace Fan Motors." Table 8. https://www.nrel.gov/docs/fy14osti/60760.pdf.

[2] DNV. 2021. "X1931-2 Load Shape and Coincidence Factor Research." Connecticut Energy Efficiency Board (EEB) and Evaluation Administrators.

[3] GDS Associates Inc. 2007. "Measure Life Report, Residential and Commercial Industrial Lighting and HVAC Measures." Table 2. New England State Program Working Group (SPWG).


***Changes from Last Version***

- Update summer demand savings from 0.129 to 0.220.
- Formatting updates.

## 3.2.14 EC MOTOR CIRCULATING PUMP

| | |
|---|---|
| Market | Residential |
| Baseline Type | Retrofit |
| Category | HVAC |

### ***Description***

Retrofit installation of an Electronically Commutated Motor (EC motor) circulating pump to replace an existing circulating pump on a residential hydronic heating system.

Savings are based on West Hill Energy and Computing's CT HVAC and Impact Evaluation of Residential HVAC and Water Heater Process and Impact Evaluation [1].

The savings methodology described in this measure is also valid for multifamily applications based on TRC's X1941 Multifamily Impact Evaluation [2].

**Note**: Ensure projects use the ECM pump (not VFD) calculator [2].

### ***Annual Energy Savings Algorithm***

*Retrofit Gross Annual Savings, Electric*

$$\Delta kWh = \Delta kWh_{Pump} \times n$$

*Retrofit Gross Seasonal Peak Demand Savings, Electric*

Cooling:

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

Heating:

$$\Delta kW_{winter} = \Delta kW_{winter,pump} \times n \times CF_h$$

### ***Calculation Parameters***

**Table 3-94 Calculation Parameters**

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| ΔkWh | Annual electric energy savings | Calculated | kWh/yr | |

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| $\Delta kWh_{Pump}$ | Annual electric energy savings per ECM circulating pump | 68 | kWh/yr | [1] |
| $\Delta kW_{winter}$ | Seasonal winter peak savings | Calculated | kW | |
| $\Delta kW_{winter, pump}$ | Seasonal winter peak savings per ECM circulating pump | 0.024 | kW | [1] |
| $\Delta kW_{summer}$ | Seasonal summer peak savings | 0 | kW | |
| $CF_{winter}$ | Seasonal winter peak coincidence factor | 1.0 | N/A | [3] |
| n | Number of ECM circulators pumps | Site specific | N/A | |

## ***Measure Life***

The measure life for EC motor circulating pumps is 15 years. [4]

## ***Peak Factors***

**Table 3-95 Peak Factors**

| Measure | Summer Coincidence Factor | Winter Coincidence Factor | Ref |
|---|---|---|---|
| EC motor circulating pump | 0% | 100% | [3] |

## ***Load Shapes***

**Table 3-96 Load Shapes**

| End Use | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % | Ref |
|---|---|---|---|---|---|
| Heating | 47.23% | 52.77% | 0.00% | 0.00% | [3] |

## ***Realization Rates***

**Table 3-97 Realization Rates**

| | Gross Realization % | | | | FR & SO | | Net Realization % | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Measure | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Delivered Fuels MMBtu | Free-ridership | Spill-over | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Delivered Fuels MMBtu | Ref |
| Boiler circulating pumps | 100.0% | 100.0% | 100.0% | 100.0% | 40.0% | 9.0% | 69.0% | 69.0% | 69.0% | 69.0% | |

## ***References***


[1] R1614/R1613 CT HVAC and Water Heater Process and Impact Evaluation, West Hill Energy and Computing, EMI Consulting & Lexicon Energy Consulting, Jul. 19, 2018, p. 86.

[2] TRC. 2021. "X1941 Multifamily Impact Evaluation."

[3] DNV. 2021. "X1931-2 Load Shape and Coincidence Factor Research – Final Report."

[4] Rhode Island TRM, Nation Grid, 2012 edition, p. M-76.


## ***Changes from Last Version***

- Formatting updates.

## 3.2.15 WI-FI THERMOSTAT

| | |
|---|---|
| Market | Residential |
| Baseline Type | Retrofit |
| Category | HVAC |

### ***Description***

This measure is the replacement of an existing manual or programmable residential thermostat with an ENERGY STAR qualified smart thermostat.

A communicating thermostat which allows remote set point adjustment and control via remote application. System requires an outdoor air temperature algorithm in the control logic to operate heating and cooling systems. The savings are per unit. Assumed baseline of either manual or programmable thermostat.

### ***Energy Savings Algorithm***

*Gross Energy Savings, Electric*

Deemed, see Table **3-99**.

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

$$\Delta \text{kW}_S = 0$$

$$\Delta \text{kW}_W = 0$$

**Note:** Connecticut is not claiming any kW demand reductions at this time and will revisit this after the evaluation of any Connecticut-specific Wi-Fi Thermostat program.

*Gross Energy Savings, Fossil Fuels*

Deemed, see Table 3-100

*Gross Peak Day Savings, Natural Gas*

$$PD_H = \Delta CCF_H \ X \ PDF_H$$

## ***Calculation Parameters***

**Table 3-98 Calculation Parameters**

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| $PD_H$ | Gross Peak Day Savings, Natural Gas | Calculated | Therms | |
| $PDF_H$ | Natural gas peak day factor | 0.009770 | N/A | |
| $\Delta kWh_C$ | Annual gross electric energy savings - cooling | Lookup in Table 3-99 | kWh/yr | [1] |
| $\Delta kWh_H$ | Annual gross electric energy savings - heating | Lookup in Table 3-99 | kWh/yr | |
| $\Delta kWh_{H-ER}$ | Annual gross electric energy savings - heating (electric resistance) | Lookup in Table 3-99 | kWh/yr | |
| $\Delta kWh_{H-HP}$ | Annual gross electric energy savings - heating (heat pump) | Lookup in Table 3-99 | kWh/yr | |
| $\Delta kWh_{H-GHP}$ | Annual gross electric energy savings – heating (ground source heat pump) | Lookup in Table 3-99 | kWh/yr | |
| $\Delta CCF_H$ | Annual gross natural gas energy savings - heating | Lookup in Table 3-100 | ccf/yr | [1] |
| $\Delta GO_H$ | Annual gross oil energy savings - heating | Lookup in Table 3-100 | Gal/yr | |
| $\Delta GP_H$ | Annual gross propane energy savings - heating | Lookup in Table 3-100 | Gal/yr | |
| $\Delta kW_S$ | Summer demand savings - cooling | 0 | kW | |
| $\Delta kW_W$ | Winter demand savings | 0 | kW | |

*Gross Energy Savings, Electric*

**Table 3-99 Gross Energy Savings, Electric (single-family)**

| | $\Delta KWH_C$ | $\Delta KWH_{H-ER}$ | $\Delta KWH_{H-HP}$ | $\Delta KWH_{H-GHP}$ | Ref |
|---|---|---|---|---|---|
| When heating fuel and cooling system is known (direct install) | 64.0 | 637.5 | 318.7 | 212.5 | [1] |
| When heating fuel or cooling system is unknown (midstream, E-commerce, etc.). | 25.0 | NA | NA | NA | [3] |

| | $\Delta KWH_C$ | $\Delta KWH_{H-ER}$ | $\Delta KWH_{H-HP}$ | $\Delta KWH_{H-GHP}$ | Ref |
|---|---|---|---|---|---|
| Additional gas, oil, propane savings from Measure 3.2.12, Table 3-83 should be claimed | | | | | |

**Table 3-100 Gross Energy Savings, Fossil Fuels (single-family)**

| | $\Delta CCF_H$ | $\Delta GO_H$ | $\Delta GP_H$ | Ref |
|---|---|---|---|---|
| When heating fuel or cooling system is known (direct install*) | 30.2 | 22.4 | 34.1 | [1] |
| When heating fuel is unknown (midstream, E-commerce, etc.) | 12.2 | 11.9 | 2.0 | [3] |

* Direct install is based on site verification that the customer has an in-home Wi-Fi network.

## *Calculation Examples*

## *Gross Peak Day Savings, Natural Gas*

For direct install when the heating system is known:

$$PD_H = \Delta CCF_H \times PDF_H$$

$$PD_H = 30.2 \times 0.009770 = 0.295\ ccf$$

For midstream when the heating system is unknown:

$$PD_H = \Delta CCF_H \times PDF_H$$

$$PD_H = 12.2 \times 0.00977 = 0.119\ ccf$$

## *Measure Life*

The measure life for Wi-Fi Thermostats is 15 years.

## *Peak Factors*

**Table 3-101 Peak Factors**

| Measure | Summer Coincidence Factor | Winter Coincidence Factor | Ref |
|---|---|---|---|
| Wi-Fi thermostat | 0% | 0% | [4] |

## Load Shapes

**Table 3-102 Load Shapes**

| End Use | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % | Ref |
|---|---|---|---|---|---|
| Cooling - Central AC | 4.83% | 4.33% | 54.40% | 36.45% | [4] |
| Heating | 47.23% | 52.77% | 0.00% | 0.00% | [4] |

## Realization Rates

**Table 3-103 Realization Rates**

| | Gross Realization % | | | | | FR and SO | | Net Realization % | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Measure | kWh or CCF | Winter Seasonal Peak kW or Peak Day CCF | Summer Seasonal Peak kW | Delivered Fuels MMBtu | Installation rate | Free-ridership | Spill-over | kWh or CCF | Winter Seasonal Peak kW or Peak Day CCF | Summer Seasonal Peak kW | Delivered Fuels MMBtu |
| Other Measures | 100.0% | 100.0% | 100.0% | 100.0% | 100% | 0.0% | 0.0% | 100.0% | 100.0% | 100.0% | 100.0% |
| Other Measures, HES [5] | 100.0% | 100.0% | 100.0% | 100.0% | 96% | 34.0% | 7.0% | 70.1% | 70.1% | 70.1% | 70.1% |

## References


[1] The Cadmus Group, Inc. 2012. "Wi-Fi Programmable Thermostat Pilot Program Evaluation." Part of the Massachusetts 2011 Residential Retrofit and Low-Income Program Area Evaluation.

[2] Navigant Consulting. 2018. "Wi-Fi Thermostat Impact Evaluation--Secondary Research Study Memo."

[3] NMR Group, Inc. October 2019."R1706 Residential Appliance Saturation Survey and R1616/R1708 Residential Lighting Impact Saturation Studies" - Savings are based on the NMR R1706 RASS saturation study reflecting the Central A/C penetration and fuel type in the state of Connecticut.

[4] DNV. 2021. "X1931-2 Load Shape and Coincidence Factor Research." Connecticut Energy Efficiency Board (EEB) and Evaluation Administrators.

[5] NMR. R1983 NTG Review Final Memo dated Sep.12, 2022.


## Changes from Last Version

- Formatting updates.
- Updated installation rate, free ridership and spillover values for HES.

## 3.2.16 FUEL OPTIMIZATION

| | |
|---|---|
| Market | Residential |
| Baseline Type | Retrofit |
| Category | HVAC |

### ***Description***

Addition of heat pump partially or fully displacing existing HVAC. The savings were calculated via simulation model runs using a weighted average of survey responses for the most accurate switch over temperature between the installed heat pump  and the secondary heating source. The annual savings are obtained by multiplying the deemed savings factor by the heat pump capacity.

### ***Annual Energy Savings Algorithm***

*Annual Gross Energy Savings, Electric*

$$\Delta kWh = CAP \times SF$$

*Annual Gross Energy Savings, Fossil Fuel*

$$\Delta \text{MMBtu} = CAP \times SF$$

*Gross Seasonal Peak Demand Savings, Electric*

$$\Delta kW_{Winter} = CAP \times SF$$

$$\Delta kW_{Summer} = CAP \times SF$$

### ***Calculation Parameters***

**Table 3-104 Calculation Parameters**

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| ΔkWh | Annual gross energy savings, electric | Calculated | kWh | |
| ΔMMBtu | Annual gross energy savings, fossil fuel | Calculated | MMBtu | |
| $\Delta kW_{Winter}$ | Gross winter peak demand savings | Calculated | kW | |
| $\Delta kW_{Winter}$ | Gross summer peak demand savings | Calculated | kW | |
| CAP | Installed unit capacity | Site-specific | Tons | |

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| SF | Savings factor | Lookup in Table 3-105 | kWh/Ton or MMBtu/Ton | |

**Table 3-105 Savings Factors**

| Proposed measure | Electric Heating SF (kWh/yr/ton) | Electric Cooling SF (kWh/yr/ton) | Summer Demand SF (kW/yr/ton) | Winter Demand SF (kW/yr/ton) | Fossil Fuel SF (Gal Oil /Prop or Gas CCF/yr/ton) |
|---|---|---|---|---|---|
| Central Ducted HP Partially Displacing existing Oil Furnace | -1,202 | -32 | -0.04 | -0.34 | 96.8 |
| Central Ducted HP Partially Displacing existing Prop Furnace | -1,668 | -32 | -0.04 | -0.48 | 189.6 |
| Central Ducted HP Partially Displacing existing Gas Furnace | -1,668 | -32 | -0.04 | -0.48 | 168.3 |
| Central Ducted HP Fully Displacing existing Oil Furnace | -2,112 | -20 | -0.03 | -0.61 | 128.7 |
| Central Ducted HP Fully Displacing existing Prop Furnace | -2,112 | -20 | -0.03 | -0.61 | 195.4 |
| Central HP Fully Displacing existing gas Furnace | -2,112 | -20 | -0.03 | -0.61 | 173.5 |
| Mini Split HP with Integrated Control Partially Displacing existing Oil Boiler | -1,326 | -179 | -0.2 | -0.37 | 115.7 |
| Mini Split HP with Integrated control Partially Displacing existing Prop Boiler | -1,564 | -179 | -0.2 | -0.37 | 199.9 |
| Mini Split HP with Integrated control Partially Displacing existing Gas Boiler | -1,564 | -179 | -0.2 | -0.37 | 177.5 |
| Mini Split HP Fully Displacing existing Oil Boiler | -1,849 | -133 | -0.15 | -0.53 | 128.2 |

| Proposed measure | Electric Heating SF (kWh/yr/ton) | Electric Cooling SF (kWh/yr/ton) | Summer Demand SF (kW/yr/ton) | Winter Demand SF (kW/yr/ton) | Fossil Fuel SF (Gal Oil /Prop or Gas CCF/yr/ton) |
|---|---|---|---|---|---|
| Mini Split HP Fully Displacing existing Prop Boiler | -1,849 | -133 | -0.15 | -0.53 | 194.7 |
| Mini Split HP Fully Displacing existing Gas Boiler | -1,849 | -133 | -0.15 | -0.53 | 172.8 |
| Air to Water Displacing, Oil | -1,849 | -133 | -0.15 | -0.53 | 128.2 |
| Air to Water Displacing, Prop | -1,849 | -133 | -0.15 | -0.53 | 194.7 |
| Air To water Displacing, Gas | -1,849 | -133 | -0.15 | -0.53 | 172.8 |
| GSHP Displacing, Oil | -1,464 | 34 | 0.01 | -1.0 | 149 |
| GSHP Displacing, Prop | -1,464 | 34 | 0.01 | -1.0 | 220 |
| GSHP Displacing, Gas | -1,464 | 34 | 0.01 | -1.0 | 195.6 |
| VRF Fully Displacing Oil | -1,801 | | | -0.97 | 164.2 |
| VRF Fully Displacing Propane | -1,801 | | | -0.97 | 225 |
| VRF Fully Displacing Gas | -1,761 | | | -0.97 | 195.3 |
| VRF Fully Displacing Electric Res | 3,439 | | | 0 | |
| VRF Partially Displacing Oil | -1,573 | | | -0.45 | 140 |
| VRF Partially Displacing Propane | -1,573 | | | -0.45 | 191.8 |
| VRF Partially Displacing Gas | -1,573 | | | -0.45 | 166.5 |
| VRF Partially Displacing Electric Res | 4,595 | | | 0 | |

## ***Measure Life***

The measure life for fuel optimization is 20 years for central heat pump [2].

Mini split is 17 years [2].

Ground source heat pump is 25 years [3].

## ***Peak Factors***

Coincidence factors are custom calculated.

## ***Load Shapes***

**Table 3-106 Load Shapes**

| Measure | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % | Ref |
|---|---|---|---|---|---|
| Partial Replacement Fuel Optimization | 43.1% | 56.9% | 0% | 0% | [1] |

## ***Non-Energy Impacts***

There are no other resource impacts identified for this measure.

## ***Realization Rates***

**Table 3-107 Realization Rates**

| | Gross Realization % | | | | FR and SO | | Net Realization % | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Measure | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Delivered Fuels MMBtu | Free-ridership | Spill-over | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Delivered Fuels MMBtu |
| Fuel Optimization | 100% | 100% | 100% | 100% | 31% | 22% | 91% | 91% | 91% | 91% |

## ***References***


[1] Guidehouse. 2021. “Energy Optimization Fuel Displacement Impact and Process Study” (MA20R24-B-EOEVAL)

[2] Michaels Energy. 2022. "X2001A: Connecticut Measure Life/EUL Update Study-Residential Measures." Connecticut Energy Efficiency Board.

[3] DNV. MA20C15-B-GSHP Ground Source Heat Pump eTRM Measure Review. Mar. 5, 2021 https://ma-eeac.org/wp-content/uploads/MA20C15-B-GSHP_GroundSourceHeatPump_final.pdf


## ***Changes from Last Version***

- Added missing measures.

## 3.3 WATER HEATING

### 3.3.1 SHOWERHEADS

| | |
|---|---|
| Market | Residential |
| Baseline Type | Retrofit |
| Category | Water Heating |

#### ***Description***

Installation of low-flow showerheads input with 2.0 gpm maximum flow rate to replace Federal Standard (2.5 gpm) or higher flow showerheads [1].

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). For a multifamily property, savings are given per dwelling or unit.

No electric demand savings are claimed for this measure because there is insufficient peak coincident data.

#### ***Energy Savings Algorithms***

*Retrofit Gross Energy Savings, Electric*

$$\Delta kWh = \frac{\Delta MMBtu}{0.003412 \times RE_e}$$

Where,

$$\Delta MMBtu = \frac{\sqrt{n_i} \times (T_{shower} - T_{supply})}{10^6} \times d_w \times SH_W \times \frac{\Delta H_2O}{10^6}$$

$$\Delta H_2O = n_e \times d_e \times 365 \times (gpm_{Fed.Std.} - gpm_{WaterSense.}) \times \frac{1}{n_a}$$

*Retrofit Gross Energy Savings, Natural Gas*

$$\Delta CCF = \frac{\Delta MMBtu}{0.1029 \times RE_g}$$

Where,

$$\Delta MMBtu = \frac{\sqrt{n_i} \times (T_{shower} - T_{supply})}{10^6} \times d_w \times SH_W \times \frac{\Delta H_2O}{10^6}$$

$$\Delta H_2O = n_e \times d_e \times 365 \times (gpm_{Fed.Std.} - gpm_{WaterSense.}) \times \frac{1}{n_a}$$

*Retrofit Gross Energy Savings, Oil*

$$\Delta Gal_{Oil} = \frac{\Delta MMBtu}{0.138690 \times RE_g}$$

Where,

$$\Delta MMBtu = \frac{\sqrt{n_i} \times (T_{shower} - T_{supply})}{10^6} \times d_w \times SH_W \times \frac{\Delta H_2O}{10^6}$$

$$\Delta H_2O = n_e \times d_e \times 365 \times (gpm_{Fed.Std.} - gpm_{WaterSense.}) \times \frac{1}{n_a}$$

*Retrofit Gross Energy Savings, Propane*

$$\Delta Gal_{Propane} = \frac{\Delta MMBtu}{0.09133 \times RE_g}$$

Where,

$$\Delta MMBtu = \frac{\sqrt{n_i} \times (T_{shower} - T_{supply})}{10^6} \times d_w \times SH_W \times \frac{\Delta H_2O}{10^6}$$

$$\Delta H_2O = n_e \times d_e \times 365 \times (gpm_{Fed.Std.} - gpm_{WaterSense.}) \times \frac{1}{n_a}$$

## ***Calculation Parameters***

**Table 3-108 Calculation Parameters**

| Symbol | Description | Units | Value | Ref |
|---|---|---|---|---|
| ΔkWh | Annual electric savings for homes with electric water heater | kWh/yr | Calculated | |
| ΔCCF | Annual natural gas savings | ccf/yr | Calculated | |
| $\Delta Gal_{Oil}$ | Annual oil savings | gal/yr | Calculated | |
| $\Delta Gal_{Propane}$ | Annual propane savings | gal/yr | Calculated | |
| $T_{shower}$ | Temperature of water from shower | °F | 105°F | |
| $T_{supply}$ | Temperature of water into house | °F | 55°F | |
| $d_W$ | Density of water | lb/Gal | 8.31 | |
| $d_e$ | Duration of event | | | |
| $gpm_{Fed. Std.}$ | Gallons per minute flow rate, federal standard | Gal/min | 2.5 | [1] |
| $gpm_{WaterSense}$ | Gallons per minute flow rate, WaterSense | Gal/min | 2.0 | [1] |

| Symbol | Description | Units | Value | Ref |
|---|---|---|---|---|
| $n_e$ | Average number of shower events per day per household | | 1.52 | [4] p. 144, Table 41 |
| $SH_W$ | Specific heat of water | BTU/lb-°F | 1 | |

**Table 3-109 Assumed Values - Single Family vs Multi-family**

| Symbol | Description | Single Family Assumed Value | Multi-family Assumed Value | Ref |
|---|---|---|---|---|
| $n_i$ | Number of low-flow showerheads installed | Site specific<br>If unknown, assume 1.63 | Site specific<br>If unknown, assume 1.3 | [4] |
| $n_a$ | Average total number of showerheads per household | 1.63 | 1.3 | [4]*, [6] |
| $RE_e$ | Recovery efficiency of electric water heater | 0.98 | 0.98 | [3] |
| $RE_f$ | Recovery efficiency of fossil fuel water heater | 0.78 | 0.67 for shared WH. If individual, use SF value | [3] |
| $\Delta H_2O$ | Annual water savings | Calculated to be 1,327.4 gal/yr | Calculated to be 1,664.4 gal/yr | |

* pp. 185-186, Table 66

## ***Calculation Examples Single Family***

*Two showerheads are replaced in bathrooms of a single-family home which uses electric hot water heating. What are the savings per household per year?*

Annual electric savings:

$$\Delta kWh = 165.1\ {}^{kWh}/_{showerhead} \times \sqrt{n_i} = 165.1 \times \sqrt{2} = 233.5\ {}^{kWh}/_{yr}$$

Annual water savings:

$$\Delta H_2O = 1327.4\ {}^{Gal}/_{showerhead} \times \sqrt{n_i} = 1327.4 \times \sqrt{2} = 1{,}877.2\ {}^{Gal}/_{year}$$

*Two showerheads are replaced in bathrooms of a single family home which uses natural gas hot water heating. What are the savings per household per year?*

Annual natural gas savings:

$$\Delta CCF = 6.88\ {}^{CCF}/_{showerhead} \times \sqrt{n_i} = 6.88 \times \sqrt{2} = 9.73\ {}^{CCF}/_{yr}$$

Annual water savings:

$$\Delta H_2O = 1327.4\ {}^{Gal}/_{showerhead} \times \sqrt{n_i} = 1327.4 \times \sqrt{2} = 1{,}877.2\ {}^{Gal}/_{year}$$

## ***Calculation Examples Multi Family***

*Two showerheads are replaced in bathrooms of a multi-family apartment which uses electric hot water heating. What are the savings per household per year?*

Annual electric savings:

$$\Delta kWh = 206.8\ {}^{kWh}/_{showerhead} \times \sqrt{n_i} = 206.8 \times \sqrt{2} = 292.5\ {}^{kWh}/_{yr}$$

Annual water savings:

$$\Delta H_2O = 1{,}664.4\ {}^{Gal}/_{showerhead} \times \sqrt{n_i} = 1{,}664.4 \times \sqrt{2} = 2{,}353.8\ {}^{Gal}/_{year}$$

*Two showerheads are replaced in bathrooms of a multi-family apartment which uses natural gas hot water heating. What are the savings per household per year?*

Annual natural gas savings:

$$\Delta CCF = 8.61\ {}^{CCF}/_{showerhead} \times \sqrt{n_i} = 8.61 \times \sqrt{2} = 12.2\ {}^{CCF}/_{yr}$$

Annual water savings:

$$\Delta H_2O = 1{,}664.4\ {}^{Gal}/_{showerhead} \times \sqrt{n_i} = 1{,}66 \times \sqrt{2} = 2{,}353.8\ {}^{Gal}/_{year}$$

Peak day natural gas savings:

$$\Delta CCF_{PD} = \Delta CCF\ x\ PDF_{WH}$$

## ***Measure Life***

The effective useful life for this measure is 10 years.

## ***Peak Factors***

Peak day factor for natural gas water heating is 0.00321 [1].

No electric demand savings are claimed for this measure because there is insufficient peak coincident data.

## Load Shapes

**Table 3-110 Load Shapes**

| End Use | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % | Ref |
|---|---|---|---|---|---|
| Water Heating - Electric | 43.26% | 29.72% | 16.19% | 10.82% | |
| Water Heating - HP | 41.88% | 31.05% | 15.56% | 11.50% | |

### Non-Energy Benefits

*Annual water savings in gallons SF:*

$$\Delta H_2O = n_e \times d_e \times 365 \times \left(gpm_{fed.std.} - gpm_{WaterSense.}\right) \times \frac{1}{n_a}$$

When calculated using the assumptions described in Table 3-108:

$$\Delta H_2O = 1{,}327.4 \, {}^{Gal}/_{showerhead \cdot yr}$$

*Annual water savings in gallons MF:*

$$\Delta H_2O = n_e \times d_e \times 365 \times \left(gpm_{fed.std.} - gpm_{WaterSense.}\right) \times \frac{1}{n_a}$$

When calculated using the assumptions described in Table 3-108:

$$\Delta H_2O = 1{,}664.4 \, {}^{Gal}/_{showerhead \cdot yr}$$

## Realization Rates and Net Impact Factors

**Table 3-111 Realization Rates**

| | Gross Realization % | | | | | FR and SO | | Net Realization % | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Measure | kWh or CCF | Winter Seasonal Peak kW or Peak Day CCF | Summer Seasonal Peak kW | Delivered Fuels MMBtu | Installation rate | Free-ridership | Spill-over | kWh or CCF | Winter Seasonal Peak kW or Peak Day CCF | Summer Seasonal Peak kW | Delivered Fuels MMBtu |
| Water-saving Measures, HES-IE [7] | 100.0% | 100.0% | 100.0% | 100.0% | 100% | 0.0% | 0.0% | 100% | 100% | 100% | 100% |
| Water-saving Measures, HES [7] | 100.0% | 100.0% | 100.0% | 100.0% | 82% | 20.0% | 7% | 71.3% | 71.3% | 71.3% | 71.3% |

| | Gross Realization % | | | | | FR and SO | | Net Realization % | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| MF water-saving measures [8] | 100.0% | 100.0% | 100.0% | 100.0% | 100% | 20.0% | 0.0% | 80.0% | 80.0% | 80.0% | 80.0% |

## ***References***


[1] EPA WaterSense Specification for Showerheads, Version 1.0, effective Feb. 9, 2010, last accessed on Jul. 21, 2010.

[2] KEMA. 2010. “Evaluation of the Weatherization Residential Assistance Partnership (WRAP) and Helps Programs, Final Report”

[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. 2011. “California Single Family Water Use Efficiency Study.”

[5] NMR Group, Inc. 2019. "R1706 Residential Appliance Saturation Survey & R1616/R1708 Residential Lighting Impact Saturation Studies."

[6] Energy & Resource Solutions. 2019. "R1705 R1609 Multifamily Baseline and Weatherization Opportunity Study."

[7] West Hill Energy and Computing. 2019. “R1603 HES/HES-IE Impact Evaluation Final Realization Rates Memorandum.”

[8] NMR and Cadmus. 2014. “Impact Evaluation: Home Energy Services—Income-Eligible and Home Energy Services Programs: Volume 2 (R16), Final Report.”

[9] NMR. R1983 NTG Review Final Memo dated Sep. 12, 2022.


## ***Changes from Last Version***

- Formatting updates.
- Updated installation rate, free ridership and spillover values for HES.

## 3.3.2 FAUCET AERATOR

| | |
|---|---|
| Market | Residential |
| Baseline Type | Retrofit |
| Category | Water Heating |

### ***Description***

Installation of aerator specific or EPA specified faucets with flow rate of 1.5 GPM as default to replace Federal Standard (2.2 gpm) or higher flow faucet aerators [1].

Savings should be claimed based on the type of fuel used for water heating. Water savings are 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).

For a multifamily property, n and $n_e$ are given per dwelling/unit, then multiply the savings results by the number of unit/dwelling the measure is applied to.

The California Single Family Water Use Efficiency Study gave the number of toilets per household, 2.4 (Table 66, pp. 185-186) [4]. 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.

The Evaluation of the Weatherization Residential Assistance Partnership (WRAP) and Helps Programs Report recommends reducing savings for additional aerators by multiplying by the square root of the number installed [2].

***Note:*** *No demand savings are claimed for this measure since there is insufficient peak coincident data.*

### ***Energy Savings Algorithm***

*Gross Energy Savings, Electric*

$$\Delta kWh = \frac{\Delta MMBtu}{0.003412^{MMBtu}/_{kWh} \times RE_e}$$

*Where,*

$$\Delta MMBtu = \sqrt{n_i} \times (T_{Faucet} - T_{Supply}) \times d_w \, x \, SH_w \times {}^{\Delta H_2O}/_{10^6 \, {}^{Btu}/_{MMBtu}}$$

$$\Delta H_2O = n_e \times d_e \times 365 \, {}^{days}/_{yr} \times DF \times \frac{gpm_{federal\ standard} - gpm_{Water\ Sense}}{n}$$

*Gross Energy Savings, Natural Gas:*

$$\Delta Ccf = \frac{\Delta MMBtu}{0.102900\, {}^{MMBtu}/_{Ccf} \times RE_f}$$

*Where,*

$$\Delta MMBtu = \sqrt{n} \times (T_{Faucet} - T_{Supply}) \times d_w \, x \, SH_w \times {}^{\Delta H_2O}/_{10^6\, {}^{Btu}/_{MMBtu}} \; \Delta H_2O$$

$$= n_e \times d_e \times 365\, {}^{days}/_{yr} \times DF \times \frac{gpm_{federal\ standard} - gpm_{WaterSense}}{n_i}$$

*Gross Energy Savings, Oil:*

$$\Delta Gal_{Oil} = \frac{\Delta MMBtu}{0.138690\, {}^{MMBtu}/_{Gal_{oil}} \times RE_f}$$

*Where,*

$$\Delta MMBtu = \sqrt{n} \times (T_{Faucet} - T_{Supply}) \times d_w \, x \, SH_w \times {}^{\Delta H_2O}/_{10^6\, {}^{Btu}/_{MMBtu}}$$

$$\Delta H_2O = n_e \times d_e \times 365\, {}^{days}/_{yr} \times DF \times \frac{gpm_{federal\ standard} - gpm_{Water\ Sense}}{n_i}$$

*Gross Energy Savings, Propane:*

$$\Delta Gal_{propane} = \frac{\Delta MMBtu}{0.09133\, {}^{MMBtu}/_{Gal_{propane}} \times RE_f}$$

*Where,*

$$\Delta MMBtu = \sqrt{n} \times (T_{Faucet} - T_{Supply}) \times d_w \, x \, SH_w \times {}^{\Delta H_2O}/_{10^6\, {}^{Btu}/_{MMBtu}}$$

$$\Delta H_2O = n_e \times d_e \times 365\, {}^{days}/_{yr} \times r_g \times DF \times \frac{gpm_{federal\ standard} - gpm_{WaterSense}}{n_i}$$

***Retrofit Gross Peak Day Savings, Natural Gas***

$$\Delta Ccf_{PD} = \Delta Ccf \times PDF_{WH}$$

***Calculation Parameters***

**Table 3-112 Calculation Parameters**

| Symbol | Description | Value | Units | Ref |
|---|---|---|---|---|
| ΔkWh | Annual energy savings, electric | Calculated | kWh | |
| ΔCcf | Annual energy savings, natural gas | Calculated | ccf | |

| Symbol | Description | Value | Units | Ref |
|---|---|---|---|---|
| $\Delta Gal_{Oil}$ | Annual energy savings, oil | Calculated | Gal | |
| $\Delta Gal_{Propane}$ | Annual energy savings, propane | Calculated | Gal | |
| $\Delta Ccf_{PD}$ | Peak day savings, water heating | Calculated | ccf | |
| $d_W$ | Density of water | 8.31 | lb/ Gal | |
| DF | Drain factor | 0.795 | N/A | [3] |
| $gpm_{federal\ standard}$ | Federal standard flow rate Gallons per minute | 2.2 | gal/min | [1] |
| $gpm_{WaterSense}$ | EPA WaterSense flow rate Gallons per minute | 1.5 | gal/min | |
| $SH_W$ | Specific heat of water | 1 | Btu/(lb·°F) | N/A |
| $T_{faucet}$ | Temperature of water from faucet | 80 °F | °F | N/A |
| $T_{supply}$ | Temperature of water into house | 55 °F | °F | N/A |
| $PDF_{WH}$ | Peak day factor, water heating | 0.00321 | | [4] |
| $d_e$ | Average duration per event | 0.6167 | minutes | [4] |

**Table 3-113 Assumed Values - Single Family vs Multi-family**

| Symbol | Description | Single Family Assumed Value | Multi-family Assumed Value | Ref |
|---|---|---|---|---|
| $n_i$ | Number of low-flow faucet aerators installed | As found<br>If unknown, assume 2.01 | As found<br>If unknown, assume 1.4 | [4], [7] |
| $n_a$ | Average number of low-flow faucet aerators per household | 2.01 | 1.4 | [4], [7] |
| $n_e$ | Median number of faucet events per day per household | 13.8 | 10.1 | [4] |
| $RE_e$ | Recovery efficiency of electric water heater | 0.98 | 0.98 | [3] |
| $RE_f$ | Recovery efficiency of fossil fuel water heater | 0.78 | 0.67 for shared WH. If individual, use SF value | [3] |
| $\Delta H_2O$ | Annual water savings | Calculated to be 860.03 gal/yr | Calculated to be 1,234.8 gal/yr | |

## ***Calculation Examples***

*Single Family Examples*

***Example One:*** *Two aerators are replaced in bathrooms of a single-family home which uses electric hot water heating. What are the total savings?*

$$Annual\ Gal\ Water\ Savings = \Delta H_2O \times \sqrt{n_i} = 860.03\ {}^{Gal}/_{yr} \times \sqrt{2} = 1216.26\ {}^{Gal}/_{yr}$$

$$\Delta kWh = 53.53\ {}^{kWh}/_{faucet} \times \sqrt{2} = 75.70\ {}^{kWh}/_{yr}$$

***Example Two:*** *Two aerators are replaced in bathrooms of a single family home which uses natural gas hot water heating. What are the savings?*

$$\Delta CCF = 2.23 \times \sqrt{2} = 3.15\ {}^{Ccf}/_{yr}$$

$$Annual\ Gal\ Water\ Savings = \Delta H_2O \times \sqrt{n_i} = 860.03\ {}^{Gal}/_{yr} \times \sqrt{2} = 1{,}216.26\ {}^{Gal}/_{yr}$$

*Multifamily Examples*

***Example One:*** *Two aerators are replaced in bathrooms of a muti-family apartment which uses electric hot water heating. What are the total savings?*

$$Annual\ Gal\ Water\ Savings = \Delta H_2O \times \sqrt{n} = 1{,}234.8\ {}^{Gal}/_{yr} \times \sqrt{2} = 1{,}746.3\ {}^{Gal}/_{yr}$$

$$\Delta kWh = 76.72\ {}^{kWh}/_{faucet} \times \sqrt{2} = 108.5\ {}^{kWh}/_{yr}$$

***Example Two:*** *Two aerators are replaced in bathrooms of a multi-family home which uses natural gas hot water heating. What are the savings?*

$$\Delta CCF = 3.20 \times \sqrt{2} = 4.53\ {}^{Ccf}/_{yr}$$

$$Annual\ Gal\ Water\ Savings = \Delta H_2O \times \sqrt{n} = 1{,}234.8\ {}^{Gal}/_{yr} \times \sqrt{2} = 1{,}746.3\ {}^{Gal}/_{yr}$$

## ***Measure Life***

**Table 3-114 Measure Life**

| Equipment Type | Measure Life | Ref |
|---|---|---|
| Retirement RUL | 10 | N/A |
| Lost Opportunity EUL | 10 | [8] |

## ***Peak Factors***

Peak day factor for natural gas water heating is 0.00321 [1].

## ***Load Shapes***

**Table 3-115 Load Shapes**

| End Use | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % |
|---|---|---|---|---|
| Water Heating - Electric | 43.26% | 29.72% | 16.19% | 10.82% |
| Water Heating - HP | 41.88% | 31.05% | 15.56% | 11.50% |

## ***Non-Energy Impacts***

*Annual water savings in gallons SF:*

$$\Delta H_2O \ = n_e \times d_e \ \times 365 \times DF \times \ \left(gpm_{fed.std.} - gpm_{WaterSense.}\right) \times \frac{1}{n_a}$$

When calculated using the assumptions described in Table 3-108:

$$\Delta H_2O = 860.03 \, {}^{Gal}/_{faucet \cdot yr}$$

*Annual water savings in gallons MF:*

$$\Delta H_2O \ = n_e \times d_e \ \times 365 \times DF \times \ \left(gpm_{fed.std.} - gpm_{WaterSense.}\right) \times \frac{1}{n_a}$$

When calculated using the assumptions described in Table 3-108:

$$\Delta H_2O = 1{,}234.8 \, {}^{Gal}/_{faucet \cdot yr}$$

## ***Realization Rates and Net Impact Factors***

**Table 3-116 Realization Rates and Net Impact Factors**

| | Gross Realization % [9] | | | | ISR | FR & SO [5] | | Net Realization % | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Measure | kWh or CCF | Winter Peak kW or Peak Day CCF | Summer Peak kW | Delivered Fuels MMBtu | | Free-ridership | Spill-over | kWh or CCF | Winter Peak kW or Peak Day CCF | Summer Peak kW | Delivered Fuels MMBtu |
| Water-saving measures, HES-IE | 100.0% | 100.0% | 100.0% | 100.0% | 100% | 0.0% | 0.0% | 100.0% | 100.0% | 100.0% | 100.0% |

| | Gross Realization % [9] | | | | | FR & SO [5] | | | Net Realization % | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Measure** | **kWh or CCF** | **Winter Peak kW or Peak Day CCF** | **Summer Peak kW** | **Delivered Fuels MMBtu** | ISR | **Free-ridership** | **Spill-over** | **kWh or CCF** | **Winter Peak kW or Peak Day CCF** | **Summer Peak kW** | **Delivered Fuels MMBtu** |
| Water-saving measures, HES | 100.0% | 100.0% | 100.0% | 100.0% | 85% [11] | 20% [11] | 7% [11] | 74% | 74% | 74% | 74% |
| MF water-saving measures | 100.0% | 100.0% | 100.0% | 100.0% | 100% | 20.0% | 0.0% | 80.0% | 80.0% | 80.0% | 80.0% |

## ***References***


[1] US EPA WaterSense. 2007. "High efficiency Lavatory Faucet Specification."

[2] KEMA. 2010. "Evaluation of the Weatherization Residential Assistance Partnership (WRAP) and Helps Programs, Final Report".

[3] Illinois Energy Efficiency Stakeholder Advisory Group. 2013. *Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 2.0*. p. 491.

[4] Aquacraft Water Engineering & Management. 2011. "California Single Family Water Use Efficiency Study".

[5] NMR and Cadmus. 2014. "Impact Evaluation: Home Energy Services—Income-Eligible and Home Energy Services Programs: Volume 2 (R16), Final Report". Connecticut Energy Efficiency Fund.

[6] NMR Group, Inc. 2019. "R1706 Residential Appliance Saturation Survey & R1616/R1708 Residential Lighting Impact Saturation Studies".

[7] Energy & Resource Solutions. 2019. "R1705 R1609 Multifamily Baseline and Weatherization Opportunity Study." Connecticut Energy Efficiency Board.

[8] National Grid. 2012. *Rhode Island TRM*. p. M-76.

[9] DNV. 2021. "X1931-2 Load Shape and Coincidence Factor Research." Connecticut Energy Efficiency Board (EEB) and Evaluation Administrators.

[10] West Hill Energy and Computing. 2019. "R1603 HES/HES-IE Impact Evaluation Final Realization Rates Memorandum".

[11] NMR. R1983 HES NTG Review Final Memo dated Sep. 12, 2022.


## ***Changes from Last Version***

- Formatting updates.
- Updated installation rate, free ridership and spillover values.

### 3.3.3 FOSSIL FUEL WATER HEATERS

| | |
|---|---|
| Market | Residential |
| Baseline Type | Lost Opportunity |
| Category | Water Heating |

***Description***

Installation of a high efficiency natural gas or propane tankless and storage water heaters. For multifamily, this measure is applicable to water heaters with a capacity of less than 75,000 Btu/h for storage water heaters and 200,000 Btu/h for on-demand water heaters [5].

Energy and demand savings calculations for a tankless or storage water heater are shown. 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 0). Many of the inputs for this measure are based on NREL's Tool for Generating Realistic Residential Hot Water Event Schedules [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.

The following assumptions were used to develop this calculation methodology:

- The annual domestic hot water load was developed using Hartford area weather data and a three-bedroom house [1].
- Baseline is an average of the 50-gallon storage gas water heater and tankless water heater Energy Factors (EF) [2].
- The EF is defined as the overall energy efficiency of a water heater based on the amount of hot water produced per unit of fuel consumed over a typical day. This includes recovery efficiency, standby losses, and cycling losses. Available online at: www.energysavers.gov.
- A multifamily multiplier was applied to the single-family gallons per year since hot water usage is related to the number of occupants. The multiplier was found to be 0.73 = 1.9 occupants/2.6 occupants [4].

***Energy Savings Algorithm***

*Lost Opportunity Gross Energy Savings, Natural Gas*

$$\Delta CCF_W = \frac{\Delta Btu_W}{C_{NG}}$$

Where,

$$\Delta Btu_W = ADHW \times \left(\frac{1}{UEF_B} - \frac{1}{UEF}\right)$$

*Lost Opportunity Gross Energy Savings, Propane*

$$\Delta Gal_{Propane,W} = \frac{\Delta Btu_W}{C_{Propane}}$$

Where,

$$\Delta Btu_W = ADHW \times \left(\frac{1}{UEF_B} - \frac{1}{UEF}\right)$$

*Lost Opportunity Gross Peak Day Savings, Natural Gas*

$$\Delta CCF_{PD,W} = \Delta CCF_W \times PDF_W$$

## *Calculation Parameters*

**Table 3-117 Calculation Parameters**

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| $\Delta Btu_W$ | Annual Btu savings – water heating | Calculated | Btu | |
| $\Delta CCF_W$ | Annual natural gas savings – water heating | Calculated | CCF | |
| $\Delta Gal_{Propane,W}$ | Annual propane savings – water heating | Calculated | Gal | |
| $\Delta CCF_{PD,W}$ | Peak day water heating savings | Calculated | CCF | |
| UEF | Uniform Energy Factor | Site-specific | N/A | |
| ADHW | Annual domestic hot water load | 9,630,521 | Btu | [1] |
| $UEF_B$ | Uniform Energy Factor – baseline | 0.66 | N/A | [2] |
| $PDF_W$ | Peak day factor water heating | 0.00321 | N/A | |
| $C_{NG}$ | Natural gas conversion constant | 102,900 | Btu/CCF | |
| $C_{Propane}$ | Propane conversion constant | 91,330 | Btu/Gal | |

## *Calculation Examples*

*Example 1: Lost Opportunity Gross Energy Savings*

*A natural gas water heater with an UEF = 82% (0.82) is installed. What is the annual natural gas savings?*

$$\Delta Btu_W = ADHW \times \left(\frac{1}{UEF_B} - \frac{1}{UEF}\right)$$

$$\Delta Btu_W = 9{,}630{,}521\ Btu \times \left(\frac{1}{0.66} - \frac{1}{0.82}\right) = 2{,}847{,}160.7\ Btu$$

$$\Delta CCF_W = \frac{\Delta Btu_W}{C_{NG}}$$

$$\Delta CCF_W = \frac{2{,}847{,}160.7\ Btu}{102{,}900\ \frac{Btu}{CCF}} = 27.67\ CCF$$

## ***Measure Life***

**Table 3-118 Measure Life**

| Equipment Type | Measure Life | Ref |
|---|---|---|
| High efficiency storage gas water heater | 11 years | [3] |
| On-demand tankless gas water heater | 20 years | [3] |

## ***Peak Factors***

Peak day factor for natural gas water heating is 0.00321.

## ***Load Shapes***

Electric load shapes N/A for this fossil fuel savings measure.

**Table 3-119 Realization Rates and Net Impact Factors**

| | Gross Realization % | | | | FR & SO | | Net Realization % | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Measure | CCF | Peak Day CCF | Summer Seasonal Peak kW | Delivered Fuels MMBtu | Free-ridership | Spill-over | CCF | Peak Day CCF | Summer Seasonal Peak kW | Delivered Fuels MMBtu |
| Water Heating (HES Add-On) | 100.0% | 100.0% | 100.0% | 100.0% | 0.0% | 0.0% | 100.0% | 100.0% | 100.0% | 100.0% |

## ***References***


[1] West Hill Energy and Computing. 2018. “CT HVAC and Water Heater Process and Impact Evaluation and Heat Pump Water Heater Impact Evaluation.”

[2] Code of Federal Regulations, 10 CFR Parts 429, 430, and 431 as of Jun 1, 2022.

[3] California Public Utilities Commission, *2014 Database for Energy-Efficient Resources,* Feb. 4, 2014, available online at: http://www.deeresources.com/files/DEER2013codeUpdate/download/DEER2014-EUL-table-update_2014-02-05.xlsx, last accessed Sep. 3, 2020.

[4] Multifamily: NMR Group, Inc. Oct. 1, 2019 "R1706 Residential Appliance Saturation Survey & R1616/R1708 Residential Lighting Impact Saturation Studies".

[5] Energy Star Water Heater Key Product Criteria https://www.energystar.gov/products/water_heaters/residential_water_heaters_key_product_criteria.

## ***Changes from Last Version***

- Updated UEF baseline value.
- Formatting updates.

## 3.3.4 HEAT PUMP WATER HEATERS

| | |
|---|---|
| Market | Residential |
| Baseline Type | Retrofit/Lost Opportunity |
| Category | Water Heating |

### ***Description***

Installation of a heat pump water heater (HPWH). For tanks > than 55 gallons, the baseline would be a blended mix of electric resistance and minimally compliant HPWH.

**Retrofit:** Electric resistance water heater for sizes < 55 gallons and a minimal code compliant HPWH for sizes > 55 gallons.

Energy and demand savings values for a HPWH are shown below. The savings are based on the R1614/R1613 HVAC and Water Heater Evaluation [1]. The savings in the study represent a combination of electric savings and fossil fuel savings.

### ***Energy Savings Algorithm***

*Annual Gross Energy Savings, Electric*

$$\Delta kWh = lookup\ in\ \text{Table 3-120}$$

*Annual Gross Energy Savings, Oil*

$$\Delta Gal_{Oil} = lookup\ in\ \text{Table 3-120}$$

*Annual Gross Energy Savings, Propane*

$$\Delta Gal_{Propane} = lookup\ in\ \text{Table 3-120}$$

**Table 3-120 Annual Gross Energy Savings**

| Existing DHW Type | ΔkWh Savings (≤ 55 gallons) | ΔkWh (> 55 gallons) | $\Delta Gal_{Oil}$ | $\Delta Gal_{Propane}$ |
|---|---|---|---|---|
| Electric resistance (Retrofit) | 1,818 kWh | 197 kWh | | |
| Unknown (Lost Opportunity) | 961 kWh | 565 kWh | 15.5 Gals | 23.54 Gals |

Seasonal Peak Demand Savings

$$\Delta kW_{Summer} = lookup\ in\ \text{Table 3-121}$$

$$\Delta kW_{Winter} = lookup\ in\ \text{Table 3-121}$$

**Table 3-121 Gross Seasonal Peak Demand Savings**

| Existing DHW Type | $\Delta kW_{Summer}$ (≤ 55 gallons) | $\Delta kW_{Winter}$ (≤ 55 gallons) | $\Delta kW_{Summer}$ (> 55 gallons) | $\Delta kW_{Winter}$ (> 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 |

## ***Calculation Parameters***

**Table 3-122 Calculation Parameters**

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| ΔkWh | Annual electric energy savings | Lookup in Table 3-120 | kWh/yr | [1] |
| $\Delta Gal_{Oil}$ | Annual oil savings | Lookup in Table 3-120 | Gals | |
| $\Delta Gal_{Propane}$ | Annual propane savings | Lookup in Table 3-120 | Gals | |
| $\Delta kW_{Summer}$ | Summer electric demand savings | Lookup in Table 3-121 | kW | [1] |
| $\Delta kW_{Winter}$ | Winter electric demand savings | Lookup in Table 3-121 | kW | [1] |

## ***Calculation Examples***

*Retrofit Gross Energy Savings Example*

*A 50 Gallon HPWH replaces an electric resistance water heater. What are the annual and peak day savings?*

$$\Delta kWh = 1818\ kWh$$

$$\Delta kW_{Summer} = 0.296\ kW$$

$$\Delta kW_{Winter} = 0.234\ kW$$

*Lost Opportunity Gross Energy Savings 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:*

$$\Delta kWh = 961\ kWh$$

$$\Delta kW_{Summer} = 0.175\ kW$$

$$\Delta kW_{Winter} = 0.134\ kW$$

*For oil savings:*

$$\Delta Gal_{Oil} = 15.5\ Gal$$

*For propane savings:*

$$\Delta Gal_{Propane} = 23.54\ Gal$$

## ***Measure Life***

**Table 3-123 Peak Factors**

| Measure | Retrofit RUL | Lost Opportunity EUL | Ref |
|---|---|---|---|
| Heat Pump Water Heater | 5 | 15 | [3] |

## ***Peak Factors***

**Table 3-124 Peak Factors**

| Measure Type | Summer Coincidence Factor | Winter Coincidence Factor | Ref |
|---|---|---|---|
| Domestic Hot Water | 11.47% | 17.47% | [4] |

## ***Load Shapes***

**Table 3-125 Load Shapes**

| Measure Type | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % |
|---|---|---|---|---|
| Water Heating – HP | 41.88% | 31.05% | 15.56% | 11.50% |

## ***Realization Rates***

**Table 3-126 Realization Rates**

| | Gross Realization % | | | | FR & SO [2] | | Net Realization % | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Measure | kWh or CCF | Winter Seasonal Peak kW or Peak | Summer Seasonal Peak kW | Delivered Fuels MMBtu | Free-ridership | Spill-over | kWh or CCF | Winter Seasonal Peak kW or Peak | Summer Seasonal Peak kW | Delivered Fuels MMBtu |

| | Gross Realization % | | | | FR & SO [2] | | Net Realization % | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Day CCF | | | | | | Day CCF | | |
| Heat pump hot water heater | 100.0% | 100.0% | 100.0% | 100.0% | 24.0% | 1.0% | 77.0% | 77.0% | 77.0% | 77.0% |

## ***References***


[1] West Hill Energy and Computing, EMI Consulting & Lexicon Energy Consulting. Jul. 19, 2018. "R1614/R1613 CT HVAC and Water Heater Process and Impact Evaluation." pp. 8.6-8.8.

[2] Michaels Energy. Jun. 26, 2020. "Efficiency Maine HPWH Free-ridership and Baseline Assessment Results Memo." available online at: https://www.efficiencymaine.com/docs/Heat-Pump-Water-Heater-Free-ridership-and-Baseline-Assessment.pdf

[3] Michaels Energy. 2022. "X2001A: Connecticut Measure Life/EUL Update Study-Residential Measures."

[4] DNV. 2021. "X1931-2 Load Shape and Coincidence Factor Research." Connecticut Energy Efficiency Board (EEB) and Evaluation Administrators.


## ***Changes from Last Version***

- Formatting updates.

### 3.3.5 SOLAR WATER HEATER

| | |
|---|---|
| Market | Residential |
| Baseline Type | Lost Opportunity |
| Category | Water Heating |

***Description***

Installation of a solar water heater to displace residential hot water load.

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.

Solar Pathfinder is a residential energy analysis software which 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.

***Annual Energy Savings Algorithm***

*Lost Opportunity Gross Energy Savings, Electric*

- Based on the Solar Path Finder (SPF) report.

*Lost Opportunity Gross Energy Savings, Electric*

- Based on the SPF report.

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

- Based on the SPF report.

*Lost Opportunity Gross Peak Day Savings, Natural Gas*

- Based on the SPF report.

## *Calculation Parameters*

Table 3-127 presents key parameters to be used in the SPF energy savings calculations.

**Table 3-127 Calculation Parameters**

| Parameter | Description | Value | Units | Ref |
|---|---|---|---|---|
| No. of Occupants | Number of occupants in the home | Site-specific | N/A | |
| No. of Storage tanks | Number of water heater storage tanks | Site-specific | N/A | |
| Storage tank capacity | Size of storage tanks | Site-specific | Per SPF software | |
| Efficiency | Efficiency of back-up system | Site-specific | Per SPF software | |
| SRCC rating | SRCC "C" Mildly Cloudy Day rating | C | N/A | |

## *Measure Life*

**Table 3-128 Measure Life**

| Equipment Type | Measure Life | Ref |
|---|---|---|
| Retirement | N/A | N/A |
| Lost Opportunity | 20 | [3] |

## *Peak Factors*

**Table 3-129 Peak Factors**

| Measure | Summer Coincidence Factor | Winter Coincidence Factor | Ref |
|---|---|---|---|
| Domestic Hot Water | 11.47% | 17.47% | [2] |

## *Load Shapes*

**Table 3-130 Load Shapes**

| End Use | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % | Ref |
|---|---|---|---|---|---|
| Water Heating - Electric | 43.26% | 29.72% | 16.19% | 10.82% | [2] |
| Water Heating - HP | 41.88% | 31.05% | 15.56% | 11.50% | [2] |

## *Non-Energy Impacts*

Increases a home's value.

## *Realization Rates and Net Impact Factors*

**Table 3-131 Realization Rates**

| | Gross Realization % | | | | FR & SO | | Net Realization % | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Measure | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Delivered Fuels MMBtu | Free-ridership | Spill-over | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Delivered Fuels MMBtu |
| Other measures | 100.0% | 100.0% | 100.0% | 100.0% | 0.0% | 0.0% | 100.0% | 100.0% | 100.0% | 100.0% |

## *References*

[1] Solar Pathfinder solar thermal tool www.solarpathfinder.com

[2] DNV. 2021. “X1931-2 Load Shape and Coincidence Factor Research.” Connecticut Energy Efficiency Board (EEB) and Evaluation Administrators.

[3] Tim Merrigan, Solar Thermal Systems Analysis, National Renewable Energy Laboratory, available online at: https://www1.eere.energy.gov/solar/pdfs/solar_tim_merrigan.pdf.

## *Changes from Last Version*

- Formatting updates.

## 3.3.6 PIPE INSULATION

| | |
|---|---|
| Market | Residential |
| Baseline Type | Retrofit |
| Category | Water Heating |

***Description***

Installation of insulation on domestic hot water (DHW) pipes and or heating pipes in unconditioned basements to reduce heat loss.

Annual savings for DHW pipes estimated based on pipe size. The savings values are per foot of hot pipe coming from the water heater in unconditioned space and are based on NAIMA's 3E Plus software as recommended by Nexant's Home Energy Solutions 2011 Evaluation Report [1], [2].

The savings should be limited to the first 6 linear feet of installed pipe insulation per water heater [4].

***Annual Energy Savings Algorithm***

*Annual Gross Energy Savings, Electric*

*Heating:*

$$\Delta kWh_H = AWH_H \times L$$

*Water Heating:*

$$\Delta kWh_{DHW} = AKWH_{DHW} \times L$$

*Annual Gross Energy Savings, Natural Gas*

*Heating:*

$$\Delta FF_H = ACCF_H \times L$$

*Water Heating:*

$$\Delta CCF_{DHW} = ACCF_{DHW} \times L$$

*Annual Gross Energy Savings, Oil*

*Heating:*

$$\Delta OG_{H} = AOG_{H} \times L$$

*Water Heating:*

$$\Delta OG_{DWH} = AOG_{DWH} \times L$$

*Annual Gross Energy Savings, Propane*

*Heating:*

$$\Delta PG_{H} = APG_{H} \times L$$

*Water Heating:*

$$\Delta PG_{DWH} = APG_{DWH} \times L$$

*Gross Seasonal Peak Demand Savings, Electric*

$$\Delta kW_{summer} = \frac{\Delta kWh \times CF_{summer}}{1000}$$

$$\Delta kW_{winter} = \frac{\Delta kWh \times CF_{winter}}{1000}$$

*Gross Peak Day Savings, Natural Gas*

$$\Delta CCF_{PD} = \Delta CCF \times PDF$$

## ***Calculation Parameters***

**Table 3-132 Calculation Parameters**

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| ΔkWh | Annual electric energy savings | Calculated | kWh | |
| ΔCCF | Annual natural gas energy savings | Calculated | CCF | |
| $\Delta Gal_{oil}$ | Annual oil savings | Calculated | Gal | |
| $\Delta Gal_{propane}$ | Annual propane savings | Calculated | Gal | |
| $\Delta kW_{summer}$ | Summer peak demand savings, electric | Calculated | kW | |
| $\Delta kW_{winter}$ | Winter peak demand savings, electric | Calculated | kW | |
| $\Delta CCF_{PD}$ | Peak day savings, natural gas | Calculated | CCF | |

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| L | Length of pipe insulation | Site-specific | Feet | |
| AKWH | Annual kWh savings coefficient | Heating: Table 3-133<br>DHW: Table 3-134 | kWh/ft | |
| ACCF | Annual natural gas savings coefficient | | CCF/ft | |
| AOG | Annual oil savings coefficient | | Gal/ft | |
| APG | Annual propane savings coefficient | | Gal/ft | |
| $CF_{winter}$ | Winter seasonal coincidence factor, heating | Table 3-136 | W/kWh | [3] |
| $CF_{summer}$ | Summer seasonal coincidence factor, heating | | W/kWh | [3] |
| $PDF_H$ | Peak day factor for heating pipes | 0.00977 | N/A | |
| $PDF_{DHW}$ | Peak day factor for DHW pipes | 0.00321 | N/A | |
| Conversion factor | Watts per kWh | 1,000 | W/kWh | |

**Table 3-133 Savings per Linear Foot of Heating Pipe Insulation**

| Pipe Diameter (inches) | Electric - $AKWH_H$ (kWh/ft) | Natural Gas - $ACCF_H$ (CCF/ft) | Oil - $AOG_H$ (Gallons/ft) | Propane - $APG_H$ (Gallons/ft) |
|---|---|---|---|---|
| ¾" (0.75) | 12.9 | 0.5 | 0.4 | 0.6 |
| 1" (1.00) | 16.0 | 0.6 | 0.5 | 0.7 |
| 1 ¼" (1.25) | 19.6 | 0.8 | 0.6 | 0.9 |
| 1 ½" (1.50) | 22.2 | 0.9 | 0.7 | 1.0 |
| 2" (2.00) | 57.74 | 1.91 | 1.42 | 2.16 |

**Table 3-134 Savings per Linear Foot of DHW Pipe Insulation**

| Pipe Diameter (inches) | Electric - $AKWH_{DWH}$ (kWh/ft) | Natural Gas - $ACCF_{DWH}$ (CCF/ft) | Oil - $AOG_{DWH}$ (Gallons/ft) | Propane - $APG_{DWH}$ (Gallons/ft) |
|---|---|---|---|---|
| ½" (0.50) | 12.1 | 0.55 | 0.40 | 0.60 |
| ¾" (0.75) | 18.1 | 0.81 | 0.58 | 0.88 |

## ***Calculation Examples***

*Example 1: Gross Energy Savings*

*Five feet of pipe insulation are installed on a ½" diameter hot water pipe. The home has oil hot water heating. What are the annual energy savings?*

$$\Delta Gal_{Oil} = AOG \times L$$

$$\Delta Gal_{Oil} = 0.40\frac{Gal}{ft} \times 5ft = 2.0\frac{Gal}{yr}\ of\ Oil$$

*Example 2: Peak Day Energy Savings*

*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?*

Calculate ΔkWh:

$$\Delta kWh = AKWH \times L$$

$$\Delta kWh = 12.9\frac{kWh}{ft} \times 5ft = 64.7\frac{kWh}{yr}$$

Calculate summer peak demand savings:

$$\Delta kW_{Summer} = \frac{\Delta kWh \times CF_S}{1{,}000}$$

$$\Delta kW_{Summer} = \frac{64.7\ \Delta kWh \times 0.1147\frac{W}{kWh}}{1{,}000\frac{W}{kW}} = 0.0074\ kW$$

Calculate winter peak demand savings:

$$\Delta kW_{Winter} = \frac{\Delta kWh \times CF_W}{1{,}000}$$

$$\Delta kW_{Winter} = \frac{64.7\ kWh \times 0.1747\frac{W}{kWh}}{1{,}000\frac{W}{kW}} = 0.0113\ kW$$

## ***Measure Life***

**Table 3-135 Measure Life**

| Equipment Type | Retirement RUL | Lost Opportunity EUL | Ref |
|---|---|---|---|
| Pipe Insulation | N/A | 15 | [5] |

## Peak Factors

**Table 3-136 Peak Factors**

| Equipment Type | Summer Coincidence Factor | Winter Coincidence Factor | Ref |
|---|---|---|---|
| Heating | 0% | 57% | [3] |
| DHW | 11.47% | 17.47% | [3] |

## Load Shapes

**Table 3-137 Load Shapes**

| End Use | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % | Ref |
|---|---|---|---|---|---|
| Heating | 47.23% | 52.77% | 0.00% | 0.00% | [6] |
| Water Heating - Electric | 43.26% | 29.72% | 16.19% | 10.82% | [6] |
| Water Heating - HP | 41.88% | 31.05% | 15.56% | 11.50% | [6] |

## Non-Energy Impacts

There are no other resource impacts identified for this measure.

## Realization Rates

**Table 3-138 Realization Rates**

| | Gross Realization | | | | FR and SO [4] | | Net Realization | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Measure | kWh or CCF | Winter Peak kW or Peak Day CCF | Summer Peak kW | Delivered Fuels MMBtu | FR | SO | kWh or CCF | Winter Peak kW or Peak Day CCF | Summer Peak kW | Delivered Fuels MMBtu |
| Water pipe wrap, HES IE | 100.0% | 100.0% | 100.0% | 100.0% | 100% | 0.0% | 0.0% | 100.0% | 100.0% | 100.0% |
| Water pipe wrap, HES [7] | 100.0% | 100.0% | 100.0% | 100.0% | 28% | 7% | 76.6% | 76.6% | 76.6% | 76.6% |

## References

[1] NAIMA, 3E Plus software tool, Version 4.1, Released 2021.Last accessed Aug. 19, 2021.

[2] Nexant. Mar. 2011. "Home Energy Solutions Evaluation: Final Report" Connecticut Energy Efficiency Board.

[3] KEMA. Sep. 10, 2010. "Evaluation of the Weatherization Residential Assistance Partnership (WRAP) and Helps Programs, Final Report."

[4] NMR and Cadmus. Dec. 31, 2014. "Impact Evaluation: Home Energy Services—Income-Eligible and Home Energy Services Programs: Volume 2 (R16), Final Report."

[5] California Public Utilities Commission, *2014 Database for Energy-Efficient Resources,* Feb. 4, 2014, available online at: http://www.deeresources.com/files/DEER2013codeUpdate/download/DEER2014-EUL-table-update_2014-02-05.xlsx, last accessed Sep. 3, 2020.

[6] DNV. 2021. "X1931-2 Load Shape and Coincidence Factor Research." Connecticut Energy Efficiency Board (EEB) and Evaluation Administrators.

[7] NMR. R1983 NTG Review Final Memo dated Sep. 12, 2022.


## ***Changes from Last Version***

- Formatting updates.
- Updated installation rate, free ridership and spillover values.

# 3.4 ENVELOPE

## 3.4.1 INFILTRATION REDUCTION TESTING (BLOWER DOOR TEST)

| | |
|---|---|
| Market | Residential |
| Baseline Type | Retrofit |
| Category | Envelope |

### ***Description***

Blower Door Test equipment is used to verify infiltration reduction.

Energy modeling was conducted using Ekotrope RATER 4.0.0 software. Version 4.0.0 is the current version of the software. This tool is accredited by RESNET for HERS energy modeling and approved by the US Department of Energy for Section 45L tax credit verifications. The average energy savings in MMBtu and kWh were estimated from the results of the Ekotrope RATER simulations, then converted to the appropriate fuels using unit conversions and assumed distribution losses.

This methodology is used to estimate infiltration savings only when savings are a result of sealing surfaces that provide direct separation between conditioned and non-conditioned spaces. For multifamily units (defined as more than 4 units) that share common boundaries or connecting hallways, either a guarded blower door test should be performed by pressurizing all adjacent units to isolate the leakage to the outside, or the leakage of the entire structure should be measured using a single test. If an unguarded test of a unit is performed (i.e., individual units or sections of a building are tested) that result should be corrected using the adjustment equation below. This equation adjusts for inter-unit leakage through shared surfaces. For all blower door testing, savings may be subject to a final analysis which may include a billing analysis, calibration, engineering models, or other applicable methods.

**Note**: *These savings are based on envelope reductions only and should not be applied to duct sealing reductions which are addressed as a separate measure (Measure 3.2.11).*

The following assumptions were used to develop this calculation methodology:

- $Calculated\ blower\ door\ CFM\ reduction = BF \times Measured\ CFM\ (Unguarded\ Blower\ Door\ Test)$
- Room A/C cooling savings are derived from factors in references [2], [3], [4]

### ***Annual Energy Savings Algorithm***

*Retrofit Gross Energy Savings, Electric*

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

$$\Delta kWh_H = HERS \times (CFM_{Pre} - CFM_{Post} - DLR50) \times BF$$

$$\Delta kWh_H = kWh/CFM \times (CFM_{Pre} - CFM_{Post} - DLR50) \times BF$$

$$\Delta kWh_H = F_{CFM} \times (CFM_{Pre} - CFM_{Post} - DLR50) \times BF$$

Where,

$$DLR50 = 1.569 \times (LTO\ CFM25_{Pre} - LTO\ CFM25_{Post})$$

$$BF = 0.7818 - 0.0002 \times D + 0.0012 \times F$$

For fossil fuel heating with air handler unit:

$$\Delta kWh_H = HERS \times (CFM_{Pre} - CFM_{Post}) \times BF$$

For homes with cooling

$$\Delta kWh_C = HERS \times (CFM_{Pre} - CFM_{Post}) \times BF$$

*Retrofit Gross Energy Savings, Natural Gas*

$$\Delta CCF_H = HERS \times (CFM_{Pre} - CFM_{Post} - DLR50) \times BF$$

*Retrofit Gross Energy Savings, Oil*

$$\Delta Gal_{Oil,H} = HERS \times (CFM_{Pre} - CFM_{Post} - DLR50) \times BF$$

*Retrofit Gross Energy Savings, Propane*

$$\Delta Gal_{Propane,H} = HERS \times (CFM_{Pre} - CFM_{Post} - DLR50) \times BF$$

*Retrofit Gross Seasonal Peak Demand Savings, Electric*

$$\Delta kW_{Winter} = HERS_{PD} \times (CFM_{Pre} - CFM_{Post} - DLR50) \times BF$$

$$\Delta kW_{Summer} = HERS_{PD} \times (CFM_{Pre} - CFM_{Post} - DLR50) \times BF$$

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

*Retrofit Gross Peak Day Savings, Natural Gas*

$$\Delta CCF_{PD,H} = \Delta CCF_H \times PDF_H$$

## ***Calculation Parameters***

**Table 3-139 Calculation Parameters**

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| $\Delta kWh_H$ | Annual electric savings – heating | Calculated | kWh | |
| $\Delta kWh_C$ | Annual electric savings – cooling | Calculated | kWh | |

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| $\Delta CCF_H$ | Annual natural gas savings - heating | Calculated | CCF | |
| $\Delta Gal_{Oil,H}$ | Annual oil savings – heating | Calculated | Gal | |
| $\Delta Gal_{Propane,H}$ | Annual propane savings – heating | Calculated | Gal | |
| $\Delta CCF_{PD,H}$ | Natural gas peak day savings – heating | Calculated | CCF | |
| $\Delta kW_{Summer}$ | Summer demand savings | Calculated | kW | |
| $\Delta kW_{Winter}$ | Winter demand savings | Calculated | kW | |
| DLR50 | Duct leakage reduction factor at 50 Pa | Calculated | CFM | |
| BF (MF) | Blower door CFM reduction factor, multi-family | Calculated | N/A | |
| BF (SF) | Blower door CFM reduction factor, single family | 1 | N/A | |
| $CFM_{Pre}$ | Infiltration before air sealing measured with the house being negatively pressurized to 50 Pa relative to outdoor conditions | Site-specific | CFM | |
| $CFM_{Post}$ | Infiltration after air sealing measured with the house being negatively pressurized to 50 Pa relative to outdoor conditions | Site-specific | CFM | |
| LTO $CFM25_{Pre}$ | Leakage to outside duct blaster test results, pre-measure | Site-specific | CFM | |
| LTO $CFM25_{Post}$ | Leakage to outside duct blaster test results, post-measure | Site-specific | CFM | |
| D | Shared surface area between conditioned spaces | Site-specific | $ft^2$ | |
| F | Envelope perimeter is used to describe the sum of all the lengths of the edges of the unit, common, and exterior surfaces | Site-specific | ft | |
| HERS | Savings factor at 50 Pa | Lookup in Table 3-140 HERS Savings Factor per CFM Reduction (at 50 Pa) | | [11] |
| $HERS_{PD}$ | Peak demand savings factor | Lookup in Table 3-141 HERSPD Peak Demand Savings Factor per CFM Reduction (at 50 Pa) | kW per CFM reduction | |
| $PDF_H$ | Natural gas peak day factor – heating | 0.00977 | N/A | |

**Table 3-140 HERS Savings Factor per CFM Reduction (at 50 Pa)**

| Measure | HERS | Unit per CFM Reduction | Ref |
|---|---|---|---|
| Electric Resistance Heat | 2.840 | kWh | |
| Heat Pump Heating | 1.257 | kWh | |
| Geothermal Heating | 0.861 | kWh | |
| Air Handler Heating (fan) | 0.112 | kWh | |
| Cooling (central A/C only) | 0.0594 | kWh | |
| Cooling (room A/C: window, sleeve, or PTAC) | 0.0169 | kWh | [5], [6] |
| Natural Gas | 0.118 | CCF | |
| Propane | 0.133 | Gal | |
| Oil | 0.087 | Gal | |
| Fossil Fuel Heating | 0.012 | MMBtu | |

**Table 3-141 $HERS_{PD}$ Peak Demand Savings Factor per CFM Reduction (at 50 Pa)**

| Measure | Season | $HERS_{PD}$ |
|---|---|---|
| Electric Resistance and Heat Pump | Winter | 0.00124 |
| Geothermal – Retrofit | Winter | 0.00038 |
| Central A/C and HP | Summer | 0.00008 |
| Room A/C | Summer | 0.00002 |

## ***Calculation Examples***

*Example 1: Retrofit Gross Energy Savings*

*A blower door test is performed in a 2,400 ft2, 1940's Cape Cod style home in Hartford, Conn. The home is heated primarily by an oil boiler and cooled by a Room A/C. Blower door test equipment is used to measure the infiltration of the home at 50 Pa. The readings on the test equipment show CFMPre of 1,850 and CFMPost of 1,575. No duct sealing measures are performed in between blower door tests. What are the electric and fossil fuel savings for this home?*

Oil heating savings may be calculated using the following equation:

$$\Delta Gal_{Oil,H} = HERS \times (CFM_{Pre} - CFM_{Post} - DLR50) \times BF$$

$$\Delta Gal_{Oil,H} = 0.087 \times (1{,}850 - 1{,}575 - 0.00) \times 1 = 23.9\ Gal$$

Cooling savings may also be claimed as follows:

$$\Delta kWh_C = HERS \times (CFM_{Pre} - CFM_{Post} - DLR50) \times BF$$

$$\Delta kWh_C = 0.0169 \times (1{,}850 - 1{,}575 - 0.00) \times 1 = 4.64\ kWh$$

*Example 2: Retrofit Gross Peak Demand Savings*

*For the above retrofit example, what is the summer demand savings for this home?*

$$\Delta kW_S = HERS_{PD} \times (CFM_{Pre} - CFM_{Post} - DLR50) \times BF$$

$$\Delta kW_S = 0.00002 \times (1{,}850 - 1{,}575 - 0.00) \times 1 = 0.0055\ kW$$

## ***Measure Life***

The measure life for residential blower door test is 20 years.

## ***Peak Factors***

**Table 3-142 Peak Factors**

| Measure | Summer Coincidence Factor | Winter Coincidence Factor | Ref |
|---|---|---|---|
| Infiltration Reduction Testing (Blower Door Test) | 100% | 100% | [4] |

## ***Load Shapes***

**Table 3-143 Load Shapes [4]**

| End Use | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % |
|---|---|---|---|---|
| Cooling - Central AC | 4.83% | 4.33% | 54.40% | 36.45% |
| Cooling - Room AC | 1.75% | 2.10% | 51.81% | 44.34% |
| Cooling - Ductless HP | 8.56% | 10.20% | 47.51% | 33.73% |
| Heating | 47.23% | 52.77% | 0.00% | 0.00% |

## *Realization Rates and Net Impact Factors*

**Table 3-144 Realization Rates and Net Impact Factors**

| | Gross Realization | | | | | FR & SO | | Net Realization | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Measure | Energy kWh or CCF | Winter Peak kW or Peak Day CCF | Summer Peak kW | Delivered Fuels, MMBtu | ISR | Free-ridership | Spillover | Energy kWh or CCF | Winter Peak kW or Peak Day CCF | Summer Peak kW | Delivered Fuels, MMBtu | Ref |
| Blower Door Air Sealing, Electric/ Delivered Fuels, HES IE | 50% | 50% | 50% | 50% | 100% | 0.0% | 0.0% | 50% | 50% | 50% | 50% | [8] |
| Blower Door Air Sealing, Gas, HES IE | 50% | 50% | N/A | N/A | 100% | 0.0% | 0.0% | 50% | 50% | N/A | N/A | [8] |
| Blower Door Air Sealing, Electric/ Delivered Fuels, HES | 50% | 50% | 50% | 50% | 100% | 11.0% | 7.0% | 48% | 48% | 48% | 48% | [8] |
| Blower Door Air Sealing, Gas, , HES | 50% | 50% | N/A | N/A | 100% | 11.0% | 7.0% | 48% | 48% | N/A | N/A | [8] |
| MF Blower Door Air Sealing | 98% [172%] | 86% | 100% | 92.5% | 100% | 0.0% | 0.0% | 98% [172%] | 86% | 100% | 92.5% | [9], [10] |

## *References*


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

[2] Nexant Market Research, Inc. 2007. “Market Assessment for ENERGY STAR Room Air Conditioners in Connecticut.” pp. 17-18.

[3] RLW Analytics. 2008. “Final Report: Coincidence Factor Study: Residential Room Air Conditioners.” pp. iv, 22.

[4] ADM Associates, Inc. 2009. “Residential Central A/C Regional Evaluation” pp. 4-4.

[5] O. Faakye & D. Griffiths, *Technical Report: Multifamily Envelope Leakage Model,* Consortium for Advanced Residential Buildings, Feb. 2014.

[6] Steven Winter Associates, Inc. Jul. 26, 2017.”Estimating Energy Savings for Multifamily Air Sealing Measures.”

[7] DNV. 2021. “X1931-2 Load Shape and Coincidence Factor Research.”

[8] West Hill Energy and Computing. 2018. “R1603: HES/HES-IE Impact Evaluation.”, Oct.22, 2019.

[9] TRC. 2021. “CT EEB X1941 Multifamily Impact Evaluation.” Table 6.

[10] NMR and Cadmus. 2014. “Impact Evaluation: Home Energy Services—Income-Eligible and Home Energy Services Programs: Volume 2 (R16).”

[11] “Ekotrope RATER.” Ekotrope, 4.0.0, https://www.ekotrope.com/. Accessed 28 June 2022.

[12] NMR. R1983 Gas Weatherization PSD Review Final Memo dated September 6, 2022
[13] NMR. NTG Review Final Memo dated Sep. 12, 2022.

## ***Changes from Last Version***

- Formatting updates.
- Updated realization rate,  installation rate, free ridership and spillover values.

## 3.4.2 INFILTRATION REDUCTION (PRESCRIPTIVE)

| | |
|---|---|
| Market | Residential |
| Baseline Type | Retrofit |
| Category | Envelope |

***Description***

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 from this measure shall only be claimed if a Blower Door Test (Measure 3.4.1) 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.

***Annual Energy Savings Algorithm***

*Retrofit Gross Energy Savings, Electric*

$$\Delta kWh = Look\ up\ in$$

Table 3-146

*Retrofit Gross Energy Savings, Fossil Fuel*

$$\Delta Btu = Look\ up\ in$$

Table 3-147 $or\ calculate\ as$:

$$\Delta Btu = \Delta kWh \times 3412 / EF$$

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

$$\Delta kW_{Winter} = \Delta kWh \times \frac{CF_W}{1000}$$

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

*Retrofit Gross Peak Day Savings, Natural Gas*

$$\Delta CCF_{PD} = \Delta CCF \times PDF$$

## ***Calculation Parameters***

**Table 3-145 Calculation Parameters**

| Symbol | Description | Values | Units | Ref |
|---|---|---|---|---|
| ΔkWh | Annual electric energy savings | Lookup in Table 3-146 | kWh | [1] |
| ΔCCF | Annual natural gas savings | Lookup in Table 3-147 | ccf/yr | |
| ΔOG | Annual savings for oil heat | Lookup in Table 3-147 | Gal/yr/unit | |
| ΔPG | Annual savings for propane heat | Lookup in Table 3-147 | Gal/yr/unit | |
| ΔBtu | Annual Btu savings | Calculated | Btu | |
| ΔkW | Winter seasonal peak electric demand savings | Calculated | kW | |
| $\Delta CCF_{PD}$ | Peak day natural gas savings | Calculated | ccf | |
| EF | Fossil fuel system efficiency, including distribution loss | Site specific if unknown, use Table 3-148 | N/A | |
| $CF_W$ | Winter coincidence factor | 0.46 | W/kWh | [1] |
| PDF | Peak day factor – natural gas heating | 0.00977 | N/A | |
| $…_{gasket}$ | Installation of air sealing gasket on an electric outlet | | | |
| $…_{door\ kit}$ | Installation of door sweep or door kit | | | |
| $…_{sealing}$ | Foot of caulking, sealing, or polyethylene tape | | | |
| $…_{wx}$ | Window repaired, window weather-stripped, or door weather-stripped | | | |

**Table 3-146 Electric Savings for Infiltration Reduction Measures**

| Savings | Units | Annual Savings for Electric Resistance Heating (kWh) | Annual Savings for Heat Pump (kWh) |
|---|---|---|---|
| $\Delta kWh_{gasket}$ | kWh per gasket | 9 | 4.5 |
| $\Delta kWh_{door\ kit}$ | kWh per sweep | 173 | 86.5 |
| $\Delta kWh_{sealing}$ | kWh per linear ft | 9.9 | 4.95 |
| $\Delta kWh_{wx}$ | kWh per linear ft | 11.5 | 5.75 |

**Table 3-147 Fossil Fuel Savings for Infiltration Reduction Measures**

| Measure | Units | ΔCCF | ΔOG | ΔPG |
|---|---|---|---|---|
| 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 |

**Table 3-148 Heating System Efficiencies**

| Equipment Type | EF |
|---|---|
| Boiler | 80% |
| Furnace (natural gas/propane) | 78% |
| Furnace (oil) | 76% |

## ***Measure Life***

The measure life for infiltration reduction is 15 years [2].

## ***Peak Factors***

**Table 3-149 Peak Factors**

| Measure | Summer Coincidence Factor | Winter Coincidence Factor | Ref |
|---|---|---|---|
| Infiltration reduction (prescriptive) | 0% | 46% | [3] |

## *Load Shapes*

**Table 3-150 Load Shapes**

| Measure | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % | Ref |
|---|---|---|---|---|---|
| Heating | 47.23% | 52.77% | 0.00% | 0.00% | [4] |

## *Non-Energy Benefits*

Increased personal comfort and decreased draftiness.

## *Realization Rates*

**Table 3-151 Realization Rates**

| | Gross Realization % | | | | | FR and SO | | Net Realization % | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Measure | kWh or (ccf) | Winter Seasonal Peak kW or (Peak Day ccf) | Summer Seasonal Peak kW | Delivered Fuels, MMBtu | Installation rate | Free ridership | Spill-over | kWh or (ccf) | Winter Seasonal Peak kW or (Peak Day ccf) | Summer Seasonal Peak kW | Delivered Fuels, MMBtu |
| Prescriptive air sealing, HES-IE [4] | 50% | 50% | 50% | 50% | 100% | 0.0% | 0.0% | 50%% | 50% | 50% | 50% |
| Prescriptive air sealing, HES [4] | 50% | 50% | 50% | 50% | 92% | 28% | 7% | 36.3% | 36.3% | 36.3% | 36.3% |
| MF prescriptive air sealing [4] | 56.5% | 56.5% | 56.5% | 56.5% | 100% | 0.0% | 0.0% | 56.5% | 56.5% | 56.5% | 56.5% |

## *References*


[1] KEMA, Evaluation of the Weatherization Residential Assistance Partnership and Helps Programs (WRAP/Helps), Sep. 10, 2010. *, p. 1-11, Table ES 9.

[2] GDS Associates Inc., *Measure Life Report, Residential and Commercial Industrial Lighting and HVAC Measures*, Jun. 2007.

[3] DNV (2021). X1931-2 Load Shape and Coincidence Factor Research – Final Report.

[4] NMR and Cadmus, *Impact Evaluation: Home Energy Services—Income-Eligible and Home Energy Services Programs: Volume 2 (R16)*, Final Report, Dec. 31, 2014.

[5] NMR. R1983 Gas Weatherization PSD Review Final Memo dated September 6, 2022 and NTG Review Final Memo dated Sep. 12, 2022.

## ***Changes from Last Version***

- Updated FR, SO, installation rate and realization rate.
- Updated winter coincidence factor in peak kW savings formula.
- Formatting changes.

### 3.4.3 WINDOW OR SLIDING GLASS DOOR REPLACEMENT

| | |
|---|---|
| Market | Residential |
| Baseline Type | Retrofit/Lost Opportunity |
| Category | Category |

***Description***

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.

The measure's savings are calculated using the installed area of the replacement window and usage factors develop using RESFEN to model different window/sliding glass door types and heating fuels [1]. The results of this analysis are shown in Table 3-153 and Table 3-154, 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.

Heat pump energy savings are one-half of electric resistance savings based on a 2.0 COP. Since heat pumps use backup resistance heat during winter peak, winter demand savings for heat pumps equal to one-half those of resistance heat demand savings.

The usage values were developed for different fuel types and windows/sliding glass doors using RESFEN [1]. The values from that analysis are shown in the tables.

Room A/C cooling savings are derived from factors found in Ref [3], Ref [4], and Ref [5].

**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.

***Annual Energy Savings Algorithm***

*Area - used in all calculations*

$$A = \frac{D_H \times D_W}{144 \, ^{in^2}/_{ft^2}}$$

*Annual Gross Energy Savings, Electric*

Heating - Electric Resistance

$$\Delta kWh_{H,R} = 2 \times (AEH_b - AEH_{es}) \times A$$

Heating - Heat Pump

$$\Delta kWh_{H,HP} = (AEH_b - AEH_{es}) \times A$$

Cooling – Central A/C

$$\Delta kWh_{C,CAC} = (AEC_b - AEC_{es}) \times A$$

Cooling – Room A/C

$$\Delta kWh_{C,RAC} = (28.3\%) \times \Delta kWh_{C,CAC}$$

*Annual Gross Energy Savings, Natural Gas*

$$\Delta CCF = (AGU_b - AGU_{es}) \times A$$

*Annual Gross Energy Savings, Oil*

$$\Delta Gal_{Oil} = (AOU_b - AOU_{es}) \times A$$

*Annual Gross Energy Savings, Propane*

$$\Delta Gal_{Propane} = (APU_b - APU_{es}) \times A$$

*Gross Seasonal Peak Demand Savings, Electric*

Heating - Electric Resistance

$$\Delta kW_{winter,R} = \left(2 \times (AEH_b - AEH_{es}) \times \frac{PF_w}{1000}\right) \times A$$

Heating - Heat Pump

$$\Delta kW_{winter,HP} = \left((AEH_b - AEH_{es}) \times \frac{PF_w}{1000}\right) \times A$$

Cooling – Central A/C

$$\Delta kW_{summer,CAC} = \left(AEH_b - AEH_{es} \times \frac{CF_w}{1000}\right) \times A$$

Cooling – Room A/C

$$\Delta kW_{summer,RAC} = (25.1\%) \times \Delta kW_{summer,CAC}$$

*Gross Peak Day Savings, Natural Gas*

$$PD_H = \Delta CCF_H \times PDF_H$$

***Calculation Parameters***

**Table 3-152 Calculation Parameters**

| Symbol | Description | Values | Units | Ref |
|---|---|---|---|---|
| A | Area of the window/sliding glass door | Calculated | ft2 | |
| ΔkWhC | Annual electric energy savings - cooling | Calculated | kWh/yr | |
| ΔkWhH | Annual electric energy savings - heating | Calculated | kWh/yr | |
| AEC | Annual electric cooling usage | Table 3-153 | kWh/ft2/yr | [1] |
| AEH | Annual electric heating usage | Table 3-153 | kWh/ft2/yr | [1] |
| ΔCCFH | Annual natural gas savings - heating | Calculated | ccf/yr | |
| AGU | Annual natural gas usage | Table 3-154 | ccf/ ft2/yr | [1] |
| ΔOGH | Annual oil savings - heating | Calculated | gal/yr | |
| AOUH | Annual oil usage | Table 3-154 | gal/ft2/yr | [1] |
| ΔPGH | Annual propane savings - heating | Calculated | gallons/yr | |
| APU | Annual propane usage | Table 3-154 | gal/ft2/yr | [1] |
| CFs | Summer seasonal coincidence factor | 0.69 | W/kWh | [7] |
| DH | Height of the window/sliding glass door | Input | inch | |
| DW | Width of the window/sliding glass door | Input | inch | |
| CFw | Winter coincidence factor | 0.57 | W/kWh | [7] |
| kWPDwinter | Winter coincident peak demand savings | | kW | |
| kWPDsummer | Summer coincident peak demand savings | | kW | |

| Symbol | Description | Values | Units | Ref |
|---|---|---|---|---|
| PDFH | Peak day factor - heating | 0.00977 | | [7] |
| PDH | Peak day savings - heating | | | |
| 28.3% | Room AC Derating factor, Gross Energy Savings | Calculated based on Blower Door Ratio Room AC to Central AC | | |
| 25.1% | Room AC Derating factor, Gross Peak Demand Savings | Calculated based on Blower Door Ratio Room AC to Central AC | | |
| …b | Baseline | | | |
| …es | ENERGY STAR | | | [6] |
| …HP | Heat pump heating only | | | |
| …R | Electric resistance heating only | | | |
| …CAC | Central A/C (cooling only) | | | |
| …RAC | Room A/C (cooling only) | | | |

**Table 3-153 Annual Electric Energy Usage**

| Window /Sliding Glass Door Type | AEH (kWh/ft$^2$) | AEC (kWh/ft$^2$) |
|---|---|---|
| Single pane (“leaky”) | 35.50 | 6.86 |
| Single pane (“tight”) (baseline) | 32.96 | 6.76 |
| Double pane (or single with storm) | 28.69 | 6.34 |
| ENERGY STAR - double pane | 27.58 | 5.09 |
| ENERGY STAR – triple pane | 24.85 | 3.01 |

**Table 3-154 Annual Fossil Fuel Energy Usage**

| Window/Sliding Glass Door Type | AGU (Ccf/ft$^2$) | AOU (gal/ft$^2$) | APU (gal/ft$^2$) |
|---|---|---|---|
| Single pane (“leaky”) | 2.76 | 1.99 | 3.02 |
| Single pane (“tight”) | 2.50 | 1.80 | 2.73 |

| | | | |
|---|---|---|---|
| Double pane (or single with storm) | 2.05 | 1.48 | 2.24 |
| ENERGY STAR – double pane | 1.95 | 1.40 | 2.13 |
| ENERGY STAR – triple pane | 1.67 | 1.20 | 1.82 |

***Calculation Examples***

*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.*

*Retrofit Gross Energy Savings, Example*

Area

$$A = \frac{24\ in \times 36in}{144\ {in^2}/{ft^2}} = 6\ sq\ ft$$

Heating Savings

$$\Delta kWh_{H,R} = 2 \times (AEH_b - AEH_{es}) \times A$$

$$\Delta kWh_{H,R} = 2 \times (32.96 - 27.58) \times 6$$

$$\Delta kWh_{H,R} = 10.76 \times 6$$

$$\Delta kWh_{H,R} = 64.56\ kWh$$

Cooling Savings

$$\Delta kWh_{C,CAC} = (AEC_b - AEC_{es}) \times A$$

$$\Delta kWh_{C,CAC} = (6.76 - 5.09) \times 6$$

$$\Delta kWh_C = 1.67 \times 6$$

$$\Delta kWh_C = 10.02\ kWh$$

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

Winter – Resistance Heat

$$\Delta kW_{winter} = \left(2 \times (AEH_b - AEH_{es}) \times \frac{CF_w}{1000}\right) \times A$$

$$\Delta kW_{winter} = \left(10.76 \times \frac{0.570}{1000}\right) \times 6$$

$$\Delta kW_{winter} = (64.56 \times 0.00057) \times 6$$

$$\Delta kW_{winter} = .0061 \times 6$$

$$\Delta kW_{winter} = 0.0366\ kW$$

Summer – Central A/C

$$\Delta kW_{summer} = \left((AEH_b - AEH_{es}) \times \frac{CF_s}{1000}\right) \times A$$

$$\Delta kW_{summer} = \left((6.76 - 5.09) \times \frac{0.69}{1000}\right) \times 6$$

$$\Delta kW_{summer} = (1.67 \times 0.00069) \times 6$$

$$\Delta kW_{summer} = (1.67 \times 0.00069) \times 6$$

$$\Delta kW_{summer} = 0.001 \times 6$$

$$\Delta kW_{summer} = 0.0069$$

***Measure Life***

**Table 3-155 Measure Life**

| Equipment Type | Measure Life | Ref |
|---|---|---|
| Window replacement EUL | 25 | [8] |

***Peak Factors***

**Table 3-156 Peak Factors**

| Measure | Summer Coincidence Factor | Winter Coincidence Factor | Ref |
|---|---|---|---|
| Window or sliding glass door replacement | 74% | 46% | [7] |

***Load Shapes***

**Table 3-157 Load Shapes**

| Measure | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % | Ref |
|---|---|---|---|---|---|
| Residential General | 30.30% | 36.30% | 15.50% | 17.90% | [7] |

***Non-Energy Impacts***

**Table 3-158 Residential NEIs [9]**

| NEI | HES | HES-IE | Rebate | Multifamily |
|---|---|---|---|---|
| Comfort | 0.25 | 0.17 | 0.31 | 0.14 |
| Outside noise | 0.04 | 0.05 | 0.06 | |
| Appliance noise | 0.05 | 0.06 | 0.15 | |
| Maintenance | 0.07 | 0.08 | 0.18 | 0.15 |
| Home value | 0.12 | 0.07 | 0.24 | 0.09 |
| Home appearance | 0.03 | 0.06 | 0.04 | |
| Home safety | 0.05 | 0.07 | 0.05 | 0.21 |
| Lighting quality | 0.08 | 0.14 | | |
| Complaints | 0 | 0 | 0 | 0.08 |
| **Total** | **0.69** | **0.70** | **1.03** | **0.67** |

***Realization Rates***

**Table 3-159 Realization Rates**

| | Gross Realization | | | | | FR and SO | | Net Realization | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Measure | kWh or CCF | Winter Seasonal Peak kW or Peak Day CCF | Summer Seasonal Peak kW | Delivered Fuels MMBtu | ISR | Free-ridership | Spill-over | kWh or CCF | Winter Seasonal Peak kW or Peak Day CCF | Summer Seasonal Peak kW | Delivered Fuels MMBtu |
| Other measures | 100% | 100% | 100% | 100% | 100% | 0% | 0% | 100% | 100% | 100% | 100% |
| Energy-efficient windows, HES [10] | 100% | 100% | 100% | 100% | 98% | 33% | 7% | 72.5% | 72.5% | 72.5% | 72.5% |

***References***


[1] Lawrence Berkeley National Laboratory, RESFEN 6.0 computer software, August 23, 2021, available online at: http://windows.lbl.gov/software.

[2] KEMA, *Evaluation of the Weatherization Residential Assistance Partnership and Helps Programs (WRAP/Helps)*, Sep. 10, 2010.

[3] Nexus Market Research, Inc. 2007. "Market Assessment for ENERGY STAR Room Air Conditioners in Connecticut." pp. 17-18. Northeast Utilities – Connecticut Light and Power, The United Illuminating Company.

[4] RLW Analytics, "*Final Report: Coincidence Factor Study: Residential Room Air Conditioners*," Middletown, CT, 2008, pp. iv and 22.

[5] ADM Associates, Inc. 2009. "Residential Central A/C Regional Evaluation." pp. 4-4.

[6] ENERGY STAR Program Requirements for Residential Windows, Doors, and Skylights – Partner Commitments, Jan. 1, 2016.

[7] DNV. 2021. "X1931-2 Load Shape and Coincidence Factor Research." Connecticut Energy Efficiency Board (EEB) and Evaluation Administrators.

[8] GDS Associates Inc. 2007. "Measure Life Report, Residential and Commercial Industrial Lighting and HVAC Measures." Table 1.

[9] NMR Group, Inc. 2016. "Project R4 HES/HES-IE Process Evaluation and R31 Real-Time Research." CT EEB, Eversource, and United Illuminating. R4HES-HESIE_Process_Eval2016_0413_Final (energizect.com)

[10] NMR. R1983 NTG Review Final Memo dated Sep. 12, 2022.


***Changes from Last Version***

- Formatting updates.
- Updated installation rate, free ridership and spillover values.

### 3.4.4 INSTALL STORM WINDOW

| | |
|---|---|
| Market | Residential |
| Baseline Type | Retrofit |
| Category | Envelope |

***Description***

Installation of a storm window on the interior or exterior of the existing single-pane window.

The savings for this measure are calculated using the installed storm window area and usage factors develop using RESFEN to model different window types and heating fuels [1]. The results of that analysis are shown in Table 3-161 and Table 3-162. 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.*

***Annual Energy Savings Algorithm***

*Annual Retrofit Gross Energy Savings, Electric*

Heat pump savings are approximated as one-half of electric resistance savings, based on the ratio of efficiencies. Since heat pumps use backup resistance heat during winter peak, winter demand savings for heat pumps equals resistance heat demand savings

$$\Delta kWh_{H,R} = \left(\mathrm{AEH}_b - \mathrm{AEH}_{dp}\right) \times A$$

$$\Delta kWh_{H,HP} = \frac{\left(\mathrm{AEH}_b - \mathrm{AEH}_{dp}\right) \times A}{2}$$

Where,

$$A = \frac{D_H \ x \ D_W}{144 \ {}^{\mathrm{in}^2}/_{\mathrm{ft}^2}}$$

*Annual Retrofit Gross Energy Savings, Natural Gas*

$$\Delta CCF_H = \left(\mathrm{AGU}_b - \mathrm{AGU}_{dp}\right) \times A$$

Where,

$$A = \frac{D_H \ x \ D_W}{144 \ \text{in}^2/_{\text{ft}^2}}$$

*Annual Retrofit Gross Energy Savings, Oil*

$$\Delta OG_H = \left(\text{A}OU_b - \text{A}OU_{dp}\right) \times A$$

Where,

$$A = \frac{D_H \ x \ D_W}{144 \ \text{in}^2/_{\text{ft}^2}}$$

*Retrofit Gross Energy Savings, Propane*

$$\Delta PG_H = \left(\text{A}PU_b - \text{A}PU_{dp}\right) \times A$$

Where,

$$A = \frac{D_H \ x \ D_W}{144 \ \text{in}^2/_{\text{ft}^2}}$$

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

$$\Delta kW_{Winter} = \Delta kWh_H \times \frac{PFW}{1000 \, ^{W}/_{kWh}}$$

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

## ***Calculation Parameters***

**Table 3-160 Calculation Parameters**

| Symbol | Description | Units | Values | Ref |
|---|---|---|---|---|
| $\Delta kWh_H$ | Annual electric energy savings - heating | kWh | Calculated | |
| $\Delta CCF_H$ | Annual gas savings - heating | CCF | Calculated | |
| $\Delta OG_H$ | Annual oil savings - heating | Gallons | Calculated | |
| $\Delta PG_H$ | Annual propane savings - heating | Gallons | Calculated | |
| $\Delta kW_{Summer}$ | Summer coincident peak demand savings | kW | Calculated | |
| $\Delta kW_{Winter}$ | Winter coincident peak demand savings | kW | 0 | |
| A | Area of the window | $ft^2$ | Calculated | |
| $D_H$ | Height of the window | inch | Site-specific | |
| $D_W$ | Width of the window | inch | Site-specific | |
| AEC | Annual electric cooling usage | $kWh/ft^2$ | Table 3-161 | [1] |
| AEH | Annual electric heating usage | $kWh/ft^2$ | Table 3-161 | [1] |

| Symbol | Description | Units | Values | Ref |
|---|---|---|---|---|
| AGU | Annual natural gas usage | ccf/ft$^2$ | Table 3-162 | [1] |
| AOU | Annual oil usage | gal/ft$^2$ | Table 3-162 | [1] |
| APU | Annual propane usage | gal/ft$^2$ | Table 3-162 | [1] |
| PFW | Winter peak factor | W per kWh | 0.570 | [2] |
| $..._b$ | Baseline | | | |
| $..._{dp}$ | Double pane | | | |
| $..._{HP}$ | Heat pump heating | | | |
| $..._R$ | Resistance heating | | | |

**Table 3-161 Annual Electric Energy Use**

| Window Type | AEH (kWh/ft$^2$) | AEC (kWh/ft$^2$) |
|---|---|---|
| Single pane ("leaky") | 35.50 | 6.86 |
| Single pane ("tight") | 32.96 | 6.76 |
| Double pane (or single with storm) | 28.69 | 6.34 |

**Table 3-162 Annual Fossil Fuel Energy Use**

| Window Type | AGU (kWh/ft$^2$) | AOU (gal/ft$^2$) | APU (gal/ft$^2$) |
|---|---|---|---|
| Single pane ("leaky") | 2.76 | 1.99 | 3.02 |
| Single pane ("tight") | 2.50 | 1.80 | 2.73 |
| Double pane (or single with storm) | 2.05 | 1.48 | 2.24 |

## ***Calculation Examples***

*Retrofit Gross Energy Savings Example*

*A new storm window is added to a single-pane 24" x 36" window heated by electric resistance.*

$$A = \frac{24\ in\ \ x\ 36\ in}{144\ {in^2}/{ft^2}} = 6\ sq\ ft$$

$\Delta kWh_H$= 4.27 x 6 = 25.62 kWh

*Retrofit Gross Peak Demand Savings, Example*

*For the above example with electric resistance heat and Central A/C, demand savings are as follows:*

$$\Delta kW_{Winter} = 0.0064\ {}^{kW}/_{sf}\ x\ 6\ sqft = 0.038\ kW$$

$$\Delta kW_{Winter} = 0.00243 \text{ x } 6 \text{ sq ft}$$

$$= 0.01458 \text{ kW}$$

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

## *Measure Life*

The measure life for residential storm windows is 20 years.

## *Peak Factors*

**Table 3-163 Peak Factors**

| Measure | Summer Coincidence Factor | Winter Coincidence Factor | Ref |
|---|---|---|---|
| Install storm window | 0% | 46% | [3] |

## *Load Shapes*

**Table 3-164 Load Shapes**

| Measure | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % | Ref |
|---|---|---|---|---|---|
| Residential Heating | 47.23% | 52.77% | 0.00% | 0.00% | [3] |

## *Non-Energy Impacts*

There are no other resource impacts identified for this measure.

## *Realization Rates*

**Table 3-165 Realization Rates**

| | Gross Realization % | | | | FR & SO | | Net Realization % | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 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 |
| Other Measures | 100.0% | 100.0% | 100.0% | 100.0% | 0.0% | 0.0% | 100.0% | 100.0% | 100.0% | 100.0% |

## ***References***


[1] Lawrence Berkeley National Laboratory, RESFEN 6.0 computer software, August 23, 2021, Available online at: http://windows.lbl.gov/software.

[2] KEMA. 2010. "Evaluation of the Weatherization Residential Assistance Partnership and Helps Programs (WRAP/Helps)."

[3] DNV. 2021. "X1931-2 Load Shape and Coincidence Factor Research – Final Report."


## ***Changes from Last Version***

- Formatting updates.

## 3.4.5 INSULATE ATTIC OPENINGS

| | |
|---|---|
| Market | Residential |
| Baseline Type | Retrofit |
| Category | Envelope |

***Description***

Baseline assumptions included no insulation. This is for uninsulated attic hatch, attic stairs, or whole house fan.

The energy savings are estimated in two parts: conductive savings and infiltration reduction savings. The conductive savings are calculated using a degree day analysis. The infiltration reduction will be included in the Infiltration Reduction Testing (Measure 3.4.1 Infiltration Reduction Testing (Blower Door Test)) whenever possible or be estimated based on the KEMA Evaluation in combination with ASHRAE 1997 Fundamentals Handbook [1] [5].

***Reminder***: *Only include infiltration savings if not included in blower door measure.*

The following assumptions were used to develop this calculation methodology:

- The fossil fuel savings are calculated using an equipment efficiency of 75%.
- ASHRAE 1997 Handbook – Fundamentals, p. 25.16, was used to calculate relative infiltration of these measures to the infiltration savings [5].

  Baseline assumptions:

  - $R_{existing}$ = 0.61 + 0.47 + 0.61 = 1.69 for hatch and stairs
  - $R_{existing}$ = 0.61 + 0.10 + 0.61 = 1.32 for fan

    Where:

    - 3/8” particle board = R 0.47
    - Air film = 0.61
- 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.

## ***Annual Energy Savings Algorithm***

*Annual Retrofit Gross Energy Savings, Electric*

$$\Delta kWh = \Delta kWh_C + \Delta kWh_I$$

or,

$$\Delta kWh = \frac{\Delta Btu_C + \Delta Btu_I}{C_{kWh}}$$

Where,

$$\Delta Btu = see\ below$$

When calculated using the assumptions in Table 3-166, savings reduce to the values in Table 3 -169 Annual Electric Savings – Conduction and Infiltration.

***Reminder**: Only include infiltration savings ($\Delta kWh_I$) if not included in blower door measure.*

*Annual Retrofit Gross Energy Savings, Natural Gas*

$$\Delta CCF = \frac{\Delta Btu}{E \times C_{NG}}$$

Where,

$$\Delta Btu = see\ below$$

When calculated using the assumptions in Table 3-166, savings reduce to the values in Table 3-170 Annual Fossil Fuel Savings – Conduction and Infiltration

*Annual Retrofit Gross Energy Savings, Oil*

$$\Delta Gal_{Oil} = \frac{\Delta Btu}{E \times C_{Oil}}$$

Where,

$$\Delta Btu = see\ below$$

When calculated using the assumptions in Table 3-166, savings reduce to the values in Table 3-170 Annual Fossil Fuel Savings – Conduction and Infiltration

*Annual Retrofit Gross Energy Savings, Propane*

$$\Delta Gal_{Propane} = \frac{\Delta Btu}{E \times C_{Propane}}$$

Where,

$$\Delta Btu = see\ below$$

When calculated using the assumptions in Table 3-166, savings reduce to the values in Table 3-170 Annual Fossil Fuel Savings – Conduction and Infiltration

*Annual Retrofit Gross Seasonal Peak Demand Savings, Electric*

$$\Delta kW_{Winter} = \Delta kWh \times \frac{PF_W}{1{,}000}$$

When calculated using the assumptions in Table 3-166, savings reduce to the values in Table 3-171 Electric Winter Demand Savings

*Annual Retrofit Gross Peak Day Savings, Natural Gas*

$$\Delta CCF_{PD} = \Delta CCF \times PDF$$

When calculated using the assumptions in Table 3-166, savings reduce to the values in Table 3-172 Natural Gas Peak Day Savings

*Annual Retrofit Gross Energy Savings, Btu*

$$\Delta Btu = \Delta Btu_C + \Delta Btu_I$$

Where,

$$\Delta Btu_C = A \times \left(\frac{1}{R_E} - \frac{1}{R_I}\right) \times HDD \times 24\frac{hr}{day} \times AF$$

$$\Delta Btu_I = follow\ blower\ door\ methodology\ or\ lookup\ in\ \text{Table 3-168}$$

$$A = \frac{D_H \times D_W}{144\frac{in^2}{ft^2}}$$

When calculated using the assumptions in Table 3-166, savings reduce to the values in Table 3-167 Annual Btu Savings - Conductive

***Reminder**: Only include infiltration savings ($\Delta Btu_I$) if not included in blower door measure.*

## *Calculation Parameters*

**Table 3-166 Calculation Parameters**

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| ΔkWh | Annual electric savings | Calculated, lookup in Table *3-169* if unknown | kWh | |
| ΔCCF | Annual natural gas savings – heating | Calculated, lookup in Table 3-170 Annual Fossil Fuel Savings – Conduction and Infiltration if unknown | CCF | |
| $\Delta Gal_{Oil}$ | Annual oil savings – heating | Calculated, lookup in Table 3-170 Annual Fossil Fuel Savings – Conduction and Infiltration if unknown | Gal | |
| $\Delta Gal_{Propane}$ | Annual propane savings – heating | Calculated, lookup in Table 3-170 Annual Fossil Fuel Savings – Conduction and Infiltration if unknown | Gal | |
| $\Delta kW_{Winter}$ | Winter seasonal demand savings – heating | Calculated, lookup in Table 3-171 if unknown | kW | |
| ΔBtu | Annual Btu savings | Calculated, lookup in tables Table 3-167 and Table 3-168 if unknown | Btu | |
| $\Delta CCF_{PD}$ | Peak day savings – heating | Calculated, lookup in Table 3-172 if unknown | CCF | |
| $..._C$ | Due to conductive heat transfer | N/A | N/A | |
| $..._I$ | Due to air infiltration | N/A | N/A | |
| A | Total area of thermal barrier | Calculated, lookup in Table 3-167 Annual Btu Savings - Conductive if unknown | $ft^2$ | |
| $R_E$ | Effective R-value – existing | Calculated, lookup in Table 3-167 Annual Btu Savings - Conductive if unknown | $ft^2 \cdot hr \cdot °F/Btu$ | |
| $R_I$ | Effective R-value – installed | Calculated, lookup in Table 3-167 Annual Btu Savings - Conductive if unknown | $ft^2 \cdot hr \cdot °F/Btu$ | |
| $D_H$ | Attic opening dimension – height | Site-specific | in | |
| $D_W$ | Attic opening dimension – width | Site-specific | in | |
| HDD (UI, SCG, CNG) | Heating degree days – UI, SCG, CNG | 5,165 | °F·day | [2] |
| HDD (Eversource) | Heating degree days – Eversource | 5,473 | °F·day | [2] |
| AF | Adjustment factor | 0.61 | N/A | [3] |
| E | Equipment efficiency | Site-specific, use 0.75 if unknown | N/A | |
| $PF_W$ | Peak factor – winter | 0.57 | W/kWh | [1] |
| $PDF_H$ | Peak day factor – natural gas heating | 0.00977 | N/A | |
| $C_{kWh}$ | Electric conversion constant | 3,412 | Btu/kWh | |

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| $C_{NG}$ | Natural gas conversion constant | 102,900 | Btu/CCF | |
| $C_{Oil}$ | Oil conversion constant | 138,690 | Btu/Gal | |
| $C_{Propane}$ | Propane conversion constant | 91,330 | Btu/Gal | |

**Table 3-167 Annual Btu Savings - Conductive**

| Insulation Measure | $R_E$ | $R_I$ | A | Eversource $\Delta Btu_C$ | UI, SCG, CNG $\Delta Btu_C$ |
|---|---|---|---|---|---|
| Attic Hatch | 1.69 | 21.7 | 5.60 | 244,825 | 231,047 |
| Attic Pull-Down Stairs | 1.69 | 11.7 | 11.25 | 456,332 | 430,651 |
| Whole House Fan | 1.32 | 11.3 | 4.00 | 214,439 | 202,372 |

**Table 3-168 Annual Btu Savings - Infiltration**

| Insulation Measure | Eversource, UI, SCG, CNG $\Delta Btu_I$ |
|---|---|
| Attic Hatch | 154,876 |
| Attic Pull-Down Stairs | 533,461 |
| Whole House Fan | 243,195 |
| ***Reminder**: Only include infiltration savings ($\Delta kWh_I$) if not included in blower door measure.* | |

**Table 3-169 Annual Electric Savings – Conduction and Infiltration**

| | Eversource (Electric and Gas) | | | | UI, SCG, CNG | | | |
|---|---|---|---|---|---|---|---|---|
| Insulation Measure | Electric Resistance | | Heat Pump | | Electric Resistance | | Heat Pump | |
| | $\Delta kWh_C$ | $\Delta kWh_I$ | $\Delta kWh_C$ | $\Delta kWh_I$ | $\Delta kWh_C$ | $\Delta kWh_I$ | $\Delta kWh_C$ | $\Delta kWh_I$ |
| Attic Hatch | 71.8 | 45.4 | 35.9 | 22.7 | 67.8 | 45.4 | 33.9 | 22.7 |
| Attic Pull-Down Stairs | 133.8 | 156.4 | 66.9 | 78.2 | 126.3 | 156.4 | 63.2 | 78.2 |
| Whole House Fan | 62.9 | 71.3 | 31.5 | 35.7 | 59.4 | 71.3 | 29.7 | 35.7 |

***Reminder**: Only include infiltration savings ($\Delta kWh_I$) if not included in blower door measure.*

**Table 3-170 Annual Fossil Fuel Savings – Conduction and Infiltration**

| | Eversource (Electric and Gas) | | | | | | UI, SCG, CNG | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Natural Gas | | Oil | | Propane | | Natural Gas | | Oil | | Propane | |
| Insulation Measure | $\Delta CCF_C$ | $\Delta CCF_I$ | $\Delta Gal_C$ | $\Delta Gal_I$ | $\Delta Gal_C$ | $\Delta Gal_I$ | $\Delta CCF_C$ | $\Delta CCF_I$ | $\Delta Gal_C$ | $\Delta Gal_I$ | $\Delta Gal_C$ | $\Delta Gal_I$ |
| Attic Hatch | 3.18 | 2.01 | 2.36 | 1.49 | 3.58 | 2.27 | 3.00 | 2.01 | 2.23 | 1.49 | 3.38 | 2.27 |
| Attic Pull-Down Stairs | 5.92 | 6.92 | 4.39 | 5.13 | 6.67 | 7.79 | 5.59 | 6.92 | 4.15 | 5.13 | 6.29 | 7.79 |
| Whole House Fan | 2.78 | 3.16 | 2.07 | 2.34 | 3.14 | 3.56 | 2.63 | 3.16 | 1.95 | 2.34 | 2.96 | 3.56 |

***Reminder**: Only include infiltration savings ($\Delta CCF_I$; $\Delta Gal_{Oil,I}$; $\Delta Gal_{Propane,I}$) if not included in blower door measure.*

**Table 3-171 Electric Winter Demand Savings**

| Insulation Measure | Eversource (Electric and Gas) | | | | UI, SCG, CNG | | | |
|---|---|---|---|---|---|---|---|---|
| | Electric Resistance | | Heat Pump | | Electric Resistance | | Heat Pump | |
| | $\Delta kW_{Winter,C}$ | $\Delta kW_{Winter,I}$ | $\Delta kW_{Winter,C}$ | $\Delta kW_{Winter,I}$ | $\Delta kW_{Winter,C}$ | $\Delta kW_{Winter,I}$ | $\Delta kW_{Winter,C}$ | $\Delta kW_{Winter,I}$ |
| Attic Hatch | 0.05 | 0.03 | 0.03 | 0.02 | 0.04 | 0.03 | 0.02 | 0.02 |
| Attic Pull-Down Stairs | 0.08 | 0.09 | 0.04 | 0.05 | 0.08 | 0.09 | 0.04 | 0.05 |
| Whole House Fan | 0.04 | 0.05 | 0.02 | 0.03 | 0.04 | 0.05 | 0.02 | 0.03 |

**Table 3-172 Natural Gas Peak Day Savings**

| | Eversource (Electric and Gas) | | UI, SCG, CNG | |
|---|---|---|---|---|
| | $\Delta CCF_{PD,C}$ | $\Delta CCF_{PD,I}$ | $\Delta CCF_{PD,C}$ | $\Delta CCF_{PD,I}$ |
| Attic Hatch | 0.04 | 0.02 | 0.03 | 0.02 |
| Attic Pull-Down Stairs | 0.06 | 0.07 | 0.06 | 0.07 |
| Whole House Fan | 0.03 | 0.04 | 0.03 | 0.04 |

## ***Measure Life***

The measure life for insulating attic openings is 25 years.

## *Peak Factors*

**Table 3-173 Peak Factors**

| Measure | Summer Coincidence Factor | Winter Coincidence Factor | Ref |
|---|---|---|---|
| Insulate attic openings | 0% | 46% | [6] |

## *Load Shapes*

**Table 3-174 Load Shapes**

| End Use | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % | Ref |
|---|---|---|---|---|---|
| Heating | 47.23% | 52.77% | 0.00% | 0.00% | [6] |

## *Non-Energy Impacts*

There are no other resource impacts identified for this measure.

## *Realization Rates and Net Impact Factors*

**Table 3-175 Realization Rates and Net Impact Factors**

| | Gross Realization % | | | | FR & SO | | Net Realization % | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 | Ref |
| Insulation, electric/ delivered fuels **Home Energy Solutions** | 50% | 50% | 50% | 50% | 23% | 7.0% | 42% | 42% | 42% | 42% | [7][10] |
| Insulation, electric/ delivered fuels **HES – Income Eligible** | 50% | 50% | 50% | 50% | 0.0% | 0.0% | 50% | 50% | 50% | 50% | [7] |
| Insulation, gas **Home Energy Solutions** | 50% | 50% | N/A | N/A | 23% | 7.0% | 42% | 42% | N/A | N/A | [7][10] |
| Insulation, gas **HES – Income Eligible** | 50% | 50% | N/A | N/A | 0.0% | 0.0% | 50% | 50% | N/A | N/A | [7], |

## ***References***


[1] KEMA, Evaluation of the Weatherization Residential Assistance Partnership and Helps Programs (WRAP/Helps), Sep. 10, 2010, pp. 1-10, see Table ES-8.
[2] DNV, X1931-7 PSD HDD/CDD Update Study, Jul. 29, 2021.
[3] ASHRAE degree-day correction. 1989 ASHRAE Handbook – Fundamentals, 28.2, see Fig 1.
[4] Cadmus, High Efficiency Heating Equipment Impact Evaluation Final Report, 2015.
[5] ASHRAE 1997 Handbook – Fundamentals, p. 25.16.
[6] "DNV (2021). X1931-2 Load Shape and Coincidence Factor Research – Final Report".
[7] West Hill Energy and Computing. 2019. R1603: HES/HES-IE Impact Evaluation.
[8] NMR Group, Inc., HES/HES-IE Process Evaluation and Real Time Research, Apr. 13, 2016.
[9] NMR. R1983 Gas Weatherization PSD Review Final Memo dated Sep. 6, 2022.
[10] NMR. R1983 NTG Review Final Memo dated Sep. 12, 2022.


## ***Changes from Last Version***

- Updated realization rate, free ridership and spillover values.
- Formatting updates, inclusion of MF .

## 3.4.6 WALL, CEILING, AND FLOOR INSULATION

| | |
|---|---|
| Market | Residential |
| Baseline Type | Retrofit |
| Category | Envelope |

### ***Description***

Installation of insulation in walls, ceiling or floors that separates conditioned space and unconditioned space, including unconditioned basements, attics, and crawl spaces.

Energy savings are calculated using parallel flow method based on a typical 2x4 wall, ceiling and floor structure. Factors 7/12 and -4 are used in the effective R-value calculations 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. Floor insulation applies to floors over unconditioned spaces where the walls of the unconditioned space are not insulated. Floor insulation only has heating savings associated with it. Do not apply to ceilings between conditioned spaces and fully enclosed unconditioned spaces, such as basement ceilings. It is assumed that attics are properly ventilated to the outside.*

The following assumptions were used to develop this calculation methodology:

- Room A/C cooling savings are derived from factors. [3], [5], and [6].
- $R_{effective}$ of uninsulated wall assembly is based on R-values from http://www.allwallsystem.com/design/RValueTable.html.
- Grade Factors were developed using home energy rating software (HERS).
- 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).

### ***Annual Energy Savings Algorithm***

*Retrofit Gross Energy Savings, Electric*

*Heating savings*

*For a heat pump*

$$\Delta kWh_{H,HP} = \frac{\Delta kWh_{H,R}}{2}$$

*<u>For electric resistance heating</u>*

$$\Delta kWh_{H,R} = \frac{\Delta Btu_H}{C_{kWh}}$$

*Where,*

$$\Delta Btu_H = \left(\frac{1}{R_E} - \frac{1}{R_N}\right) \times HDD \times 24\frac{hr}{day} \times AF \times A \times GF$$

*<u>For wall and floor insulation</u>*

$$R_E = \left(\frac{7}{12} \times R_{Pre}\right) + 4$$

$$R_N = \left(\frac{7}{12} \times R_{Post}\right) + 4$$

*<u>For ceiling insulation</u>*

*If $R_{Pre} < 10$*

$$R_E = (0.5 \times R_{Pre}) + 3$$

*If $R_{Pre} \geq 10$*

$$R_E = R_{Pre} - 2$$

*If $R_{Post} < 10$*

$$R_N = (0.5 \times R_{Post}) + 3$$

*If $R_{Post} \geq 10$*

$$R_N = R_{Post} - 2$$

<u>Cooling savings</u>

*<u>For room A/C only and above grade walls</u>*

$$\Delta kWh_{C,RAC} = 0.283 \times \Delta kWh_{C,CAC}$$

*<u>For central A/C only and above grade walls</u>*

$$\Delta kWh_{C,CAC} = \left(\frac{1}{R_E} - \frac{1}{R_N}\right) \times \Delta T_{Bin} \times A \times \frac{1}{SEER_B \times 1{,}000\frac{W}{kW}}$$

*Retrofit Gross Energy Savings, Natural Gas*

$$\Delta CCF_H = \frac{\Delta Btu_H}{E \times C_{NG}}$$

*Where,*

$$\Delta Btu_H = \left(\frac{1}{R_E} - \frac{1}{R_N}\right) \times HDD \times 24\frac{hr}{day} \times AF \times A \times GF$$

*Retrofit Gross Energy Savings, Oil*

$$\Delta Gal_{Oil,H} = \frac{\Delta Btu_H}{E \times C_{Oil}}$$

*Where,*

$$\Delta Btu_H = \left(\frac{1}{R_E} - \frac{1}{R_N}\right) \times HDD \times 24\frac{hr}{day} \times AF \times A \times GF$$

*Retrofit Gross Energy Savings, Propane*

$$\Delta Gal_{Propane,H} = \frac{\Delta Btu_H}{E \times C_{Propane}}$$

*Where,*

$$\Delta Btu_H = \left(\frac{1}{R_E} - \frac{1}{R_N}\right) \times HDD \times 24\frac{hr}{day} \times AF \times A \times GF$$

*Retrofit Gross Seasonal Peak Demand Savings, Electric*

*For homes with a heat pump*

$$\Delta kW_{Winter} = \frac{\Delta kWh_{H,HP}}{1{,}000\frac{W}{kW}} \times CF_{Winter}$$

*For homes with electric resistance heat*

$$\Delta kW_{Winter} = \frac{\Delta kWh_{H,R}}{1{,}000\frac{W}{kW}} \times CF_{Winter}$$

*For room A/C only*

$$\Delta kW_{Summer,RAC} = 0.251 \times \Delta kW_{Summer,CAC}$$

*For central A/C only*

$$\Delta kW_{Summer,CAC} = CF_{Summer} \times \left(\frac{1}{R_E} - \frac{1}{R_N}\right) \times \Delta T_{Summer} \times A \times \frac{1}{EER_B \times 1{,}000\,\frac{W}{kW}}$$

*Retrofit Gross Peak Day Savings, Natural Gas*

$$\Delta CCF_{PD,H} = \Delta CCF_H \times PDF_H$$

## Calculation Parameters

**Table 3-176 Calculation Parameters**

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| $\Delta kWh_{H,HP}$ | Annual electric savings from heat pump heating | Calculated | kWh | |
| $\Delta kWh_{H,R}$ | Annual electric savings from electric resistance heating | Calculated | kWh | |
| $\Delta kWh_{C,RAC}$ | Annual electric savings from room A/C | Calculated | kWh | |
| $\Delta kWh_{C,CAC}$ | Annual electric savings from central A/C | Calculated | kWh | |
| $\Delta Btu_{H}$ | Annual Btu savings – heating | Calculated | Btu | |
| $\Delta CCF_{H}$ | Annual natural gas savings – heating | Calculated | CCF | |
| $\Delta Gal_{Oil,H}$ | Annual oil savings – heating | Calculated | Gal | |
| $\Delta Gal_{Propane,H}$ | Annual propane savings – heating | Calculated | Gal | |
| $\Delta kW_{W}$ | Winter peak demand savings | Calculated | kW | |
| $\Delta kW_{S,RAC}$ | Summer peak demand savings for room A/C | Calculated | kW | |
| $\Delta kW_{S,CAC}$ | Summer peak demand savings for central A/C | Calculated | kW | |
| $\Delta CCF_{PD,H}$ | Peak day savings – heating | Calculated | CCF | |
| $R_{E}$ | Effective R-value before upgrade | Calculated | ft$^2$·hr·°F/Btu | |
| $R_{N}$ | Effective R-value after upgrade | Calculated | ft$^2$·hr·°F/Btu | |
| $R_{Pre}$ | Insulation R-value before upgrade | Site-specific | ft$^2$·hr·°F/Btu | |
| $R_{Post}$ | Insulation R-value after upgrade | Site-specific | ft$^2$·hr·°F/Btu | |
| A | Total area of wall insulation | Site-specific | ft$^2$ | |
| GF | Ground factor; percent of unconditioned space walls above-grade | Lookup in Table 3-177 Grade Factors | N/A | |
| HDD (UI, SCG, CNG) | Heating degree days – UI, SCG, CNG | 5,165 | °F·day | [2] |
| HDD (Eversource) | Heating degree days – Eversource | 5,473 | °F·day | [2] |
| AF | Adjustment factor | 0.61 | N/A | [1] |

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| $\Delta T_{Bin}$ | Sum of the temperature BIN hours multiplied by Delta between outside air for each BIN, and average indoor temperature | 3,888 | hr·°F | [3] |
| $SEER_B$ | Seasonal Energy Efficiency Ratio – baseline | 13 | Btu/W·hr | |
| E | System efficiency | Site specific, use 0.75 if unknown | N/A | |
| $CF_{Winter}$ | Winter coincidence factor | 0.57 | W/kWh | [4] |
| $CF_{Summer}$ | Summer coincidence factor | 0.59 | N/A | |
| $\Delta T_{Summer}$ | Temperature difference | 20.5 | °F | [3] |
| $EER_B$ | Energy Efficiency Ratio – baseline | 11 | Btu/W·hr | |
| $PDF_H$ | Peak day factor – heating | 0.00977 | N/A | |
| $C_{kWh}$ | Electric conversion constant | 3,412 | Btu/kWh | |
| $C_{NG}$ | Natural gas conversion constant | 102,900 | Btu/CCF | |
| $C_{Oil}$ | Oil conversion constant | 138,690 | Btu/Gal | |
| $C_{Propane}$ | Propane conversion constant | 91,330 | Btu/Gal | |

**Table 3-177 Grade Factors**

| Grade Type | Description | Value |
|---|---|---|
| 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 |
| Mixed Grade | Adjustment for a wall between conditioned and ambient space which is between 31% and 99% above grade (inclusive) on average | 0.75 |
| 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 |

## ***Calculation Examples***

*Example 1: Retrofit Gross Energy Savings*

*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 electrical resistance heating system and has a central A/C. What are the annual electric energy savings?*

$$R_E = \left(\frac{7}{12} \times R_{Pre}\right) + 4$$

$$R_E = \left(\frac{7}{12} \times 6\ \frac{ft^2 \cdot hr \cdot °\text{F}}{Btu}\right) + 4 = 7.5\ \frac{ft^2 \cdot hr \cdot °\text{F}}{Btu}$$

$$R_N = \left(\frac{7}{12} \times R_{Post}\right) + 4$$

$$R_N = \left(\frac{7}{12} \times 13\ \frac{ft^2 \cdot hr \cdot °\text{F}}{Btu}\right) + 4 = 11.6\ \frac{ft^2 \cdot hr \cdot °\text{F}}{Btu}$$

*Using the equation for heating savings and HDD for UI, SCG, CNG:*

$$\Delta Btu_H = \left(\frac{1}{R_E} - \frac{1}{R_N}\right) \times HDD \times 24\frac{hr}{day} \times AF \times A \times GF$$

$$\Delta Btu_H = \left(\frac{1}{7.5\ \frac{ft^2 \cdot hr \cdot °\text{F}}{Btu}} - \frac{1}{11.6\ \frac{ft^2 \cdot hr \cdot °\text{F}}{Btu}}\right) \times 5{,}165\ °\text{F} \cdot day \times 24\frac{hr}{day} \times 0.61 \times 100\ ft^2 \times 1 = 356{,}349.37\ Btu$$

*Heating savings for electric resistance system:*

$$\Delta kWh_{H,R} = \frac{\Delta Btu_H}{C_{kWh}}$$

$$\Delta kWh_{H,R} = \frac{356{,}349.37\ Btu}{3{,}412\frac{Btu}{kWh}} = 104.44\ kWh$$

*Cooling savings:*

$$\Delta kWh_{C,CAC} = \left(\frac{1}{R_E} - \frac{1}{R_N}\right) \times \Delta T_{Bin} \times A \times \frac{1}{SEER_B \times 1{,}000\frac{W}{kW}}$$

$$\Delta kWh_{C,CAC} = \left(\frac{1}{7.5\ \frac{ft^2 \cdot hr \cdot °\text{F}}{Btu}} - \frac{1}{11.6\ \frac{ft^2 \cdot hr \cdot °\text{F}}{Btu}}\right) \times 3{,}888\ hr \cdot °\text{F} \times 100\ ft^2 \times \frac{1}{13\frac{Btu}{W \cdot hr} \times 1{,}000\frac{W}{kW}} = 1.4\ kWh$$

*Example 2: Retrofit Gross Peak Demand Savings*

*Insulation in a house is upgraded from R-6 to a total of R-13. The total square feet insulation added is 100. The home is heated by electrical resistance heating system and has a central A/C. What are the demand savings?*

*From Example 1: Retrofit Gross Energy Savings:*

$$\Delta kWh_{H,R} = 104.44\ kWh$$

*Using the equation:*

$$\Delta kW_W = \frac{\Delta kWh_{H,R}}{1{,}000\frac{W}{kW}} \times WPF$$

$$\Delta kW_W = \frac{104.44\ kWh}{1{,}000\ \frac{W}{kW}} \times 0.57\ \frac{W}{kWh} = 0.060\ kW$$

$$\Delta kW_{S,CAC} = CF \times \left(\frac{1}{R_E} - \frac{1}{R_N}\right) \times \Delta T_{Summer} \times A \times \frac{1}{EER_B \times 1{,}000\ \frac{W}{kW}}$$

$$\Delta kW_{S,CAC} = 0.59 \times \left(\frac{1}{7.5\ \frac{ft^2 \cdot hr \cdot °F}{Btu}} - \frac{1}{11.6\ \frac{ft^2 \cdot hr \cdot °F}{Btu}}\right) \times 20.5\ °F \times 100\ ft^2 \times \frac{1}{11\ \frac{Btu}{W \cdot hr} \times 1{,}000\ \frac{W}{kW}} = 0.0052\ kW$$

## ***Measure Life***

The measure life for insulation is 25 years.

## ***Peak Factors***

**Table 3-178 Peak Factors**

| Measure | Summer Peak Factor | Winter Peak Factor | Ref |
|---|---|---|---|
| Wall Insulation | 74% | 46% | [7] |

## ***Load Shapes***

**Table 3-179 Load Shapes**

| End Use | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % | Ref |
|---|---|---|---|---|---|
| Residential General | 30.30% | 36.30% | 15.50% | 17.90% | [7] |

## ***Non-Energy Impacts***

There are no other resource impacts identified for this measure.

## ***Realization Rates and Net Impact Factors***

**Table 3-180 Realization Rates and Net Impact Factors**

| | Gross Realization % | | | | FR & SO | | Net Realization % | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 | Ref |
| Insulation, electric/ delivered fuels **Home Energy Solutions** | 50% | 50% | 50% | 50% | 23% | 7% | 42% | 42% | 42% | 42% | [8], [9] |

| | Gross Realization % | | | | FR & SO | | Net Realization % | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Insulation, electric/ delivered fuels **HES – Income Eligible** | 50% | 50% | 50% | 50% | 0.0% | 0.0% | 50% | 50% | 50% | 50% | [8] |
| Insulation, gas **Home Energy Solutions** | 50% | 50% | N/A | N/A | 23% | 7% | 42% | 42% | 42% | 42% | [8], [9] |
| Insulation, gas **HES – Income Eligible** | 50% | 50% | N/A | N/A | 0.0% | 0.0% | 50% | 50% | N/A | N/A | [8] |
| MF insulation | 100% | 100% | 68.8% | 68.8% | 6.0% | 0.0% | 94% | 94% | 64.7% | 64.7% | [9], [10], [11] |
| MF insulation, income-eligible | 100% | 100% | 68.8% | 68.8% | 0.0% | 0.0% | 100% | 100% | 68.8% | 68.8% | [9], [10], [11] |

## ***References***


[1] ASHRAE degree-day correction. 1989 ASHRAE Handbook – Fundamentals, 28.2, see Fig 1.

[2] DNV. 2021. “X1931-7 PSD HDD/CDD Update Study.”

[3] ADM Associates, Inc. 2009. “Residential Central A/C Regional Evaluation” a) Table B-4 (Hartford) and p. B-9 and b) Figures 4-1&2 (Hartford) and pp. 4-15.

[4] KEMA. 2010. “Evaluation of the Weatherization Residential Assistance Partnership and Helps Programs (WRAP/Helps)” pp. 1-10. Table ES-8.

[5] Nexant Market Research, Inc. 2007. “Market Assessment for ENERGY STAR Room Air Conditioners in Connecticut.” pp. 17, 18.

[6] RLW Analytics. 2008. “Final Report: Coincidence Factor Study: Residential Room Air Conditioners,” pp. iv and 22.

[7] “DNV. 2021. “X1931-2 Load Shape and Coincidence Factor Research.”

[8] West Hill Energy and Computing. 2019.” R1603: HES/HES-IE Impact Evaluation.

[9] NMR Group, Inc. 2016. “HES/HES-IE Process Evaluation and Real Time Research.”

[10] NMR and Cadmus. 2014. “Impact Evaluation: Home Energy Services—Income-Eligible and Home Energy Services Programs: Volume 2 (R16).”

[11] TRC. (2021). CT EEB X1941 Multifamily Impact Evaluation, Jul. 22, 2021 (Table 6).

[12] NMR. R1983 Gas Weatherization PSD Review Final Memo dated Sep. 6, 2022.

[13] NMR. R1983 NTG Review Final Memo dated Sep. 12, 2022.

***Changes from Last Version***

- Formatting updates.
- Updated realization rate, free ridership and spillover values.

## 3.5 APPLIANCES

### 3.5.1 RESIDENTIAL APPLIANCES

| | |
|---|---|
| Market | Residential |
| Baseline Type | Retrofit/Lost Opportunity |
| Category | Appliances |

***Description***

Installation of qualified appliances.

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 and can be modified using the instructions in the Retrofit portion of the measure. Notice that the input and equipment tabs within the spreadsheet have default values that can be overridden by the user when project specific details are available. The peak electric and natural gas demand savings are calculated as specified below. Refrigerator and freezer recycling savings are based on removing and properly recycling a secondary refrigerator or freezer in working condition, the summer and winter kW are obtained by dividing the annual kWh savings by 8,760 operating hours for the sake of establishing conservative peak demand.

For clothes washers and dishwashers, if the hot water and dryer fuels are both unknown, the fuel mix in Table 3-183 is estimated typical for Connecticut. Savings are claimed for all fuel types according to the listed percentages; the 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.

***Annual Energy Savings Algorithm***

*Annual Gross Energy Savings*

Deemed Savings Values found in Table 3-182

*Lifetime Energy Savings, Electric*

$$\Delta kWh_{retrofit} = (\Delta kWh_{retire} \times RUL) + \left(\Delta kWh_{LostOpp} \times EUL\right)$$

***Calculation Parameters***

**Table 3-181 Calculation Parameters**

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| $\Delta kWh_{LostOpp}$ | Annual gross electric energy savings | Table 3-182 | kWh | |

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| $\Delta CCF_{LostOpp}$ | Annual natural gas savings | Table 3-182 | CCF | |
| $\Delta kWh_{retire}$ | Annual gross electric savings of replaced equipment | Workbook calculated | kWh | [6] |
| $\Delta kWh_{lifetime}$ | Lifetime electric energy savings | Calculated | kWh | |
| $\Delta kW_{summer}$ | Average summer demand savings | Calculated | kW | |
| $\Delta kW_{winter}$ | Average winter demand savings | Calculated | kW | |
| $\Delta CCF_{PD}$ | Peak day gas savings | Calculated | CCF | |
| EUL | Estimated useful life of installed equipment | Table 3-184 | years | |
| RUL | Remaining useful life of equipment replaced | Table 3-184 | years | |

**Table 3-182 Savings**

| | ΔkWh | $kW_{summer}$ | $kW_{winter}$ | Oil (Gal) | Propane (Gal) | Natural Gas (ccf) | Water (Gal) | Ref |
|---|---|---|---|---|---|---|---|---|
| Air cleaner/purifier | 214 | 0.024 | 0.024 | | | | | [1] |
| Clothes washer, Tier I | 88.1 | 0.012 | 0.014 | 0.14 | 0.44 | 0.29 | 823 | [4] |
| Clothes washer, Tier II | 120 | 0.016 | 0.019 | 0.72 | 2.08 | 1.65 | 1795 | [4] |
| Clothes dryer (ENERGY STAR) | 194 | 0.025 | 0.042 | | | | | [2] |
| Clothes dryer (hybrid) | 412 | 0.053 | 0.09 | | | | | [2] |
| Clothes dryer (heat pump) | 658 | 0.085 | 0.143 | | | | | [2] |
| Dehumidifier | 229 | 0.053 | 0.004 | | | | | [1] |
| Dishwasher | 11.0 | 0.001 | 0.002 | 0.16 | 0.16 | 0.01 | 87 | [5] |
| Refrigerator Tier I (10% greater than ENERGY STAR) | 59.0 | 0.01 | 0.007 | | | | | [2] |
| Refrigerator Tier II (15% greater than ENERGY STAR) | 89.0 | 0.015 | 0.01 | | | | | [2] |
| Room A/C | 10.7 | 0.016 | 0 | | | | | [2] |
| Freezer, upright | 44.0 | 0.006 | 0.004 | | | | | [2] |
| Freezer, chest | 24.0 | 0.003 | 0.002 | | | | | [2] |
| Induction Cook Top | 20 | 20/8760=0.0023 | 20/8760=0.0023 | | | | | [20] |

| | ΔkWh | $kW_{summer}$ | $kW_{winter}$ | Oil (Gal) | Propane (Gal) | Natural Gas (ccf) | Water (Gal) | Ref |
|---|---|---|---|---|---|---|---|---|
| Refrigerator recycling | 932 | 0.169 | 0.072 | | | | | [2], [18] |
| Freezer recycling | 760 | 0.107 | 0.069 | | | | | [2], [18] |
| Multifamily clothes washer (in unit) | 27.0 | 0.006 | 0 | | | | | [5] |
| Multifamily clothes dryer | 30.0 | 0.008 | 0.002 | | | | | [5] |
| Multifamily dishwasher | 32.0 | 0.002 | 0.007 | | | | | [5] |
| Multifamily refrigerator | 73.0 | 0.011 | 0.008 | | | | | [5] |
| Multifamily Room A/C | 13.0 | 0.016 | 0 | | | | | [5] |

**Table 3-183 Estimated Fuel Mix**

| Appliance | Electric | Gas | Oil | Propane |
|---|---|---|---|---|
| Water Heater | 30% | 27% | 41% | 2% |
| Clothes Dryer | 93% | 5% | 0% | 2% |

## ***Measure Life***

**Table 3-184 Measure Life**

| Equipment Type | Retirement RUL | Lost Opportunity EUL | Ref |
|---|---|---|---|
| Room air cleaner | N/A | 9 | [7] |
| Clothes washer | 4 | 11 | [8], [9] |
| Clothes dryer | 4 | 11 | [8], [9] |
| Dehumidifier | 4 | 12 | [9], [10] |
| Dishwasher | 4 | 10 | [8], [9] |
| Freezer | 4 | 11 | [8], [9] |
| Freezer (low income) | 8 | 11 | [8], [9] |
| Refrigerator | 5 | 12 | [8], [9] |
| Refrigerator (low income) | 10 | 12 | [8], [9] |

| Equipment Type | Retirement RUL | Lost Opportunity EUL | Ref |
|---|---|---|---|
| Room A/C unit | 3 | 13 | [9], [4] |
| Refrigerator recycling | 5 | N/A | [3] |
| Freezer recycling | 4 | N/A | [3] |
| Induction Cook Top | 5.3 | 16 | MA Assumption ETRM |

***Peak Factors***

**Table 3-185 Peak Factors* [11]**

| Equipment Type | Summer Coincidence Factor | Winter Coincidence Factor |
|---|---|---|
| Air cleaner/purifier | 100% | 100% |
| Clothes washer, Tier I | 117% | 140% |
| Clothes washer, Tier II | 117% | 140% |
| Clothes dryer (ENERGY STAR) | 113% | 191% |
| Clothes dryer (hybrid) | 113% | 191% |
| Clothes dryer (heat pump) | 113% | 191% |
| Dehumidifier | 202% | 15% |
| Dishwasher | 110% | 144% |
| Refrigerator Tier I (10% greater than ENERGY STAR) | 151% | 100% |
| Refrigerator Tier II (15% greater than ENERGY STAR) | 151% | 100% |
| Room A/C | 1298% | 0% |
| Freezer, upright | 123% | 79% |
| Freezer, chest | 123% | 79% |
| Refrigerator recycling | 159% | 68% |
| Freezer recycling | 123% | 79% |
| Multifamily clothes washer (in unit) | 196% | 13% |
| Multifamily clothes dryer | 232% | 54% |
| Multifamily dishwasher | 66% | 192% |

| Equipment Type | Summer Coincidence Factor | Winter Coincidence Factor |
|---|---|---|
| Multifamily refrigerator | 129% | 93% |
| Multifamily room A/C | 1065% | 0% |

*Values are relative to average demand savings. Average demand savings is defined as total energy (kWh) savings divided by 8,760. Data available during X1931-2 did not include sufficient detail to calculate maximum connected loads for each profile, which necessitated the use of seasonal peak coincidence factors relative to average demand.

## ***Load Shapes***

**Table 3-186 Load Shapes [11]**

| Measure/Facility/Equipment Type | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % |
|---|---|---|---|---|
| Cooling - Room AC | 1.75% | 2.10% | 51.81% | 44.34% |
| Refrigeration - Fridge | 30.34% | 30.85% | 19.57% | 19.24% |
| Refrigeration - Freezer | 28.73% | 31.76% | 19.11% | 20.40% |
| Residential General | 30.30% | 36.30% | 15.50% | 17.90% |

## ***Non-Energy Impacts***

The annual customer bill savings are multiplied by the factors 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 (see section Four - Appendix) of the measure.

**Table 3-187 Residential NEIs [12]**

| NEI | HES | HES-IE | Rebate | Multifamily |
|---|---|---|---|---|
| Comfort | 0.25 | 0.17 | 0.31 | 0.14 |
| 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 |
| Complaints | 0 | 0 | 0 | 0.08 |
| **Total** | **0.69** | **0.70** | **1.03** | **0.67** |

## *Realization Rates*

**Table 3-188 Realization Rates**

| | Gross Realization % | | | | FR & SO | | Net Realization % | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Measure | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Installation rate | Free-ridership | Spill-over | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Ref |
| Appliances **HES and HES-Income Eligible** | 94.3% | 94.3% | 94.3% | 100% | 0.0% | 0.0% | 94.3% | 94.3% | 94.3% | [13] |
| Air cleaners/purifiers **Retail Products** | 100.00% | 100.00% | 100.00% | 100% | 43.0% | 0.00% | 57.00% | 57.00% | 57.00% | [14] |
| Clothes Dryers **Retail Products** | 100.00% | 100.00% | 100.00% | 100% | 38.0% | 0.00% | 62.00% | 62.00% | 62.00% | [14] |
| Clothes washers **Retail Products** | 100.00% | 100.00% | 100.00% | 100% | 50.0% | 0.00% | 50.00% | 50.00% | 50.00% | [14] |
| Clothes washers **HES** | 100.00% | 100.00% | 100.00% | 96% | 42.0% | 7% | 62.4% | 62.4% | 62.4% | [19] |
| Dehumidifiers **Retail Products** | 100.00% | 100.00% | 100.00% | 100% | 80.0% | 0.00% | 20.00% | 20.00% | 20.00% | [14] |
| Dehumidifiers **HES** | 100.00% | 100.00% | 100.00% | 100% | 43.0% | 7.00% | 64.00% | 64.00% | 64.00% | [19] |
| Dishwashers **Retail Products** | 100.00% | 100.00% | 100.00% | 100% | 91.0% | 0.00% | 9.00% | 9.00% | 9.00% | [14] |
| Freezers **Retail Products** | 100.00% | 100.00% | 100.00% | 100% | 30.0% | 0.00% | 70.00% | 70.00% | 70.00% | [14] |
| Freezers, **HES** | 100.00% | 100.00% | 100.00% | 100% | 47.0% | 7.00% | 60.00% | 60.00% | 60.00% | [19] |
| Freezer recycling **Appliance Turn-In** | 83.0% | 83.0% | 83.0% | 100% | 50.0% | 0.0% | 41.5% | 41.5% | 41.5% | [15] [18] |
| Refrigerators **HES-Income Eligible** | 100.0% | 100.0% | 100.0% | 100% | 0.0% | 0.0% | 100.0% | 100.0% | 100.0% | [16] |
| Refrigerators **HES** | 100.0% | 100.0% | 100.0% | 97% | 47.0% | 7.00% | 58.2% | 58.2% | 58.2% | [19] |
| Induction Cooktop | 100% | 100% | 100% | 100% | 0% | 0% | 100% | 100% | 100% | |
| Refrigerators – Multifamily **HES and HES-Income Eligible MF** | 80% | 81% | 80% | 100% | 0.0% | 0.0% | 80% | 81% | 80% | [17] |
| Refrigerators **Retail Products** | 100.00% | 100.00% | 100.00% | 100% | 43.0% | 0.00% | 57.00% | 57.00% | 57.00% | [14] |
| Refrigerator Recycling **Appliance Turn-In** | 90.0% | 90.0% | 90.0% | 100% | 54% | 0.0% | 41.4% | 41.4% | 41.4% | [15] [18] |

## *References*


[1] TRC. 2021. “R1973 Retail Non-Lighting Evaluation.” CT Energy Efficiency Board.

[2] Efficiency Vermont. 2018. “Technical Reference User Manual.”

[3] New York State of Public Utilities. 2019. “New York Standard Approach for Estimating Energy Savings from Energy Efficient Programs, Version 7.”

[4] NMR. 2019. “R1706 Residential Appliance Saturation Survey & R1616/R1708 Residential Lighting Impact Saturation Studies”. CT Energy Efficiency Board.

[5] ERS. 2019. “R1705 R1609 Multifamily Baseline and Weatherization Opportunity Study.”

[6] ES Products Measures-7_19_2017.xlsx.

[7] EPA Next Gen Product Analysis_10.9.14.xlsx, last accessed on Jul. 1, 2015.

[8] *Appliance Magazine*. *U.S. Appliance Industry: Market Share, Life Expectancy & Replacement Market, and Saturation Levels*, Jan. 2010. p. 10.

[9] California Public Utilities Commission, 2014 Database for Energy-Efficient Resources, Feb. 4, 2014, available online at: http://www.deeresources.com/files/DEER2013codeUpdate/download/DEER2014-EUL-table-update_2014-02-05.xlsx, last accessed Sep. 3, 2020.

[10] GDS Associates Inc. 2007. “Measure Life Report, Residential and Commercial Industrial Lighting and HVAC Measures”.

[11] DNV. 2021. “X1931-2 Load Shape and Coincidence Factor Research.” Connecticut Energy Efficiency Board (EEB) and Evaluation Administrators.

[12] NMR Group, Inc. 2016. “Project R4 HES/HES-IE Process Evaluation and R31 Real-Time Research.” CT EEB, Eversource, and United Illuminating.

[13] MR and Cadmus, Impact Evaluation: Home Energy Services—Income-Eligible and Home Energy Services Programs: Volume 2 (R16), Final Report, Dec. 31, 2014.

[14] ENERGY STAR, Unit Shipment and Market Penetration Report Calendar Year 2019 Summary. Available at: https://www.energystar.gov/sites/default/files/asset/document/2019%20USD%20Summary%20Report.pdf.

[15] NMR, Massachusetts Appliance Turn-in Program Impact Evaluation, Jun. 15, 2011, p. 2, see Table ES-3.

[16] West Hill Energy and Computing, *R1603 HES/HES-IE Impact Evaluation Final Realization Rates Memorandum*, Aug. 8, 2019.

[17] TRC . 2021. “CT EEB X1941 Multifamily Impact Evaluation.” Table 6.

[18] NMR Group, Inc. 2022. “R2120 Appliance Recycling Incentives Memo”.

[19] NMR. R1983 NTG Review Final Memo dated Sep. 12, 2022.

[20] Frontier Energy (2019). Residential Cooktop Performance and Energy Comparison Study ( used average usage difference from induction and electric resistance Table 7).

## ***Changes from Last Version***

- Formatting updates.
- Updated gross savings and net-to-gross values for refrigerator and freezer recycling.
- Updated installation rate, free ridership and spillover values for HES appliances (freezer, refrigerators, clothes washer and dehumidifier).
- Updated coincidence factors and associated demand savings based on X1931-2.

## 3.5.2 ELECTRONICS

| | |
|---|---|
| Market | Residential |
| Baseline Type | Lost Opportunity |
| Category | Appliances |

### ***Description***

Purchase of an advanced power strip. The savings estimates in Table 3-190 are for advanced power strips versus conventional power strips.

***Note:*** *No demand savings have been identified for this measure.*

### ***Annual Energy Savings Algorithms***

Lookup in Table 3-190. Deemed values are based on a 2018 evaluation study [1].

### ***Calculation Parameters***

**Table 3-189 Calculation Parameters**

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| ΔkWh | Annual electric energy savings | Table 3-190 | kWh | |
| $kW_{Summer}$ | Summer demand savings | 0 | kW | |
| $kW_{Winter}$ | Winter demand savings | 0 | kW | |

**Table 3-190 ENERGY STAR Electronics Annual Savings**

| Electronics Equipment | Energy Savings ΔkWh | Ref |
|---|---|---|
| Advanced power strips Tier I | 105 | [1] |
| Advanced power strips Tier II (IR) | 236 | [1] |
| Advanced power strips Tier II (IR-OS) | 174 | [1] |

## Measure Life

**Table 3-191 Measure Life**

| Equipment Type | Retirement RUL | Lost Opportunity EUL | Ref |
|---|---|---|---|
| Advanced power strip | N/A | 5 | [4] |

## Peak Factors

**Table 3-192 Peak Factors [3]**

| Measure | Summer Coincidence Factor | Winter Coincidence Factor |
|---|---|---|
| Advanced power strips Tier I | 0% | 0% |
| Advanced power strips Tier II (IR) | 0% | 0% |
| Advanced power strips Tier II (IR-OS) | 0% | 0% |

## Load Shapes

**Table 3-193 Load Shapes**

| Measure/Facility/Equipment Type | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % | Ref |
|---|---|---|---|---|---|
| Residential general | 30.30% | 36.30% | 15.50% | 17.90% | [3] |

## Non-Energy Impacts

There are no other resource impacts identified for this measure.

## Realization Rates

**Table 3-194 Realization Rates**

| | Gross Realization % | | | | FR & SO | | Net Realization % | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Measure | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Installation Rate | Free-ridership | Spill-over | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Ref |
| Power strips Tier 1 | 92% | 92% | 92% (x) | 86% | 100.0% | 100.0% | 79.1% | 79.1% | 79.1% | [1], [2] |
| Power strips Tier 2 | 92% | 92% | 92% | 78% | 100.0% | 100.0% | 71.8% | 71.8% | 71.8% | [1], [2] |

## References


[1] NMR Group, Inc. “RLPNC 17-3: Advanced Power Strip Metering Study” 2019.

[2] NMR Group, Inc. 2018. "RLPNC 17-4 and 17-5: Products Impact Evaluation of In-Service and Short-Term Retention Rates Study."

[3] DNV. 2021. "X1931-2 Load Shape and Coincidence Factor Research." Connecticut Energy Efficiency Board (EEB) and Evaluation Administrators.

[4] Plug Load –Smart Strips, 2015 Massachusetts TRM, p. 162.

[5] EPA Next Gen Product Analysis_10.9.14.xlsx, last accessed on Jul. 1, 2015.

***Changes from Last Version***

- Removed electronics types except for advanced power strips.
- Updated advanced power strip deemed savings.
- Formatting updates.

# 3.6 MOTORS AND DRIVES

## 3.6.1 POOL PUMP

| | |
|---|---|
| Market | Residential |
| Baseline Type | Retrofit |
| Category | Category |

***Description***

Installation of an Energy Star rated pool pump replacing an existing pool pump in residential applications.

Demand savings are derived from the demand impact model which is developed as part of the Residential Baseline Study. The baseline efficiency case is a pump that meets the July 2021 federal standard.

***Annual Energy Savings Algorithm***

*Annual Gross Energy Savings, Electric*

$$\Delta kWh = UEC_{annual,baseline} - UEC_{annual,efficient}$$

$$UEC_{annual} = UEC_{day} \times days$$

$$UEC_{day} = \frac{(hours_{low} \times P_{low} + hours_{high} \times P_{high})}{1{,}000\ \frac{W}{kW}}$$

When calculated using the 2021 nationwide pool pump shipment distribution, the deemed savings value becomes:

$$\Delta kWh = 151\ kWh$$

*Gross Seasonal Peak Demand Savings, Electric*

Deemed seasonal peak demand savings are based on the 2021 nationwide pool pump shipment distribution.

$$\Delta kW_{Summer} = 0.13\ kW$$

$$\Delta kW_{Winter} = 0\ kW$$

## *Calculation Parameters*

**Table 3-195 Calculation Parameters**

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| ΔkWh | Gross annual electric savings | Calculated or use 151 | kWh | |
| ΔkWSummer | Peak demand savings | 0.13 | kW | |
| ΔkWWinter | Winter peak demand savings | 0 | kW | |
| $UEC_{annual,baseline}$ | Unit Energy Consumption per year for the baseline condition | Calculated | kWh | |
| $UEC_{annualefficient}$ | Unit Energy Consumption per year for the efficient condition | Calculated | kWh | |
| $UEC_{day}$ | Average Unit Energy Consumption per day | Calculated | kWh/day | |
| Days | Annual days of operation | Site-specific or use 122 | days/year | [3] |
| $P_{high}$ | Input power at high speed | Site-specific or use baseline = 1,192 and efficient = 1,016.5 | Watts | [3] |
| $P_{low}$ | Input power at low speed | Site-specific or use baseline = 174.1 and efficient = 185.9 | Watts | [3] |
| $hours_{high}$ | Daily operating hours at high speed | Site-specific or use baseline = 3.3 and efficient = 2.1 | hr | [3] |
| $hours_{low}$ | Daily operating hours at low speed | Site-specific or use baseline = 17.4 and efficient = 14.3 | hr | [3] |

## *Measure Life*

The measure life for residential pool pumps is 6 years [4].

## *Peak Factors*

Summer and winter coincidence factors are estimated using the demand allocation methodology described in the residential baseline study [2].

## *Load Shapes*

Load shapes are not yet identified for this measure.

## *Non-Energy Impacts*

There are no other resource impacts identified for this measure.

## *Realization Rates*

**Table 3-196 Realization Rates**

| | Gross Realization % | | | FR & SO | | Net Realization % | | | |
|---|---|---|---|---|---|---|---|---|---|
| Measure | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Free-ridership | Spill-over | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | Ref |
| Pool Pump | 100.0% | 100.0% | 100.0% | 13.0% | 0.0% | 87.0% | 87.0% | 87.0% | [5] |

## *References*


[1] Guidehouse. 2021. “Pool Pump Savings Estimate.”

[2] Guidehouse. 2020. “Residential Baseline Study Phase 4.”

[3] DOE Direct Final Rule Technical Support Document.

[4] Guidehouse. 2021. “Comprehensive TRM Review.”

[5] NMR Group and DNV. 2021. “Residential Products Net-to-Gross Study (MA20X04-E-PRODNTG).” Massachusetts Electric Program Administrators.


## *Changes from Last Version*

- New measure.

# 3.7 CUSTOM

## 3.7.1 RESIDENTIAL CUSTOM

| | |
|---|---|
| Market | Residential |
| Baseline Type | Retrofit/Lost Opportunity |
| Category | Custom |

***Description***

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.

These custom measures can be evaluated using either the appropriate measure, if found in this document, or other acceptable modeling tools, including but not limited to:

- Engineering-based tools such as DOE-2, Elite Software, or RESNET-approved programs such as Ekotrope.
- Billing analysis tools such as PRISM or other regression tools that follow IPMVP option C.

Custom measures should use site-specific information when available (i.e., existing conditions, etc.). The analysis of the site-specific measures will be reviewed for reasonableness by a qualified internal program administrator or independent third-party engineer. Whenever possible, site utility billing history must be utilized as appropriate.

When a measure meets the requirements for early retirement (existing equipment is in good working order), use the partial savings methodology outline for that measure (or similar measure) outlined in this document. For an early retirement measure the savings may need to be calculated in two parts, as follows:

1. Retrofit savings based on the early retirement of a working existing unit; and
2. Lost Opportunity savings for installing a new efficient unit for the life of the measure.

In case where interactive effects between two or more measures are present, a comprehensive analysis must be conducted and fully documented with assumptions and methodology clearly indicated.

Notes:

**DOE-2** is a widely used and accepted building energy analysis program that can predict the energy use and cost for all types of buildings. DOE-2 uses a description of the building layout, constructions, operating schedules, conditioning systems (such as lighting and HVAC) and utility rates provided by the user, along with weather data, to perform an hourly simulation of the building and to estimate utility bills. Available online at: http://www.doe2.com/.

**Elite Software** is the world's premier software developer for HVAC, electrical, plumbing, and fire protection design software. Over 30 programs are offered for such applications as HVAC load calculations, building energy analysis, HVAC duct and pipe sizing, plumbing & lighting design, fault current calculations, voltage drops, fuse and breaker coordination, and much more. Their HVAC software sets the standard for excellence and ease-of-use in the industry. Available online at: https://www.elitesoft.com/.

**Ekotrope** provides innovative software tools for raters and providers, utilities and utility program administrators, building product manufacturers, and lending institutions that aid in the construction, improvement, and financing of energy efficient homes. Available online at: https://www.ekotrope.com/.

**PRISM** is an established statistical procedure for measuring energy conservation in residential housing. The PRISM software package was developed by the Center for Energy and Environmental Studies, Princeton University. The tool is used for estimating energy savings from billing data. Available online at: PRISM (princeton.edu).

## ***Measure Life***

Measure life will be specific to the installed equipment type. For custom measures using technologies that are the same or similar to those addressed in other PSD measure chapters, refer to those chapters for EULs. For other measures refer to Table 3-197 below.

**Table 3-197 Selection of Measure Lives**

| Measure | Retirement RUL | Lost Opportunity EUL |
|---|---|---|
| Electronically commutated motor (fan) | N/A | 18 |
| Wi-Fi thermostat | N/A | 15 |
| Room air cleaner | N/A | 9 |
| Clothes washers, clothes dryer | 4 | 11 |
| Dehumidifier | 4 | 12 |
| Dishwasher | 4 | 10 |
| Freezer | 4 | 11 |
| Refrigerator | 5 | 12 |
| Room A/C unit | 3 | 13 |
| Refrigerator recycling | 5 | N/A |
| Freezer recycling | 4 | N/A |
| Television | N/A | 6 |
| Blu-Ray player | N/A | 7 |
| DVD player | N/A | 7 |
| Telephone | N/A | 7 |
| Computer monitor | N/A | 7 |
| Laptop/desktop computer | N/A | 4 |

| Measure | Retirement RUL | Lost Opportunity EUL |
|---|---|---|
| Sound bar | N/A | 7 |
| Broken window repair | N/A | 5 |
| Window replacement | N/A | 25 |
| Water heater thermostat setting (existing unit) | N/A | 4 |
| Water heater wrap | N/A | 7 |

### ***Peak Factors***

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 (see section 1.8). These measures are typically analyzed by a third-party consultant and reviewed for reasonableness.

### ***Load Shapes***

Load shapes will be specific to the custom measure.

### ***Non-Energy Impacts***

There are no other resource impacts identified for this measure.

### ***Realization Rates***

Measure life will be specific to the installed equipment type. For custom measures using technologies that are the same or similar to those addressed in other PSD measure chapters, refer to those chapters for EULs. For other measures refer to Table 3-198 below.

**Table 3-198 Selection of Realization Rates**

| | Gross Realization | | | | | FR & SO | | Net Realization | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Measure | kWh or (ccf) | Winter Peak kW or (Peak Day ccf) | Summer Peak kW | | MMBtu | Free ridership | Spill-over | kWh or (ccf) | Winter Peak kW or (Peak Day ccf) | Summer Peak kW | MMBtu |
| HES other measures | 100.0% | 100.0% | 100.0% | 100.0% | 0.0% | 0.0% | 0.0% | 100.0% | 100.0% | 100.0% | 100.0% |

| | Gross Realization | | | | | FR & SO | | Net Realization | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| HES heating system retirement | 63.7% | 63.7% | 63.7% | 63.7% | 0.0% | 0.0% | 0.0% | 63.7% | 63.7% | 63.7% | 100.0% |
| Room A/Cs | 100.0% | 100.0% | 100.0% | - | 50.0% | 0.0% | 0.0% | 50.0% | 50.0% | - | 100.0% |
| Sound bars | 100.0% | 100.0% | 100.0% | - | 19.0% | 0.0% | 0.0% | 81.0% | 81.0% | - | 100.0% |
| Room air cleaners | 100.0% | 100.0% | 100.0% | - | 43.0% | 0.0% | 0.0% | 57.0% | 57.0% | - | 100.0% |
| Set-top boxes | 100.0% | 100.0% | 100.0% | - | 9.0% | 0.0% | 0.0% | 91.0% | 91.0% | - | 100.0% |
| Computers | 100.0% | 100.0% | 100.0% | - | 77.0% | 0.0% | 0.0% | 23.0% | 23.0% | - | 100.0% |
| Blu Ray player | 100.0% | 100.0% | 100.0% | - | 69.0% | 0.0% | 0.0% | 31.0% | 31.0% | - | 100.0% |
| Refrigerator recycling | 100.0% | 100.0% | 100.0% | - | 31.0% | 0.0% | 0.0% | 69.0% | 69.0% | - | 100.0% |
| Freezer recycling | 100.0% | 100.0% | 100.0% | - | 41.0% | 0.0% | 0.0% | 59.0% | 59.0% | - | 100.0% |

## ***References***


[1] *Appliance Magazine*. *U.S. Appliance Industry: Market Share, Life Expectancy & Replacement Market, and Saturation Levels*, Jan. 2010. p. 10.

[2] GDS Associates Inc., *Measure Life Report, Residential and Commercial Industrial Lighting and HVAC Measures*, Jun. 2007.

[3] California Public Utilities Commission, 2014 Database for Energy-Efficient Resources, Feb. 4, 2014, available online at: http://www.deeresources.com/files/DEER2013codeUpdate/download/DEER2014-EUL-table-update_2014-02-05.xlsx, last accessed Sep. 3, 2020.

[4] 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.

[5] Environmental Protection Agency (2010), *Life Cycle Cost Estimate for Programmable Thermostats*, last accessed on Oct. 12, 2011.

[6] EPA Next Gen Product Analysis_10.9.14.xlsx, last accessed on Jul. 1, 2015.

[7] ENERGY STAR Consumer Electronics Calculator, as recommended by ERS, *X1931 PSD Review, EUL Comparative Analysis*, Jul 2020.


## ***Changes from Last Version***

- Moved measure lives not listed elsewhere in PSD to this section.
- Formatting updates.

## 3.8 OTHER

### 3.8.1 BEHAVIORAL CHANGE

| | |
|---|---|
| Market | Residential |
| Baseline Type | Retrofit/Lost Opportunity |
| Category | Other |

***Description***

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.

Because the characteristics of behavioral programs make them amenable to randomized, controlled trials, and because Connecticut is expected to regularly evaluate its behavioral energy efficiency programs, use of evaluated savings estimates is recommended. Evaluations should be conducted, and savings calculated in accordance with the DOE's SEE Action Recommendations, including but not limited to the use of a randomized controlled trial and a panel data model [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.

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.

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.

## ***Calculation Parameters***

**Table 3-199 Calculation Parameters**

| Variable | Description | Value | Units | Ref |
|---|---|---|---|---|
| $\Delta kWh_H$ | Annual electric energy savings, heating | Calculated | kWh | |
| $\Delta kWh_C$ | Annual electric energy savings, cooling | Calculated | kWh | |
| ΔCCF | Annual natural gas savings | Calculated | CCF | |
| ATE | Average treatment effect | Site-specific | n/a | |
| Usage Electric | Annual electric consumption | Site-specific | kWh | |
| Usage Gas | Annual gas consumption | Site-specific | CCF | |

**Table 3-200 Savings and Persistence Assumptions for UIL HERs Program**

| Persistence | | | | |
|---|---|---|---|---|
| Year 1 | Year 2 | Year 3 | Year 4 | Year 5 |
| 1 | 0.71 | 0.4 | 0.3 | 0.1 |

| Percent Savings | | |
|---|---|---|
| | Electric | Natural Gas |
| 1st year | 1.17% | 0.60% |
| 2nd year adjustment for extension customers | 1.35% | 1.35% |
| Maximum percent savings | 1.58% | 0.81% |

## ***Measure Life***

The measure life for behavioral programs (Lost Opportunity) is 2 years [2].

## ***Load Shapes***

**Table 3-201 Load Shapes**

| End Use | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % | Ref |
|---|---|---|---|---|---|
| Cooling - Central AC | 4.83% | 4.33% | 54.40% | 36.45% | [3] |
| Cooling - Room AC | 1.75% | 2.10% | 51.81% | 44.34% | [3] |

| End Use | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % | Ref |
|---|---|---|---|---|---|
| Cooling - Ductless HP | 8.56% | 10.20% | 47.51% | 33.73% | [3] |
| Heating | 47.23% | 52.77% | 0.00% | 0.00% | [3] |
| Lighting | 42.10% | 32.50% | 13.90% | 11.50% | [3] |
| Refrigeration - Fridge | 30.34% | 30.85% | 19.57% | 19.24% | [3] |
| Refrigeration - Freezer | 28.73% | 31.76% | 19.11% | 20.40% | [3] |
| Water Heating - Electric | 43.26% | 29.72% | 16.19% | 10.82% | [3] |
| Water Heating - HP | 41.88% | 31.05% | 15.56% | 11.50% | [3] |
| Residential General | 30.30% | 36.30% | 15.50% | 17.90% | [3] |

## ***Realization Rates and Net Impact Factors***

**Table 3-202 Realization Rates and Net Impact Factors**

| | Gross Realization % | | | | FR & SO | | Net Realization %[4] | | |
|---|---|---|---|---|---|---|---|---|---|
| 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 |
| Home Energy Reports | 100.0% | 100.0% | 100.0% | 100.0% | 0.0% | 0.0% | 100.0% | 100.0% | 100.0% |

## ***References***


[1] DOE, SEE Action (May 2012). “Evaluation, Measurement, and Verification (EM&V) of Residential Behavior-Based Energy Efficiency Programs: Issues and Recommendations,” p. xi.

[2] NMR (Oct. 15, 2017). “1606 Eversource Behavior Program Persistence Evaluation.”

[3] DNV (2021). “X1931-2 Load Shape and Coincidence Factor Research,” Final Report.

[4] West Hill Energy and Computing (Aug. 8, 2019). “R1603 HES/HES-IE Impact Evaluation Final Realization Rates Memorandum.”


## ***Changes from Last Version***

- Formatting updates.

### 3.8.2 ACTIVE DEMAND RESPONSE

| | |
|---|---|
| Market | Residential |
| Baseline Type | Retrofit |
| Category | Other |

***Description***

Residential Active Demand Reduction is a bring-your-own-device program that compensates customers for reducing demand during times of regional peak load. Connected residential devices can be controlled through a distributed energy resource management platform. The platform sends signals to enrolled devices during an event that causes the controller to reduce the demand of the connected device. Events are called in the summer (June - September) during afternoon and evening hours. Customers can opt-out of events; however, they may be removed from the program if they regularly do not participate. Measures include Direct Load Control, Battery Storage Daily Dispatch, and EV Load Management. Events are called in the summer (June - September) during afternoon and evening hours.

The peak demand savings will be the difference between the estimated peak demand of a customer baseline in the absence of a demand response program and the measured peak demand after implementation of a demand response program. Reporting for demand response measures should include ex-post reporting or ex-ante reporting. For ex-post reporting, measure savings should be quantified by using meter-based methods, such as day- or weather-matching customer baseline including a control group, regression-based methods on customer historical data, or similar methods. For ex-ante reporting, measure savings should be estimated by using a scalar weather normalization method, a time-temperature matrix, or similar methods.

*Program Offerings*

- Direct Load Control includes Wi-Fi/communicating thermostats controlling central air conditioning units and cooling loads. Additional eligible connected devices under the Direct Load Control offerings may include water heaters, pool pumps, and other devices that can be controlled by the demand response management platforms. Thermostats are set to pre-cool for a period of time in advance of demand response event window and the temperature is allowed to rise during the event. Direct Load Control devices are dispatched for up to 15 events each summer.
- The Battery Storage Daily Dispatch offering provides pay-for-performance incentives to customers with battery storage that can reduce load on a daily basis. Customers are routinely dispatched to reduce regional peak loads on non-holidays June to September up to 60 times per summer.
- EV Load Management includes networked Level 2 chargers. During demand response events, the rate of charging is decreased from Level 2 to Level 1. EV Chargers are dispatched for up to 15 events each summer.

*Baseline*

- For Direct Load Control, evaluators determined baseline conditions using an established design methodology. When this is not possible, a within-subject methodology or savings adjustment factor for demand reduction events is used.
- For Storage Daily Dispatch, demand and energy impacts of the energy storage are measured directly from the battery inverter.
- For EVs, demand impact factors are measures based on telemetry data provided by the vehicle manufacturers and engineering calculations. The baseline is the kW draw for the EV and is based on what amount of power would have been drawn in absence of an event for each participant and event.

### ***Annual Energy Savings Algorithm***

Savings for Direct Load Control Residential Active Demand Reduction measures are based on vendor estimates.[11]

### ***Calculation Parameters***

Savings for Direct Load Control Residential Active Demand Reduction measures are based on vendor estimates.[11]

### ***Measure Life***

The measure life for active demand response is one year.

### ***Peak Factors***

Peak factors have not yet been determined for this measure.

### ***Load Shapes***

Load shapes have not yet been determined for this measure.

### ***Non-Energy Impacts***

There are no other resource impacts identified for this measure.

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[11] CT EEB Evaluation Report *X1932: Demand Response EM&V Support Study* recommends dropping the vendor assumption of connected load per thermostat from 3.5 kW to 2.1 kW based on ex-post evaluated results to be applied to UI Smart Savers Rewards program.

## ***Realization Rates***

**Table 3-203 Realization Rates**

| | Gross Realization % | | | Install Rate (ISR) | FR & SO | | Net Realization % | | |
|---|---|---|---|---|---|---|---|---|---|
| Measure | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW | | Free-ridership | Spillover | kWh | Winter Seasonal Peak kW | Summer Seasonal Peak kW |
| Direct Load Control | 100% | 100% | 100% | 100% | 0.0% | 0.0% | 100% | 100% | 100% |
| Battery Storage Daily Dispatch | 100% | 100% | 100% | 100% | 0.0% | 0.0% | 100% | 100% | 100% |
| EV Load Management | 100% | 100% | 100% | 100% | 0.0% | 0.0% | 100% | 100% | 100% |

The realization rates, installation rates and net-to-gross ratios are assumed to be 1.0 until evaluation results are available.

## ***References***

- None.

## ***Changes from Last Version***

- New measure.

### 3.8.3 RESNET ENERGY MODELING SAVINGS

| | |
|---|---|
| Market | Residential |
| Baseline Type | Lost Opportunity |
| Category | Other |

## Description

Savings attributed to Residential Energy Services Network (RESNET) approved energy modeling software for residential new construction.

Homes certified through Home Energy Rating Systems (HERS) index approach, must use a RESNET-approved energy modeling software. This software can be used for any residential new construction building type and the savings methodology can be applied to any residential dwelling unit.

A HERS rating involves inputting the key energy features into a RESNET-approved HERS modeling software (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. The software calculates heating, cooling, hot water, lighting, and appliance energy loads, consumption/costs for new/existing single and multifamily homes.

The main feature of this RESNET energy modeling approach is that it enables users to define a reference home/dwelling unit (i.e., a "base" model) and calculate the savings of an as-built home/dwelling unit relative to that baseline. The reference home/dwelling unit is the same size as the as-built home/dwelling unit and utilizes the same type of mechanical systems and fuels. However, the reference home/dwelling unit in this case has default baseline values for areas such as thermal envelope, mechanical efficiencies, lighting, appliances, and other key end-uses. These default values for the reference home are 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. Current reference home/dwelling unit values are based on the 2017 RNC Study [1].

## Annual Energy Savings Algorithm

*Lost Opportunity Gross Energy Savings, Electric*

The reference home/dwelling unit report generates heating, cooling, lighting, and water heating consumption for the "as-built" home and the defined "base" home (i.e., *Table 3-204*). The difference between those values is the energy savings. This savings is referred to as RESNET Energy Modeling savings.

**Table 3-204 Example of a Typical Fuel Summary 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 RESNET Energy Modeling savings above include the effect of installing a programmable thermostat, so additional savings should not be claimed if one (or more) programmable thermostat(s) is installed. The savings do not include savings for appliances. These savings (if any) are calculated separately.

Since RESNET Energy Modeling savings are 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 HERS 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 based on the 2017 RNC Study [1].

**Note:** The baseline may differ from a home built to minimum prescriptive code. While many homes fail to meet some aspects of the energy code, their performance overall exceeds minimum code performance substantially and therefore, the baseline exceeds minimum code performance as well.

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

Described above in Lost Opportunity Gross Energy Savings – Electric.

*Lost Opportunity Gross Peak Day Savings, Natural Gas*

Described above in Lost Opportunity Gross Energy Savings – Gas.

## *Calculation Parameters*

**Table 3-205 Calculation Parameters**

| Symbol | Description |
|---|---|
| HERS | Home Energy Rating Software |

## *Measure Life*

**Table 3-206 Measure Life**

| Equipment Type | Lost Opportunity EUL | Ref |
|---|---|---|
| Cooling | 25 | [3] |
| Domestic water heating | 25 | [3] |
| Heating | 25 | [3] |

## *Peak Factors*

**Table 3-207 Peak Factors**

| Measure | Summer Coincidence Factor | Winter Coincidence Factor | Ref |
|---|---|---|---|
| RESNET Modeling Savings | 100% | 100% | [4] |

## *Load Shapes*

**Table 3-208 Load Shapes**

| Measure | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % | Ref |
|---|---|---|---|---|---|
| Residential General | 30.30% | 36.30% | 15.50% | 17.90% | [4] |

## *Non-Energy Impacts*

- Improves personal comfort and health. It also increases a home's durability and value.

## *Realization Rates*

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.

**Table 3-209 Realization Rates**

| | Gross Realization % | | | | FR & SO | | Net Realization % | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 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 | Ref |
| Residential new construction, HERS-rated† | 100.0% | 100.0% | 100.0% | 100.0% | 69.0% | 125.0% | 156.0% | 156.0% | 156.0% | [2] |
| Residential new construction, whole building/MF | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | |

## *References*


[1] R1602 Residential New Construction Program Baseline Study, Dec. 5, 2017, NMR Group, Inc.

[2] NMR. 2018. "R1707: Net-to-Gross Study ("NTG") of Connecticut Residential New Construction." p. 3. Table 1.

[3] GDS Associates Inc. 2007. "Measure Life Report, Residential and Commercial Industrial Lighting and HVAC Measures." Table 1.

[4] DNV. 2021. "X1931-2 Load Shape and Coincidence Factor Research – Final Report."

## ***Changes from Last Version***

- Formatting updates.

# 4 APPENDIX

## APPENDIX A: NON-ENERGY IMPACTS

The Companies include the table below in the CTET test and  Total Resource Cost Test, for HES-IE only. The test is described in Section 5 of the 2022-2024 2022-2024 Plan.

**Table 4-1 Summary of Monetized NEIs – Annual NEI per Participant [1]**

| NEI | Connecticut | | |
|---|---|---|---|
| | Eversource | UI | Statewide |
| Reduced arrearage carrying cost (Utility) * | $0.38 | $0.50 | $0.41 |
| Reduced bad debt write-off (Utility)* | $3.14 | $3.61 | $3.31 |
| Fewer shutoffs and reconnects (Utility) * | $0 | $0 | $0 |
| Avoided reconnect fees (Participant) * | $0 | $0 | $0 |
| Reduced quantity of energy sold at the discounted rate (Utility) * | N/A | N/A | N/A |
| Fewer notices ** | $0.60 | $0.60 | $0.60 |
| Fewer collection calls** | $0.90 | $0.90 | $0.90 |
| Fewer safety-related and emergency calls** | $3.25 | $3.25 | $3.25 |
| **TOTAL** | **$8.27** | **$8.86** | **$8.47** |

***References***

[1] NMR Group, Inc. June 3, 2022. “X1942A Cross-cutting NEI Study – Utility NEI and Arrearage Data Analysis Results.”  * p. 5. ** p. 13.